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Operations Training for Everyone – The GSOC "Spacecraft Operations Course"

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Abstract

For more than 20 years, the German Space Operations Center (GSOC) has regularly offered a unique training program. One or two times per year, within five days, a group of up to 18 participants receives lectures and exercises on most aspects of spacecraft operations. The curriculum ranges from project and resource management to flight dynamics, ground station design and operations, and aspects of satellite subsystems. The hands-on portion includes mission planning, flight dynamics, creation of flight procedures, voice communications, and a realistic LEOP simulation. Lecturers from other agencies supplement the course offerings. The course is given by highly experienced space operations people.

It's an experience shared by many colleagues in space operations: The thrill of designing a new mission and building a spacecraft trumps operational needs. Limitations and bottlenecks in budget and operability then need to be compensated for by the operations centers. The course aims to provide a deep understanding of the operational hurdles and aspects, as well as the constraints that must be considered.

What makes this course special, is the target audience. It is not a training for professional operators, but a course aimed at attracting people from a wide range of interests. Of particular note are two groups: future users of space missions who want to understand what they are buying (procurement, contract management, insurances), and employees of manufacturers (including software specialists) who are looking over the fence to see how "their machines" experience daily life in an operations center.

This presentation firstly reflects on the development of the course content and lessons learned with instructors and participants. Secondly it presents the plans for additional courses and future expansion opportunities are presented. It also shows how course variants are used for lectures at universities.

1. Introduction

Is operating a spacecraft real rocket science? For a random visitor it is surely is. The shear excitement of a rocket launch, the control over objects at unbelievably high speed with a breath-taking precision, the demand for highly-reliable work either because of the cost of the object or the involvement of human life. The casual onlooker is normally deeply impressed by the operations facilities, the engineering and the knowledge involved. At GSOC we offer visitor tours of the control center for the general public for many decades. For most of them visiting the space control center is their first and only direct contact with the space world apart from the news coverage in media. The majority of the visitors are simply stunned, however there are some people who want to know more details about the mission organization and technology.

On the other side, when working with customers, academia and industry, we experienced that for a long time it was quite common to assume that all necessary knowledge also about the operations aspects are with the industry, the research institutes and the program managers of the agencies. We also experienced that in many projects – especially when a new generation of managers, engineers and scientists were coming in – that important aspects are neglected and valuable lessons were forgotten or ignored. Because of the prototype nature of space flight missions, it is typically too late or too costly to make corrections late in a project or even after launch in orbit. Any deficiencies then have to be corrected or amended by the operations team and result in reduced capabilities or increased costs or both.

Real-life examples include necessary ground tests that were about to be omitted. Also under-estimating the effort for flight procedure generation of the necessity to meticulously prepare in-orbit tests several times often lead to many months of delay before launch or before beginning the operational phase.

It is also quite common in the classic space world that industry acts as a one-stop-shop for the customer (main contractor), acting in the middle and thus creating a distance between the mission operator and the end user/customer.

In that situation, in 1999, the idea came up to create a training course specializing on operations. Attending the *Space Systems Engineering Course* [1] at the University of Southampton served as a role model, offering that course since 1974. However, at the course the topic of space operations was only addressed in one short lecture. The idea was to complement the *Space Systems Engineering Course* by a new Course focusing on Space Operations. Like in the systems engineering course, the target audience should be open, available to anyone. The knowledge would be comprehensive, but at a general level, yet directly based on concrete tasks and projects in our control center. The aim was to make the tasks and responsibilities accessible, lay out the methods of project management and finally to allow participants to ultimately experience the work-life in a space operations control room by conducting practical exercises.

This paper reflects on the task to spread the knowledge about space operations to space stakeholders that are not directly working in space operations. It will show the format and the development of the current training portfolio.

2. The "Classic" Course

2.1. *Format*

The course is given in a five-day week full of lectures, excursions and exercises. A total of 22 learning units are on the agenda. Participation is limited to 18 persons. This is mainly caused by the fact, that some of the exercises are held in dedicated operational rooms of limited size and because it is better that one trainer does not instruct and coach more persons at one time to keep up the quality. This also gives a more manageable audience size creating a seminary atmosphere, where people are more attentive and also ask more questions.

