

# The Future of Columbus Operations

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After 6 years of successful Columbus operations a decision point for the Columbus Control Center has been reached. The trade-off between operational flexibility and cost saving effects has to be well balanced. Based on the experience of the operations of a manned vehicle in orbit and the science goals for the experiments performed in Columbus over the next years the way forward has to be determined. Looking at the mid- and long-term plan the tasks for the Columbus Control Center will increase over the next years. On the one side a large number of new payloads and experiments are ready to be executed, which will enhance the science return from the Columbus module and will ask for a control center in full swing to support science operations. On the other side there is high activity time for European Astronauts on ISS in the next two years with Luca Parmitano already in orbit during Incr. 36/37, Alexander Gerst in Increment 40/41 launched in May 2014, Samantha Cristoforetti during Increment 42/43 starting December 2014 and Timothy Peake in Increment 46/47 from December 2015 onwards. This will be complemented by the short-term flight of Andreas Mogensen in September 2015. Additionally the last ATV-5 flight will be supported by Col-CC in 2014. These missions will need full support from the control center to ensure the success of the mission and to achieve the envisaged science return. To be able to support these European payloads and missions and in addition to support the NASA payloads in Columbus continuously, a minimum infrastructure for the control center is needed. Col-CC has already severely reduced the costs for operations in the last years and increased the efficiency to support long-term Columbus operations until 2020 and beyond. Now a stable configuration is necessary to be able to achieve the goals set for Columbus science return in the next years.

## I. Introduction

The staffing of the Col-CC Operations Team has been changed several times in the 6 years of Columbus operations. During the preparation phase of Columbus operations studies were performed to determine the necessary number of on-console and off-console staffing for Columbus Control Center (Col-CC). This early approach described in Col-CC preparation documents with six 24/7 FCT positions and two 24/7 GCT on console was the basis for the preparation phase and the first training phase in 2005 and 2006. In the Flight Operational Readiness Review (FORR) in December 2006 ESA introduced a reduced on-console concept with 4 24/7 FCT positions, only, for the time after the 1<sup>st</sup> European Flight (1E). The switch from six to four 24/7 FCT positions was done immediately after the end of the 1E mission and was kept with only minor changes until April 2013. The reduction from four to three 24/7 FCT positions starting April 2013 was introduced gradually during a transition phase. On 15 January 2014 the next reduction in the FCT has been introduced going from three to two 24/7 FCT positions. A reduction of the GCT 24/7 position from two to one is currently planned for the beginning of 2015. In the following chapters the step by step reduction of the FCT is explained. We will also present the work constraints for each step

which will show that in order to ensure smooth operations of Columbus also in the future the necessary minimum is now reached.

## II. Col-CC Setup during 1E and first years of steady-state operations

In Col-CC preparation documents as well as in [1], [2], [3], [4] and [5] the Col-CC setup for 1E and the steady-state operations is developed and described based on experience gained in former manned space missions like FSLP (STS-9, First Spacelab Payload), D1 (STS-61A, First German Spacelab mission), D-2 (STS-55, Second German Spacelab mission) and SRTM (STS-99), all operated and supported by the German Space Operations Center (GSOC). From the experience gained during this mission the following setup of the Col-CC FCT was deemed necessary to fully support all mission requirements in Columbus during the steady state phase:

- 1 Flight Director (Col-Flight, 24/7)
- 1 Systems Engineers (Col-SYS, 24/7)
- 1 Data Management Systems Experts (DMS, 24/7)
- 1 Communication Subsystem, Expert (COMMS, 24/7)
- 1 Operations Communicator (OC, 24/7)
- 1 Columbus Operations Planner (COP, 24/7)
- 1 Columbus On-Orbit Stowage and Maintenance Officer (COSMO, 8/5)
- 1 Crew Communicator (Eurocom, 8/5)

Each group staffing a 24/7 position has to be staffed by at least 6 persons to ensure the continuous covering of the console position over long time (a year or more). Additional team-members were foreseen to work the offline tasks of the group and to create a small buffer for staff attrition. This setup was also the baseline for the 1E Mission (STS-122) in 2008 during which Columbus was brought to orbit, installed and activated the module. These positions were complemented by additional positions dedicated to this initial mission like the Activation and Checkout Engineer (ACE) as described in [6].



