ESA Hands-on Space Education Project Activities for University Students: Attracting and Training the Next Generation of Space Engineers

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Abstract—**ESA provides numerous opportunities for university students from ESA Member and Cooperating States to gain practical hands-on engineering experience on real space projects. These opportunities cover a broad spectrum of flight project activities ranging from student experiment payloads on microgravity platforms, atmospheric balloons, and sub-orbital sounding rockets to instruments and small platforms for Earth and Moon orbiting satellites. The education satellite projects range in size from pico-satellites to mini-satellites and are complemented by a global network of education institution and radio amateur ground stations. This paper describes the hands-on space engineering education programme and its setup, the engineering education methods, and the knowledge/skills transferred to the students, in addition to summary technical information on the projects concerned.**

Keywords-space; engineering; education; projects; student satellites.

I. INTRODUCTION

The ESA Education Office was established in 1998 with the purpose of motivating young people to study Science, Engineering and Technology subjects and ensuring a qualified workforce for ESA and the European space sector in the future. In achieving this, the ESA Education Office set up a hands-on space engineering education programme comprising a number of different projects underpinned by the principle that students learn engineering skills most effectively by application of their theoretical knowledge to the complete engineering process, from requirements and design, through developing, manufacturing and testing their product, to later flying it in a suitable operational environment in order to analyse the flight data for valuable lessons learned. For space engineering education, the ultimate operational environment is orbital flight (often low Earth orbit), but also sub-orbital flight has proven to be a useful learning ground for many students.

By participating in these projects, students gain the technical/programmatic knowledge and practical skills necessary for entering into the space engineering workforce, and immediately making a solid contribution to the European space programme, thus underpinning and building upon European capabilities in the space domain. The product of these projects is a set of qualified, fully trained engineers covering not only specialist technical disciplines in space engineering, such as structural, thermal, avionics, instrument, propulsion, and ground segment, but also systems engineers capable of developing complete satellites from end to end.

Since ESA hands-on space project activities began in the mid-1990's with the first student parabolic flight campaign, through the completion of three student satellite projects, to present day activities, it is estimated that over 3,600 students distributed over 22 ESA Member and Cooperating States have benefited from it. In implementing the programme, the ESA Education Office works closely with a wide network of engineering faculties in universities across Europe, with space industry companies and with ESA technical experts to ensure that supervision, seniority guidance, mentoring and knowledge transfer is provided to the participating students by experienced professionals. In this context, ESA Education Office, with its partners, also provides the necessary collaboration tools, software, facilities, independent technical reviews, workshops, and internships sponsorship to enable an effective working and learning environment. Crucially, launch opportunities are also provided by ESA in order to actually fly the student-built systems, thus giving high motivation and important post-mission learning experiences.

Past education satellite projects were the SSETI Express micro-satellite designed, built and tested by students, and launched into Low Earth Orbit (LEO) on a Russian Cosmos rocket in 2005; and the first and second Young Engineers Satellites (the latter being an in-orbit demonstration of space tether technology, which was carried on the ESA Foton-M3 microgravity mission in 2007). Ongoing student satellite projects include the ESEO (European Student Earth Orbiter) micro-satellite and the ESMO (European Student Earth Orbiter) mini-spacecraft, both currently under design and development by university students together with industrial prime contractors, and due for launch in 2012 and 2013 respectively. In addition, 9 university-developed "CubeSat" pico-satellites have been selected for launch on Europe's new small launch vehicle, Vega, in 2010. In support of future education satellite missions, the ESA Education Office is leading an international project called GENSO (Global Education Network for Satellite Operations) to establish a world-wide network of university and radio amateur ground stations in order to greatly increase communications coverage. The network commenced early operations during 2009.

Student experiments are developed and flown on a variety of platforms in order to encourage scientific research by students in subjects such as microgravity effects, atmospheric physics and technology demonstration. These platforms include the REXUS sounding rockets and BEXUS stratospheric balloons launched from Esrange in Sweden in collaboration with Swedish National Space Board and the German space agency, and the Airbus A300 Zero-G parabolic aircraft used for the Fly Your Thesis project. These platforms are flown on an annual basis, giving rise to frequent opportunities offered to students.

