Telescience and Space Missions Operations at the Belgian User Support and Operation Centre

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ABSTRACT

The International Space Station (ISS) is the largest space programme that has ever been undertaken on the basis of international cooperation (United States, Russia, Japan, Canada and Europe). Within the framework of this programme, Europe is in charge of the Columbus Module. More particularly, the Belgian User Support and Operation Centre will be the Facility Responsible Centre (FRC) for the SOLAR Observatory and the Facility Support Centre (FSC) for the Proteins Crystallization Diagnostic Facility (PCDF), which will be part of the European Drawer Rack (EDR).

The past two years, the B-USOC, as part of the European Space Agency (ESA) Decentralized Ground Segment Infrastructure, managed telescience and operational aspects in four space missions: the OdISSea mission to the International Space Station by using a Russian Soyuz Taxi-flight, performed by Belgium (Federal Science Policy Office) with the support of ESA (October-November 2002), the 15 days STS-107 Shuttle mission (January 2003), the CERVANTES mission to the ISS, a Russian Soyuz Taxi-flight performed by Spain (October 2003), and a 30 days ESA-NASA mission onboard the ISS (February-March 2004).

In those missions, B-USOC implemented and maintained, in collaboration with ESA and NASA, a dedicated ground segment for operations in order to link together all centres involved via international communication networks, and to manage several types of data interfaces (Telemetry, Command, Video, and Voice). B-USOC also collected all ground segment requirements from the Belgian users community and allowed Belgian User Home Bases to connect to the missions ground infrastructure.

The present paper gives details of the ground segment implemented for the above-mentioned missions and emphasizes the specific role of the B-USOC and its interactions with the other partners' operation centres. In conclusion, the future operational activities of the B-USOC and its involvement in the European Columbus project will be described.

INTRODUCTION

The main role of the Belgian Space Remote Operation Centre (SROC) is to promote space research programmes and flight opportunities to Belgian scientific community in universities and federal institutes. Subsequently, it provides support to scientists concerning the definition, the development and the operation of their experiments conducted in the different space research fields: microgravity, earth sciences, space sciences and space technology.

Since 1983, a large number of experiments/facilities have already been operated from the Belgian Space Remote Operation Centre located on the premises of the Space Pole in Brussels, with the technical support supplied by the Belgian Institute for Space Aeronomy (BISA) and Belgian universities.

The past experiences of this centre include the support and performance of space missions and facilities, amongst which are EURECA (SOVA, ORA, SGF); IML-2 (BDPU); Atlas-2 and -3 (SOLCON, SOLSPEC); EuroMIR 94, 95/96 (CSK-1), RMS 2-Rip, TITUS); MIR 95 (MIRAS); LMS (BDPU); Neurolab(ALFE); and SpaceHab-98 (BIOBOX/HUDERM, BIOBOX/MARROW, AGHF-2).

Over the last decades, technological progresses led human Spaceflight programmes to international programmes such as the International Space Station (ISS). In this framework and to conduct operations of European facilities on board the ISS, European Space Agency (ESA) decided to implement a decentralized and hierarchical user centre approach. In that prospect, ESA assigned to already existing national User Support and Operations Centres (USOCs) the responsibility to handle in-flight operations of pressurized and/or non-pressurized multi-users facilities.

With this approach, the USOCs play a key role for the implementation of the ISS ground segment for payload operations preparation, real-time data dissemination and provisions for instantaneous experiment command processing. The fundamental role of USOCs is then to act as the link between the user community and ESA's ISS utilization programme.

RUSSIAN SOYUZ TAXI-FLIGHTS

The Belgian OdISSea Mission

A mission to the ISS using a Russian Soyuz Taxi-flight was performed by Belgium (Federal Science Policy) with the support of ESA, RKK Energia and NASA [1]. This ten days mission was launched on October 30th 2002 from Baïkonour and returned on November 10th 2002 in Kazakhstan.

During this Mission the European Astronaut of Belgian nationality, Frank De Winne, member of the European Astronaut Corps of ESA performed a large scientific programme. He was assisted by the Russian cosmonauts, commander Sergei Zalyotin and flight engineer Yuri Lonchakov , and by the resident Expedition-5 crew: Peggy Whitson, Valeri Korzun, Sergei Treschev.