**Fig. 1: Main Control room of the Columbus Control Center during 1E preparation (Photo: DLR)**

The Ground Control Team (GCT) positions at Col-CC take care of the European Ground Segment (IGS, communications lines, services, nodes) as well as the GSOC internal systems necessary to provide data (on-board/ground), commanding capability, voice and video services to the FCT and the European-wide ESA user community. The GCT consists of:

- 1 Ground Controller (GSOC-GC, 24/7)
- 1 System Controller (Syscon, 24/7)
- 1 Video Controller (GSOC-Video, 8/5 (*this position was planned but not realized see below*))
- 1 Ground Operations Planner (GSOC-GOP, 8/5 off-console)

These 24/7 positions are supported by a group of Subsystem Engineers (SSE), who work 8/5 and are experts for the various subsystems used at Col-CC like the Video Distribution System (ViDS), Voice Conferencing Subsystem (VoCS), Monitoring and Control System (MCS) or Data Services Subsystem (DaSS). The GCT and the SSEs are operating the Ground Segment to support various missions in parallel:

- Columbus Operations
- The ATV missions (in support to ATV-CC)
- Early utilization pre-Columbus
- ESA Experiments outside Columbus

Already during the preparation phase of 1E and the steady-state operation phase it was realized that the approach taken from short-term missions like D2 are not fully applicable for a long term mission like Columbus. Here the experience gained in 2006 during Astrolab, the first ESA ISS long-term mission, was very helpful to get an insight into the ISS operations approach and lessons learned from this mission (see [4], [5] and [3]). In this regard, the Video controller was never staffed as a separate position, but was – from the beginning – executed by a Video Subsystem Engineer whenever this function was required. Additionally first cost reduction efforts were performed for the steady-state operations phase of the upcoming years. Hence, a reduced FCT setup needed to be developed with combined positions taking into account the additional experience and the new boundary constraints:

- 1 Col-Flight (24/7)
- 1 Col-SYS (24/7)
- 1 DMS/COMMS (24/7)
- 1 OC/COP, (24/7)
- 1 Columbus On-Orbit Stowage and Maintenance Officer (COSMO, 8/5)
- 1 Crew Communicator (Eurocom, 8/5)

plus

- 1 Ground Controller (GSOC-GC, 24/7)
- 1 System Controller (Syscon, 24/7)

The main difference to the original (1E) approach was the merging of the DMS and the COMMS positions to one merged position called DMS/COMMS as well as the merger of the OC and the COP position to the new OC/COP position. In effect the number of 24/7 positions in the FCT was reduced from six to four, while the 8/5 positions stayed. Also the 24/7 positions (GC and Syscon) of the Col-CC ground control team were not changed. But the off-line subsystem engineering team was reduced. SSE teams for different subsystems were crosstrained or totally combined. The operational team (GC and Syscon) were trained to get more subsystem knowledge and taking over off-line tasks from the SSEs (see [3]).

This setup which is shown also in Fig. 2 was used for the first six years of operations from 2008 until 2013. This setup was very successful as described in [7] to [10] and offered adequate knowledge and workforce on console which in consequence allowed performing all the necessary tasks to ensure mission success:

- fast reaction to on-board events
- work on real-time (R/T) change requests in case of troubleshooting
- Keeping the full FCT knowledge on console in order to provide competent R/T support for Col Flight in critical situation
- Taking over of some USOC tasks like payload monitoring in idle time
- Flexibility on short term timeline changes to increase mission success probability
- Keeping a high availability of the entire European ground segment

Because of the frequent launch delays before 1E the need date for the full FCT staffing showed large uncertainties. Therefore at 1E launch the available number of team members per positions was lower than longterm required. Hence, a number of trainees had to be hired before and after 1E. This was partly compensated by the reduced need of on-console personnel due to the reduction of the number of positions to six to four. Nevertheless a significant number of flight controllers had to be hired and trained in short time frame to increase the team size. In parallel the already certified Flight Controllers had to be cross-certified for the combined positions.

