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From ISS European Institutional Training to Private Astronauts Training Services

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Abstract

The introduction of the 6 crew rotations phase in 2009 (Expedition 20) and the completion of its assembly in 2010 (Node 3 and cupola installations with Shuttle mission STS-130) resulted in greater availability of crew time and functional modules for usage on-board the International Space Station (ISS): the ISS entered a new "utilization phase". After more than 10 years of well-oiled machinery, 2021 marked the official start into a cohabitation phase on-board ISS, with the arrival of private astronauts. In 2021, the ESA Instructor Team staffed by a group of co-operating companies welcomed 3 private crews at the European Astronaut Centre (EAC) for training implementation: Ax-1, Soyuz MS19/18, and Soyuz MS20. With more than 15 years of experience in agencies' astronaut training, the instructor team was excited to deliver training to this new category of astronauts, but what about the training content and the training method. Indeed, private astronauts constitute a new generation of ISS visitors who must receive training, but adapted to the characteristics of this population. Different to agency astronauts, private astronauts build a heterogeneous group with different characteristics and potential discrepancies not only in academic background and prior involvement in space business, but also in vocation, motivation, and expectations; preliminary training, culture and ecosystem; investment/readiness to make sacrifices; media coverage; medical/psychological background/mind-set. Training for ISS OPS is one thing, but for the future when Space Agencies step back and become one of many facility developers and users in a commercialized space, future training concepts and methodology require a tailoring for most efficient results maintaining all safety standards. This requires a team having a comprehensive background in institutional space business requirements and the capability to translate complex space business expertise into simple and smart training modules.

But not only the concepts of training are changing: the new era is actually a novel market, a new growing sphere of the space economy. Indeed, the training of the commercial se Private Astronauts and Space flight Participants is not covered by existing ESA obligations towards NASA and Roscosmos and is procured directly by the private company organizing the missions concerned. To this end, ESA has empowered ALTEC, being ESA's prime contractor for the supply of Training, Logistics and Operations services for the International Space Station, and as such, together with an industrial team lead by Lufthansa Aviation Training, in charge of Crew Training activities at the European Astronaut Center, to provide training for astronauts via direct contract with the mission provider.

This paper provides a deeper insight of these conceptional ideas together with the lessons learned from the first commercially provided training and the future plans for the service evolution.

Keywords: Training, Commercial, Private Astronauts, Space Flight Participants, Astronauts, Cosmonauts

Acronyms/Abbreviations

ALTEC	Aerospace Logistics Technology Engineering Company
ATU	Audio Terminal Unit
BLB	Biolab
CDH	Command and Data Handling
CDR	Commander
COL	Columbus
COMMS	Communications
DMS	Data Management System
EAC	European Astronaut Centre
ECLSS	Environmental Control and Life Support System
EDR	European Drawer Rack
EMER	Emergency
EPDS	Electrical Power Distribution System
EPM	European Physiology Module
ERA	European Robotic Arm
EUROCOM	European Communicator
FSL	Fluid Science Lab
ISS	International Space Station
ITCB	International Training Control Board
GCTC	Gagarin Research & Test Cosmonaut Center
LSR	Life Support Rack

JEM	Japanese Experiment Module
JEM-EF	JEM External Facility
MMI	Man Machine Interface
MS	Mission Specialist
MST	Multi Segment Training
OBT	On-Board Training
ODF	Operations Data File
OPS	Operations
ORU	Orbital Replaceable Unit
OSTP	On-board Short-Term Plan
PA	Private Astronaut
PAM	Private Astronaut Mission
PCS	Portable Computer System
PLT	Pilot
PWS	Portable Workstation
SFP	Space Flight Participant
SSRMS	Space Station Robotic Maneuvering System
SUP	Standard Utility Panel
TCS	Thermal Control System
USOS	US On-orbit Segment

1. Introduction

A typical definition of an astronaut is the following: *An astronaut is a person trained to serve as a professional crew member during a spaceflight beyond Earth's atmosphere and to perform duties related to space exploration. Due to the challenges and hostility of life in space, astronauts spend a large part of their career in training. Representing all humankind, these space travelers test the limits of the human body in space, perform research, support the development of new technologies, and explore the wonders of the Universe in one of the most extreme environments imaginable.*

Figure 1 A historical event – the Mercury Seven crew selection in 1959 (credit NASA)

Since the commencing of the space era, the selection and training of astronauts and cosmonauts constitute the backbone of the US and Russian Human Space Flight programs. To enable them to fulfil their duties, astronauts are uniquely trained.