Spacecraft Operations Course October 2022

Monday (10.10.)	Tuesday (11.10.)	Wednesday (12.10.)	Thursday (13.10.)	Friday (14.10.)
F: 8:30 - 9:00 Registration		8:00 - 9:00 Bus transfer OP --> WHM		
L: 9:00 - 9:30 **Welcome & Introduction**	L: 9:00 - 10:00 **AOCS Ops**	W: 9:00 - 10:00 **Ground Station Design & Ops.**	L: 9:00 - 10:30 **Interplanetary Operations (ESOC)**	L: 9:00 - 10:00 **CubeSat Operations (CNES)**
L: 9:30 - 10:30 **Space Environment**	L: 10:15 - 11:15 **Orbital Dynamics**	W: 10:00 - 11:15 **Tour at Weilheim Ground Station**	L: 10:45 - 11:45 **Power/Thermal**	K1: 10:15-14:15 **Simulation** including lunch break
L: 10:45 - 11:45 **Mission Ops Preparation**	L: 11:30 - 12:30 **Attitude Dynamics**	11:15 - 12:00 Bus transfer WHM-->OP	L: 12:00 - 13:00 **Human Spaceflight Ops**	
S: 12:00 - 13:00 Lunch Buffet	S: 12:30 - 13:30 Lunch Buffet	S: 12:00 - 13:00 Lunch Buffet	S: 13:00 - 14:00 Lunch Buffet	
F: 13:00 - 14:15 **Tour at O'hofen Control Center**	K1: 13:30 - 14:00 **Console Intro**	K1 / 005b / K2a: 13:00 - 14:45 **SIM Intro (Team 1)** / **Flight Dynamics (Team 2)** / **Mission Planning (Team 3)**	K1 / 005b / K2a: 14:00 - 15:45 **SIM Intro (Team 2)** / **Flight Dynamics (Team 3)** / **Mission Planning (Team 1)**	
L: 14:30 - 15:30 **Mission Ops Execution**	K1: 14:00- 16:45 **FOP Exercise** including coffee break	K1 / 005b / K2a: 15:00 - 16:45 **SIM Intro (Team 3)** / **Flight Dynamics (Team 1)** / **Mission Planning (Team 2)**	K1 / 005b / K2a: 16:00 - 17:15 **VoCS Training**	L: 14:30 - 15:30 **Closing Remarks**
L: 15:45- 16:45 **Ground Data Systems**				
L: 17:00 - 18:00 **Flight Procedures**	L: 17:00 - 18:00 **Mission Planning**	L: 17:00 - 18:00 **Repeater Ops** (external lecturer)	L: 17:30- 18:30 **On-Orbit Servicing**	
F: 18:00 - 20:00 **Welcome Reception**			19:00 **Social Event**	

Locations:
F = Foyer
L = Lecture Room (Red Salon)
S = SIM-Hall
W = Weilheim
K1 = Control Room K1
K2a = Control Room K2a
005b = Room 005b

Figure 1: Example Course Timetable

Figure 1 shows a typical agenda. The course comprises 16 lectures, 2 visits and 6 exercises. We placed the exercises into the early afternoon to compensate for the after-lunch fatigue. There is an early morning timeslot necessary for the long bus drive to DLR's ground station site at Weilheim which is 45 minutes south from our control center. The lectures are separated by coffee breaks also to encourage the interactive contacts between the participants and to give them a chance for extra discussions with the lecturer. We are placing the more introductory lessons to the beginning of the week and some exercises require to have heard a specific earlier lecture.

The topics cover a wide range from Mission Management, Ground System Design, Mission Operations, Mission Planning Software to Spaceflight Dynamics.

A welcome cocktail on Monday serves as an icebreaker and a common dinner on Thursday night rounds up the course. During the week, lunch is provided by the DLR cafeteria. At the end of the course the participants receive their certificates for the course attendance.

The course material is provided in the form of the Book [2] (cf. chapter 2.6). Also, the participants receive the presentation slides on a USB memory stick.