The OdISSea experimental programme was composed of 24 experiments covering various research fields in Life science (biology, microbiology, physiology in-flight and on-ground), Physical science (Fluid Science - diffusion -, Material Science - crystallization, combustion -, among which four were performed in the NASA Microgravity Science Glovebox), Earth Science (ionosphere study) and

Education (physical phenomena occurring in space, radio-amateur contacts). Among those 24 experiments, 16 were under the responsibility of Belgian Principal Investigators (PIs). Belgian industry and members of the BISA provided all their technological know-how for the design definition and development of the experimental hardware and software.

Ground segment description

Although the Soyuz missions are controlled by the Russian Mission Control Centre in Moscow (MCC-M), the OdISSea mission required the setting up of a specific ground segment. This in order to coordinate operations of experiments that had to be conducted in the two international partners' modules, the Russian and American Modules of ISS, by a crew belonging to a third partner, ESA.

As mentioned above, the Belgian-USOC (B-USOC, pursuing the former mission of the SROC, and housed in the Belgian Space Pole facilities) is part of the ISS Ground Segment and is connected to the Manned Spaceflight and Microgravity (MSM) Ground Segment via the ESA Interconnection Ground Subnetwork (IGS). This dedicated ESA ground network, called IGS Phase-1, is based on the following elements:

- A central IGS Node at the European Support and Operation Centre (ESOC) that implements the routing function and communication management function for the overall IGS network
- An IGS node at the Marshall Space Flight Center (MSFC) representing the ESA relay to MSFC for ISS operations
- The use of PSCN/ESANET communication trunk (Leased Lines) to carry out multiplexed data, voice and video signals between MSFC and ESOC
- IGS nodes with dedicated configuration in each International Partner Centre, remotely configurable from the IGS management node at ESOC in order to provide fixed or on-demand connectivity services
- The use of on-demand ISDN lines to allow connection from remote sites.

To fulfill the OdISSea specific ground requirements, all International Partner Centres hosting the teams involved in the OdISSea payloads operations were interconnected through this IGS Phase-1 and the Global Internet network [Figure 1]:

- Europe: ESOC, the ERASMUS User Information Centre (UIC) hosting the Taxi-Flight Operations Coordination Centre (TOCC) at the European Space Research and Technology Centre (ESTEC), the European Astronaut Centre (EAC), B-USOC and two Belgian User Home Bases (UHBs) - the PIs' locations at the "home" universities -.
- United States: the White Sands Ground Terminals (WSGT), the Johnson Space Center (JSC) Mission Control Center of Houston (MCC-H, ISS Operations) and the MSFC hosting the Huntsville Operation Support Center (HOSC), the Payload Operation Information Center (POIC, ISS Payloads Operations), and the MSG Telescience Support Center (MSG TSC)

- Russia: Mission Control Centre in Moscow (MCC-M).

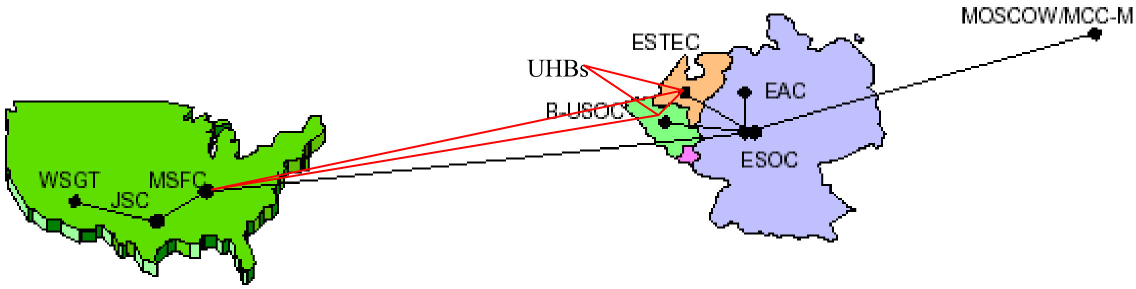

Figure 1: OdISSea mission International Ground Segment (IGS – Internet)

Such a configuration aimed at a decentralized operations network, the main operations coordination team being located at TOCC. The objective was to allow for smooth coordination of payloads operations as the European crew moved back and forth across the Russian (RS) and American (United States On-board Segment, USOS) ISS segments linking up to the different networks, and to make use of both international partners station and ground networks capabilities.