Currently human space flight concentrates on the International Space Station (ISS). European, American, Japanese and Canadian certified astronauts, as well as Russian Cosmonauts and worldwide institutional spaceflight

participants or private astronauts, participate in short or long-duration missions on the ISS, performing experiments in microgravity and operating the Station's systems. Certified professional astronauts on ISS assemble, activate, and test new Station elements, undertake scientific research, perform spacewalks beyond the Space Station and act as test subjects in life sciences experiments, requiring a very complex and intense training program.

But the role of an astronaut is constantly evolving. Specifically, for the ISS, until recent times with the commencing of new commercial astronauts missions era, the role of the professional astronauts requires a training program with the objective to provide crew members with the appropriate knowledge, skills and attitude required for Station operations, safety and mission success.

On the contrary, the role of the private and commercial astronauts may vary from the pure tourist, to the pilot of a commercial spaceship or a former professional astronaut acting as commander, and consequently their training needs and program varies as well.

2. The Professional Astronauts Training Flow

The overall training and certification flow for a professional astronaut being Station crew member is shown in Figure 2.

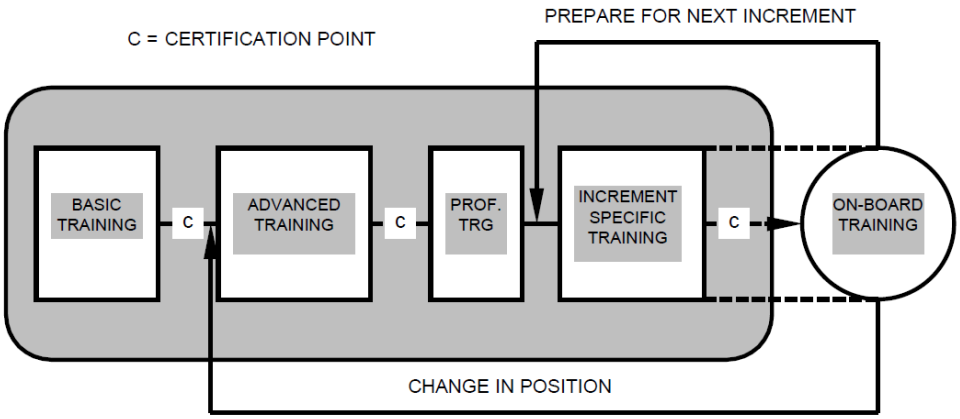

Figure 2 Overall Station Crew Member Training Flow

Each International Partner Agency is responsible for the Basic Training of its astronauts and cosmonauts. For the Advanced and Increment Specific Training of the Station crew members each agency is responsible for its elements, payloads and transport vehicles. Training which requires interaction of the elements, payloads and transport vehicles of more than one partner will be coordinated amongst the involved partners. Multi-segment Training (MST) is a common activity of all partners. The Multi-Segment Training is part of the Increment Specific Training program as described below.

2.1 The Structure of Overall training Flow

The training program sequence is based on three training phases with specific objectives, characteristics, contents and certification as introduced above:

Basic Training provides to the candidate astronauts and cosmonauts basic knowledge on space technology and science, basic medical skills and basic skills related to their future operational tasks including those related to the Station systems and operations. It also includes the training of special competencies, e.g. scuba diving.

Pre-Assignment Training provides to Station crew members knowledge and skills related to operations of the Station space elements, payloads, transport vehicles and related interaction with the ground crew. It builds up on Basic Training and is normally generic in nature and does not focus on increment specific tasks. It is given to international classes of crew members from all the ISS partners and will take place at all partner's facilities to enable

crew familiarity with partners' flight elements and operations. Upon successful completion of the Pre-Assignment Training a crew member is eligible for assignment to a mission.