II. Description of Hands-on Projects

A. European Student Moon Orbiter (ESMO) mini-satellite

ESMO is a mini-satellite mission to be designed, developed, built, tested and operated by students under the guidance and supervision of an industrial prime contractor, with the goal to fully prepare a well qualified workforce for performing challenging future ESA missions in the next decades [1]. Its mission objectives are: to launch the first lunar spacecraft to be designed, built and operated by students across ESA Member States and ESA Cooperating States; to place and operate the spacecraft in a lunar orbit; to acquire images of the Moon from a stable lunar orbit and transmit them back to Earth for education outreach purposes; and to perform new measurements relevant to advanced technology demonstration, lunar science and exploration. In order to achieve these objectives, a miniaturised payload would perform measurements in lunar orbit over a six-month period.

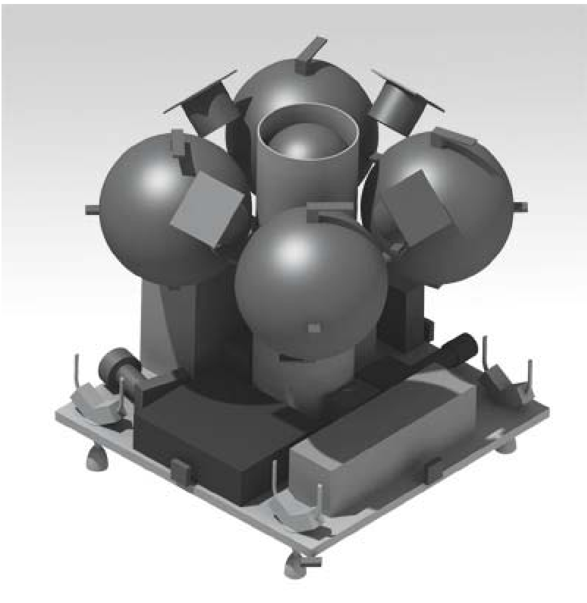

Fig. 1: Interior view of the ESMO mini-satellite (size of 80 cm on a side) showing propellants tanks and other equipment

The core payload is a 2.5 kg narrow angle camera for optical imaging of specific locations on the lunar surface upon request from schools. This will be operated from a highly eccentric lunar polar orbit similar to SMART-1. Other payloads being studied are a small radar payload, a radiation monitor, a 2.5 kg passive microwave radiometer (temperature of the regolith a few metres below the surface), and a telecommunication experiment to test a lunar internet protocol. All may be operated from the same orbit as the camera.

ESMO is planned to be launched into a Geostationary Transfer Orbit (GTO) in the 2013/2014 timeframe, as an auxiliary or secondary payload. The launcher is to be confirmed, but the spacecraft design is required to be compatible with a number of launch vehicles in order to allow flexibility in launch options. Over a period of three months, an onboard liquid bipropellant propulsion system will be used to transfer the spacecraft from GTO to its operational lunar orbit via the Sun-Earth L1 Lagrange point in order to save propellant.

The ESMO spacecraft (see Fig. 1) is designed to have a mass at launch of 190 kg (including propellant) and cubic dimensions of less than 80 cm on a side. It is fully 3-axis stabilized in attitude control and has an end of life power generation of 120 W from the solar panels mounted to the spacecraft body. Communication between the spacecraft and ground stations is performed at S-band frequencies for transfer of commands and telemetry/payload data to/from the mission control centre. Ground stations are located in Malindi, Kenya (10m antenna), Raisting, Germany (30 m), Villafranca, Spain (15m) for nominal operations. Additional stations in Perth/Kourou are envisaged to support the Launch and Early Operations Phase and mission-critical periods such as major spacecraft manoeuvres (e.g. Earth escape, lunar orbit insertion).

The project successfully completed a one-year Phase A Feasibility Study and passed its Phase A Review at a workshop in ESTEC in December 2007.

Surrey Satellite Technology Limited (SSTL), as System Prime Contractor, is managing the ESMO project for the ESA Education Office and providing considerable system-level and specialist technical support to the university student teams during the implementation of the project until launch and early operations. Some 200 students from 17 universities in 10 countries are currently participating in the project. Student work on the first part of the preliminary design (Phase B1) has progressed through 2008 and 2009. The ESMO Phase B2/C/D/E1 contract for the development and qualification of the complete system commenced in October 2009. Contractual relationships are to be put in place between the prime and the universities in order to establish academic supervisors as formal points of contact and local supervisors of the student teams for the purposes of assuring continuity and delivery. Universities are provided with funding for their participation.

