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horizons Mission – Challenges and Highlights

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HORIZONS MISSION – CHALLENGES AND HIGHLIGHTS

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ABSTRACT

After his first spaceflight and his 6 months stay on ISS in 2014, ESA astronaut Alexander Gerst is returning to the outpost in orbit this year. His second mission to the International Space Station is named “horizons” and contains interesting tasks and experiments for him like Airway Monitoring, GRIP/GRASP, SpaceTex, MagVector-2, Metabolic Space and Myotones, along with a whole educational outreach program.

Compared to the “blue dot” mission in 2014 a number of challenges have to be overcome especially in the planning of the mission:

- Alexander Gerst will be ISS Commander in the last two months of his 5 months stay in orbit. During this period less time for experiments is available leading to less flexibility in planning.
- Shortly before the mission the launch was postponed by more than a month reducing the time on orbit significantly. Hence, the experiment and activity planning had to be reworked in a short timeframe.
- Some major events or milestones of his stay in orbit, e.g. a possible EVA or a possible extension of his stay on-board could come up in the course of the ongoing mission. In this case the Columbus Flight Control will react as fast as possible to ensure a highly successfully mission.

The preparation phases and the first part of the execution phase of both missions will be compared. The challenges in the preparation of the horizons mission will be shown and the progressive solutions found by the Col-CC flight control team will be explained. Also some highlights of the first phase of the horizons mission will be presented.

The paper will focus mainly on the planning and preparation phase of the horizons mission together the preparation of the ISS Increments 55/56 and 57/58 at GSOC/Col-CC.

Introduction

This year the Columbus Control Centre celebrated the tenth anniversary of Columbus Operations. During this decade, Col-CC has supported 10 long-duration and two short-duration missions with 11 different ESA astronauts. In June 2018 the 11th long duration mission “horizons” with Alexander Gerst started. Besides the large amount of experiments waiting for him, Alexander Gerst will serve as ISS commander from October to December 2018. Based on the long experience of DLR’s German Space Operations Centre (GSOC) in manned space operations and the missions to ISS described below, Col-CC is ready to support Alexander Gerst during his second mission and especially for his special tasks during these 6 months.

In the Interim Utilization Phase, which was done in parallel to setting up Col-CC ([3] to [5]) for the later Columbus operations, the Eneide Mission in 2005 and the Astrolab mission with Thomas Reiter in 2006 (see [1] and [2]) were successfully supported. In February 2008 Col-CC started Columbus operations (see [6] to [11] and [13] to [15]) and prepared and supported successfully all missions and increments up to now. With this experience Col-CC will be able to operate Columbus until at least 2024, assuming that the basic setup will not change (see [12]).

Early Preparation of the horizons Mission

More than two years before the launch of Soyuz-MS09 on 6 June 2018 the preparation of the horizons mission began. For the coordination of the activities during the mission a regular coordination meeting was set up to discuss and fix the experiments planned for the mission. It was also announced that Alexander Gerst is the ISS commander during Increment 57.

In May 2017 the mission logo and name of the "horizons" mission were presented (see Fig. 1) and an outlook of the mission was given.

Fig. 1: horizons Logo (Credits: ESA)

In the course of his training and preparation for his second mission to the ISS, Alexander Gerst visited Col-CC in September 2017 for an exchange with the Columbus Flight Control Team (Col-FCT) (Col-CC main control room see Fig. 2).

Fig. 2: Col-CC Main Control Room (Photo: Zoeschinger)

During the meeting information between the astronaut and the FCT were exchanged and details of the cooperation between the FCT during the mission were discussed. This includes also a photo with all available flight controllers at Col-CC in one of the Col-CC control rooms (see Fig. 3)

Fig. 3: Alexander Gerst with Col-FCT in the control room (Photo: Zoeschinger)

In the course of the regular coordination meetings the status of the foreseen experiments, the planned time table of the mission and changes to the sequence of events have been discussed. Until end of 2017 the changes to the mission were small and the planned corridor for the stay of Alexander Gerst on ISS was still April to October 2018.