Assigned Crew Training provides to assigned Station crew (and to a backup crew if applicable) the knowledge and skills required to perform the planned and contingency onboard tasks of that specific increment. To enable good crew integration, the crew is trained together as team, whenever possible. In Increment Specific Training standardized training techniques are agreed amongst the partners. It will comprise the following:

- job orientated training: the training is driven by the payload and specialties at all partner sites.
- partner element training: uses "team-orientated" training involving tasks and systems knowledge. But the main purpose concentrates on multiple crew member training on multiple jobs. It includes to train competencies as crew coordination, multiple-jobs interaction, crew/ground interaction and timeline training, e.g. payload operations within a module simultaneously
- multi-segment training: the crew participates in Multi-Segment Training (MST) putting together payload and systems operations for the entire Station. The crew will work as a team, sometimes with ground controllers via integrated simulations.
- on-board training: On-Board Training (OBT) is considered to be part of increment specific training and will be used by the crews to retain proficiency in skills and knowledge gained in ground training or as Just-in-Time training to learn new tasks on a case-by-case basis.
- Refresher training in key Station systems and operations will be provided on crew request during the advanced and increment specific periods, between missions and onboard. The limited time available for training and extended periods between ground training on specific systems and payloads and actual on-board operations due to the distributed training system will require On-board Training**.**

Table 1 shows the distribution amongst the ISS Partner Agencies and contents of Station flight element training implementation tasks.

International Partner	Partner Element Training	Integrated Station Training
NASA	US-Lab, Habitation, US payloads, Station internal / external systems / subsystems, Dragon	Multi Segment Training
RSA	Russian segment systems / subsystems, Russian research labs, Russian payloads, Soyuz, Progress, ERA	
ESA	Columbus, ESA payloads	
JAXA	JEM, JEM-EF, Japanese payloads	
CSA	SSRMS, Canadian Payloads	

Table 1 Overall Station Training Distribution

Recently, after the end of the Shuttle program and with the commencing of the US Commercial Crew Vehicles program, the training flow includes dedicated classes held at the Commercial Vehicle provider premises, specifically at SpaceX premises for the Dragon capsule.

2.2 The Columbus and ESA Payloads Training Curriculum

For the European Participation to the ISS program, ESA has therefore developed a training flow to fulfil the integrational agreements on the Basic Training and to implement the Partner Element Training associated to the Columbus laboratory and the ESA payloads.

Columbus comprises a pressurized module which accommodates 10 International Standard Payload Racks (ISPRs). Some of the ISS ISPRs are allocated for ESA payloads. The Columbus curriculum will cover those features specific to the Columbus system and payloads, interfaces and operations and is compatible with Station systems and operations core training. The resulting training curriculum for Columbus and ESA payloads is summarized in Table 2 and conforms to the following criteria:

- flight element and payload system, subsystem overview and operations with emphasis on commonalities, differences and subsystem and system to payload interaction,
- over-ride of automated procedures in response to contingencies,

- conduct real-time payload manual operations integrated with ground payload operators and investigators support according to the On-board Short-Term Plan (OSTP) and Operations Data File (ODF),
- Columbus Laptop specific man machine interface (MMI) and operations,

The following subjects are "common across Partner flight elements and are assumed to be part of Station core training and provided by NASA:

- generic maintenance for standard racks, tools usage and handling,
- failure detection, caution and warning and the use of audio in generic simulations,
- environmental and health monitoring,

Generic Station Portable Computer System (PCS) and element specific laptop MMI and operations are covered by Station core training provided by NASA.

The ESA Training Catalogue is based on a curriculum structure which accounts for the advanced through increment specific training flow.

Figure 3 ESA EAC Training Hall, Cologne - Germany (credit ESA)

The standard ESA crew training curriculum for the Columbus and ESA payloads is summarized in Table 2 below.