Three types of communication links connected the B-USOC operations control room to the partner operation centres. Therefore, Belgium could acquire, archive and display in real-time all relevant mission data and video transmissions, and to be connected by voice to the other mission centres:

- The dedicated and private ESA IGS phase-1 network (IGS node with 4 on-demand ISDN lines) had been used as the primary source of data, voice and video services
- The Internet network (implementing VPN technology, very restrictive firewall configuration and services access authorization for security, controlled by the BISA network and security management team) as backup for the IGS data and video links, and as primary source of Web-based services
- The Belgian public telephone network as backup for the voice links to the other mission centres.

Two Belgian UHBs - the Microgravity Research Centre (MRC) at the Université Libre de Bruxelles (ULB), and the Department of Metallurgy and Materials Engineering (MTM) at the Katholieke Universiteit Leuven (KULeuven) used the Internet network to get from B-USOC and ESOC their experiment TM and scientific (e.g. the video images for PromISS) data in real-time, allowing them to follow the mission remotely. All the other PIs monitored their respective experiment from the B-USOC facilities.

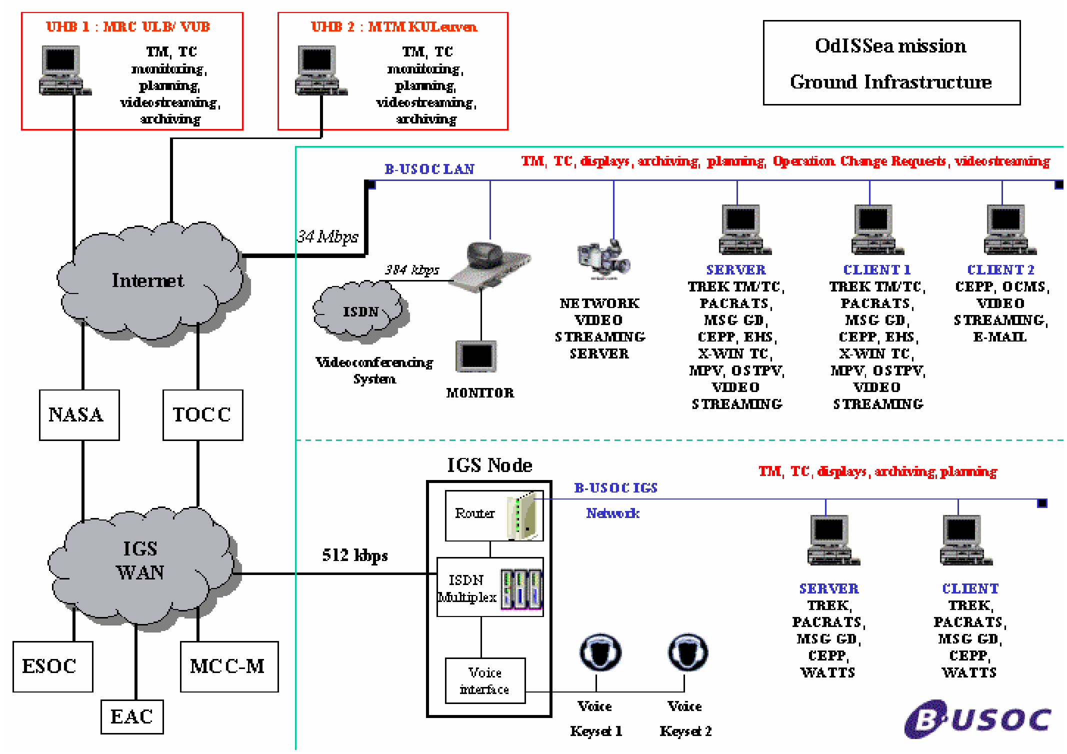

Figure 2: OdISSea mission B-USOC Ground Segment

<u>Data links</u>

The ground capability in the B-USOC control room included 2 IGS and 3 Internet connected workstations with all tools allowing to [Fig.2]:

- Acquire, archive, display and monitor in real-time the MSG experiments telemetry (TM) data: NASA tools: the Telescience Ressource Kit (TreK), the Payloads And Components Real-time Automated Test System (PACRATS) and the Microgravity Science Glovebox Ground Displays (MSG GD)
- Display and monitor the ISS real-time Telemetry, the mission/stage timers and clocks, the Acquisition/Loss Of Signal (AOS/LOS) indicator, track the orbit parameters and position of Soyuz and ISS: NASA tools: Web Application Telemetry and Tracking System (WATTS), (McsBev)
- Display and monitor in real-time the mission planning and procedures: ESA Customized ESA Plan Publisher (CEPP); NASA tools: Enhanced HOSC System (EHS) applications - Payload Management Information System (PIMS) -, Manual Procedures Viewer (MPV), On-board Short-Term Plan Viewer (OSTPV)
- Send tele-commands (TC) to one MSG experiment (ProMISS): TReK, X-windows interface (X-Thin Pro) to NASA servers
- Send and follow all requests exchanges between the mission centres. These requests were used to make changes to the mission timeline and the crew procedures: ESA Operation Change Management System (OCMS), NASA Operation Change Requests (OCR)
- Exchange e-mails between operation consoles in all Partner Centres.

Other dedicated workstations were at disposal of the scientists present at B-USOC during the operations, in order to acquire and further process data, to install any other needed applications, to write reports, to access web applications and to send e-mails to their scientific and industrial partners.

The two Belgian UHBs used Internet connected workstations with only a part of these tools toacquire, archive, display and monitor in real-time their respective experimental data (TreK, PACRATS, MSG GD), and display and monitor the mission planning information (CEPP).

Voice links

B-USOC used the NASA HVoDS (HOSC Voice Distribution System) connected to the IGS network. The HOSC managed the remote configuration and control of the HVoDS keysets (implementing up to 48 aggregate voice channels) as well as the voice distribution. Two keysets installed in B-USOC provided voice conferencing with all control centres. They also gave access to Russian Space to Ground voice loop via Houston. Telephone lines were dedicated to contacts with UHBs and any other involved person if necessary, and were also used as backup of the HVoDS system.

Video links

B.USOC used three channels to acquire of all relevant mission videos - Scientific, Educational, Public Relations (PR): a videoconferencing system linked via 3 ISDN lines to the ESOC IGS video matrix (this was also used to make playbacks and to send some mission videos recorded at B-USOC to the partner centres), the public Internet to connect to dedicated ESOC videostreaming servers, and a Satellite ground terminal for the reception of Eutelsat quality video that was relayed by ERASMUS User Information Centre (UIC) video studio, during the mission highlights (Launch, PR activities).

The Belgian UHBs had access to the dedicated ESOC videostreaming servers via public Internet. Two videostreaming webcams installed in B-USOC were accessible to authorized teams (partner operations centres, UHBs, scientists, the Brussels Planétarium hosting the OdISSea Mission Centre for the Belgian public) in order to follow the B-USOC activities in real-time.

Operations

International Coordination

During the short period of time (10 months) preceding the launch, all working forces were used to fulfill successfully the numerous steps leading to the readiness for real-time operations: ground segment implementation and tools setting-up, documentation preparation, teams training, validation and qualification of the ground segment, and finally the operations simulations. Specific roles were also distributed to all the international centres involved in the whole operations:

- **MCC-M**: overall coordination of the mission, operations and planning, crew and vehicle safety on RS
- **MCC-H**: ISS crew mission operations and overall ISS planning, crew and vehicle safety on USOS
- **MSFC POIC**: operations of all payloads on the USOS including operations of MSG experiments