Change of Boundary Conditions of the horizons Mission

In parallel to the return of Paolo Nespoli from ISS in December 2017 (see [17]), the final phase of mission preparation started. At that time the launch for Alexander Gerst and his Crew was planned for April 2018 with a return end of October 2018. Due

to the re-planning of the previous flight first the launch date was moved from April 2018 to 6 June 2018 and a few weeks later the landing date was moved from end of October to 10 December 2018 (see Fig. 4). This step by step change of the flight plan created many challenges to the increment team here at Col-CC and the other ESA team all over Europe:

- The cargo flights mostly were moved to a later launch date, i.e. the provision of experiments, samples and new hardware occur later in the mission schedule.
- Many experiments on human physiology are inherently bound to launch and return, so that an early and late measurement can be compared to investigate the effect of long-term exposure to micro-gravity. These had to be re-planned according to the new dates.
- Requirements for experiments from all International Partners which had been incorporated in an overall ISS work plan had to be re-planned and de-conflicted again.
- Especially when the launch of Gerst and his crew was moved to later with an unchanged return date, essentially cutting short his whole mission, it was challenging to fit all experiments into the unusually short mission corridor. This became easier once the return was moved to December 2018.

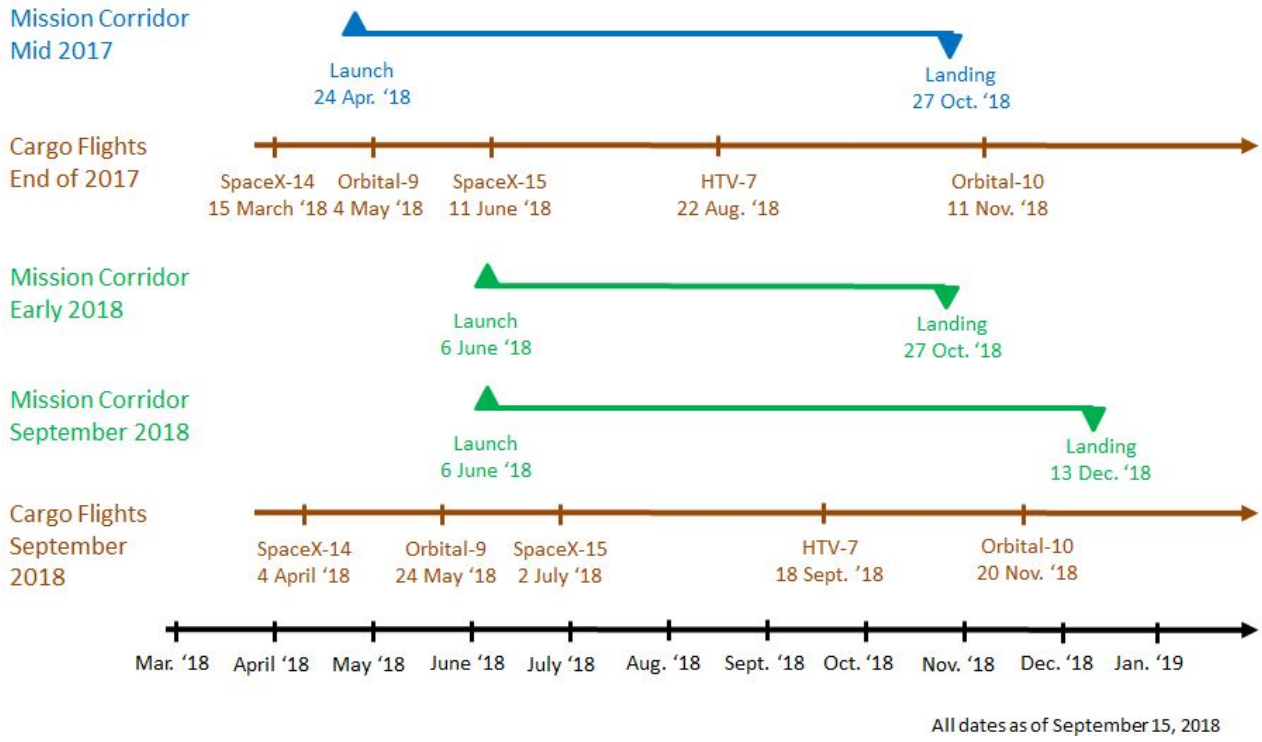

Fig. 4: Shifting of horizons launch and landing schedule (Diagram: DLR)

The ISS Planning Process

In this paragraph, a rough outline of the planning processes for ISS on ESA side shall be given, so that the impact of moving vehicle traffic dates can be assessed.