The students are expected to provide most of the spacecraft subsystems, payload and ground segment systems under supervision by their universities and the prime contractor as part of their academic studies. The students obtain hands-on training and knowledge transfer by technical experts during internships, in addition to using facilities at SSTL for spacecraft assembly, integration and testing. Flight spare hardware, on-board micro-processor cores, and software is also provided by ESA to the universities where justified to lower project cost and risk.

B. *European Student Earth Orbiter (ESEO) micro-satellite*

The European Student Earth Orbiter (ESEO) is a micro-satellite mission to Low Earth Orbit. It is being designed, developed, integrated, and tested by European university students as part of their academic studies at university. The education objective of the ESEO project is to provide students with valuable hands-on space project experience in order to prepare a well qualified space engineering workforce for deployment on near-term space projects. The ESEO satellite will orbit the Earth taking pictures for outreach purposes, measuring radiation levels and testing technologies for future education satellite missions.

ESEO is a sub-100 kg micro-satellite (see Fig. 2) currently due for launch into low Earth orbit (LEO) as a secondary payload in 2012. To achieve its mission objectives, ESEO will carry a narrow angle camera for taking images of the Earth. A Tritel-S 3-axis dosimeter will measure the accumulated radiation dose in low Earth orbit, and a Langmuir probe will measure the instantaneous plasma environment. ESEO will also test technologies in orbit, for example, a reaction wheel, and a star tracker developed by students that will be space-qualified for later use on ESMO.

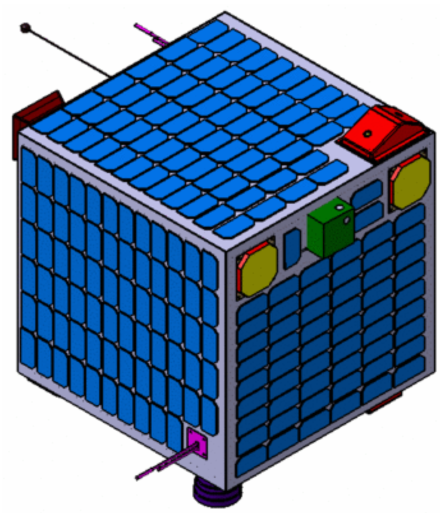

Fig. 2: Exterior view of ESEO micro-satellite (Warsaw University of Technology)

The exact launch opportunity has yet to be confirmed, although ESEO has been selected for launch with the first of the VEGA VERTA flights. However, the design aims at preserving adaptability to other launch vehicles. In LEO the spacecraft will perform its payload operations over a period of six months, with the possibility for mission extension. The orbit will be Sun Synchronous, and the remaining orbit parameters (maximum altitude < 600 km) will be selected to ensure that re-entry occurs within 25 years due to natural atmospheric drag, thus complying with the European space debris code of conduct. The ESEO satellite, as with ESMO, has 3-axis attitude stabilization (principally pointing the camera at Earth) and <100 W of power generation from the solar panels. Communication with ground is provided by an S-band transponder with also an additional transponder provided by AMSAT for communication at amateur frequencies.

As with the ESMO project, an Industrial System Prime Contractor (Carlo Gavazzi Space, CGS, Milan, Italy) is managing the ESEO project and in coordination with the ESA Education Office. They provide system-level and specialist technical support to the university student teams during the execution of the project. The students obtain training and benefit from access to the CGS and ESA in-house expertise, and can use Industry and ESTEC facilities for spacecraft assembly, integration and testing. The student teams are expected to provide most of the spacecraft subsystems, payload and ground segment systems (mission control centre, ground stations) in coordination with their universities and the prime contractor in order to deliver their elements of the mission as part of their academic studies.

The project is currently in Phase B2 (preliminary design activities in order to define the complete system down to component-level), and has recently successfully passed the Mission Definition Review and System Requirements Review during 2009. At the present time about 100 students are actively involved from 13 Universities across all Europe making preparations for the Preliminary Design Review by ESA experts in 2010.

