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Wednesday, April 27th
Panel: Space Education for Everyone

Vertex Auditorium, 10:00 am – 11:00 am
Space Education in Europe: Status and Prospects

Sara Dalledonne¹, Maria Vittoria Prest², Michelle Hermes³, Lina Pohl⁴

Abstract
The space education landscape in Europe continues to evolve as the demand for a skilled workforce with interdisciplinary and multidisciplinary backgrounds, grows. This study aims to map the higher education landscape in Europe and understand trends and patterns among the higher education programmes within the European space sector. Indeed, the space sector is changing constantly as new technologies, challenges, and actors emerge, and the educational background must meet this demand for highly specialised and competent professionals. This analysis stems from the consolidation of a database of all higher educational space study programmes across all ESA and EU Member States within Europe, as well as a comprehensive view from students and young professionals entering the space sector. Further analysis groups the study programmes across Europe into so-called “macro-areas”, which support an in-depth analysis of the fields of study available for students in Europe, as well as their distribution across the continent. Overall, the study demonstrates key trends at the national level, both in terms of study programmes available and government strategies and initiatives influencing the space education landscape per country. European-wide trends are also identified. The study contributes to a better understanding of the space sector overall and allows for the identification of key trends among European higher education in space-related study fields. Additional key messages can be gleaned from an increased understanding of how the space sector is perceived by students and young professionals, complementing the analysis conducted of the space education landscape at the university level.

Keywords
Higher education, space education, Europe, students, young professionals.

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Six-year evolution of a space-inspired collaborative problem-solving study program in Finland

Ana Gebejes¹, Heikki Immonen², Charles J. Camarda³

Abstract
This paper presents the results of the six-year qualitative longitudinal case-study of the Epic Challenge study program in Finland. Created in 2008 for NASA engineers, the Epic Challenge program has grown and evolved to teach collaborative problem solving that reaches across different disciplines and ages. The paper presents an overview and evolution of program features and teaching methodologies. In the program, students learn a challenge-based methodology called Innovative Conceptual Engineering Design (ICED) and use this methodology to develop innovative solutions connected to the overarching challenge of sustainable human habitation of Mars. The program is built around the assumption that space exploration as a complex, multidisciplinary challenge provides the inspiration, a driving force and integrated curriculum for teaching Science, Technology, Engineering and Math (STEM) concepts and problem-solving techniques in four key areas: teamworking, networking, systems thinking and innovation. In 2015 the program was adopted and fused with a phenomenon-based learning curriculum in Finland, and it grew to be taught to students of various backgrounds from high-school to doctoral level. The course delivery and content were modified annually based on lessons learned and more than 500 students have gone through the program in Finland. The paper presents the evolution of key program features and concludes by presenting the most robust features of the program implementations that could benefit space agencies, companies and faculty interested in promoting space and STEM related competences.

Keywords
challenge-based learning, collaborative problem solving, innovation education, STEM

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Establishment of the Space Engineering Program in Hungary

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Abstract
The Hungarian space age started in 1946 with the successful Lunar Radar experiment by Zoltán Bay. In the past 75 years, the Hungarian space sector evolved and grew dramatically, achieving international recognition in space communications, material science, picosatellites, dosimetry, and many more domains. However, there was no space engineering related higher education program in the country.

After hosting the 2nd Symposium on Space Educational Activities in 2018 in Budapest, there was an emerging need for starting a space program for engineering students. A summer workshop organized by the Hungarian Astronautical Society in 2018 fostered further the process, and the Budapest University of Technology and Economics (BME) officially initialized the establishment of the space engineering master curriculum in 2019. By the end of 2020, the relevant ministry approved the national space engineering master curriculum. This means that every Hungarian university, which has the necessary competences, can start a space engineering program for their students. In early 2021, the BME Faculty of Electrical Engineering and Informatics at BME requested approval for its space engineering master program. In October 2021, the relevant body approved the program, allowing the first class of space engineering students to arrive to the university in September 2022. The Hungarian space engineering master curriculum is a 2-year-long master program for 120 credits (in the European Credit Transfer and Accumulation System, ECTS). The master's program at the Budapest University of Technology and Economics has 26 subjects and a 4-week-long industrial training. We outline the establishment process of the national space engineering curriculum and introduce the curriculum of BME.

Keywords
university education; space engineering master program; curriculum establishment

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A multi-project student space association
Alexis Leon Delgado¹, Alex Carmona Peña², Yi Qiang Ji Zhang³, Arnau Torrent Duch⁴, Jordi Grau Rifà⁵, Adrià Barja Pelàez⁶

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

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Implementation of Space Clubs in Kenya

Charles Mwangi\textsuperscript{1}, Malkia Kelele\textsuperscript{2}

Abstract
The Kenya Space Agency Strategic Plan 2020-2025 identified the need for capacity building in infrastructure and human resource as a priority focus area to enable Kenya to tap into the potential of the space industry. With this in mind, several initiatives were put forth to encourage innovation, education and awareness on space related matters. The concept of Space Clubs in Kenya was mooted in 2020 as an education and outreach program that comprises of interactive scientific activities, competitions, events and learning sessions with students from schools around Kenya.

The Space Club initiative is aimed at creating awareness and interest on Geography, Science, Engineering, Arts and Mathematics by educating the next generation of learners on the significance of these subjects in supporting the space industry. It seeks to broaden and enhance the quality of education for Kenyan students and allow them to understand and actively pursue the opportunities that Space related disciplines portend for them. With the support of teachers in primary school (our current target audience) in Kenya, KSA has created an all-rounded program that encompasses a variety of aspects pertaining to space.

The initiative has identified and prioritized four disciplines that are critical for the advancement and growth of Kenya’s space sector. These include; Space Systems Engineering, Information Technology and Robotics, Space Science and Astronomy and Earth Observation. The development of the initial learning and training content on these focus areas was concluded in November 2021. The first phase of the project has seen the development of 12 topical student’s books and 4 comic books. These materials, which are under review, will be free for use and will be hosted on the Kenya Space Agency website.

Since July 2021, the Space Club team has been hosting a mentorship and training program aligned with these focus disciplines. The Space Club team use of tools such as Cubesat models, water rockets, robotics kits, telescopes and portable planetariums to engage students in hands-on activities. These events have elicited a lot of interest and curiosity amongst students with many expressing interest in Space related careers. The team has noted the significance of student mentorship for the space industry and would recommend that programs of a similar nature be developed, more especially in developing countries, to build a strong foundation for the growth of a vibrant and indigenous Space industry.

Keywords
Education and Outreach, Kenya Space Agency, Space Club,

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Panel: ESA & Space Education

Vèrtex Auditorium, 11:30 am – 12:30 pm
Fly a Rocket! ESA’s hands-on programme for undergraduate students

Claudia Guerra¹, Sam Beckers², Arthur Tavares Quintão³, Jakub Zemek⁴

Abstract
The Fly a Rocket! programme is a hands-on project offered by the European Space Agency’s (ESA’s) Education Office in collaboration with Andøya Space Education and the Norwegian Space Agency (Norsk Romsenter). The programme represents a unique opportunity for entry-level university students from diverse backgrounds to build, test, and launch an actual sounding rocket and obtain otherwise unattainable practical experience. In September 2020, the ESA Education Office announced the third edition of the programme, for which 30 students from the ESA Member States and the Associate Member States were selected. Of these, 24 participated in the launch campaign which took place throughout the second week of October 2021 at the Andøya Space in Northern Norway. The Fly a Rocket! programme comprises an online pre-course with two assignments and a hands-on launch campaign. The pre-course is self-paced and aims to widen the participants’ understanding of basic rocket science topics such as the rocket principle, aerodynamics, and orbital mechanics in preparation for the campaign. During their stay at Andøya Space, the students were assigned to one of three teams, each with different responsibilities: Sensor Experiments, Telemetry and Data Readout, and Payload. As members of the Telemetry and Data Readout team, the authors’ role was to set up the student telemetry station and ensure that accurate data was collected from the sensors on the rocket. In addition, they were an integral part of the countdown procedure, operating two of the three telemetry stations used for the mission. Following the launch, all the teams worked in conjunction to analyse and present the data according to four previously defined scientific cases.

This paper will be concerned with the activities carried out throughout Fly a Rocket!’s third cycle, with a particular focus on the work done by the Telemetry and Data Readout team.

Keywords
Andøya Space, ESA Education, sounding rocket, telemetry

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A student perspective into ESA Academy Space Systems Engineering 
Training Course

Davide Bellicoso¹

Abstract
The ESA Academy’s Space Systems Engineering Training Course is a unique educational 
opportunity offered by the European Space Agency’s Education Office. It allows Bachelor, 
Master and PhD students to learn about the fascinating world of Systems Engineering and its 
applications within the space sector, while bringing this captivating framework of challenges 
and satisfaction to life for the participants of the Training Course. During this course, the whole 
life-cycle of a space project is explored from a System Engineering viewpoint, and students 
can learn about the challenges of Space Systems Engineering. Moreover, the Systems 
Engineering process is explored in detail [1]. Taught by ESA experts, the Training Course is 
delivered through formal lectures, with a heavy emphasis on the interaction with the students. 
During the course, students take part in group exercises aimed at putting the theory learnt into 
practice. This paper purposes at giving an overview of the training course, as it took place 
online on the 12th-20th of July 2021, and at addressing the benefits of the Author’s participation 
into the Training Course for his studies and future space career.

Keywords
Systems Engineering, ESA Academy, Training Course

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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
Development of a Concurrent Engineering Tutorial as part of the “ESA_Lab@” initiative

Jennifer Hoffmann¹, Marlon Deutsch², Reinhold Bertrand³

Abstract
As part of the “ESA_Lab@” initiative, a Concurrent Engineering facility has been constructed at the Mechanical Engineering department of Technical University Darmstadt. Concurrent Engineering is a well-proven concept for designing complex space systems and missions in the pre-phase 0/A mission phase. The Concurrent Engineering methodology and processes are enabled by a multidisciplinary team and specific infrastructure in terms of both hardware and software, which generate an effective and time efficient design management system.

The university’s “Concurrent Engineering Lab” provides an environment for both researchers and students to explore and apply the Concurrent Engineering approach in areas such as (model-based) systems engineering, Industry 4.0/ Space 4.0, and space traffic management. Furthermore, collaboration with the European Space Operations Centre – also located in Darmstadt – regarding the application of Concurrent Engineering for Ground Segment & Operations is planned.

The first addition to the university’s curriculum centered around the Concurrent Engineering Lab will be a “Concurrent Engineering Tutorial”, an opportunity to introduce the Concurrent Engineering methods and tools via hands-on experience to students of the newly established master’s degree program “Aerospace Engineering”. “Tutorials” are elective block courses of the degree program which offer practical learning experiences in many different fields, awarding 4 credit points upon successful completion.

Building on the lectures “Fundamentals of Space Systems” and “Space Systems and Space Operations”, the week-long “Concurrent Engineering Tutorial” will challenge students to use their acquired knowledge to develop a preliminary design for a predefined CubeSat mission. This Tutorial will not only provide a closer understanding of the individual subsystems of the space segment of a mission, the Concurrent Engineering process and the relevant software “COMET” by RHEA Group but will also create a synergy with a student association of the university, as one of their projects is the development of a CubeSat.

This paper describes the background and approach to the development of the Tutorial, in particular the structure of the re-usable model architecture in “COMET”, which was specifically derived and implemented for this purpose and validated via a pilot study.

Keywords
Concurrent Engineering, CubeSat, Space Systems Design, Tutorial

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From educational programmes to professional projects: finding flight opportunities

Frenea-Schmidt Armelle¹, Johansson Henrik², Krämer Stefan³

Abstract

Nowadays, lots of opportunities are offered to students to fly their own experiment on board of rockets or balloons. Thanks to those opportunities, young scientists have a chance to experience hands-on project and even to find a vocation: pursuing experimentations on-board of flight missions. However, it can appear, for these young professionals, that flying on board sounding rockets or stratospheric balloons is hard to access or to afford. Yet the opportunities exist and are waiting for them!

Space educational programmes enable students to learn, in a short period of time, all phases of a scientific project; a unique chance to experience a full project cycle from objectives’ definition to the publication of the results. Thus, students define mission requirements, design, manufacture, test and finally launch their own experiment! On REXUS/BEXUS [1] for example, students experience an end-to-end project with all disciplines required by a Space project (science, mechanics, electronics, software, system engineering, management, finances, outreach). The concretisation of all efforts occurs during the launch campaign, organised at SSC Esrange (Sweden). The campaign is always an intense period for the participants: high level of concentration, pressure, stress but a massive work that pays off during the flight and after. Usually, this key event enables ideas and improvements to pop up; a prolific event to define the next step of an experiment, maybe on a future mission!

Many students start their professional career after the campaign. Despite new ideas and the drive to pursue, a common idea of these young professionals is that it is hard to access to flight opportunities on sounding rockets or stratospheric balloons while not being a student anymore: too expensive to finance a campaign? too complex to organise? who to contact? Many questions that it is time to answer. Yes, it is possible! At SSC, we enable access to stratospheric balloons, sounding rockets and drop tests on a cost-efficient entrance level or fully funded through national and international programmes. One of these examples is the EOSTRE mission [2] (Experiment on Outliving Microorganisms under Stratospheric Environment), developed by FH Aachen University of Applied Sciences (Germany) in collaboration with the University of Oulu (Finland); a former BEXUS team that developed its own balloon mission, launched successfully from Esrange in March 2020. Several former students from REXUS/BEXUS have joined professional opportunities, such as the HEMERA [3] programme, with the experiments GRASS from INAF (Istituto Nazionale di Astrofisica) and STRAINS (Sapienza University, Rome) and launched it from Esrange in September 2021. Today, SSC is also offering ride share opportunities on sounding rockets with the programme SubOrbital Express [4]; first successful launch was in June 2019 on board MASER 14 (S1X-1). Opportunities are still open for the next missions in fall 2022 (S1X-3) and in 2023 (S1X-4).

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Panel: Space Education Programs in Europe

Vèrtex Auditorium, 12:30 pm – 1:30 pm
The Student Aerospace Challenge: a European multidisciplinary contest and tertiary educational programme

Natacha Callens¹, Marie-Christine Bernelin², Philippe Coué², Marine Regnier³, Mathieu Beylard⁴

Abstract
Inspired by the first successful tests of a private manned spaceplane in 2004, the Student Aerospace Challenge was created in 2006 by the European Astronaut Club and its partners - Dassault Aviation, the European Space Agency, the International Astronautical Federation, Safran and Thales at the time - to allow European university students to explore some aspects of manned suborbital vehicles. Until 2020, the Challenge focused on a local reusable vehicle reaching Mach 3.5 and an altitude of 100 km. Since the 15th edition, to better respond to the evolution of the sector, a second vehicle is proposed: a hypersonic vehicle dedicated to point-to-point transportation taking, for example, less than two hours to travel from Barcelona to Tokyo.

Each year, the Steering Committee defines several work packages corresponding to a large variety of study domains realistically related to this type of innovative vehicles like aerodynamic and flight control, structure, reusable propulsion, airworthiness, promotion, market analysis, legal frame & medicine. The introduction of a second vehicle having a quite different mission led the Committee to introduce dedicated topics. In addition, for the current edition, a new work package was proposed to cover potential applications of suborbital flights other than carrying passengers.

In function of their background and interest, European University students have the opportunity to work, during several months, on a topic related to one of the work packages and to explore new solutions. Proposed projects should be technically realistic, economically viable and environmentally friendly. Reports and posters issued by student teams are evaluated by the Steering Committee some weeks before the “Suborbital Day”, a dedicated event organised like a mini-symposium, usually on-site where students present orally their projects and meet representatives of the different partners. The best-quoted projects are rewarded with prizes, among them, the ESA Grand Prize offering the winner team the unique opportunity to present their project in an appropriate European space-related event.

To date, 216 teams and 998 University students coming from all over Europe already took part in the Student Aerospace Challenge, a motivating and ambitious multidisciplinary educational programme. Their participation allowed them to complement their knowledge, learn new skills and enlarge their network in the space sector.

Keywords
Challenge, Education, Manned spaceplane, Project-based learning Suborbital

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Student perspective and lessons learned from participating in the European Rover Challenge 2021

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GRASS Mission, UPCSP, EUROAVIA Terrassa, Escola Superior d’Enginyeries Industrial, Aeroespacial i Audiovisual de Terrassa. ESEIAAT, Universitat Politècnica de Catalunya - BarcelonaTECH, Spain

Abstract

The European Rover Challenge (ERC) is a competition where multiple teams from all around the world must face the technical, logistical, scientific and managerial difficulties of designing, building and operating a rover capable of performing a myriad of different tasks in a Mars analogue terrain (also known as Mars Yard). The competition, held in Kielce, Poland and organized by the Kielce University of Technology in collaboration with the European Space Foundation, regional governments, the European Space Agency, the Mars Society and other honorary patrons showcases each team’s creativity, innovation, drive and passion to an expecting audience, serves as an entry point to complex large-scale engineering projects for students from all backgrounds, supplying them with essential soft skills often overlooked during regular university education and connects like-minded individuals from different countries, encouraging international communication and collaboration in the aerospace industry. The authors of this paper participated in last year’s competition, ERC2021, and achieved 10th position. In this paper the insider perspective from first-time ERC participants will be discussed, including all the steps made to apply and qualify, the issues faced along the way, the lessons learned and the final experience of the on-site trials.

Keywords

Rover; European Rover Challenge; Robotics; Planetary Science; Planetary Exploration; Mars Analogue
Experiment collaboration program during a Martian analogue mission to introduce young students to human space exploration

Léa Rouverand\textsuperscript{1}, Cerise Cuny\textsuperscript{1}, Elena Lopez-Contreras Gonzalez\textsuperscript{1}, Marine Prunier\textsuperscript{1}, Mathéo Fouchet\textsuperscript{1}, Nicolas Wattelle\textsuperscript{1}, Valentine Bourgeois\textsuperscript{1}

Abstract
The last decade has demonstrated an increased public and private interest towards crewed missions through the emergence of New Space and the Artemis program. There is therefore a need to form the next generation of scientists to prepare future crewed space exploration missions. In this context, it is important to familiarize teenagers with the scientific issues of today’s world and to inspire them to engage in the space sector. Crew 263 is a group of seven students preparing a Martian analogue mission at the Mars Desert Research Station (MDRS) in the desert of Utah (United States). A Martian analogue mission at the MDRS, because is the perfect set-up to introduce young students to human space exploration. In the context of their mission, Crew 263 has organized a program of space educational activities for middle and high school students surrounding the topics of altered gravity, astronomy, health and safety procedures and robotic systems. Precisely, a set of four experiments that will be performed by the students was conceived to bring into light the various scientific topics surrounding space exploration missions.

The experiment “Plants in Microgravity” aims to illustrate the influence of gravity on plant growth by planting seeds in pots mounted on a rotating platform in a vertical plane, which will disturb their gravitational cues. “Beginner Astronomer” aims to introduce students to astronomy and astrophotography by establishing with the students a list of galaxies/nebulas to be observed during the Mission. Then, for “Emergency situation at the MDRS” students will put into practice the scientific approach by creating protocols to mitigate risk situations during space exploration missions. Finally, for the “Perseverance’s little brother” experiment, students will develop a small rover to analyze the atmosphere condition around the MDRS station.

To maximize their involvement, prior to the mission at the MDRS, the middle and high school students prepare the experiments with the support of the crew. Then, the prepared experiment will be performed in parallel with the crew while they are simulating Martian life. To allow students to be immersed in the mission when the crew will be at the MDRS, short podcasts will be recorded describing the crew’s daily life and the evolution of the different experiments. This podcast will be sent to the classes during the simulation, thus allowing the students to have an insight on the daily life of the analogue astronauts at the station.

Keywords
Analog, Education, Human, Outreach, Spaceflight

\footnotesize{\textsuperscript{1} ISAE-Supaero, France}
University of Nottingham Student Space Activities to Enrich the Traditional Curriculum

Slaveya Abadzhieva¹, Ines Oleiro Carreiro¹, Robert Mcleod¹, Rovin Perez¹, Daniel Robson²

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Abstract
Students at the University of Nottingham have been establishing several student-run extra-curricular groups to build their own space technology. These include model rockets, CanSat and CubeSat projects, involving students from bachelors up to PhD level across a variety of Departments. These projects have been supported through staff supervision, international collaboration, and access to facilities including a new space-focused laboratory space. Some students have recently benefitted greatly from modules and thesis projects being tailor made to further train them in hands-on space research and enable them to earn credits from participating in these projects.

This paper presents their initial findings and products of their work, along with their honest experiences which may be of interest to other new student groups hoping to establish similar programs at their university. Students have had to learn and put into practice a range of new skills and experiences, not normally found within taught course modules, and all of this under their own organisation. While the experiences are hugely valuable, for both professional and personal development, students need to work hard to maintain project longevity and team spirit when faced with difficulties from coursework deadlines, new skill demands and handover to new students after graduation.

Keywords
Rocket Design, CubeSat, CanSat, Hands-on Space Projects, Student Competitions
CANSAT Competition 2020: Best technical development by OrbiSat team

David Hernando-Diaz

Abstract

OrbiSat is a high school educational project that was part of the CANSAT SPAIN 2020 student competition organized by ESERO. This project has ranked first in the Catalonia Championship and second at the National Championship, winning the prize for the best technical development. OrbiSat has successfully fulfilled the objective of creating a mini satellite with the size of a soda can that was later launched by a rocket of the COSMIC Research UPC Students Association to analyze physical aspects of the air such as pressure, temperature, humidity, or the amount of UV solar radiation of a territory.

Thanks to the CanSat presented by this team, during the launch we were able to know the presence of up to 15 chemical elements in the air. Elements ranging from hydrogen and oxygen can indicate water in the atmosphere or other greenhouse gases such as CO2 or methane.

The launched rocket reached an approximate height of 532.7 ± 1.5 meters, with the sensors we were able to determine the apogee of the rocket and the subsequent release of the minisatellite and deployment of the parachute. We were also able to interrelate the altitude data with parameters such as humidity, UV radiation, presence of hydrogen, among others.

The CanSat presented by the OrbiSat team had a unique design never seen before in other CanSat competitions, solving problems such as high weight and overheating. This design made by AutoCAD was an open concept where the air can refrigerate the CPU and also the 3D printed concept saved 125 grams over a third of the maximum allowed. In addition, all the data collected was broadcast in real-time and received by a ground station every 0.25 seconds.

Before the launch, a simulation was completed estimating a 61 seconds flight, finally, the real flight was 59 seconds. The vast majority of the project was done during the COVID-19 pandemic, the consequence was new methodologies to carry on the project with a minimum time for the workshop and test phase that were supplied with simulations having a better performance than expected.

Keywords
CanSat, Educational Project, ESERO

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Panel: Smallsats Applications I

Secondary Auditorium, 11:30 am – 12:30 pm
TOLOSAT project: Gravimetry and Communication

Knight Tristan¹, Rousse Axel², Allietta Clémence³, Bérat Benjamin⁴

Abstract
The use of Constellations for weather science, security and disaster monitoring is a major challenge for space application services. Satellite to satellite communication using existing constellations has not been extensively explored yet. It can improve the communication times for small-satellite missions which have limited access to ground stations. Thus, a mission to demonstrate the feasibility of this link is required.

Another element of interest in space application is Earth Observation, especially in the context of Climate Change. Gravimetry allows an understanding of mass transport in the Earth System through the remote sensing of the time variation of the Earth gravity field. CubeSats are low-cost small-scale and hence lower risk solutions to Earth Observation missions. University CubeSats have shown their success in demonstration and scientific missions, and have a great potential in providing students with practice and application on real space systems.

In this context, the student associations ASTRE and SUPAERO CubeSat Club have joined in a CubeSat program called TOLOSAT, with the hope of demonstrating such technologies. Gathering 70 students from Toulouse, the team was split into subsystems in accordance with the concurrent engineering principles. The work performed followed recommendations from experts from the French National Centre for Space Studies (CNES) and the industry.

The TOLOSAT payloads have to test and demonstrate new means of measuring gravity and addressing communication issues. Firstly, for the gravimetry mission, our approach relies solely on GNSS to compute the gravity field, avoiding expensive gravimeters. For the communication mission: the Iridium constellation will be used as an intermediate between the CubeSat and the ground station. Off-the-shelf components such as patch antennas are planned to prove their efficiency in orbit. This would improve the coverage and the communication window.

The preliminary design was completed. TOLOSAT was designed as a 3-unit nanosatellite, on a 97.4° inclined, 500km high orbit. Margins were also ensured to allow a third payload to be defined in the future, that will be used for finance and partnerships.

Detailed designs are still required, but the educational purposes have been fulfilled, in terms of discovery of the development of space missions as well as in the teamwork culture. The team is now moving on to a new phase, dedicated to a more detailed conception with an on-going focus on the introduction to students to technical - but not only - fields of knowledge applied to space systems.

Keywords
Gravimetry, Iridium, Students

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RITA: A 1U multi-sensor Earth observation payload for the AlainSat-1

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Abstract

The Remote sensing and Interference detector with radiomeTry and vegetation Analysis (RITA) is one of the Remote Sensing payloads selected as winners of the 2nd GRSS Student Grand Challenge in 2019, to fly on board of the 3U AlainSat-1. This CubeSat is being developed by the National Space Science and Technology Center (NSSTC), United Arab Emirates University.

RITA has been designed as an academic mission, which brings together students from different backgrounds in a joint effort to apply very distinct sensors in an Earth Observation mission, fusing their results to obtain higher-accuracy measurements. The main payload used in RITA is a Total Power Radiometer such as the one on board the FSSCat mission. With these radiometric measurements, soil moisture and ice thickness will be obtained. To better characterize the extensive Radio-Frequency Interferences received by EO satellites in protected bands, several RFI Detection and Classification algorithms will be included to generate a worldwide map of RFI. As a novel addition to the 3Cat family of satellites and payloads, a hyper-spectral camera with 25 bands ranging from 600 to 975 nm will be used to obtain several indexes related to vegetation. By linking these measurements with the soil moisture obtained from the MWR, pixel downscaling can be attempted. Finally, a custom-developed LoRa transceiver will be included to provide a multi-level approach to in-situ sensors: On-demand executions of the other payloads will be able to be triggered from ground sensors if necessary, as well as simple reception of other measurements that will complement the ones obtained on the satellite. The antennas for both the MWR and the LoRa experiments have been developed in-house, and will span the entirety of one of the 3U sides of the satellite. In this work, the latest development advances will be presented, together with an updated system overview and information about the operations that will be conducted. Results obtained from the test campaign are also presented in the conference.

Keywords

Microwave Radiometry, Hyper-spectral camera, CubeSat, RFI, LoRa, GRSS

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Meteor observation with the SOURCE CubeSat – Developing a simulation to test on-board meteor detection algorithms

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Abstract

The scientific mission objectives of the Stuttgart Operated University Research CubeSat for Evaluation and Education are meteor observation, measurement of the lower Earth's atmosphere during re-entry as well as technology demonstrations. The meteor observation is done by pointing a camera towards Earth and continuously taking images during Eclipse. Since it is not possible to downlink all images, an on-board detection algorithm is necessary and mission critical. Therefore, this algorithm needs to be tested thoroughly. Realistic test data showing meteors from orbit is needed to properly develop and test the algorithm. Existing videos, provided by the Planetary Exploration Research Center, captured from the ISS are used as a baseline but are not sufficient to test the algorithm. The videos do not have the diversity of meteors needed and the meteor properties are not settable which makes it difficult to test the detection algorithm in as many scenarios as possible. Therefore, an artificial meteor program was developed to simulate meteors with given properties as perceived from a meteor observation system in a low Earth orbit. Here, we present the details of the artificial meteor program, its working principle and how we tested an algorithm for meteor detection.

The user can choose between different background videos, the existing ISS videos from PERC or the self-generated videos. Each different background is used to test a different aspect of the meteor detection algorithm. The ISS videos from PERC provide more diverse backgrounds than the self-generated videos with e.g., clouds and lightning. For these self-generated videos, a program is developed to take image sections of NASA’s Black Marble and putting them frame by frame together into a video. These videos are more suitable for simulating satellite rotation and camera properties.

Independent of the background video, settable meteor properties contain important characteristics of a meteor like the light curve, brightness, speed, direction and shape. Additionally, the user can choose the meteor position in the video frame, in which frame it appears and which distance it covers. Furthermore, distortion settings can be applied which contain airplanes with adjustable parameters and scalable noise.

Only a properly working meteor detection algorithm leads to a success of a mission critical part of the SOURCE CubeSat. Therefore, the development of this artificial meteor generation program is crucial. Furthermore, this technology demonstration of developing and especially testing a meteor detection algorithm will enable future space-based missions for meteor observations.

Keywords

Meteor simulation, Detection algorithm, On-board processing, Earth observation

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Development of a CubeSat CLIMBing to the Van-Allen belt

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Abstract

Based on its successful CubeSat mission PEGASUS, the University of Applied Sciences Wiener Neustadt (FHWN) is preparing its new CubeSat mission called CLIMB. CLIMB is a 3U CubeSat that will be launched to a low, circular orbit of about 500 km. Using a Field Emission Electric Propulsion (FEEP) system commercialized by the company ENPULSION, the satellite will be lifted to an elliptical orbit with its apogee around 1000 km – well inside the inner Van Allen belt. During its 1.5 yearlong ascent and its operation in the Van Allen belt, the satellite will continuously monitor the space radiation with a RadFET dosimeter payload and the impact on CLIMB’s subsystems. Comparisons with radiation testing on ground will allow the assessment of the capability of ground tests to predict effects of space radiation on CubeSat subsystems.

The operation of the propulsion system will raise the satellite’s apogee on average 16 times a day. A comprehensive analysis has been conducted to assess its collision probability throughout its mission time. Using various tools, provided by ESA (CROC, MASTER and the DRAMA ARES python package), the collision probability for the entire mission duration (~3 years) was calculated to be $3.38 \times 10^{-5}$, i.e. a magnitude smaller than the requested probability of $10^{-4}$.

The second payload of CLIMB is an anisotropic magnetoresistance (AMR) magnetometer with a, for CubeSats high, sensitivity of about 10 nT RMS. The first results of measurements with this COTS based magnetometer are presented as well as experimental assessments of the satellite’s magnetic cleanliness.

The benign thermal conditions on CubeSats operating close to Earth are complicated by the relatively high-power propulsion system onboard CLIMB. Detailed numerical analysis (ANSYS, ESATAN) and experimental verifications resulted in the identification of possible methods to deal with up to 18 W of dissipated electric power. The main heat sources are the thruster and the battery unit, during thruster operation.

