

Aspects of Dedicated Operator Training: Experiences from Erasmus USOC and B.USOC

Arif Muhammad Arshad¹ and Saliha Klai²
Training responsible for Erasmus USOC and B.USOC

Zeholy Pronk³
NLR, Erasmus USOC Manager, ESA ESTEC, the Netherlands

and

Dr. Didier Moreau⁴
B.USOC Manager, Brussels, Belgium

For the support of European payload operations on board the International Space Station (ISS) ESA has applied a distributed operation concept with multiple User Support and Operations Centres (USOCs) located across Europe. Each USOC supports a variety of tasks related to the preparation and in-flight operations of the European payloads assigned to it.

To ensure the necessary qualification and certification of the USOC operators, generic coursed as part of the ESA training concept is provided by the ESA European Astronaut Centre (EAC), supported by the Columbus Control Centre (Col-CC) and the Industrial operations Team (IOT). Complementary to this, each USOC is responsible for its own payload specific training.

This paper focuses on how the Belgian B.USOC and the Erasmus USOC supported by the Netherlands and Belgium, used their experiences of nearly two years of continuous ISS payload operations to develop and implement a dedicated payload training concept for their operator. It outlines the approach for continuous improvement of the USOCs' specific training and explains the training concept used for current and future payloads. Complementing the generic course, the overall USOC operator training covers internal and external theoretical courses, as well as practical exercises consisting of On-the-Job training (OJT), Stan-Alone Simulations (SAS), European Simulations (ES), and Multi-Segment trainings (JMST).

Nomenclature

CD-MCS = Columbus Distributed Monitoring & Control Subsystem
COL-CC = Columbus Control Centre
DHPU = Data Handling and Power Unit
EAC = European Astronaut Centre

¹ Erasmus USOC Training Responsible, National Aerospace Laboratory, Erasmus USOC, Arshad@nlr.nl

² B.USOC Training Responsible, Space Application Services, Saliha.Klai@spaceapplications.com

³ Erasmus USOC Manager, National Aerospace Laboratory, Pronk@nlr.nl

⁴ B.USOC Manager, B.USOC, Didier.Moreau@busoc.be

EDR	=	European Drawer Rack
EM	=	Engineering Model
EPM	=	European Physiology Modules Facility
ES	=	European Simulation
ESA	=	European Space Agency
ESM	=	EuTEF Instrument Simulator
ESTM	=	Engineering Structural Thermal Model
EuTEF	=	European Technology Exposure Facility
EXAM	=	Experiment Activity Manager
FRC	=	Facility Responsible Centre
FSL	=	Fluid Science Laboratory
FSC	=	Facility Support Centre
IOT	=	Industrial Operator Team
ISS	=	International Space Station
JMST	=	Joint Multi-Segment Training
OJT	=	On-the-Job Training
OPDCS	=	Operational Planning & Data Collection Tool Set
PCDF	=	Protein Crystallisation Diagnostics Facility
SAS	=	Stand Alone Simulation
SOLAR	=	SOLSPEC, SOL-ACES and SOVIM (Solar Observatory acronyms)
TCB	=	Training Control Board
TQCP	=	Training Qualification & Certification Plan
TQP	=	Training Qualification Plan
USOC	=	User Support and Operations Centre
UTC	=	USOC Training Coordinator
VoCS	=	Voice Conferencing Systems

I. Introduction

In 1998, ESA's Manned Space Program board decided to adopt a decentralized infrastructure for the support of European payloads on-board the International Space Station (ISS). This concept was based on operating multiple User Support and Operations Centres (USOCs), each assigned to supporting a majority of tasks related to the preparation and in-flight operations of European payloads. The USOCs are based in national centres distributed throughout Europe. Depending on the tasks assigned to a USOC, they have the responsibility of a Facility Responsible Centre (FRC) or Facility Support Centre (FSC). While FRC is delegated the overall responsibility for a multi-user rack facility or class-1 payload an FSC takes up the responsibility for a sub-rack facility, class-2 payload (e.g. experiment container, drawer payload etc.) and/or self-standing experiments utilising experiment specific equipment. Also individual experiments performed in a facility fall under the responsibility of a FSC. It is mainly focussed on science and experiment operational matters. As the USOCs were responsible for the payload operations, the Columbus Control Centre (Col-CC) at Oberpfaffenhofen, Germany, was tasked with the responsibility of the Columbus module on system level. Together with the USOCs, the Col-CC coordinates all the European operations on system and payload level.



