A multi-project student space association

Alexis Leon Delgado[1], *Alex Carmona Peña*[2], *Yi Qiang Ji Zhang*[3], *Arnau Torrent Duch*[4], *Jordi Grau Rifà*[5], *Adrià Barja Peláez* [6]

Abstract
The aerospace sector has always been a challenge. The complex nature of the field requires for talented, skilful engineers. And while the university does great on the development of the theoretical background, it barely gets into the practical application. This is why embracing educational activities is critical to help students develop their technical and teamwork skills in the professional sector.

UPC Space Program is an engineering student association based in the Terrassa campus of the Polytechnical University of Catalonia (Spain), and formed by 5 missions and 80 members. Each mission targets a field of interest in the space sector: rocketry, UAVs for space exploration, High Altitude Balloons, rovers and CubeSats. The sharing of the common spaces by such a number of people who are working on so many and diverse projects creates a vibrant and creative environment that incites learning.

Our work is aligned with the current activities in the space sector. As the exploration of the terrestrial bodies of the Solar System highly benefits from the use of rovers, our Grass mission is focused on the development of planetary exploration rovers. After achieving 10th place in the European Rover Challenge 2021, the objective is to further upgrade the vehicle for the next edition. But currently, a new exploration focus is appearing as flying vehicles are entering the stage. In this context, our Aldora mission is based around a concept mission to Titan via an autonomous plane capable of deploying scientific probes. Obviously, space exploration is not possible without the presence of space transport vehicles. In this matter, Ares mission is focused on the development of High Power amateur rockets. Currently, Ares is developing a supersonic rocket set to participate in EUROC 2022 competition. But most of the payloads carried by rockets are satellites. In this field, the Horus mission aims to investigate and optimize the manufacture of a CubeSat, along with mission performance, to create a fully operational satellite, currently set to participate in the Europe to Space competition. Finally, there is yet another way to perform space science. Our Zephyros mission works in the development of High Altitude Balloons, also developing a set of experiments to test in near-space conditions. The next objective is to achieve the first student-developed zero pressure balloon in Spain.

Keywords
Multi-project, Student's Association, Rocketry, High Altitude Balloons, CubeSats, UAVs, Rovers

[1] UPC Space Program, ESEIAAT (UPC - BarcelonaTech), Spain, leon.delgado.alexis@gmail.com
[2] UPC Space Program, ESEIAAT (UPC - BarcelonaTech), Spain, alexcarmonacole@gmail.com
[3] UPC Space Program, ESEIAAT (UPC - BarcelonaTech), Spain, yiqiangjizhang@gmail.com
[4] UPC Space Program, ESEIAAT (UPC - BarcelonaTech), Spain
[5] UPC Space Program, ESEIAAT (UPC - BarcelonaTech), Spain
[6] UPC Space Program, ESEIAAT (UPC - BarcelonaTech), Spain

Acronyms/Abbreviations

ADCS	*Attitude Determination and Control Subsystem*
CAD	*Computer Aided Design*
CFD	*Computational Fluid Dynamics*
FEA	*Finite Element Analysis*
RTG	*Radioisotope Thermoelectric Generator*
STEM	*Science, Technology, Engineering and Mathematics*
UPCSP	*UPC Space Program*
VTOL	*Vertical Take Off and Landing*

1. Introduction

1.1. Introduction and state of the art

The curriculum of engineering degrees tends to have a scarcity of hands-on experience. It is logical, as the class hours are limited and there is a considerable amount of theoretical knowledge that has to be passed on if the students have to become, one day, engineers.

That said, this creates a disconnection between the student and the real world. It is a problem, as students end up mistaking the mathematical models for the real thing when it is not the case.

It is for this reason that getting involved in student projects is one of the best things to do when coursing an engineering degree. It allows the students to take the theoretical teachings to build the real things, learning important lessons like those computations that have to be verified with experimentation or some designs that are very nice in theory may not be the most practical when it comes to building them.

Nowadays, student projects in the space field are widespread among worldwide aerospace engineering universities. Only in Spain there are various rocket teams, cubesat student projects, rover groups... in cities like Madrid, Bilbao and, as is the case for this paper, Terrassa (Barcelona province). Most of them share one thing in common, their association is focused on only one project kind. Space projects in real life, except for private companies, have a different approach. Usually, space agencies develop various space missions.