- **MSFC MSG TSC**: command and control of the MSG facility, MSG experiments tele-operation, support and troubleshooting for MSG facility
- **TOCC**: coordination of the experiments operations execution on RS and USOS, interface with MCC-M and MSFC-POIC/MSG TSC
- **EAC**: medical operations and astronaut support
- **ESOC**: services related to the operation of IGS Phase-1 communication infrastructure
- **B-USOC** accommodated:
  1. The Science Payload Operations Team (SPOT, composed of the Operations Managers and Science Coordinators), whose roles were: main science coordination and operations for Belgian experimental program and scientific support to the mission. This implied coordination and interface between PIs and ESA representatives, scientific support to PIs at the B-USOC and to TOCC science coordinators, flight planning support of experiments, monitoring of all relevant mission information (telemetry, video, timelines, mission status reports), voice conferencing with the ERASMUS and the MSG TSC and monitoring capability of all other voice loops. B-USOC really played a pro-active role, given the fact that it was the main authority for the Belgian experimental program (e.g. for experiments troubleshooting) and when commanding to MSG was necessary (e.g. for PromISS) - the requests being coordinated with the TOCC and voiced over to the MSG TSC-
  2. The ground infrastructure team took care of the whole ground segment coordination and maintenance. This team included B-USOC ground operations coordinators but took also advantage of the operational experience of members from the Belgian SROC Ground Operations/Telescience team.
  3. The Public Relations (PR) team worked on the coordination and implementation of PR for Belgian events.

<u>Relations with others centres</u>

Operations were performed with a very good collaboration between B-USOC and:

- **TOCC** for the day-to-day coordination and operations. The ESA Operations Manager (OPS-MAN) and Flight Activities Coordinator (FAC) were the principal interface for the B-USOC Operations Manager (OM): they coordinated the whole operations execution, discussed and relayed the wishes and requirements of the scientists to the other actors. The ESA Science Coordinators (SC) at TOCC were the principal interface for the B-USOC SCs: they played a role of moderator to keep B-USOC informed on the different processes and to formulate possible options to the scientists as well as their order of preference. Concerning the Life science experiments (CARDIOCOG), the B-USOC SCs and the scientists themselves interacted also with the Safety responsible at TOCC. ESA Ground Operations Coordinators (GOCs) were the principal interface for the B.USOC Ground infrastructure Coordinators (GCs) in order to answer to the technical questions.

- **The MSG team** at MSG TSC for excellent and efficient performance in the recovery of PromISS (an activation problem happened, that was solved by direct contacts and collaboration with Huntsville from B-USOC), and their part in the coordination of COSMIC operations.
- **The POIC team** at MSFC for the coordination of PromISS TC upload
- **ESOC** for the efficient monitoring and fast recovery of IGS services when problems occurred.

Organization and running

At B-USOC side, one keyset was allocated to the OM and another one to the SCs. Telephone lines were allocated to the GCs to contact TOCC and ESOC for ground segment problems reporting. The roles of the different B-USOC console positions (OM, SC, Science Support, Ground Infrastructure) were well performed. The communication was excellent between the OM and the SCs, allowing both teams to have continuous follow-up of the mission operations. Console logs were written in a detailed way and were intensively used for tracking back needed information (e.g. exact time of an experiment activation) and for the hand-over of the shifts.

Shift Operations

Due to the high intensity and to the short duration of the mission it has been necessary to man all key operational positions throughout the crew wake period, at least until the final evening operations and/or reporting by the crew. In order to cover the long duration of the working day (about 14 to 16 hours) induced by on ground following of the on-orbit Crew working day, a specific shift/overlap scheme was adopted for key positions which required extended presence during the mission such as the OM, SCs and GCs. The operating cycle (on-console support) of the ground teams was mainly driven by the experimental timeline and related crew activity period (defined as: Crew Wake-up: 08:30 Coordinate Universal Time (UTC) and Crew Sleep: 00:00 (UTC), the working ISS Mission time being UTC/GMT).