The planning of all crew activities on-board ISS and the corresponding ground commanded activities is governed by so called Increments; usually one planning period is a double-Increment. One Increment starts whenever a Soyuz vehicle undocks from ISS and ends when the next Soyuz vehicle undocks. Typically this is a 3-month period.

The horizons mission is laid out to launch in Increment 56 and return, i.e. marking the end of, Increment 57. Since for planning purposes the double-Increment assignments were 55/56 and

57/58, the horizons mission spans two different Increment pairs and hence was planned, organized and executed by two different CoI-CC Flight Control Teams with responsible Increment Lead assignments in each of the disciplines. Coordination and preparation together until handover was crucial to ensure a flawless continuation of the horizons mission.

Prior to the execution of an Increment pair, the preparation phase is ongoing for quite some time: The operations teams, namely the assigned Increment Lead Flight Controllers from each discipline, start their preparation one year before the execution phase.

At ESA, this preparation of the ops teams starts with the Integrated Requirements Definition document (IRD), which is issued one year out by ESA and contains all experiments and maintenance activities (so called objectives) which shall be executed during the corresponding Increment. It gives an overview of planned vehicle traffic and cargo manifests and most importantly the crew time allocation per Increment objective.

About half a year before execution, the Certification of Flight process is started (CoFR). Here all stakeholders, from user support centres to the FCT, analyse which tasks need to be done for each payload in terms of integration and execution readiness and a snapshot analysis of open and completed tasks is performed. This process should lead to readiness for on-orbit operations and covers readiness for documentation, training, launch, execution (e.g. procedures) and all corresponding reviews (i.e. Safety).

Since some payloads might be late in the preparation or would have to be added late to revisions of the IRD, the CoFR process is performed in two rounds, the latter round being the last chance for payloads to enter the regular certification cycle. In case there are still payloads to be added on short notice, a so called delta-CoFR can be conducted separately, as an exception.