Keywords

Field Emission Electric Propulsion System, FEEP, Van-Allen Belt, Magnetometer, Magnetic cleanliness, DRAMA, Thermal analysis, ENPULSION, magnetic cleanliness, CLIMB
Panel: Smallsats Applications II

Secondary Auditorium, 12:30 pm – 1:30 pm
On-board Image Classification Payload for a 3U CubeSat using Machine Learning for On-Orbit Cloud Detection

Mark Angelo C. Purio¹, Timothy Ivan Leong², Yasir M. O. Abbas³, Hoda Awny Elmegharbel⁴, Koju Hiraki⁵, Mengu Cho⁶

Abstract

CubeSats are giving the opportunity for educational institutes to participate in the space industry, develop new technologies and test out new ideas in outer space. CubeSat missions are developed to perform scientific research and demonstrate new space technologies with relatively cheap cost and limited resources. This category of satellites has many limitations such as the short development time, the power consumption and the limited time and capability of data downlink. Earth Observation from a Low Earth Orbit is one of the most appealing applications of CubeSats developed by students or non-space faring countries. Investigating new technologies to improve image quality and studying ways to increase acquisition adequacy is very promising. This paper aims to introduce a mission hardware design and machine learning-based algorithm used within an Earth Observation (EO) CubeSat. The case study of this paper is Alainsat-1 project which is a 3U CubeSat developed with the support of IEEE Geo-science and Remote Sensing Society (GRSS) at the National Space Science and Technology Center, UAE. The satellite is planned to be launched by 2022. A low-resolution Commercial off-the-shelf (COTS) camera for EO is developed as a primary mission in this CubeSat. The compatible hardware design and software algorithm proposed is responsible for classifying the images captured by the camera into different categories based on cloud intensity detected in these images before downloading them to the ground station. A microcontroller-based architecture is developed for controlling the mission board; it is responsible for accessing the memory, reading the images, and running the cloud detection algorithm. The cloud detection algorithm is based on a U-net architecture while the algorithm is developed using a Tensor-flow library. This model is trained using a dataset of images taken from the Landsat 8 satellite project. Moreover, the SPARCS cloud assessment dataset is used to evaluate the developed model on a new set of images. The overall accuracy achieved by the model is around 85% in addition to the acceptable performance of the model observed on a set of low-resolution images. The plan is to make the design modular and optimize its performance to be used on-board CubeSats fulfilling the size constraint and overall power consumption limitation of an add-on module to a camera mission.

Keywords

CubeSat, Cloud Detection, Image Classification, U-net architecture, Microcontroller

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Development of Commercial-Off-The-Shelf Imaging Payload for Cloud Coverage Monitoring

Edwar ¹, Shindi Marliana Oktaviani ², Aipujana Tiara Santoso ², Syachrul Gibran Muzhaﬀar ², Irvan Husni Saugi ², Muhammad Alif Putra Dafi ², Galuh Mardiansyah ², Maulana Muhammad Aziz ², Lita Kurnia Fitriyanti ², Putri Nurani ², Nurul Izzah ², Giyan Sukma Pratama ²

Abstract
Locana Bhumi payload is one of the selected payloads in The 2nd GRSS Student Grand Challenge, and it will be installed in a 3U Cube Satellite. Its main mission is to monitor cloud coverage in several regions such as Indonesia, United Arab Emirates, Oman, and Australia. Clouds have a role in climate change, they are able to reflect infrared light and cool the surface of the earth that is covered by clouds. At the same time, clouds are also able to trap heat, as a result, they warm the earth. By monitoring cloud coverage over the selected areas, it is expected that we will be able to study how cloud coverage could affect the climate system on the earth. In order to monitor the cloud coverage, the Locana payload will capture cloud images by using a small serial camera that is equipped with a low voltage 1/4-inch 5-megapixel OV5642 image sensor. This camera also employs a 4.14 mm focal length fixed-infrared-cut-ﬁlter lens. This camera is able to capture 500 x 375 km² of the area from about 575 km above the earth's surface, with that area observation, the cloud coverage is expected to be easier to observe. In terms of image storage, this payload is integrated with a 1 Gigabit memory. This memory is also used for saving the payload housekeeping data. To prevent the payload from overcurrent situations, the payload system is integrated with an Over Current Protection module. Moreover, an alloy-based enclosure has been designed to protect the component from outer space radiation. The material used for the enclosure is aluminum alloy 7075. The payload has a compact dimension, which fits in 0.5U of Cube Satellite size. Currently, the development of this payload has reached the Critical Design Review stage and it is expected to be ready in Quartal-1 2022.

Keywords
Climate change, cloud coverage, Cube Satellite, RGB camera

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Abstract
Alba CubeSat UniPD is a student team of University of Padova with the aim to participate to the ESA Fly Your Satellite! (FYS!) programme and to launch for the first time at University of Padova a CubeSat made by students.

The proposed mission has three independent objectives: (1) to collect in-situ measurements of the sub-mm space debris environment in LEO, (2) to study the micro-vibration environment on the satellite throughout different mission phases, (3) to do precise orbit determination through laser ranging and evaluate procedures for fast satellite Pointing, Acquisition and Tracking (PAT) from ground. The proposed technological experiments aim to obtain data that will enrich the current knowledge of the space environment and will provide precious information useful for the further development of some research projects currently performed at University of Padova.

In order to reach these objectives, the teams have been committed, for the past two years, in the development of a 2U CubeSat equipped with three payloads. The first payload is an impact sensor that will be placed in one of the outer faces of the satellite and will be able to count the number of debris impacting the spacecraft thus being able to measure the energy/momentum transferred to the satellite. The second one is a Commercial Off The Shelf (COTS) sensor that measures the micro-vibrations experienced by payloads in a CubeSat in different mission phases. The third one consists in a number of COTS Corner Cube Retroreflectors that will be placed onboard the satellite. Thanks to this, Satellite Laser Ranging (SLR) will be done to collect data on the satellite range and range rate using a facility currently under development at University of Padova.

This paper presents the motivations that moved the team towards this project, and its mission objectives and mission phases. In addition, the preliminary design of the CubeSat reached during the activities of the project is shown. Particular attention is given to the payloads which are the most challenging aspect of this project.

Keywords
CubeSat, Impact sensor, Micro-vibrations, Laser Ranging
Further evidence of the long-term thermospheric density variation using 1U CubeSats

Adrián Martínez¹, Carlos Lledó², Jordi L. Gutiérrez³, Pilar Gil-Pons⁴

Abstract
Faculty members, undergraduate and graduate students of the School of Communication and Aerospace Engineering (Politecnical University of Catalonia) are participating in a series of studies to determine the thermospheric density. These studies involve planning a space mission, designing and constructing small satellites, and performing related data analysis. This article presents a method for determining the thermospheric density and summarises the academic context in which we develop our work.

Several studies have reported the existence of a downtrend in thermospheric density, with relative values ranging from $-2\%$ to $-7\%$ per decade. Although it is well known that solar and geomagnetic activity are the main drivers of the variations of the thermospheric density, this downtrend was reported to be caused by the rise of greenhouse gases. We present an update of this progression, considering the last solar cycle (2009-2021) and using Two-Line Elements sets (TLE) of 1U CubeSats and the spherical satellites ANDE-2. TLEs were used to propagate the orbits numerically using SGP4 (Simplified General Perturbations), and then compute the average density between two consecutive TLEs by integrating the appropriate differential equation. Then, using the NRLMSISE-00 (Picone 2002) and JB2008 (Bowman 2008) atmospheric models, we calculated an average density deviation per year.

We built a comprehensive time series of the thermospheric density values, ranging from 1967 to the present. We merged Emmert (2015) thermospheric density data and our results computed both with NRLMSISE-00 and with JB2008. A linear regression on the combined dataset yields a decreasing trend of $-5.1\%$ per decade. We also studied the geomagnetic and solar activity to isolate the possible greenhouse gasses effect during the considered period. Our results show a strong correlation between geomagnetic activity and density deviation near the solar minima, and we propose that the cause of the previously reported long-term density deviation could be a poor adjustment of the effects of geomagnetic activity. Finally, we proved that orbital information from small satellites could be efficiently used to assess the evolution of thermospheric density variations. Additional data obtained from future missions (as the one proposed by our group) will eventually allow a better characterisation of the atmospheric density and help disentangle the possible greenhouse gasses effects on its variations.

Keywords
Thermosphere, Femtosatellite, Space Climate

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4 Department of Physics, UPC, and Institut d’Estudis Espacials de Catalunya, Spain
ERMES: Design and preliminary simulations for an autonomous docking manoeuvre

Alessandro Bortotto¹, Giuliano Degli Agli², Federico Favotto², Fabio Mattiazz², Miroljub Mihailovic², Nicola Pozzato², Francesco Branz³, Lorenzo Olivieri⁴, Alex Caon⁴, Alessandro Francesconi⁵

Abstract

In the last decades, small satellites have played an important role in space missions. Due to their reduced dimension and costs, they became affordable to smaller companies and research laboratories to conduct scientific experiments and technological demonstrations in space. In addition, the number of these satellites has considerably increased due to their wide use in technological, scientific and commercial domains. In this scenario, autonomous architectures, as well as miniaturized mechanical subsystems for small satellites, are continuously investigated.

Experimental Rendezvous in Microgravity Environment Study (ERMES) is a student project that focuses on the simulation of an autonomous docking manoeuvres between two CubeSats mock-ups equipped with miniaturized Guidance Navigation and Control systems and mechanical docking interfaces. ERMES aims to integrate different subsystems for autonomous docking, to increase the Technology Readiness Level and to study possible applications for in-orbit servicing. This paper deals with the design and development of the tests for autonomous docking manoeuvres between two CubeSats mock-ups to be performed in a reduced-gravity environment during a parabolic flight. A Target-Chaser configuration has been selected, where the Chaser is fully active and the Target is cooperative. The Chaser is equipped with a miniaturized cold gas propulsion system with eight thrusters to control its attitude and position; in contrast, the Target has a set of three reaction wheels to control only its attitude. The tested miniaturized mechanical docking interfaces employs a probe-drogue configuration. The most demanding aspect of the development phase will be the dedicated software for the proximity navigation. The reduced-gravity conditions will be achieved during a campaign of parabolic flights thanks to the participation to the European Space Agency “Fly Your Thesis!” programme 2022.

Keywords

Autonomous docking, CubeSats mock-ups, miniaturized systems, parabolic flight, proximity navigation software.

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Panel: Solar System Exploration

Auxiliary Room, 11:30 am – 12:30 pm
Designing Greenhouse Subsystems for a Lunar Mission: 
The LOOPS - M Project

Riccardo Restivo Alessi, Giulio Metelli, Alessio Bergami, Luca Furlani, Marco Garegnani, Riccardo Pagliarello, Michela Boscia, Michela Piras, Sidhant Kumar, Tommaso Torrini, William Picariello, Damiano Salvitti, Carlo Pirolo, Tommaso Monello, Walter Dragonetti, Stefano Martinelli, Marco Panetti, Chiara Pozzi, Matteo Gargari, Sofia Torlontano, Paolo Marzioli, Luca Guglielmetti, Luca Nardi, Elena Lampazzi, Lorenzo Frezza, Eugenio Benvenuto, Fabio Santoni

Abstract

The 2020s is a very important decade in the space sector, where international cooperation is moving towards the exploration of the Moon and will lead to stable lunar settlements, which will require new, innovative, and efficient technologies. In this context, the project LOOPS–M (Lunar Operative Outpost for the Production and Storage of Microgreens) was created by students from Sapienza University of Rome with the objective of designing some of the main features of a lunar greenhouse. The project was developed for the IGLUNA 2021 campaign, an interdisciplinary platform coordinated by Space Innovation as part of the ESA Lab@ initiative. The LOOPS-M mission was successfully concluded during the Virtual Field Campaign that took place in July 2021. This project is as a follow-up of the V-GELM Project, which took part in IGLUNA 2020 with the realization in Virtual Reality of a Lunar Greenhouse: a simulation of the main operations connected to the cultivation module, the HORT, which was already developed by ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development) during the AMADEE-18 mission inside the HORTSPACE project. This paper will briefly describe the main features designed and developed for the lunar greenhouse and their simulation in a VR environment: an autonomous cultivation system able to handle the main cultivation tasks of the previous cultivation system, a bioconversion system that can recycle into new resources the cultivation waste with the use of insects as a biodegradation system, and a shield able of withstanding hypervelocity impacts and the harsh lunar environment. A wide overview of the main challenges faced, and lessons learned by the team to obtain these results, will be given. The first challenge was the initial inexperience that characterized all the team members, being for most the first experience with an activity structured as a space mission, starting with little to no know-how regarding the software and hardware needed for the project, and how to structure documentation and tasks, which was acquired throughout the year. An added difficulty was the nature of LOOPS-M, which included very different objectives that required different fields of expertise, ranging from various engineering sectors to biology and entomology. During the year, the team managed to learn how to handle all these hurdles and the organizational standpoint, working as a group, even if remotely due to the Covid-19 pandemic. Through careful planning, hard work and the help of supervisors, the activity was carried out through reviews, up to the prototyping phase and the test campaign with a successful outcome in each aspect of the project. By the end of the year everyone involved had acquired new knowledge, both practical and theoretical, and learned how to reach out and present their work to sponsors and to the scientific community.

Keywords

Education, LOOPS-M, IGLUNA

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AMORE - Mission concept overview for a progressively independent and self-sustainable lunar habitat

Apoorva Joshi¹, Christian Korn², Michail Magkos³, Yassin Amara², Abhishek Anil², Souktik Bhattacherjee⁴, Sisinio Dargent de Vicente⁵, Patrick Haffmans⁶, Nicolas Heinz², Andrea Hinkel², Merve Karakas², Aleksandar Kolchin⁷, Vipul Mani⁸, Ilja Skrypnyk⁸, Anne Stadtmüller⁹

Abstract

Throughout the last decade a renewed interest for lunar space exploration has been expressed through the announcements of many ambitious missions such as Artemis. Annually the Space Station Design Workshop (SSDW) tasks students and young professionals to design a space station concept in a concurrent engineering environment. In line with the elevated interest on the Moon this year’s SSDW was centred around a self-sustainable lunar habitat. This paper presents the conceptual design of Team Blue at the SSDW 2021. Advanced Moon Operations and Resource Extraction (AMORE) is conceptualized as a public-private cooperation for the creation of a lunar platform that acts as an outpost for human exploration and robotic In-situ Resources Utilization (ISRU). AMORE’s proposed location is near the rim of Shackleton Crater at the Lunar South Pole. This location provides opportunities in science and ISRU and favourable sun coverage and thermal conditions. The terrain offers a natural shield for debris and storage advantages for ISRU. The mission architecture allows for incremental crew size increase through a modular dome structure, an initial prioritization of ISRU and a sustainable resource management strategy. Based on the identified system requirements, the initial configuration envisions one core module and two modular structures that would serve as greenhouses or living spaces. The phasing of the base assembly is designed to allow for adequate conditions of an increasing crew size capacity. The greenhouse modules are designed to provide all required oxygen and most required food supply. The modules are constructed using lightweight inflatable structures, while a regolith shell will provide radiation as well as thermal and micrometeorite protection. For reliable communication, a custom relay network named Lunar Earth Telecommand Telemetry Relay (LETTER) is proposed. The mission architecture analysis includes several methods to financially utilize the mission. These include a range of services on the lunar surface such as training facilities for deep space missions, leasing habitats to other Moon explorers, and performing scientific and technological demonstrations. A variety of rovers will be used throughout the mission that will assist in various aspects. In addition to this, a scalable hybrid power generation system that utilizes the abundant sunlight and nuclear energy assures a sufficient power supply throughout the entire mission lifetime. This research presents a holistic architecture for a Moon base, which provides an approach to initially utilize the Moon. Within this context, the mission concept is primarily based on already existing or currently in-development technologies. Hence, AMORE offers an approach for a financially and technologically feasible as well as a continuous and expandable human presence on the lunar surface.

Keywords
Moon, Lunar-base, space-exploration, ISRU, self-sustainability, SSDW, AMORE

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DEAR project: Lunar Dust Surface interactions, Risk and Removal investigations

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Abstract

The DEAR project (Dusty Environment Application Research) investigates the interaction between lunar regolith and surfaces and components relevant for lunar exploration. Based on the TUBS regolith simulant which is representative in chemistry, size and shape properties to Moon soils to study the regolith transport, adhesion and strategies for cleaning. The regolith simulant will be applied to thermal, structural, optical sensor, sealing and other astronautic systems, providing input for requirements, justification and verification.

The key applications are split in human space flight regolith investigations, wrinkled surface with random movement and hardware surfaces, flat material defined movement. The paper provides an overview of the DEAR project including a discussion of the first results, in particular vibration, shock and micro-vibration on regolith bearing surfaces. The investigation shall enable better understand the regolith layers interaction and the release mechanism, as well as potential cross contamination and cleaning strategies. The research is complemented by simulation of the regolith motion as parameter surface plasma interactions. The project is funded and supported by the European Space Agency (ESA). DEAR specifically addresses the development and testing of lunar dust removal strategies on optics, mechanisms and human space flight hardware (e.g., space suits). As the Moons regolith is known to be highly abrasive, electrically chargeable, and potentially chemically reactive, lunar dust might reduce the performance of hardware, such as cameras, thermal control surfaces and solar cells. The dust can cause malfunction on seals for on/off mechanisms or space suits. Of particular interest are risk assessment, avoidance, and cleaning techniques such as the use of electric fields to remove lunar dust from surfaces. Representative dust (e.g., regolith analogues of interesting landing sites) will be used in a dedicated test setup to evaluate risks and effects of lunar dust. We describe designs and methods developed by the DEAR consortium to deal with the regolith-related issues, in particular an electrode design to deflect regolith particles, cleaning of astronautical systems with CO\textsubscript{2}, design of a robotic arm for the testing within the DEAR chamber, regolith removal via shock, and regolith interaction with cleanroom textiles.

Keywords

Astronaut space suit, Electrode design, Regolith (lunar dust), Robot arm, Specific cleaning (CO\textsubscript{2})

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Mission design of a Exploratory and Sample Return Mission from Venus’s Clouds

Vipul Mani

Abstract
Named after the ancient Roman goddess of beauty, Venus is known for its exceptional brightness in the night sky. But behind this facade is a world of storms and infernos unlike anywhere else in the solar system. Venus, the second planet from the sun, is very similar to Earth from a distance. But up close, it’s a very different world. Venus is about the same size as Earth, just slightly smaller. It's structure is also nearly identical, with an iron core, a hot mantle, and a rocky crust. Venus also has a thick layered atmosphere. It's full of clouds that rain (thunder cracking) sulfuric acid, and whip around the planet at speeds up to 224 miles per hour, faster than some category five hurricanes. Venus being the hottest planet in the solar system [1] is inhospitable, neither humans nor spacecraft are able to survive the planet's surface for long. While there have been proposals to realize floating cities in Venus’s atmosphere, information about the contents in the Venusian clouds is still debatable. This case study presents a mission to study Venusian atmosphere and its clouds. The mission architecture consists of multi-agents exploratory probes which shall be placed in multiple orbits around Venus to maximize the scientific data and type of scientific data obtained. A special maneuver using current propulsion techniques has been developed to devise a sample return from Venusian clouds. Comprehensive tables and graphs will be given, which will depict the amount of time that will pass at each mode of travel, delta-V budgets and more importantly some idea on the cost in terms of energy as well as money will be discussed within today’s context. With the possibility of phosphine in Venus’s atmosphere, there has been an increased interest in the idea of life in Venus's clouds [2], which is why it becomes more important to perform these exercises to increase the mankind’s understanding of life in Solar System.

Keywords
Venus clouds, Sample return, Delta-V budgets, Mission Design

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Domi Inter Astra (DIA) Moon Base: an interdisciplinary approach for cooperation to build a near-future Moonbase and how to use it as an educational tool
Chien Lin Soh 1, Jay Kamdar 1, Khushi Shah 1, Martine Irog 1, Nitya Jagadam 1, Pablo Arriazu 1, Paras Adlakha 1, Richal Abhang 1, Saad Rayees 1, Sanket Kalambe 1, Sejal Budholiya 1,2, Selene Canelli 1, Dr Arun Tom Mathew 2

Abstract
Permanent human settlements outside of low-earth orbit face technical and psycho-social challenges for the crew members and programmatic risks around funding and operating these missions, without clear public support and international involvement. A concept for the construction and operation of a lunar settlement named "Domi Inter Astra" (DIA), near the Shackleton Crater, was developed to understand the feasibility of a near-term permanent settlement crewed by international researchers and tourists. This project was created by a team under the Space Generation Advisory Council's auspices and a follow-on to our First Place design in the Moon Base Design Contest by The Moon Society. Technologies for infrastructure, life-support, environment control, and robotics were selected using high-level trade studies to balance resource requirements, safety, reliability, operability, and maintainability of the base over a long (20+ year) operating life with 10-30 inhabitants. Technology roadmaps were developed for gaps in existing technologies, considering opportunities with ISRU and methods of closing the environment control and life support system loops. A wider range of human factors pertaining to the social environment onboard the base is discussed to ensure long-term stability. Architectural design choices were made, keeping these factors in mind while also considering technical and economic viability. Large-scale space exploration projects must mitigate both public interest and funding risks throughout their life cycle. Economic roadmaps are introduced to diversify revenue streams throughout the settlement's design, deployment, and operation. Funding opportunities that evolve with the base design and functionality over time are identified for long-term economic sustainability. A polycentric model for international collaboration is explored to promote interest from current space-leading countries while providing opportunities for emerging space nations. The DIA lunar settlement case study showcases the interrelation between engineering, economics, architecture, science, social and management scopes. It highlights the interdisciplinary approach and inclusivity in the field of space sciences. This case study can help international and public-private partnerships to develop human space exploration capabilities further. The current DIA base plan could be used in many ways for educational activities, for any level of students and professionals. Two types of activities could be design and analysis based and mini analogue missions. Students could devise and perform small experiments that relate to the base's day-to-day activities as well as resources required, for example growing microgreens and plants in different conditions, geology surveys, 3D printing different objects and many such mini-projects. Graduate students and professionals could work on CAD modelling for structures, improving the architectural plan and the statistical analysis for the economical model.

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Panel: Solar System Science

Auxiliary Room, 12:30 pm – 1:30 pm
Analysis of planetary spacecraft images with SPICE
Teresa Peña¹, Manel Soria², Paula Betriu², Enrique García-Melendo²

Abstract
Spacecraft images are an invaluable source of information in Planetary Science. However, they must be processed and the initial stage is to navigate them, i.e., determine the longitude and latitude coordinates of each pixel on the image plane. The main goal of the present work is to develop an open-source tool to do so. It will be independent of proprietary software and implemented in a widely used language (Java, Python). It will be able to analyse planetary images taken by different spacecraft, such as New Horizons, Cassini or Voyager, with minimal user intervention. Here we present the first steps of the process illustrating the techniques to navigate an image of an ellipsoidal body, obtained from mission kernels using NASA Jet Propulsion Laboratory SPICE library, considering that the attitude and position of the spacecraft are available; correct the camera attitude information; determine the image resolution for each pixel; and combine different images of a body to generate mosaics with high resolution.

Keywords
Planetary Science, Planetary Image Processing, SPICE, Open Software

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TEASPOON: a once in a lifetime opportunity to Sedna

Francesco De Cecio¹, Marco Aspert², Andrea Babato², Elia Bassetto³, Lorenzo Beccari³, Lorenzo Capra¹, Rosario Iaccarino³, Gerardo Littoriano⁴, Paolo Matteoni³, Marco Modè²
Michèle Lavagna⁴

Abstract

In the challenge of unveiling the enigmas that still surround the origin and early evolution of the Solar System, the study of trans-Neptunian objects plays a crucial role. For this purpose, Sedna is probably the most intriguing candidate for a space mission. A better understanding of its highly elliptical orbit could improve our knowledge of the evolution of the Solar System and could potentially lead to the discovery of an unknown planet. Moreover, the planetoid is expected to host a significant amount of tholins and probably a subsurface ocean of liquid water, making the analysis of its composition extremely interesting. In 2076, Sedna will reach its minimum distance of 76 AU from the Sun. This is a scientific opportunity that will not happen again in the next 11400 years.

Exploiting this instance, TransnEptuniAn Sedna PrOb for Outer exploratioN (TEASPOON) is a mission proposal to send a probe to Sedna, featuring a payload suite to perform an optical characterization, study the particle environment and conduct a radio-science experiment. Moreover, the long travel will be an opportunity to explore the Kuiper Belt looking for observations or, hopefully, discover new objects. The harsh environment, characterized by objects with unknown trajectories, requires Collision Avoidance strategies, while long-term radiation exposition demands electronics shielding and the preference for rad-hard components. More generally, the 77 AU distance and 30 years duration of the mission makes the design even more demanding. Therefore, solving those challenges would inaugurate a new generation of space missions to the edges of the Solar System and beyond.

This proposal has been developed in the framework of a Space Mission Analysis and Design course by a team of students at the master level in Space Engineering at Politecnico di Milano. A concurrent engineering approach has been followed, leading the study through its phase 0/A. This enabled them to practice in actual working conditions of a space agency’s mission study, and underlined the importance of this kind of experience at a Master’s level course.

Keywords
Concurrent engineering, mission proposal, Sedna, Solar System exploration, Trans-Neptunian Objects

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Mubody, an astrodynamics open-source Python library focused on libration points

Juan Bermejo-Ballesteros¹, José María Vergara Pérez², Alejandro Fernández-Soler², Javier Cubas²

Abstract
Mubody is an astrodynamics open-source Python library focused on the libration points. Such points result from the equilibrium of the gravitational forces between two massive bodies as the Sun and Earth, for example. The library is mainly aimed at the generation of orbits in these regions, which is not a straightforward process, specially if perturbations are considered. Currently, the library allows to generate Lissajous orbits in the second Lagrange point of the Sun-Earth system under the influence of perturbations such as the Earth orbit eccentricity. The next milestone, as a result of a master student work, is the incorporation of Halo orbits and the expansion to all three collinear libration points from any two massive bodies of the Solar System. This tool has been developed as part of a PhD, motivated by the need of performing mission analysis in libration point regions. Nevertheless, since its creation it has also proven to be an excellent academic tool for both enhancing the library itself and using its results for further studies (collision risk, thermal analysis, formation flight control, etc). As a result, the tool has rapidly evolved, building onto the knowledge and experience that the students gather while working on their academic projects (bachelor’s degree dissertations, master theses, subjects, internships). The participation on the library development provides students with experience in orbital mechanics, software design, version control and it compels them to ensure that their work can be readily used by others as it is properly documented. The project is hosted in GitLab under a MIT licence.

Keywords
Astrodynamics, Libration Points, Python, mission analysis, education, open-source

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Demonstrating Cosmological and Doppler Redshift in the Classroom

Oriel Marshall¹, Rita Tojeiro², Anne-Marie Weijmans²

Abstract

Cosmology is often a difficult subject to teach as it can involve many confusing and sometimes abstract concepts. One particular topic with many existing misconceptions and difficulties surrounding it is redshift, specifically the difference between Doppler shift (due to the peculiar velocities of galaxies) and cosmological redshift (due to the expansion of the Universe). Redshift of galaxies, despite being an extremely useful and interesting scientific tool, can often become a tedious subject to teach as it is largely theoretical and usually doesn’t include demonstrations or interaction in the classroom. It can be challenging to understand, and therefore also challenging to explain, the differences between Doppler and cosmological redshift, often leading to this distinction being overlooked entirely. The set of demonstrations developed during this astrophysics masters project, along with the accompanying presentation, worksheet, and teacher notes, aim to explain both Doppler and cosmological redshift clearly and in an engaging and memorable way. The demonstrations use remote control vehicles to represent peaks of a traveling wave of light. When demonstrating Doppler shift, the vehicles are released from a plastic board that is being pulled away, representing a receding source of light. When demonstrating cosmological redshift, the vehicles are driven along a wide stretchy exercise band, representing a section of the expanding Universe through which this wave of light is traveling. This teaching resource will introduce interactive learning, proven to be very effective when teaching astronomy, and provides a useful and fun physical analogy to demonstrate an often-misunderstood subject.

Keywords
Cosmology, classroom, demonstrations, interactive, redshift

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Presentations

Thursday, April 28th
Panel: Space Education at University I

Vèrtex Auditorium, 9:30 am – 11:00 am
Blended-Learning Educational Concept for Earth Observation at University Level

Clémence Dubois\textsuperscript{1}, Robert Eckardt\textsuperscript{1}, Christiane Schmullius\textsuperscript{1}

Abstract
The field of Earth observation has been undergoing a tremendous transformation for several years. From commercial data that used to be processed only by a circle of specialists, we are now in an era where numerous high-quality satellite data can be made available for free and used by diverse user groups in many applications. It is therefore of fundamental importance for new users to understand and use these data in an application-specific way, and teaching concepts need to be adapted accordingly. Specifically for the field of radar remote sensing, several activities already exist that intend to adjust educational offers with needs of the market place and to provide hands-on material for self-paced learning in many fields of application. At university level however, many courses still happen in a traditional classroom way, the lecturer being the principal source of information. We present here a blended-learning approach aiming the integration of high-quality eLearning material in traditional face-to-face courses to enhance the teaching and learning experience. The approach can be resumed in two main goals: 1) the specific integration of eLearning elements on a learning platform for a better preparation and follow-up of the course content by the students; 2) the creation of new eLearning content by the students in a peer-to-peer approach. For the first goal, existing content from Massive Open Online Courses (MOOC) are broken down into learning modules and supplemented with external digital learning content in order to best match the needs of the face-to-face course week by week. This prevents students from being overwhelmed by the enormous volume of online educational resources of the MOOCs and allows a better preparation of students for the current content of the lecture. For the second goal, a further deepening of what has been learned takes place through active co-creation of new digital content. This is based on the principle of the pyramid of learning that the best way to remember something is to explain it yourself. In this way, students who create new content from what they have learned should be able to remember it much longer as if they just listen to it. This blended learning educational model is conducted successfully since two years at university level with bachelor and master students and is being enriched regularly with new material, both from the open educational resources and students contributions.

Keywords
Blended-Learning, Earth observation, Peer-to-peer, university

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Engineering and Management of Space Systems (EMSS) - an international joint Master's double-degree program

Jasminka Matevska¹, Justyna Szostak², Zbigniew Łubniewski², Szymon Krawczuk²,³, Marek Chodnicki²

Abstract
Dynamic development of the space sector of European, and especially of Polish and German economies results in a necessity for suitable Higher Education Institution graduates. The increasing digitization, distribution and networking of technical systems leads to the necessity of a degree programme teaching “the systems view” and “interdisciplinarity” methods and skills. Furthermore, it is necessary to consider the entire life cycle of the systems starting with the analysis of the requirements, through design, integration, verification, to operation and maintenance, with supplementation of management, social and intercultural skills.

Since interdisciplinarity and internationality are essential for engineering and management of space systems, the international project was launched early last year by two universities – Hochschule Bremen (Bremen City University of Applied Sciences, HSB, Germany) and Politechnika Gdańska (Gdańsk University of Technology, Gdańsk Tech, Poland) establishing an international interdisciplinary joint Master's double-degree program - Engineering and Management of Space Systems (EMSS). It consists of three different fixed three- or four-semester study paths of several mobility schemes, though individual educational pathways adjusted to students' preference are also allowed. Each path includes a joint academic year – first semester is conducted in Gdańsk, the second in Bremen. The remaining semesters can be studied at either of the universities. All of the EMSS curricula meet the highest education standards of both countries.

Several mandatory modules and many elective courses are included in the EMSS curricula. Upon graduation, students of the program are awarded two Master’s degrees - in Space and Satellite Technologies, issued by Gdańsk Tech, and, depending on the chosen study path, in Aerospace Technologies, Computer Science, or Electronics Engineering issued by HSB.