2.2. Teaching by experts, not teachers

One of the major attraction points of the course is that all content is provided by experts who are normally working in their project. This results in a less academic approach and is maybe less pedagogic in the presentation. Also, in many cases it is presented only from the perspectives of the lecturers. However, their credibility about the relevance of the content is beyond doubt and we usually indicate where we the limits of our specific experience can be seen.

On the other hand, using in-house experts also limits the number of courses that can be given per year and also can affect the availability of our lecturer. This is normally handled by changes in the agenda, but we try not to exhaust their willingness of being part-time teachers. Over time we identified backup lecturers for the most important topics.

2.3. Maturing Content

During the first courses back in the 2000s, the content was very hardware oriented and mission specific. This is good on one hand as many of our customers are not space engineers, but on the other hand it takes up time form the operational aspects. In many cases the presentations were very tightly oriented at the lecturer’s project and in many cases restricted to the scope of geostationary projects that were dominant at GSOC at that time. We worked with the lecturers to widen the scope to other types of missions and spacecraft and in general to put more focus on the operations aspect, the work style and the virtues of doing operations. Each year the lecturers were asked to evolve and update their lectures, with varying success, as project work and flying missions of course always have priority. This resulted in only little progress over the years.

From 2010 we began to update and evolve the content and improve the presentation quality. “Train the trainers” was the idea and we were using professional presentation training for the lecturers. Together with new support by in-house graphics design experts we managed to reform the presentations into a good lecture aid that is not distracting from the lecturing person and only highlights the contents. We also phased out some lectures that presented yet another satellite subsystem, but are more or less redundant in the operations style. This made room for new lectures and we received very good support from colleagues in collaborating control centers in special topics like interplanetary mission operations. In that way a much wider range of expertise can now be presented (cf. 2.5).

In a next step we converted the presentation material into book chapters (cf. 2.6). The most recent change was to establish a dedicated team to support the further evolvement of the course. In that effort we started to accompany and actively support the lecturers in the revision of their papers in respect of clearness and structure. Clear learning objectives were set up for the lesson and the content checked for completeness. Also, we decided to include more practical exercises in the course schedule. From the feedback of the participants we could see that the exercises are the most highly appreciated. So, we established a four-hour simulation, a voice protocol and a flight procedure generation exercise.

These constant updates and extensions kept the course attractive over time. The content and agenda have changed over the years, but the original concept is still visible and remains valid.

2.4. The role of exercises

The training offers five hands on exercises of different areas.

After an introduction, the trainees are going to transfer the theory learned in the lectures into practice by solving tasks on the control room consoles and using mission software. They work in groups or independently. Thus, a very deep knowledge transfer can be ensured not least as the fun level of the exercises is very high. The practical exercises nicely interrupt the frontal lessons during the long days, keeping up the attention level.

Exercise 1: Flight Procedure Generation

During mission preparation, the Subsystem Engineers have to write the Flight Operation Procedures (FOPs). Thus, the FOP exercise gives a practical insight to hands on writing of FOPs.

The trainees will work with the procedure editing tool created by and used at GSOC (cf. Figure 2).