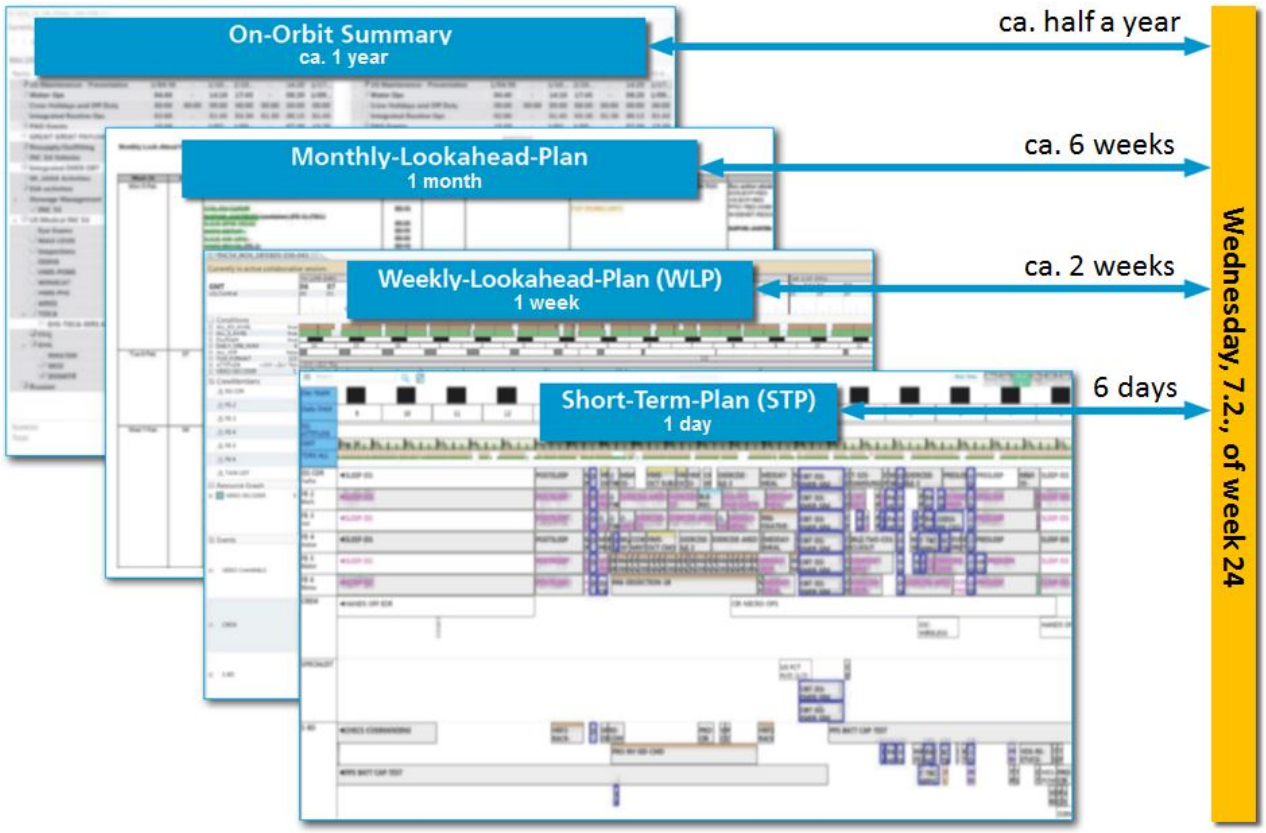

Fig. 5: OOS to STP planning (Diagram: DLR)

At the same time, the On-Orbit Summary (OOS) is being prepared. At ESA, the European Planning and Increment Coordination (EPIC) Team is responsible for this task. After gathering all Increment-related activities for the Crew, a plan is drafted which assigns activities to days in the Increment pair. The actual time-of-day is still unknown, but the activities hereafter fit the work plan for the ISS crew on a day-to-day basis.

In the process of OOS generation, time constraints for experiment execution and maintenance requirements are fit together and de-conflicted where possible. Conflicts which cannot be resolved will be apparent at this stage and would be elevated at agency level. Hence, this process is very important to identify potential risks in an early stage.

The operations planners (EPIC team at ESA) then meet for a Technical Interface Meeting (TIM) to discuss and integrate the OOS on international level.

The OOS usually has two cycles, a preliminary and final OOS process. In the latter, changes in the IRD will be assessed and integrated into the overall plan.

In the past years, a mid-term OOS process has been added to the preparation schedule to incorporate late changes in the ongoing Increment, so it happens during the execution phase. Since the Increment-pair then has already started, the mid-term OOS only covers the second of the double-Increment.

In the near-realtime environment, the on-orbit timeline is created from the OOS at 2 weeks prior to execution. All activities are now assigned a time-of-day and form the timeline for operations. This is the so-called Weekly Look-ahead Plan (WLP).

Similar to the WLP the STP (Short Term Plan) is created one week prior to execution. It is similar to the WLP but instead of covering a whole week it is now being updated on a daily basis, i.e. one STP covers one day of operations (see Fig. 5).

Planning Challenges

In the previous chapter it became apparent that the planning for any activity on ISS is a long process which inherently benefits from stable vehicle launch and return dates.

Looking back to Fig. 4, the vehicle dates have changed a lot in the course of the ongoing planning processes.

The supply vehicles of the SpX-14 (Dragon, Space-X) and SpX-15 missions have considerably been moved to a later date, as well as the OA-9 (Cygnus, Orbital) mission. On top, 70P (Progress, Roscosmos) and HTV-7 (H-II Transfer Vehicle, JAXA) have been moved as well.

Vehicle traffic drives most of the planning, besides experiment requirements. This is due to the great amount of time which is needed for vehicle unpacking and trash- and sample-preparation and -loading for return (depending on whether the vehicle is disposed of or returns to Earth), but also due to the delivery of new experiments and hardware. For an assignment of ESA hardware to vehicles for Increments 55 and 56, see Fig. 6.