Work on the establishment of a new, international, joint field of study - Engineering and Management of Space Systems, run by both universities is currently in progress. The curriculum of the new study programme will be based on the recommendations of the International Council On Systems Engineering (INCOSE) and its German Chapter, Gesellschaft für Systems Engineering (GfSE), and will offer the possibility of certification as a Systems Engineering Professional, Associate Level.

This paper includes the lecturers’ and students’ perspective on the program and its future development.

Keywords
Engineering and Management of Space Systems, International joint double-degree program

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Space Games:
Evaluating Game-Based Virtual Reality in Higher Education

Lana Laskey

Abstract
With increasing global dependence on satellite technology, space traffic has grown exponentially over the last decade. Enhanced education and training of future mission operators will be necessary to meet this growing demand. The complexity of satellite mission operations poses a challenge in education and training. Remote spacecraft are elusive and difficult for a trainee to visualize and involve a steep learning curve. However, the integration of game-based virtual reality into spacecraft simulation and training may assist in overcoming these challenges. This research study explored the integration of game-based virtual reality into a university course involving spacecraft operations. Virtual spacewalks allowed student participants to conduct visual inspections and interact directly with spacecraft components. The immersive virtual reality environment prolonged cognitive engagement and game mechanics influenced motivation, both cornerstones in learning. After completing the training scenarios, user experience was assessed with several validated scales measuring system usability, user satisfaction, cognitive load, and any potential simulator sickness. Results revealed satisfactory scores in all categories with minimal simulator sickness. The integrated use of game-based virtual reality in the classroom provided an enhanced learning experience in a safe and repeatable environment that might be difficult with traditional teaching methods. This paper will evaluate game-based virtual reality when integrated into higher education or other training environments.

Keywords
Game-Based Virtual Reality, Instructional Design, Simulation, Spacecraft Operations, Training

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From Soyuz-docking manoeuvres to microalgae cultivation: hands-on training for Master's students

Gisela Detrell¹, Sebastian Wenzel², Miquel Bosch Bruguera², Tharshan Maheswaran², Markus Grass², Johannes Martin², Moritz Vogel²

Abstract
A strong connection between research and teaching at a university is crucial to offer students a unique opportunity to put in practice the concepts taught in theoretical lectures. At the University of Stuttgart, several hands-on training courses have been offered for eight years within the module “Selected hands-on training for space”. Those are adapted to the current research at the Institute of Space Systems. During one semester, students participate in two of the offered courses and are evaluated through an exam or a report. Three ECTS for the space specialization in the aerospace engineering Master are granted after successful completion. The limited places offered are usually filled up in matter of hours and the students’ feedback has been very positive every year. The module includes up to five different courses, depending on the semester. The Life Support Systems seminar is focused on the cultivation of microalgae, linked to the institute’s ISS Experiment photobioreactor PBR@LSR. After learning the basic life support system concepts, the students build and conduct their own microalgae photobioreactor experiment. In the Missions Analysis practical seminar, based on the work of several PhD candidates, the participants learn and put in practice aspects of mission planning with the help of the Astos Solutions software as well as the SPICE toolkit. During the Rendezvous and Docking practical training, students learn about the operation and handling of a spacecraft. Besides theoretical lectures, guided sessions in the simulator allow to put into practice the handling of common complex procedures, audio-visual perception and motor skills. This seminar is linked to the research carried out in the SIMSKILL experiment. In the Earth Remote Sensing seminar, students learn how to handle payload data for Earth observation and their scientific evaluation. The Flying Laptop, a satellite fully built at the institute and launched in 2017, is used for this course. Finally, the research carried out in the field of electrolysers and fuel cells for space applications at the institute prompted the establishment of a training course. After deepening their knowledge on both electrolysers and fuel cells, the students prepare, carry out and evaluate various experiments. This paper presents the different training courses from our institute and their link to the current research.

Keywords
Earth-Observation, Fuel Cell, Hands-on training, Life Support System, Mission Analysis, Soyuz simulator

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An example of Space Engineering Education in Spain: a master in space based on Project-Based Learning (PBL)

Javier Cubas¹, Santiago Pindado¹, Elena Roibás-Millán², Javier Pérez-Álvarez², Ángel Sanz-Andrés³, Sebastián Franchini¹, Isabel Pérez-Grande³, Gustavo Alonso¹, Andrés García-Pérez¹, Marcos Chimeno-Manguán¹, Ignacio Torralbo¹, Juan Zamorano³ and Alejandro Alonso³

Abstract
This work describes the successful education experience for five years of space engineering education at the Universidad Politécnica de Madrid (UPM), Madrid, Spain. The MSc. in Space Systems (MUSE, Máster Universitario en Sistemas Espaciales) is a 2-year and 120-ECTS (European Credit Transfer and Accumulation System) master program organized by the Microgravity Institute ‘Ignacio Da Riva’ (IDR/UPM), a research institute of UPM with extensive experience in the space sector. The teaching methodology is oriented to Project Based Learning (PBL), taking advantage of the IDR/UPM Institute experience. The main purposes are to share the IDR/UPM knowledge with the students and promote their collaboration with several space scientific institutions, both national and international. In the present work, the most relevant characteristics of this master program are described, highlighting the importance of the student’s participation in actual missions.

In addition, to offer practical cases in all aspects of satellite development, the IDR/UPM decided to create its own satellite development program, the UPMSats. The latest, the UPMSat-2, is an educational, scientific, and in-orbit technological demonstration microsatellite (50 kg-class) that was launched in September 2020 on-board a Vega launcher (VV-16 flight). MUSE students have participated in all phases of the mission, from design to integration, calibration, and testing, and (at present) in-orbit operation. The construction of a microsatellite, although it exceeds in time the academic duration of the master, has proven to be a very interesting and versatile tool for PBL education, since it provides practical cases at all levels of development. Furthermore, the continuity of the project encourages graduated students to continue their education with a Ph.D. and the collaboration of master and doctoral students. These reasons have made MUSE one of the most successful academic programs in space systems engineering in Spain, with high employment rates in the most prestigious space engineering institutions.

Keywords
Space Systems, Master, Education, Project Based Learning
Establishing Thriving University-Level Space Education
Chantal Cappelletti¹, Daniel Robson², Mark Jabbar³, Katy Voisey³

Abstract
Recent analyses of the UK National Space Strategy [1], Space Sector Skills Survey [2] and The 2020 Space Census [3], have investigated and highlighted many of the established strengths and weaknesses of the current UK Space Sector and the role of training and educational programs supporting it. Furthermore, there is additional research into what self-reported roadblocks early career students and workers (and employers) consider important in this journey [4]. Academia, employers, schools, colleges, and museums all have considerable roles to play in shaping the future science capital of our populace and establishing people on the tech workforce pipeline. Rising to meet this challenge, The University of Nottingham wants to develop the UK’s space workforce and is proud to have begun its first dedicated aerospace undergraduate course in 2016. In addition to the core lecture modules, added project experience is available in the form of group and individual supervised projects. These practical activities are a rare opportunity to learn unique space skills and work hands-on with spacecraft technology, something in short supply in the UK at the undergraduate level [2]. The practical, hands-on components are an important part of the space education programme and involve different platforms and projects going from simple electronics workshops to CanSats, FlatSats and experimental Rockets.

These activities culminate in the CubeSat Program: a student-led group of projects to develop, build and fly CubeSat missions with a variety of payloads. The students have the possibility to present their own mission idea or join existing ones of interest to the research community. To support these high-fidelity opportunities for students and early career workers, a permanent on-site COTS Ground Station will serve as a control center for all these student-built satellite missions. To help with the establishment of this facility, The University of Nottingham has been cooperating with the local amateur radio community to train and license the student team.

This paper deals with the description of the different projects and presents the University’s point of view about the strengths and weaknesses of our Space educational programme.

Keywords
Space Education, CubeSats, Hands-On Activities.

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Design and methodology for a Remote Sensing course

Josep Sitjar Suñer

Abstract

Remote sensing offers Geographic Information Systems specialists the possibility of integrating useful and powerful information into their analyses. As at least a basic knowledge of remote sensing principles and methodologies are desirable for anyone working in the geospatial industry, we include this competence as a mandatory subject in the curricula of our online master's degree in GIS analysis.

The topics of this remote sensing course have been selected based on our experience in the sector, but also with the support of tools like the body of knowledge developed by the GI2NK and EO4GEO projects. These applications can be very useful for anyone starting with the creation of new courses, as they take into consideration the recommendations of experts related to different sectors: from university to private companies, and also from the public sector.

The course is fundamentally based on practical work, but since it is introductory and most of the students are not familiar with the principles of remote sensing, it is essential for them to start understanding basic concepts such as electromagnetic radiation, electromagnetic spectrum, spectral signature, bands, etc. After that, they are prepared to start searching the best images for a specific project, perform image enhancements and corrections, compute indices and apply supervised and unsupervised classifications.

During the course, students are encouraged to use open-source software to develop the mandatory activities and the optional ones. Most of the tutorials are based on QuantumGIS and some of its main extensions to work with raster data and remote sensing images, but there are also tutorials based on GRASS Gis and SNAP. Nevertheless, students have total freedom to choose any available software (open-source or not) to perform the mandatory activities, and the tutor is open to resolving doubts about them.

Finally, the module is designed to practice with Copernicus and Landsat images. The use of these free catalogues offers the possibility to analyse phenomena from all over the world without cost, and it empowers students to carry out their own projects more economically. Also, the historical series of Landsat Images is very useful to evaluate changes over long periods of time.

Keywords
Remote sensing, GIS, e-learning, open-source, open data

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Trade-Off between Concurrent Engineering Software Tools for utilisation in Space Education and beyond

Christian Bach¹, Christian Drobny², Martin Tajmar³

Abstract
Concurrent engineering is an approach to the development of complex systems that is characterised by direct communication between the disciplines involved. Instead of processing the individual disciplines one after the other, as in sequential design, or processing via a single contact person, as in centralised design, all systems work simultaneously. Learning this interaction and understanding what information needs to be communicated between disciplines are among the central learning objectives of the course "Spacecraft Design" at Technische Universität Dresden, Institute of Aerospace Engineering. In this course, the students represent different disciplines and work out a mission study that is commissioned by the lecturers. The lecturers thus participate in the development process in the role of customers.

Key to the concurrent engineering approach is that each discipline has access to the most current design data at all times. This can be done via a dedicated software solution. Both commercial and open source software tools are available. Within the frame of the above-mentioned course, several tools have been tested. The covered software solutions comprise ESA Open Concurrent Design Tool (OCDT), RHEA Concurrent Design Platform (CDP), Valispace and IBM Rhapsody.

This contribution presents the experience that we gathered with these concurrent engineering software tools. First, the tools are described and their commonalities and distinctions are highlighted. Subsequently, a detailed trade-off between the tools is being presented. This trade-off will particularly focus on the utilisation of these tools within the scope of course work at universities, as this entails special requirements and boundary conditions, such as very limited time for introducing the software, highly heterogeneous user group, limited utilisation of the software in terms of depth and functionality, to only name a few. Within this contribution, we will also explore alternative approaches, such as using no software at all.

The aim of this contribution is to offer other teachers and students some guideline for selecting a concurrent engineering software solution and implementing it in course work, in a way that using the tool itself does not become the central learning challenge of the course. The results might be of interest beyond university courses, as some requirements, like short times to get familiar with the software or certain interface requirements, also apply to other environments in research and development.

Keywords
Concurrent engineering, concurrent design, software tools, education

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3 Technische Universität Dresden, Germany, Martin.Tajmar@tu-dresden.de
Panel: Space Education at University II

Vèrtex Auditorium, 11:30 am – 12:30 pm
ASCenSlon Innovative Training Network: mid-term overview and lessons learned

Alessia Gloder¹, Martin Tajmar², Christian Bach²

Abstract
The field of access to space is complex and wide, and it involves several disciplines and areas of expertise such as propulsion physics, software development, experimental studies, numerical simulations, thermodynamics, missionisation, etc. A gap in the training of young European researchers has been identified in the field, as no high-level education programme exists with the ability to range across such a large range of research topics. With the aim to fill this gap, 24 European entities from academia, industry and research centers have partnered in the framework of "ASCenSlon", an Innovative Training Network funded by the European Commission within the Horizon 2020 Marie Sklodowska Curie Actions. The research objective of the project is to advance the State Of The Art by contributing to the establishment of a both ecologically and economically sustainable space access for Europe. This will be achieved by training 15 Early Stage Researchers of different background, gender, age and provenance, to become experts in their fields and to have a deep understanding of the access to space domain, which is tackled with an interdisciplinary and international approach. Within ASCenSlon, the Early Stage Researchers, who are enrolled in a PhD programme, will acquire both technical and transferable skills thanks to an inclusive and diverse training programme held at local and project level. Unlike more ordinary PhDs, the training offered by ASCenSlon does not only focus on narrow scopes of research fields, one domain (e.g. industry or academia) and one country. It features instead an interdisciplinary, intersectoral and multicultural approach. The offer includes training events in different forms, such as workshops, lectures, experimental weeks and summer schools, which are complemented by the participation in conferences and similar events. Each researcher is trained by expert supervisors and advisors on technical topics that not only cover their specific research topic, but the entire spectrum of space access. Moreover, the PhD students experience at least two period of secondments in academia and industry in different European countries, with the scope of acquiring both a solid theoretical foundation and practical experiences in real-world engineering problems. Given that the project started in January 2020 and will end in December 2023, this paper provides a midterm overview of the project, including lessons learned based on the remote vs in-person training experience forced by the Covid-19 pandemic outbreak.

Keywords
Access to Space, Innovative Training Network, Interdisciplinarity, PhD, Training

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UPC NanoSat-Lab - Past, Present and Future Activities

A. Camps

Abstract
The Universitat Politècnica de Catalunya UPC NanoSat Lab is part of the CommSensLab-UPC Specific Research Center of the Department of Signal Theory and Communications, and counts with the support of the School of Telecommunications Engineering (Telecom Barcelona, ETSETB). It is located in the UPC Campus Nord. The lab was originally created in 2007 to promote the testing of novel remote sensors and techniques in space, taking advantage of CubeSats. Over time, the lab has also started the study of Earth-to-space IoT and RF intersatellite link communications, as key enabling technologies for the next revolution of Earth Observation.

At the time of writing this abstract, the UPC NanoSat Lab has developed and launched four CubeSats, and is working in three new missions that will be launched in Q4 2022 - Q1 2023. At present, the Lab is developing an "Open PocketQube Kit" for IEEE as a low-cost educational platform on space-related technologies.

The lab has also a Class 8 clean room equipped with a shaker and thermal vacuum chamber, and Helmholtz coils, air bearing system, and Sun simulator for attitude determination and control system testing to conduct the environmental tests.

Finally, in the MontSec Astronomical Observatory (OAdM), which is managed and operated by IEEC, hosts the UPCNanoSat Lab VHF/UHF and S-band ground station [3], where the data from the 3Cat-5/A satellite where downloaded.

Since its inception in 2007, about 300 students have been trained in the lab, either as undergraduate students in the "Advanced Engineering Project" of the ETSETB, as Final Degree or Master Thesis projects, as graduate students, or just for an internship.

This paper presents a quick overview of the past, present and future activities of the UPC NanoSat Lab.

Keywords
CubeSats, Laboratory, Testing facilities, Ground Station, Education, Research

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Teaching computational thinking to space science students

Robert Jeffrey¹, Megan Lundy², Deirdre Coffey², Sheila McBreen², Antonio Martin-Carrillo², Lorraine Hanlon²

Abstract

Computational thinking is a key skill for space science graduates, who must apply advanced problem-solving skills to model complex systems, analyse big data sets, and develop control software for mission-critical space systems. We describe our work using Design Thinking to understand the challenges that students face in learning these skills. In the MSc Space Science & Technology at University College Dublin, we have used insights from this process to develop new teaching strategies, including improved assessment rubrics, supported by workshops promoting collaborative programming techniques. We argue that postgraduate-level space science courses play a valuable role in developing more advanced computational skills in early-career space scientists.

Keywords

Space Education; Postgraduate Education; Computational Thinking

Acronyms/Abbreviations

UCD University College, Dublin
SS&T Space Science & Technology

1. Introduction

Computational thinking has been identified as a key skill for 21st century graduates. It refers to the ways we think when we design computer programs to solve problems [1] [2]. This should be distinguished from “coding” or “computing” [3], which means implementing a solution in a specific programming language.

While computational thinking is an increasingly influential idea in education [3] [4], it has always played a key role in solving problems in space science. Modern space scientists will use it for Earth observation, data analysis, and flight system control, with space software a major area of growth in the space industry [10]. However, little has been written on how space science education helps early-career space scientists to develop these skills.

1.1. Computation & the MSc Space Science & Technology at UCD

The MSc in Space Science & Technology (SS&T) at University College Dublin (UCD) is a taught program designed to prepare science and engineering graduates for careers in the global space sector.

A typical cohort consists of 12–16 students, most of whom are recent graduates from Irish universities. Typically, 20–30% of the class are female. Approximately one third of the class are international students and about 10% join after a period working in industry. Most students have degrees in physics or astrophysics (about 60%) or engineering (about 30%, usually aerospace or electrical engineering).

The 12-month course consists of a total of 90 ECTS credits. It includes classroom-based modules covering the space environment, applications of space science, and professional development, as well as optional modules on Earth-observation, climate physics, advanced astronomy and astrophysics, and data science. Three 10-credit laboratory or project-based modules cover space detectors, CubeSats, applied systems engineering and space mission design. A final 30-credit 12-week internship with a space agency, company, or research group leads to a minor thesis and presentation.

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The advanced Master of Space Studies at KU Leuven and Ghent University: a programmatic analysis

Hugues Sana¹, Clio Gielen²

Abstract

Organized by KU Leuven and Ghent University, two leading Belgian universities, the Master of Space Studies is an interdisciplinary post-master program that aims to equip the students with the skills they need to initiate a career in the space sector. Beyond the deepening of their initial expertise, the program exposes the participating students to a broad range of topics, from human science (space laws, international organizations, project management, ...), to technical science (space missions, spacecraft and payload engineering, satellite telecommunications, ...), to exact sciences (Earth and Space observations, medical sciences, human explorations, ...) with the aim to provide the students with a broad overview of the interdisciplinary expertise required by many space projects. Initiated in the late 2000s, the program has served as a gateway into the space sector for over 100 students since its creation.

After a brief introduction to the program, we present a programmatic analysis, based on quantitative and qualitative surveys of students and alumni. We present the demographic, career tracks and current professional situations of students in the last 10 years, allowing us to identify trends that affects tertiary education to space sector. We conclude by briefly highlighting other ongoing space education activities, from the Belgian antenna of ESER O to the involvement of students in CubeSpec, a 6U CubeSat platform selected as ESA in-flight demonstrator to enable low-cost versatile spectroscopy of astronomical targets.

Keywords
Tertiary interdisciplinary post-master education

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Space Education: Challenges and Strategies in Teaching Space Policy to Technical University Students

Dr. Sara Langston

Abstract
Law and policy provide the foundation for space actors engaging in space activities. Likewise, various levels of policy and regulation apply internationally, domestically, and even institutionally to both governmental and nongovernmental entities. Consequently, teaching the frameworks for existing and developing space policies, rules and best practices is essential for a comprehensive university curriculum in space education. Challenges arise, however, when instructing technical and non-policy university students in humanities-centered topics. Reading comprehension, writing ability, critical thinking, and communication skills are critical elements of policy education, yet many technically oriented students struggle with these requirements. Given these are fundamental skillsets necessary for success in both academia and a dynamic space workforce, adapting traditional teaching methodologies may be required to optimize desired learning outcomes for technical student audiences. Customizable strategies exist that can combine and scale these fundamental skillsets with substantive content and materials, providing a range of teaching and learning modalities for study, assessment, and experience. This presentation will highlight potential learning approaches tried at one aeronautical university to address these challenges.

For instance, overarching strategies may include commencing with a visual of the student journey (much like a user journey in an investment pitch) delineating the value-added experience for students engaging in course content, and building substantive skill-based learning components which are introduced sequentially and with increasing level of difficulty. Examples of learning methodologies include applying Bloom’s Taxonomy in assignment creation. Most importantly: 1) Knowledge: involves identifying, understanding and remembering core content (e.g. pop quizzes, reading quizzes, cumulative review quizzes, question bank assessments); 2) Analysis: involves reading comprehension, interpretation, evaluation, analysis (e.g. essays, summaries, case studies); 3) Application: involves investigation, research and designing research projects (e.g. research articles, posters, digital presentations, short videos). Scaffolding assignments and artifacts into manageable pieces throughout the semester is key to guiding students towards success and reducing potential for ‘expert blind spots.’ Lastly, an end-of-course review and self-reflection of the student journey is helpful in underlining the critical thinking process and provide a visual review of the student journey in acquiring substantive knowledge, skills, and experience throughout the term.

Keywords
Space Policy, Space Education, Critical Thinking, Taxonomies of Learning

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Panel: Space Education Initiatives I

Vèrtex Auditorium, 12:30 pm – 1:30 pm
Asociación Aeroespacial Cosmos: educational impact and returns of a three-year-old student aerospace association

Alondra Solá Molina¹, Pablo Solano-López², Sergio Cuevas del Valle³, Ester Velázquez Navarro³, Patrick Townsend³, Paula Alberca Díez³, Hodei Urrutxua Cereijo²

Abstract
Cosmos Aerospace Association is a leading engineering students’ group, located in the Universidad Rey Juan Carlos (URJC) in Madrid, Spain. Providing a one-of-a-kind opportunity to all varieties of students for both personal and engineering growth, it is one of the few active aerospace student associations in Spain. Within this work, we introduce the achievements, influence and lessons learned from our association in these years. We focus on its educational impact in the environment of the university: not only from the perspective of aerospace-related degrees but also in the promotion of STEM careers on students of all ages.

Conceived by undergraduate aerospace students and supported by professors and university staff, Cosmos was born to provide a creative and learning environment in the promotion of our passion for space and science in general. Bringing together students with similar mindsets, it has become a symbiotic platform in which all university actors share their efforts and join forces to enhance the university experience both from a curricular and extracurricular perspective.

The association is divided into three main areas: Administration and Legal, Construction, and Education. Each of these areas branch with Projects and smaller teams both transversal and vertically. Under the Construction branch, both aeromodelling, satellite and rocketry projects are found and developed. An autonomous VTOL vehicle and a solid combustion rocket are being designed with internal and external funding. Special mention goes to the design and construction of CosmoSat-1, our very first CubeSat mission, which is now starting to take off. The Education area involves the organization of cultural and educational activities, from coding seminars, hackathons to film forums or Women in STEM days, all of them transversal to the aerospace industry. In this regard, our most ambitious project to date has been SpaceCon URJC: a space-themed conference by and for university students, bringing together professionals from aerospace companies, space agencies, and research groups in a month-long virtual conference. Over a series of presentations and interviews, students can get a glimpse of a variety of possible careers in everything from satellite manufacturing, orbital mechanics, space debris, and everything in between. With an initial run in 2020, SpaceCon has been repeated in 2021 with great success.

In short, COSMOS, while promoting a passionate interest for Space, has become a common meeting point for students and professors outside the fixed and fitted courses, where creativity can boom and grow.

Keywords
Aeromodelling, Rocketry, Sci-Comm, Spacecraft-ing, SpaceCon, Student association

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Simulating Atmospheric Turbulence: Code Development and Educational Applications

Ferran Salazar¹, Antonio Marzoa¹,², Marc Crusellas², Oriol Casamor¹,², Jordi Mazón¹, Justo Arines³

Abstract
Earth atmosphere turbulence affects many areas of interest related with Space studies, such as optical communications or Astronomy. In fact, it is a key topic for such applications and, thus, it is important for students in aerospace and aeronavigation studies to get some knowledge of the basis of such phenomena, and how to compensate for it. The phenomenon of turbulence is tangent to many areas such as Optics, Meteorology, Fluid Dynamics, Astronomy, Space Science and Telecommunications, among others. To properly understand the effect of such phenomena on the propagation of an optical signal is imprescindible to properly evaluate and implement the corrections introduced with Adaptive Optics [1] and for understanding the limitations of optical free-space communications channels. The simulation of optical propagation through turbulence constitutes an intuitive and powerful tool for visualizing and understanding such phenomena. Within those ideas, a Final Degree Project, based on the development of simulation tools of atmospheric turbulence is carried out in the Escola d’Enginyeria de Telecomunicacions i Aeroespacial de Castelldefels (EETAC) of the Universitat Politècnica de Catalunya (UPC). In this communication the development of an application, written in MATLAB®, for the simulation of optical propagation through turbulent mediums is presented.

The project consists of the development of a software based on scalar diffraction theory [2] and Kolmogorov’s turbulence theory for the generation of turbulent phases under specific meteorological conditions and the simulation of the propagation of an electromagnetic signal through them. With this tool, different applications are going to be analysed.

As an example of application, at the moment this communication is presented, the code is capable of performing the reconstruction of the generated phase in terms of Zernike coefficients [3], providing key information for the understanding of the aberrations introduced by the turbulence and also for correcting them with a proper design. The communication first describes the main basis of the problem, in terms of scalar diffraction theory, and the structure of the application. Later, some results are presented and discussed. Finally, the application of the tool for adaptive optics, optical free-space communications and as an educational application for aeronavigation and aerospace students is discussed, with emphasis in the context of the different degrees, courses and subjects taught in the EETAC.

Keywords
Turbulence, Propagation, Application

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Challenge of teaching complex, end-to-end space system design and development process: Earth Observation Satellite System Design training course

C.C. Lin\textsuperscript{1}, D. Southwood\textsuperscript{1}, R. Meynart\textsuperscript{1}, R. Aguirre\textsuperscript{1}, M. Tossaint\textsuperscript{2}, C. Buck\textsuperscript{1}, M. Endemann\textsuperscript{1}, A. Tobias\textsuperscript{1}, M. Gollor\textsuperscript{2}, P. Norris\textsuperscript{1}, G. Spinella\textsuperscript{2}, M. Borgeaud\textsuperscript{2}, P. Lecomte\textsuperscript{1}, M. Aguzzi\textsuperscript{2}, C. Boever\textsuperscript{2}, V. Gupta\textsuperscript{5}, N. Callens\textsuperscript{2}

Abstract
The Earth Observation Satellite System Design training course was first offered in 2018 at ESA Academy’s Training and Learning Facility at ESA’s ESEC Galaxia site in Belgium, and again in 2021 in an online format under the Covid-19 pandemic situation. The course covers the end-to-end design and development process of satellite Earth observation systems.

Two major challenges were faced by the teaching experts, consisting of the active and retired ESA staff, as well as ESA Academy’s instructional designers for its development:

(1) Condensing such a vast subject domain, associated with a complex, multi-disciplinary engineering undertaking, into a compact format (e.g. 4.5 days in 2018) without sacrificing the quality of the essential technical knowledge, engineering practices and logic as taught;

(2) Presenting the course materials in a comprehensive form to a group of 30 M.S. and Ph.D. students with their backgrounds generally not covering all of the technical disciplines associated with the course subject domain.

The 2021 online edition of the training course, which drew on lessons learnt from 2018, consisted of 18 lectures, plus 5 group project sessions where the students put their acquired knowledge into practice and learned to work in a project team environment.

This paper concentrates on the approach and logic adopted by the instructional team to address the above 2 challenges. Difficulties encountered in some of the areas, e.g. remote sensing instrumentation designs, are discussed.

Keywords
Earth observation, end-to-end system engineering, ESA Academy, instructional design, satellite system design

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gLAB hands-on education on satellite navigation

Adrià Rovira-García¹, ², Deimos Ibáñez-Segura¹, Mowen Li¹, María Teresa Alonso¹, Jaume Sanz¹, José Miguel Juan¹, Guillermo González-Casado¹

Abstract

The Global Navigation Satellite System (GNSS) allows computing the Position, Velocity and Time (PVT) of users equipped with appropriate hardware (i.e. an antenna and a receiver) and software. The latter estimates the PVT from the ranging measurements and ephemeris transmitted by the GNSS satellites in frequencies of the L band.

The research group of Astronomy and Geomatics (gAGE) at the Universitat Politècnica de Catalunya (UPC) has been developing the GNSS LABoratory (gLAB) tool suite since 2009, in the context of the European Space Agency (ESA) educational program on satellite navigation (EDUNAV). gLAB is a multi-purpose software capable of determining the PVT in several modes: stand-alone (e.g. as a smartphone or car navigator), differential (e.g. surveying equipment or precise farming), and augmented with integrity (e.g. civil aviation or safety of life applications).

gLAB has been designed for two main sets of users and functions. The first one is to educate University students and professionals in the art and science of GNSS data processing. This includes newcomers to the GNSS field that highly appreciate the Graphical User Interface (GUI), the default templates with the necessary configuration or the messages with warnings and errors. The second group of users are those with previous experience on GNSS. Those are interested in a high computation speed, high-accuracy positioning, batch processing and access to the intermediate computation steps.

In the present contribution, we present some examples in which gLAB serves as an education platform. The data sets are actual GNSS measurements collected by the publicly available International GNSS Service (IGS), together with other IGS products such as the satellite orbits and clocks broadcast in the navigation message. The proposed methodology and procedures are tailored to understand the effects of different error components in both the Signal in Space (SIS) and the position domain, by activating or deactivating different modeling terms in gLAB. The results illustrate some examples of how the PVT can be enhanced or deteriorated when using different processing strategies or propagation effects present in the GNSS signals traversing the atmosphere, among others.

We conclude that gLAB is a useful tool to learn GNSS data processing or to expand any prior knowledge.

Keywords

Global Navigation Satellite System (GNSS), open-source, International GNSS Service (IGS)

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Abstract

SAR² is a prototype educational simulation software for the Microsoft Hololens, developed by students as part of a geoinformatics course. The aim of this software is to provide a tool to introduce and explain the concept of synthetic aperture radar (SAR) to students, as well as the general public, by visualizing and interactively exploring the process of a SAR acquisition in a 3D virtual environment.

A distinctive feature of SAR² is that the SAR acquisition procedure is simulated in real time within a Unity Engine environment, using a set of algorithms which replicate the real-life SAR processing algorithms. While this provides a challenge due to the limited computational power available on the Microsoft HoloLens 1 device, it allows maximal freedom to the user in setting whatever configuration they would like to see. This would not have been possible if an approach using a pre-selected set of scenarios was chosen.

The augmented-reality (AR) app works in 3 phases:

- In the first step, the user is shown a terrain model, and a satellite model inspired by the TerraSAR-X. The user can adjust selected parameters of the acquisition by manipulating the satellite and model using intuitive AR controls (e.g. by physically grabbing and rotating the objects with their hands).
- After configuring the parameters, the user launches the acquisition and observes it in real time. The satellite model flies over the terrain, and the “flow” of the data into the storage is immediately visualized.
- After the acquisition is finished, the user can explore the focusing procedures that need to be applied to the data - namely the range and azimuth compression. Different geometrical effects (shadowing, layover) can also be explored at this stage.

The SAR² app used in concert with conventional educational approaches can reinforce the learned material, clarify misconceptions, and provide intuition for the complicated concepts of synthetic aperture radar.