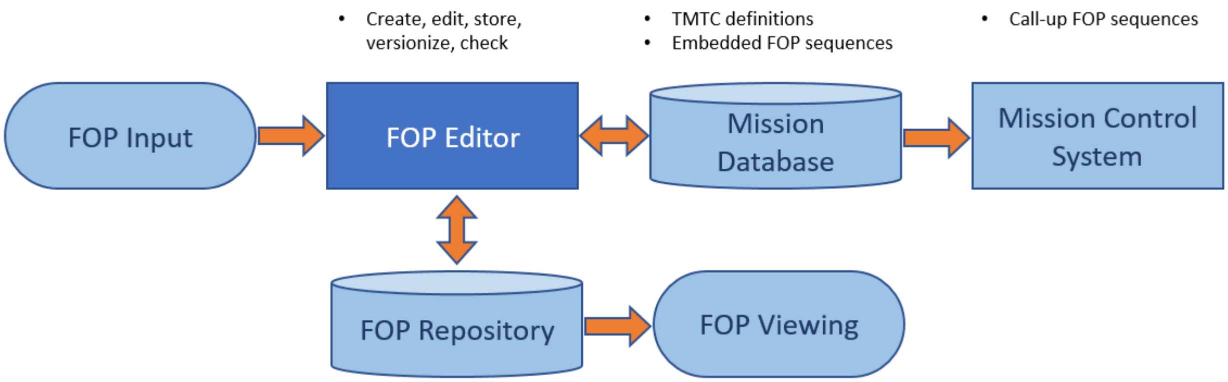

Figure 2: The Flight Operations Procedure (FOP) Environment

They learn to create sequences of steps containing execution instructions, telemetry item references their expected values and telecommands. The trainee also learns when to split up a procedure in order to handle it easier and faster, and that it is important to write an extra sequence for external input to avoid mixtures and guarantee a flexibility while the procedure is straight forward, can be easier loaded or reloaded. Further the trainee learns that only the procedure relevant Telecommands (TC) are loaded or can be easily reloaded unnecessary loading and deleting of TCs should be avoided.

The trainees also learn to integrate connected activities in one step with sub-steps if appropriate and to use special step types with care (like e.g. if, repeat, for, precondition, etc.) to avoid a decrease of readability and thus slow down operations. They also learn when to implement FOP comments for additional information which is relevant to the FOP execution. Further the trainees learn about accompanying work like creating a FOP list, creating implantation notes as well as quality assurance.

The focus of the exercise to teach the trainees to always aim for maximum clarity writing a FOP by sticking to a straight step structure, short and concise comments and avoiding double negations, developing FOPs per sequence of events if possible and applicable to avoid double or vain activities in subsequent FOPs, and to stick to uniform norms for the whole operations team, like the FOP creation guideline.

After an introduction how to use the tool with which Flight Operation Procedures are written, each trainee receives the task to write his/her own procedure.

One possible task is to develop a nominal FOP for manual execution in the LEOP of a geostationary satellite that aims to get to the so-called Normal Mode (NM) for the first time in the mission. Major activities planned beforehand as part of the Sequence of Events (SOE) following the first contact after launch are the propulsion venting and priming, sun acquisition and partial solar arrays deployment. Furthermore, AOCS (Attitude and Orbit Control System) units necessary to get to the first NM (i.e. star tracker and reaction wheels) will have already been switched on, checked, and configured properly (same goes for the correct telemetry (TM) configuration according to TM budget plan).

The tasks of the FOP exercise are to configure the spacecraft for NM and switch over. The initial configuration is predefined e.g.: AOCS mode is CPSA and the satellite is rotating as well as the end configuration, e.g. AOCS mode is NM, the Manual Attitude Profile is uploaded with a sun pointing profile, satellite is 3-axis stabilized.

First the trainees have to gather the required information of different sources and inputs from a guideline, operational procedures an additional information given. Each trainee is asked to think ahead, creating a rough structure, putting all activities in an order and organizing them in steps with an appropriate step logic by creating a sequence layout. After developing the FOP using all inputs, the trainee has to save his/her procedure and commit it to a repository.

Exercise 2: Voice Communications Training

The VoCS exercise introduces trainees to the voice communication protocol used at GSOC and its technical components, like setup of VoCS loops, roles and rights resulting of this concept. It is done in the main control room of GSOC. The exercise starts with a few slides about the VoCS hardware used. Voice loops, roles and rights are explained. All trainees are assigned an individual call sign which they have to use.

The focus of the exercise and thus the major part of the VoCS exercise is the voice communication protocol as used in spacecraft operations at GSOC and in most control centers around the world. Here the most important phrases are introduced and examples are provided how these are used correctly in operations in order to avoid misunderstandings.

The trainees are exercising typical dialogue situations using the VoCS System. In that part the trainer only interrupts the exercise to either guide to the next exercise or to correct the trainees. The trainees are going to learn how to shorten the dialogues and stick to the protocol in order to avoid errors or creating chaos or panic in critical situations.