C. *CubeSat nano-satellites*

A CubeSat (see Fig. 3) is a fully operable nano-satellite developed by a university for educational purposes which measures 10 x 10 x 10 cm in cubic dimensions, weighs up to 1 kg and uses Commercial Off-The-Shelf electronic components. The CubeSat standard was defined in 1999 by Stanford University and California Polytechnic State University [2]. A CubeSat can be built for €50000–€100000 by a university, plus €25000–€50000 is needed for the launch. This very cost has made CubeSats a viable option for universities across the world. Apart from the standard satellite subsystems (power, telecommunications, attitude determination and control, onboard data handling and storage) most CubeSats carry one or two scientific instruments or a technology demonstration payload.

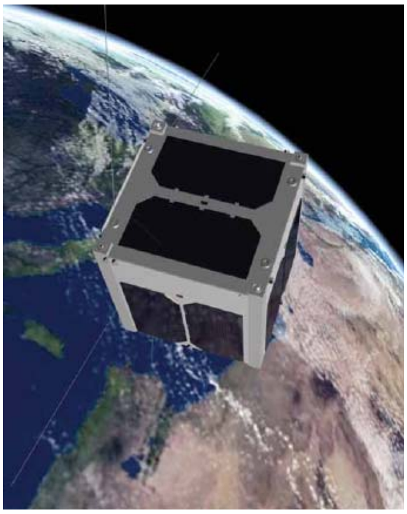

Fig. 3: Artist's impression of a Cubesat in orbit

In May 2007, ESA signed an internal inter-directorate agreement to include an educational payload on the maiden flight of Vega, ESA's new small launch vehicle which is currently under development and presently slated for launch in November 2010. This educational payload consists of nine CubeSats with two back-up CubeSats that can replace the primary satellites should they not be ready in time. The CubeSats that have been selected for the flight opportunity are given in Table 1 below.

TABLE I. UNIVERSITY CUBESATS SELECTED FOR VEGA LAUNCH

Name	**University**	**Country**	**Mission**
SwissCube	EPFL	Switzer-land	Air glow
Xatcobeo	Vigo	Spain	Software-defined radio; solar panel deployment
UNICube-SAT	Rome "La Sapienza"	Italy	Atmospheric neutral density measurements
Robusta	Montpellier 2	France	Radiation effects on bipolar transistors
AtmoCube	Trieste	Italy	Space weather measurements
e-st@r	Politecnico di Torino	Italy	test active 3-axis Attitude Control
OUFTI-1	Liège	Belgium	test D-STAR amateur radio protocol in space
Goliat	Bucharest	Romania	Earth imaging; space environment measure
PW-Sat	Warsaw Uni of Technology	Poland	deployable drag augmentation device

To support the selection of the CubeSats for Vega, a workshop was organised by the Education Office on 22 –24 January 2008. The workshop at ESTEC was the first of its kind at a European level and brought together almost all of the European CubeSat teams for the first time. There are now 35 teams developing CubeSats in ESA Member States and Cooperating States. A second workshop was organized in January 2009 in order to facilitate information exchange amongst this large community and to discuss possible concepts for future CubeSat missions, such as multiple satellite constellations/networks for communications/space weather.

D. Global Educational Network for Satellite Operations

As a complementary hands-on activity to CubeSats, GENSO is a planned network of over 100 small ground stations that is intended to provide global, near-continuous coverage of educational satellites in LEO (see Fig. 4). The network is being implemented under the auspices of the International Space Education Board (ISEB) with CNES, CSA, ESA, JAXA and NASA as member space agencies.

At present, a university typically builds a small satellite (e.g. a CubeSat) and launches it into low Earth orbit. It also builds, or already has available, a ground station to track the satellite and facilitate uplink/downlink telecommunications.

The period of a low Earth orbit is typically about 90 minutes, but the duration of a satellite pass over the ground station is very short and varies from approximately 10 minutes in the best case to no coverage at all for most of the orbits. When supporting only one satellite project, the ground station is not in operation 97% of the time. This is highly inefficient and often, despite onboard data storage capability, a limiting factor in mission return. Moreover, there are sometimes mission critical operations requiring uninterrupted coverage for several hours. However, the situation would dramatically improve if the satellite could be tracked by other ground stations along its ground track.