Block	Subjects	Contents
COL System	COL Core	System Overview Component/ORU Functionality Operations Philosophy Crew Controls & Displays Emergencies
	COL Data Management System COL Environmental Control & Life Support System COL Thermal Control COL Electrical Power System COL Communications	System Overview Component/ORU Functionality Operations Philosophy Crew Controls & Displays Telemetry Analysis Nominal Operational Procedures / Practice / Proficiency Malfunctions Operational Procedures / Practice / Proficiency
	COL Structures & Mechanisms	System Overview Component/ORU Functionality
	COL On-Orbit Maintenance	COL Cleaning & Inspection COL Preventative Maintenance COL Corrective Maintenance COL Stowage
	COL Simulations	Integrated Joint

Block	Subjects	Contents
COL Payload Facilities	Biolab (BLB)	Orientation
	Fluid Science Lab (FSL)	Science Background & Applications
	European Physiology Modules (EPM)	Systems Overview
		Operations Overview
	European Drawer Rack (EDR / EDR2)	Nominal Operations/Maintenance
		Malfunctions Operations
	Life Support Rack (LSR)	Transfer Operations
ESA Experiments	According to mission assignment	Science Background
		Experiment execution

Table 2 Crew member Training on ESA Elements and Payloads

3. Implementation of Commercial Training for Columbus and ESA Payloads

3.1 The current setup of the Columbus and ESA Payloads training service

As part of the ESA ISS utilization program, ALTEC has, since 2015, the responsibility of the Training, Logistics and Operations support services (TLO) for ESA. In fact, ALTEC covers the role of Prime Contractor in the TLO contract, coordinating a pool of European and American companies that collaborate for the provision of the various services to ISS. In addition, ALTEC holds the European Logistics Centre.

Figure 4 Columbus Emergency Training (credit ESA)

In the frame of the Training Service, ALTEC is leading an international consortium that exploits its own instructors at ESA EAC, at Columbus Control Center and at NASA JSC, with the main goal to prepare the international crew for the on-orbit activities during their stay on ISS. The Training Service is responsible of the training development and implementation planned and organized by ESA for the different crew complements in the ISS environment. The training team, under the overall TLO contract of ALTEC, is composed of instructors coming from ALTEC itself (the German branch of ALTEC SpA) and ones from a consortium of companies composed by Lufthansa Aviation Training GmbH, that also technically leads the training activities, GMV GmbH, LSE Space GmbH, Space Applications Services SV/SA, Space System Engineering France EuRL, Telespazio Germany GmbH, Airbus Space and Defense Inc. This industrial team takes care of the lessons development and implementation of Columbus and ESA Payloads. The instructors are all certified according to the NASA & ESA regulations, being prepared on different topics, starting from Basic Training that gives an ISS environment overall overview, functionalities of Columbus system and subsystems, for its own maintenance and operations, to the operability of each single experiments under the ESA responsibility, mainly passing through the main Payload Racks that are installed into the European module (e.g. Biolab, FSL, EDR etc.).
The experienced instructors are involved in this business since several years. Their competences and skills are based on the heritage of the team that, from the very beginning of the Columbus history, contributed to the development and consolidation of training concept now at the basis of ESA Training Division. The instructors take also advantage of training experience external to this specific contract, in order to improve more and more their stable and consolidated contribution to ISS training.

3.2 The Evolution of Space Economy and Need of Dedicated Training for Commercial Crews

The Human Space Flight is evolving together with the evolution of the space economy. Indeed, although it is a fact that in early years of the ISS life, during its assembly phase, when the Space Shuttle was still available, there have been some Space Tourists visiting the ISS as passengers of the Russian Soyuz capsules, it is only in recent years that the start of a global interest in commercial cargo and human flight services has created a new market of the Low Earth Orbit Space Economy: **Flight Services for Private and Commercial Astronauts**.

In this frame, NASA and Roscosmos have put in place a framework for implementing Private Astronauts and Space Flight Participants Missions under commercial contracts. This framework has been coordinated with, and is supported by, the ISS international partners.

The NASA Private Astronauts (PAs) and Russian Space Flight Participants (SFPs) have a requirement to be trained to a certain knowledge and skills to ensure safety and the undisturbed operations at the ISS. The required level of training will depend upon the activities the PAs and the SFPs are planning to perform on the ISS.

For instance, a Dragon commander (typically a former NASA professional astronaut), who has also the role to "escort" and support the rest of the Dragon crew, might need a complete systems-training curriculum, while a tourist who has no mission tasks or payload activities will only need a minimum set of training to ensure a safe and effective mission. Furthermore, for the commercial case it is not just a matter of requirements, of training curriculum to obtain a certification, as the Customer might be interested in additional or dedicated training activities to prepare the mission, for special needs, or just for personal interest.