This led to the major problem in the first years because it took a long time to reach the defined number of team members per position (on-console + off-console). First the training resources could not be increased to the needed

number, because there were not sufficient facilities and personnel available on the training side. Secondly the fast pace of the ISS assembly sequence with the impact on Columbus operations put a high load on the on-console and the off-console team (1J/A (STS-123), 1J (STS-124), ULF2 (STS-126) and 15A (STS-119)). This didn't allow extra effort from the certified Flight Controllers to certify the new trainees faster than the standard process. Hence, the first time when all groups have reached their full size of certified people was in 2010, only. From this time onwards, the teams could exploit the availability of the full FCT knowledge and could improve the working setup of the FCT.

The training and certification of the Ground Control Team (GCT) was completely decoupled from the Flight Controller training already in the early preparation phase for 1E. The initial team was trained during the validation phase of the Ground Segment by doing all the testing. Therefore the team could be kept small in the beginning. As one of the tasks of the GCT was to provide training resources for the FCT (in terms of simulations support), early-on it was evident that the GCT had to follow a less formal but faster training approach. By doing the majority of the training supervised on-console the training time could be reduced and therefore the number of trainees could be reduced to one per position.

### **III. Introduction of STRATOS and Ground Segment changes**

In 2010 the first ideas on how to improve the efficiency of the FCT were investigated, which is on the one side described in [9] and on the other side in the ISS cost reduction report [11] of 2010. In this investigation the improved working setup, the enhanced efficiency and the gained experience of the FCT was taken into account and it was started to analyze how the performance and the efficiency of the FCT can be improved. In the course of this effort it was also analyzed how possible mergers of 24/7 positions with 8/5 position to gain efficiency across the borders of the position, which was not possible in the existing setup.

In parallel to this effort the boundary conditions for reduction of resources for the next years were fixed. The in depth investigation and comparison with the envisaged changes showed that the exploitation of the gained increase of experience and efficiency in the FCT was not enough to counteract the requested manpower reduction. Hence, the performance of the FCT has to be reduced.

To comply with the given boundary conditions several options were analyzed but all results showed that the only possibility to meet the given constraints was to decrease the number of 24/7 FCT console positions from four to three as described in [12] and [13]. Given this it was analyzed which console positions should be merged to reduce the necessary resources. The study showed that the less impacting solution with respect to transition phase and final implementation phase was the following:

- 1 Col-Flight (24/7)
- 1 STRATOS (24/7)
- 1 OC/COP, (24/7)
- 1 Columbus On-Orbit Stowage and Maintenance Officer (COSMO, 8/5)
- 1 Crew Communicator (Eurocom, 8/5)

plus

- 1 Ground Controller (GSOC-GC, 24/7)
- 1 System Controller (Syscon, 24/7)

The GCT console positions were kept unchanged but another reduction of the off-line support team SSEs was done leading to a bare bone minimum to 1.5 persons average per subsystem. In order to provide a permanent availability of one engineer per subsystem, 1.5 persons are the absolute minimum to overcome holidays and illness. The cross-training of GCT members to subsystem matter experts was advanced and again more SSE duties were moved to the GCT.

After a management agreement in August 2011 on this reduced operations concept, the concept details were evaluated, the changed interfaces investigated and a list of procedures established, which have to be changed. The merger of Systems and DMS/COMMS included the two positions taking care of the central Columbus system, therefore an in-depth analysis of all ops products which took some months had to be performed. In parallel a cross-training concept was developed covering the needs of both groups – DMS/COMMS and Systems – to close the knowledge gaps for the merged position STRATOS. After about 9 months of preparation time the first STRATOS

trainees started with their training and were able to go on console in their new role in April 2013. Due to the reduced number of on-console positions the available knowledge on console and the capabilities of the on- and off-console team has been reduced and the flexibility especially of the on-console work has more constraints than before.

Due to the cross training requirements and the restricted number of simulations the cross training was scheduled over more than two years and is planned to be finished by the end of 2014. With more than half of the STRATOS team members certified it allowed a reduction of the DMS and Systems double shifts to a very low number. The long transition time of more than 3 years was driven by the ongoing operation which only allowed putting a small part of the team members in training because the others have to prepare and execute realtime operations.