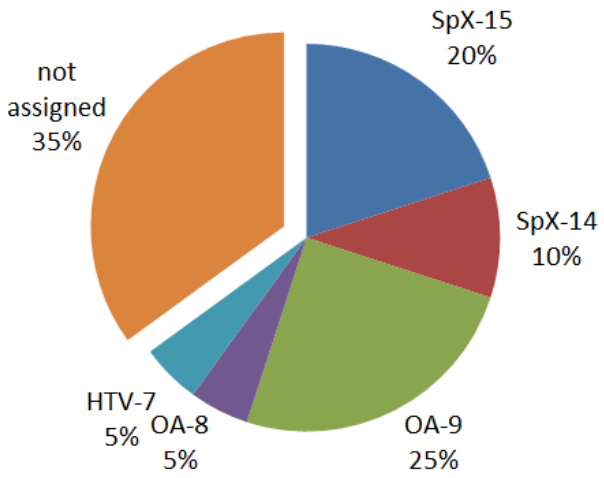

Fig. 6: ESA Experiment hardware assignment per vehicle, as of early 2018 (Diagram: DLR)

The ISS Crew usually is working several days on vehicle cargo operations. A vehicle launch which is moved to and earlier or later date (and be it only one day) has a tremendous effect on the scheduled timeline, both for Crew and FCT ground commanded activities.

For vehicle launches, usually a so-called slip plan is drafted along with the nominal WLP/STP. In case the launch has to be moved or aborted on short notice (“slips”), it serves as a back-up plan which takes the new assumed launch date into account. Developing such a plan is basically doubling the work of the EPIC team, but it is a

useful exercise once a slip is confirmed, to sustain continuous operations.

As outlined above, the Increment-pair 55/56 covers the horizons mission partly in Increment 56. Since ESA's main objectives for this period are tied to German astronaut Alexander Gerst and the horizons mission, many experiments were planned to be exclusive for Gerst as a subject. This means that on the one side the OOS had to be changed during the planning phase considerably, taking the changing launch dates into account. On the other side, the Increment pair of 55/56 saw an unbalanced distribution of requirements.

In Fig. 7 the required execution timeframe of experiments is shown across the various Increment Stages. The second letter of a stage denotes the number of on-board crew at the time of the Increment. For example, Stage 56-3 is the time when the Soyuz 53S has left (marking the start of Increment 56) but Soyuz 55S has not arrived yet (bringing 3 new crew members).

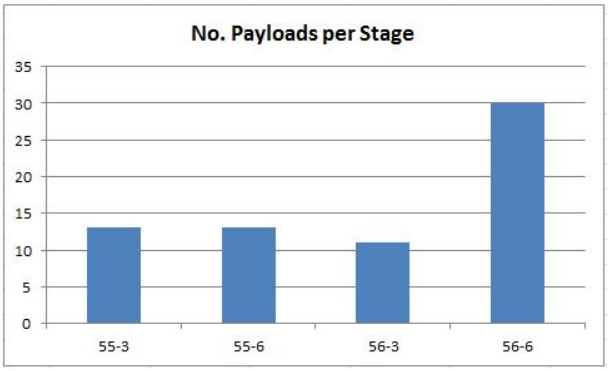

Fig. 7: No. of ESA Payloads per Stage, as of early 2018 (Diagram: DLR)

It is clearly visible, that with the arrival of Alexander Gerst (Stage 56-6) the majority of payloads are planned for execution, driven by their requirements.

The late execution date with respect to the period the OOS covers has the advantage that there is more time for preparation of required documentation and coordination within the Increment pair preparation cycle. The main disadvantage is that in case there would have been crew time available early in the Increment pair, many experiments would not have been able to be conducted since Alexander Gerst would not have been on board yet.

Increment 55 was executed with a relatively low number of ESA experiments but always having in mind the huge increase of workload during Stage 56-6.

Fig. 8 shows the COMET/EPIC console on the lower right, where the Col-CC real-time planners sit on shift and re-plan the schedule in the period starting from one week before the execution day.

