IAC-10.B6.1.5

Highlights in Columbus Operations and Preparation for Assembly Complete Operations Phase

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61st International Astronautical Congress,
27 September – 1 October, 2010
Prague, Czech Republic

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HIGHLIGHTS IN COLUMBUS OPERATIONS AND PREPARATION FOR ASSEMBLY COMPLETE OPERATIONS PHASE

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ABSTRACT

Since the activation of Columbus on 12 February 2008 two and a half years of busy and partly challenging operation have been performed by the Columbus FCT. With a total of 9 experiment racks, 1 external payload and several stand-alone experiments situated in Columbus the Columbus Flight Control Team is very busy to prepare and execute operations in the European module, taking into account the larger workforce onboard ISS since the permanent 6 person crew has been established in May 2009. The major challenges of the third year of Columbus operations was the maintenance of the WOOV8 valve of the Thermal Control System by a combined crew/ground activity including a necessary rack tilting and the recovery of a Columbus Onboard DMS problem with some ripple effects on operations. The preparation work concentrated on new ESA experiments like the 5th ESA rack called MARES delivered with Shuttle flight 19A (STS-131) and the Vessel-ID payload delivered in spring 2010.The MARES rack is installed in F3 location in Columbus during 19A flight and a first short commission is planned in ULF4 stage. The major commissioning is foreseen for Increment 25&26 starting in October 2010, which needs to be prepared by the responsible USOC – CADMOS – together with the Col-OCs. After the retirement of the Shuttle in autumn 2010 the possibilities to transport defect parts to earth and spare parts to orbit will vanish or reduced, respectively. Hence the maintenance approach of Columbus after Assembly Complete of the ISS in 2010 has to be adapted to allow smooth operations and to ensure full support of the Columbus system for payload operations to fulfill the science objectives of the European module.

Introduction

The overall perspective of ISS operations has been turned from a medium term perspective until 2016 to a more long-term perspective until 2020 or even 2028 after the speech of US president Barack Obama in spring 2010.

Since then all International Partners have started to investigate the boundary conditions for a extended lifetime of their ISS participation or already started projects to ensure the future usage of this unique laboratory in space.

As a result of that the Columbus Control Center started with first investigations how the operations of Columbus, the usage of the whole facility and the maintenance of the ground segment can be ensured over the next 10+ years. This leads to a different perspective especially in preventive maintenance of both the onboard and the ground systems. Subsystems with a lifetime until 2016 must not be exchanged before but now a thorough investigation has to be performed if the lifetime

could be extended or a replacement programme has to be initiated.

The ground systems of the Columbus Control Center have been used since the Eneide Mission in 2005, during the Astrolab mission with Thomas Reiter in 2006 (see [1] and [2]) and continuously for Columbus Operations (see [6] and [7]). Since 2008 the Industrial Operations Team (IOT, see [3] and [5]) at Col-CC operates, monitors and maintains the new ISS element. Now IOT is starting to prepare the Columbus Control Center for a long-term operations period until at least 2020.

First ESA ISS-Commander

On 9 October 2009 the command of the ISS was handed over to Frank de Winne for the Increment 21. Hence, he was the first ESA Commander of the ISS for about two months (see change of command ceremony video on http://www.esa.int/esaCP/SEMC0TXRA0G_index_0.html).

Fig. 1: Expedition 20 and 21 crewmembers in the Node#2 (Credits ESA/NASA)

On this occasion the ESA head of Human Space flight Ms. Simonetta die Pippo came to Col-CC on 13 October 2009. She congratulates Frank de Winne to this honour and wishes him all the best for his new tasks.

Frank de Winne returned to Earth on 01 Dec. 2009 with his two crewmates Roman Romanenko and Bob Thirsk. Undocking and de-orbit went as planned and Soyuz TMA-15 landed in Kazakhstan on 1 December on 7.17 GMT (see Fig. 2).