Figure 1. Erasmus Ops and Sim Room

Erasmus USOC has been developed by ESA/ESTEC with support from the Netherlands and Belgium. It is the Dutch USOC located at the ESA ESTEC site and jointly operated by the Dutch National Aerospace Laboratory NLR and the Belgian company Space Applications Services under contract with ESA. In the last two years, Erasmus USOC, Fig 1. has functioned as the FRC for the European Drawer Rack (EDR) and the European Technology Exposure Facility (EuTEF)¹.

The Belgian USOC B.USOC has been set-up by ESA and Belgium and is located in Brussels, Belgium. It is jointly operated by the B.USOC and the Belgian company Space Applications Services. .

B.USOC, Fig.2, has been tasked with being the FRC for the sun observatory SOLAR, a class-1 payload and FSC for the class-2 payload, Protein Crystallization Diagnostics Facility (PCDF) located inside the EDR. The PCDF mission was a huge success and yielded in a very high science return. This success was due to the close cooperation in training and preparation between the B.USOC and Erasmus USOC. Both USOCs are now further evaluating their training concept and starting to implement the improvements.



Figure 2. B.USOC Ops and Sim Room

II. USOC Training Concept

The basic USOC training concept contains of Familiarization, Generic Courses and the Payload Specific Training, as depicted in Fig.3.

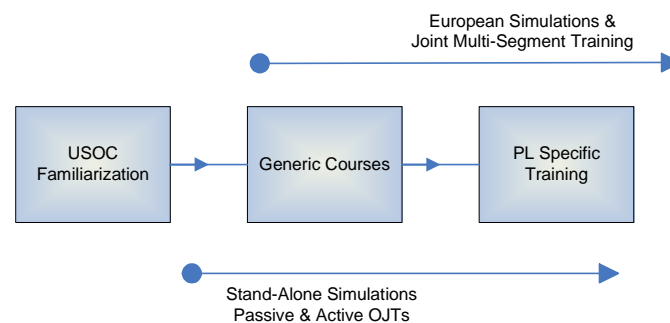


Figure 3. General USOC Training Flow

Distinction is made between qualification and certification. While qualification is more the internal training, under the sole responsibility of the USOC, to a certain acceptable level of payload and operations knowledge, the certification is a more formal matter in the hands of ESA IOT Training Control Board (TCB). After passing the formal generic courses, performing several training simulation and then passing the formal simulations successfully the operator is given a certification from Training Control Board to operate a certain payload.

During the qualification, the trainee first starts with a USOC Familiarization training, consisting of a small set of internal USOC courses on the basic USOC operations concept as well as lessons on how the USOC works, which tools/software and hardware are used. Moreover, the baseline payload operations supported by the USOC are also provided. After this familiarization course, the operator can already start with Stand-Alone-Simulations (SAS), which simulate the operational environment and operations without Col-CC, sometimes including other USOCs. The operator is also enrolled into the generic USOC training programs, which are a set of courses given by the European Astronaut Centre, IOT and Col-CC. Passing these courses successfully the trainee can start with European Simulations (ES) and the Joint Multi-Segment Training (JMST) simulations. Additionally a set of payload specific courses is given internally by the USOC to qualify the operator for the payload and to give him the amount of knowledge required to operate the payload (including anomaly handling). The operators are evaluated after some ES and JMST sessions, in which they are thoroughly tested. The official ES and JMST training including the generic courses is called the certification process, while the USOC specific familiarization and payload training by the USOC are organized to qualify the operator.

Additional On-the-Job Training (OJT), oriented specifically towards the payloads assigned to the USOC, is given by the USOC. This includes passive OJT and active OJT. During the passive OJT, the trainee is sitting next to an experienced certified operator and follows the on-going operations. While during the active OJTs the trainee is performing all the operations with the certified operator sitting next to him. In this case the trainee falls under the responsibility of the certified operator.

The USOC training concept is laid out by the ESA Training Control Board. The training concept contains a list of so-called generic courses that will be provided by the ESA Astronaut Centre (EAC), supported by Col-CC and the Industrial Operator Team (IOT) and the USOC itself. In addition, Erasmus USOC and B.USOC organizes their own USOC specific courses to get the USOC operators ready and qualified for Columbus payload operations. The Erasmus/B.USOC Training and Qualification Program (TQP) is a document providing identification, description and planning for all training courses to be followed by the USOC operators.

