Continuous Training for Supporting Long-term Payload Missions

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B.USOC, the Belgian User Support and Operations Centre, is the centre responsible for the operations of ESA's SOLAR payload, which is externally accommodated on the Columbus Module and has been operating continuously since February 2008. The B.USOC operators, as all ISS ground Support Personnel have successfully followed the specific training and certification programme which guarantee the operational safety and mission success to the maximum extent. This certification programme mainly consists of the internal qualification and the successful participation of a number of European Simulations (ES) and Joint Multi-Segment Trainings (JMST), organized by ESA/EAC and NASA, respectively. The certification permits operators to execute on-console operations on a specific payload. However, a long-term and complex mission like SOLAR calls for additional, payload specific training. The B.USOC has set up an internal qualification programme for future SOLAR operators. The already certified operators receive continuous training through refresher sessions, optimisation boards, operations tools, and practical exercises. Especially during long-term missions, where payload operations are optimized continuously and become routine, the acquired skills and knowledge of the operators need to be maintained at a high level in order to achieve a successful mission.

I. Introduction

For the operations of the European Payloads on-board the International Space Station (ISS), ESA has adopted a decentralized infrastructure, based on the concept of the User Support and Operations Centres (USOCs). Each USOC is assigned to support the majority of tasks related to the preparation and the in-flight operations of European payloads. USOCs are generally located in national centres across Europe.

The B.USOC (Belgian User Support and Operation Centre) is a USOC set up by ESA and the Belgian Science Policy Office. Within the Columbus general framework, the B.USOC is the Facility Responsible Centre (FRC) for the Solar Monitoring Observatory (SOLAR).

SOLAR (Figure 1) is an integrated platform accommodating three instruments complementing each other to allow measurements of the solar spectral irradiance throughout a large part of the electromagnetic spectrum, ranging from the extreme ultraviolet (EUV) to the near infrared (IR)[1,2].

Figure 1: SOLAR payload

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After the successful launch of the STS122, SOLAR has been installed on the Columbus External platform on February 15th, 2008. Since the power-on of the platform, SOLAR has been operating continuously and the B.USOC supports these SOLAR operations on a 24/7 basis.

Throughout the four years of SOLAR Operations, all the involved teams have gone through a learning phase on how to operate the payload in the best way. Both the operations concept as well as on-console tools have been updated to optimize the real-time operations and maximize the science return. Many aspects of SOLAR were included in the operations concept and require specific attention during training. the three most important characteristics of SOLAR operations are summarized below:

1) Sun Visibility Windows[2]:

Due to ISS orbital mechanics and due to the mechanical range of the SOLAR Coarse Pointing Device (CPD), the Sun is not always observable by SOLAR. The visibility is mainly dependent of the "ISS beta angle", which relates the Sun position with the ISS orbital plane that varies slowly over time. In the nominal +XVV+ZLV ISS attitude, SOLAR observations are possible when the beta angle is between -24° and +24°, imposed by the CPD X axis rotation limits. In practice, this leads to so called Sun Visibility Windows lasting typically 10 to 15 days, as can be derived from Fig.2. During these days SOLAR is tracking the Sun with its instruments measuring following the scientists input.

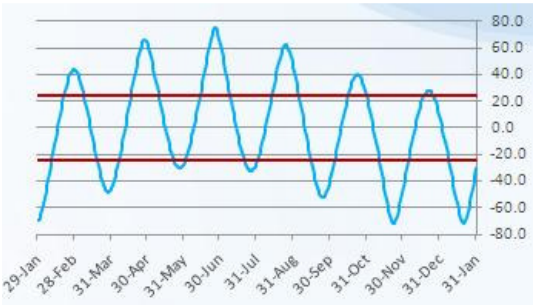

Figure 2: Sun Visibility Windows

From this, it is clear that the ISS attitude influences the Sun Visibility Windows. A yaw or roll different from zero will shift the start and end times of the Sun Visibility Window by up to two days. A good prediction of the ISS attitude is therefore important to be able to properly predict a Sun Visibility Window and plan science activities.