It became clear that the well-structured and intense training flow that was developed for the ISS professional Astronauts and Cosmonauts is therefore not suitable for the commercial customer, who will not require and therefore will not purchase an extremely long and expensive training. Consequently a dedicated training flow is required.

3.3 Agreements on a Minimum Training Requirement for Commercial crews

As above mentioned, for the ISS case the partner Agencies agreed on the need to establish a set of requirements to ensure that PAs and SFPs get certification by the relevant Agencies to ensure safe and undisturbed operations on the ISS. This requires that the visiting astronauts have a sufficient knowledge to:

- be proficient to the reaction to emergency conditions, until their required level of involvement.
- be familiar with the basics of the ISS Operations to be able to interact with the on-board colleagues and ground operators
- be autonomous for the basic on-board activities concerning their own life on-board (hygiene systems, galley, basic comms, etc.)
- be sufficiently familiar with the ISS Systems and Payload Facilities to minimize disturbance to ISS operations and protect Agencies assets.

To meet those goals, the partner Agencies, responsible to operate the ISS, are still providing their requirements for the training of commercial astronauts, requirements that are then implemented by commercial training companies. For the Columbus and ESA asset cases, the assessment brought to initial agreement on the minimum training flow to be given to the visiting private/commercial astronauts, in comparison with the complete Columbus User Level training flow as follows:

COL User Flow	PAM Minimum	Rationale
COL Sys H/W Tour	YES	* Situational awareness of COL layout and safety are required
Laptop Handling	NO	* Minimum trained crew would not be expected to utilize the PWS
COL EMER Response	REDUCED	* PAM EMER response is to retreat to their vehicle and safe themselves while ISS crew deals with EMER event. * NASA EMER training provides necessary training for PAM response
DMS User Skills	NO	* PAMs not expected to interface with CDH systems on USOS. * Prerequisite NASA training is not being provided for minimum trained crew.
EPDS User Skills	REDUCED	* Utilizing a SUP to power a portable device is possible

COL User Flow	PAM Minimum	Rationale
		* Safety aspects of utilizing COL power outlets is required
TCS User Skills	REDUCED	* PAMs not expected to interface with TCS on USOS. * Prerequisite NASA training is not being provided for minimum trained crew.
ECLSS User Skills	REDUCED	* PAMs not expected to interface with ECLSS on USOS. * Prerequisite NASA training is not being provided for minimum trained crew.
COMMS User Skills	YES	* Training on usage/location of ATUs and C&W panels provided at JSC. No other interface with USOS comm assets expected. * Potential usage of COL video system if ESA desires would require this unique training * NASA C&T Operator training will not be provided
User Eval Sim	NO	* Wouldn't be required if not intended to be qualified as a User
COL Payload Overview	REDUCED	* PAMs not expected to interface with Payloads on USOS. * NASA Payload training is not being provided for minimum trained crew.

Table 3 Columbus User Level vs PAM Minimum training – initial agreement

As mentioned, the above constitutes the first cut of the assessment on the minimum training needs. After the first implementations, those have been evaluated and updated to better balance the minimum needs with the efficacy of the training considering the experience gained.

3.4 Implementation of the Columbus commercial training

It is important to mention that the training of the PAs and SFPs is not covered by existing ESA obligations towards NASA and Roscosmos. Moreover, ESA does not have the mandate from the participating countries to perform activities in support of foreign commercial entities like Axiom Space and Space Adventures. The Columbus and ESA Payloads training can therefore best be procured directly by the private company organizing the PA and SFPs mission concerned.

In this context, the availability of the TLO service, where an industrial organization provides a complete set of Columbus training courses, represented the optimal solution to simultaneously:

- implement the training through a direct purchase contract between the SFP or PAM organization and the TLO service provider;
- provide a training course that is recognized by ESA and the other ISS Partners, and that results in obtaining an ESA certification for SFP and PAM astronauts.

ESA has therefore empowered ALTEC S.p.A, being ESA's prime contractor for the supply of TLO services for the International Space Station, to organize and provide training for PAs and SFPs via direct contract with the private companies. Furthermore, with the aim of guaranteeing the expected quality of the service, supporting ESA with the endorsement of the results, but also to facilitate the training implementation, it was requested and agreed to rely as much as possible on existing roles and processes. This is also fundamental to facilitate the coordination with the ongoing training of Agency astronauts, as still provided by the TLO service and with the same facilities. In these circumstances, indeed, ALTEC uses ESA facilities to run the training program in order to be able to efficiently implement the ESA recognized training, while still staying in the frame of a commercial contract envelope. To allow this, the use of EAC facilities as well as the support of ESA to the training is reimbursed on full cost basis to ESA by ALTEC.

