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One Year of Columbus Operations and First Experience with 6 Persons Crew

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ABSTRACT

On 12 February 2009 the first year of operation of the Columbus Module was passed. These 12 months of Columbus in orbit have shown a lot of successes of the whole Columbus operations teams but also has shown some open topics which have already been addressed to ensure a long-term operation of Columbus. In the first year 4 NASA racks were successfully relocated from the Destiny module to the Columbus module, re-activated and used by NASA for various experiments with support from Col-CC and other European centres. The first Columbus software transition in orbit from Cycle 10 to Cycle 11 to be compatible with the NASA R7 software upgrade has been performed smoothly in August 2008. Many European experiments performed by the USOCs like WAICO (in the BIOLAB rack), GEOFLOW (in the FSL rack) and PCDF in EDR have been successfully supported by Columbus Flight Control Team (Col-FCT). The paper will present the experiences gained during more than one year of Columbus operations and will give a first insight in the changes of the Col-FCT work due to the 6 person crew on board ISS starting in May 2009.

Introduction

Since the launch and activation of Columbus more than 500 days of operations have been performed at the Columbus Control Center (Col-CC) at DLR Oberpfaffenhofen. In addition to the major achievements like software transition, rack relocation and activation as well as support to payload operations the Col-FCT was also able to perform corrective and preventive system maintenance like sensor replacement, exchange of an air fan and rebooting of one of the central computer systems. This ensured full support of the Columbus systems for payload operations in this first year in orbit. The team structure was enforced to allow continuous support of ISS operations for the next years. The Flight Control Team is prepared to support the permanent 6 person crew on ISS which started with Soyuz 19 in May 2009 and the enhanced possibilities in payload operations which is enabled by this crew ramp up. The astronauts, including the ESA Astronaut Frank de Winne, are now able to perform more experiments in parallel, which will increase the preparation and execution work of the teams on ground.

The Industrial Operations Team (IOT see [3]) at COL-CC operates, monitors and maintains the new ISS element over its planned lifetime period of about 10 years. Based on the experience starting from the Astrolab mission with Thomas Reiter in 2006 (see [1] and [2]) up to the ongoing Columbus operations, improvement for preparation and operations are already planned, in development or already implemented (see [4] and [6]). This will allow continuous operations and enhanced efficiency in operations of the full lifetime of the Columbus module.

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Launch of the first permanent 6 Person Crew to ISS

One of the most important events for the whole ISS community was the launch of the first permanent 6 person crew to the ISS on 27 May 2009. The three cosmonauts and astronauts Roman Romanenko, Bob Thirsk and Frank de Winne were brought to orbit with the Soyuz TMA15 capsule in a "picture-perfect" launch from Baikonur Cosmodrome in Kasachstan (see Fig. 1).

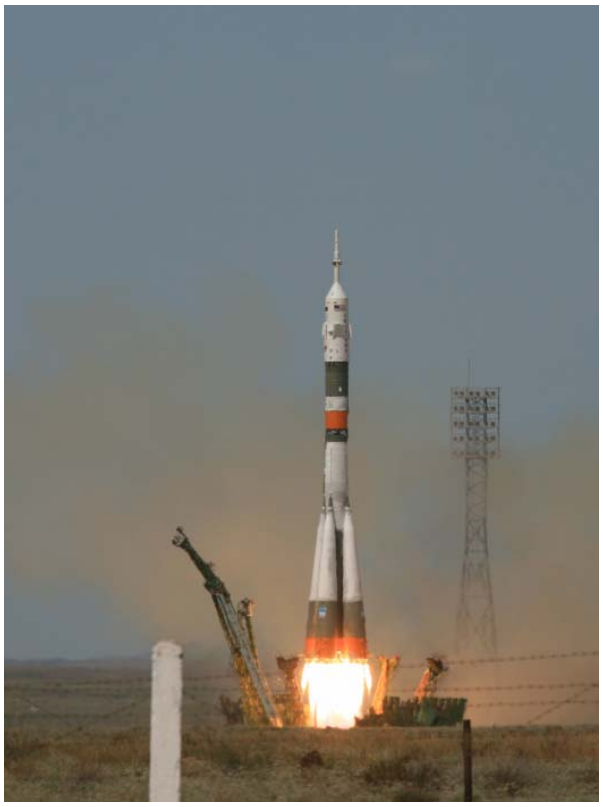

Fig. 1: Launch of Soyuz TMA-15 (19S) from Baikonur on 27 May 2009

Frank de Winne and his two crewmates were in good mood before the launch and reached the ISS two days later after a smooth coast and docking. Since the arrival of the additional crew members the work load of the Flight Control Teams (FCT) has increased because more work has to be prepared, planned and supported from ground.