Keywords

augmented reality, public outreach, synthetic aperture radar, visualization

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Moon Rover Challenge. An educational space robotics resource to teach programming and promote space careers at secondary education levels

Elena Álvarez Castro\(^1\)\(^2\), Miguel Ángel Rubio Escudero\(^3\), Domingo Escutia Muñoz\(^2\)

Abstract

Nowadays, space educational activities are essential in schools, in order to show the importance of space research and exploration in our daily and future life. Space related activities provides teachers tools and a fascinating context to get students involved in different disciplines which are ‘difficult’ for them. In addition, programming is one of the most important skills in technological areas. Space technology is full of programming, algorithms, and code. However, students’ perception is different because they think coding is difficult and they will not be able to program a satellite or a rover, so they are not very interested and motivated to learn to program.

A widely useful tool to motivate students to learn programming is educational robotics, which uses physical robots and block-based programming interfaces to attract their attention. However, these robots are not accessible for all schools, and it is difficult to use robots in the online environment created by COVID-19. Therefore, online tools are becoming more and more important in education, because they make activities more flexible and accessible for schools and students.

In this paper, we show an educational resource that used space robotics as a context achieving two main objectives: to promote space careers and teach and motivate high school students to learn how to program. We also show our conclusions and lessons learned, after implementing this project in two different situations. The students’ challenge is to control a Moon rover, which is on the Moon surface in order to fulfil a space mission. The activities can be performed completely online using an online simulation tool and block-based programming language.

We tested the educational material in an online event with many high school pupils and also in a face-to-face lesson with pupils studying a technical module. The experiences and feedbacks were positive and allowed us to improve the initial activities. Moreover, the results show students are more interested in space careers after completing the challenge. Space robotics give us a perfect opportunity to introduce subjects such as programming, robotics, and technology to students. These areas will be essential in the future and we have to change perception of the space industry because it is fundamental for the development of space exploration and our society.

Keywords

Block-based programming, Educational resources, Outreach activities, Robotics, Space context.

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Panel: Smallsats in Education I

Secondary Auditorium, 9:30 am – 11:00 am
FlatSat Workshops Teaching Fundamental Electronics Skills for CubeSat Building

Luis Cormier¹, Daniel Robson², Henry Cope¹

Abstract
The University of Nottingham (UoN) recently established its own CubeSat programme, with the team commencing design, construction and testing of the first CubeSats in late 2020. However, one major challenge encountered was a common lack of practical applied electronics skills amongst students. This was repeatedly noted by students as a major obstacle to project success in progress reviews for WormSail, our first CubeSat project. Notably, these sorts of skills are also an area of common concern for young workers and employers in the UK Space Sector. This skill gap existed despite the student team coming from a variety of STEM (Science, Technology, Engineering and Math) undergraduate backgrounds, including physics, computer science, and aerospace and mechanical engineering. With insufficient time to recruit students with electronic engineering backgrounds, it proved difficult to find "all-rounders" to join the team with the broad range of skills required for the project.

One advantage that several students had however was their experience from informal hobbies involving Arduino and Raspberry Pi (RPI) based microcontroller electronics. These were found to endow highly transferrable skills, with these members providing significant contributions to the team through their skills and teaching. Team members found these so useful, that the “FlatSat” programme was set up to provide electronics teaching resources for new members of the CubeSat team. Sessions within the programme could be planned and delivered by the experienced team members, and hence be targeted to include applicable, referrable, and important skills and knowledge for building CubeSats.

Through developing these resources, the team realised it may be beneficial to include this programme in taught modules offered in the Faculty of Engineering, to enhance practical skills for all students enrolled in these modules.

This paper is intended to overview the work carried out in developing the FlatSat teaching workshop, and highlight the resources and their benefits to groups including other higher education space module conveners, developing CubeSat teams, School and further education teachers, STEM Outreach Coordinators, and general hobbyists. It is hoped that boosting confidence with such in-demand skills will be of great benefit to learners. We will also review case studies of the first large-scale workshop sessions and outline plans for future developments, particularly taking into consideration the feedback of demonstrators, students, and observers to the workshop.

Keywords
FlatSat, CubeSat, Electronics, Education, Outreach

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Abstract

While many secondary schools offer courses or extracurricular activities that focus on satellite engineering, e.g. CanSats or the assembly of ground stations, these projects usually stay close to ground. With SpaceTeamSat1, the TU Wien Space Team wants to enhance this approach and tackle the challenge to perform various experiments in space, enabling students to participate in a space mission that actually orbits our planet. Therefore, our goal is to develop a 1U CubeSat platform, which allows students at secondary schools to access a set of different sensors connected to a Raspberry Pi. Consequently, students can write their own software experiments in Python and exploit the possibilities of sensors in space.

In this context, participation happens at different stages: For one, students are getting in contact with Python, which also allows an easy step into software engineering paradigms. Moreover, our team will pose some challenges, such as re-doing an earlier satellite mission and giving impressions about how CubeSats can be used, e.g. to combat climate change. To complete these challenges, the CubeSat is equipped with various sensors such as temperature sensors, gyrometers, magnetometers, as well as two cameras. Moreover, the participating students also have the possibility to design their own experiments independently to leave room for creativity.

Further enhancing this educational mission, participating students are also invited to work on hardware topics. This is mainly aimed at engineering schools, which are encouraged to assemble Raspberry Pi HATs which contain the actual mission sensors, as well as a SatNOGS ground station, which also enables students to get an insight on satellite communication. It needs to be considered that the educational mission follows a modular setup since the combination of all individual tasks is not realizable within a single school year. Thus, schools are also able to individually select appropriate tasks.

In the past we were already collaborating with the European Space Education Resource Office as we are acting as launch provider of CanSats for ESERO’s Austrian CanSat competition. In this sense, STS1 shall be an extension to the space educational program in Austria. Based on that, we believe that the STS1 mission has a high potential to bring something that is currently out of reach for most people, outer space, closer to a demographic with a lot of talent and enthusiasm for engineering and potential future engineers.

Keywords

CubeSat, Python, Raspberry Pi, SatNOGS, software engineering

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Abstract

The 3Cat-4 mission is a 1-unit CubeSat platform that serves as a technology demonstrator and educational platform for students at Universitat Politècnica de Catalunya (UPC). Promoted by the UPC Nanosatellite and Payload Laboratory (UPC NanoSatLab), the most notable subsystems that innovate in the nanosatellite scenario are (1) the Flexible Microwave Payload - 1 (FMPL-1) [1], a cost-effective payload to execute Global Navigation Satellite System Reflectometry (GNSS-R), and L-band microwave radiometry experiments using a commercial off-the-shelf (COTS) software-defined radio (SDR) and (2) the Nadir Antenna Deployment Subsystem (NADS) [2], an in-orbit deployable high-directivity antenna used by Earth Observation (EO) payloads. This paper presents the findings of the 3Cat-4 mission during Phase D, the qualification and production phase of the project. Since the publication of the first introductory work for this mission in 2019[3], several sections of the subsystems have been redesigned and upgraded to correct previous design flaws or to meet new requirements. In addition, this paper addresses the educational perspective of this mission, analyzing its performance and usefulness in the aforementioned subject.

Keywords

CubeSat, Earth Observation, Phase D, COTS, SDR, Education

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A selection of lessons learned from phase C/D of CubeSat projects of the Fly Your Satellite! programme

Alexander Kinnaird¹, Cristina del Castillo², Hasse Hansen³, David Palma⁴, Gilberto Grassi⁵

Abstract
Fly Your Satellite! (FYS) is a recurring programme part of ESA Academy’s portfolio of “hands-on” activities. The programme was established to support University student teams in the development of their own CubeSat missions and aims at transferring knowledge and experience from ESA specialists to students. Selected teams are guided through project reviews and supervised through design consolidation and verification activities, conducted according to ESA professional practice and standards, tailored to fit the scope of university CubeSat projects.

As part of the educational goal of the programme, a systematic effort of capturing, discussing and contextualising difficulties, mistakes, and anomalies in general, is carried out. From this effort, the participating students benefit from a unique framework where lessons learned from one project can be transferred to other ones. This exercise is blended with the “regular” transfer of knowledge from the ESA professionals that support the programme and occurs both concurrently (lessons learned from current cycles) and from previous projects (lessons learned from previous cycles).

This paper reports a revised and updated collection of lessons learned during phase C/D of the FYS CubeSat projects, in particular the projects now participating in the 2nd cycle (FYS2). At the same time potential changes and mitigating approaches are discussed.

Particular focus is given to lessons learned from issues which arose in hardware development activities, as well as from planning and execution of system-level assembly, integration, and verification (AIV) activities.

This approach is taken since first-time developers tend to underestimate the number of issues arising when their design is translated from documentation and models into real hardware. In general, it has been observed that many of these issues typically arise from lack of (space) project management experience of the student teams, or from the lack of resources which prevent the application of standard/established methodologies to small satellite/educational projects.

Keywords
Assembly, Integration, Testing, Verification, CubeSats, Education, Phase D, Phase C,
Development and Flight Results of TalTech University CubeSat Mission

Muhammad Shadab Khan\textsuperscript{1}, Rauno Gordon\textsuperscript{2}, Martin Simon\textsuperscript{3}, Kristjan Tonismae\textsuperscript{4}, Dzmitry Kananovich\textsuperscript{5}, Veljo Sinivee\textsuperscript{6}, Marko Karm\textsuperscript{7}, Kaarel Repän\textsuperscript{8}

Abstract

Student Satellite program at TalTech, Tallinn University of Technology, Tallinn, Estonia was initiated in 2014 with an aim to impart space technology knowledge to the Estonian students as well as assist towards development of new Space Technologies in Estonia. Two 1-Unit CubeSat named Koit and Hämarik that translates respectively as Dawn and Twilight in Estonian are part of the TalTech Satellite Program. The main scientific mission of the CubeSats was to demonstrate Earth observation and Optical Communication technology. Satellites had two types of cameras, an RGB Camera and an NIR Camera to carry out Earth Observation over Estonia. Testing High Speed Optical communication technology from LEO (Low Earth Orbit) was the second major scientific goal and for this purpose the CubeSats had LED (Light Emitting Diode). Koit CubeSat was successfully launched to space on-board Soyuz rocket on July 5, 2019 and Hämarik CubeSat was launched to Space on September 3, 2020 on-board ArianeSpace Vega Rocket. Koit CubeSat did not contact the Ground station for more than a year since its launch and it was assumed to be lost but on November 21, 2020 it made the first contact with the Ground Station. Hämarik CubeSat was first contacted on November 15, 2020. The team has been successful in updating software of Hämarik and further work is being done on the software with broader functions. Optical communication has not been tested yet because ground station for optical communication has not been developed yet but a good achievement in the path to optical communication was to see the satellites with small hobby telescope and one of the satellite team member was successful to detect the Hämarik CubeSat on 17 August 2021 which was at a distance of about 792 Kilometres. Satellite team is in contact with the Hämarik and has been successful to download a few thumbnails and is working to establish a quick data connection with it and determine its exact position so that the cameras can be focused towards the Earth in order to get the whole images captured by the CubeSat.

Keywords

CubeSat, TalTech, Estonia

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Space Communication System for Education

Anton Atanasov\(^1\), Viktor Danchev\(^2\)

Abstract

This article describes EnduroSat’s Space Educational modules which are used to physically simulate radio wave communication in space applications for small satellite missions. The educational modules generate physical ultra high frequency radio waves and recreate the conditions of the environment. They can also simulate the effects of S-band and X-band frequencies by changing the losses accordingly while the physical simulation remains at ultra high frequencies. They are intended for practical hands-on exercises of students in the space communications sector. The modules utilize the same equipment currently used in space and are used to experimentally analyze the link budget, noises and error rate of signal. Simulating a given configuration of a satellite and ground station’s parameters with them exposes the system’s vulnerabilities and its reliability when transmitting signals. The system consists of two identical transceiver modules that can emit and receive information in the form of radio waves, and a free space propagation simulator module. Each of the modules connects via Universal Serial Bus to a host computer with the simulation software. In this paper we present the modules and some of their uses for education.

Keywords

Budget, Communication, Link, Satellite, Simulation

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Update on the status of the Educational Irish Research Satellite (EIRSAT-1)

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Abstract
The Educational Irish Research Satellite, EIRSAT-1, is a 2U CubeSat being implemented by a student-led team at University College Dublin, as part of the 2nd round of the European Space Agency’s Fly Your Satellite! programme. In development since 2017, the mission has several scientific, technological and outreach goals. It will fly an in-house developed deployment module, along with three custom payloads, which are integrated with commercial off-the-shelf subsystems.

In preparation for the flight model, a full-system engineering qualification model of the spacecraft has undergone an extensive period of test campaigns, including full functional tests, a mission test, and environmental testing at the European Space Agency’s CubeSat Support Facility in Redu, Belgium.

Beyond the technical, educational, and capacity-building goals of the mission, EIRSAT-1 aims to inspire wider study of STEM subjects, while highlighting the importance of multidisciplinary teams and creating greater awareness of space in everyday life. A wide range of outreach activities are being undertaken to realise these aims.

This paper provides a status update on key aspects of the EIRSAT-1 project and the next steps towards launch.

Keywords
EIRSAT-1, CubeSat, Fly Your Satellite!

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DESIGN CHALLENGES, AND OUTCOMES OF BUILDING A SATELLITE
THE SIZE OF A SODA CAN

Rovin Perez¹, Slaveya Abadzhieva²

Abstract
A Mach contest is part of an annual event, organized by UKLSL, which combines both CanSat and rocket competitions. The first Mach event in 2021 was focused on the design of “Simple and Advance CanSats”, and culminated on a 3-day activity at Machrihanish Airbase in Scotland. It involved setup, pre-flight checks, and system adjustments. This paper focuses on the design challenges, and outcomes from building a satellite the size of a soda can by reviewing the event, the mission designed for the competition, and students’ feedback on what could have been improved to prepare the next team competing in Mach-22 which would involve developing a Rocket design and launching an “Advance CanSat”.

The competition allowed undergraduate students at The University of Nottingham to experience a practical learning style by solving real engineering problems and practicing professional development skills through design review presentations and providing a flight readiness review to the launch providers of the competition. The proposed mission statement was part of the “PEAK” category, which involved atmospheric studies, where it acts as a simulation model for measuring the atmosphere on different planets and as a deployable probe from rovers to measure varying atmospheric levels. The competition exposed students to perform AITV (Assembly, Integration, Testing, Verification) processes to their CanSat and constructed procedures to test and validate the recovery system. Results from the first Mach event prove a solid starting point for future CanSat competition and space activities within our university. In the future, there are aspirations to grow a student space society and get students involved in extra-curricular STEM (Science, Technology, Engineering, Math) projects, and allow them to apply the theory and concepts learned in their academics.

Keywords
CanSat, Space Education, Mach-21, Mission design, Spacecraft systems and instruments

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Panel: New Space Opportunities

Secondary Auditorium, 11:30 am – 12:30 pm
What They Want and What They Need: The New Role of the Jurist in Assisting the Young Space Companies

Maura Zara¹, Sifat Kaur Alag²

Abstract

'New Space' economy is an all-inclusive concept that synthesises a real economic revolution in the space industry. It is characterised by the proliferation of new private actors that operate separately from institutional and governmental structures to seek their place in the market. Their primary objective is to allow low-cost access to space technologies, establishing themselves as one of the major growth engines of the space economy, fostering market competitiveness and technological development. Aware of this key role played by these new actors in the future development of the space industry, this paper adopts an empirical approach in order to obtain relevant information from those directly concerned, with the aim of identifying the crucial factors for their successful integration into the market and for their long-term permanence in the market. We have conducted 50 live interviews with founders and executives of small scale and start-up space companies from all around the world. The interviews are recorded and answers quantified to produce meaningful statistical data. Based on these results, the paper will focus on one of the fundamental problems for new actors. It will analyse these and further present possible inputs that can contribute to the development of the new space economy: The legal and bureaucratic dimensions in which new space companies are born and how they develop. In particular, the paper will explore the need to improve access to legal services from an economic point of view, with a focus on paralegal services; the difficulty shown by those directly concerned in guiding legislation on space activities and the need to rethink the training of lawyers, to make it more adherent to the peculiarities of the new space economy. In conclusion, after a reflection on the impact of the new space economy on the current market dynamics, with the analysis of the area of interest identified above, the paper will infer useful elements to set up some guidance suggestions for the implementation of the pathways of integration and development of young companies operating in the space market. This perspective, includes a reflection on the multidisciplinary dimension involving space activities and the opportunity to stimulate educational programmes with a training offers that reflects the now inevitable need for a less sectoral preparation that allows professionals in the space sector to acquire a more comprehensive view of the dynamics of the market.

Keywords

New Space; New Actors; Legal Services.

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Competition, Research and Extension: The three approaches to the Popularization of Small Satellites in the Alto Paraopeba region in Brazil.

André Teixeira¹, João Pedro Polito², Júlio Santos³, Marcos Kakitani²

Abstract
There are several approaches to the diffusion of the space technologies, three of them are in this work: competition, research, and extension. Thus, the objective of this work is to focus on presenting the results of the Brazilian nanosatellite team called NoizOrbita, and also to qualify quantitatively the impact of using these approaches in popularizing the topic of small satellites for space educational purposes. The team was founded on September 29, 2020, by three people: an alumni of Telecommunications Engineering at Federal University of São João del-Rei (UFSJ), Alto Paraopeba Campus (CAP), currently pursuing his Ph.D. in CubeSat Antennas at UFSC; a student currently in the 6th period of the Telecommunications Engineering undergraduate course (class of 2019); and a professor in the Department of Telecommunications and Mechatronics Engineering (DETEM). This initiative is intended to be a gateway to the space/satellite technologies in the institution and is based on three main pillars: Competitions, Research, and Extension in Nanosatellites. The team aims to obtain and develop small satellite technologies involving CAP undergraduate and graduate students, which enables them to learn the concepts of Space Engineering with the methodology of "learning by doing", covering the entire lifecycle of a spacecraft, even in a less complex way, through Systems Engineering approach. It also encourages the students to carry out scientific studies, prepare and publish papers, participate in conferences, and through extension, spread all the knowledge acquired in the various layers of society in the Alto Paraopeba region. Team members are all undergraduate and graduate students. Considering that one of the main characteristics of the team is its multidisciplinary nature, it leads to the advantage that students from all courses offered at CAP can join the group. This is reflected a lot by the concept of satellite engineering, since professionals from various areas of knowledge are sought for working with satellites and small satellites. Thus, in this work the main numbers related to the team were gathered, collected and presented in order to assess the impact and/or reach of the activities in its first year of existence. Data were extracted from databases, histories, and records on the various knowledge and information dissemination platforms. Regarding the research approach, the team obtained a significant number of scientific productions; regarding extension, presentations with satellite subjects were performed; and a great achievement with the competition aspect was obtained, which shows the effectiveness of these three approaches.

Keywords
Alto Paraopeba, NoizOrbita, Small satellites, Space education.

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Nanospace and Open-source Tools for CubeSat Preliminary Design: Review and Pedagogical Use-case

Thibault Gateau¹, Sophia Salas Cordero², Jérôme Puech³, Rob Vingerhoeds⁴

Abstract
This paper aims to facilitate getting acquainted with CubeSat preliminary design by presenting a review of open-source tools commonly used during project first steps, and a concrete example. The light but realistic preliminary design framework is based on a real 3U CubeSat use-case, the CREME project, relying on Nanospace and a package of selected Open-Source tools. This example should allow students and non-related field experts to fully grasp the concepts needed to achieve the basics of a typical preliminary design.

Keywords
Preliminary design, CubeSats, Softwares

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SGAC Global Satellite Tracking Initiative

Daniel Sors Raurell ¹, Laura González Llamazares ¹, Sergio Tabasco Vargas ¹, Lucille Baudet ¹

Abstract
The Global Satellite Tracking Initiative aims to support international students and young professionals to set up ground stations to download real-time data and images from satellites orbiting above their regions. The objective is to empower and build capabilities among space enthusiasts around the world and to promote the space sector through hands-on activities and real space technologies related to satellite communications.

The Space Generation Advisory Council, together with SatNOGS as an integral part of the Libre Space Foundation, have been supporting the initiative to enhance the development of a global open source network of satellite ground stations. The initiative will be providing all the resources, hardware, and know-how that is needed to set up ground stations. A competition was launched by the end of 2021 to select teams of space enthusiasts and supply them with a kit and step-by-step instructions on how to build their own ground stations.

By setting up ground stations in backyards, local universities, or maker clubs, teams are not only self-learning about telecommunications and satellite technologies, but they are creating a meaningful impact in their local communities by bringing the broad society closer to science, technology, engineering, mathematics and, in particular, space. The initiative also intends to support space missions while engaging local communities from different regions around the world in the space sector through appealing imagery and tools.

After closing the Call for Applications in this pilot initiative, 10 winning teams were selected upon receiving almost 200 applications from more than 60 countries. The selected winners are based in the following emerging space faring nations: Benin, Bolivia, Egypt, Ethiopia, Nepal, Peru, Philippines, Rwanda, Vietnam, and Zimbabwe. They are being supplied with a basic Ground Station Kit and instructions on how to receive live images and data from different space missions, starting with the following frequency bands:

- 137 megahertz: To receive images from National Oceanic & Atmospheric Administration satellites.
- 144-146 megahertz: To receive images and data from the International Space Station.
- 440 megahertz: To receive data from numerous scientific and educational small satellites.

Those teams that manage to set up the basic ground station kits and conduct some outreach and educational activities will receive a more advanced system. This paper captures the process to be followed by the selected teams, from the unboxing of the hardware to the reception and processing of data from operational space missions.

Keywords
Education, Satellite tracking, Ground station

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Development of a Low-Cost Ground Segment Capable of Receiving Data from Nanosatellites: a Partnership between Brazil and Portugal

Júlio Santos¹, João Braga², Henrique Alves³, Jeremy Silva³, Daniel Resende³, André Teixeira⁴, Marcos Kakitani²

Abstract

Two universities joined forces to develop a shared ground segment (Ground Stations and Mission Operation Centers) for satellite signals reception, capable of working together autonomously in a network to receive telemetry data and decode information. The main objective of this cooperation and network is to, firstly, give both universities an infrastructure capable of receiving signals in VHF and UHF. Secondly, and most importantly, it aims to create an exchange of experiences between students from these universities while also contributing to the regional development of each country in nanosatellite data reception technology. The ground segment itself provides mutual data collection on a private server, using two ground stations located in different hemispheres to expand global coverage and minimize revisit time, which also contributes to supplying the nanosatellite telemetries database, which is being built in Portugal. The server architecture allows both universities to schedule future passes of their chosen satellites, recording them in a log file that can be used in future studies, enabling research groups to gain experience in signal processing analysis. The modular system is developed entirely using Commercial Off-The-Shelf (COTS) components and 3D printed parts, including Antennas, Amplifiers, Filters and also SDRs (Software Defined Radio), leaving the door open to new integrations that can expand frequency coverage, or system performance improvements. The design supports a wide variety of missions, operating on amateur radio frequency in VHF (2 m band of 144-146 MHz) and UHF (70 cm band of 430-440 MHz), enabling remote access and remote control of the antennas and their recorded data.

All the ground segment architecture, hardware, and software, as well as its operational procedures, are discussed in this paper and can be found in detail on our public repository in GitLab. As of March 21st, it has completed several observations for verification. The results are being processed on a low-cost computer (Raspberry Pi4) connected to an SDR which in turn connects to the antennas. The assembly of this interface intends to give a friendly user experience and, if desirable, an easy expansion of this system. The project developed can be easily replicated in other locations around the world, mainly because of its low price and ease of use.

Keywords
Antennas, COTS, Ground-Station, Low Cost, Nanosatellites

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Panel: Smallsats in Education II

Secondary Auditorium, 12:30 pm – 1:30 pm
Lessons learned during the development of LEDSAT from the students of the S5Lab

Lorenzo Frezza1, Paolo Marzioli2, Andrea Gianfermo2, Niccolo Picci2, Emanuele Bedetti2, Federico Curiano3, Diego Amadio2, Fabio Santoni3, Fabrizio Piergentili2

Abstract
The LEDSAT 1U Cubesat, a satellite roughly 10x10x11cm, was developed between late 2016 and 2021 by students of Sapienza University of Rome. The project was conceived with the help of the University of Michigan and started being developed by space engineering master students of Sapienza in a class context. The team of the S5Lab (Sapienza Space System and Space Surveillance Laboratory) continued the project and applied for the Fly Your Satellite! Programme of ESA Education, which has followed the development of the CubeSat, providing important expert support and periodic reviews. The approach brought to the students an invaluable educational experience as they participated actively in the development of a spacecraft with the typical milestones of satellite projects. The mission objectives of LEDSAT include the use of onboard LEDs for improved orbit determination, experimental attitude determination and backup light communication. Each of the six sides of the CubeSat houses an LED board of a different color (red, green, and blue) with opposite sides with paired color. The LEDs can flash a pattern predefined by radio telecommand and the light is observed using ground telescopes. The design of the spacecraft started in late 2016 and was presented at the selection workshop of the Fly Your Satellite! Programme in May 2017. Final assembly took place in mid-2020 after which the team performed functional and environmental testing between October and December 2020, with the objective of ensuring the survivability of the spacecraft in the space environment and characterization of its behavior. After successful testing, the spacecraft was integrated inside the deployer in July 2021 in Brno, Czech Republic and was launched from Kourou, French Guiana on August 17th, 2021, aboard the Vega VV19 launcher. The spacecraft is now in orbit and operating nominally, with the LED flashes having been observed several times. The development of the spacecraft was not without difficulty, with preventable issues arising through testing that imposed design changes and further analysis - the paper will walk through the project since its conception, throughout the development, the functional and environmental testing of the payload and at system level, emphasizing the lessons learned by the students.

Keywords
CubeSat, nanosatellite, lessons learned, education

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A Model-Based Systems Engineering Approach to Space Mission Education of a Geographically Disperse Student Workforce

Michael Halvorson¹, Jared Fuchs², Patrick Kung³, Dale Thomas⁴

Abstract
The Alabama Burst Energetics eXplorer (ABEX) is a 12U CubeSat commissioned by the Alabama Space Grant Consortium; its astrophysics mission is to study the low energy, prompt emission of Gamma-ray Bursts in both gamma and X-ray spectra. The ABEX program is unique in that its workforce is comprised of individuals at seven colleges and universities around the state of Alabama. ABEX management releases Requests for Proposals (RFP) for Senior Design (SD) projects or university research groups to design and build spacecraft subsystems; university faculty with experience and facilities for the development of that subsystem respond to the RFPs to create a team. ABEX supports undergraduate SD students, graduate student mentors, and faculty technical advisors for all spacecraft subsystems in both ground and flight mission segments. Each team has between 5-15 undergraduate students, meaning ABEX teaches spacecraft design to ~85 undergraduate students at any given time; ABEX may be the largest collegiate CubeSat program in the world. The undergraduate labor force turns over, or cycles to new students, every 4-8 months, so ABEX can teach hands-on spacecraft design to over 100 students every year and has taught over 200 to date. Two features of ABEX create a difficult Systems Engineering (SE) environment: the undergraduate labor force turnover rate and the geographically disperse workforce. Most subsystem teams exist within two-semester SD courses, but some teams, like Flight Software, only exist for one semester before the undergraduate team turns over. This means the student onboarding process must be efficient and the material hand-off process effective if any substantive contribution to the spacecraft is to be made in their brief course period. A Model-Based Systems Engineering (MBSE) Integrated System Model (ISM) was created using SysML as a full-program organization of mission requirements, subsystem architectures, verification and validation procedures, and team interaction tracking methodologies for workforce turnover effect mitigation with ISM-exported artifacts as central objects of stage-gate reviews. An ABEX website was created with processes for first-time student onboarding, ISM artifact dissemination, and intercollegiate document transfer in addition to being a public relations arm for the program. With education at the forefront of ABEX, educational requirements and performance measures detailing onboarding efficiency, workforce preparedness, and alumni vocation results are defined within the ISM and used to evaluate program education proficiency. Program organization, ISM structure, and spacecraft design is presented with an emphasis on quantifying student education as a result of program involvement.

Keywords
Space Education, Model-Based Systems Engineering, Workforce Development

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Developing a 3U CubeSat Engineering Model - FlatSat & Chassis Design

William Crofts\(^1\), Mattias Langer\(^2\), Alex Bolland\(^2\), Tahrim Uddin\(^2\), Chiara Biquet\(^2\), Eduard Hopkins\(^2\), Jai Bassi\(^2\), Myles Ing\(^2\), Julia Hunter-Anderson\(^2\)

Abstract
WUSAT-3 is a 3U CubeSat being designed to carry an experimental RF signal direction finding payload in Low Earth Orbit (LEO). Successful outcome of this experiment could lead to significant benefits for the field of wildlife monitoring from Space. Commercial adoption of this process would enable the development and use of much smaller, lighter RF tracking tags, which in turn would considerably increase the potential range of species that could be tracked by Satellites. The effect of the Covid-19 pandemic lockdowns has limited physical progress over the past 18 months, but the team continues to gain enormous experience and motivation from pursuing this exciting project with a very real-world mission. A recent return to near-normal working patterns has enabled the team to fully engage with the practicalities of progressing the previously produced WUSAT-3 Configuration Model, towards a testable Engineering Model. This paper outlines the development of both the initial chassis prototype (including mechanisms) and a subsystem FlatSat as a first stage towards building the complete Engineering Model. The chassis prototype was required to meet all the requirements of the FYS Design Specification [1], the NanoRacks CubeSat ICD [2], the CubeSat Design Specification [3] and those features identified by the outcomes of the WUSAT-3 Configuration Model. The FlatSat was required to include all subsystems capable of being constructed and tested without the availability of certain proprietary items that will be purchased later. The function and interface of these items, where it was necessary for the purpose of testing the assembled subsystem units that were available, was met by the design and inclusion of temporary substitute arrangements that provided similar performance. Systems Engineering methodologies were employed throughout as a means of ensuring that the design features of both chassis and FlatSat met all necessary requirements.

Keywords
CubeSat, Engineering-Model, FlatSat, Space, Systems,

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ATTITUDE CONTROL RESEARCH WITH EDUCATIONAL NANOSATELLITES

Úrsula Martínez\textsuperscript{1,3}, Luis Bravo\textsuperscript{2}, Dan Gligor\textsuperscript{1}, Karl Olfe\textsuperscript{1}, Álvaro Bello\textsuperscript{1}, José Miguel Ezquerro\textsuperscript{1}, Jacobo Rodríguez\textsuperscript{1}, Pablo Salgado\textsuperscript{1}

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Abstract
This paper introduces the three-axis attitude control of the ESAT platform. ESAT is a modular nanosatellite that implements the popular 10x10x10 cm CubeSat standard, designed for hands-on learning at different educational levels as well as professional training. ESAT features the full set of characteristic spacecraft subsystems (power, on-board data handling, attitude control, communications, and payload). The satellite can be disassembled to focus on each subsystem, one at a time, or used all together, and features a flexible ground segment. Courses using the ESAT platform are imparted in our university, as part of the last year of the master’s degree in Aerospace engineering, and in other institutions like the ESA Academy. They cover aspects ranging from subsystems design to testing and spacecraft operations. In addition, the platform is used in master’s thesis and research activities.

Although the version that is currently being used in the courses allows only one-axis attitude control, the ESAT is in continuous development and two prototypes of the satellite have already been developed that allow three-axis control based on reaction wheels and/or magnetorquers, which is essential for the testing and verification of attitude determination and control algorithms. For this purpose, the ground support equipment has also been updated to be able to carry out the turns in three axes, with the development of new testbeds and a complete magnetic field simulator. The present work aims to show the new three-axis platform designs and its main functionalities.