2) Operations constraints[3]:

On a regular basis, the ISS thrusters or a visiting vehicle's thrusters need to be activated. This can be for a reboost, for testing a thruster, for changing the ISS attitude, or to execute a Debris Avoidance Manoeuvre. During those events SOLAR, according to a Payload Regulation, should not perform science. There is also the possibility of contaminating the instruments with corrosive gasses emanating from the thrusters or near-by vehicles. For this reason the instruments should be configured in such a way that contamination is avoided. Another operations constraint for one of the instruments is the South Atlantic Anomaly (SAA). When passing through this region of charged particles, some science measurements should not be performed as they are influenced by the strong radiation. These are the main external events which have a significant impact on the SOLAR operations and for which solid tools are required to thoroughly plan activities mitigating the impact on the science return.

3) SOLAR anomaly handling

Yet another aspect influencing the operations are potential anomalies impacting the on-going science measurements. Over the years of operations, SOLAR has experienced a number of re-occurring anomalies, such as reboots or those caused by the nominal degradation of the platform. After thorough investigations, the payload developer has set-up workaround procedures in cooperation with the B.USOC and ESA, which consist of preventive actions or fast and efficient semi-automatic recovery procedures.

Because of the long-term perspective of the mission (more than four years), B.USOC has invested in the development of specific mission operations tools[4] and in the training of the operators in order to guarantee the quality of the operations service. Especially during long-term missions, where payload operations are optimized continuously and become routine, the acquired skills and knowledge of the operators need to be maintained at a high level in order to support a successful mission. In the following section, the generic training concept as well as the internal qualification programme B.USOC has set up for the future SOLAR operators is briefly introduced. Next, the paper focuses on the tools used to identify areas for enhancement and on the continuous training the already certified operators receive through refresher sessions, optimization boards, operations tools and practical exercises. The conclusions of this paper are summarised in the closing section III.

II. Generic Training Concept

This section first provides a brief overview of the generic USOC requirements and consequently presents the B.USOC training concept[5].

A. Generic USOC Training Concept

Training and formal certification are required as part of the Columbus Flight Readiness (CoFR) process for all ESA Ground Support Personnel participating in the on-line and real-time operations of ESA elements of the ISS programmes. The basic USOC training concept as provided as a directive from the Ground Support Personnel Control Board (GCP-CB) is depicted in Figure 2.

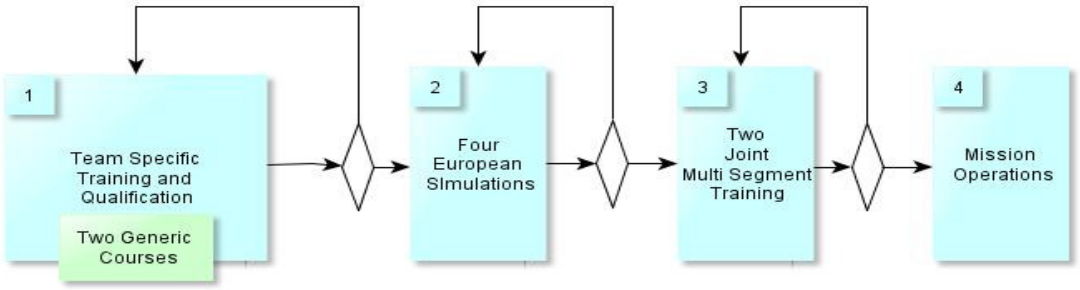

Figure 3: Generic USOC Training concept

1. Team Specific Training and Qualification

As required by the GSP-CB, the USOCs are assigned as the sole responsible for the Team Specific Training and Qualification of their on-console operators supporting the operations, which is depicted as the first step in Figure 3. For this step, each USOC needs to provide a Training and Qualification Plan, which has to be approved by the ESA Training Control Board, providing a detailed overview of the qualification required for new operators with respect to a payload. Moreover, each USOC should document the training and qualification status (training record) of each team member according to the training and qualification flow defined in the respective team specific plan. As a prerequisite to enter to the next step, the trainee needs to have followed two so-called mandatory Generic Courses, both conducted at EAC:

1) USOC Ops Training:

The USOC operations training course is a week long course on multiple operations subjects required for the generic on console work. It provides a detailed overview of the whole European Flight Control Team, as well as some basic knowledge about the European Ground Segment, which includes the telemetry and telecommand connections. The Joint Operational Interface Procedures (JOIPs) are also discussed: these are documents describing the interfaces, protocols and procedures ruling interactions between the involved centers supporting payload operations in the Columbus module. Lessons in the use of voice protocol are taught and information is given on the used Voice Conferencing System (VoCS), which is the main communication system between the different USOCs, Col-CC and EAC. In addition, a small course is taught on the ISS and especially ESA mission planning. The training session is concluded with a formal test.

2) Columbus User Level Training:

This course provides detailed knowledge about the Columbus module on subjects such as its command & control, hard/software, data management, thermal control, power distribution, communications, environmental control and life support systems. In one week the trainee is familiarized with all the necessary knowledge about the European Columbus module. This course is also finalized with a formal test.

There are on regular base additional courses conducted at EAC, such as Advanced Payload Training or Planning Training, but these are not mandatory for a successful qualification.

2. Simulations participation

After successful participation in these generic courses the trainee is allowed to enter the following step, the participation of the European Simulations (ESs). Generally, the trainee is required to take part in four ESs prior to being admitted to the participation in two Joint Multi Segment Training (JMST), organized by NASA. All this information is tracked by the USOC Training Coordinator (UTC). This position is assigned by the Training Control Board (TCB), and is in charge of observing the trainees' performance during simulations, providing at least two evaluation sheets, one for the final ES and one for the final JMST.

Once the qualification process has been completed, the USOC Training Coordinator submits all these documents to the GSP-CB. They are in charge of verifying that all the requirements are satisfied and they grant or deny the certification of the trainee. After successful certification the trainee is allowed to enter the real-time operations and support operations for the payload for which he or she has been certified.

The requirements for delta-certification, allowing an already certified operator to support another payload, are depicted by the GSP-CB on a case by case base, depending on the payload.

Each USOC has an assigned USOC training responsible who coordinates the qualification and certification process with the UTC. The main responsibilities of the USOC training responsible are:

1) Detail the Increment training requirements.
2) Nominate the USOC's candidates to the training sessions.
3) Interface with the UTC for all the training and simulations topics or requests.
4) Define, together with the UTC, the simulations objectives.
5) Detail the timeline inputs for the simulations.
6) Provide inputs for anomalies or scenarios to be played in the simulations to UTC.
7) Agree with the UTC on the simulations and training participants list.
8) Prepare the proper arrangement for the trainee's participation to the simulation and training session.
9) Plan the participation of the FRC trainees in the On the Job sessions.
10) Provide training logs and On the Job Training (OJT) records to the UTC.
11) Manage the qualification.
12) Manage the internal training and schedule.
13) Validate the assessment performance.
14) Document individual Training Records and update the Training Qualification Plan.

B. B.USOC Team Specific Training and Qualification

Prior to the start of the operations in 2008, B.USOC had a limited number of only four certified operators and two in training to support the 24/7 operations for SOLAR. All the operators were involved in the mission preparation and were as such familiar with SOLAR. Next to the generic courses, the knowledge and skills acquired during the preparation phase were adequate to properly participate to the required simulations and to get certified. To properly sustain the 24/7 support new staff members were recruited, which had to be trained properly, as they lacked the experience both with the payload and the operational functioning of the USOCs.

Over time, with the differentiation between people leaving and joining the team, the need for a formal implementation of the B.USOC qualification was obvious. Moreover, for existing payloads, already being on-orbit for several months, the amount of experience and data available gave additional opportunities for the practical side of the payload training. By means of stand-alone simulations and telemetry replays, both nominal operations and known anomalies could be fully emulated.