There are more events in the schedule but due to the team ramp up initiated in 2008 the FCT at the Columbus Control Center (Col-CC) is able to cope with the new work load. The nominal staffing at Col-CC is the following (see [5]):

- 1 FD 24/7,
- 1 OC/COP 24/7,
- 1 DMS/COMMS 24/7,
- 1 SYS 24/7,
- Eurocom 8/5,
- COSMO 8/5
- 1 additional OC/COP as purple shift
- PASO and EST 8/5

Fig. 2: Farewell ceremony of the TMA-15 crew at Baikonur

For the ESA OASIS Mission of Frank de Winne the Eurocom is on console for 16 hours per workday and a Eurocom is on-call on the weekends to provide full support to the European Astronaut.

Training and Preparation for 6 Person Crew

To be prepared for the 6 person crew onboard ISS the Flight Control Team has to be trained especially for any possible emergency onboard ISS. Hence, an updated Emergency Training has been developed by the Col-CC Training Team with support from NASA and has been teached in small groups to the whole Col-CC FCT over the last months. The knowledge of all FCT members at Col-CC and of the onboard crew has been renewed and tested in several On-Board Trainings (OBT) concerning the three different emergency cases fire, toxic spill and depress.

Besides the training the Flight Control Team at Col-CC has to check together with NASA and the other International Partners (IPs) if all operational products are up to date and applicable for the 6 person crew. The products which have been checked are the Flight Rules (FR) given the boundary conditions for operations, Operational

Interface Procedures (OIP), defining the interfaces between the IP control centers and the Joint Operational Interface Procedures (JOIP), defining the interfaces between the ESA control centers.

Overview on the first 500 Days of Operations

Columbus is now active since February 2008 and has been operated in the following increments:

- Increment 16
- Increment 17
- Increment 18
- Increment 19&20

There were a lot of highlights but also the lessons learned and changes in the setup in the more than 1.5 years of operations.

Fig. 3: Greg Chamitoff during installation of Geoflow experiment (Source: NASA)

Increment 16 was dominated by the berthing and activation of Columbus which has been described in [6]. The first Columbus experiment started already a week after shuttle undock in the BIOLAB rack. The WAICO I experiment – Arabidopsis plants growing in weightlessness – was performed during the whole stage 1E and brought back to earth with Flight 1J/A. Additionally one external payload and two NASA racks have been relocated into Columbus.

The most important event in increment 17 was the update of the Columbus on-board software called Cycle 11 upgrade. This added some features to the onboard computer and corrected some flaws in the system (see [6]). In addition 2 more NASA racks were added to the Columbus module.

In increment 18 the first year of Columbus in space was celebrated (see Fig. 4) and important pay-loads were performed in Columbus; on the one side GEOFLOW to simulate the development of vortices in the outer liquid core of the earth and Protein Crystallisation Diagnostics Facility (PCDF) to grow protein crystals in µ-gravity conditions.

Fig. 4: Birthday cake for the Columbus FCT at the celebration of 1 year Columbus in orbit

Increment 19&20 focus besides the 6 person crew on the next Columbus onboard software upgrade called cycle 12 including a new LAPAP MkII software for the portable workstations (PWS) and on the return of the PCDF as well as the EUTEF experiment.

Payload Operations Support by Col-CC

After the Columbus setup was completed in October 2008 by moving the HRF1 & 2 racks to Columbus, a number of payload experiments were started and supported by Col-CC. One of most the important one was GEOFLOW, which is shown in Fig. 5. GEOFLOW shall show the creation of vortices in the outer core of the earth which seems to be responsible for establishing the earth magnetic field. After a number of successful runs the GEOFLOW experiment was brought back to Earth with STS-119 (15A) in March 2009 and will be refurbished for the GEOFLOW 2 experiment.

Fig. 5: GEOFLOW Experiment in FSL

The PDCF experiment was brought to orbit with the same Shuttle flight 15A in March 2009 and installed in the European Drawer rack (EDR). In a number of campaigns until Shuttle flight 2 J/A in August 2009 the growth of protein crystals was investigated in this facility.