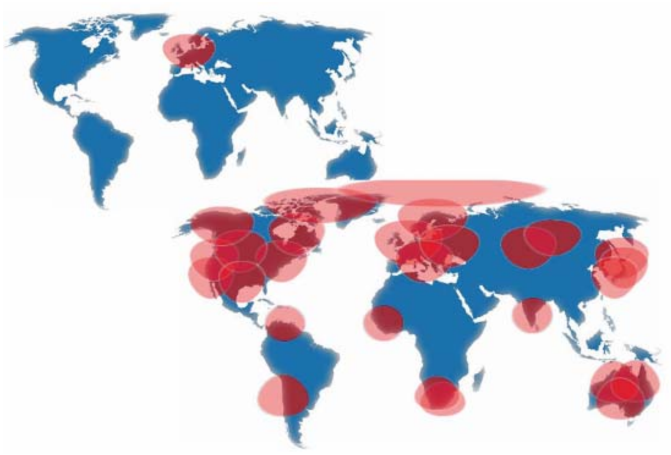

Fig. 4: Coverage of a single ground station in Europe (upper image) compared with envisaged coverage of the GENSO network (lower image)

GENSO provides an attractive solution to these limitations by linking together university/radio amateur ground stations around the world over the internet via the use of standard client software installed in the Ground Station Server (GSS), Mission Control Client (MCC) connected to a central Authentication Server (AUS). Through this network architecture (see Fig. 5) it becomes possible for an operator of an educational mission to transmit commands from its mission control centre to its satellite and receive telemetry from its satellite to its mission control centre even when the satellite is not in view of its own ground station [3].

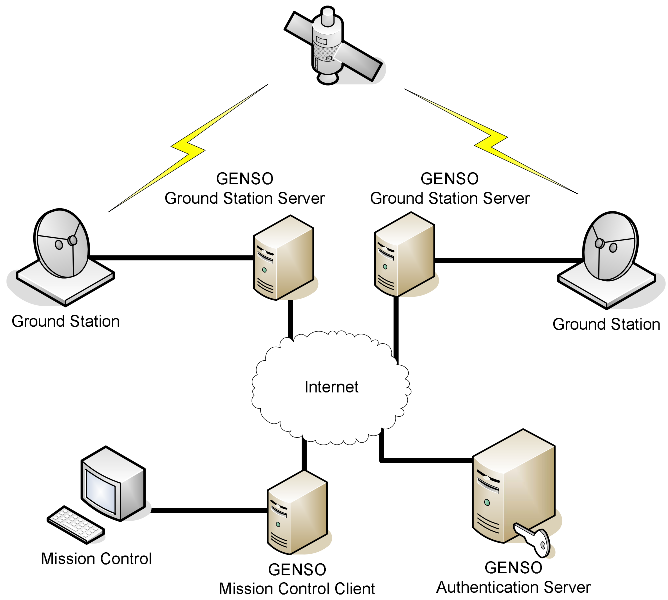

Fig. 5: GENSO network architecture

During a workshop at the University of Aalborg in November 2007, a successful proof-of-concept was demonstrated when an Authentication Server in Austria was connected to the GSS and the MCC software applications installed on the Aalborg ground station. Japanese and American hardware drivers were configured to control the ground station hardware, and telemetry was received from four student satellites – the passes were scheduled, the satellites tracked from horizon to horizon, the radio set and corrected for Doppler, and data decoded. Since then, the GSS application has been installed in five further ground stations in the UK, California and Japan to run tests for tracking satellites and automatically scheduling passes.

In parallel, two dedicated GENSO ground stations have been installed at the European Space Operations Centre (ESOC) in Darmstadt, Germany and at the International Space University (ISU) in Strasbourg. The ISU ground station was installed during August 2008. Installation of a ground station at ESTEC in the Netherlands is currently planned for 2010. These stations are used as nodes in the network but also to test new features and hardware/driver configurations.

ESA is responsible for the overall management of the GENSO project, on behalf of the ISEB. System engineering and technical support is being provided by Selex (Vega) UK under contract. The core software development teams are based at Aalborg University (Denmark), TU Vienna (Austria), Uni. Jean Monnet Paris (France), CalPoly (USA) and UNISEC (Japan). Further teams from Poznan (Poland), Politecnica de Madrid (Spain), and University of Tartu (Estonia) have joined during 2009 to support graphical user interface, scheduling, and driver developments. AMSAT UK is an integral partner in the project on ground station hardware configuration and provides the interface to the radio amateur community participation. University of Vigo (Spain) has recently been selected as the European Operations Node for GENSO to run the Authentication Server in Europe.