Fig. 8: The COMET/EPIC planning console at Col-CC (Photo: Zoeschinger)

Start of the horizons Mission

After a long preparation time as well for the astronauts and cosmonauts as for the teams on ground, Alexander Gerst and his two crew mates Serena Auñón-Chancellor and Sergei Prokopyev were launched to space with Soyuz-MS09 (55S) on 6 June 2018.

Fig. 9: Arrival of 55S crew on-board ISS (Photo: NASA)

After a 34 orbit approach to the ISS they docked to ISS on 8 June and were welcomed on board by their crewmates on-board ISS (see Fig. 9).

Challenges of the First Months

Already in the first days Alexander Gerst performed some new and complex experiments like GRIP/GRASP which tests how spaceflight affects grip force and upper limb movements.

This experiment requires the setup of a large amount of hardware. Arm movements and grip forces are measured with two tracking cameras and there is a chair-like system to be set up that keeps the astronaut in a stable position. There are experiment sessions in a quasi-free floating configuration, where the astronaut would strap himself into the middle of the Columbus module volume (see Fig. 10) for which the chair and related hardware needs to be torn down again.

Fig. 10: Alexander Gerst during GRASP experiment (Photo: ESA)

Overall, this experiment setup and conduct spans a whole week of on-orbit operations, with several hours of work and experiment sessions to be completed by the astronaut each day.

Since other experiments require a setup in the module volume as well, these had to be de-conflicted per schedule, to allow GRIP/GRASP to be set up and be left deployed in order to avoid tear-down and set-up activities each day.

Especially the new experiment “Myotones” cannot be operated in parallel to GRIP, since the chair and tracking camera setup does not allow the astronaut to lay down flat on any rack surface (usually the deck area, the “floor” in the module), which is in turn necessary for Myotones execution.

As stated above, these human physiology experiments have strict requirements with regards to the on-board execution timeframe. Since ESA is only one of the International Partners looking to perform human physiology experiments, the planning of the first weeks on orbit is a special challenge.

A whole different challenge was the integration of the new Video Managing Unit (VMU) of the 2nd generation into the FSL (Fluid Science Laboratory) Rack. Since the old unit has had problems for quite a while, a 2nd generation unit was flown for exchange and upgrade of the video systems, which are used to monitor experiments and collect visual science data.

This VMU is a so-called “ORU”, an on-board replaceable unit. While the removal and installation is technically possible, it does not mean the unit is easy to access and quick to be exchanged. I.e. there is no hot standby/swap possibility, as it is possible for example for hard drives in always-on servers.

Each rack in the US segment of ISS is standardized and can technically be exchanged by one another. To access the rear side of each rack, it has pivot bearings installed which allow rotation while still being fixed on one side to the structure.

The removal and installation of the VMU of FSL involves full rack rotations. It requires the de-mating of the water cooling system hoses which lead towards FSL, as well as some data lines and optical fibre cables.

During the installation procedure, the rack is rotated several times: During the removal of the old unit, but again during the installation of the new one.

It is easy to imagine that every rack rotation requires coordination between the Crew and the FCT. For instance the cooling umbilicals should only be de-mated once upstream water valves are closed, and accessing the internals on the rear rack side would ask for several confirmations that

the rack is indeed off and no power provided to any internal system.

A considerable amount of preparation was necessary prior to execution of this activity on-board. Since the VMU exchange itself takes several hours, the ground teams needed to make sure that all steps in the procedure were in order and no necessary coordination and synchronization between FCT positions and Crew were missing.

If the checkout of the new unit, done by ground commanding, would show any error, gaining access to the unit again to investigate the issue would involve as much crew time as the actual replacement. For activities like these it is crucial that the ground teams work together and consider all eventualities to be best prepared for any situation the Crew might find the VMU in.

In Fig. 11 Alexander Gerst works on the rotated rack and installs the new VMU.

Fig. 11: Alexander Gerst installing the VMU mk 2 in FSL (Photo: ESA)

Challenges of the Next Months

The upcoming months of the horizons mission continue to be as challenging as the previous months. The greatest of those are rack relocations in Columbus, the arrival of the Life Support Rack (LSR) with HTV-7 and the fact that Alexander Gerst is the ISS Commander starting early October (as the first German astronaut in this role).