The TLO training service team, on the basis of this empowerment and on the above mentioned first cut on the minimum training requirements, has developed a first set of training services to be offered to the PAM and SFPs providers. In this frame two options have been made available that would both qualify according to ESA on the level of knowledge and skills on the Columbus module to ensure the safety of the private astronauts and space flight participants and the undisturbed operations in Columbus.

The first option is the full **Columbus User Level training.**

- It is the same training flow that is given to ISS professional astronauts and cosmonauts to familiarize with the Columbus module basic features and ESA ISS operations.
- An Astro Training immersion of PAM trainees into ”real spaceflight experience“ at EAC
- It is therefore a solid foundation to provide confidence to Private Astronauts in accessing Columbus as well as to let other astronauts and ground operators trust on Private Astronauts level of competency.
- This provides the best training quality with flight-like training facilities, and very well exercised set of lessons, with several years of experience and feedbacks from professional astronauts.
- It is a 4 days training module to be held at EAC.
- Up to 4 Trainees can be accommodated in the same 4 days class.

Second option is the so-called **Minimum Training.**

- It is a reduced version of the Columbus User Level Training.
- Only basic lessons on Columbus module familiarization are kept and are simplified.
- It can be reduced to only 2 days, but shall still be held at EAC.

However:

- ❖ The trainee will not have the same level of knowledge and skills of other astronauts.
- ❖ A dedicated tailoring of the course is necessary to customize the content to the level of knowledge, skills as well as expectations and needs of each astronaut.
- ❖ The trainee will not obtain the full qualification as Columbus User and will require escort and support to perform most of activities within the Columbus laboratory.

3.5 The First Commercial Customers

In the course of the long ISS life, there have been several “tourists”, paying passengers, but the first cases to apply the new partners agreements on the minimum training requirements were the Space Flight Participants mission to ISS on-board Soyuz mission 66S organized by Space Adventures, and the first Private Astronaut Mission to ISS organized by Axiom Space, namely Ax-1 mission. The second Axiom Space mission training is also being prepared while we write this paper.

Space Flight Participants of Soyuz mission S66

Soyuz MS-20 mission 66S, launched on Dec 8th 2021 and commanded by cosmonaut Alexander Misurkin, carried on-board the ISS for 11 days Spaceflight Participants Mr. Yusaku Maezawa and Mr. Yozo Hirano.

Space Adventures Inc. was in charge of organizing the mission, that falls under the category of commercial Russian Space Flight Participants mission.

With the purpose of adequately train the SFPs to safely access the Columbus laboratory according to the ESA requirements to interact with the ESA assets, ALTEC and Space Adventures negotiated and finalized a contract for the provision of the **Minimum Training** at EAC premises.

The setup was specific for 66S mission, namely for a single training session at the European Astronaut Center for the following SFPs:

I. Mr. Yusaku Maezawa (SFP-1)
II. Mr. Yozo Hirano (SFP-2)
III. Mr. Shun Ogiso (Backup)

It must be reminded that the SFP missions include a professional cosmonaut from the Russian Space Agency in charge to command the Soyuz and two participants, the customers of the mission. In the 66S mission case, the commander was Alexander Misurkin, an experienced RSA cosmonaut, who did not require a dedicated additional training. Therefore, for this case, only the SFP prime and backup crew required to be trained. Due to 66S SFPs tight schedule and upon agreement among Space Adventures, ESA and ALTEC, option 2 the Minimum PAM Training was chosen to be held at EAC, during an interruption of SFPs GCTC and a short trip from Moscow.