The GENSO software applications have been developed and tested to a first release by an international university student development team. An initial operations phase recently commenced in October 2009 with a limited number of ground stations playing an active role (<20 stations are being connected). Operational experience and requests/ideas for extended features will be fed into the ongoing development of GENSO software release 2.0, which is planned to be available in April 2010. At this time, the network will become open to all compatible education/radio amateur ground stations requesting to join through the world, aiming at the widest possible geographical distribution in order to maximize communications coverage for the benefiting satellites.

E. *Sounding rockets & balloon experiments*

REXUS and BEXUS are five-year programmes providing Swedish and German university students with the opportunity to launch educational experiments on sounding rockets and stratospheric balloons [4]. Three cycles are envisaged during these programmes, each beginning with a Call for Experiment Proposals and ending with the launches. A cycle comprises two rocket launches and two balloon launches. All launches are managed by Eurolaunch and take place from Esrange, near Kiruna, in northern Sweden. On each launch, half of the payload resources are available to Swedish students, the other half to German students. The flights are funded by the Swedish National Space Board (SNSB) and the Deutsches Zentrum für Luft- und Raumfahrt (DLR).

For their share of the payloads, SNSB has decided to invite students from all ESA Member States to participate in the REXUS and BEXUS campaigns. To this end, SNSB has asked the ESA Education Office to make European-wide announcements for the two annual opportunities, select the experiments, manage the interface between the selected experiment teams from European universities and SNSB and Eurolaunch/Esrange, and cover the expenses of European students to attend all of the associated activities (workshops, training week, reviews and launch campaign) [5].

In the REXUS campaign, a spin-stabilised, solid-propellant, single-stage rocket with an 'Improved Orion' motor is used, reaching an altitude of 90–100 km (see Fig. 6). The total available mass for student experiments is about 30 kg. BEXUS uses a 12SF helium balloon from Zodiac (France), which can carry a student experiment mass of 40 kg to a ceiling of 35 km. The floating phase at ceiling altitudes can last up to four hours.

The BEXUS-6/7 flight campaign took place in Kiruna, Sweden, from 3-10 October 2008. Both balloons were launched successfully on Wednesday 8 October, and the following ESA-sponsored experiments were flown:

- TimePiX@Space - Luleå University of Technology, Sweden, Charles University, Prague and Czech Technical University, Czech Republic. Detection of particles in the stratosphere using a hybrid imaging pixel detector developed at CERN [6].
- Stratospheric Census - An international team from the 'Erasmus Mundus' Space Masters course,

currently based at Luleå University of Technology, Sweden. Using innovative nanofilters combined with a strong airflow to gather dust particles from the stratosphere [7].

- Aurora – School of Aerospace Engineering, University of Rome, Italy. A study of the physical properties of the stratosphere, including temperature and magnetic field intensity [8].
- Low Cost Inertial Navigation System (Low. Co. I. N. S.) – La Sapienza University of Rome, Italy. Validation of an inertial measurement unit built with low cost sensors and components [9,10].

All experiments flown on BEXUS-6/7 were successful in collecting data and the teams have since analysed and reported on their results.

The BEXUS-8/9 flight campaign took place on 4-12 October 2009. The five ESA-sponsored experiments flown on BEXUS 9 on 11 October 2009 were:

- COMPASS (Calculating and Observing Magnetic Polar field intensity in the StratoSphere) – University of Bologna, Italy.
- CRIndIons (Measuring Cosmic Ray Induced Ionisation) – Luleå University of Technology, Sweden, Charles University, Prague and Czech Technical University, Czech Republic.
- NAVIS (North Atlantic Vessel Identification System) – Aalborg University, Denmark. A technology test for a student satellite which will receive Automatic Identification System (AIS) signals from nearby ships.
- reel.SMRT – 'Erasmus Mundus' Space Masters course, a collaboration between six European universities. An experimental gravity research platform for high altitude balloons.
- SO-hIgh – Université Catholique de Louvain-la-neuve, Belgium. A 'weather report' experiment using MEMS ((Micro-Electro-Mechanical Systems) built with Silicon-on-Insulator (SOI) technology.

Preliminary analysis indicates that the NAVIS experiment provided excellent coverage at high altitude and was successful beyond expectations. The team received and decoded 24,000 AIS packets from ships in the area. The COMPASS, SO-hIgh and CRIndIons experiments also performed well, though the reel.SMRT experiment experienced breaks in the line attached to the deployed microgravity platform and was only partially successful.