For all USOCs a USOC Training Coordinator (UTC) has been assigned, who functions as the main interface between the TCB and the USOC regarding courses, training and simulations. Moreover as a USOC requirement, 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^{2,3}:

- 1) Detail the Increment training requirements
- 2) Nominate the USOCs 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 simulations timeline inputs
- 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 trainees participation to the simulation and training session
- 9) Plan the participation of the FRC trainees to the On the Job sessions
- 10) Provide training logs and 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 Plans and update the Training Qualification Plan

In the following sections a brief overview is given of the different blocks in the USOC training Concept.

A. USOC Familiarization Training

This is the first set of courses and instructions given to a new operator joining the operations team at the USOC. Its main goal is to give the operator in training basic information in the ISS operations concept and the European operations structure. The operator will be given a presentation and a small course on the basics of various subjects:

1) General ISS operations concept and the European USOC concept. It provides general and practical aspects of USOC operations, namely the overall operations layout, Voice protocol, use of OSTPV, Joint Operational Interface Procedures, etc. Although these are later given in more detailed way by EAC, some preliminary knowledge enhances detailed understanding later on.

2) USOC Ground Segment; a small course is given on the basic layout of the Interconnection Ground Sub-network (IGS) and its connections to the USOC, including the hard- and software used at the USOC like the Columbus Distributed Monitoring & Control Subsystem (CD-MCS).

3) More in-depth knowledge of Columbus and its payloads is given, so that the operator can prepare for the generic courses later on.

During this training period, the operator in training is spending around one month continuously in the USOC to familiarize himself with the operations setting. Together with this training block the USOC training responsible starts arranging all the needed user accounts for the operator. These are later also used in the generic USOC training.

B. Generic USOC Courses

The generic USOC courses consist of several mandatory and optional courses given by IOT, EAC and Col-CC at their premises. Operators in training from all USOCs and trainees from other European centres like Col-CC/IOT and EAC participate in these courses. The operator is evaluated with a small test-session after each course, which he must pass to acquire the certification. Besides the theoretical knowledge also practical exercises and small simulations are done with all the participants. During these courses operators from different centres have the chance

to get to know each other better which has a positive influence on the centre-to-centre interaction. The following courses are mandatory for all USOCs for the operator's certification process:

The generic USOC courses consist of several mandatory and optional courses given by IOT, EAC and Col-CC at their premises. Each course is given around 3 times a year, with the possibility of optional classes at the USOCs request. A usual course consists of a small group of trainees, around 10 participants, given intensive and close guidance of lecturers. Operators in training from all USOCs and trainees from other European centres like Col-CC/IOT and EAC participate to these courses. The operator is evaluated with a small test-session after each course, which he must pass. Except the theoretical knowledge also practical exercises and small simulations are done with all the participants. During these courses operators from different centres have the chance to get to know each other better which has a positive influence on the centre-to-centre interaction. The following courses are mandatory for all USOCs for the operators certification process:

1) Columbus User Level Training

This course provides detailed knowledge about the Columbus module on subjects as its command & control, hard-software, data management, thermal control, power distribution, communications, environmental control and life support systems. Also it gives insight into the Columbus systems operations concept, in how and which commands can be issued and telemetry received by ground. In one week time the trainee is familiarized with all the needed knowledge about the European Columbus module. This course is finalized with an official test.

2) USOC Operations Training

The USOC operations training course consists of a week long course on multiple operations subjects. It gives a detailed overview about the whole European Flight Control Team, it gives some basic knowledge about the European ground segment, over which the telemetry and commands are going through. The Joint Operational Interface Procedures are discussed; these are documents describing the interfaces, protocols and procedures to which the centres, Col-CC versus USOCs, communicate to each other. Lessons in the use of voice protocol are taught and information is also given on the used Voice Conferencing Systems (VoCS), which is the main communication system between the different USOCs, Col-CC and EAC. Also a small course is given on the ISS and especially ESA mission planning. The training session is concluded with a test.

The following optional courses are given to the USOCs and European centres according to their needs.

3) Payload Training

This is a detailed course on the four European internal pressurized payload racks inside the Columbus module, the European Drawer Rack, Fluid Science Laboratory (FSL), Biolab and the European Physiology Modules Facility (EPM). It does not deal with the external facilities, EuTEF and SOLAR, or the smaller class-2 payloads. This is optional for the USOCs.