Considering the status of the most recent version and content of the professional astronauts lessons and of the reduced / simplified versions, the ISS and Columbus Laboratory status and the planned on-board activities and the known training records of the trainees the following lessons have been selected in agreement with ESA for the short session dedicated to 66S SFPs:

Lesson Code	Lesson Title
COL-COP-USR-TOU	Columbus System Hardware Tour
COL-GSP-OVR-SOC)	Columbus System Operations Concept
BRF-COL-DMS	DMS/Laptop Briefing
COL-EPS-USR-USK	EPDS User Skills
COL-COM-USR-USK	COMMs User Skills
COL-ECS-USR-USK	ECLSS User Skills
COL-TCS-USR-USK	TCS User Skills
COL-COP-USR-EME	Columbus Emergency Response
CPT-CPL-GEN-EPL	ESA Payloads Overview

Table 4 66S Training Flow

Lessons Learned:

Specifically, a shorter / simplified version of some of the lessons have been organized with the aim of fitting a one and half day schedule in a weekend.

During the implementation of the course, it was quite soon clear that this version of minimum training flow needed a better adaptation to the required skills and to the actual needs and also wishes of the customer.

The very skilled instructors' team was able to adapt the lessons in real time during the training campaign, through a good interaction with the trainees. In parallel on organization level, the flow and the schedule were re-worked and adapted near-real-time.

Finally, the course was completed and the SFP successfully accomplished their certification.

Figure 5 66S Space Flight Participants at Completion of Training at EAC (from a Mr. Maezawa twitter post)

Axiom Space Ax-1 Private Astronauts Mission

The Axiom Space Inc. (Axiom) Ax-1 mission, that launched on April 8th 2022 and lasted 17 days, was the first Private Astronaut Mission (PAM) and carried 4 Private Astronauts (PA) to stay on-board the International Space Station.

Axiom Space Inc. was in charge of organizing the Ax-1 mission, that falls under the category of commercial NASA Private Astronauts Missions, for which ESA has no training obligations towards NASA.
Here as well ALTEC was responsible to negotiate the private astronaut training program directly with Axiom Space Inc. The final contract comprised the provision of the **Columbus User level training** at EAC premises

The setup was specific for Ax-1 mission, namely for a first training session at the European Astronaut Center for Ax-1 primary crew, following PAs:

I. Michael López-Alegría (CDR)
II. Larry Connor (PLT)
III. Mark Pathy (MS)
IV. Eytan Stibbe (MS)

Differently from the Soyuz case, in this type of PAM mission, flying to the ISS with a SpaceX Crew Dragon, the whole crew is private, as the Dragon is a commercial vehicle. Therefore any required additional training had to be included in the privately purchased training flow.
For this reason, the whole crew was included in the commercially provided Columbus Training even though the commander Michael Lopez-Alegria is a skilled former NASA astronaut and now Chief Astronaut for Axiom Space..

Considering the type of mission and Ax-1 PAs needs and expectations, Axiom Space, ESA and ALTEC agreed on the provision of full User Level Training. Moreover, as some crew member signed up for activities including the use for specific payload facilities and equipment to fulfil their mission, additional and dedicated payload training was included.

Lesson Code	Lesson Title
COL-COP-USR-TOU	Columbus System Hardware Tour
COL-GSP-OVR-SOC	Columbus System Operations Concept
COL-DMS-USR-USK	DMS User Skills
COL-COP-USR-LHD	Laptop Handling
COL-EPS-USR-USK	EPDS User Skills
COL-COM-USR-USK	COMMs User Skills
COL-ECS-USR-USK	ECLSS User Skills
COL-TCS-USR-USK	TCS User Skills
COL-COP-USR-EME	Columbus Emergency Response
CPT-CPL-GEN-EPL	ESA Payloads Overview
	+ ICECube Operations
COL-SYS-USR-EVL	User Level Evaluation Simulation

Table 5 Ax-1 Training Flow

In addition to the training, the Customer asked to accommodate filming crews to document the astronauts' activities during their preparation and to make interviews to the crew and to the instructors. For Ax1 mission, considering 4

different filming crews (one for each astronaut), this implied dedicated time slots and organization within the training flow and the facilities.
Considering than that some of the lessons had to be implemented two times as for those the number of trainees shall be limited in order to allow proper access and interaction with the training facilities and the instructors, the total amount of training time, integrated with appropriate breaks and technical times, allows to accommodate the entire flow for max four trainees in four (4) consolidated days.