Exercise 3: Flight Dynamics

The Flight Dynamics (FD) Exercise deals with two tasks, an Orbit Determination for a LEO and a Fine Station Acquisition for a Geo-Stationary Mission.

In the first task, the Orbit Determination for a Low Earth Orbit (LEO), the trainees are given a scenario i.e. the spacecraft is launched into a polar LEO orbit with a specific inclination and semi-major axis at a dedicated separation time and first scheduled ground station contacts of the first orbits. After some instructions the trainees are asked to perform the orbit determination (OD) according to a certain procedure using the provided GSOC-developed software tool.

In the second task, a Fine Station Acquisition for a Geo-Stationary Mission, the trainees are given a special scenario i.e. after the last main engine firing the spacecraft is drifting in a drift orbit (DO) close to the geo-stationary altitude. Here the DO is predefined starting at a specific longitude, and defined by a given apogee radius and perigee value below the geostationary altitude, the satellite drifts to the East with a certain drift rate.

Based on the computed drift rate, in this task the trainees have to plan two maneuvers to:

1. change the current drift rate to bring the satellite into the target control box (pre-defined longitude) while avoiding other satellite control boxes (pre-defined longitude) at the same time, and
2. stop the drift in the reached target box.

Exercise 4: Mission Planning

In the first part of the Mission Planning exercise, the trainees have to act as operators of a geostationary data relay satellite. That fictitious mission can support different types of services like television or science tasks, but only one at a time, at different durations, demand on resources, prices and priorities.

The task of the trainees is to optimize and maximize the mission utilization by arranging and implementing ten different activities within a predefined time window using a generic planning tool.

The exercise is arranged similar to a game. The trainee groups can achieve scores and compete against each other. They have to consider the available resources and priorities while trying to achieve the most profit. The goal is to teach players the mindset of a planner. The tool assists in that task, but does not take over the planning.

In the remaining time of the exercise, typical planning scenarios are then demonstrated to the players. Through their own fresh experience, they can then understand these examples very well.

Exercise 5: LEOP Simulation

The most intense exercise session, which is also a highlight of the course week, is the Launch and Early Orbit Phase (LEOP) Simulation. It takes about four hours and will be done from the Main Control Room of GSOC. We use a setting with training accounts, but are using real-life control systems, support tools and flight procedures. A spacecraft simulator provides the data stream and allows realistic command interaction. Each trainee is connected to the VoCS System and is logged-in to all system components with their personal credentials.

Participants learn the interdependencies within the Flight Operations Team while executing Flight Operations Procedures in real-time. They learn the working rhythm of flight control and feel the unique tension of working in a tightly controlled team.

During the simulation, trainees are assigned to specific roles. They are divided in groups of two at one position to support each other as the learning curve can be very steep. The position assignments will be rotated during the simulation. Thus, each trainee gets the possibility to act in different roles. The role of Flight Director is very demanding because it guides the team through the flight operations procedures, sets the pace, and has to keep all other positions involved, requesting information or getting a “Go-Ahead” from them.

This position also instructs the command operator to send prepared telecommands or reconfigure the mission control system. As the trainees are new to theses tasks, plenty of explanations are provided in the flight procedures and by GSOC staff that prompts and supports the positions from behind. In parallel, like in real operations, the trainees need to write Anomaly Reports and Recommendations as well as to log their operational activities in the OPSLOG continuously. All operations are running in real time. Milestones have to be met within a prescribed time. Flight engineer skills like thinking ahead, reacting timely and being proactive are trained as well. A small number of unexpected situations are included in the setup.

The procedures to be executed are taken from a LEOP of a communications satellite in transfer orbit to geostationary position.

We prepared the activities in the same sequence as in real-life beginning with First Acquisition and continuing with the Spacecraft Health Check, the activation of the propulsion system, the first sun-pointing mode and solar-array deployment. The simulation is however time-limited and we will have to interrupt at some point.

2.5. External Contributions

GSOC is involved in many but not in all different types of space missions. In order to offer a more complete course agenda we used our close ties with other space operations centers in Europe. For many years we include invited lectures from ESOC, from CNES and from a former DLR colleague. Thus the lectures about Interplanetary Missions, Cubesat Operations and Repeater Payload Operations are highlights contributed by external colleagues.