4) Operational Planning & Data Collection Tool Set (OPDCS) Course

This course is given to the operators at EAC, which are assigned for planning responsibilities by their USOCs and other centres. It deals with the OPDCS tool, which is the main tool used for inserting input by different centres regarding activity planning. It is also useful for the training responsables, as they have to insert their simulation inputs using the same tool.

5) CD-MCS Training

The CD-MCS training is provided by the IOT, and mainly oriented to the needs of the Ground Controllers (GCs), who support the operators by keeping the ground segment up and running. However, also operators join the course to further improve their knowledge in the used ground systems. During the training, the CD-MCS and other ground systems are discussed in a great detail.

C. USOC Payload Specific Training

The initial USOC specific training for new team members mainly consists of

- 1) A familiarization course of the payload, based on the initial familiarization course provided by the Payload Developer. This course is provided by the USOC training responsible or the payloads Experiment Activity Manager (EXAM), which is the main responsible operator from the USOCs side for operations coordination for a certain payload.

- 2) A familiarization course on the baselines of operations, which provides an overview of the VoCS system and voice protocol and the general structure and role of the USOCs, Col CC, International Partners. The ground rules and constraints, as well as payload Specific Regulations or Flight Rules are also covered with this training.
- 3) Self Study of the available payload and operational documentation.
- 4) Internal simulation sessions with Engineering Models (EM) and payload simulators. At Erasmus USOC the EuTEF Instrument Simulator (ESM) was used to train the operators, Fig.4. This simulator was interfaced with the EuTEF Data Handling and Processing Unit (DHPU) and simulated the various instruments of the EuTEF platform. It could be programmed to respond to the instrument commands in a pre-programmed manner. The trainee could play with various commands without damaging the instruments. Also an EDR-PCDF software simulator was used various times during training sessions between Erasmus USOC and B.USOC.

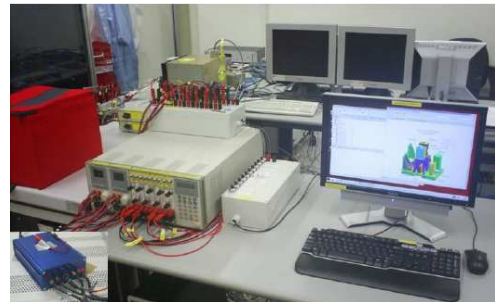


Figure 4. EuTEF Instrument Simulator



Figure 6. SOLAR ESTM



Figure 5. EDR-PCDF EM

Also the EDR-PCDF EM was jointly used by Erasmus as well as B.USOC during various in-house training sessions and SASs, Fig.5. It provided hands-on experience on the CREW part of operations as well as the operator side of it. In the same manner B.USOC also has the possibility of using the SOLAR Engineering Structural Thermal Model (ESTM) for educational purposes, Fig.6, although it was not used during the simulations. Besides training, these EMs were also used for research of anomalies and implementing new operation strategies and procedures¹. Additional Payload specific training is provided whenever there is need for it.

D. Simulations & Certification

When the trainee has reached a certain level of qualification, the certification process can start. The certification process is led by the TCB. It consists of the participation in European Simulations (ES) and Joint Multilateral simulations (JMSTs). After a successful evaluation, the trainee is then certified for operations and the specific payload. In case of a bad evaluation during the Certification process, the trainee shall participate to a number of additional simulations determined by the Training Control Board for an additional evaluation. Together with the simulations, the trainee also starts participation in the Active OJT.

When fully certified the operator is allowed to perform the daily on console operations at the USOC. The complete qualification and certification process takes an average of 8 months. Obviously this was very dependent of the trainee and the pace they worked at during the self study and the passive on the job sessions.

A need can arise of a waiver on the full certification of operators in case of resource problems. During the EuTEF mission, Erasmus experienced that a lack of simulations was hindering its need for certified operators in a short time. In these cases a temporary waiver can be given by the TCB on the full certification of the operator trainee. To qualify for a waiver, the operator has to be enrolled and participating in the training process.

When a USOC is assigned with a new payload, the delta certification for already certified operators consists of the USOC Payload Specific training and a reduced number of simulations.