Fig. 2: Landing of the TMA-15 crew in Kazakhstan

DMS Failure and Recovery

One of the most challenging events during the last year were the Columbus DMS failures which lead once to a problem on the NASA computers, too. Already in the beginning of 2009 a first DMS failure had occurred which could be solved by a partial shutdown and reactivation of the Columbus onboard computer system. Throughout the year 2009 and also before and after the Cycle 12 transition the DMS worked without problems. Nevertheless on 18 February 2010 a failure occurred in the nominal DMS leading to partial loss of Columbus onboard functions while the Space Shuttle was docked to the Station. Comparable to the approach in 2009 the onboard computer were partially deactivated and reactivated afterwards. During the reactivation procedure which has to be postponed by one day due to Shuttle undocking, a false command was sent deactivating an onboard data packet. The reactivation of the onboard data packet routes the package to the wrong storage area in a NASA computer leading to a failover in the system.

After investigating the root cause of the problem NASA updates their onboard software to avoid such problems in the future and Col-CC marked in first reaction the packet commands as hazardous. The fast recovery of the whole computer system was only possible due to the good cooperation between the control centers and their engineering support teams.

System Maintenance Activities

The main task of the Columbus Flight Control Team is the monitoring, commanding and maintenance of the Columbus Module. While the monitoring and commanding task can be mostly performed by the FCT alone, the maintenance tasks are often combined crew and ground activities. In the last 12 months a continuous flow of known and new maintenance activities have been performed to ensure that all capabilities of the module are permanently available and full support for payload operations can be given. Among the different tasks the examples of protective and corrective maintenance given below provide a good overview on the variety of work to be fulfilled by crew and FCT.

During regular maintenance activities in autumn 2009 it was detected that one of the water on off valve in the thermal control system of Columbus is stuck open. This is the nominal position of the WOOV 8 valve; therefore there is no direct impact on the Columbus cooling loop. Using redundant valves the Columbus TCS can also thermally isolated from the rest of the ISS, if necessary. Nevertheless the problem has to be solved and a special task force of EST and FCT develops procedures for the WOOV 8 recovery with crew intervention since first attempts to move the valve with extensive ground commanding did not work. This time also NASA has to be included because a NASA rack has to be tilted before the astronaut could reach the valve for the necessary manual override. All groups together develop procedures for tilting the rack, for manually closing the valve, for monitoring and confirming the remote controlled motion of the unblocked valve and for bringing everything back into the starting position. The WOOV 8 troubleshooting has been performed in September 2010 but has not shown the expected result; therefore a second step of the maintenance is now under preparation

One of the regular tasks which have to be performed by the astronauts in Columbus is the smoke detector cleaning. The two cabin smoke detectors are located in the cabin air return loop, to be able to detect a combustion process in the ventilated cabin area. Unfortunately also dust and dirt is transported by the return air, which cannot be removed completely by the installed filters. Hence, some of the dust is accumulating on the smoke detectors and is slowly leading to a degradation of the smoke detector function. Before a critical value is reached the astronauts have to clean the smoke detector by hand, to re-establish it's fully functionality. This has to be done second time in the on-orbit lifetime of Columbus on 20 January 2010. The procedure requires a close cooperation between flight crew and ground crew, e.g. to inhibit some of the sensors before the cleaning starts and to test and re-establish the whole reaction chain afterwards. This maintenance task has not been considered before hand but as a regular preventive maintenance task but has become now to a regular one due to the air flow in the Columbus cabin transporting all the dust onto the smoke detector.

Fig. 3: Frank de Winne with water loop refill equipment and the open Deck rack 1 (Credits NASA)

Beside these major tasks a lot of routine maintenance activities like valve cycling, leak checks, water sampling and check of the OPA levels in the water loop were performed in the last year as well as the regular water loop refill operations carried out by ground and crew several times now (see Fig. 3). In addition always new operational scenarios need to be developed and analysed between the FCT and the EST teams like the current discussed topic of the water transfer between the WPA2 and WPA1 accumulators that is becoming necessary due to the fact that the preferred WPA for a water refill is WPA2.