The three experiments flown in the REXUS-5/6 sounding rocket campaign on 3-11 March 2009 were:

- Nordic Ionospheric Sounding rocket Seeding Experiment (NISSE) - University of Bergen, Norway, University of Oulu, Finland & Finnish Meteorological Institute. Detection of ionized water by the EISCAT radar to study particles dynamics in the polar magnetic field [11].
- Itikka - Castor Space Club of the Tampere University Of Technology, Finland. A test of an inertial measurement unit.
- Vibration effects on biphasic fluids (VIB-BIP) - Universitat Politecnica de Catalunya, Spain. Study of the behaviour of a biphasic fluid (a liquid containing gas bubbles) in a low gravity environment under vibrations.

Unfortunately the NISSE experiment failed to function correctly. Although the rocket was clearly detected by the EISCAT radars, a malfunction in the spraying system prevented the water from leaving the spray nozzles, so no ionized water cloud was detected. The Itikka experiment was successful in acquiring acceleration data. The VIB-BIP experiment was a partial success with images of the fluid obtained, but unfortunately no vibrations in the fluid during the low gravity phase of the flight.

Fig. 6: Used in the REXUS programme, the Improved Orion M112 is an unguided solid-propellant single-stage rocket, launched from Kiruna in Sweden (SNSB)

The REXUS 7/8 launch campaign is scheduled for 22 February to 5 March 2010 when three ESA-sponsored experiments will be flown. The Call For Proposals for the next REXUS and BEXUS flights was completed during November 2009 and the selection of experiments is ongoing.

F. Parabolic flight experiments

Parabolic flights were proposed by ESA with the intention of fostering university student interest in microgravity research all over Europe. The Student Parabolic Flight Campaign, started in 1994, was the first hands-on activity offered by ESA. The last full ESA student campaign was held in 2006.

Thereafter, the whole programme was subjected to a thorough review, resulting in several managerial and safety recommendations for future campaigns. Following these recommendations and specific interactions between the ESA Education Office and the ESA Directorate of Human Spaceflight, a new programme concept called “Fly Your Thesis! – An Astronaut Experience” (FYT) was launched [12].

This programme offers European students the unique opportunity to design, build, and eventually fly a scientific experiment for microgravity, as part of their last year of University, i.e. for their Master or PhD thesis.

Fig. 7: Airbus A300 'Zero-G' aircraft, operated by Novespace, used by ESA for its Microgravity Research Campaigns (credit: Novespace)

Teams composed of two to four students and supported by an endorsing professor can apply, each year, by submitting a Letter of Intent to ESA Education Office. A Review Board composed of experts from the European Low Gravity Research Association (ELGRA), the ESA Directorate of Human Spaceflight and ESA Education Office pre-selects up to 20 teams who are then invited to develop detailed scientific and technical proposals with the support of an ELGRA scientific mentor. At the end of this pre-selection phase the student teams present their projects to the Review Board during a dedicated workshop held at an ESA centre. Following evaluation by the Review Board, up to four teams are finally selected to build and fly their experiments in an ESA Microgravity Research Campaign. The students accompany their experiments onboard the Airbus A300 Zero-G aircraft (see Fig. 7) for a series of three flights, each consisting of 30 parabolas of about 20s duration each. During this campaign, they work in close contact with renowned European Scientists carrying out their own research. ESA Education Office financially supports the cost of the flights, part of the hardware development, as well as necessary travel and accommodation.

For the first edition of this programme, the Review Board selected four student experiments to participate in the ESA 51st Microgravity Research Campaign which took place on 3-5 November 2009 in Bordeaux:

- *Complex* - a team of three students from the Norwegian University of Science and Technology, in Trondheim, Norway. They studied the flow birefringence of a solution of clay particles in salty water, allowing them to have a deeper understanding of the self-organisation of those small particles.
- *The Dust Side of the Force* - a team of five students from the Institute of Planetology at the University of Münster, Germany. The experiment was about the greenhouse and thermophoretic effect, which can lift particles off the ground in low gravity conditions. This effect is thought to be important in planet formation and the formation of dust storms on Mars.
- *AstEx* - a team of three students from the Open University in the United Kingdom and the University of Nice-Sophia Antipolis, France. Their experiment investigated the behaviour of granular material under shear stress, with the possibility of using their results in the design of future asteroid sample return missions.
- *ABCtr MicroG* - a team of four students from the Autonomous University of Barcelona and the Polytechnic University of Catalonia in Spain. Their experiment investigated the behaviour of particular biological agents involved in the assimilation of drugs by the human body. The results could help to improve treatments in space.