Figure 6 Ax-1 Crew (credit Axiom Space)

Lessons Learned:

In this case as well, it was quite evident after a few lessons that the straight implementation of the full Columbus User Level training flow was not completely fitting the needs of the private astronaut crew.

Indeed, although differently from 66S SFP there was the need and the wish to get a more technical and thorough training. The lessons are for some cases too detailed for a crew who has not gone through the full set of training at the other International Partner sites (e.g. at NASA) and who will not need to operate all the ISS systems. On the other hand, there are cases were dedicated additional skills have to be taught to allow the astronaut to perform their own mission tasks (e.g. performing actions to assemble/use a payload facility). It as well was recognized that they do not have the same level of proficiency as professional astronauts have. Therefore during the course of that training week, the scheduling and the content was therefore modified several times, to accommodate the needs for lessons adaptations. Even the filming crew needs changed during the implementation, as it was quite clear that the organization of the training and the facilities allowed to accommodate in less time the filming and documenting needs.

The whole setup was though very successful, thanks to the professionality and flexibility of all involved teams and the enthusiasm of the astronauts who successfully obtained their certification.

3.6 Implementation of the lessons learned - Axiom Space Ax-2 Private Astronauts Mission

The next PAM is the Axiom Space Ax-2 mission, currently planned to be launched to ISS onboard a Space-X Crew Dragon in spring 2023.

Based on the Ax-1 commercial training experiences, the TLO industrial training team in agreement with ESA worked on a new training flow for the Ax-2 crew to better fulfil requirements and needs for the private astronauts.
Indeed, taking into account not only the experience gained with Ax-1 training but as well with 66S training, a new version of the **Columbus PAM Training** course was developed.
Considering:

- the understanding of the PAs needs and expectations,
- better knowledge of the predecessor training classes (e.g. at NASA),
- better understanding on the activities that might be done autonomously by the PAs and the skills needed,

- a review of the minimum skills required to fulfil the agency requirements to ensure safe and undisturbed operations on ISS and in Columbus,

a set of tailored lessons to be implemented as European Astronaut Center was created with ad-hoc content and a dedicated training sequence, that can be scheduled in a 3 days course.

Lesson Code	Lesson Title
PAM-CMT-TOU	Columbus System Hardware Tour
PAM-CMT-DMS	DMS User Skills
PAM-CMT-EPS	EPDS User Skills
PAM-CMT-COM	COMMs User Skills
PAM-CMT-ECS	ECLSS User Skills
PAM-CMT-EME	Columbus Emergency Response
BRF-OPS-EUR	EUROCOM Briefing
CPT-CPL-GEN-EPL	ESA Payloads Overview
	+ ICECube Media Set
COL-SYS-USR-EVL	User Level Evaluation Simulation

Table 6 Ax-2 Training Flow

It must be noted that the new PAM training flow is dedicated to train the Private Astronauts with the exception of the PAM Escort. Indeed, based on the first PAM experience, it was agreed that one PAM crewmember, typically the commander, being an experienced ex-professional astronaut, takes also the duty of helping and escorting as necessary the other PAM Crewmates. This allowed to slightly relief the training requirements for the other astronauts still maintaining an efficient and operational setup on-board the ISS. For the PAM Escort, a curriculum with the full Columbus User Level training maintains required.

4. Conclusions

The performance of the first Space Flight Participants and Private Astronauts missions on board ISS as well as commercial training implementation before allowed to learn extremely useful lessons. Especially due to the fact that the two missions (66S and Ax-1) represented very different type of the missions themselves as well of humans being the astronauts, permitting the TLO training team to exercise a broad set of cases.

The main lesson learned is that, while the training of a generic Professional Crew is not only more intense and complex, but it does not vary from crewmember to crewmember, except for the additional / mission specific requirements training, as the needs are exactly the same independently from the individual astronaut. They all run through the standardized training program agreed amongst the partner agencies (described in 2.1). In case of private astronauts the needs, skills and expectations are different, implying the need to deeply analyze and prepare the courses, potentially with ad-hoc lessons and sequence.

The training team is eager to implement the setup that was prepared for Ax-2 mission training to understand if the lessons learned were successfully implemented.

This will constitute an important step forward to continue with an always improving service provision to ISS private astronauts and to proceed with the development of commercially provided training in a growing human space flight economy.

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