Payload Operations Support by Col-CC

On 26 Oct. 2009 the Columbus module was crowded with 2 astronauts, a new experiment called Flywheel and a lot of support equipment. Flywheel is a prototype of a possible future training system for the astronauts, which should be tested by Frank de Winne. The Flywheel setup was

equipped with various sensor, e.g. with accelerometers, to measure the impact on other Columbus racks and equipment by the running Flywheel. Frank de Winne enjoyed the test of the Flywheel experiment (see Fig. 4) and delivered a lot of valuable information back to ground for the further development.

Fig. 4: Frank de Winne during the test of the Flywheel experiment (Credits NASA).

During STS-131 (19A) the next rack for Columbus was brought to space and installed in the module. The MARES rack (Muscle Atrophy Research in Space) will be used for investigations on astronaut's physiological changes during their stays in space and especially in microgravity. During the 19A flight the rack was mechanically installed, only (see Fig. 5). Now a two stage commissioning is in preparation. The first stage will be performed by NASA with ESA support and shall take part in autumn 2010. The second stage is planned for 2011 under ESA responsibility and will lead to an operational usage of the rack in 2011. Col-CC is then responsible for the system to payload interfaces comparable to the other racks and will support the responsible USOC – CADMOS – in preparation and execution of the experiment.

One of the most prominent experiments in the last year was the second run of the WAICO experiment in Biolab rack. After a lot of refurbishment work on the Biolab rack the WAICO 2 experiment started end of April 2010 and was finalized with the return of the samples with STS-132 (ULF4) with a lot of support by Col-CC. Due to some problems during the experiment run, the Biolab rack shall be checked again before the next experiment will be performed in the first quarter of 2011.

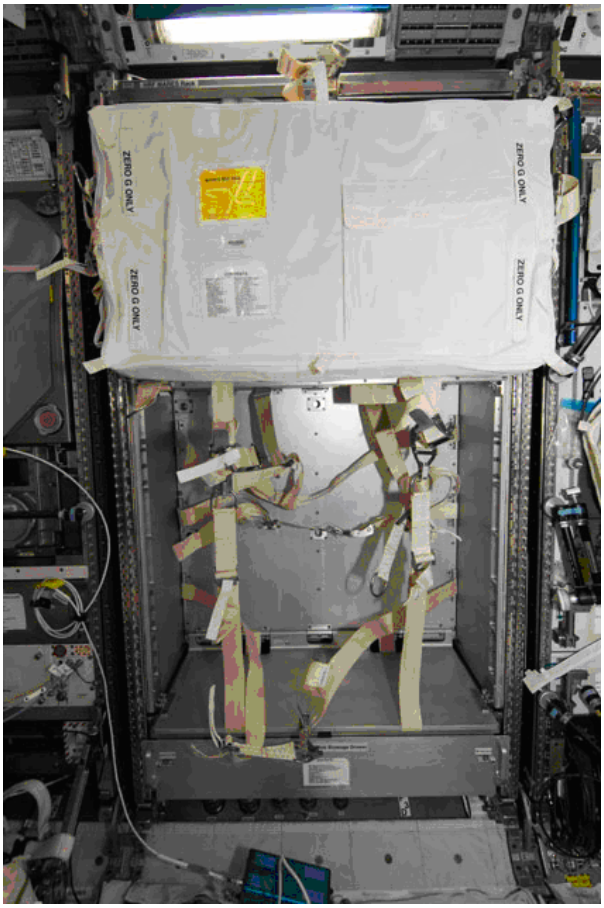

Fig. 5: MARES rack installed in Columbus (Credits NASA)

Col-CC also support the SOLO experiment for measuring the salt input and the effects on a human body in µ-gravity conditions as well as the 3D Space experiment to investigate the change of human perception in space.

To measure the radiation in Columbus the DOSIS experiment was installed in the module in summer 2009 and permanently operated since this time. For experiments like SOLO, NEUROSPAT and CARD several ESA and NASA assets in Columbus were used to run the full chain of experiment steps. The coordination between the different USOCs in Europe, the POIC in Huntsville and the crew onboard ISS was performed by Col-CC flight control team.