Fig. 6: PCDF experiment in EDR

Beside the permanent support of Col-CC during the experiment runs the preparation and execution of the transfer of PCDF between the Shuttle middeck logger and EDR was the most important task because of the time criticality (thermal clock) of these activities.

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 in parallel to the NASA experiment Tissue Equivalent Proportional Counter (TEPC) was installed in the module in summer 2009. For experiments like SOLO, NEUROSPAT (see Fig. 7) 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.

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 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.

After one year of operations it became evident, that the cooling loop of the Columbus module needs some additional water, due to water sampling, opening and closing of quick disconnects (QDs) and small leakages in the lines. The EST together with the FCT developed the necessary procedures for a water refill in the Columbus cooling loops which were checked by the teams using simulators and during expert meetings. After ensuring that the necessary crew time was available the water refill activity was

successfully performed in August 2009. This ensures a fully operational cooling system over the next year up to the next necessary water refill.

In July 2009 the prime Command & Memory Unit 1 (CMU 1) failed and the hot backup CMU 1 took over the task. This was done without any impact on nominal system or payload operations. Nevertheless Columbus has lost some redundancy and in case of a second failure, i.e. the failure of the backup CMU1 some subsystems of Columbus would no longer be reachable from ground. Hence, it was decided to exchange the CMU 1 as soon as possible and to bring back the old CMU 1 with the shuttle flight 17A for analysis and repair. This again initiated the setup of a special task force of EST and FCT to develop procedures for the CMU exchange. In this case the preparation work also involves NASA because a NASA rack in Columbus has to be tilted to reach the unit to be exchanged. After some adjustments of the foreseen day of exchange and the inclusion of the necessary crew time for preparation and execution in the timeline the exchange was successfully performed on 21 August 2009.

Fig. 7: Tim Kopra working with Neurospat in Columbus in July 2009

Beside these major tasks a lot of routine maintenance activities like valve cycling, leak checks, water sampling, Intermodule Return Fan Assembly (IRFA) replacement and smoke detector cleaning were performed in the last year.

Columbus Software Upgrade

The main task of the Col-CC during the 17A stage was the preparation and execution of the Columbus onboard software upgrade called Cycle 12. The Col-CC team together with the Columbus Engineering Support Team prepared themselves in simulations for the transition scheduled for 22 September and established all the products needed for operations after the transition, e.g. the development, test and validation of the new ground software needed to work with the new onboard software. A second operational control room was set up to allow the flight control team to work with the Columbus module using the old software in main control room before the transition and the new software in the second control room after the onboard transition without reconfiguration on ground. After about 4 weeks and an upgrade of the software in main control room, the flight control team changed back to the main control room. This software upgrade has to be performed to improve the capabilities of the Columbus onboard system including a new LAPAP MkII software for the portable workstations (PWS) in Columbus.

Supported Shuttle Missions

The ULF2 Shuttle mission (STS-126) in November 2008 was a mainly “standard” Shuttle mission from Col-CC point of view. The Columbus FCT supports the mission with the pre-planned load shedding, unloading and temporary stowage of supplies in Columbus as well as water sampling of the Columbus cooling water for return to Earth and analysis. In the course of the mission Columbus receives an additional rack called Zero-G Stowage Rack (ZSR) for stowage items in Columbus.

The next Shuttle mission started with one month delay despite desperately awaited by European scientists: STS-119 carries beside the main payload – the fourth solar array – a major ESA experiment called PCDF. Col-CC was heavily involved in the start of the experiment because PCDF had a very narrow timeline for the transport from the shuttle middeck locker to the EDR. Hence, the mission has to be prepared very well together with the USOCs and with JSC to ensure a smooth start of this payload. Additionally it had to be ensured that the ESA ground segment and the Col-CC infrastructure are well prepared and in full redundant mode to be able to activate the experiment within the given time.

The following shuttle mission 2 J/A (STS-127) – the main payload was the JEM Exposed Facility (JEM-EF) – has a delay of more than a month which allows in return to prolong the experiment time of PCDF before the planned return to Earth

with this flight. As for the start of the experiment the transfer from the EDR rack to the Shuttle middeck locker must take place within a given timeframe of 100 minutes. Due to the experience gained in 15A the preparation was easier but the same precautions have to taken into account. Nevertheless the delay of the launch leads to some interference with other ground activities like training and tests, which have to be moved to other control rooms or to other days.