#### **IV. Implementation of the New Operations Concept**

While the STRATOS cross training and transition was in full swing by mid of 2013 the next reduction was initiated in August 2013 after long-term negotiations on the future setup of the Col-CC Operations Team. Starting from the high level “night watch” concept created in short timeframe an “improved night watch” concept was established which was able to fulfil the baseline ESA requirements of Columbus operations with reduced resources.

- 1 Col-Flight (24/7)
- 1 STRATOS (24/7)
- 1 Columbus On-Orbit Stowage and Maintenance Officer (COSMO, 8/5)
- 1 Crew Communicator (Eurocom, 8/5)
- 1 Columbus Operations & Mission Execution Timeline Engineer (COMET, 8/7)

plus

- 1 Ground Controller (GSOC-GC, 24/7)
- 1 System Controller (Syscon, 16/5)

The initial assumptions/boundaries for this new operations concept were on-board payload operations and activities to be mainly during day-time and working days only and a reduction of the Col-CC operations teams (FCT and GCT) during night and on weekends down to a small emergency team.

This reduced concept shrunked the Flight Control team to two 24/7 positions and removed the payload coordination function of the OC from console. The COMET took over the planning function of the OC in a timely restricted manner and brief payload coordination was done by the Col-FD. All payload responsibility, beside the Joint-System-Payload-Interface taken over by STRATOS, were given to the USOCs, which increased the responsibility of the user centers in Europe. In parallel the Ground Control Team was reduced to one 24/7 position while the Syscon was available during crew awake time, only. The off-line GCT was reduced to one person per position, which guaranteed console manning in case of e.g. sickness, etc. but limited off-line and preparation work to an absolute minimum.

While the restrictions of the FCT were valid from beginning of 2014, the restrictions of the GCT will only be active after the last ATV flight, at earliest. This approach was followed, because the ATV mission requires 24/7 full performance as well as a guaranteed availability for off-line tasks.

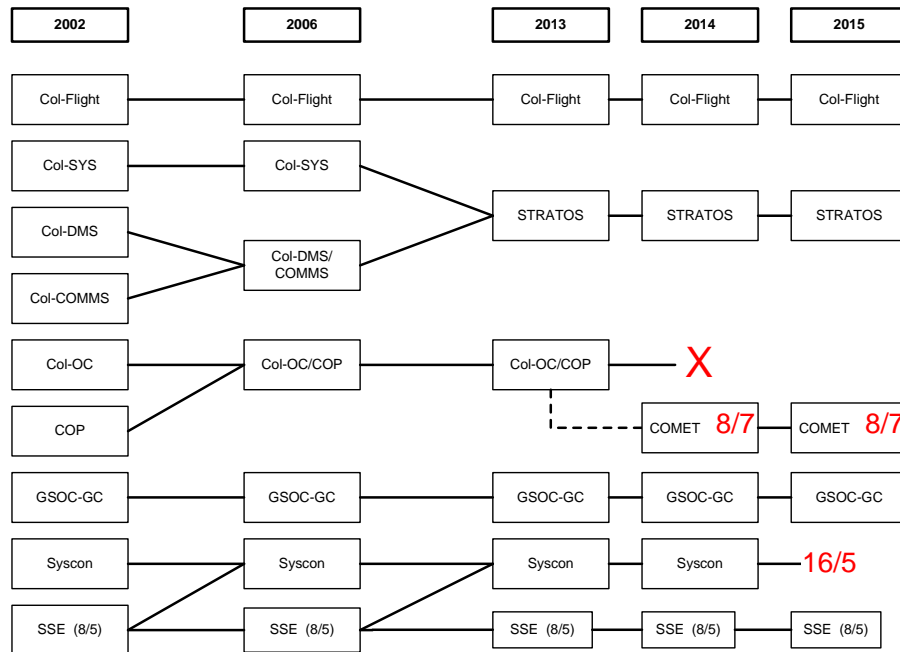
These restrictions reduced the flexibility of both, the FCT and the GCT, and led to the necessity to redefine some of the interfaces to the international partners due to the reduced availability of the planning function and the missing in-depth coordination of the former OC position.