Keywords
Attitude control, Educational satellite, ESAT, Hands-on training, Nanosatellites.
Flights Hardware and Software Operations Performance Review for BAMMsat-on-BEXUS – a BioCubeSat Prototype Flown on BEXUS30

Mateusz Zalasiewicz¹, Aqeel Shamsud², Giovanni Sinclair², Adrien Bolliand², Romain Giraud², David Cullen², Michael Cooke³

Abstract
BAMMsat-on-BEXUS is a student-led project in which a CubeSat-compatible payload was designed, manufactured, and flown on the BEXUS30 stratospheric balloon. The prototype payload – BAMMsat (Biology, Astrobiology, Medicine, and Materials Science on satellite) – is a modular CubeSat-compatible miniaturised laboratory termed a bioCubeSat. The core flight objective was to perform technology demonstration of the bioCubeSat technology, demonstrating capability to perform experiments in space, and to understand system performance and identify future requirements. The mission aimed to validate pre-flight, flight, and post-flight operations, with a focus on biological and autonomous operations and the novel payload hardware. *C. elegans* samples were flown in the payload. The mission was partially successful, as the BAMMsat systems and autonomous software operated successfully despite challenging conditions and a large volume of payload performance data was collected; however, there were issues maintaining the viability of the samples during flight and microfluidic system issues that impeded sample containment and imaging operations. Post-flight analysis has been performed, the root causes of the issues identified, and upgraded novel payload hardware is currently being developed and tested.

Keywords
BioCubeSat, Laboratory, Operations, Stratospheric balloon

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Panel: Mitigating the Impact of COVID-19 in Space Education

Auxiliary Room, 9:30 am – 11:00 am
ESA Academy Activities during COVID-19

Alexander Kinnaird\textsuperscript{1}, Joost Vanreusel\textsuperscript{1}, Natacha Callens\textsuperscript{2}, Nigel Savage\textsuperscript{3}, Maximilian Nuermberger\textsuperscript{4}, Manuela Aguzzi\textsuperscript{5}, Merel Van Walleghem\textsuperscript{5}

\textbf{Abstract}

The ESA Academy is the ESA Education Office’s overarching programme for university students. The Academy’s portfolio consists of both ‘hands-on’ activities, and a Training and Learning Programme. Conventionally both of these elements involve a significant number of in person events, for example training sessions, workshops and test and launch campaigns. The educational nature and practical aspects of such events has traditionally necessitated in person participation.

Additionally, most of the Academy’s ‘hands-on’ programmes revolve around student teams designing, building, testing and operating an experiment or spacecraft, activities which rely on the availability and delivery of commercial components, and access to manufacturing, testing and launch facilities, and laboratories.

In March 2020, as the COVID-19 pandemic, and associated restrictions, began to take hold in Europe, nearly all the ESA Academy programmes were affected. Despite the challenges, the Academy continued to deliver activities, and the student teams participating in the Academy’s programmes continued to achieve major milestones, including launching experiments to the ISS, CubeSat testing and launch and execution of micro- and hyper-gravity experiments.

This paper explores the challenges faced during COVID-19 and how both the programmes and the students participating in the programmes adapted to meet their educational, scientific, and technical goals. Furthermore, the longer-term adaptation of some of these changes into the future execution of the programmes is discussed.

\textbf{Keywords}

COVID-19, ESA Academy, Space Education,
Adaptation of the AcubeSAT nanosatellite project into remote working during the COVID-19 era

Anastasios-Faidon Retselis\(^1\), Theodoros Papafotiou\(^2\), Konstantinos Kanavouras\(^2\)

Abstract
The global COVID-19 pandemic has undoubtedly forced the global community to embrace the transition to a world where remote and hybrid work models are becoming the new standard. But for the space engineering community, this change is more impactful than other engineering fields. Switching the entire workload from in-person concurrent design and verification activities to a hybrid or an online model has dominated the discussions in relevant symposia since the start of the pandemic. This switch is also more challenging when you must accommodate more than 50 developers who are volunteer students.

The AcubeSAT team underwent this transition during 2020-2021, where all design and prototyping activities for the team’s nanosatellite were moved to a remote work scheme. After several adaptations, this scheme has been fine-tuned and experimented upon to ensure that development activities could continue at a normal pace, and that the physical and mental health of the entire team was guaranteed. These adaptations include changes in infrastructure, team structure and meetings, but most notably they attempt to answer the question of how the concurrent design technique and the review processes can be implemented in an online world.

More specifically, a number of ready-made and in-house platforms and utilities, mostly based on the open-source philosophy, were used to bridge the gap between in-person and online workloads. In an attempt to combine the advantages of online conferencing with the casualness, directness and availability of in-person meetings, we analysed and experimented with various online platforms and project management tools to foster organic collaboration. Furthermore, the use of version control systems as a main tool for internal and external reviews and the documentation produced by the team allowed for a more transparent, reliable and streamlined review process.

All of these changes enabled the conclusion of AcubeSAT’s Critical Design Review remotely in summer 2021. The project is now in the manufacturing and verification phase, with the hybrid work model still in place. With this contribution, lessons learned from the project’s transition to an online and subsequently to a hybrid work scheme will be shared, showing how a large-scale educational project can be implemented under these conditions. The changes performed to accommodate this scheme, along with the rationale behind them and the subsequent challenges posed by them, will also be discussed. Finally, the benefits of such a transition will also be presented, which include more efficient use of time, superior project documentation and the enlargement of the project to students from international universities.

Keywords
concurrent engineering, COVID-19, CubeSat, project management, remote work

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A story about how the novel ROSPIN Academy programme is bringing space education to the Romanian youth in the pandemic context

Maria Alexandra Nita\(^1\), Adrian Dumitrescu\(^1\), Rares Bisag\(^1\), Serban Anghel\(^1\), Raluca Stefanescu\(^1\)

Abstract
Continuous education is the foundation of a sustainable society and ecosystem, and this paper relates the story of one of the most ambitious educational programmes for University students from Romania. The country acceded to the European Space Agency’s Convention in 2011, but does not have a dedicated undergraduate programme for space education, although the local space industry is growing and is demanding more skilled professionals. In this context, the Romanian Space Initiative has been organizing the ROSPIN Academy educational programme since the spring of 2021. Currently, each Edition of the Academy has 3 Levels, coordinated with the least busy University periods: Level 1 is an introduction to the space sector (autumn 2021), Level 2 consists of a technical overview of the lifecycle of space missions (spring 2022), and Level 3 offers hands-on experience with industry (summer 2022).

Although the curriculum’s core is spacecraft engineering, it aims to reflect the sector’s interdisciplinarity, so topics such as astronomy, space sustainability and policy are also covered. The Lessons are delivered in English by national and international speakers from industry and academia, ranging from young graduates to experienced professionals. Participants can interact directly with them, in a context that promotes the idea that space is not only for rocket scientists. The participants’ interpersonal skills are also trained through exercises and games about space topics, which require them to work together in teams. The accepted participants of the Academy are selected based on their motivation and thinking, relevant knowledge and compatibility with the Academy learning concept. Currently, more than 400 applicants have been accepted in the past or current Editions of ROSPIN Academy. Last but not least, the national outreach achieved through this programme is a key defining value. ROSPIN Academy is present at national level, across industries, and mixes undergraduates and graduates, with focus on the former. This is demonstrated by the evolution of the distribution of the accepted participants, in terms of city, year and field of studies. Due to the organisation’s efforts to promote the second Edition nationwide with the support of professors from the biggest STEM Universities, this distribution has clearly evolved. Edition 2 shows a more diversified pool of participants compared to Edition 1, which mostly had active participants with aerospace background from Bucharest. As a result, ROSPIN Academy is uniting the local space communities while educating the next generation of space engineers.

Keywords
Community, Interdisciplinarity, Modern Space Education, Technical and Interpersonal Skills

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A multi-perspective comparison of ESA Academy’s Training and Learning Programme experiences before and throughout COVID-19 pandemic through the eyes of 6 students

Fernando Amador Pla¹, Iván Sermanoukian Molina², Andrea González Romero³, Elena López-Contreras Gonzalez⁴, Maria Magdalena Escorsa Parera⁴, Oscar Lafuente Arjona³

Abstract
The forced transition from fully in-person learning to online methodologies incurred by the proliferation of the COVID-19 pandemic has been a major blow to most organisations worldwide. The aim of the present paper is to analyse the impact of the COVID-19 in ESA educational activities from students’ perspective, in order to stimulate the future creation of both online and on-site courses.

The participation of the authors in the ESA Academy courses covers the period from February 2019 to September 2021, thus experiencing not only both on-site and online courses, but also pre- and post-pandemic learning experiences and course adaptations due to the impact of COVID-19.

The wide range of space education experiences gathered by the authors enables a multi-perspective comparison of a variety of topics involving the ESA Academy courses such as networking possibilities, course dynamics and content, motivation induced by the course environment, impact on the future career and professional development of the participants, as well as compared to the academic experience of the students at their home universities.

The analysis and comparison of the authors' experiences allow to establish correlations between the learning method (in-person or online) and the specific experience outcomes of attending an ESA Academy course. Finally, some recommendations are provided to further mitigate the COVID-19 impact on space educational activities.

Keywords
COVID-19, ESA Academy, Experience comparison, Multi-perspective, University students

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Potential application of a measurement tool for quality assurance of E-Learning content to a new MSc in Aerospace Engineering

Özlem Başman Barilaro1, Dr Mario Cardona2

Abstract
While witnessing how rapidly and frequently the human life-sustaining structure of society has changed from the past to modern times, the effects of the Covid-19 pandemic presented us a unique challenge, moving a considerable part of our life more than ever online and showing us the signs that a new era has begun. While the access to information is enormous, there is a lack of proper skills in selecting the best options available to upgrade one's educational status. Considering how fast education tools are evolving, it has become important to carry out new studies in order to increase and boost the Quality Assurance for E-learning processes in Education.

In this context, recently in Malta a new Aerospace Programme kicked off through an MSc in Aerospace Engineering. This Master's has been structured as part-time and online, aiming to attract undergraduates and professionals in aeronautics from Europe, Asia and Africa, providing the skills required by national and international aerospace companies. For these reasons, the course has been chosen as a test case for the potential application of a measurement tool for its E-Learning content quality assurance.

This paper describes the preliminary analysis to assess the main Quality Measurement parameter. An uncertainty parameter will be associated with the measurement, which will be improved with the increasing size of the statistical sample and iterations. The uncertainty parameter includes measurement errors, sampling errors, variability, use of surrogate data and the combined effect of assumptions that will be necessary to do in the preliminary phase due to the novelty of the study.

Projections suggest that in the proposed study case of the MSc in Aerospace Engineering, the Quality Measurement parameter value will increase in the next few years, thanks to continuous investments, the sharpening of teaching and learning tools, and the growth of interest from the Maltese aerospace sector; it is expected that the uncertainty of the model will similarly decrease.

Keywords
Measurement tools in Education, MSc in Aerospace Engineering, Quality assurance of E-Learning

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Lessons-learned from Teaching Satellite Operations in a Novel Hands-on Student Project Utilizing In-Orbit Spacecraft During the COVID-19 Pandemic

Tony Erdmann¹, Mara Krachten²

Abstract
The Chair of Space Technology at TU Berlin continuously develops new satellite technology and software that is verified and used in various missions in orbit. 27 satellites were launched as of 2022. Many of these satellites by far outreach their design lifetime and work until today. At the same time, an increasing number of satellites not only in the academic domain is demanding for qualified operators. Hence, some of the satellites at TU Berlin are not fully operated anymore. To enable an efficient and sustainable use of those satellites, a novel hands-on student-driven project was implemented in order to utilize these aged but functional satellites to train a new generation of satellite operators. In this lecture course, students with various backgrounds are introduced to the basics of satellite operations by student tutors. Using a laboratory model of a CubeSat as a hardware-in-the-loop operations simulation, participants can collect first experiences in the university’s own Mission Control Center (MCC). Besides theoretical and practical foundations of satellite operations they gain skills in managing and coordinating satellite missions. After finishing the basic course in a theoretical and practical operations test, students qualify to participate in the advanced project giving them the opportunity to work with and operate the available satellites in orbit under supervision. Each semester, several interdisciplinary teams conduct experiments such as Earth Observation scenarios or work on related tasks like the improvement of the operations software or Human Factors of satellite operations.

The pandemic has posed new challenges to this innovative educational concept, but was also a motivation to find alternative ways to teach satellite operations. The setup of simulated operations in the MCC was transformed into a combined setup of remote access and video conference. In this way, students are enabled to practice satellite operations from home. Theoretical lectures are prepared as screencasts. Further, the advanced project work was transferred to a remote manner. Students planned satellite scenarios from home, which subsequently were conducted by the student tutors, who provided the acquired telemetry data to the participants for analysis.

Among the results of the project are several images with the focus on environmental monitoring of Earth, a software update for a satellite and the continuous analysis and documentation of degradation of components that have been in orbit for many years. These achievements do not only provide exciting hands-on classes and new skills to the students but often even contribute to the institution’s research.

Keywords
Mitigating COVID-19, Satellite Operations, Space Education

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The Space Station Design Workshop goes digital - opportunities and challenges during pandemic-times

Markus Grass¹, Tharshan Maheswaran², Gisela Detrell²

Abstract
The Stuttgart Space Station Design Workshop, aimed at university students and young professionals, focuses on the conceptual design of a space station in an interdisciplinary and international environment within a limited timeframe. It lasts about one week and has been carried out by the Institute of Space Systems – University of Stuttgart for over 20 years. The goal of the workshop, besides its educational purpose, is to obtain creative solutions from the future generation of space experts. For the participants, the SSDW offers a unique opportunity for learning by doing and to get involved in a space project. Participants do not only need to apply their knowledge obtained during their university courses but also to put in practice and improve soft skills. The workshop starts with some lectures in relevant fields such as Project Management, Systems Engineering, as well as the different subsystems, for example Life Support. The participants are then divided into two teams. To monitor the teams’ progress several milestones and reviews are planned during the week. Several tools, guides, recipes and experts are available during the workshop. Within the team, each member has a specific role, which is defined before the workshop starts, allowing preparation. The mission statement of the workshop changes every year, adapting to the current plans on human spaceflight exploration. The results of the last editions have been presented at international renowned conferences. In 2020, due to the current COVID-19 situation the workshop was cancelled. In 2021, with increasing vaccination rates in Europe, the situation had improved. However, carrying out such an international in-person workshop was still not an option. For that, the core team decided to carry out for the first time the SSDW in a digital form. Adapting the existing workshop to a digital form presented many challenges but at the same time offered many opportunities. This version has allowed to join participants and staff, that would not have been able to attend in-person, and has also opened new possibilities of communication, using currently existing tools. This paper first introduces the main characteristics of the workshop before it presents a comparison between the 2019 edition, which took place in-person, and the 2021 edition, the first digital SSDW. It summarizes the activities that took place during the one-week workshop, the tools used, and the feedback provided by the participants and staff.

Keywords
Concurrent Design, Digital vs In-person Workshop, Space Station Design

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How to Manage a Rocketry student project in full quarantine

Júlio Santos¹, Jeremy Silva², Henrique Neves³

Abstract
The Fénix Project was created by a multidisciplinary team of forty students that aims to design and build a rocket totally Student researched and Developed (SRAD), capable of reaching three thousand metres of altitude to participate in university rocket launch competitions in Europe. It was born from the will of students at the University of Beira Interior (UBI) and the University of Coimbra (UC) who in 2022 have the goal to participate in the European Rocketry Challenge (EuRoC), organised by the Portuguese Space Agency, and to present a high powered solid rocket. In the desired category, students have to develop a motor from scratch and produce its solid fuel.

Due to the current pandemic situation it was impossible, on the one hand, to hold face-to-face meetings regarding teamwork and, on the other hand, to organise fundraising events. In this way, the team was forced to develop teleworking solutions and look for other ways to get some monetary sponsorship. For this, tools such as Discord, Trello, Google Drive and Google Meets were used.

The hardest thing to control on a team of so many people in a full quarantine is precisely the pace. For that, this project was based on an Agile methodology - Scrum approach - which encourages teams to learn through experience, reflecting on their own achievements and difficulties during work sprints of fifteen days, promoting continuous improvement and causing there to be a constant concern in complying with the initially defined timeline. To reward the effort allocated by students on the project, points were given to the several teams. Being compliant with the applicable standards of the European Cooperation for Space Standardisation (ECSS) also gave students a great sense of responsibility and endeavour, due to the proximity of the tasks that are performed in huge space agencies, such as the European Space Agency (ESA).

With the right approach, COVID-19 effects can be mitigated without ever losing the main focus, which is facilitating the acquisition of soft-skills and hard-skills by students who want to participate and be a part of this fascinating sector.

Keywords
Agile Methodologies, Education, Project Management, Remote, Rocket

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Panel: Space and Health

Auxiliary Room, 11:30 am – 12:30 pm
Artery in Microgravity (AIM): Assembly, Integration, and Testing for a Student Payload for the ISS

Luis García Mozos¹, Devonjit Saroya², Yannick Roelvink², Naël Dos Santos D’Amore², Stefano Gabetti², Jorge Galván Lobo², Catarina Lobo², Mrunmayi Joshi², Guilherme Penedo², Jorge Alberto Rodríguez Encinas², Elena Torta³, Seungah Lee², Baptiste Laulan—Souilhac², Roman Mouchel², Sacha Lustro², Alexis Butin², Mário Gabriel Campos², Laura Passoni², Luigi Avallone², Abin Alex²

Abstract

The Artery in Microgravity (AIM) project was the first experiment to be selected for the “Orbit Your Thesis!” programme of the European Space Agency Academy. It is a 2U cube experiment that will be operated in the International Commercial Experiment (ICE) Cubes facility onboard the International Space Station. The experiment is expected to be launched on SpaceX-25 in mid-2022. The project is being developed by an international group of students from ISAE-SUPAERO and Politecnico di Torino.

The objective of the experiment is to study haemodynamics in the space environment applied to coronary heart disease. The outcomes of this testbench will contribute to understanding the effects of radiation and microgravity on the circulatory system of an astronaut, specifically the behaviour in long-term human spaceflight. It will also help to ascertain the feasibility of individuals suffering from this kind of disease going to space someday. The cornerstones of the experiment are two models of 3D-printed artificial arteries, in stenotic and stented conditions respectively. Blood-mimicking fluid composed of water and glycerol is circulated through the arteries in a closed hydraulic loop, and a red dye is injected for flow visualisation. Drops of pressure and image analysis of the flow will be studied with the corresponding sensors and camera. The pH of the fluid will also be monitored to assess the effect of augmented radiation levels on the release of particles from the metallic stent.

Some delays were experienced in the project due to the COVID-19 pandemic and to implement design improvements. Improvements were made to several aspects of the design including mechanics (e.g. remanufacturing the reservoir with surface treatment against corrosion, leak prevention measures), software (e.g. upgrading to Odroid-C4 and migrating the code to Python), and electronics (e.g. several iterations of the interface PCB design). This iterative process of identifying areas of concern and designing and implementing solutions has resulted in many lessons learned.

The paper will outline in detail Phase D – Qualification and Production of the AIM experiment cube, with special insight on the implementation of the improvements. Previously, at the Symposium on Space Educational Activities in 2019 in Leicester, the initial phases of the design and development of the cube were presented. This year, the final flight model and the results of validation testing before launching on SpaceX-25 are presented. Lessons learned throughout the course of the project are also highlighted for students embarking on their own space-related educational activities.

Keywords

AIT, haemodynamics, leak prevention, microgravity, Orbit Your Thesis!

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The effect of spaceflight on the otolith-mediated ocular counter-roll

Catho Schoenmaekers¹, Chloë De Laet¹, Ludmila Kornilova², Dmitrii Glukhikh², Steven Moore³, Hamish MacDougall⁴, Ivan Naumov², Erik Fransen⁵, Leander Wille¹, Steven Jillings¹, Floris L. Wuyts¹

Abstract

The otoliths of the vestibular system are seen as the primary gravitational sensors and are responsible for a compensatory eye torsion called the ocular counter-roll (OCR). The OCR ensures gaze stabilization and is sensitive to a lateral head roll with respect to gravity and the Gravito-Inertial Acceleration (GIA) vector during e.g., centrifugation. This otolith-mediated reflex will make sure you will still be able to maintain gaze stabilization and postural stability when making sharp turns during locomotion. To measure the effect of prolonged spaceflight on the otoliths, we measured the OCR induced by off-axis centrifugation in a group of 27 cosmonauts before and after their 6-month space mission to the International Space Station (ISS). We observed a significant decrease in OCR early post-flight, with first-time flyers being more strongly affected compared to frequent or experienced flyers. Our results strongly suggest that experienced space crew have acquired the ability to adapt faster after G-transitions and should therefore be sent for more challenging space missions, e.g., Moon or Mars, because they are noticeably less affected by microgravity regarding their vestibular system.

Keywords

otolith deconditioning, ocular counter-roll, spaceflight, centrifugation, learning effect

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Hypergravity induces changes in physiology, gene expression and epigenetics in zebrafish

Marcela Salazar¹, Silvia Joly¹, Guillem Anglada-Escudé², Laia Ribas¹

Abstract
All living organisms that inhabit Earth have evolved under a common value of gravity, which amounts to an acceleration of 9.81 m/s² at mean sea level. Changes on it could cause important alterations that affect vital biological functions. The crescent interest in spatial exploration has opened the question of how exactly these changes in gravity would affect Earth life forms on space environments. This work is the result of a collaborative co-supervision of a master thesis between experts in the area of space sciences and biology, and it can serve as a case study for training experts in such interdisciplinary environments. In particular, we focus on the effect of gravity as a pressure factor in the development of zebrafish (Danio rerio) in the larval stage as a model organism using up-to-date (genomic and epigenetic) techniques. Given the high cost of any experiment in true low gravity (which would require a space launch), we performed an initial experiment in hypergravity to develop the methodologies and identify good (epi)genetic markers of the effect of gravity in our model organism. Previous studies in zebrafish have shown how alteration in gravity effects the development and the gene expression of important regulatory genes. For this study, we firstly customized a small laboratory scale centrifuge to study changes in fish physiology together with changes at molecular levels. We exposed zebrafish larvae from 0 to 6 days post fertilization to the simulated hypergravity (SHG) (100 rpm ~ 3g). After 6 days of hypergravity exposition the larvae showed changes in their swimming and flotation patterns, and presented corporal alterations. Then, we assessed gene expression of genes implicated in important biological processes, (e.g., epigenetics), and an upregulation were observed when compared to the control. Taken together, these preliminary findings show how gravity alterations could affect some basic biological responses, and illustrate the potential of developing new science cases to be developed by students at postgraduate level (MSc and beyond) in a multidisciplinary environment.

Keywords
Biology, Behavior, Gravity, Gene Expression, Multidisciplinary, Space Environment

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Proposal of studies to verify the variation in functionality of cytochrome P450 2E1 in microgravity.

Giorgio Lorini¹, Luca Arborio², Gaia Capoferri³, Anna Emmanuele⁴, Edoardo Imbarrato⁵, Lorenzo Marchioni⁶, Daniel Oldani⁷, Abdullatif Shaar⁸

Abstract

Different medications and drugs are administered to astronauts during spaceflight missions to treat the physiological stress caused by this environment. Microgravity and hard condition in spaceflight can lead to the variations of certain genes, affecting the drug metabolism. One of the main pathways of drug metabolism that seems to be altered is Cytochrome p450. This study is focused on isoform Cytochrome p450 2E1, which belongs to the Cytochrome P450 family, and its difference in gene expression in astronauts during space missions.

In particular, analyses the metabolism of Acetaminophen/Paracetamol, one of the most used drugs on the International Space Station. The research is made using data from Rodent Research-1 mission carried out by Space X. Rodent genetics were compared with a value tool, through WebGestal program and GeneLab, in order to highlight variations in gene expression. The results show that the intensity of the expression of this gene in the test subject is increased by 59% of the intensity of the same gene in the control group. This could lead to a change in the effects of this pharmacological agents such as an increased toxicity. The study is based on omics approach, suggesting the future challenge to develop a more personalized medicine.

Keywords

Acetaminophen, Cytochrome P450 2E1, Microgravity, Paracetamol, Spaceflight

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Panel: Space for Sustainability, Equity and Diversity

Auxiliary Room, 12:30 pm – 1:30 pm
Abstract

“Spazio allo Spazio”, active since 2010, involves students aged 5 to 20. This educational project was launched by a group of Italian teachers from the Middle School Fermi in Villasanta who believed Space exploration could be an efficient way to convey the idea that the extraordinary experience of the astronaut, who on the International Space Station must acquire new skills and be able to dominate a challenging and unpredictable context, similar to a disabled person's routine in daily life. This was a winning choice because gradually international institutions promoted similar initiatives. The central theme of space exploration is used to promote values of sustainability, equity and diversity, allowing students to become acquainted with the world of astronauts while facing subjects related to integration and disability. Several national and international universities and institutions, at the forefront of scientific research, have contributed to this project. The main topics of the project are: 1) Space exploration: the astronaut's experience is the starting point for lessons, cultural exchanges, lectures and interdisciplinary strategies to raise awareness about humans in space, the international cooperation for the International Space Station, physical training, technical, scientific and cultural preparation. 2) Career orientation: meetings with experts in different fields, from Science, Technology, Engineering, Mathematics to Arts and Physical Education, help students achieve better knowledge of themselves, their potential and limits acquiring skills in scientific research methodology in a multilingual environment. 3) Inclusion: as astronauts experience the limits of gravity and disability in Space, students can face their limits, through experiences of adapted physical activity, addressing issues related to the integration and insertion of people with different skills in school and society. 4) Team building: starting from the example of collaboration which takes place in space missions and scientific research, students are encouraged to experience teamwork. This is true for the teachers too, thanks to the strengthening of cooperative teaching, in the sharing of resources and good practices as well as in the implementation of innovative forms of communication and multimedia documentation. The project aims at making students able to face new and more advanced educational challenges and cognitive objectives, developing work strategies by transferring already tested approaches and processes to new situations. This is noticeable in the more self-conscious choices that former students have made about their future. An example is illustrated by an ex-student who directed his training path in the Science and Engineering field.

Keywords
Astronaut, Career education, Inclusion, Team building
Abstract
The low representation of women (~33%) in Science, Technology, Engineering and Mathematics (STEM) careers is extremely concerning and cultivates male-dominant cultures across a variety of academic and professional disciplines. In Spain, only 39% of national projects are led by women, thus evidencing the so-called “leaking pipeline”, that is, the tendency of women and other underrepresented groups to eventually abandon STEM-related fields. This social disequilibrium is particularly strong in the international space sector, where women represent less than ~20% of the workforce. The Hypatia I mission—a multi-generational and multi-disciplinary crew of 9 female scientists—seeks to help address this problem. In April 2023, the Hypatia I crew will participate in a two-week Martian analog mission at the Mars Desert Research Station (Utah, United States) with the goal of (i) performing high-quality space-related research in a simulation environment, (ii) conducting outreach and science communication activities, and most importantly, (iii) promoting female role models in STEM-related fields and inspiring future generations of scientists, particularly young girls interested in space careers.

Keywords
Female, Space exploration, Space outreach, Mars, Analog mission
JSRI Space Design Competitions: Education and Outreach for Emerging Space Countries

Sahba El-Shawa1,2,3*, Mema Alzurikat4, Zainab Abu Sha’ar1,2, Moh’d Sami Ashhab4

Abstract
As countries around the world are racing towards realizing the common dream of humans creating long-term habitats in space, emerging space countries like Jordan, with no established space agency, are struggling to participate in the development of research and projects in the field. Additionally, due to the deteriorating economical situation in Jordan, students now seek professions with higher market demands and payment rates to ensure a safe career path. This led Jordanian students to overlook emerging fields of study like space. From here arises the need to conduct proper outreach to spread awareness on space research and its benefits, and to incorporate space studies in the Jordanian educational system in order to build a strong base of human resources in the field. Since Jordan is lacking in both educational and theoretical, as well as professional and practical sides, students mostly turn to completing their studies and gaining professional experience in the space field abroad. Therefore, before establishing Jordanian-targeted education programs and initiatives for space studies, there is the need for the establishment of local space institutes, projects, and programs which ensure that students will have access to training programs and practical experience as well as securing future job opportunities, thereby making space careers a viable option. In 2020, under the Moon Village Association’s Participation of Emerging Space Countries program, a roadmap for Jordan’s contribution to lunar exploration and the Jordan Space Research Initiative (JSRI) were created. This 20-year roadmap focuses on establishing an analog R&D facility in Jordan’s Wadi Rum desert, aiming to support the emerging space field in Jordan, while contributing to its national priorities and sustainable development goals. Beginning with the outreach element to foster space education, JSRI launched two space design competitions in 2021 to engage students and professionals interested in the field. These competitions allowed the participants to learn about spacesuit and rover design, as well as develop their own prototypes in a hands-on educational exercise. By providing funding and expert support, JSRI ensured that a diverse group of Jordanians was able to participate, regardless of their backgrounds. This approach proved to be successful in enabling the participation of various segments of the Jordanian society, and has shown that people with a passion for space can thrive through educational initiatives such as these competitions. Building on this success, future partnerships and educational initiatives are being established, aiding in the formation of a space network in Jordan.

Keywords
Education, Outreach, Space Design Competitions, Emerging Space Countries, Jordan

1 Jordan Space Research Initiative, Jordan
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Earth observation education for Zero Hunger: A Massive Open Online Course towards achieving SDG #2 using EO

Stefanie Steinbach\textsuperscript{1,2}, Nesrin Salepci\textsuperscript{3}, Robert Eckardt\textsuperscript{3}, Christiane Schmullius\textsuperscript{3}, Andreas Rienow\textsuperscript{1}

Abstract
Persisting hunger and malnourishment continue to be a problem of global concern, which recent climate change, as well as environmental and socio-economic crises and their impacts along the food chain further exacerbate. Earth observation (EO) holds the capacity to deliver large temporal and spatial coverage information that allow for better decision-making in food production and distribution. Furthermore, the rapidly increasing amount of freely available data and tools potentially enable an expanding user community to bring this information into practice. However, more people need access to EO education to realize this potential. EO Connect (funded by the German Ministry of Education and Research) addresses this demand by developing a Massive Open Online Course (MOOC) towards the UN Sustainable Development Goal (SDG) 2: Zero Hunger. Since a conventional course can barely reflect the comprehensiveness of SDG #2 regarding both content and the people involved in achieving the goal, the Zero Hunger MOOC leverages modern learning approaches in a non-linear, adaptive learning environment to cater to a large audience and diverse target groups, and to their different scopes and levels of desired learning outcomes. The use of micro-content, drip-feeding and feedback-guided course development shall ensure maximum effectiveness. To accomplish this ambitious endeavour, the Zero Hunger MOOC is developed with a community of stakeholders from the realms of EO, education, information technology, and food security. It builds on contents from this community which are adapted, streamlined and assembled to course modules, as well as on the expertise from the over 20 contributing universities, space agencies, national institutions and international organizations. While the Zero Hunger MOOC contributes to bridging the gap between the available EO technology and its application to increase food security, it likewise promotes stronger stakeholder connection in EO education.

