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# Consolidating Columbus Operations and Looking for New Frontiers

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# CONSOLIDATING COLUMBUS OPERATIONS AND LOOKING FOR NEW FRONTIERS

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**ABSTRACT**

In January 2014, the Columbus Flight Control Team (FCT) started with a modified real-time operations scenario. Since then the 24/7 shift coverage was reduced to the Col-Flight Director and the STRATOS position. The whole year of 2014, and also partly 2015, was needed to consolidate the new set-up, with its new and profound constraints, to find workarounds for special operational cases, to finalize operational product adaptations, but also to reduce the workload of the Columbus Flight Control team taking into account the reduced resources. Nonetheless, it is clear that the Col-FCT is at the limit of their capabilities, especially during high activity phases. The consolidation phase was necessary due to the short preparation and implementation phase in late 2013 and early 2014. In parallel, the Columbus Execute Level Planning team was merged with the Operations Coordinator team.

ESA astronaut Samantha Cristoforetti together with NASA astronaut Terry Virts started a completely new type of experiment called Airway Monitoring, which broadened the experience of the Col-FCT outside of the Columbus module, and gave them the opportunity to prepare an experiment in both the Destiny module and in the US airlock. Col-CC supported the responsible USOC, the Danish Aerospace Company (DAC), in the development of the Ops Products, coordinated the preparation work, and established and maintained the necessary interfaces to NASA for the new environment, i.e. the US Airlock.

## Introduction

The years 2014 and 2015 show the highest frequency ever of ESA astronauts on-board the ISS. Shortly after the six-month sojourn of the German astronaut, Alexander Gerst, which ended mid-November 2014, the Italian astronaut, Samantha Cristoforetti, flew to the station. She stayed – with an unplanned extension - until June 2015 leading to the longest single stay of a female astronaut in space. In September 2015, the Danish ESA astronaut Andreas Mogensen was on ISS for 10 days for the ESA Short Duration Mission called IRISS. Finally in December 2015, the next, long-term, British ESA astronaut Timothy Peake, is bound for the ISS.

Based on the long experience of Col-CC in manned space operations starting with the Eneide Mission in 2005 and the support of the Astrolab mission with Thomas Reiter in 2006 (see [1] and [2]) and then from 2008 onwards with Columbus operations (see [6] to [13]) all these missions could be successfully prepared and supported. Despite some limitations the new operations concept offers enough robustness to support such peak loads and will allow operating Columbus until at least 2020 assuming that the boundary conditions won't change (see [10]).

In parallel to the restructuring and the consolidation of the new setup of the Col-CC FCT the preparation of new exciting experiments like Airway Monitoring, EML or PK4 have been performed. As an example for such experiments the preparation, coordination and execution support for the Airway Monitoring experiment will be described below.

## European Astronauts on ISS

In the first months of his stay at ISS Alexander Gerst had already very exiting tasks like ATV-5 docking support, installation of MagVector and Wisenet as well as EML (Electro-Magnetic Levitator) installation. (see [13]) But the second half was bringing even more highlights. After a screw was broken during the first part of the EML installation in August a special procedure was established in close cooperation between ground team and ISS team to remove the screw (see Fig. 1). After the successful removal of the screw the EML could be completely installed and is now used in operations.

Fig. 1: Alexander Gerst removing a broken screw during EML installation (Photo: NASA)

Some weeks before his return to Earth ESA astronaut Alexander Gerst was working outside the ISS together with Reid Wiseman (see Fig. 2).

On 10 November 2014 Alexander Gerst returned safely to Earth in Soyuz 39 together with his crewmates Reid Wiseman and Maxim Suraev. This time there was no big pause for the Flight Control Teams all over Europe because already 2 weeks later Samantha Cristoforetti was heading towards ISS.

On 23 November 2014 the next expedition consisting of T. Virts, R. Shkaplerov and S. Cristoforetti docked with their Soyuz 41 spacecraft to the ISS. In the following weeks a full programme was waiting for the astronauts starting with the first session of Airway Monitoring, installation of the Plasma-Kristall (PK-4) experiment hardware and the second run of Airway Monitoring which is described later in more details. Shortly after Christmas the ISS crew and the teams on ground had a stressful day because a supposed ammonia leak kept all teams busy for some hours until it was confirmed as a false alarm. This was one of the biggest contingency events since ISS is in orbit but it showed that the teams on board and on ground were able to fulfil their tasks even in this very demanding situation.

Fig. 2: Alexander Gerst during his EVA (Photo: NASA

After the loss of Progress 59 the whole flight plan was reworked extending the stay of Expedition 43 by about one month. Due to this prolongation of the mission Samantha Cristoforetti was setting a new record for the longest single stay of woman in space. Beside this personal record the ESA astronaut used the extra time to install some long-awaited new hardware. First the Solid State Disk (SSD) was installed replacing the outdated video tape recorder still in use in Columbus. Second one of the Water-on-off-Valves (WOOV) could be replaced because the spare valve was already waiting on board of the ISS.

On 11 June 2015 expedition 43 return safely to earth with Soyuz 41 ending a very exiting mission.