The biggest challenge of the implementation of the new FCT setup was the speed of implementation from August 2013 to January 2014, i.e. in less than six months. This was only possible because the recertification of the modified position was not necessary: It was agreed with ESA and the International Partners that the OPS products won't be available at the start of the new setup. Work-arounds using on-concole Flight Notes were acceptable for the transition phase. The transition phase will last from the start of implementation on 15 January 2014 until mid-2014 when all Ops Products will be up to date and will reflect the new setup and interfaces of Col-CC.

#### **V. Current Status of the FCT and GCT**

The development described in the previous chapters is summarized in short form in Fig. 2. It can be clearly seen that the number of 24/7 positions at Col-CC has been reduced from 6 FCT plus 2 GCT in the beginning of

Columbus operations to 2 FCT plus 1 GCT position from 2015 onwards. In parallel the number of SSEs has been continuously reduced to a bare bone minimum to 1.5 persons average per subsystem.



**Fig. 2: Development of the 24/7 Positions at Col-CC**

It is evident that the performance of the on-console team has considerably decreased over the last years even taking into account the efficiency increase of the team in the more than six years of Columbus operations. This had strong implications on the overall work on console reducing flexibility, the output and in some cases the quality of the on-console work while increasing the risk for on-consoles errors. The consequences of these reductions were:

- Sequential working of payloads, i.e. activation of racks and payloads
- Adding buffer between activities to allow clean-up work or to cope with delays if necessary
- Reduced re-planning capabilities, i.e. only one shift instead of three shifts
- Reduced knowledge in technical details on console
- Loss of flexible reaction to real-time changes including anomalies
- Loss of the four- eyes principle for technical decisions because of one technical position available, only
- Loss of Ground Segment flexibility and availability

Hence, the Columbus Flight Control cannot provide the same support to on-board operations as in the last years and many tasks had to be reduced to the absolute minimum or had to be moved to other entities like the USOCs. It was the goal of the FCT to minimize the impacts on operations to the absolute minimum, but constraints cannot be avoided.

After the on-console setup without OC has been established on 15 January 2014, the transition will be carried on until mid of 2014. The following Ops Products have to be analyzed and – if necessary – updated to reflect the current situation on console and the newly established or changed interfaces:

- Operations Data File (ODF)
- Flight rules
- Payload regulations
- Operations Interface Procedures (OIP)
- Joint Operations Interface Procedures (ESA JOIP)
- Flight Control Operations Handbook (Col-CC FCOH)

The transition period using work-around solution established in short time before 15 January like Columbus Flight Notes (CFN) and Electronic Flight Notes (NASA EFNs) shall be as short as possible returning to a nominal working environment by end of June 2014. This will also help to reduce part of the risk established with the new concept. After achieving this next step the Flight Control Team is heading for a consolidation in the second half of 2014 and beyond to come back to a mostly smooth operations approach.

## VI. First experience and Future Outlook

As explained above, the transition to the new setup in 2014 has been performed for the FCT, only. For the GCT the transfer to the new team structure is foreseen for 2015. Hence, there are experiences with the new setup available at the FCT side, only. The first weeks of operations since January 2014 showed that the reduced team on-console without OC is constantly at the rim of their operational capabilities and is partly overloaded in case several activities have to be performed in parallel. This is nominally avoided in the course of the planning process but for unplanned events or during high activity phases this couldn't be avoided all the time. During pre-planned high activity phases it is possible to temporarily support the console team by additional people but this is restricted by the given resource constraints. This increases the operational risk and shows that the analysis done before and the increased risk of operational errors which have been found are correct. The consequences of loss of the majority of support for non-operational activities from the GCT in 2015 are still not solved. Training, simulation support, as well as support to public relation activities have been essential up to now.

The proof of the new concept will be reached during the upcoming high activity periods like Space-X 3 and 4, ATV-5 and the "blue-dot" mission of the German ESA astronaut Alexander Gerst, which has a high visibility in Germany and at Col-CC.