With the experience gained, the complete B.USOC training concept was revised in 2010. Based on the input provided by the trainees and the experiences on console, a training flow was developed, which formalizes the process of the B.USOC qualification. Figure 4 visualises this training plan.

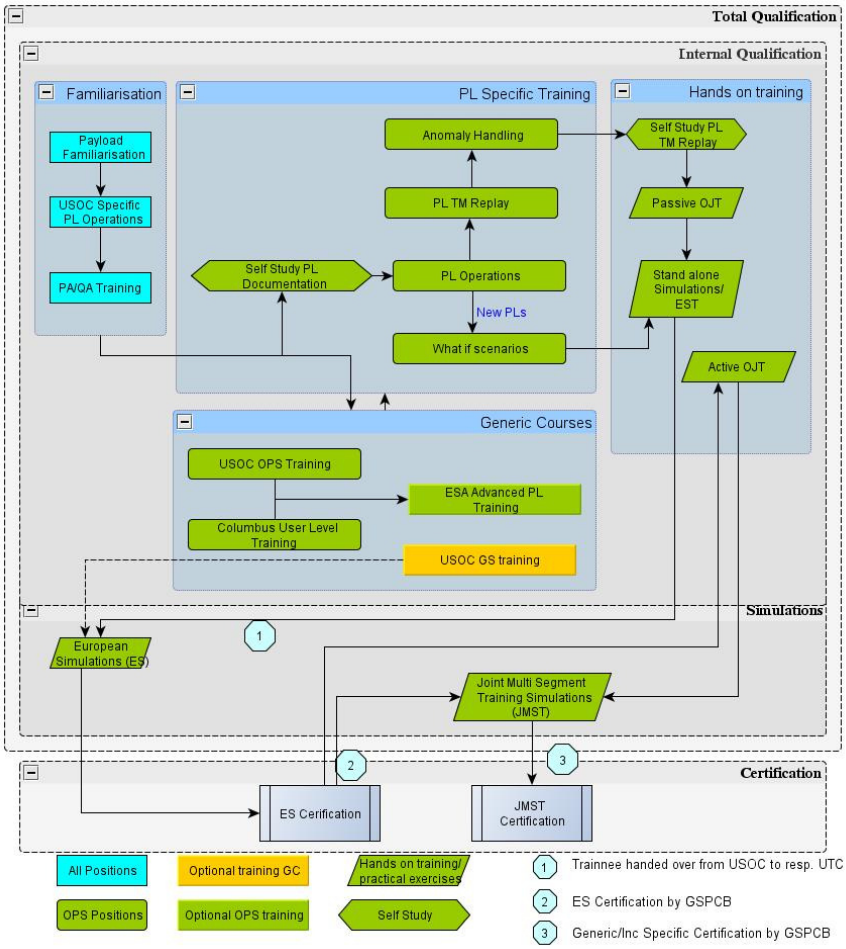

Figure 4: BUSOC Training plan

As shown in the above figure the focus of the B.USOC Qualification and Certification is on the qualification rather than the certification. For long running payloads such as SOLAR, more hands-on training is organized based on the available telemetry in the archive, where nominal operations as well as anomalies are covered in depth. These practical exercises or hands-on training corresponds with the PL TM replay, Anomaly Handling, Self Study PL TM, Stand-alone simulations and Passive and Active On the Job Training in Figure 4. This significantly enhances the monitoring skills of the operator for the differentiated number of science operations as well as the resolution time for known anomalies.

The training flow has proved to be far more effective for new operators, reducing the total duration of their qualification process, whilst increasing their availability to support the offline operations preparation work.