This approach, up to a certain extent, is followed by UPC Space Program (UPCSP) [1]. UPCSP consists of 5 missions that are each related to a space project. Mission Ares is working on supersonic amateur rockets, Mission Grass is working on rovers for planetary exploration, Mission Zephyros is working on high altitude balloons for scientific research, Mission Horus is working on nanosatellites and Mission Aldora is working on a drone for the exploration of Titan. All this, obviously in the frame of the student and university capabilities.

Having all the missions under one association nurtures a creativity-rich environment. Missions share the spaces when working on the projects, which allows for talking about the different missions, sharing of knowledge, and some members even end up working on various missions at the same time, which would be very difficult to do if it were separate associations.

1.2. Objectives and scope

UPC Space Program, which is part of EUROAVIA Terrassa [2], is an engineering student program formed by more than 80 members from different engineering backgrounds whose objective is to apply the knowledge acquired during their degrees in missions related to the aerospace field. Each mission targets a field of interest in the aerospace sector, as mentioned before. UPCSP does not only focus on the technical part, but also the social and human part. In this aspect, the creation of a multidisciplinary project was conceived to accomplish different objectives.

Firstly, UPCSP serves as a learning and professional launchpad for all students [3]. The main goal of this organisation has always been the capability of giving means to all students to develop their skills and put to practice the knowledge obtained during university. UPCSP provides the perfect tools and conditions to gain experience in an environment where team cooperation and learn-by-doing are the foundation principles of the team's daily basis. Moreover, UPCSP not only gives access to technical knowledge by the participation as an active member in the organisation, but also by performing training sessions open to all students interested.

Secondly, UPCSP aims to enable technological progress in the region of Catalonia, thereby helping to pave the way in the development of disruptive and experimental technologies that will enable easy access to space and its exploration. These activities serve as the perfect foundation to establish the basic knowledge and experience needed to successfully start a career in the space sector, which is sometimes difficult to access. Overall, all these aspects are in consonance with the new and innovative space economy, NewSpace [4], currently being developed.
The early stage of this sector makes difficult a fast development of the infrastructure and technical interest in the field. To tackle this problem, UPCSP is involved in projects where

universities and companies cooperate to create a proper environment that enables the easier development of technology and their industries. In fact, UPCSP aims to help the sector and provide value by performing collaborations with relevant companies. Examples of past collaborations are Everis Aeroespacial, HP, etc.

In addition, UPC Space Program is a key platform that enables social interaction and interpersonal skills. Bringing students together and stimulating teamwork is critical to enable the creation of a working environment that promotes equality, honesty and cooperation. Specifically, UPCSP contributes to promote aerospace activities in the university and society, as well as to encourage early involvement in STEM careers among the female sector (Figure 1).

Figure 1. Some of the female members of the UPC Space Program

Finally, one of the main objectives of the UPC Space Program since its creation has been to promote and increase the interest in aerospace activities among young students. This allows university students to better understand technical processes, as well as to enhance their motivation in developing careers in the sector. To accomplish this, UPCSP empowers its participation in competitions, attendance to public events and university talks, etc. Great examples of successful promotions of the aerospace sector have been the XXIII Congreso Virtual AEAE, Splashdown Festival 2019, SURTAM and XVI Exposició Anual de Modelisme, among others.

2. Methodology

2.1. Technical methods

While the specific approach to the development of the mission projects varies depending on mission and on the particular element being developed, in the general point of view, the missions follow a lifecycle similar to the mission phase scheme used at ESA, albeit simpler and without the rigorous scrutiny that an ESA space mission is put through.

The project begins with an idea or concept, which is debated and analyzed by the mission team. If the mission agrees that it is interesting and doable, it is carried on. This could be related to phase 0 in the ESA mission lifecycle.

In the next phase, simplified designs are made and put through initial computational analysis to define a baseline for the design of the vehicle or payload. This could be related to phase A.

When that is done, the baseline created in the previous phase is materialised in CAD, incorporating the required elements for a functional vehicle, like the internal structure. By means of more elaborated computational analysis like CFD and FEA analysis, the design's correctness is assessed. Then, based on the results the design is modified accordingly (this could be related to phase B). And finally, the design is further improved, adding more elements and complexity, until everything is included (this could be associated with phase C).

While the design is being improved, the vehicle may begin to be built. The time available to develop these is much more limited than in a real mission, and, at the same time, mistakes are not as expensive. The electronics departments may even begin development at the same time that the CAD is being made. As the vehicles are being developed, the built structures are tested for resistance and the electronics are tested to verify their performance. This building and testing phase may be related to phase D in ESA missions.