2.6. The Slides vs. The Book

In the beginning all training documentation was given to the participants as print-outs of the slides used during the lectures. The work for the back-office was enormous. All updates and changes had to be requested from the lecturers a few weeks before to begin with the photocopying process. And as a result of good presentation tradition, good slides should generally have little text and will be only helpful in later study when additional notes are taken. A little could be gained from printing also the slide speaker comments. The resulting slides compendium was then handed to the participants in two large office folders. In later years we produced glue-bound simple books which were slimmer and easier to carry. The yearly few changes resulting in small reworks were not really worth the repetitive effort. The idea came up to again follow the example of the Southampton course [3] and to produce a book as course documentation.

This has the advantage that each author had to go through their slides and put them into a clear text form, thereby making the content more up to date. It is understandable that the content of a book cannot follow each and every new development, but gives a solid and sound knowledge basis. This took the pressure out of the documentation production. The slides can still be updated, but since that time it is enough if the presenter brings them along at the time of the lecture.

The downside of the book was that it was very hard to bring the experts into book-writing. It took intense support from the editors to shape and fill the chapters. A positive side aspect is that the book can be even more complete that the course in that more operational fields can be included than can be presented in one course.

The book [2] was an instant success and also gained a readership beyond the course. In 2022 a second edition was released.

3. Deriving Formats, Methods and Contents

3.1. Internal Benefits

Very early it was recognized that the course content is also extremely helpful for the on the job training of new staff in our own control center or for colleagues from other DLR institutes. Even a few years after they started their work at GSOC, many young professionals did not have the full overview with all the aspects of the work in a space operations center. So, we invite a handful of them to follow the lectures (in the backrow of our classroom). We keep them at a certain distance to the official participants because we want to make it evident that our external customers are getting our prime focus and attention. Internal staff will not be part of the exercises, excursions, lunches and other amenities.

However, the exercises actually are of high importance to our new DLR colleagues. Therefore, with a delay, we conduct the exercises exclusively for them. Meanwhile taking part in the course is part of GSOC's on-the job training process.

In that way we establish, harmonize and stabilize our know-how in house and strive to have a common view on our work across all departments and groups.

3.2. Reaching out to Academia

Around the year 2010, we received an inquiry from the Technical University of Munich, if it was possible to for a student course to visit the center and do some simulation and exercises. This was recognized as the chance to improve the perception of operations right from the beginning. If students are in touch with the reality of space operations early on, they will be more aware of the challenges and importance of mission operations. In a yearly arrangement we installed a set of lectures and exercises for the students. The units were taken from the commercial course and could thus be re-used. The students come to the control center for half a day every other week as part of their curriculum. This student course is embedded in a regular official university lecture. In that way there is no further organizational overhead for the control center.

Over the years we established more schemes like this, as there are a number of universities in the Munich area reaching out as far as to the university of Stuttgart. All receive individual arrangements of lectures and exercises still being built upon the already existing units of the regular Spacecraft Operations Course.

Figure 3: Students of the University Stuttgart during a simulation in the main control room of GSOC

3.3. Expansion and its Limitations

The course was originally given once per year, usually in October. The rising interest in our course resulted in growing waiting list. Those who could not be accommodated in one course, had to wait for a year for their chance. This was not very satisfying, as their interest is often based on being newcomers in the space business or is related to new project tasks.

A few years ago, we decided to implement a second course per year to provide more capacity and more flexibility for participants. This was usually given in spring time. We will evaluate the continued interest, because there is also a reasonable lower limit in the number participants where the effort would exceed the return. This was not done up to now, but if we would not reach a certain number of participants then a course could be cancelled, with the bookings being taken over to the next course date if possible for and desired by the customers.

The downside of running the courses with our experts as lecturers is that we need to fix the dates for the courses already several months in advance. Project work is sometimes limiting the time available of the experts. Also, as mentioned above, lecturing is not the main task for everybody. Some experts enjoy the opportunity of teaching, for others it is not their first priority. And as long as there is no year-round course activity, using professional lecturers is not an option. However, even if some teaching skills are missing it is compensated by the special credibility of the experts.