## New Operations Concept

In [13] the new operations setup implemented in January 2014 is described. Meanwhile this setup has been fully implemented and experience during two ESA long-term missions – blue dot and Futura – has been gained. Experience showed that the new approach is feasible but some deficiencies cannot be avoided after this large reduction of the on-console team. Standard working days can be

fully supported with the reduced team but for high activity phases either an activity specialist will enhance the console team or the sequence of operations has to be slowed down to reduce the risk of on-console errors.

One of the most visible impact to the other partners is the reduction of the planning position from a 24/7 to an 8/7 scheme. Despite some adjustments which have been implemented to optimize the setup the availability of the COMET – the Col-CC planning position – is much less than the planning position of the other partners. Hence, some processes have to be adapted to find a suitable approach with all partners.

Meanwhile the transition to STRATOS is fully implemented with the last DMS/Systems shift in December 2014 after all STRATOS team member have been successfully cross-certified (see [11]). Due to the restructuring of the ESA ISS exploitation project, the Columbus FCT is asked to setup and establish new interfaces and take over some new tasks like reporting for payload outside Columbus and taking over book-manager and authoring of most of the Columbus Onboard Data Files (ODF).

The next big challenge for the Col-FCT was the short duration mission of ESA astronaut Andreas Mogensen (see Fig. 3) in the first half of September 2015. He performed a large number of experiments during his short stay in orbit from 2 to 12 September. Hence, the preparation and execution of the mission was very demanding for the Columbus Flight Control Team and the involved USOCs to ensure a well prepared mission setup for the astronaut during his stay in orbit. To ensure this some extra support by additional COMET shifts and an increased off-console team had been established at Col-CC.

## New Planning Software

Also in 2014, NASA started to introduce a new planning system called OPTIMIS, consisting of SCORE, WebAD and Viewer. It is intended to replace the well-proven, but less user-friendly, planning system suite composed of CPS and OSTPV. After overcoming some initial challenges, SCORE is in use for operations since start of Increment 43/44 onwards. The next step is the implementation of the new Viewer in the third quarter 2015. The viewer replaces the up to now used OSTPV (On-board Short Term Plan Viewer) to display timeline and procedures on ground and on board ISS. During summer 2015 several test were performed to ensure a smooth start of the new tool for all users and it is in operational use since September 2015.

Fig. 3: Andreas Mogensen tests a 'biomimetic' membrane (Photo: NASA)

The final step of the transition at Col-CC is the operational implementation of the WebAD tool. WebAD will be used for planning data collection and will replace the currently used OPDCS (Operations Planning Data Collection System). In autumn 2015 the ESA teams are trained on the new tool to be ready by end of 2015. With the start of the preparation phase for increment 49/50 the WebAD tool will be used for the data collection and planning of the increment. Until September 2016 OPDCS and WebAD will be used in parallel for operation and preparation, respectively. From mid of September 2016 onwards it is planned to retire OPDCS and to use WebAD for all planning tasks.

## Airway Monitoring

The scientific goal of ESA's Airway Monitoring experiment is to investigate how space flight affects lung health by measuring exhaled nitric oxide (NO) levels as evidence of airway inflammation. Previous research indicates that humans in space are prone to airway inflammation

due to the increased risk of inhalation of dust and other free-floating particles. Exhaled NO is an indicator of airway inflammation and clinically used to monitor asthma and other inflammatory airway diseases. In order to investigate the effects of microgravity and the combination of microgravity with low pressure on exhaled NO, the Airway Monitoring experiment requirements foresee on-board measurements at ambient pressure and low pressure (10.2 psi – 700 hPa). The US Airlock on ISS serves as hypobaric facility for the low pressure measurements, the ambient pressure measurements are performed in both the US Airlock and the US Lab as the supporting hardware has been designed and certified for these modules. Airway Monitoring is the very first science experiment which has been conducted in the US Airlock and the first experiment led by Col-CC which is entirely outside of the Columbus module (see [14]).

The experiment setup in the US Lab and in the US Airlock required close collaboration of the Mission Control Center in Houston (MCC-H), the Payload Operations and Integration Center (POIC) in Huntsville, the Danish Aerospace Company (DAC) as User Support and Operations Center (USOC) and Col-CC as prime responsible center for the experiment. Based on the expected amount of work for the pre-coordination and preparation of Airway Monitoring, it was decided to establish a dedicated “Airway Monitoring Team” at Col-CC, consisting of a Flight Director and an Operations Coordinator from the European Planning and Increment Coordination (EPIC) team. The Airway Monitoring Team worked alongside DAC and the Increment teams at Houston and Huntsville.

The operational pre-coordination started with an Airway Monitoring workshop held in Houston in May 2014. The MCC-H and POIC teams were provided with an experiment overview including a briefing about the equipment setup for the US Lab and US Airlock sessions and associated planning requirements. Necessary support from MCC-H and POIC teams was worked out which represented the baseline for the definition of roles, responsibilities and coordination choreography in a dedicated Airway Monitoring Operations Interface Procedure (OIP). The OIP is furthermore defining specific stowage agreements, communication interfaces and the treatment of anomalies which could occur during the experiment execution. In the following months, the teams elaborated step by step procedures for the experiment execution in the US Lab and US Airlock, documented mandatory onboard system configurations and medical requirements in Flight Rules and worked out the planning details for each session.