Keywords
SDG #2, Zero Hunger, MOOC, networking, community building

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Developing low-cost, reusable solar observation platforms to advance sustainable heliophysics research

Joseph E. G. Middleton¹ Ida A Janiak²,

Abstract
The objective of this paper is to describe a methodology for cheaper solar observation, which would make it available to research institutions of all sizes. This is done through the use of low cost, reusable components, innovative manufacturing and by using high altitude balloons to transport the payload. The aims of the project are to produce clear, sharp images of the solar chromosphere. Proving that it is possible to produce research-grade images without the need for expensive alternatives such as adaptive optics on ground telescopes or satellites. As well as discussing the technical points of the project, the paper will discuss the technical hurdles encountered before this design iteration and how these have been overcome. The other aims of the project are to facilitate students introduction to the space industry and allow them to practice their skills in a practical manner. This is very different from the work done theoretically in the classroom and exposes students to the challenges of working in industrial teams.

Keywords
Heliophysics, Reusable, Low-Cost

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Presentations

Friday, April 29th
Panel: Experiments under Microgravity Conditions

Vèrtex Auditorium, 09:30 am – 11:00 am
Challenge-Based Learning and the Barcelona ZeroG Challenge: A Space Education Case Study
Antoni Perez-Poch¹,², Jordi Torner¹, Daniel V. González³,⁶, Laura Gonzalez-Llamazares⁴, Maria Josep Martí⁵, Rosa Pasquets³, Francesc Alpiste¹, Miguel Brigos¹, Gloria García-Cuadrado⁶

Abstract
Challenge-Based Learning is a STEM Education methodology that has been used as a collaborative and hands-on approach to encourage students to put their knowledge in practice by addressing real-life problems. Space Education is a field particularly suited to apply it, with hands-on research projects which require students to take actions and communicate their efforts in a multicultural, international scenario in order to produce an optimal response a specific goal. We herein present a successful Challenge-Based Learning Case Study which involves designing, implementing, and actually flying a microgravity experiment in parabolic flight. The Barcelona ZeroG Challenge is an international competition addressed to University students worldwide. It challenges students to build a team with a mentor, propose, design, build and fly their experiment in microgravity and finally communicate their findings. The experiment has to meet the requirements of a unique microgravity research platform available in Barcelona for educational and research purposes.

More than fifty students have flown their experiments on board an aerobatic CAP10B aircraft in Barcelona in previous educational campaigns; having published their results in relevant symposiums and scientific journals. These campaigns have always attracted media attention. The current edition is underway with the winner team expected to fly their experiment before the end of 2022. This edition is jointly organized by Universitat Politècnica de Catalunya, the Barcelona-Sabadell Aviation Club and the Space Generation Advisory Council. Up to fifteen projects have been submitted to this edition, an unprecedent number so far. A panel of experts from the European Space Agency Academy conducted the selection of the winner team, who receives a 2500 euros grant to develop its experiment, aside from the opportunity to fly it in parabolic flight. Furthermore, students from our own University have also the opportunity of designing and testing their microgravity experiments during their studies.

Principles of Challenge-Based Learning are herein described as well as how this methodology is applied to this Case Study. Results from our experience are very satisfactory as most of the students who have been involved in it perceive this experience as a boost for their careers. Three key factors to success have been identified: a strong involvement from students' associations, a need for international cooperation and the quality of the students' mentoring. The experience can be of interest for other organizations to conduct a successful CBL educational project.

Keywords
Aerobatics, Challenge-based learning, Microgravity, Parabolic flight, Space education.

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Supporting an ISS experiment as PhD students: a case study of the PARTICLE VIBRATION project

Georgie Crewdson¹*, Alessio Boaro¹, Monica Kerr¹, Marcello Lappa¹

Abstract
This paper provides an insight into the involvement of two PhD students in the PARTICLE VIBRATION project, a multiphase fluid experiment, also known as, “Thermovibrationally-driven Particle self-Assembly and Ordering mechanisms in Low grAvity” (T-PAOLA) to be launched on the International Space Station by the end of 2022. The project aims to identify self-organization phenomena in dispersed phase flows when vibrations are applied to the system. It will therefore underpin the development of new contactless particle manipulations and materials processing strategies. In this short paper, the work of two PhD candidates, working within the T-PAOLA project framework, is discussed. In doing so, the various research activities undertaken are highlighted, both experimental and numerical, as is the peripheral or supporting research being undertaken by both students in order to expand the scope of the project and identify new lines of enquiry regarding convection-based control mechanisms.

Keywords
Microgravity, Thermovibrational convection, Particle aggregation, ISS experiment, T-PAOLA project

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OSCAR-QUBE: Student made diamond based quantum magnetic field sensor for space applications

Boo Carmans¹, Siemen Achten¹, Musa Aydogan¹, Sam Bammens¹, Yarne Beerden¹, Dries Hendrikx¹, Jeffrey Gorissen¹, Teoman Köseoglu¹, Jens Mannaerts¹, Remy Vandebosch¹², Siemen Vandervoort¹, Sebastiaan Vanspauwen¹, Milos Nesladek¹² and Jaroslav Hruby¹²*

Abstract
Project OSCAR-QUBE (Optical Sensors Based on CARbon materials - QUantum BElgium) is a project from Hasselt University and research institute IMO-IMOMEC that brings together the fields of quantum physics and space exploration. To reach this goal, an interdisciplinary team of physics, electronics engineering and software engineering students created a quantum magnetometer based on nitrogen-vacancy (NV) centers in diamond in the framework of the Orbit-Your-Thesis! programme from ESA Education. In a single year, our team experienced the full lifecycle of a real space experiment from concept and design, to development and testing, to the launch and commissioning onboard the ISS. The resulting sensor is fully functional, with a resolution of $< 300$ nT/ $\sqrt{\text{Hz}}$, and has been gathering data in Low Earth Orbit for over six months at this point. From this data, maps of Earth’s magnetic field have been generated and show resemblance to onboard reference data. Currently, both the NV and reference sensor measure a different magnetic field than the one predicted by the International Geomagnetic Reference Field. The reason for this discrepancy is still under investigation. Besides the technological goal of developing a quantum sensor for space magnetometry with a high sensitivity and a wide dynamic range, and the scientific goal of characterizing the magnetic field of the Earth, OSCAR-QUBE also drives student growth. Several of our team members are now (aspiring) ESA Young Graduate Trainees or PhD students in quantum research, and all of us took part in the team competition of the International Astronautical Congress in October 2021, where we won the Hans Von Muldau award. Being an interdisciplinary team, we brought many different skills and viewpoints together, inspiring innovative ideas. However, this could only be done because of our efforts to keep up a good communication and team spirit. We believe that if motivated people work hard to improve the technology, we can change the way magnetometry is done in space.

Keywords
Quantum Magnetometer, Interdisciplinarity, International Space Station

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The “Effect of Marangoni convection on heat transfer in Phase Change Materials” experiment, from a student project to the International Space Station

Pablo Salgado Sánchez¹, Jose Miguel Ezquerró², Dan Gilgor², Úrsula Martínez², Jose Fernández², Ignacio Tinao²

Abstract
This manuscript summarizes the educational and scientific outcome of the Research-based learning activities performed in the bachelor’s, master’s, and doctorate programmes in aerospace engineering at the Technical University of Madrid. The activities are related to the line of research in Phase Change Materials in microgravity developed at the Spanish User Support and Operations Centre. The principal scientific results obtained during these years are outlined, drawing particular attention to those related to the “Thermocapillary Effects in Phase Change Materials in Microgravity” experiment and the “Effect of Marangoni convection on heat transfer in Phase Change Materials” project. The outcomes of this research are discussed from an educational perspective. Since 2016, we observe an increased interest from students to participate in research activities, which has had direct positive impact on the production of scientific results.

Keywords
Active learning, ISS, Marangoni in PCMs, Microgravity experiments, Research-based learning

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Lotus: Testing Origami-Inspired Structures in Microgravity

Augustin Gallois¹, Karthik Mallabadi², Clément Lopez², Eliott Marceau², Sérgio Silva³, Stéphanie Lizy-Destrez²

Abstract
Many space technologies are enabled by deployable mechanisms or structures to function: solar panels, radiators, and even crewed stations and rovers subsystems need to be stowed and deployed to fit in a launcher fairing and avoid unwanted vibrations during launch. Among those structures, the deployment of large membranes and panels can be designed with the help of an unexpected technique: origami folding. The idea has been spreading in every field of engineering in the past few years; compact, rigid-folded structures that can change shape in one simple motion fascinate micro-robotics as well as aerospace engineers.

Origami-inspired structures can be engineered to answer many needs. The available launch volume can be optimized, creases can improve the rigidity of a structure while keeping it lightweight, thickness can be accounted for, and complex surfaces can be approximated by flat-foldable mechanisms. Several major space actors, such as the National Aeronautics and Space Administration (NASA) and the Japan Aerospace Exploration Agency (JAXA), have already implemented such techniques successfully or plan to do so in the near future.

Following these breakthroughs, student project “Lotus” was submitted to the Parabole 2022 contest, an opportunity to test student projects in microgravity during a parabolic flight campaign organized by the French Space Agency and its subsidiary Novespace. The 5-members international student team will characterize and analyse the deployment and folding of innovative origami structure models for current and future space applications, especially volumes for deployable habitats, fuel tanks, or other resource containers such as asteroids and regolith; three stereo cameras will capture the geometry at different set speeds. To maximize the scientific return, several shapes and geometric parameters will be tested: three distinct structures are proposed to be tested, mostly limited by the volume available for the experiment. The models tested will be as similar as possible to their full-size counterparts, being made of space-grade polyimide, and their dynamics will be assessed in near-0g conditions to have a deployment environment that is as accurate as possible. These results will be compared with on-ground experiments with a similar experimental setup.

Keywords
deployable structures, origami, parabolic flight, student project

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LEOniDAS Drag Sail Experiment on the 2021 ESA Fly Your Thesis! Parabolic Flight Campaign

Zaria Serfontein\textsuperscript{1}, Marco Rigamonti\textsuperscript{7}, Edouard.Demers\textsuperscript{1}, Gonzalo Temprano\textsuperscript{1}, Jennifer Kingston\textsuperscript{1}

Abstract
Space engineering students and academics from Cranfield University have developed two space debris mitigation drag sail concepts and three sails are currently in orbit. The sails enable a reduced time to atmospheric re-entry by increasing the natural aerodynamic drag forces acting on the host satellite. Intended to be used on small, low Earth orbit satellites, these sails provide a low-cost solution to achieving compliance with the IADC target of removal from orbit within 25 years of end-of-mission.

The LEOniDAS team, comprising one PhD and three MSc students, submitted a proposal to the ESA Fly Your Thesis! parabolic flight campaign to perform microgravity deployment testing on a more scalable and adaptable hybrid design. The project aimed to qualify the new design, provide a better understanding of deployment behaviour in microgravity and allow for a deeper understanding of the effect of deployment on the host satellite. Participation in the programme provided significant educational benefits to the students involved, resulting in three Masters theses and a major input to a PhD thesis, as well as publications and outreach activities.

The experiment was presented by the students at the ESA Academy Gravity-Related Training week in January 2021. There followed extensive design, prototyping and assembly work, with regular review and input from ESA and Novespace, culminating in the two-week parabolic flight campaign in October 2021. The planned deployment experiments were successfully completed across all three flights, with the experimenters accumulating a total of more than 30 minutes of microgravity. Data on dynamics of the sail deployments was recorded via high-speed video cameras, accelerometers and torque sensors.

This paper will highlight the key scientific and educational achievements of the project, and summarise the lessons learned for the benefit of future participants in this exceptional student opportunity.

Keywords
Space Debris, Deorbit Sail, Microgravity Testing

1. Introduction
The European Space Agency (ESA) released the 2021 Annual Space Environment Report \cite{1} with the following analogy:

“Imagine driving down a road which has more broken cars, bikes and vans lining the street than functioning vehicles. This is the scene our satellites face in Earth orbit.”

Space debris poses a problem for all current and future space missions by increasing the risk of involuntary collisions with operational satellites. If no action is taken to stabilise or decrease the debris population, the situation in low Earth orbit (LEO) could deteriorate well beyond the boundary where remediation is achievable with current resources \cite{2}.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Number of cumulative collisions in LEO in simulated scenarios of the long-term evolution of the space environment \cite{1}}
\end{figure}

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A 3-axis Stabilisation Platform to Improve Experiment Conditions in Parabolic Flights

Deepa Anantha Raman, Bruno Comesaña Cuervo, Viktoría Jurčáková, Arnau Busom Vidal, Estelle Crouzet, Antoni Eritja Olivella, Juan Gracia García-Lisbona, Rebecka Kjellman, Minka Suomela, Thomas Kuhn, René Laufer, Olle Persson

Abstract

There are different ways of providing free-fall conditions on Earth in order to test a component, perform an experiment or demonstrate equipment before it can be included in a space mission. One of these options is a parabolic flight: briefly, the aircraft flies on a parabolic trajectory with the on-board payload experiencing several seconds of weightlessness. These flights have been performed since the 1950s to simulate space conditions for experiments as well as astronaut training.

The project objective is to develop a cubical platform to perform 3-axis attitude stabilisation for experiments during the microgravity phase of a parabolic flight. The goal is to stabilise the platform and thus reduce perturbations and vibrations that diminish the quality of the microgravity achieved. To do so the attitude control system, composed of three reaction wheels in orthogonal configuration, will counterbalance the disturbances measured by the attitude determination system, an inertial measurement unit. The platform will be tested using a small aircraft in a self-organised flight campaign.

Comprising nine students, this project is currently in the preliminary design phase. However, the prototyping and testing of the platform structure has already been initiated using a small-scale design and several hardware components have been ordered. The platform will be printed using additive manufacturing due to the numerous benefits of this process. The component integration is expected to be completed in time in order to facilitate the laboratory testing of the various subsystems before the flight campaign in May 2022. After the flight campaign, the collected data will be analysed, processed and published to ensure that it is accessible to the scientific community.

Keywords
Attitude control, microgravity, parabolic flight, reaction wheel, student experiment

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Lessons Learned when Developing a High Performance Attitude Controlled Platform to Achieve Microgravity for Low-Cost Experiments

Andreas Wolnievik¹, Noel Janes², Flavia Pérez Cámara³, Ric Dengel⁴, Diane Delley⁴, Anne Hartmann⁴, Paloma Maestro Redondo⁴, Miguel Llamas Lanza⁴, Erik Samuelsson⁴, Íñigo de Loyola Chacartegui Rojo⁴, Jonathan Lange⁴, Elena Fernández Bravo⁴, Cornelis Peter Hiemstra⁴, Sebastian Scholz⁴, Henning Isberg⁴, Tõnis Kull⁴, Spyridon Gouvalas⁴

Abstract

Available Attitude Control Systems are often targeted at orbital flights, and therefore manoeuvre slowly. As such, these solutions are suboptimal for sounding rocket experiments, as experiments such as those conducted on free falling units have restricted flight times. Furthermore, current attitude control systems are usually aimed at projects with extensive funding, and are therefore out of the budget range of low-cost experiments. Taking these constraints into account, the objective of project ASTER is to design and test a low-cost, fast-acting solution, to stabilise and orientate a free-falling platform, which is capable of providing microgravity conditions for experiments. The proposed design utilises three reaction wheels, controlled by a closed loop system, to stabilise the Free Falling Unit within seconds. The platform will be able to perform predefined slewing manoeuvres, which can be adapted to a wide range of applications. The free falling unit is a cube weighing around 3kg with a side length of 150 x 150 x 180 mm, with a recovery parachute system included. Designed to act as a system platform for free falling units, it will be able to accommodate future experiments, providing an easily adaptable payload bay with dimensions up to 56 x 91 x 77 mm. Furthermore, the system will be recovered after the experiment has been concluded and the results obtained will be published on an open source basis to ensure its future availability to other student and low budget research projects, thereby allowing further improvement, optimisation, and customisation. The experiment development began in September 2019 and is scheduled to fly on a sounding rocket in March 2023. Team ASTER wants to contribute to the student community by sharing the experiences and lessons learned during the project development, which is what will be focused upon in this paper and accompanying presentation.

Keywords
Attitude Control System, Free Falling Unit, Learning Project, Microgravity, Sounding Rocket

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Panel: Space Education Initiatives II

Vèrtex Auditorium, 11:30 am – 12:30 pm
3D printed telescopes: an interesting tool for teaching Astronomy, Science and Technology

Roger Macías*, Antonio Marzoa¹, ², Oriol Casamor¹, ², Daniel Fernández³

Abstract

3D printing technologies experienced a huge evolution both in techniques and applications since its invention in the early 1980s. Fused Deposition Modelling (FDM) was the first term used to describe an additive manufacturing technique and from that point on, many different ways of 3D printing have been developed to fulfil a variety of needs.

Nowadays, 3D printing has become more accessible to the general public because of the big drop in prices caused by the big technical developments. As a result of that, a community of “makers” has been taking shape internationally making access to designs and advice easier.

3D printing is without a doubt one of the key developments of the last decades and covers from highly technical research fields (like medicine-related investigations) to individual makers or even educational programs to encourage young people to create.

As a result of that, it can be seen daily that the so-called 3D printing has gained a big amount of fame between fabrication processes for its accessibility and ease of use, it only takes a computer, a 3D printer and time. On behalf of that, an idea for a final degree thesis was proposed: designing and printing using fused deposition modelling a telescope for astronomical and educational purposes.

The main goal of the project is to, first check the capabilities of the 3D printing technology to build telescopes for amateur astronomers, comparing its performance with the current commercial products, and secondly, to develop a set of educational resources that permit the easy construction of low-cost custom instruments for the teaching and diffusion of Astronomy and Space Science. The set of resources derived from this project will be an interesting tool for Astronomy beginners, Engineering and Science students, teachers, and makers.

In this work, we summarise the current status of the project and the results obtained with the first built prototype, as well as the design and choices made to fulfil our needs in a practical and feasible way. Last but not least, a list of possible educational activities to be carried out with the developed resources will be exposed.

Keywords
3D printer, Additive manufacturing, Astronomy, Education, Telescope

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Educational activities with Arduino to learn about astronomy

Federico Di Giacomo¹, Maura Sandri²

Abstract

There is a need to promote better science, technology, and mathematics (STEM) education at all school levels. Arduino makes it possible by creating the next generation of STEAM programs that empower students on their learning journey through middle school, high school, and university. These kinds of technologies make it possible to make abstract concepts concrete and manipulable, far from the experience of children and young people, increasing the possibilities of learning. Following the constructionist ideas and practices, the National Institute for Astrophysics has developed play.inaf.it, a web platform that collects various coding, educational robotics, making, and tinkering activities, using astronomy and astrophysics as a tool to develop computational thinking and all the skills that are typical of scientific research in the STEM field.

In this paper we want to present two projects created by the Play group. The first one aims to create, using an Arduino board, one LED and a photoresistor, an exhibit capable to describe one of the methods most used to identify exoplanets: the transit method, which exploits the fact that the brightness of a star decreases when the planet passes in front of it, with respect to our line of sight. Thanks to this project it is possible both to know Arduino and understand the information that astronomers can obtain from so-called light curves, such as the orbital period, the size of the planet, etc. The second activity aims to create and turn on one or more constellations using Arduino and some LEDs. In this way it will be possible to describe - through an active, cooperative, and operational approach - what are the stars, the constellations and the close relationship that has linked man to the sky since the dawn of time.

Thanks to Arduino it is possible to encourage creativity, allowing everyone to give shape and substance to their ideas because the only limit we can set is our imagination.

Keywords

Arduino, Astronomy, Coding

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Come fly with us: services provided by the Space Weather Education Centre

Elke D'Huys¹, Petra Vanlommel², Jan Janssens³, Ronald Van der Linden³

Abstract
The Solar-Terrestrial Centre of Excellence brings together and supports sun-space-earth research and services present at the federal level in Belgium. In 2019, the STCE was a founding member of a European network, PECASUS, that provides space weather services for civil aviation. Our expertise in solar observations and research combined with the experience of our Global Navigation Satellite System and solar particle radiation group proved to be crucial.

The STCE invests also strongly in education and training as these are a back bone of quality research and services, and therefore created the Space Weather Education Centre. This centre offers the Space Weather Introductory Course covering the Sun, solar storms, heliosphere, ionosphere, magnetosphere, instruments and methods to observe solar and space weather activity, as well as reading and interpreting our space weather bulletins. This course is taught to future space weather advisory staff, both military and civilian. It is based upon the STCE’s expertise gained through scientific research, involvement in space missions and space weather monitoring, and forecasting capabilities. The course is given by qualified staff.

In addition to the Space Weather Introductory Course, the STCE has been and remains involved in a wide range of outreach activities, from public lectures, over dedicated classes and workshops at schools, organization of public events like open doors, publications in popular journals and on online media, scientific newsletters and press releases, to the participation in science festivals and the organization of events for the scientific community.

In this paper, we present more details of our educational programme, reflect on the methodologies used, and provide an overview of the obtained results.

Keywords
Space weather, outreach, education, aviation

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The Sat-Comms Game: teaching a complex subject for interdisciplinary audiences

Dr. Paul ILIFFE¹

Abstract
This paper addresses general space education for interdisciplinary audiences. In particular, this paper considers education in the field of Satellite Telecommunications (Sat-Comms).

The challenge in presenting the field of sat-comms for effective learning is two-fold. Firstly, this field is interdisciplinary, the disciplines are coupled, and it is complex. Secondly, the typical audiences for this subject often have diverse backgrounds. Hence, a suitable teaching strategy is required, so that all students can learn from a training session.

Publicly available sat-comms training is largely engineering focused. This study could not find suitable training for the purpose of interdisciplinary sat-comms education.

Hence, to address this absence in available training, the author has created a workshop, which provides sat-comms education to interdisciplinary audiences. The workshop was empirically developed from the author’s experience at Inmarsat and at the International Space University. The workshop uses elements from Constructivist, Behaviourism, Cognitive, Connectivism, and Experiential learning theories. Furthermore, it was designed to be taught in person and online.

The Sat-Comms Game was first trialled in an online format in 2021. The workshop worked well in engaging the participants during the session. Additionally, feedback on the workshop was positive. Hence, this trial indicated that the workshop could function logistically and engage people pedagogically.

The author intends to conduct further trials and corresponding assessment methods to gauge the pedagogic effectiveness.

Keywords
Interdisciplinary Space Education, Satellite Telecommunications, Student focused teaching

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The role of the key educational paths for ESA new member states as a risk reduction index for the newcomers.

Katarzyna Malinowska¹, Michał Szwajewski²

Abstract

The new ESA member states are an important factor in the development of European sustainability and independence in space. Cooperation between European countries in the field of space, gives a strong conviction that we operate without borders in space. It is therefore necessary to create not so much international links, but rather supranational ones. This also applies to space education. One of the primary missions of ESA is to create a community of highly specialized engineers, managers, as well as scientists who will focus on developing the space economy and allowing societies to understand our role and interactions with space.

Based on the experience gained in the period after Poland's accession to ESA, the authors would like to emphasize the role of key educational pathways that can guide ESA officers in new member countries and in any country that has already entered ESA structures or plans to enter in the near future. The authors would like to emphasize that there are several ways to share and improve knowledge and would like to present the main insights of the study conducted in this respect.

Drawing on the Polish space industry and using it as a reference basis, but also applying some observations from the Czech Republic and now Latvia, the authors identified the following main learning paths:

- The activity of students within student associations, who implement space projects through dedicated programs;
- The role of YGTs who, after a period of training at ESA, return with a set of knowledge to their countries;
- The importance of the know-how of the international space market, in particular global companies setting up subsidiaries in new ESA member countries and bringing their experience and knowledge there;
- Dedicated educational programs for people who do not have a formal space education (engineering) but want to develop in various areas of the space industry;

The sequence of the presented educational pathways is not accidental. The authors want to present the role of each pathway and show how it can be applied in practice. The authors recognize some deficiencies in the presented pathways, as well as note a trend towards strengthening interest in dedicated educational programs at the undergraduate and postgraduate levels. Based on their own educational experience and taking into account the status quo of space education (at least) in central Europe, the authors would like to present ideas for structuring professional education in the space industry, taking into account its recent changes, where the demanding factor of business competition should be added to the technological factor. So, where an interdisciplinary approach should be adopted. Each educational pathway has been analysed from the point of view of risks and opportunities. This analysis can be applied by new participants in the commercial space market (understood as new companies or scientific groups), but also by new ESA member states at the institutional level.

Keywords

space education, space economy, risk management

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Panel: Educating Space for Young Students

Vèrtex Auditorium, 12:30 pm – 1:30 pm
Finestres al cel
Laia Casamiquela*, Víctor Moreno de la Cita**, Ignasi Pérez-Ràfols***, Santi Roca-Fàbrega****

Abstract
We present an astronomy educational project intended for 16-year-old high school students that has been successfully deployed for 7 years under the Youth and Science Program of the Catalunya La Pedrera Foundation. The Youth and Science Program aims to encourage talented students to pursue careers in science and technology and a future as researchers. It consists of a two-week crash course covering all major topics in astronomy: stellar evolution, black holes, galaxy formation and evolution, cosmology, simulations, and gravitational waves, among many others. The classes focus on the relevant concepts in each of the aforementioned fields but without a detailed description of the math formalism or the most advanced concepts in modern physics, this to develop the students’ intuition and interest in the wonders of the Universe without overwhelming them. Theoretical sessions are complemented with a set of practical sessions that help students to consolidate the concepts. All theory and practical sessions in this project are being compiled in an outreach book addressed not only to the students of this project but also to the entire amateur astronomy community.

Keywords
Astronomy course, High school, Observations, Practical sessions

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Cosmic Call Tech – A hands-on space radio workshop for students in secondary education

Stefan Lobas¹, Mario Geisler², Frank Fischer³

Abstract
The DLR_School_Lab Braunschweig, Germany, organized an amateur radio contact with an astronaut on board the International Space Station (ISS) for students from five different schools for the third time. While the contact itself was always an exciting event for the participating students our goal was to increase the sustainability in learning with a deeper understanding of the technology used for the radio contact. As a result, we present our concept for engaging with the students and preparing them for the actual radio contact with an inexpensive hands-on space radio workshop that was conducted remotely via video conferencing and thus is independent in regard to distance between the lecturer and the group.

During the workshop the students built their own ground station to receive amateur radio satellites and the ISS. Due to the COVID-19 pandemic the workshop could not be conducted fully as an in-person learning experience.

To overcome this obstacle, we chose a hybrid approach. Each session started with a short introductory lecture using a video conferencing software. After the introduction the students worked in groups following a written guide which we provided. During the rest of the session we assisted online in case of any questions or technical difficulties. We also supplied the schools with a Raspberry Pi single board computer, an inexpensive software defined radio and some coaxial cables for building antennas. The tasks necessary building the ground station included setting up the hardware, configuring the software and building antennas.

The written guide gave detailed information on how to complete the individual steps. It also provided some optional more in-depth information on propagation of electromagnetic fields, antenna theory and orbital mechanics to accommodate the range of participating school forms with different levels of proficiency and wide range of age of the students participating.

The students were very motivated to take part in this workshop, even as an extracurricular activity during their spare time. The students as well as the teachers involved also highlighted the interesting and useful lectures and the professional support via video conferencing software. This kind of hybrid approach was a new and innovative learning experience for the schools.

Our workshop offered the students an introduction to radio technology and space which would be otherwise beyond most teachers’ knowledge and capabilities. We demonstrated that such a workshop can be realized over distance besides pandemic conditions broadening the field of schools that can be involved.

Keywords
Amateur Radio, Education, International Space Station, Software Defined Radio

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Design and implementation of space educational activities to motivate young students in Catalonia

Guillem Olivella\textsuperscript{1}, Marcel Marin\textsuperscript{2}

Abstract

STEM education is a new interdisciplinary concept that fuses the learning objectives of sciences, technology, engineering and mathematics. After concluding that many undergraduate students are not interested in STEM disciplines and taking into account the admiration for space, a series of educational activities have been developed to increase their engagement in this field. The proposed project-based workshops are diverse: designing and launching High Altitude Balloons; building water rockets; protecting an egg from the impact with the ground after being dropped from a drone; designing and building paper gliders; 3D printing customized quadcopters, etc.

One of the most impressive activities consisted of designing, manufacturing and launching a low-cost high-altitude balloon to take photographs of the stratosphere. To do so, a kit was developed and validated: this contains a GPS tracker, a camera, an EPS box, a parachute and a helium balloon. The selection of the components was done trying to minimize the operational cost and maximizing the reliability of the design; the final High Altitude balloon weighs 350g and has reached altitudes around 27,000 - 30,000 m. The educational activity is a 3 to 4 days workshop in which the students go through the process of building their own HAB, launching it and eventually recovering it to obtain the photographs.

The activities have been implemented in multiple schools and high schools in Catalonia, and all of them have shown excellent results. After evaluating the reasons why the workshops were well-received, it was concluded that students were more implicated than in standard lectures because they went from a passive to an active mindset. Moreover, the workshops were designed to make them become curious and increase their eagerness to learn, while forcing them to think and to take important decisions that ultimately influence the final result, rather than observing and admiring somebody else’s work.

Keywords

STEM, Space, Workshop, HAB

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Collaborative Space Design project: A student’s experience

Francesco Bianchi¹,², Roorderick Ciggaar², Ludovica Formisan², Benjamin Harrison², Carla Tama², Vassili Tunjov²

Abstract
The student members of the Collaborative Space (systems) Design (CSD) project discuss its implementation and highlight its concepts. The CSD project is an elective course at the MSc Space Flight programme at the Delft University of Technology, Faculty of Aerospace Engineering, where students exercise the design process of a space mission, spacecraft or a major spacecraft subsystem in a team setting, along with several important external stakeholders. Focus was given to the application of concurrent engineering and systems engineering techniques. Interaction between the students and the external stakeholders was also extremely valued. Two teams participated, one designing a liquid oxygen electric pump and one a CubeSat asteroid observer mission. In this work the students report their experience, highlighting how they approached the different phases of the design process. Positives and negatives of the course are also presented, together with some feedback on potential modifications to future editions of the course.

Keywords
Engineering, Space, Education, Design Project
Space education activities at the Romanian Science Festival

Sandor Kruk¹, Oana Romocea¹, Eliza Casapopol¹, Cristian Ignat¹, Iuliana Bledea¹, Alina Vizireanu²

Abstract
Eastern European countries, in particular Romania, offer much fewer opportunities for science and space outreach and informal science education compared to the West. Romanian Science Festival was founded in 2018 with the aim of answering questions raised by the inquisitive minds of children all over Romania. In 2019, we reached over 20,000 people with our live events: open-air science festivals, space talks and astronomical observations. During the COVID-19 pandemic, we organised 53 live webinars of over 70 hours in total, one of the largest scientific resources in the Romanian language. Moreover, we visited 150 schools across the country, including rural areas, providing an opportunity for students to meet scientists online.