III. Acquired Experience & Lessons Learned

A. Lessons Learned

Prior to the start of operations in 2007, B.USOC and Erasmus had a limited number of operators, with Erasmus USOC starting with 6 operators and B.USOC with only 4. This was based on the assumption of providing 24/7 support for the commissioning phase and 16/5 support to the nominal operations. All the operators at the time were involved with the mission preparation and were by consequence familiar with the payloads they would operate¹. Next to the generic courses, the knowledge and skill acquired during the preparation phase was adequate to properly participate to the required simulations and to get certified.

At the start of the SOLAR and EuTEF operations, it became clear that the preliminary 24/7 support should be extended. Therefore both USOCs engaged new personnel to staff the on console operations which had to be trained properly, as they lacked the experience both with the payloads and the operational functioning of the USOCs. At Erasmus a need of 10 operators was identified to maintain the 24/7 operations support. Taking into account the turn-around of 2 operators leaving a year, at Erasmus it translated into training 6 operators during the first year of operations. Also at B.USOC, 4 operators needed to be trained during the first year, while an average of 2 enrolling in the full training program each year.

With the number of payloads growing per USOC and the on-going operations at the same time, it became more essential to plan and organize the training well. Moreover with the differentiation between people leaving and joining the teams, the need for a formal implementation of the USOC qualification was obvious. Another issue that rose was the difference in knowledge between operators, this should be evaluated by the USOC itself and not by an external party. 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.

For existing payloads, already being on-orbit for several months, the amount of experience and data available gives additional opportunities for the practical side of the payload training as well as the anomalies encountered during operations. This information together with practical experience is regularly used to hold refresher courses.

Now there was a possibility to improve the simulators, which were already used both during the certification process by EAC and simulators at the USOCs premise it selves, with actual flight data. With the experience gained, the complete training concept could now be revised. Based on the inputs provided by the trainees and experiences on console, a training flow was developed, which should formalize the process of the USOC qualification. With operations ongoing in parallel with training, the following aspects were in the enhancement exercise:

1) Duration:

The complete qualification and certification process of 8 months can be reduced to a period of 3-6 months, including the active OJT. A thorough planning well in advance together with the USOC training responsible is of great importance in order to be able to allow the trainees to start their certification process immediately when they are ready.

2) Difference in knowledge and skills:

For both new trainees as certified operators there is a need to exchange the experiences, such that the whole team has the same level of knowledge. Refresher courses and regular meetings to align the operational environment were needed. Also On-the-Job Training together with an experienced operator proved to be a good solution.

3) Practical experience

One year of operations was needed to achieve a certain regularity in the scientific activities both for the operators as well as for the supporting scientists. Meaning that the first trial and error period was finished and lessons learned.

Moreover the anomalies encountered during operations provided the team much more insight into the payloads and even in handling the operations generally. All this experience was to be reflected in the training.

4) Available Telemetry

Since all telemetry received at B.USOC and Erasmus is archived, the archive proved to be an ideal tool for hands-on training to have the trainee get familiar with the payload's telemetry during nominal operations and to recognize anomalies when they occur.

5) Pre-operational work

With the experience from on-console operations a pro-active approach is essential. Especially in case of anomalies all operators should always know the priorities of their payloads and the possible actions to take. This way real-time operations are far more effective and efficient. Therefore it was decided to include clear what-if scenarios in the training, especially for new payloads, covering all possible aspects that can go wrong or different and the anticipation on that.

B. Revised Qualification Concept

With this experience, the training concept for the USOCs has been revised. A stronger distinction in the Erasmus and B.USOC teams is now made between the formal Certification and the internal Qualification. Whereas, previously more emphasis was put on the formal certification now the qualification plays a bigger role in the whole operator training process. Based on the inputs provided by the trainees and experiences on console a training flow was developed, which should formalize the process of the USOC certification and qualification. This process is depicted in Fig. 7.