Since summer 2008 Col-CC supports B-USOC by taking over the monitoring of the SOLAR external payload if it is in the so-called "idle" mode. This releases B-USOC from a 24/7 shift scheme during that phase that the small team at B-USOC can

concentrate on the monitoring and commanding of the external payload in the active phases. Comparable to this approach Col-CC also accepted to monitor the new STDO (Station Development Test Objectives) Vessel-ID during most of the time to avoid unnecessary night and weekend shift at the responsible N-USOC in Norway. Col-CC is open to support more experiments using a similar concept if it is feasible for Col-CC and wished by a USOC.

VOCS, SAN, DASS and MCS upgrade

As described above the horizon of the ISS and Columbus usage is gradually extended to the year 2020 and even more far in the future. Hence, not only the onboard systems have to be maintained and partly replaced. Also the ground systems have to be refurbished and – if no longer deemed efficient – replaced by newer systems. Several subsystems at Col-CC, which had been inaugurated in 2004, are approaching the end of their lifetime and have to be replaced. The colleagues from the ground segment at Col-CC worked out a transition plan which will lead to a step by step upgrade of four major subsystems – VOCS, SAN, DASS, MCS and the workstations in the control rooms– in the years 2010 and 2011. The goal is to upgrade or exchange the systems with the least possible impacts on operations and to allow for cost reduction in case requirements can be retired or have changed during the last years of operations.

The VoCS (Voice Conferencing System) subsystem is already in the mid of the transition towards a new system nearly identical with the new NASA communication system also planned to be installed in this timeframe. The first step has already been performed in July 2010 by switching to the new interface between JSC and Col-CC. In the next weeks the kernel of the new VoCS will be installed at Col-CC and it is planned that Columbus Flight Control Team can use the new Subsystem from November 2010 operationally.

The Monitoring and Command System (MCS) of Columbus has already been upgraded to a new version suitable for a new version of the operations system. This upgrade has been performed together with the exchange of all workstation in one control room followed by an extensive test and validation period of the new hard- and software performed by a combined ground- and fight control team. After successfully performing all necessary checkouts the flight control team has changed control rooms in July 2010 and is working since then without problems with the new equipment. Now the main control room is refurbished and the same hard- and software is installed. It is planned to go back in the main control room in November 2010 where they can also use the new VoCS (see above).

In parallel also the Storage Area Network (SAN) which records all Columbus system data will be replaced by an enhanced system and DASS (Data Services Subsystem) will be adapted to the described changes. Despite the high effort of the subsystem engineers to reduce the disturbances of ongoing operations a large amount of flexibility is necessary on flight control team side to cope with some hours of outages due to the switchover from the prime to the backup system and back or the move from the main to the second control room and back after refurbishment. Up to now the work on ground is in the schedule and will lead to a fully refurbished Col-CC by the end of 2011.

Columbus Onboard Software Upgrade

After the big onboard software upgrade from Cycle 11 to Cycle 12 in 2009 only a small onboard upgrade a so-called “patch cluster” had to be performed in May 2010. Compared to the upgrades in 2008 and 2009 this upgrade contains only smaller changes with no need to change the ground software. Nevertheless a careful and detailed preparation had been performed to ensure that everything runs well on board. The good preparation pays off! Despite some problems with the onboard computers during transition the DMS was running fully with the new patch two days after the start of the transition.

Operations Coordination with JAXA for Matroshka

A very new chapter in ISS operation was the introduction of a closer interface between Col-CC and the Space Station Integration and Promotion Center (SSIPC) in Tsukuba (Japan). This new interface was introduced by moving Matroshka to the Kibo module. Matroshka is a torso equipped with dosimeter to measure the radiation inside a structure comparable to a human body (see Fig. 6). The experiment will reside inside JEM for several months until the dosimeter will be brought back to earth for analysis in 2011. To offer the best

support to the responsible investigators at MUSC in Cologne, Col-CC is on the way to enhance the cooperation with SSIPC by proposing adapted OIPs and other operational tools according to the new situation. This new interface could be based on already established informal interfaces between SSIPC and Col-CC during the last 2 years of KIBO and Columbus operations.