Space-related topics are a key focus of the science festival as they are not included in the Romanian school curriculum. That is why the resources in the form of the expertise and career orientation offered by our mentors are so valuable to the students. The topics we address include Astronomy (asteroids, black holes, extrasolar planets, etc.), Space Exploration, Satellite Design and Earth Observations. In 2021 we organised the ‘Space month’ during which thousands of students had the opportunity to discover careers in space, participate in a space art competition and meet the only Romanian astronaut, Dumitru Prunariu, in celebrations of 40 years’ of his space flight. Through mentorship, students discover opportunities to study and do research in astronomy. All these activities expose the public to the latest discoveries in the field, thus highlighting the importance of investing in fundamental research. This is just the beginning. The Romanian Science Festival story will continue because our team is determined to create a systemic impact in education. We will continue to add new chapters, stimulating the curiosity and imagination of people fascinated by science and space.

Keywords
astronomy, space education, science festival, webinars, meet-a-scientist

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Monitoring natural phenomena from the classroom with Edusat. Proposal for a teaching guide (and support material)

Rosa Olivella¹, Carla Garcia², Laura Olivas¹, Pep Sitjar¹

Abstract
Satellite images and remote sensing allow us to identify the effects of natural and human-made changes that occur on Earth: fires, floods, urban development, deforestation, etc. Thanks to the Copernicus programme, satellite images of the entire world are now available, with a near-daily frequency that allow the identification and monitoring of all these natural phenomena and human activities that produce notable changes to the Earth’s surface.

All these phenomena are forming part of the concerns of many young people who see the future of their planet in danger. The Edusat platform explores these phenomena from space and provides a didactic guide to understanding the effects of global environmental change, right in the classroom. In this way, we bring remote sensing closer to a public that until now was rarely involved in this discipline. We do it from a didactic and practical point of view, connected with real data from Sentinel satellites and thanks to EO Browser application.

Keywords
Climate change, Copernicus, remote sensing, satellite images, teaching material

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Panel: Smallsats Technology I

Secondary Auditorium, 09:30 am – 11:00 am
Montsec Ground Station

M. Badia\textsuperscript{12}, A. Perez-Portero\textsuperscript{12}, Aina García\textsuperscript{3}

Abstract
In every space mission, the ability to contact the satellite to transmit or receive telecommands and data is one of the critical parts, so having a good ground segment is fundamental.

In support to \textsuperscript{3}Cat-2 operations a ground station was first developed by the UPC NanoSat Lab at UPC Campus Nord premises. However, due to increasing radio frequency interference it was moved to the Institute Space Studies of Catalonia (IEEC) - Observatori del Montsec (OdM), located in Sant Esteve de la Sarga, Lleida. This location has outstanding reception conditions in terms of very weak interference levels, and excellent elevation mask (i.e. satellites can be tracked even below the horizon).

The ground station is equipped with a TX/RX Yagi antenna for amateur bands VHF (144-146 MHz) and UHF (435-438 MHz), and it also includes an S-band 3-meter dish in the commercial band (2025-2110 MHz, 2200-2290 MHz) for reception that will be upgraded for transmission in 2022. The antenna rotors, receivers etc. are remotely controlled to the operation-center in Barcelona and operations can be automated.

Nowadays, the ground station is jointly operated by the UPC NanoSat Lab and the IEEC in support to the Catalan New Space strategy, in addition to the upcoming UPC missions.

Keywords
CubeSat, Ground Segment, S-Band, UHF, VHF

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Deployable Fresnel Zone Plate antenna for CubeSats

Alejandro García 1, Adrián Márquez 2, Adriano Camps 2

Abstract
Earth Observation satellite missions can provide global and frequent coverage. In the past decade we have seen an explosion of these missions based on three unit CubeSats, notably with Planet and Spire constellations of visible and near-infrared imagers and GNSS-Radio Occultations payloads. One of the most important parts of these type of payloads is the antenna, which is limited due to the dimensions of the CubeSats. Today, the largest deployable antenna for CubeSats has a diameter of 50 cm and it was part of RainCube rain radar. ESA is currently sponsoring two studies to develop a 1 m deployable reflector antenna for CubeSats. Although the most common solutions are the deployable reflectors, Fresnel Zone Plate antennas are a simple type of antennas that can overcome some of the technical limitations of these reflectors.

In this paper we will present the design and tests of a deployable Fresnel Zone Plate antenna with 155 cm diameter, at a distance of 58 cm from the feeder. During the design, the modularity of the system has been considered, so that other antenna types can also be deployed. This antenna has a triangular shape, and each end is attached to a telescopic carbon fiber rod, which is deployed by means of a toothed belt that pushes them from its inner part. Each toothed belt is pushed with a DC motor.

If accepted for a launch of opportunity, this antenna will be used in a GNSS-Radio Occultations payload onboard 3Cat-8, one of the future satellite missions of the UPC NanoSat Lab.

Keywords
Fresnel Zone Plate, Deployable antenna, CubeSat

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**Deployment mechanism for an L-Band Helix antenna on-board the 3Cat-4 1U CubeSat**

*Lara Fernandez*, Marco Sobrin, Oriol Milian, Andrea Aguilella, Arnau Solanelles, Marc Badia Ballús, Joan Fransesc Munoz-Martin, Joan Adria Ruiz-de-Azua, Miquel Sureda and Adriano Camps

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**Abstract**

Earth Observation (EO) is key for climate and environmental monitoring at global level, and in specific regions where the effects of global warming are more noticeable, such as in polar regions, where ice melt is also opening new commercial maritime routes. Soil moisture is also useful for agriculture and monitoring the advance of desertification, as well as biomass and carbon storage.

Global Navigation Satellite System - Reflectometry (GNSS-R) and L-band microwave Radiometry are passive microwave remote sensing techniques that can be used to perform these types of measurements regardless of the illumination and cloud conditions, and -since they are passive- they are well suited for small satellites, where power availability is a limiting factor.

GNSS-R was tested from space onboard the UK-DMC and the UK TechDemoSat-1, and several missions have been launched using GNSS-R as main instrument, as CyGNSS, BuFeng-1, or the FSSCAT [1] mission. These missions aim at providing soil moisture [2], ocean wind speed [3], and flooding mapping of the Earth. L-band microwave radiometry data has also been retrieved from space with SMOS and SMAP missions, obtaining sea ice thickness, soil moisture, and ocean salinity data [4].

The 3Cat-4 mission was selected by the ESA Academy "Fly your Satellite" program in 2017. It aims at combining both GNSS-R and L-band Microwave Radiometry at in a low-power and cost-effective 1-Unit (1U) satellite. Moreover, the 3Cat-4 can also detect Automatic Identification System (AIS) signals from vessels.

The single payload is the Flexible Microwave Payload 1 (FMPL-1) [5] that performs the signal conditioning and signal processing for GNSS-R, L-Band microwave radiometry and AIS experiments. The spacecraft has three payload antennas: (1) a VHF monopole for AIS signals; (2) an uplooking antenna for the direct GPS signals; (3) a downlooking antenna that captures reflected GPS signals, and for the Microwave Radiometer. The downlooking antenna is a deployable helix antenna called the Nadir Antenna and Deployment Subsystem (NADS) which has a volume of less than 0,3U when stowed, achieving an axial length of more than 500 mm when deployed.

As part of this mission, the design of the NADS antenna, its RF performance, as well as the environmental tests performed in terms of structural and thermal space conditions will be presented.

**Keywords**

CubeSat, GNSS-R, microwave radiometry, earth observation, nanosatellite

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EIRFLAT-1: A FlatSat platform for the development and testing of the 2U CubeSat EIRSAT-1

Jack Reilly¹, ⁵, David Murphy², ⁵, Maeve Doyle², ⁵, Sarah Walsh², ⁵, Sai Krishna Akarapu², ⁵, Daithí de Faoíte², Rachel Dunwoody², ⁵, Jessica Erkal², ⁵, Gabriel Finneran², ⁵, Joseph Mangan², ⁵, Fergal Marshall⁴, ⁵, Lána Salmon², ⁵, Eoghan Somers³, ⁵, Joseph Thompson³, ⁵, Alexey Ulyanov², ⁵, Lorraine Hanlon², ⁵, David McKeown³, ⁵, William O’Connor³, ⁵, Ronan Wall², ⁵, Sheila McBreen², ⁵

Abstract

The Educational Irish Research Satellite (EIRSAT-1) is a 2U CubeSat being designed, built and tested at University College Dublin. A FlatSat platform known as EIRFLAT-1 has been constructed to enable the testing and development of the CubeSat. EIRFLAT-1 facilitates the electrical connections between CubeSat components while leaving key interfaces accessible for test equipment and allowing for the hot swapping of components. Commercial Off The Shelf and in-house developed hardware has been tested using EIRFLAT-1 at component, subsystem and full system level. In addition, the FlatSat has been used for flight software development. This paper describes the design of EIRFLAT-1 including electrical and mechanical components and additional ground support equipment developed to assist in the testing and development activities. EIRFLAT-1 has proven to be an invaluable tool for testing and has led to the discovery of issues and unexpected behaviour with flight hardware which would have contributed to schedule delays if undiscovered until after the satellite was assembled. Moreover, EIRFLAT-1 facilitated early and incremental testing of both software and operations procedures. The schematics for the electrical design of EIRFLAT-1, which is compatible with all CubeSat Kit PC/104 components, has been made publicly available for use by other educational CubeSat teams.

Keywords
EIRSAT-1, CubeSat, FlatSat, Ground Support Equipment

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STAR-XL: Student Transponder for Satellite Ranging on X & L-band

C. P. Bridges¹, P. Bladen, S. Lane, P. Hope, M. Friesch, T. Brown², D. Bowman, G. Shirville³

Abstract
The ESA ESEO Mission [1] included an amateur radio payload [2]. The results of which included the development of radio technologies that utilised final year student projects over a 5 year period. Many lessons regarding compliance and process enabled a new payload to follow: the Student Ranging Transponder Radio for X-band and L-band (or STAR-XL). The STAR-XL design leverages key aspects of the ESEO payload design for a generic CubeSat platform; including TT&C voltage and current sense circuitry, receiver circuitry, and flight software. But instead of a maximum 4800 bps telemetry and transponder system - the STAR-XL targets a 100 kHz bandwidth system that will allow faster downlink rates that are forward error correction, link margin and modulation order dependent. With 100 kHz bandwidth, the linear receiver is designed to also operate as a transponder - enabling ranging and navigation applications such as orbit determination and further experiments from amateur radio groundstations. This paper details the recent student project efforts in three key areas: a new STM32-based on-board computer, an X-band up-converter board and dual X/L band patch (as shown in Fig. 1). The new OBC includes an IQ modulator for transmitting complex waveforms and an optimised flight software suite that takes advantage of dual DMA hardware on-chip to reduce overheads. The X-band upconverter board required the development of new safety interlock and RF chain circuitry on a Rogers (RO4350B) PCB material. A new dual X/L-band patch antenna and filter circuit is also built and measured. Each of these projects has led to new lessons and increased the real-world case studies used to teach spacecraft avionics.

Keywords
Transponder, Satellite, Ranging, Radio

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Figure 1. STAR-XL CAD Blender Model
Experiences in Firmware Development for a CubeSat Instrument Payload

Joseph Mangan¹, David Murphy², Rachel Dunwoody², Maeve Doyle², Alexey Ulyanov², Mike Hibbett³, Sai Krishna Reddy Akarapu³, Jessica Erkal⁴, Gabriel Finneran⁵, Fergal Marshall⁶, Jack Reilly⁷, Lána Salmon⁷, Eoghan Somers⁸, Joseph Thompson⁴, Sarah Walsh², Lorraine Hanlon², David McKeown⁹, William O’Connor⁴, Brian Shortt⁵, Ronan Wall² and Sheila McBreen²

Abstract
Recent advancements in gamma-ray detector technology have brought new opportunities to study gamma-ray bursts and other high-energy phenomena. However, there is a lack of dissemination on the development methods, tools and techniques used in the production of instrument flight firmware. This is understandable as firmware for spacecraft payloads may be proprietary or exceptionally hardware specific and so is not always published. However, this leaves a gap in the knowledge for CubeSat teams, especially those consisting of university students who may be building a custom spacecraft payload with limited initial experience. The Gamma-Ray Module (GMOD) on-board EIRSAT-1, a 2U CubeSat in the 2nd European Space Agency Fly Your Satellite! programme, is one such instrument. GMOD features a 25x25x40mm Scionix CeBr3 scintillator, coupled to an array of 16 (4x4) JSeries OnSemiconductor MicroFJ-60035-TSV silicon photomultipliers (SiPMs) with readout provided by the SIPHRA IDE3380 application specific integrated circuit. The instrument is supported by the Gamma-Ray Module motherboard which controls and configures the instrument, providing regulated voltage and current sources as well as generating time tagged event packets and a temporary on-board flash storage. At the core of this system is the Texas Instruments MSP430FR5994 microcontroller. A custom firmware was produced for the instrument by the EIRSAT-1 team over numerous cycles of testing and development to reliably perform the long duration tasks of readout, storage and transfer of time tagged event data to the EIRSAT-1 on-board computer. Recognising the value of sharing our experiences and pitfalls on firmware development with the wider CubeSat community, this paper will provide an introduction to GMOD, with focus primarily on the development approach of the firmware. The development, testing, version control, essential tools and an overview of how the resources provided by the device manufacturer were used will be examined, such that the lessons learned may be extended to other payloads from student-led missions.

Keywords
EIRSAT-1, GMOD, FYS!, Gamma-Ray Detector, Firmware, Software, MSP430

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Development of a Proof-of-Concept Space Propulsion System for Nanosatellite applications using Additive Manufacturing

Andy Chia¹, Vinayak Prabhu¹, An Zhi Gan¹, Melvin Puah¹, Vincent Lek¹, Teoh Woik Kiong¹, Vivian Shie Thow¹

Abstract

In this project, Additive Manufacturing techniques was used to develop a proof-of-concept space propulsion system for nanosatellite applications. The main propulsion unit is made up of a metallic structural housing that is additively manufactured using aluminium powder (AlSi10Mg) on the EOS M290 machine. This housing serves as the reservoir that stores nitrogen gas as the propellant, and other components of the propellant system are assembled into it. The novel feature of the housing is that the propellant feed lines are integrated into the structure. This eliminated welds and joints typically found in conventional propellant storage tank, thereby minimizing leakage whilst simplifying assembly and integration. At the same time, the housing was designed using Design for AM techniques, and this made it possible to increase propellant storage capacity by minimizing support structures. The miniature propulsion nozzle, a key component of the propulsion system, was produced using micro-milling techniques to produce a full 3D converging-diverging profile.

A secondary objective of the project was to validate this unique approach by conducting in-space validation experiments to determine the viability of AM in the development of space propulsion applications. Work is currently on-going in the assembly and integration of the proof-of-concept propulsion payload into a 1U Cubesat, where it will serve as the primary payload. This Cubesat mission features a secondary payload which is a commercial off-the-shelf imaging sensor with M12 ruggedized lens that will be tasked with space imaging applications. The current plan is to launch the Cubesat from the International Space Station using the J-SSOD module.

The project was carried out by a multi-disciplinary staff/student team comprising faculty members with domain expertise in aerospace, additive manufacturing, avionics/electronics, advanced machining, quality assurance and mechanical testing. The faculty members were responsible for the design, development, and integration of the proof-of-concept propulsion and imaging payloads. The project also provided valuable opportunities for our students to gain hands-on experience in space and satellite engineering. The students hail from the diplomas in aerospace, aviation systems and advanced & digital manufacturing. They were co-located within the Assembly, Integration and Testing lab which features a class 10,000 clean booth. The students supported Cubesat and payload development and integration as well as mechanical testing.

Keywords
AlSi10Mg, Additive Manufacturing, Design for AM (DfAM), Direct Metal Laser Sintering (DMLS), Space Propulsion

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Design and Development of the Re-Entry Sensor System for the CubeSat Mission SOURCE

Hendrik Kuhm ¹, Hendrik Fischer ² Lars Blümmer ², Emily Seeberg ², Vincent Kirchner ²,

Daniel Galla ², Sabine Klinkner ³

Abstract
With the number of man-made objects being launched into orbit steadily increasing, space debris is one of the big challenges for future space flight. In order to better assess the danger to humans on Earth's surface, re-entry should be researched in more detail. SOURCE serves as a 3U+ satellite platform designed and developed by the small satellite student society (KSat e.V.) and the Institute of Space Systems (IRS) at the University of Stuttgart. It was selected by ESA in 2020 to be part of the 'Fly your Satellite' program, has successfully completed the CDR and is currently preparing for the MRR. SOURCE's objectives are education, verification of several cost-saving, not yet space-proven technologies for orbital use, capturing images of meteoroids entering Earth's atmosphere and documenting its own demise during re-entry by analysing atomic oxygen, heat flux- and pressure data. In order to receive data for as long as possible during re-entry, the satellite switches from S-band to Iridium (inter-satellite link) communication at an altitude below 200 km.

For the in-situ measurement during the re-entry, SOURCE is equipped with two Flux-Phi-Probe (FIPLEX) sensors for the measurement of atomic oxygen and five additional sensor arrays. Each array contains one pressure sensor and two heat flux sensors, one commercial and one developed by the IRS. The arrays are placed at five positions in-line across the satellite to reduce effects of tumbling during the re-entry and to allow for the measurement of gradients.

For a first estimation of the expected value ranges, simulations were performed with the software PICLas, developed by the IRS and the Institute of Aero-and Gas Dynamics (IAG) at the University of Stuttgart. In an iterative process, the collected data will be used to further improve this simulation software after the re-entry of the SOURCE satellite.

The aim of this paper is to describe the design philosophy and development process of the sensor readout electronics. The tests carried out are presented and the first results are presented.

Keywords
Re-Entry, CubeSat, Sensors, Tests
Panel: Smallsats Technology II
Secondary Auditorium, 11:30 am – 12:30 pm
The Structural Analysis of AlainSat-1: An Earth Observation 3U CubeSat
Wan Faris Aizat Wan Aasim¹, Mai AlMazroue², Mohamed Okasha³, Abdul Halim Jallad⁴

Abstract
This paper presents the structural analysis of a remote sensing CubeSat planned for launch in Q4 2022. AlainSat-1 is a collaborative endeavour between the IEEE Geoscience and Remote Sensing Society and the National Space Science and Technology Center at United Arab Emirates University. To ensure that the conceptual design of the satellite satisfies design requirements Quasi-Static Analysis, Modal Analysis and Random Vibration Analysis are conducted using SIEMENS NX. These analyses identify the satellite’s fundamental frequencies along with measuring the resulting deformations and stresses it experiences as a response to both the static and dynamic loads exerted by SpaceX’s Falcon 9 launch vehicle. Modal Analysis results show that the satellite’s lowest fundamental frequency 120.405Hz, complies with standards set by the QB50 Project and both Quasi-Static and Random Vibration analysis indicated that stress values are within safe limits. Issues detected during the various phases of the analyses such as occurrence of unusually high concentrated stresses and discrepancies between different element stress results are highlighted and the subsequent approach towards overcoming them are explained. Future work will involve validating obtained results experimentally using a vibration shaker test equipment on the actual AlainSat-1 structure.

Keywords
3U CubeSat, Finite Element Analysis, Modal Analysis, Structural Analysis, Vibration

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Attitude Determination and Control System

João Revés¹, Inês Viveiros²³, Rita Cunha³, Rui Rocha²³, João Paulo Monteiro³, Ana Borralho³, Paulo André²³, Manfred Niehus², Pedro Mendes², João Ruas³, Miguel Soares³, David Pinho³, Vladlen Galetsky³, Carlos Fernandes²³, Emmanuel Zambrini Cruzeiro², Rafaela Ribeiro²³, Yasser Omar²³

Abstract
This article presents the QuantSaT-PT project, an effort to create the first Portuguese nanosatellite for space to ground quantum communication. Focused on the Attitude Determination and Control System, it describes the different elements that allow for the attainment of diverse accuracy levels required for separate mission stages. Given the harsh pointing precision necessary for establishing a quantum downlink, the implementation of this module presents a major challenge in the Cubesat field. Furthermore, the introduced architecture aims to reduce system cost by replacing the state-of-the-art star tracker with ground beacon detection.

Keywords
ADCS, Beacon, CubeSat, Downlink, QKD

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Thermal Characterization Testing of a Robust and Reliable Thermal Knife HDRM (Hold Down and Release Mechanism) for CubeSat Deployables

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Abstract
Thermal knife HDRMs (Hold Down and Release Mechanisms) are commonly used in CubeSats and other small satellites. However, detailed information on proven designs is difficult to find. Design of a robust and reliable mechanism can present technical challenges which may only become apparent during testing, and often only when tested in a space representative environment.

A custom thermal knife HDRM was designed and built for the antenna deployment module of EIRSAT-1 to deploy four coil spring antenna elements, but the same or a similar design could be repurposed quite easily to release a wide range of CubeSat deployables. In this design resistors are used to cut a dyneema line.

For robustness and reliability the thermal response of the mechanism must be well understood. To reach the melting point of the dyneema (150°C) the power dissipated in the resistors must often exceed the maximum rated value. Therefore choosing the operating current and the burn time is a careful trade-off between ensuring that the resistor reliably cuts the dyneema line and also ensuring that the resistor, solder joints and any other components nearby are not damaged by the high temperatures. These choices are further complicated by the requirement that the mechanism operates over a range of temperatures.

A thermal vacuum test campaign was carried out to better understand and characterise the thermal behaviour of the EIRSAT-1 mechanism. For the test a model of the mechanism was prepared with several temperature sensors installed. Two of these sensors were installed directly on the body of the resistors using a thermally conductive epoxy. Burn tests were performed in vacuum at temperatures between -40°C and +60°C.

The test shows many interesting results including the effect of the dyneema lines on the thermal response, the possibility of desoldering the burn resistors and a comparison between the performance at ambient and vacuum conditions. Finally a summary is given of the key technical challenges associated with this type of mechanism along with some recommendations to help make future designs more robust and reliable.

Keywords
CubeSat Deployable, EIRSAT-1, Hold Down and Release Mechanism, Thermal Knife

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Design and calibration process of solar sensors for small satellite missions

Angel Porras-Hermoso¹, Daniel Alfonso-Corcuera, Javier Piqueras, Elena Roibás-Millán, Javier Cubas, Javier Pérez-Álvarez, Santiago Pindado

Abstract
In combination with magnetometers, solar sensors are one of the most used instruments for determining the attitude of small satellites. These devices use the photoelectric effect to produce an electrical current. This electrical current, or the voltage associated with the electrical circuit of the solar sensor, is measured in order to compute the angle of incident of the sun with the normal direction of the sensor. Then, together with the computed angles of other solar sensors on different faces of the satellite, the sun's direction in relation to a spacecraft can be calculated. Solar sensors are simple devices whose low-cost design based on photodiodes can be developed by students. During the design and fabrication process of a solar sensor, one of the most important tasks is the accurate estimation of the sensor response in the space radiative environment. It is possible to simulate the Sun’s radiation spectrum, but the equipment and facilities needed are costly for a university project. In this paper, the design and calibration process of satellite solar sensors carried out together by students and teachers from the Master's degree in Space Systems (MUSE) from the Universidad Politécnica de Madrid is described. The process uses a calibration method that calibrates the photodiodes for space use without simulating the Sun’s radiation spectrum in the laboratory.

Keywords
ADCS, UPMsat-2, master in space systems, photodiodes, solar sensors

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Abstract
SOURCE (Stuttgart Operated University CubeSat for Evaluation and Education) is a 3U+ research CubeSat that is being developed by students at the University of Stuttgart in cooperation with the Institute for Space Systems and the Small Satellite Student Society KSat e.V.. The objectives include technology demonstrations, atmospheric research and the investigation of satellite demise while also serving as an educational program. SOURCE was selected by ESA's "Fly your Satellite" program and is currently in Phase D.

The electrical power supply system combines commercial off-the-shelf parts with self-developed units to meet the requirements of the payloads. The solar array configuration and Power Conditioning and Distribution Unit (PCDU) are self-developed, while the battery is a commercial product.

A total of 56 solar cells provides up to 32W under ideal conditions, which can be stored in a 75Wh space-qualified lithium-ion battery. To maximise the power output of the solar cells, maximum power point tracking is performed by the PCDU. This is controlled by a radiation hardened microcontroller.

The PCDU provides regulated 3.3V, 5V and unregulated battery voltage to the subsystems with 32 switchable outputs, 27 of which are latch-up current protected. The microcontroller controls these individual output channels and the switching between the various CubeSat modes as commanded by the on-board computer. Additionally, every output channel power consumption is monitored for overcurrents. The PCDU functions as a watchdog by checking the health of the on-board computer, rebooting it in case of a failure. High priority commands can be sent directly to the PCDU from the ground via the communication system, bypassing the on-board computer. These can reset either the communication subsystem, the on-board computer or the entire satellite.

Four hybrid inhibits, using a combination of mechanical switches and FETs are integrated in the PCDU, replacing the usual fully mechanical design. Three are used to deactivate the satellite in the deployer configuration and the fourth is a remove-before-flight inhibit.

An engineering model was manufactured during phase C and is being tested functionally, environmentally and for performance. This paper presents the detailed design of the PCDU, the acquired test results and outlines issues encountered during the tests.

Keywords
CubeSat, EPS, PCDU, SOURCE
Panel: Smallsats Technology III

Secondary Auditorium, 12:30 pm – 1:30 pm
Improved Sensor Fusion for Flying Laptop Based on a Multiplicative EKF

Maximilian von Arnim¹, Steffen Gaiser², Sabine Klinkner²

Abstract
Flying Laptop is a small satellite carrying an optical communications payload. It was launched in 2017. To improve the satellite’s attitude determination, which is used to point the payload, a new sensor fusion algorithm based on a low pass filter and a multiplicative extended Kalman filter (MEKF) was developed. As an operational satellite, improvements are only possible via software updates.

The algorithm estimates the satellite’s attitude from star tracker and fibre-optical gyroscope (FOG) measurements. It also estimates the gyroscope bias. The global attitude estimate uses a quaternion representation, while the Kalman filter uses Gibbs Parameters to calculate small attitude errors. Past Kalman filter predictions are saved for several time steps so that a delayed star tracker measurement can be used to update the prediction at the time of measurement. The estimate at the current time is then calculated by predicting the system attitude based on the updated past estimate. The prediction step relies on the low-pass-filtered gyroscope measurements corrected by the bias estimate.

The new algorithm was developed as part of a master’s thesis at the University of Stuttgart, where Flying Laptop was developed and built. It was simulated in a MATLAB/Simulink environment using the European Space Agency’s GAFE framework. In addition, the new filter was applied to measurement data from the satellite. The results were used to compare the performance with the current filter implementation.

The new Kalman filter can deal with delayed, missing, or irregular star tracker measurements. It features a lower computational complexity than the previous standard extended Kalman filter used on Flying Laptop. The mean error of the attitude estimate was reduced by up to 90%. The low pass filter improves the rotation rate estimate between star tracker measurements, especially for biased and noisy gyroscopes. However, this comes at the cost of potentially less accurate attitude estimates. Educational satellites benefit from the new algorithm given their typically limited processing power and cheap commercial-off-the-shelf (COTS) sensors. This paper presents the approach in detail and shows its benefits.

Keywords
Attitude Determination Systems; Fibre-Optical Gyroscope; Kalman Filter; Sensor Fusion; Star Tracker

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Mission analysis of nanosatellite constellations with OpenSatKit
Iván Sermanoukian Molina¹, Lluís Montilla Rodríguez², David González Diez², Miquel Sureda Anfrés², Jorge Mata Díaz², Juan José Alins Delgado²

Abstract
CubeSat reliability is still considered an obstacle due to the sizeable fail rates generally attributed to the dead-on-arrival cases and early subsystem malfunctions. Thus, as CubeSats' primary purpose moves from technology demonstrations and university projects to missions where a significant risk of failure is not acceptable, an inexpensive method to emulate low Earth orbit constellations is being researched.

The results presented have been developed in the framework of the PLATHON research project, which intends to develop a Hardware-in-the-loop emulation platform for nanosatellite constellations with optical inter-satellite communication and ground-to-satellite links. Consequently, a crucial aspect of this project is to have a sufficiently precise orbital propagator with real-time manoeuvring control and graphical representation.

NASA's OpenSatKit, a multi-facet open-source platform with an inbuilt propagator known as 42, has been chosen to analyse the programme's feasibility to create a constellation testing bench. In order to develop an initial Software-in-the-loop application, the pre-processing of files has been automated; enhanced Attitude Determination and Control System manoeuvres have been added and configured through bidirectional socket interfaces, and the results format has been modified to be easily post-processed with MATLAB and Simulink.

Keywords
Constellations, Inter-Process Communication, Nanosatellites, Orbit Propagation

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Designing Avionics for Lasers & Optoelectronics

H. K. Chau, I. Boyle, P. Nisbet-Jones¹, C. P. Bridges²

Abstract

Unlike imagery-based Earth observation (EO) which has become very widely and cheaply available, gravity sensing EO has not yet emerged from its fundamental science roots. The challenge therefore is to develop gravity sensing instruments that can replicate the success of widespread imagery based EO. There are three main gravity sensing mechanisms under investigation: laser ranging (e.g., GRACE-FO [1]); atom interferometers, which measure gravitation perturbations to the wavefunctions of individual atoms; and ‘relativistic geodesy’ which uses atomic clocks to measure the gravitational curvature of spacetime. All three of these measurement systems use stabilised lasers as their main enabling technology. However traditional laboratory laser systems struggle to meet the robustness, reliability, or low size, weight, and power (SWaP) requirements for use in space.

A demonstrator was build that adapted telecommunications industry COTS components, and software radio FPGA/DSP techniques, to develop a new all-fibre space-qualified stabilised laser systems for geodesy that have equivalent performance to laboratory systems. This instrument was used to develop a 780 nm laser system that is stabilised to the Rubidium D2 line - the stabilised laser most commonly required by the quantum and atomic sensing field achieving sufficiently high laser performance for the laser system to be immediately useful for quantum applications (stability: 1-10 kHz, accuracy: 1 MHz); and in an ultra-compact package that has the potential to be used in space (1 litre, 0.5 kg, 10 W) [2].

This paper reports on the current student work that advances the instrument further towards a flight payload – and key avionics design considerations for future researchers. This takes lessons learnt from the ESA ESEO software radio payload in utilising ECSS design practices [3] to fabricate a robust and modular avionics back-end board that can operate with numerous front-end laser or opto-electronics configurations for different quantum applications.

The new board consists of a single PCB containing circuitry for TT&C reporting of power supply and voltage conditioning, the current and temperature electronics needed to control a diode laser on orbit, interfaces for photo detectors and opto-electronics, and a high-speed analogue-to-digital conversion network centred around a FPGA. As an example, digital signal processing performed frequency-modulated spectroscopy on a warm Rubidium vapour using an all-fibre optical arrangement.

Keywords
Laser, Optoelectronics, Avionics, FPGA

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Assessment of a machine-vision-assisted test bed for spacecraft magnetic cleanliness analysis

Alejandro Sans Monguílló¹, Bagus Adiwiluhung Riwanto², Jaan Praks²

Abstract
Small satellites are becoming increasingly popular in several applications, in which attitude systems might require high precision performance. These spacecrafts are susceptible to magnetic disturbances in orbit, such as the interaction between the satellite and Earth’s magnetic field. However, a major disturbance torque is generated by the residual magnetic moment. Therefore, a magnetic cleanliness analysis must be considered in order to meet the requirements for magnetic-sensitive instruments and subsystems. Studies on magnetic environment management are underway for the FORESAIL-1 and FORESAIL-2 missions using the optical magnetic test bed of Aalto University. This is particularly important for FORESAIL-2 which aims to precisely measure the orbital ambient magnetic field with a high sensitivity magnetometer.