III. Continuous Training

Figure 5 shows a high level overview of the process established at B.USOC for the Continuous Training of the already certified operators:

Figure 5: Continuous Training

A. Areas of training

As stated in the previous sections the operations have been optimized, capturing the several aspects impacting the SOLAR operations. This optimization is mainly manifested by a change in the operations on console or the development of new operator tools or procedures and processes. Therefore training need is mainly identified from those three areas:

1. *SOLAR operations:*

Continuously adapting the operations to fulfil the science requirements also implies continuous training. Moreover, an additional issue that has arisen throughout the years is the difference in knowledge between operators. In operations, it is essential that the USOC operator team is on the same level and acts on console as an entity, not as individuals. Especially during the four years of SOLAR, the payload operations have become routine, moreover they are continuously being optimized. It became clear that the acquired skills and knowledge of already certified operators should be maintained and kept on the same level. It is also essential that the on console awareness remains high, even if the operations have become routine.

2. *Operator tools*[4]*:*

To identify, track, and address the possible constraints as laid out in the introduction of this paper and the corresponding actions, SOLAR tools have been developed on-console. These provide the operator with a first suggestion in the SOLAR planning and on how the operations should be performed, respecting all possible constraints for SOLAR. These tools are set up in such a way that they not only provide the end result, but include all the aspects such as constraints and regulations. It continuously reminds the operator of the operations concept, the SOLAR constraints, the Flight Rules and Payload Regulations. Especially for recently certified operators, not having the significant experience on console, these tools maintain or improve their knowledge and on-console skills.

3. *Procedures/processes*

To properly prepare and support the operations, B.USOC has created internal processes depicting the full flow of a typical aspect in operations such as planning or documentation development, from the very beginning until the end. These consist of one-page graphical overview providing a bird's eye view of the path to follow, including references to requirement document or JOIPs.

The JOIP outlines the operational interfaces and guidelines for all mission phases of the ESA Human Spaceflight programme. It documents real-time and non real-time operational interfaces and standard procedures. Since the installation of the Columbus laboratory, the JOIP has been updated on a regular basis properly reflecting the needs of operations. To ensure a successful mission, all operators on console should know and follow these procedures and processes accurately.

B. Training need identification

The training needs are identified through the following:

1. B.USOC Optimization Board

After each Sun Visibility Window, the operations of the past month are analysed looking for unexpected events, areas subject to improvement or small or big issues flagged by the operators on-console. Note that these are not only actual issues that occurred, but also processes, events, and actions that deviate from what is expected or that may cause failures in a later stage. The B.USOC Optimization Board (BOB) is then called within the B.USOC Operations Team where the possible origins of these issues are identified and discussed. These can be a lack of information on console, a problem with the existing process, an unknown situation, an operator mistake, etc. During the board meeting suggestions for improvement are formulated and consequently action is taken to derive a workaround or backup procedures, to develop new or update existing tools, to identify new processes and training needs, and this in order to avoid similar incidents in the future. Figure 6 provides an overview of the BOB process flow.