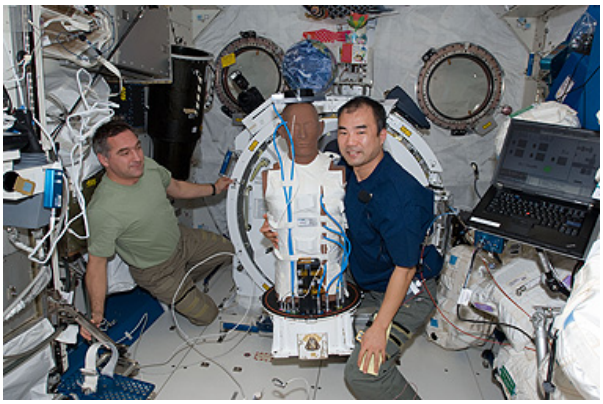

Fig. 6: Matroshka preparation for installation in JEM (Credits NASA)

Lessons Learned and Changes in Setup after 2 Year of Operations

Beside the lessons learned for the Flight Control Team that are continuously implemented into the running operations one major topic is raising more and more and has been identified as one of the big challenges for this project in the near future.

The recent announcements by NASA have given indications that the ISS is planned to be operated till the year 2020 and beyond. In order to be able to operate the Columbus Module as part of the ISS in the future with the correct technical skills and understanding as of today special attention needs to be drawn to the Know How Documentation and Know How Management.

This is applicable for the Flight Control Team (FCT) specific know how and for the engineering know how. Due to the long project runtime and the natural attrition rate of experienced team members it is very important to compensate against loss of know how.

- First the learned skills and know how needs to be systematically and repetitively documented (creation of the Know How Back Bone (KHBB))
- Secondly the documentation or know how must be accessible for each team member in an (time) efficient way (creation of a Know How Access System (KHAS), and
- The third point that needs to be established is to integrate the available know how into the formal training flow for new team members in an up-to-date manner.

As projects naturally are, the time is short and the first thing people tend to skip is to properly document the current “State of the Art” specially since human space flight is very quick developing and producing new operations cases in a short time frame. Already now it can be seen that certain project individuals are becoming single know how keeper for certain special tasks, that is at the first hand not a problem but since it is necessary to guarantee a continuous running operations the provision of that specific know how over a longer time is becoming a problem.

Talking about the access to know how is the second point mentioned above that in an integrated Know How Management System needs to be tackled. Today even problems exist that not all documentation is accessible by all working members of the project. That available documentation is partly outdated and not reflecting the current state of the Columbus Module and related operational know how. In addition the documented know how is distributed in several areas and tools that are used to coordinate and execute the real time operations, like anomaly reporting system (ARS) or flight note system (CFN).

The third “tower of strength” is that the running training for flight controllers and EST personal at Col-CC is not based on outdated information or even wrong information. A mechanism needs to be integrated into the project set up that assures the up to date training lessons in order to minimise useless training time. This will assure a better quality of the trainees when they are certified and reduces the need for special add on training for familiarizing the new team members with the current “State of the Art” of the Columbus Module.

Conclusions and Outlook

After 30 months of Columbus operations it can be stated that the module is running well, but there is continuous surveillance and maintenance - protective and corrective – necessary to keep Columbus and especially the payloads in a healthy status. Hence the flight control team and the engineering support teams are still fully loaded with the preparation, support and execution of such activities. Therefore, offline preparation work in parallel to shift work puts a high work load on the team especially after the permanent onboard crew has increased to 6 persons.

Nevertheless the FCT enjoys working with the increased crew and is looking forward to the next long-term ESA astronaut Paolo Nespoli who will fly to the ISS in December 2010. He will work in orbit in Increment 26 and 27 and will be responsible for commissioning and execution a lot of new experiments like the MARES rack.

Fig. 7: Current assembly status of the ISS after STS-132 in May 2010 (Credits: NASA)

Meanwhile the next European long-term astronaut prepares himself to live and work at the ISS in the next years: André Kuipers in Increment 30&31. This will again offer a lot of opportunities not only for European scientists but also for Col-CC flight controllers to learn more and to get more involved in ongoing ISS operations.

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