Collaboration with scientists

Most of the scientists were gathered at B-USOC and there was in general an excellent cooperation between scientists and B-USOC team. Scientists and industry representatives had been present during the decisive moments of their experiments. For some experiments (PROMISS - DCCO - NEUROCOG - CARDIOCOG) their presence was required for the duration of the experiment run. The interventions made by the scientists, industry representatives and B-USOC coordinators consisted mainly in:

- Almost immediate responses concerning the manipulations of their experiment
- Interactions with ESA – Safety – MSG – Payload Operations Director … for changes in procedures
- Development of new or recovery procedures (PROMISS, NEUROCOG, CARDIOCOG)
- Analysis of data and video (PROMISS – DCCO – COSMIC) on the spot with upload of 2 correction tables for PROMISS and GO / NO GO decision for COSMIC
- Planning and requests for scientific video requirements
- Discussion with ESA Scientific Coordinators (for Life and Physical experiments)

Interfaces with UHBs

There has been regular contacts with the two Belgian UHBs where the Ground Operations / Telescience teams were supporting the PI's during the mission. This allowed, with extending to all involved entities the monitoring of data and video and the check of the experiments performance, in order to have an in-depth view of the various aspects of the experiment status, and of the resolution of issues. About COSMIC, only one scientist was present at B-USOC while the others were gathered at the UHB, which implied an efficient way of working and decision-making. Moreover, scientists in UHBs could immediately make a pre-processing of their data in order to obtain initial scientific results.

The Spanish Cervantes Mission

This mission following OdISSea was performed by Spain with the support of ESA between October 18th 2003 and October 28th. During this mission a member of the European Astronaut Corps of ESA from Spanish nationality, Pedro Duque, performed a large scientific programme (18 experiments, among which 6 Spanish and 7 Belgian, covering the same research fields as for OdISSea.) in collaboration with the Russian cosmonaut Alexander Kaleri as Soyuz Commander, Michael Foale as Soyuz Flight Engineer and of the resident Expedition-7 crew Yuri Malenchenko (Commander) and Edward T. Lu (Flight Engineer).

The Ground Segment made a reuse of the previously implemented infrastructure and B-USOC handled almost the same responsibilities during the operations. There were also some improvements: (1) all operations centers could access to the MCC-H mission gateway - and its web applications: Short-Term Plan (STP), Electronic Flight Notes (EFN), Joint Execute package Development and Integration (JEDI) -; (2) only the Belgian MRC/ULB UHB was involved: (3) it has gain access to IGS mission quality videos forwarded from B-USOC, to the ESA OCMS system and to the voice loops transferred via the dedicated ISDN lines of the B-USOC videoconferencing system; (4) all experiments were huge successes.

The operational team working at B-USOC also involved people from the Belgian SROC and from the Belgian MTM/KULeuven UHB Ground Operations/Telescience teams. B-USOC regarded this successful mission as a further opportunity to extend the know-how of the Belgian operational community, and to demonstrate its ability to be successfully involved in real-time operations.

NASA STS-107 HITCHHIKER MISSION

From January 16th 2002 to February 1st 2002, B-USOC hosted the Belgian Remote SOLCON Payload Operation and Control Centre (POCC), which was the only European PI Centre involved and being directly connected to NASA HitchHiker operation networks (via the ESA IGS network, managed by

ESOC IGS control team). The SOLCON experiment (developed by a team at the Royal Meteorological Institute of Brussels, and that was aimed at studying the Solar Constant) had flew on many previous Shuttle missions, and was this time implemented in the project Fast Reaction Experiments Enabling Science, Technology and Research (FREESTAR).

The mission roles and responsibilities were shared between all international partners:

- The Space Shuttle Program (SSP) at JSC: overall mission management
- The Hitchhiker Project at the Goddard Space Flight Center (GSFC): management of FREESTAR payloads operations
- The GSFC Attached Shuttle Payload Center (ASPC): POCC for the FREESTAR mission. The Operations Director (OD) was the principal interface authority for overall ASPC operations, to coordinate experiment status, replanning, and anomaly resolution. He worked closely with the SOLCON PIs in order to ensure the maximum data acquisition, commanding capabilities, anomalies troubleshooting
- The Belgian POCC: centre of PIs, which determines the experiment objectives, communicates these objectives to the OD and to the experiment controllers, performs and oversees experiment operations. The SOLCON PIs worked with two operation teams: one located at B-USOC, and another located at GSFC. This allowed a 7/24 presence and backup possibilities for data reception, monitoring and commanding.