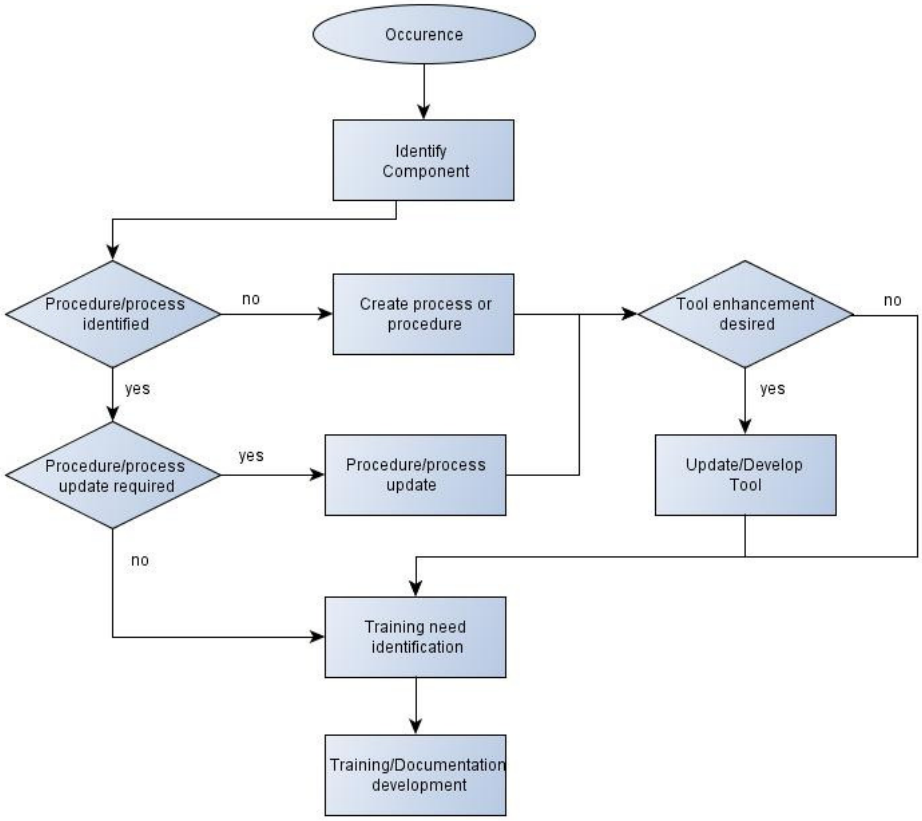

Figure 6: BOB process flow

The training needs identified during the BOB can be fulfilled by either refresher courses in case of already known aspects or by development of a new training, which in the latter case also be fed back into the BUSOC SOLAR operator qualification process. The B.USOC Training Responsible is then in charge of following these actions up and properly log them.

Note that the process for the update, development or creation of a procedure, working process or tool is a self-standing process including training.

2. *B.USOC Operations Days*

Prior to each Sun Visibility Window a full day meeting is organized with the whole B.USOC team, including operators and ground controllers, in order to prepare the upcoming window. The meeting's objective is mainly to share information on the operations between the different team members. Generally, a broad number of aspects is discussed: the past Sun Visibility Window and upcoming science objectives and schedule is presented, the status of open problems or anomalies, the status of the ground segment, the status of the preparatory activities for other payloads. These monthly meetings ensure the general awareness of the operators and having the whole team on the same page.

3. *Quality Assurance/Product Assurance*

As part of quality assurance requirement from ESA and established at B.USOC, all new processes or updates to tools are traced back into training.

4. *Training Feedback*

Over the four years of operations the B.USOC has qualified over ten operators, each with a different background. One of the key aspects in improving the training was the feedback from the trainees themselves after being certified. In many cases, the first experience on console will provide a fresh view from these new operators and suggestions are made to further improve the operations and the training. After sitting on console for a certain amount of time, each individual will identify gaps in the training or areas for improvement. It is essential to motivate newly certified people to have this critical view on the operations and to capture their comments and feed them back into the optimization process, led by the B.USOC Optimization Board.

C. Training products

The training needs are fulfilled by the update or development of different products aiming at ensuring the quality of the SOLAR operations:

1. *Cheat Sheets*

One of the typical products resulting from the B.USOC Optimization Boards or the operator training is the use of the Cheat Sheets. These Cheat Sheets are mostly graphical overviews of a typical aspect of SOLAR operations, instantly providing the operator on console with crucial information, generally including references to the operations products or manuals such as Flight Rules or Joint Operations Interface Procedures. These Cheat Sheets have proven their effectiveness on console, supporting the decision making by the operator.