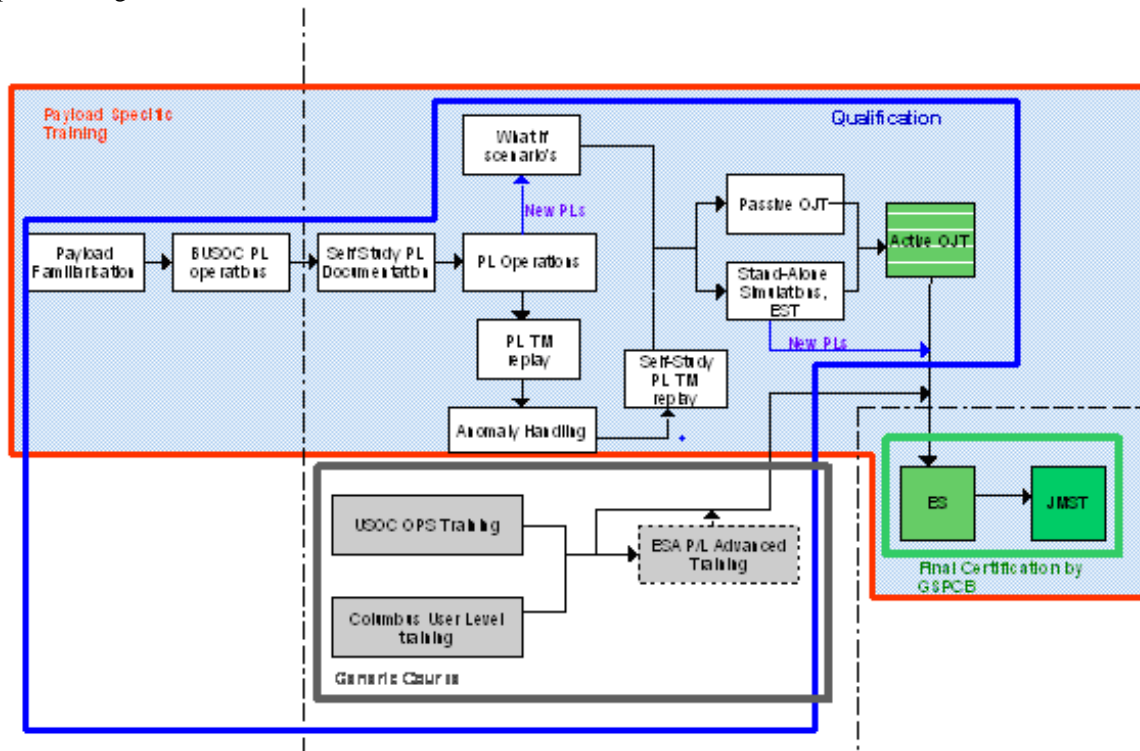


Figure 7. Training Path.

As shown in Fig 7. for existing payloads more hands-on training shall be organized based on the available TM in the archive, where nominal operations as well as anomalies shall be covered in depth.

As for new payloads a session is devoted to the payload specific what if scenario's, furthermore the Experiment Sequence Test is also considered as part of training for new payloads. The Experiment sequence Test is an end-to-end test performing a complete scientific experiment sequence using the operations set-up and all operations products. Obviously this kind of session is an excellent way to familiarise the trainee with the payload, the objectives and the operational products. Moreover operational counterparts are often also involved during EST providing the first operational interactions with all involved parties.

To formalize the complete process each block in the Training Path under the USOCs responsibility shall be evaluated and documented through a training log.

As TCB improved the certification process to meet the needs of the USOCs, the USOCs themselves further enhanced the qualification process for their operators. Further improvement was achieved in the formal certification process by focusing the mandatory courses more to the specific needs of each USOCs as previously the training was more general for all USOCs, Col-CC and EAC. After two years of European operations on Columbus, ESA together with the national USOCs are evaluating and implementing further new findings to have well trained operators to successfully support future operations together with the International Partners.

Acknowledgments

The Authors would like to thank the whole ISS operations Flight Control Team, including the International Partners for their wonderful support over the past two years of European operations. Also a lot of effort was put into

the operations concept by the IOT and the difference payload developers, which were on-call during the late nights whenever needed.

Further the authors thank the ESA Payload Operations management (ESA-POM), the ESA Mission Science office, the Columbus Control Flight Control Team for their collaboration and support. Also a special word of thanks to the ESA USOC Management, the National Aerospace Laboratory (NLR), Space Applications services and B.USOC management for their close cooperation and for providing the budget and personnel for the Erasmus and B.USOC/ This led to regular experience exchange between the two USOCs and close cooperation during the critical PCDF mission¹.

References

- ¹ Arshad, A.M., Hoppenbrouwer, T., Annes, R., Dujardin, P., “ISS Payload Operations And Support”, *Space Operations 2010 Conference*, Huntsville, AL, April 2010.
- ² Klai, S., B.USOC Training & Qualification Program, Issue 1.4, BUSOC-SAS-TQP, June 2008
- ³ Arshad, A., Erasmus Training & Qualification Program, Issue 2.2, ERASMUS-USOC-NLR-TQP, July 2009