3.4. COVID and Remote Teaching

GSOC was hit by COVID like any other control center. We overcame the situation in a very controlled way where personal contacts were minimized, spreading operations out over different work places in separate rooms while on site and otherwise work from the home office. In non-office hours the flight team could provide good support from their home, but the secure base for active spacecraft control (e.g. the sending of the telecommands) remained in the control center at all times.

This is what makes a control center unique and it is the same with out training course. Nothing can fully replace being on site and receiving the immediate and grand experience of the control rooms, installations, and antennas, interact with people face to face and see the context of applications. And then came COVID-19.

The first event affected was a student course. Everybody expected that the course would need to be cancelled. But we decided to take a chance. Holding the lectures was the easy part, simply using the videoconferencing tool provided by the university. By that time all staff was fairly well equipped to participate from home. For the site tours in the control center and at the ground station site we recorded improvised videoclips to provide a walk-through view. This was much appreciated and imperfections were accepted. The exercises were harder to provide remotely: the voice operations exercise was done using the conferencing system, assigning call-signs to the students and doing the exercises. This proved to be easy. The simulation was using the remote monitoring capabilities of the telemetry system and an external website for flight procedure access. The student in charge of command operations used a special online support system that allow to use the mouse and the keyboard. Luckily the training system was already located in a network area that allowed this type of access. We managed to do the simulation in that way. However, it was much slower and more error prone. It was clear that students were much more unsure on how to proceed. Also, they were using mainly single screen laptops which forced them to do a lot of window juggling.

The resume for us was that we did not want to do this with the normal course participants who of course expect a flawless performance for their money. And the effort for remote lectures is not much smaller than for on-site presentation. To avoid a reduced impression, we decided to cancel the courses for 2020. In the second half of 2021 it was again possible to come on site and we did two courses in October. In that year we limited the audience to those living in Europe in order to minimize the risk of travel restrictions. In 2022 we returned to completely normal execution.

4. Future Developments and Outlook

Our future steps will be to reach out for new audiences. Many customers are from Europe. But we know that in many regions of the world a new interest in doing space is emerging. Many people recognize that space is important even to smaller nations. And they also recognize that it is not future-safe to simply buy complete spacecraft and systems from established manufacturers if they want to establish higher knowledge about Science, Technology, Engineering and Mathematics (STEM) in their countries.

Also, we have to recognize that the space world is changing. A completely new wave of nano-satellites and micro-launchers is coming up. This will establish new ways to do operations. If we want to stay in a prime role as a center of excellence in space operations, we also have to gain new experiences and adapt the training.

Most participants gave us a positive feedback and ask about follow-on or customized courses. So, we investigate possibilities for advanced courses with other topics of more detailed knowledge.

5. Successes and Lessons Learned

Our biggest success is the good reputation which we take from the fact that participants recommend us to their colleagues and that their companies are continuously booking seats. We also perceive that the update rate of the knowledge we provide is very valuable. The topic of spacecraft operations and the interest for courses remain of high demand. Installing a second course per year allowed us to be more flexible and attract more customers.

Since the beginning, the course was always attracting an international audience ranging from Asia, New Zeeland, North America to Arabia, but of course also from many European countries.

Another success is the course book, which has achieved a standing on its own and has reduced the work load from course to course. We were confirmed that the control center and the ground station are unique assets and that for the upcoming years, on site courses are the way to go.

Acknowledgements

The authors would like to thank the many contributors to the Spacecraft Operation Course. The lecturers provide their knowledge willingly and usually sacrifice their project time in the process. Special thanks go to our external lecturers from ESA-ESOC, CNES and the Technical University of Munich who widen the spectrum of the course and travel to Oberpfaffenhofen again and again for the support of our courses. Our gratitude goes also to our back-office who support us in the design, preparation and organization of the course. Without every one of you, the course would not be possible. A salute goes to the university of Southampton whose Short Course on Space System Engineering was our role model and is our benchmark. And last not least, to the students of the university of Stuttgart who kindly allowed us to use their photo from one of the simulations for this paper.

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