The next phase is the operation of the vehicles (Figure 2), performing the tasks that they were designed for. This would be Phase E in the lifecycle of ESA missions.

Figure 2. Members of UPC Space Program preparing a rocket launch

There is one final phase, that takes place before the mission team takes on a new project. The old vehicle that will not be used anymore, is generally hung in the walls or ceilings of the UPC Space Program workshops, for all the members to marvel at. Not all missions may follow the same route for disposal though, as some vehicles may be broken or some may even be sent to space in the future. This would be associated with Phase F in the ESA mission scheme.

2.2. Organisation methods

In an association formed by almost a hundred members, taking care of the organisational structure and management of the resources is critical to ensure a correct operation of the entire program. In order to assess these aspects, each one of the 5 missions that conform UPC Space Program counts with its own coordinators and technical departments. Each mission is independent, but a common core is shared between all of them, and that is the UPCSP's directive board. This entity, formed by the general coordinators, mission coordinators, treasury members and secretary, is the responsible for the management of the association. The cooperation among members is crucial to guarantee the progress of the entire program.

In fact, the usage of project management techniques combined with the application of a systems engineering approach is key to develop a strategic plan which ensures the success of such a big multidisciplinary project. Each mission is responsible for defining objectives, studying their viability and ensuring the fulfilment of a yearly calendar comprising all the different stages the mission must accomplish. This schedule management, along with the articulation of specially tailored requirements and scope points, identification of risks and their response plan, economic resources management and cost reduction measurements; allow UPC Space Program to successfully develop and intelligently manage all ongoing projects.

This framework of assuming responsibility roles is an inherent benefit in such a massive project, thereby allowing the coordinators and members to prove their adaptability to new work methodologies and software tools, as well as improving their critical thinking and teamworking abilities. This, without any doubt, is not only a skillset that is really valuable if the student is to enter the professional market, but also useful to broaden their perspective of the space sector and to train possible future actors that will, in time, be part of some of the NewSpace entities that employ them.

3. Activities and accomplishments

3.1. Aldora Mission

The Aldora mission began as a mission focused on developing VTOL aircraft. That project ultimately was discarded as most of the first members finished university and left the mission. Some vertical flight prototypes were built and flew, and other two prototypes intended for VTOL flight were 3D printed with multijet fusion printing, but those two never flew because faults in the novel 3D printing technology caused the weight to be above the permissible values. Some of those original Aldora members ended up founding a start-up of VTOL drone package delivery, which today is very close to entering operation.

After that phase, a mission concept was devised, for a drone to fly on Titan and to be able to study locations that both rovers and aerial vehicles would have a hard time reaching by deploying scientific probes from the aircraft.

The drone in the real mission most likely would have to be given VTOL capability in order to take-off and land on Titan, as landing would be required to charge the batteries from an onboard RTG. During the flights, the aircraft would scout the surface in search for points of interest to deploy probes in order to study the locations. The aircraft itself would also carry instruments in order to perform measurements in the areas where it did actually land.

A big advantage of the concept is the capability that the aircraft would have of studying the hydrocarbon lakes. The probes could be designed to sink when reaching the lakes, thus allowing for the study of the depths of the lakes, and later activate an inflatable device in order to return to the surface and send the data. On another note, cryovolcanic regions would highly benefit from this probe approach to take measurements. By carrying various probes, losing one or various does not mean end of mission and thus riskier activities can be undertaken.

Regarding the actual work being developed by the Aldora mission, its objective is to perform an analogue mission to the Titan concept, but on Earth. Aldora has designed a conventional aircraft (instead of VTOL, for simplicity) with space for storing the probes inside the fuselage. This aircraft is a 3 meter-span drone designed for Earth flight being built with composite materials.

Once built, the aircraft will be equipped with probes also designed by the team and it will perform flights, deploying the probes in points of interest. The probes will take measurements and send them to the aircraft. It is also expected to deploy probes in masses of water and test the sinking and then resurfacing approach that would be performed in the hydrocarbon lakes of Titan.

3.2. Ares mission

The Ares mission is the branch of the UPC Space Program dedicated to the development of High Power amateur rockets based on additive manufacturing techniques, ranging from 2-stage subsonic launchers to 1 stage supersonic rockets.

The ultimate goal of Ares mission is to successfully design, build, test and launch a two-stage supersonic amateur rocket, Ares III.