One of the parts of a spacecraft magnetic cleanliness analysis is the modelling of the residual magnetic moment as a set of magnetic dipoles. The dipoles are estimated from the measured magnetic field surrounded by the device-under-test (e.g., complete satellite, or its individual subsystems) using a stochastic estimation algorithm. The measurements are performed in a Helmholtz cage where the device and a low-noise magnetometer are placed, and detected by a smart camera using visual detection markers (ArUco). Information provided by the detection of the markers is then used for representing the position of the magnetometer and measured magnetic field points in the device-under-test coordinate frame.

The camera detection accuracy is improved with data fusion from several ArUco markers, and the system performance is assessed by verifying the estimated magnetic moment results using known permanent magnets. Using this methodology for calculating the residual magnetic moment, the system is able to estimate the dipole’s position and magnetic vectors with a mean absolute error of 0.004 ± 9·10⁻⁷ m and 0.007 ± 1·10⁻⁴ A·m² respectively. The test bed can be used for the characterization of the magnetic moment when measuring small satellites, or its components, in order to mitigate the residual magnetic moment.

Keywords
Magnetic dipole moment, Optical magnetic test bed, Residual magnetic moment, Small satellite, Spacecraft magnetic cleanliness analysis

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Mechanical Design and Deployment of a Quasi-Rhombic Pyramid Drag Sail for Safe De-Orbit of a 3U CubeSat

Gregor MacAskill¹, Stefano Messina², Ignacio Serrano Martín-Sacristán³

Abstract
Orbital debris is rapidly becoming a more prevalent and alarming obstacle that, without immediate intervention, will undoubtedly become disastrous for human activity in space. The University of Glasgow’s microsatellite society, GU Orbit, has taken action to equip its 3U CubeSat ASTRAEUS-01 with a drag sail de-orbit device. This payload represents a simple and low-cost solution for the mitigation of debris in Low Earth Orbit (LEO) and is expected de-orbit the CubeSat within 12 to 24 months, depending on solar activity. These aspects are deemed fundamental for the mission and align with GU Orbit’s ethics of promoting space sustainability and accessibility.

In this article, the studies on the structure, material and Hold-Down and Release Mechanism (HDRM) of the drag sail system are evaluated and briefly discussed. The discussion starts by illustrating the 7m² quasi-rhombic drag sail that will deploy to increase the satellite’s atmospheric drag and allow the spacecraft to lose altitude and re-enter the atmosphere. Various aspects of the geometry and folding technique used to fit the drag sail on the CubeSat are analysed. Phenomena of material degradation such as thermal and oxygen degradation have been accounted for in the design to mitigate their effect over the duration of the mission. Tape spring booms coiled around a spool will release the drag sail from its folded state maintained throughout the mission. These have been dimensioned through a mathematical model in order to provide optimum deployment dynamics for the drag sail. The paper describes also how a simple and economic nichrome burn-wire HDRM has been integrated with the drag sail design to trigger the release sequence of the cover doors and the drag sail itself.

Keywords
GU Orbit, CubeSat, ASTRAEUS-01, drag sail, deployable, gossamer, space debris, LEO, student society, HDRM, sustainability

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Panel: REXUS/BEXUS

Auxiliary Room, 09:30 am – 11:00 am
Testing campaign for ECRIDA: the UV resin 3D printer flying on REXUS

Radu-Andrei Cioaca 1, Delia Vitalaru 2, Constantin Romica Stoica 2, Alexandru Hantascu 2, Cosmin-Florin Calcii 2, Ionut Adrian Sisman 2, Valentin Mocanu 2, Iulia Roman 2

Abstract
ECRIDA is a student project participating in the REXUS/BEXUS campaign that develops a UV resin 3D printer device capable of working in the low-gravity environment offered by the REXUS rocket flight. Our main objective is to describe the impact of low gravity on the UV resin 3D printing process by comparing samples printed on Earth with samples printed in space. Due to the requirements of the host vehicle and driven by the novel design of our device, a thorough testing campaign must be planned and completed to qualify the device for flight and maximise the success of the scientific objectives. This paper describes the requirements that the device must fulfil and goes into the design of our test plan describing the procedures and the results. Vacuum, vibration, pressure, and functional tests were performed and described together with our learned lessons and conclusions in our will to help student teams with their testing activities.

Keywords
3D printing, REXUS/BEXUS, milligravity, testing

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Lessons learnt during the REXUS program on how to manage a student project

Esmée Menting\textsuperscript{1}, Thomas Britting\textsuperscript{2}, Lars Pepermans\textsuperscript{2}, Bram Koops\textsuperscript{2}

Abstract
The paper discusses the lessons learnt during the SPEAR mission that takes part in the 12th cycle of the Rocket EXperiment for University Students (REXUS) sounding rocket programme. The mission originated after Delft Aerospace Rocket Engineering (DARE) designed a supersonic-capable drogue parachute and was unable to test it supersonically on the existing platforms available to the team. Hence, an experiment was proposed containing an ejectable test vehicle to deploy the parachute in supersonic conditions.

Throughout the 12th cycle of the REXUS program, the team has faced a number of challenges. Although during the project cycle the focus lied on resolving technical problems, in retrospect the logistical, social, and managerial challenges were just as relevant. Despite the fact that there is ample literature and knowledge available on methods to run commercial projects, it can be difficult to connect these practices to the workings of a student team. Therefore, this paper aims to collect and present the experience of the team on how to navigate challenges specifically related to student projects and their limited resources. Amongst which: ‘employment’ management (entry, performance and exit of team members), how to conduct internal and/or external technical reviews, assembly, integration and testing (AIT) efforts, planning and task management. As the team has gained these insights through trial and error, the mistakes made will be shared together with how this impacted the progress of the mission.

Keywords
Project management, mission planning, student project, REXUS.

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Abstract
Current developments in the aerospace industry point towards more frequent interplanetary travel in the future. However, the main focus of developments is on launcher technology, yet the descent of interplanetary probes is of high importance for the success of future missions. Additionally, to the present landing approaches using either a powered descent requiring fuel or a combination of different parachutes, a third method is investigated in this project. The chosen approach is called autorotation and is commonly used in helicopters. When a helicopter suffers a loss of power, it can still land and even choose its landing site without the utilization of an engine. Similar to parachutes, the presented technology can be applied to various atmospheric conditions by modification of rotor and control parameters. Moreover, a rotor in autorotation can provide directional control and thus the choice of a landing site, which is not feasible using a parachute. All these factors make autorotation an interesting option as an entry descent and landing (EDL) technology for interplanetary missions. Our project, Daedalus 2 implements the autorotation landing strategy as part of the REXUS student project campaign under DLR / ESA / SNSA supervision. Since 2018 we are developing the SpaceSeed Mk.2, a technology demonstrator that incorporates a rotor and all necessary technological means to perform an autorotation EDL maneuver from an apogee of 80 km. The mission concept is laid out within the presented paper. This includes the main challenges like miniaturization of the SpaceSeed v2 due to the size constraints of the REXUS rocket or the used sensors for height and position determination. The importance of a technology demonstrator tested on a sounding rocket to prove the feasibility of our presented system is laid out in our publication. Furthermore, the custom development of electrical, mechanical and software sub systems is discussed. Additionally, the planned mission profile will be explained, including flight phases and different activities conducted by the SpaceSeeds during flight. Moreover, the main differences and improvements to Daedalus 1 are being discussed.

Keywords
Reentry, Landing, Autorotation, Parachutes, Rotors
An investigation into cold weld adhesion for spacecraft repair after a space debris impact using space education based sub-orbital sounding rocket platform.

Mark Wylie¹, Leonardo Barilaro ²

Abstract

It has been observed that similar metallic materials, when in contact and undergoing relative displacements, can fuse or weld. In standard atmospheric conditions it is not common but in the space environment the inability of the surface interfaces to re-oxide after abrasive contact is hindered, atomic diffusion of the metal occurs, and this can lead to fusion. Oscillatory motion and Hertzian contact stress between the two surfaces plays a major role in the strength of the cold welded joint. It has been shown that the action of a low fretting load can almost double the adhesion force under cyclic loading even in terrestrial atmospheric conditions. In space, cold welding was first identified in the 1960’s as an adverse reaction. It has been attributed to anomalies and failures of deployable mechanisms. Other research has alluded to the potential of this phenomena for use in spacecraft repair in space. Examples where this may hold promise is repair of a spacecraft hull breach after hypervelocity impacts due to micrometeoroids or orbital debris. This research proposes an investigation into cold welding for use in spacecraft hull repair. The research intends to qualify an experimental apparatus to TRL 4 using a sub-orbital sounding rocket platform. A joint research effort between the Aerospace, Mechanical and Electronic Department at I.T. Carlow, Ireland, the Department of Aviation at Malta College of Arts, Science, and Technology, Malta is underway. The project aims at developing a test apparatus to apply a number of custom patches to simulated hypervelocity spacecraft hull breaches and investigate the adhesion properties during re-entry for a range of mechanical application conditions. A number of chambers may be tested and monitored using pressure transducers. After Phase 1 (terrestrial development and validation using a vacuum chamber), there will be an application to education based space programmes such as the one offered by the European Space Agency (REXUS). The core of the activity will be the design and testing of the experimental payload, simulating hull breaches, deployment the repair patch and monitoring of its performance during re-entry (Phase 2). The recovery of the payload will allow further metallurgical analysis of the cold welded joint (Phase 3). A conceptual 3-D model of the payload has been developed and is presented here. The data acquired from the sub-orbital flight experiment will test the validity of the hypothesis for use of cold welding for spacecraft hull repair but will also detail the development and implementation of mock hypervelocity impacts to rocket skin for the purposes of simulating hull breaches in the space environment.

Keywords
Cold welding adhesion, Hypervelocity impacts, Space debris, Spacecraft repair, Sub-orbital flight

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From BEXUS to HEMERA: The application of lessons learned on the development and manufacturing of stratospheric payloads at S5Lab

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Abstract
In the last years the S5Lab (Sapienza Space Systems and Space Surveillance Laboratory) from Sapienza University of Rome has given to the students the opportunity to gather knowledge on stratospheric payloads by supporting the design and development of two experiments selected for the participation in the REXUS/BEXUS educational Programme, managed by three european space institutions. The insights and lessons learned gathered during the participations in the REXUS/BEXUS educational programme gave the possibility to the student to take part in the development of a third experiment in the frame of the professional research programme HEMERA and complete it successfully. STRATONAV (STRATOspheric NAVigation experiment) was a stratospheric experiment based on Software Defined Radios (SDRs) technology whose aim was the testing of the VOR (VHF Omnidirectional Range) navigation system, evaluating its performance above the standard service volume, which was launched on BEXUS 22 in October 2016. TARDIS (Tracking and Attitude Radio-based Determination In Stratosphere) was developed as a follow up of STRATONAV between 2018 and 2019. Similarly to its predecessor TARDIS was a stratospheric experiment aimed at exploiting the VOR signal, with the aid of SDRs, to perform in-flight attitude and position determination, and was launched on BEXUS 28 in October 2019. After the launch of TARDIS, a team composed both by former STRATONAV and TARDIS students was formed for the development of a third stratospheric experiment going by the name of STRAINS (Stratospheric Tracking Innovative Systems), conceived by Sapienza University of Rome and ALTEC and supported by ASI. STRAINS main objective was the proof of concept of the possibility of achieving the Time Difference of Arrival (TDOA) and the Frequency Difference of Arrival (FDOA) for navigation purposes with the aid of SDRs. The experiment was developed between 2020 and 2021 exploiting the lessons learned from the former team members of the two BEXUS campaigns and was launched on board of the Hemera H2020 stratospheric balloon in September 2021 from Esrange Space Center, Kiruna, Sweden. After a brief description of the stratospheric payloads design and manufacturing, the paper will present the major lessons learned from the previous stratospheric experiments, STRATONAV and TARDIS, and their application to the development and manufacturing of the latest launched stratospheric experiment STRAINS, as well as their educational return to the students involved in the projects.

Keywords
Stratosphere; lessons learned; Students; REXUS/BEXUS; HEMERA

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Abstract

In the field of space travel, space communications has always presented a slew of obstacles and hurdles that must be overcome in order to complete a successful mission. Space limits inside a satellite or spaceship, vast distances between satellites and ground stations, and a phenomenon known as "Faraday Rotation" in the ionosphere are only a few of the most typical issues. Satellite antennas must be small, compact, efficient, and circularly polarized as a result of the aforementioned issues. The helix antenna is an excellent answer for all of the requirements. In this work we develop a deployment and pointing mechanism of a helix antenna operated with software defined radio algorithms. The features of helix antennas are exceptional, and they are especially suitable for satellite communication. Three coaxial cylinders, two stepper motors, one pulley, and one thread make up a deployment-pointing mechanism. The mechanism deploys the antenna along its longitudinal axis and turns it horizontally towards the ground station. During the flight, the antenna is deployed and retracted. Under different positioning situations, the GPS, an altimeter, and a compass calculate the gondola's position in order to rotate the antenna towards the Ground Station and close the communication link. The antenna's rotation mechanism is triggered by the integrated attitude determination and control system algorithms in order to correct the pointing and orientation towards the Ground Station. The antenna uses software defined radio algorithms to achieve weight and volume reductions while maintaining high efficiency and reconfigurability. The experiment includes a high-definition camera that provides real-time information on the antenna's orientation and condition. SHADE's flight on the BEXUS 28/29 balloon resulted in effective deployment and transmission, as well as the ability to receive and decode transmitted packets. The rotating mechanism met the pointing requirements, and all of the sensor's data was correctly saved to our system. Throughout the trip, there were no signs of thermal risk.

Keywords
Antenna Deployment, Helix Antenna, REXUS/BEXUS, Software Defined Radio, Stratospheric Balloon

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O-ZONE: affordable stratospheric air dynamic sampling device
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Abstract
The current situation regarding air pollution, global warming and the world approaching the point of no return have led the United Nations to focus on improving the environmental situation through the SDGs [1]. In line with these ambitions, O-ZONE team, was born in 2019 with the clear objective of taking concrete action against climate change [2].

The team’s goal is to build a compact, low-cost, and reusable device to sample stratospheric pollutants, at various altitudes and thus provide air quality indications in mid-range areas for monitoring, prevention, and rapid intervention in case of unpredictable events.

The O-ZONE team was therefore born as an idea of some students from the Aerospace Engineering course at the same University. The students took part in the REXUS/BEXUS project by Swedish National Space Agency (SNSA), Deutsches Zentrum für Luft- und Raumfahrt (DLR) and European Space Agency (ESA) [3]. As in each of these projects, the team tackled the various steps of space missions but, in this case, with extra constraints. They had to work during the lockdown with various complications due to the pandemic. Although the launch was delayed, the students carried on with their motivation and then launched their device on board the BEXUS 30.

The prototype launched in Kiruna - Sweden (at the Esrange base), and which reached an altitude of 27.8 km, is a sampling system for Volatile Organic Compounds (VOCs), such as NOx and SOx, Particulate Matter (PM) and Chlorofluorocarbons (CFCs) responsible for the depletion of the Ozone layer [4].

These types of samplers [2] fill the technological gap in atmospheric analysis; the current state of the art allows air to be monitored only statically from ground stations or by satellite analysis [5], while O-ZONE presents an accessible, easy-to-use and rapid in situ sampling method.

This paper describes the technical specifications and design aspects of the device and the experience that has allowed the students to grow as a team, especially in terms of personal skills and the ability to work with concurrent engineering and interdisciplinarity.

Finally, the experiment results will be shown.

Keywords
Atmospheric Pollution, SDGs, Sampling, CFCs, BEXUS30.

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Panel: Rocketry I

Auxiliary Room, 11:30 am – 12:30 pm
Findings from the ESA Education Fly a Rocket Campaign - Sensor Experiments Team

Ota Michalek¹, Mike Timmerman², Filip Szczechak³, Theodore Youds⁴, Jorge Alcañiz Gomez Del Pulgar⁵, Gloria Nallo⁶, Viktoria Kutnohorsky⁷, Helena Katarina Lehtiniemi⁸, Georgios Psaltakis⁹

Abstract

The paper summarises the endeavour of 24 students during a Fly a Rocket campaign in October 2021. The programme is an educational week-long activity aimed at university students with limited hands-on experience. The campaign took place at Andøya Space Center and was possible by the collaboration of ESA Education, Andøya Space, and the Norwegian Space Agency. The participants learnt about the fundamental aspects of a rocket launch campaign, from deciding the scientific case, rocket assembly, safety briefings and countdown procedures. The students came from diverse backgrounds, such as aerospace engineering, electrical engineering, physics, mathematics and astronomy. They were divided into three groups for the campaign: payload, telemetry and sensor experiments. The paper mainly focuses on the findings of the sensor experiments group. It first introduces the launch campaign details and the online course. Then, all the steps that went into the scientific cases which students had to prepare are summarised. The cases they decided to work on included a comparison of the trajectory simulation done in OpenRocket and the real-life measurements, cloud detection using optical and humidity sensors, the measurement of the spin of the rocket and the collection of data from the atmosphere that was compared to the international standard atmosphere. This paper aims to share the learning outcomes from this campaign with the wider public and students. The collaboration and responsibilities of the students taught them many important lessons, most notably the importance of diversity and the significance of cross-communication between teams.

Keywords

Andøya Space Center, ESA Education, Fly a Rocket, OpenRocket, Sensor experiments

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Selection Criteria for Parachutes of Student-Built Sounding Rockets

Thomas Britting¹, Wesley Leonardus Jacobus Rudolf Toussaint², Kristina Vukosavljević², Mohamed Sahir Sujahudeen², Niklas Emil Knöll², Lars Pepermans³ and Yohan Pascal Hadji³

Abstract
Various parachute-type decelerators can be considered in the design of a sounding rocket recovery system. During the development of various flagship missions of Delft Aerospace Rocket Engineering (DARE), the Parachute Research Group of DARE has developed several methods and criteria to select the right parachutes for a given mission. This paper presents and discusses the operational envelopes, advantages, and disadvantages of different parachute types. The parachutes described in the paper are variations of cross parachutes, disk-gap-bands, ringsails, conical ribbon parachutes, and hemisflo ribbon parachutes. Variants of these parachute types have previously been developed in-house and flown, allowing for acquaintance with their design, manufacturing and performance. Apart from the more traditional parachutes used for student-built sounding rockets, this paper will also cover the opportunities and challenges that are associated with the use of less conventional parachutes, such as ringsails, ringslots, and parafoils. Each parachute is described in detail after which all are compared to one another based on several sets of typical requirements. Factors that influence the parachute selection process are, for example, the parachute flight envelope, stability behaviour, and manufacturing complexity.

Keywords
Parachute selection, recovery system design, sounding rocket

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Final testing, pre-launch activities, launch and post-launch analysis of a sounding rocket made by students in Spain

Alba Badia Rifá¹, Daniel Cantos Gálvez², Adam El Ghaib Bougrine², Javier Hidalgo Martí², Marc Martí Arasa², Arnau Pena Sapena²

Abstract
This paper summarizes the final launch preparation tests, the operations before, during, and after the launch, and the results of the launch of a supersonic sounding rocket developed by university students in Spain with the collaboration of INTA (National Institute of Aerospace Technology). The students are part of the Cosmic Research association, based at the Polytechnic University of Catalonia ESEIAAT, and the rocket is called Bondar. INTA is a Public Research Organization under the Spanish Ministry of Defense dedicated to scientific research and development of systems and prototypes in the fields of aeronautics, space, hydrodynamics, security, and defense. The staff of the El Arenosillo Experimentation Center (CEDEA) collaborated in the Bondar mission with their knowledge and launch capabilities. The launch of the rocket took place on the 30th of November 2021. Two students from BiSky, a rocketry team from the University of the Basque Country, also participated in this project, specifically in the development of the on-board and ground-based avionics subsystems. The paper presents information on the mission systems, the operations before, during, and after the countdown to the launch, the documentation required by INTA-CEDEA for the launch, and the results of said launch. In short, the systems developed by Cosmic Research for the launch are: the rocket, the launch pad, the rocket transport box, the flight simulator, and the ground-based rocket tracking station. The documentation required by INTA includes: a detailed description of the systems, a ground risk assessment, a flight risk assessment, structural analysis, aerodynamic analysis, and a list of countdown operations. Launch post-analysis activities evaluate the performance of systems and operations during the most critical phase of the mission. The Bondar Mission, due to its technical and operational complexity, was the most ambitious project ever developed by students in Spain in the field of rocketry. After a successful launch, Bondar became the highest-flying Spanish student-made rocket, with its apogee around 8 km AGL (Above Ground Level).

Keywords
INTA, launch operations, sounding rocket, Spain, students.

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Design, Manufacture, and Validation of a Student-Made Ringsail Parachute for Sounding Rocket Recovery

Thomas Britting\textsuperscript{1}, Isabelle Joosten\textsuperscript{2}, Bram Koops\textsuperscript{2}, Wesley Leonardus Jacobus Rudolf Toussaint\textsuperscript{2}, Mohamed Sahir Sujahudeen\textsuperscript{2}, Kristina Vukosavljević\textsuperscript{2}, Niklas Emil Knöll\textsuperscript{2}, Adriano Casablanca\textsuperscript{2}, Nachiket Dighe\textsuperscript{2}, Sebastian Oliver Scholts\textsuperscript{2}, Soham Kumar\textsuperscript{2}, Tom van der Wee\textsuperscript{2}

Abstract
In the previous years, the Parachute Research Group (PRG) of Delft Aerospace Rocket Engineering (DARE) has been relying mainly on cruciform, ribbon, or disk-gap-band parachutes for the retrieval of its capsules and smaller sounding rockets. However, heading towards a more sustainable future, with the prospect of full rocket recovery and reusability of larger flagship missions in the future, a new, high-performance main parachute had to be developed. As a result of these, a ringsail-type parachute was selected because of its excellent reefing capabilities, good drag performance, and flight heritage within the professional industry. This paper will focus on three main phases of the development of the new parachute type. Firstly, detailed designs and selection of these different designs created will be presented. Furthermore, considering the fact that this type of parachute is notoriously difficult to produce, new manufacturing methods will be proposed and discussed. Lastly, the results of the wind tunnel tests performed will evaluate and further elaborate on the drag performance, stability characteristics, inflation loads, and reefing capabilities of this parachute type.

Keywords
Ringsail, Sounding rocket recovery, Parachute production

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Ice Moon Research – A phenomenon called plume
Mario Andre Zuegner

Abstract
Based on the observations of the Cassini-Huygens space exploration mission, Saturn's moon Enceladus was found to be a very promising subject in the solar system for further exploration and follow-up research, especially focusing on the potential of extraterrestrial life and its origin. Near its South Pole, fountains, specified plumes, consisting mostly of water vapor and small salt-rich ice grains with intermittent activity were observed at the surface. With supersonic speed the water vapor is exiting the trenches known as Tiger Stripes. The driving force of these plumes are not completely understood yet. In current models, Enceladus is expected to consist of a rocky core, surrounded by an ocean of liquid water and covered by a layer of ice. The observed phenomenon is assumed to be caused by the tidal forces that act upon Enceladus. However, several models try to describe the underlying physical processes. Various investigations have recognized the astrobiological potential of Enceladus, even proposed a concept for a sample return for further research in relation to the subsurface ocean. Cassini’s existing analysis already identified CH4, CO, CO2, simple and complex organics at an altitude of approximately 190 km which allow the assumption of supersonic speeds.

That said, the goal of our experiment is to gain further indices/evidence to support the current models of the plumes. Our experiment takes place on a sounding rocket which gives access to a stable vacuum and microgravity in addition. The achieved altitude with its physical environment provides almost the conditions at Enceladus related to the gravitation. The rocket module contains a pressurized and heated water reservoir which is connected via an injection system with the evaporation chamber. On the top a convergent-divergent nozzle is welded. Furthermore a nozzle cover system and a locking mechanism are integrated. At apogee, the nozzle shall be opened and the fluid stream (assumingly made up of ice, water droplets and vapor) shall exit the module at about Mach 2. The necessary fluid-dynamic data is gathered by multiple temperature and pressure measurements at different points on the module. So, the vapor stream shall be compared to the expectations based on the models.

Finally it is to mention that our project is still running and waiting for its launch. Caused through the Corona crisis and the Ukraine war the launch cycle was canceled two years in succession. With much luck the rocket will launch in March 2023.

Keywords
Enceladus, Ice moon, Plume

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Panel: Rocketry II

Auxiliary Room, 12:30 pm – 1:30 pm
Fly A Rocket! Programme: Assembly, Testing and Post-Flight Review of a Sounding Rocket Payload

Blanca Crazzolara¹, Patrick Gowran², Jordi Vázquez i Mas³

Abstract

The Fly a Rocket! programme is a hands-on project offered by the European Space Agency’s Education Office in collaboration with Andøya Space Education and the Norwegian Space Agency (Norsk Romsenter). The programme, which comprises an online pre-course and a hands-on launch campaign, represents a unique opportunity for European university students from different backgrounds to build, test, and launch a sounding rocket and obtain practical experience. The pre-course strengthened the understanding of rocket science of the students, and taught them about topics such as the rocket dynamics, propulsion, and orbital mechanics in preparation for the campaign. The students were divided into three teams, each with different responsibilities: Sensors Experiments, Telemetry and Data Readout, and Payload. The paper will focus on the work done by the team responsible for the rocket payload. The Payload team was responsible for the sensor placement of the rocket. They ensured the readiness of all the sensors and key components of the rocket. In addition, they were an integral part of the countdown procedure, the arming of the rocket and the performance of the sensors. After the launch, the data was analysed and presented according to four previously defined scientific cases. A GPS and a barometer were used in order to obtain the rockets trajectory. Both methods showed similar results. The GPS detected an apogee of 8630.11 ±2.4m. With an optical sensor it was possible to detect clouds which were verified with a humidity sensor. Additionally, the spin rate of the rocket could be detected with the optical sensor and a magnetometer by doing a Fourier Analysis. The rocket reached a spin rate of about 19 Hz after approximately 10 s after the firing. The results of the spin rate correspond to the results obtained with an accelerometer.

Keywords
Payload, Sounding Rocket, Student Programme

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Design and optimization of a rocket structure following the requirements for the European Rocketry Challenge (EUROC) to be fabricated using additive manufacturing

Jordi Grau Rifà, ESEIAAT UPCSP Spain

Abstract

Amateur rocket structures are usually made of composite materials, wood or aluminium, their internal geometries and interfaces are usually restricted by the available manufacturing techniques. However, with the appearance of the additive manufacturing sector new possibilities arise for the design of the structures and its complexity.

In this paper a PA-12 and glass fibre composite structure for the Phobos rocket is designed which the UPC Space Program aims to use to participate in the European Rocketry challenge. The Phobos rocket structure is designed and optimized to be fabricated using additive manufacturing by Hewlett-Packard. The structure is designed using a lattice approach to obtain a PA-12 skeleton which is then reinforced with a skin of glass fibre composite.

Moreover, to obtain the desired structure an optimization methodology is set using a design loop in which the critical section of the rocket is parametrically optimized to reach the equivalent traditional structure performance. The structure is optimized in the size of the lattice geometry and in the thickness of the skin as parameters. To do so, the critical load during the flight of the rocket is identified and translated to the Nastran environment to run a parametric optimization of the structural model. The optimized geometry is then extended to the rest of the rocket to obtain the overall optimized structure. In addition, several analyses are conducted to validate the structure behaviour for the different load cases. Finally, both the optimized critical case and the overall optimized structure are compared to traditional design structures to obtain conclusive results about the use and limitations of the available additive technology and its materials.

Keywords
Rocketry, Students, Design, Optimization, Structure
Progress of the Development of a Two-Stage Supersonic Rocket within a Student’s Association

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Jordi Grau, ESEIAAT UPCSP Spain,
Albert Soler, ESEIAAT UPCSP, Spain,
Ignacio Llansó, ESEIAAT UPCSP, Spain,
Joel Campo, ESEIAAT UPCSP, Spain,
Jordi Gallart, ESEIAAT UPCSP, Spain

Ares Mission, UPCSP, EUROAVIA Terrassa, Escola Superior d’Enginyeries Industrial, Aeroespacial i Audiovisual de Terrassa. ESEIAAT, Universitat Politècnica de Catalunya - BarcelonaTECH, Spain

Abstract
The Ares mission is part of a student-led project with the aim of developing a two-stage supersonic amateur rocket. This paper discusses the progress since its foundation in 2016 and how it is planned to continue progressing to achieve this objective.

Currently, 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. The final objective of the Ares Mission is to launch a two-stage supersonic rocket, the Ares III.

Keywords
Rocket, two-stage, supersonic, composite materials, 3D printing
Analysis of the Effectiveness of Sensors to Fulfil Scientific Cases in the Fly a Rocket! Campaign

Jasmine Brittan [1], Ingrid Hjelle [2]

Abstract
With space becoming a newly ubiquitous phenomenon, due to the evident popularisation of space travel, the European Space Agency Education has a mission to educate the future generations of engineers and scientists to accelerate new findings in the field. The Fly a Rocket campaign was curated to involve early undergraduates in the full launch of a sounding rocket, notably the Mongoose 98. In collaboration with Andøya Space Centre, the aim of the launch was to successfully meet the 4 predefined scientific cases. These were named Oliver Twist, The Cloud Atlas, 451 Degrees Fahrenheit and Rock & Roll and the cases were assigned to the three teams working on the campaign: sensors, payload, and telemetry. The week consisted of learning through the form of lectures and practical understanding via the instruction of the Andøya Space Team. The rocket launch culminated on the 4th day of the 5-day campaign, with a weather balloon also gathering atmospheric conditions.

Among the presenters of this report, both members had notable roles as the Principal Investigator and Range Control Officer, allowing us to provide both an overall analysis of the mission and in-depth insights, associated with the varying sensors. The Range Control Officer led the countdown procedure to launch alongside the Range Safety Officer, while simultaneously building the pressure sensor. Moreover, the Principal Investigator worked on the magnetometer.

Our team will present on behalf of the sensors team and evaluate the accuracy of the sensors to provide valid conclusions for the scientific cases. The team will present whether the accuracy of the data was reliable enough to answer our proposed questions. Additionally, thorough analysis was conducted using OpenRocket to determine its viability for future rocket launches.

Issues during the campaign launch included the mismanagement of payload integration being slowed and OpenRocket being inaccurate past a Mach number>2. Ultimately, this report verified some of our cases and provided important telemetry data to improve the use of future launches.

Keywords
Fly a Rocket, students, sensors

Acronyms/Abbreviations

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<tr>
<th>Acronym</th>
<th>Description</th>
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<tr>
<td>ESA</td>
<td>European Space Agency</td>
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<tr>
<td>IMU</td>
<td>Inertial Measurement Unit</td>
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<tr>
<td>NAROM</td>
<td>Nasjonalt senter for romrelatert opplæring</td>
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<tr>
<td>OR</td>
<td>OpenRocket software</td>
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<tr>
<td>PI</td>
<td>Principal Investigator</td>
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<tr>
<td>PTU</td>
<td>Pressure, Temperature, and Humidity Sensor</td>
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