ESA Academy's Orbit Your Thesis! programme

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Abstract

ESA Academy is the European Space Agency's overarching educational programme for university students. It takes them through a learning path that complements their academic education by offering a tailored transfer of space knowledge and interaction with space professionals. As a result, students can enhance their skills, boost their motivation and ambitions, and become acquainted with the standard professional practices in the space sector. This happens through the two pillars of ESA Academy, the Training and Learning Programme and the Hands-on Programmes. The latter enables university students to gain first-hand, end-to-end experience of space-related projects.

One of the latest additions to the portfolio of opportunities for university students is "Orbit Your Thesis!". It offers bachelor, master, and PhD students the opportunity to design, build, test, and operate their experiment onboard the International Space Station. The experiment operates within the ICE Cubes Facility in ESA's Columbus module, where it can operate for up to four months in microgravity. Throughout the programme students develop essential scientific, academic, and professional skills that will help them build their future careers. These skills include project management, risk identification and mitigation, problem-solving, and working within a diverse workplace. Participating teams will experience first-hand the project management process for space missions and participate in multiple reviews of their experiment and design throughout the programme.

Participating students are supported and guided through the process by engineers and scientists from ESA, Space Applications Services, and members of the European Low Gravity Research Association. The programme schedule follows a similar path to many space-faring projects. The design, development, testing, launch preparation and operations are structured in a series of project phases and technical reviews. Participating teams are guided towards the subsequent milestones to pass the necessary safety reviews and achieve launch readiness.

The first team that successfully sent up their ICE Cube is OSCAR-QUBE, a multidisciplinary team from the University of Hasselt in Belgium. Their experiment is the first diamond-based quantum magnetometer that ever operated in space. Thanks to the unique characteristics of their sensor, they have been mapping the Earth's magnetic field from inside the Columbus module aboard the ISS without the need to be housed on the exterior. This paper will describe the various phases and technical aspects of the programme in more detail.

Keywords

Academy, ESA, Hands-on, ISS, Microgravity

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Acronyms/Abbreviations

AIM	*Artery In Microgravity*
ATV	*Automated Transfer Vehicle*
CDP	*Critical Design Phase*
CR	*Cargo Review*
ECSS	*European Cooperation for Space Standardization*
EFSDP	*Experiment Flight Safety Data Package*
ELGRA	*European Low Gravity Research Association*
ERA	*European Robotic Arm*
ESA	*European Space Agency*
ESTEC	*European Space Research and Technology Centre*
FAR	*Flight Acceptance Review*
FSR	*Flight Safety Review*
ICF	*ICE Cubes Facility*
ICMCC	*ICE Cubes Mission Control Centre*
ISS	*International Space Station*
OYT	*Orbit Your Thesis!*
OSCAR-QUBE	*Optical Sensors based on CARbon materials: QUantum BElgium*
PDP	*Preliminary Design Phase*
RID	*Review Item Discrepancy*
UHB	*User Home Base*

1. Introduction

The International Space Station (ISS), with a weight of 420 tonnes and a pressurised volume of 916 m^3, is the world's most expensive international project. The construction of the ISS started in 1998 and grew over the years to its current size [1]. It gained a plethora of modules, robotic arms, and laboratory equipment. Most notable European contributions are the European Robotic Arm (ERA) [2], Cupola [3], the Automated Transfer Vehicles (ATV) [4], and the Columbus module [5].

The Columbus module is home to many experiments aboard the ISS, as it acts as Europe's permanent research facility in space. Europe's most significant contribution to the ISS features state-of-the-art equipment and allows external platforms to support various experiments. Within its 75 m^3 of space, the Columbus laboratory houses ten standardised racks capable of providing power, data, and cooling systems [5]. Aside from ESA payloads such as Biolab [6], the Fluid Science Laboratory [7], and the European Physiology Modules Facility [8], it also offers room for commercial partners and payloads such as the ICE Cubes Facility (ICF).

The ICE Cubes Facility is a commercial European research facility operated by Space Applications Services aboard the ISS [9]. The facility offers a total capacity of up to 20 units, based on the ten-centimetre cube standard, one unit, and provides communication, power, and cooling. This offers unprecedented timescales when compared to standalone CubeSats, "From idea to reality in a year, anybody's experiment can be launched to the Space Station" [10].

Within ESA Education, the ESA Academy's hands-on programmes offer gravity-related research platforms for university students. The addition of Orbit Your Thesis! (OYT) meant that a gap in the portfolio got filled [11]. The need for this programme manifested most notably for experiment proposals where the duration of microgravity was of paramount importance. Parabolic flights offer up to 22 seconds of microgravity [12], while access to the ISS enables weeks to months of microgravity exposure with a substantial increase in its quality.

For the students to maximise their educational experience in a professional setting, the programme's philosophy is to adopt the same approach as any space-faring project. This is done by using the European Cooperation for Space Standardization standards. However, these standards are geared towards the students and are thus less strictly applied, leading to a light, adapted version mimicking industry-accepted ECSS standards.