**Fig. 3: Main Control room of the Columbus Control Center during Increment 39 (Photo: DLR/Zoeschinger)**

For the next years of future Columbus operations the recent cost reductions, the analysis performed and the first experience on console showed that there is no margin in the team for further reduction. For the FCT on-console team two 24/7 positions are the absolute minimum because it is not possible to combine the technical knowledge of the Columbus module, the commanding function, the emergency response, the handling of the multiple interfaces within ESA and with the IPs, the safety responsibility and the overall coordination function in one position. This is also supported by the main ESA requirements for Columbus operations and by NASA looking for an on-console team at Col-CC taking full responsibility for the Columbus module.

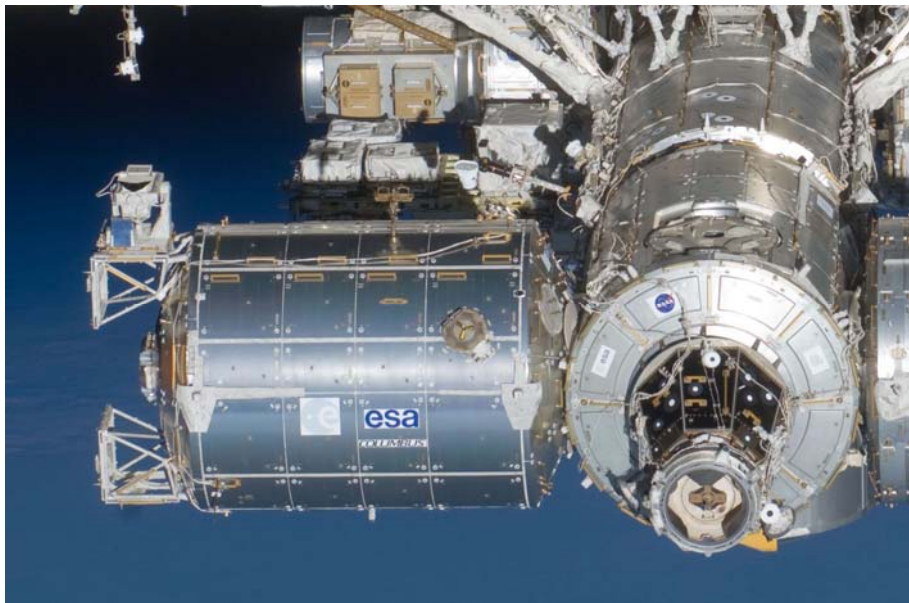
Also the pure knowledge to run Columbus operations cannot be provided to one person alone. The effort during the cross certification from DMS/COMMS and Systems to STRATOS showed that the level of Columbus system knowledge has to be strapped down to the absolute minimum. Including more knowledge in one position will lead to a clear overload of the team members during training and operations, and leads to unacceptable risks for on-console operations.

Due to the reduced on-console team, the preparation of the tasks is even more important than before because gaps in the preparation work cannot be overcome by the on-console team and activities would have to be skipped in the worst case. Hence, the currently available off-console resources are absolutely necessary to keep the work running and to avoid severe impact on the work flow on console and on-orbit.

Additionally a large number of payloads and payloads racks have to be integrated in the Columbus module in the upcoming years and increments:

- Rapidscat
- EDR II
- ACES
- ACLS

To support the preparation and the installation of the payload or the racks the Flight Control Team needs at least the currently available resource. This will ensure an up to date Columbus module in the upcoming years and the full usage of the Columbus capabilities until 2020 and beyond.



**Fig. 4: ISS with Columbus Module (Photo: NASA)**

## **VII. Conclusion**

The Columbus Control Center has gained a lot of experience in the course of Columbus operations in the last six years. These experiences are used to increase the efficiency of the monitoring and control of the module but the exploitation of this effect is restricted. The reduction in resources which have to be implemented during the last 15 months is much larger than the gained efficiency increase. Hence, the performance, the flexibility and the availability of the teams at Col-CC have to be reduced to adapt to the new boundary conditions while increasing the risk of operational errors. Any further reduction in on-console or off-console work force could increase the risks to an unacceptable level with potential impacts on the long-term operations of the Columbus module. For the sake of



successful and smooth Columbus operations in the upcoming years the size of the Col-CC team should not be further reduced or restructured.

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