Due to bad weather at satellite tracking sites (which are used for the launch of the vehicle), the launch of HTV-7 had to be postponed a few times in September 2018. HTV-7 carries consumables, hardware and new payloads. For the Columbus teams there is the Life Support Rack (LSR) on-board, which is the first ESA rack which is installed in NASA's LAB on ISS.

Integrating a rack payload in another Partner's module requires extensive coordination between all affected parties, e.g. engineering, operations teams, scientists, to be able to operate it in the ISS environment. Questions like responsibilities, reactions in case of anomalies and information flow both on the planning side as well as on the execution side needed to be solved before launch. Even very basic and seemingly standard tasks like resource allocation and negotiation, activity planning and routing and download of telemetry and science data had and have to be worked and integrated by multilateral teams, both by the hosting (NASA) and the operating (ESA) centres.

Another rack movement impacting Columbus itself is the arrival of Express-Rack 9b (ER-9b). Similar to LSR it is launched with HTV-7. The installation location is inside Columbus in the Forward-2 (F2) rack bay.

As the ER-9b is a NASA rack, similar to LSR it is operated by both ESA and NASA in collaboration. This already has been done for years with the Human Research Facilities 1 and 2 (HRF-1/2) and Express-Rack 3 (ER-3) which are installed in Columbus as well. Col-CC is responsible for assisting the power-up and power-down and integrated planning with regards to potential conflicts inside the Columbus module. With the experience of the HRF and ER-3 operations, the integration of ER-9b follows the same principle.

To allow the installation of ER-9b in the desired location, the MARES (Muscle Atrophy Research and Exercise System) rack had to be removed from the Forward-3 (F3) bay and disposed of. In addition the Zero-g Stowage Rack (ZSR) of NASA had to be moved from F2 to F3. A ZSR provides a basic storage room for any kind of hardware; hence it is relatively easy to move and does not need extensive hardware reconfiguration (i.e. it has no cooling, hence no coolant hoses to be de-mated, and similarly no data and power lines).

These preparatory activities have been conducted in Increment 56 prior to HTV-7 arrival.

With Soyuz 54S undock, Increment 57 starts and the current ISS Commander, NASA astronaut Andrew Feustel, returns to Earth. Prior to undock, in a hand-over ceremony, Feustel passes on the role of the ISS Commander to Alexander Gerst.

While the Commander role does not have a huge impact on day-to-day operations, it comes with certain duties and responsibilities. Alexander Gerst has to focus more on the well-being of his crew members and spend more time on general station-keeping activities which perhaps are less favoured by the others. This involves activities the ISS crew is offered via the so-called Task List: It is a list of activities which crew may choose to complete, knowing that they are not as high in priority and time-constrained compared to normal activities on the timeline. Usually recorded messages for press affairs fall into this category, for which the ISS Commander has less opportunities for in his free time on the weekends.

Summary and Outlook

As a summary of the first months of leading the horizons mission, it can be said that many objectives have already been completed. The mission was laid out to have a majority of experiments on Alexander Gerst within his first months on orbit, which was a challenge for the planning teams to achieve the objectives while integrating all activities on the international work plan of ISS.

This article has explained that vehicle traffic is a major driver for planning of many activities on ISS. Vehicle traffic is always subject to change and no less can be expected for the upcoming flights.

Changing dates, deferred launches due to technical or weather issues and especially the changing mission duration of Alexander Gerst and his crew continued to create outstanding effort on the planning side but ultimately could be solved. This achievement is to a large amount only possible because of the experience the planning teams all over the world and especially for horizons at Col-CC are bringing in. By constantly analysing the requirements and possible on-orbit schedules, Increments 55/56 were extremely successful while Increments 57 (and subsequently 58) still pose a challenge to the new Increment-responsible Flight Control Team Leaders.

Starting early October, Alexander Gerst acts as the first German ISS Commander. In such a position, he has to focus more than ever on the well-being and safety of his fellow crew members and station-keeping activities, which decreases his flexibility to perform actions “on-the-spot” when needed.

At the same time as the teams are already preparing future Increments in the background beyond the horizons mission, Col-CC is ready to support Alexander Gerst and his crew during these exciting coming months and continuous to provide its contribution to the ISS program.

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