Since its foundation in 2016, 4 rockets have been built and launched, evolving different aspects of the design and construction process in each one. From the Ares I, a two-stage rocket intended to test the electronics and the structure, the mission has evolved into designing the Phobos, a rocket whose aim is to compete in European Rocketry Challenges for universities. Such rocket project is also being presented in SSEA 2022.

3.3. GRASS

GRASS is the robotics branch of the UPC Space Program, and it focuses on ground rovers for planetary exploration. Their main goal is to participate in international competitions by designing and building a rover able to perform a series of tasks.

The team is currently participating in the European Rover Challenge (ERC) where the teams and their rovers are tasked with performing a series of trials in a Mars analogue terrain. The trials cover a myriad of functionalities: the capability to traverse rough terrain, the fine motricity of the robotic arm, to probe placement or scientific exploration…

The team's first participation in the ERC in 2021 yielded a 10th position, and the team's vision is to become a habitual participant in the ERC, and participate in additional worldwide competitions across the globe. To accomplish this the team is building a competitive base which can be adapted for the multiple tasks and requirements of such competitions. This project is also being presented in SSEA 2022.

3.4. Zephyros Mission

Mission Zephyros is the mission dedicated to high altitude balloons. It began being called Neslab, a mission with the objective of creating an experimentation platform in the stratosphere. Neslab went on to the Global Space Balloon Challenge 2016 and won the prize for the best photograph (Figure 3).

Figure 3. Earth photograph taken by Zephyros

Then, the Astronaut Children project was developed: drawings made by children from the Sant Joan de Déu hospital were carried with the balloon and it was retransmitted live for the children to see.

Then Neslab changed its name to HAB, and made it its objective to standardize and improve the subsystems from the previous missions.

The next and current phase has been named Zephyros. The current main objective is to develop the first amateur zero pressure balloon of Spain. This will give Zephyros a robust platform with the ability to stay airborne for an indefinite amount of time for the development of various experiments. This implies the development of a suite of subsystems such as telemetry, killswitch and valve control.

In parallel, work on such experiments to fly on this balloon or in BEXUS has been performed. Two experiments are being developed:

- An experiment to fly a drone in the stratosphere, in order to study flight in a lower density environment.
- A cloud chamber experiment to detect cosmic rays, where the cosmic ray detections at the surface and in the stratosphere will be compared.

The cloud chamber experiment is being presented also in SSEA 2022.

3.5. Horus mission

We know that space missions are ever-changing, with increasingly sophisticated operations, that is why now, more than ever, satellite missions require innovation and solutions to eschew the famous issue on space debris. In November 2021 we formed a new team of multidisciplinary students to investigate and optimize every process related to the manufacture of a CubeSat.

The goal of this Horus mission is to develop the attitude control system for two 1-unit CubeSats in order to establish laser-based communication between them.

With the aforementioned goal in mind Horus mission engaged with Selene, the first UPC Space Program 1U CubeSat prototype. The ADCS department, which develops the orientation control of the satellite, investigated whether the control was more precise using reaction wheels and magnetorquers regarding its accuracy and energetic efficiency. Another point was to use additive manufacturing so it induces less space debris. The communication subsystem intends to make use of a laser system to establish communication between two satellites and regarding propulsion, Horus has researched on ways to propel the satellite with electrostatic ion thrusters or solar sails.

Overall, the idea has been presented for the Europe to Space challenge, which aims to give university students, from any major, the possibility to work on a real space mission, from its conception to the operations in orbit, in just one year. Our idea was accepted and successfully got to the second phase.

The next step of the mission resides in integrating all the components that have been developed and build the first prototype following the standards that are present in a space-related project.

4. The future of UPC Space Program

What does the future hold for UPC Space Program? It is only anyone's guess how the future will be, but we know where we want to be headed.

First of all, we want to maintain the friendly, collaborative and creative environment that has been accomplished, while at the same time we want to improve certain aspects. For one, the ratio of female to male members is low, as is usually the case in engineering disciplines. We want to increase our outreach efforts to show every girl that engineering is also for her if she wants it to be.

On another note, we want to further increase the quality and level of our projects. This means upgrading the materials and techniques used and entering higher class competitions.

GRASS, for example, hopes in the future to not only go to ERC but also to the University Rover Challenge. Aldora has plans to make its drone autonomous as that would be required for flight in a place where messages from Earth take an hour and a half to reach. Horus is determined to send a satellite to space. Ares will continue to build larger and more powerful rockets to compete in international competitions and Zephyros will keep improving its balloon technology to enable more science to be performed in a near-space environment.

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