The students are encouraged to form multidisciplinary teams with skills spanning disciplines such as software, electronics, science and mechanical engineering.

2. ISS and Ice Cubes Facility environment

The ISS provides an environment of microgravity averaging at 10^{-6}g during nominal operations for a potentially unlimited amount of time in a pressurised (1bar) environment. The

ICF hosts experiment cubes within the ISS and maintains the temperature between 20 and 25 degrees Celsius [13].

The available electrical interfaces provide GND, +5 V, and +12 V. The +5 V line can deliver up to 1 A of current (5 W max), and the +12 V line can deliver up to 3.1 A of current (37.2 W max). However, the maximum power an experiment can use for preliminary design purposes is 10 W per unit [13].

The communication with IP-enabled cubes happens through an Ethernet connection. The maximum data rates for the entire ICF are 4Mbps for downlink and 0.5Mbps for uplink [13].

3. Benefits of ESA Academy

ESA Academy provides expert training in crucial topics including but not limited to requirement definition, risk and project management, systems engineering, space structures and software architecture, verification and validation, environmental testing and outreach/communication workshops. With this knowledge, student teams begin their project with all the necessary tools to complete the programme successfully.

ESA Academy conducts regular meetings with the teams to monitor progress and guide the students throughout the various phases of their project. In line with ECSS practice, ESA Academy also conducts reviews during Phases C, D and E. Each Phase begins with an introduction of expectations and success criteria thus anticipating potential misunderstandings and project derailment.

Additional assistance is also given by payload engineers from Space Applications Services particularly with respect to interfaces with the Ice Cubes Facility and ISS safety aspects. For scientific insight, ELGRA provides services for review of applications but also dedicated mentorship once teams are selected.

Some costs of student travel and accommodation during test campaigns are also absorbed by ESA Academy, and in general test campaigns performed at ESA premises such as ESEC-Galaxia for the vibration test campaign are also covered by ESA Academy. Thus, the team may focus all their efforts on raising funds for hardware through external sponsorship and university sources.

4. Schedule

Being a student driven project with the aim of being initiated and completed by the same team of students, the project must fit in an academic schedule and therefore not exceed 2 years. Within this relatively short time frame, ESA Academy must deliver an authentic industry-level space project. To this effect the ECSS-driven schedule can be split up into five main parts with defined time frames despite the fact that at the start of the OYT programme, some dates, such as the launch date, may be tentative. These parts are selection, design and development, launch, operations and disposal/retrieval and data analysis.

4.1 Selection (~14 weeks)

It is expected that before selection, teams perform Phase A analyses, as per the ECSS, at their institute and join the programme only at Phase B. This ensures that the feasibility assessments and preliminary requirements definitions are in line with the platform and programme requirements.

Upon submission of an experiment proposal using provided templates, teams elaborate on their team composition and the academic supervisor who will endorse their project. ESA Academy advocates multidisciplinary teams with complementary skills and backgrounds to increase chances of success. The experiment proposal also provides detailed scientific and technical details, programmatic milestones, and basic management information which gives the selection panel sufficient information to judge the proposal on several aspects. ESA Academy also encourages projects that are in line with ESA exploration or technical roadmaps. In addition to the experiment proposal, the team is also expected to deliver an Experiment Flight Safety Data Package (EFSDP), indicating to the board if the experiment can be safely executed on the ISS.

Shortlisting of student proposals is done by a selection board hosted by ESA Academy and a selection of industry experts. All eligible teams that show knowledge of the subject and prove their compatibility with the ICF are shortlisted during this process.

After the shortlisting, the teams are invited to participate in a selection meeting organised at ESA's European Space Research and Technology Centre (ESTEC) in Noordwijk, the Netherlands. This meeting allows the students to present their projects to the selection board. This allows the students to perfect their presentations skills in an international and interdisciplinary setting. The board is composed of three large main groups.

- The engineers and scientists from Space Applications Services; will review the experiment based on safety aspects and feasibility.
- ESA specialists from Human Spaceflight and Robotic Exploration and ESA Education Office; investigate the scientific or technological relevance and educational return of the project.
- Members of the European Low Gravity Research Association (ELGRA); focus on the scientific and technology achievements for the respective field of research.

4.2 Design and Development (~20 weeks)

Soon after selection, the team(s) are given expert training on topics mentioned above, after which the students may begin to develop and refine the design of their experiment. Within this stage, three ECSS Phases can be observed. The Preliminary Design Phase (Phase B), Critical Design Phase (Phase C), and the Qualification and Production phase (Phase D). Phase D encompasses all the environmental tests and functional tests which give confidence that the hardware is ready to survive the launch environment, and to operate on the ISS (see Figure 1 & 2).