With the arrival of the dedicated Airway Monitoring hardware on ISS via the SpaceX-5 vehicle and the opening up of the science window for Samantha Cristoforetti and Terry Virts, the first Airway Monitoring session was executed in January 2015. Due to a less complicated setup of the experiment hardware in the US Lab in comparison to the US Airlock (8 extra hours of stowage relocation from the US Airlock has to be planned!), it was decided to perform the ambient part of Airway Monitoring first. The US Lab session was planned over 3 days, with a familiarization for both crewmembers on the first day and the gathering and setup of the Airway Monitoring hardware in the US Lab on the second day.

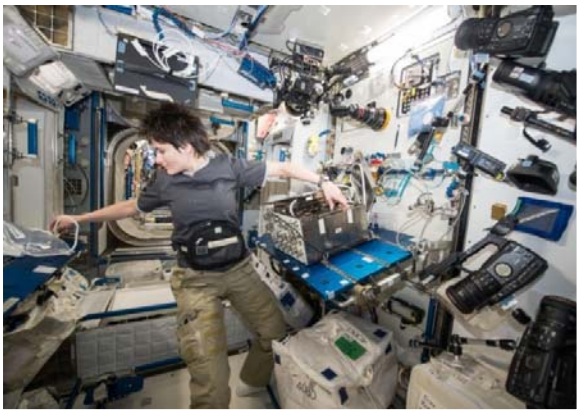

Fig. 4: Samantha Cristoforetti unstowing the Airway Monitoring hardware (Photo: NASA)

Following hardware activation by the crew, a software upgrade for one of the involved units and subsequent checkout steps had to be performed from ground to get the equipment ready for the actual experiment. The science measurements were then performed by Samantha Cristoforetti and Terry Virts on the third day including science data downlink and hardware teardown.

Based on scientific requirements the two Airway Monitoring sessions in the US Lab and the US Airlock had to be at least 30 days apart from each other. This gave the Airway Monitoring team at Col-CC some time to integrate lessons learned gained during the ambient pressure session in the planning of the US Airlock session. For example, the allocated time for the hardware setup was increased based on crew’s feedback following the US Lab activities, also the planning sequence was

changed to allow more time for ground commanding in case of software hiccups, without impacting the crew's schedule. The Lessons learned and the readiness status for the US Airlock session were discussed via telephone conference ("Joint Operations Panel") with the involved operations centers and final agreements made in preparation of the low pressure session.

Fig. 5: Samantha Cristoforetti performing Airway Monitoring measurements in the US Lab (Photo: NASA).

The second low pressure science session of Airway Monitoring was planned over 5 days, with US Airlock preparation and hardware relocation activities, medical briefings and conferences for both crewmembers and Airway Monitoring hardware preparation activities on the first 2 days. The science measurements including depressurization of the US Airlock, further medical conferences with the crew and science data downlink occurred on day 3, while restow activities and US Airlock reconfiguration tasks performed by the crew were distributed over another 2 days.

On the most intensive day 3, Col-CC FCT as prime responsible control center for the Airway Monitoring experiment coordinated the support of the Houston and Huntsville Flight Control Teams for the Airlock depressurization and Airway Monitoring hardware commanding, supported the crew during the experiment execution and ensured a safe conduction of the experiment in line with the previously elaborated Flight Rules. Due to the high workload and responsibility of Col-CC it was decided to have the "Airway Monitoring Team" actively supporting real-time operations alongside the standard FCT in the control room. While the "Airway Monitoring Flight Director" solely concentrated on the coordination of the experiment, the Flight Director who normally covered the shift remained responsible for all other real-time tasks. This special setup ensured that the executing FCT had all necessary information and previously made agreements available during the experiment execution and task sharing prevented the FCT from being overloaded.

Fig. 6: Samantha Cristoforetti performing the Airway Monitoring experiment in the US Airlock (Photo: NASA)

With flexibility and short term deviation from the nominal FCT setup Col-CC managed to successfully coordinate challenging new experiments like Airway Monitoring, even outside of the Columbus Module. The establishment of dedicated teams within the Col-CC FCT that prepare and execute demanding new experiments could be a way to face similar challenges in the future.

## Conclusion

The years 2014 and 2015 were one of the most exciting but also most challenging phase of the Columbus flight control team. Shortly after the second restructuring and resource reduction of the Columbus team two ESA astronauts – Alexander Gerst and Samantha Cristoforetti – spent together more than a year nearly continuously in orbit. They installed several new experiments in Columbus like EML and PK4 and performed new style experiments like Airway Monitoring. The new

reduced setup of the Col FCT made it sometimes difficult to fulfil the requirements and some adaptation to the timeline and restriction to operations were needed. Nevertheless nearly all goals of the increments could be fulfilled and both increments were successfully performed.

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