The ground segment was implemented using both the IGS and the Internet networks in order to access NASA mission resources. Two HVoDS (managed by HOSC) keysets were used to contact operations partners. All tools necessary for data reception, monitoring, commanding (the experimental scenario asked for commanding on a very regular basis), timelines visibility and Shuttle tracking were implemented. The operation team included the SOLCON PIs, and ground infrastructure controllers from both SROC and B-USOC.

This mission was considered as a very good preparation for the SOLAR Monitoring Observatory (SMO) (accommodating three solar experiments, among which an upgraded SOLCON experiment called SOVIM that was developed by the same team in collaboration with the Observatory of DAVOS (Switzerland), and that will be installed on the Columbus external pallet), as it allowed B-USOC and SROC operation teams to familiarize with SOLAR experiment context.

<u>ESA-NASA MISSION</u>

The ESA PromISS 3 Mission

PromISS is an interferometric microscope developed to monitor protein crystal growth by using the contradiffusion technique [2] . This equipment has been developed in response to the growing demand of performing techniques for protein crystallization. It consists of (1) a digital holographic microscope able to measure the depletion zones around the crystal and to refocus crystal images, (2) PromISS related equipments: Power harness, Data harness and a separate Clamp to attach PromISS to MSG, (3) 14 Videotapes and 2 PCMCIA Microdrives that are stored in the PromISS Kit 2 which is uploaded by Progress. .

The PromISS-1 experiment has already been performed during the 10 days of the OdISSea mission in November 2002. Preliminary results obtained show that the instrument was strongly affected by vibrations and the temperature profile of the mission. These factors had a bad impact on the quality of the results obtained. **The PromISS-2 experiment** was developed in the frame of the Spanish Soyuz Mission flight opportunity. An upgraded version of the Flight-Model hardware, called PromISS-2 experiment has been uploaded with Progress 11P in August 2003. This PromISS-2 experiment was performed successfully during the Cervantes mission in October 2003: 6 experimental cells were uploaded with the Soyuz 7S, analyzed with the PromISS-2 optical diagnostic payload into MSG during 10 days, and downloaded with the Soyuz 6S. **The PromISS-3 experiment** is a re-flight of the previous PromISS-2 experiment performed during the Cervantes mission, but with an investigation of the experimental cells into the Digital Holography Interferometric Microscope of 30 days and then stowage of them in an incubator (AQUARIUS) during 2 months, to fit the Progress 13P and Soyuz 8S/7S operation timeline.

The operations of Promiss-3/MSG were conducted continuously throughout 30 days; it constituted a first time for ESA and NASA. During this mission, B-USOC was the European responsible centre for operations with mission management support from ESTEC. B-USOC was in charge of all the science follow-on (for scientific telemetry reception and commanding of the PromISS experiment; with support from the PIs and the ESA Science Coordinator) and of the resolution of any routine matter arising from operations. The same ground segment as during OdISSea and Cervantes Missions was used.
At NASA side, MSG TSC played the same role as during the Russian Soyuz Taxi-Flights; all NASA teams involved worked in very good collaboration with B-USOC. At ESA side, all console positions were not manned full time during the mission days, as the ESA team was preparing the next Dutch Soyuz Mission. The ESA Science Coordinator was on console most of the time and was of great help to solve science matters, the other ESA Coordinators (Mission Management, Ground Segment) being on-call for any matter regarding the mission conduct. As an example, the ESA Operation Manager was responsible to sign and submit OCRs to MSFC and JSC, those OCRs being defined by B-USOC and/or the ESA Integration Coordinator and/or the ESA Science Coordinator.

CONCLUSIONS

Lessons learned

The Belgian OdISSea Mission has been the first step in coordinating ISS Operations with numerous partners. Neither NASA nor Russia had done payload operations across numerous control centres and continents. The OdISSea requirements were established in order to link all partners and to operate smoothly in nominal and off-nominal situations. For the first time, all ISS partners involved in Payload operations depended on each other to achieve mission success.