Figure 1. OSCAR-QUBE in the Ice Cubes Facility ground model

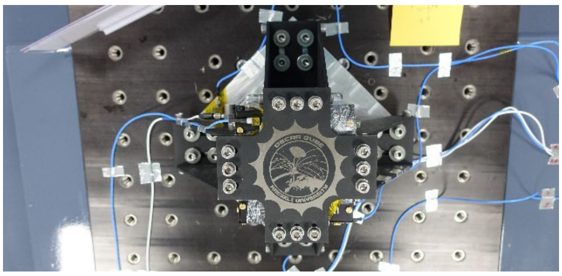

Figure 2. OSCAR-QUBE vibration testing

Each phase concludes with the associated data package submission by the team. For a successful transition to the next phase of the schedule, the teams must pass a Preliminary Design Review (PDR- Phase B), a Critical Design Review (CDR – Phase C) and finally a Flight Acceptance Review (FAR- Phase D). The reviews are conducted by the experts from the selection board and any experts pertinent to the payload. In parallel a series of Flight Safety Reviews (FSR) occurs to ensure that the development of the payload remains safe for operational use on the ISS.

4.3 Launch Campaign (~6 weeks)

When the team pass the Flight Acceptance Review, the hardware is shipped to ALTEC in Turin, Italy. Here a final cargo review (CR) is performed to check proper packaging, labelling and outwardly appearance before the experiment Cube is sent to the launch site and integrated into the launch vehicle.

4.4 Operations, retrieval/disposal (~16 weeks)

After launch and berthing, the experiment is removed from the vehicle and is installed in the ICF (Figure 3 & 4). The ICE Cubes Mission Control Centre (ICMCC) based at Space Applications Services, in Belgium, subsequently activates the experiment. The control is then passed to the students who can operate their experiment from their User Home Base (UHB) according to their predefined operations plan.

After, typically, four months in orbit, the experiment cube is removed from the ICF and disposed of through destructive re-entry of a cargo vehicle or returned intact for further analysis. Data can also be stored on removable media and be sent back to the team using the next available return vehicle.

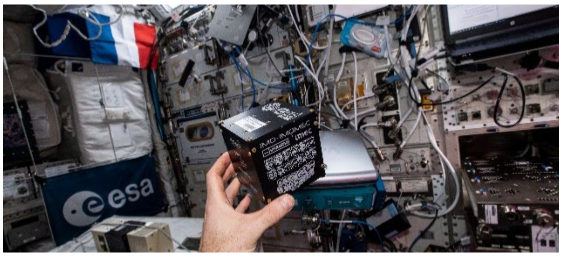

Figure 3. OSCAR-QUBE in the Columbus module


Figure 4. OSCAR-QUBE in the Ice Cubes Facility

4.5 Data Analysis (~16 weeks)

Using the OYT programme, the team is expected to draft a scientific paper for publication in a peer-reviewed journal and present its findings at an international congress. For archival purposes in line with ESA mandate, the students will enter all their OYT information into a database repository. This will include all the raw data, analysed results and conclusions from the project.

5. Requirements

Students willing to participate in the OYT programme must fulfil some eligibility criteria. They need to be citizens of either an ESA member state or be a citizen of Canada, Latvia, Lithuania or Slovenia. It is also required that the field of study is focussed on a scientific or engineering subject.

At least one of the students within the team is required to have the experiment as an integral part of their thesis. This can be a master's thesis, PhD thesis, research programme, or a project course supported by the applying students at their university.

Application is only possible if the students can prove their university's support through a letter of endorsement, from the academic supervisor(s).

To participate, at least six team members should fulfil the eligibility criteria. The upper limit of participants is limited by the experiment requirements.

It is highly recommended for purposes of knowledge management to have one or more PhD students in the team as the timeline of this project spans over more than one academic year.

To participate, a team must finally be supported by an endorsing professor, a team leader and/or a system engineer.

6. Discussion and Conclusions

So far, two teams have participated in the programme; OYT-1 Artery In Microgravity (AIM) from ISAE-SUPAERO (FR) and Politecnico di Torino (IT) and OYT-2 Optical Sensors based on CARbon materials: QUantum BElgium (OSCAR-QUBE) from University of Hasselt (BE). Team AIM will launch to the ISS June 2022, and team OSCAR-QUBE have been on board since August 2021. Currently, the OSCAR-QUBE experiment is still gathering data in orbit.

Both teams provided positive feedback in their participation in Orbit Your Thesis, from the educational nature of the programme but also in the form factor as the platform proves to be suitable for student experimentation. In addition, the schedule of the programme is particularly favourable for academic research and projects whilst also remaining very flexible. The opportunity to work on a project that is operated on the International Space Station during university studies provides several competitive advantages to participants as they become young professionals and enter the job market.

The third cycle will soon pick up pace once a team has been selected and it is envisaged that ESA Academy will continue to offer the educational programme.

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