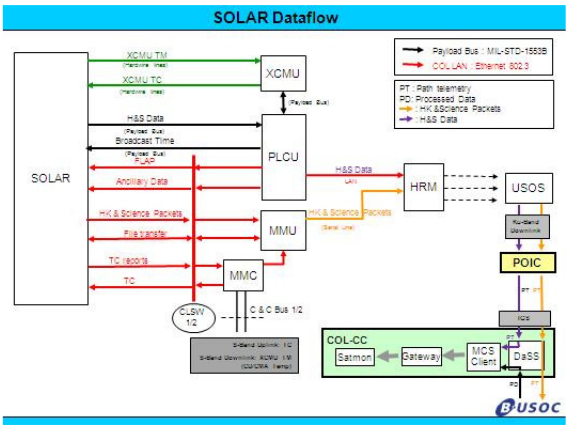

Figure 7: SOLAR Cheat Sheet

2. *User manuals/wiki pages*

With the development of the SOLAR Mission Tools the guidelines have been documented in user manuals or wiki pages. For all updates of these tools or in the case wrong use of the tool has been identified, the documentation has to be updated accordingly and all operators are obliged to go through the changes.

3. *Refresher Courses/New training*

During the BOB the need for refresher courses or new training can be identified. Mostly this consists of training a single aspect within the operation, such as Flight Rules impacting SOLAR operation. The Training Responsible is then responsible for the preparation of the training material and the organization of the training. These training sessions are often included in one of the B.USOC Ops days and further logged in the individual training records. The training material is also kept available to the operators via the different documentation sources.

4. *B.USOC Operations (Ops) Days*

The outcomes and the refresher courses, evolved from the training needs discussed during of the B.USOC Optimization Boards, are also organized during the B.USOC Operations Days. Not only these classroom sessions are provided to the team, but work-around procedures, changes in the operations concept, updates in operations tools

or processes are also covered. All is presented and discussed in detail to ensure all operators supporting the on-console operations are aware.

5. USOC processes

Revision or development of a USOC process might be required as an outcome of the BOB, discussions during the Ops Days or from the update of one of the supporting tools. This will then be presented and thoroughly reviewed during one of the B.USOC Ops Days. After final approval it will be issued and should be followed by all operators.

IV. Conclusion

Especially for a long-term mission such as SOLAR, initial training and qualification is not sufficient to ensure a successful mission. Often the mission itself changes throughout the years and the operations are significantly optimized with experience. For SOLAR operations, the B.USOC is continuously searching for ways to improve the operations, to mitigate impacts on the science measurements, and to ensure quality. These changes need to be fed back into the training, and training itself also clearly becomes an area where continuous improvement is the aim. The organisation of the optimization boards, development of the SOLAR operations tools and products are time consuming, but have been proven to be a good investments in the long run. During the SOLAR mission, it has become clear that training is a constant effort that is part of the real-time operations and it cannot be considered as just the first step to operations. The will of B.USOC to keep investing in training and to continuously optimise the operations is a key aspect in performing successful and qualitative operations in a long-term mission, such as SOLAR.

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References

[1]Thuillier, G., Frohlich, C., and Schmidtke, G., Spectral and Total Solar Irradiance Measurements on Board the International Space Station," Utilisation of the International Space station 2, edited by A. Wilson, Vol. 433 of ESA Special Publication, 1999, p. 605.

[2]Schmidtke, G., Fr□ohlich, C., and Thuillier, G., ISS-SOLAR: Total (TSI) and spectral (SSI) irradiance measurements," *Advances in Space Research*, Vol. 37, 2006, pp. 255{264.

[3]Brantschen S., De Smet L, Michel A, SOLAR Payload Operations: Achieving Flexibility to Support a Long term Science Mission, *Proceeding of SpaceOps 2010,* AIAA 2010-1951, Huntsville April 2010.

[4]Wislez J., Hoppenbrouwers T, Michel A, Dealing with Operations Constraints for External Payloads on ISS, *Proceeding of SpaceOps 2010,* AIAA 2010-2056, Huntsville April 2010.

[5]Sela, A, SOLAR Mission Tools, *Proceeding of SpaceOps 2012*

[6]Arshad, A. M., Klai S., Pronk Z., Moreau D. Aspects of Dedicated Operator training: Experiences from Erasmus USOC and B.USOC, *Proceeding of SpaceOps 2010,* AIAA 2010-2224 , Huntsville April 2010.