STS-128 (17A) was again a shuttle mission of major importance for Col-CC: During this flight the European Technology Exposure Facility (EUTEF) was de-installed during an EVA and brought back to Earth for analysis of the material samples exposed to space environment over more than 18 months. The Col-CC Flight Control Team had to ensure that all inhibits were set before the de-installation began and has to support the NASA acitivities during the EVA. To ensure this the timeline and the flowcharts had to be developed, checked and finalized together with the relevant USOC and with JSC flight controllers (see Fig. 8). The same has to be performed for the external NASA payload on Columbus called MISSE-6 which was also de-installed and transferred to the Shuttle for return to Earth. Hence, this mission was one the most important one since the 1E mission and very complex preparation.

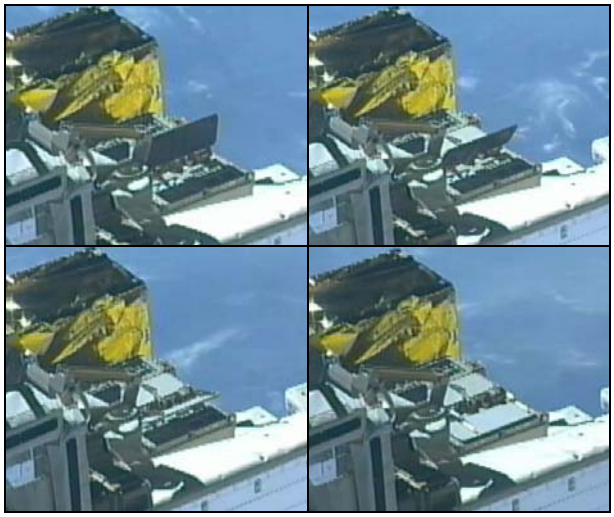

Fig. 8: Pictures from the closure of Expose-E lids on 20 August 2009 (Source: NASA)

Lessons Learned and Changes in Setup after 1 Year of Operations

After more than 18 months of continuous 24 hours / 7 days staffing of the main Columbus control room a lot of experience has been gained by the whole team. To improve the work flow of parallel work on console and preparation work a lot of countermeasures and process changes have been introduced during the last months. The lead increment flight director who cares about the coordination of the ongoing increment is released mostly from console work that he can focus on coordinating the Col-CC tasks with ESA Mission Director (MD), the ESA/IOT Increment Manager and the NASA Increment Lead Flight Director. Additionally the Lead Increment FD of the following increment will get a reduced shift work load that he can cope with the preparation work. Together with improvement of the processes and adaptation of the necessary documentation the preparation work was more streamlined in the last months.

These measures were only possible because the ramp up of the team introduced in spring 2008 shows positive results and the Columbus Flight Control Team comes closer to the foreseen standard team size of 42 certified flight controllers. Despite some team members already leaving the team in 2008 shortly after 1E the Mission Operations Service together with Training Service was able to train and certify enough new team members to overcompensate the attrition rate. The Col-CC FCT is looking forward to reach the full number of certified flight controllers by the end of 2009. The training will carry on ensuring that enough team members are trained and certified to compensate the normal attrition rate.

Conclusions and Outlook

After 18 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. Hence, 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 especially with ESA astronaut Frank de Winne who is in orbit since May 2009. The next challenge is already waiting for Frank de Winne and the Col-CC team: Frank de Winne will be the first ESA ISS commander in Increment 21 starting in the first half of October 2009. The FCT is eager to give Frank the support needed to fulfil his new job in orbit.

While the first external payload has already brought back from orbit and the second – SOLAR - is waiting for its return in 2010, Columbus will receive an additional internal rack called MARES in spring 2010. MARES will be brought into orbit with inside a Multi-Purpose Logistics Module (MPLM) with Shuttle flight 19A (STS-131) and permanently installed in Columbus. This will again increase the experiment capability of Columbus with all internal slots filled.

Fig. 9: Current assembly status of the ISS after STS-127 (Source: NASA)

Meanwhile two new European long-term astronauts are announced to live and work at the ISS in the next years: Paolo Nespoli in Increment 25&26 as well as 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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