This operational architecture, which includes some specific adaptations reflecting the specific experimental programme and involvement of possible national User Support Operations Centres supported the next Spanish Soyuz Taxi-flight mission and may later on move towards the integration of the Columbus Ground Segment, which will be coordinated by the Columbus Control Centre.

The OdISSea, Cervantes and PromISS 3 Missions offered a remarkable opportunity for all teams to acquire an understanding of ISS processes, and an experience in using operational infrastructure and tools that are precursor compared with those currently under development to support Columbus payload operations. The benefit which a user site such as B-USOC got from the participation in Soyuz, STS and ISS missions is a real scenario in order to understand the issues in operating payloads in the ISS environment, considering that all European payloads in US-Lab will be operated on a similar way with similar interfaces to the MSFC/POIC. It may also provide an observation function for Columbus development and Operations teams who are looking for early feedback on ISS and Columbus tools utilization.

Future ISS - Columbus activities

During the phase of increment preparation of the Columbus programme, the USOCs will be concerned with activities such as ground segment implementation, ground model operations, experiment procedure development, payload and experiment operations optimization and calibration, and support to crew training activities. During the in-orbit payload operations, the USOCs will receive facility and experiment data and give support to the Columbus Control Centre by performing the operations of the payloads they are responsible for.

According to the scope of the task assigned to a USOC, three basic levels of responsibility exist [3]:

- The Facility Responsible Centre (FRC) is delegated the overall responsibility for a payload facility (full rack payload).
- The Facility Support Centre (FSC) is delegated the responsibility for a sub-rack payload (e.g. facility insert, experiment container, drawer payload, a bioreactor).
- The Experiment Support Centre (ESC) is delegated the responsibility for single experiments. An ESC is focusing mainly on science and experiment operational matters.

The associated Support Centres (FSCs/ESCs) will support FRC payload operations according to a defined potential for interactions and collaborations.

In addition, for specific experiment operations, dedicated User Home Bases (UHB) will be set up if required. UHBs, which are the investigator's location at the "home" institutes, are typically national institutions (e.g. universities), which need to obtain the adequate communication and data processing infrastructure allowing real-time data monitoring and control of the respective experiment (e.g. for remote operations). The FRCs will coordinate and support this setup, and be the focal point for the operations preparation activities for the UHB, more particularly for the definition of experiment operations requirements, the specifications of hardware and software, and the connectivity requirements of the UHB to the ISS ground segment.

The European Columbus module not only provides accommodation capabilities for 10 internal, pressurized payload facilities, but it also carries provisions to accommodate up to four external payload facilities [4]. External payloads offer experiments in the space environment with the major advantages of long duration exposure and return to Earth for examination. Within the Columbus general framework, B.USOC will assume the management of the FRC for the external Solar Monitoring Observatory and of the FSC for European Drawer Rack (EDR) / Protein Crystallization Diagnostics Facility (PCDF) in collaboration with the ERASMUS Centre (USOC located at ESTEC) as FRC.

For the SMO, three complementary space science instruments will measure the solar spectral irradiance with an unprecedented accuracy across almost the whole spectrum: 17-3000 nm. This range carries 99% of the Sun's energy emission. Apart from the contributions to solar and stellar physics, knowledge of the solar energy flux (and its variations) entering the Earth's atmosphere is of great importance for atmospheric modeling, atmospheric chemistry and climatology. The three instruments are (1) SOVIM (Solar Variable and Irradiance Monitor, jointly developed by the Observatory of DAVOS, Switzerland and the Royal Meteorological Institute, Belgium), SOLSPEC (Solar Spectra Irradiance Measurements, developed by CNRS, France) and SOL-ACES (Auto-Calibrating Extreme Ultraviolet and Ultraviolet Spectrophotometers, developed by the Fraunhofer Institute, Deutschland)

The PCDF is a multi-user instrument for the fundamental study of the processes of nucleation and crystallization of biological macromolecules, and more specifically, it studies how these processes are influenced by gravity. The PCDF is a candidate experiment for accommodation in the first payload complement of the EDR, which is scheduled for launch into space inside the European Columbus Laboratory

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