A second call for the FYT programme was launched in April 2009 and a preliminary selection of 12 student teams has been announced at the beginning of September 2009.

G. Drop tower experiments

The ESA Education office is endeavouring to extend the range of hands-on activities by developing student programmes for other microgravity ground-based platforms. This year, a new hands-on activity called “Drop Your Thesis!” (DYT) has been launched. The aim of this educational programme is to give European students access to the ZARM Drop Tower, in Bremen, in Germany. Each year one university student team will be offered the opportunity to drop, a few times, a microgravity scientific experiment as part of their Masters or PhD thesis. This facility is composed of a 146 m tall steel tube, designed as a vacuum unit, which houses all technical parts to handle the drop capsule. Below the tower, a chamber of 11 m depth contains the catapult system. The installation delivers 4.74 s of microgravity in dropping mode and 9.3 s in the catapulting mode. The first call for proposals was launched in November 2009 and a first campaign will be held in autumn 2010.

H. Large diameter centrifuge experiments

In parallel to the FYT and DYT programmes, the ESA Education Office has launched a complementary gravity-related programme called "Spin Your Thesis!" (SYT) to provide European students with access to the Large Diameter Centrifuge facility, in Noordwijk, in the Netherlands. This centrifuge has a diameter of eight meters and is composed of four arms which can support up to six gondolas (see Figure 8). In order to perform the experiments, the acceleration of the facility varies from 1 to 20 times Earth’s gravity within at least

60 s. The objective of this educational programme is to have, each year, a two-week campaign with four university student experiments. The first call for proposals was made during autumn 2009 and first campaign should take place in spring 2010.

Fig. 8: Picture of the ESA Large Diameter Centrifuge (ESA)

I. CanSat activities

A CanSat is a mock ‘satellite’ accommodated within the volume and shape of a regular soft drink can (see Fig. 9). The CanSat concept was introduced in 1998 by Professor Robert Twiggs from Stanford University. Just like a real satellite, a CanSat consists of a ‘bus’ and a payload. The bus comprises the structure (the aluminium soft drink can, antenna, circuit board), power (battery), telecommunications (transmitter), onboard computer and the recovery system (parachute). The payload may consist of sensors for measuring accelerations, the ambient air temperature, pressure and humidity, a differential GPS, a camera (pictures or video), attitude determination sensors or a mini-rover.

A CanSat is launched by an amateur rocket to an altitude of 500–4000 m. Balloons have also been used as release platforms. After release from the rocket at apogee, a parachute or parafoil opens and 5–20 minutes later the CanSat makes a soft landing. The drop time, during which it transmits telemetry, is comparable to the horizon-to-horizon pass of a satellite in low Earth orbit. Their advantages are that they can be built at very low cost, typically under €1000 and can be proposed, designed, built, tested and launched in six to nine months.

The building of a CanSat usually involves participation in a competition for university and high school students. Such competitions are organised regularly in different parts of the world. The competitions are in generally two categories:

- the standard CanSats (370 g)
- the Open Class’ (over 1 kg), which often includes a mini-rover.

Over the past three years, there has been growing interest amongst European countries for CanSat activities. In The Netherlands, a pilot demonstration was organised in 2007, followed by national competitions for upper secondary school students in 2008 and 2009. Further pilot competitions took place on a national level in Spain, France and Norway in 2008 and 2009 and these activities look set to continue in the future.


Fig. 9: Typical Cansat deployment with parachute (CanSat Nederland)

Based on the objectives of the ESA Education Office and its existing profile of hands-on activities, ESA's first priority for supporting CanSat activities is to encourage the set-up of activities in more of its Member States, focusing in particular on secondary schools. A workshop was held in October 2009 to brainstorm possible collaborations with the organisers of national competitions and other interested parties. Several possibilities are under consideration, including the establishment of a common website for European CanSat activities, the development of a CanSat kit and the organisation of a European-level competition.

III. ENGINEERING EDUCATION METHODS

Focusing students on real world engineering problems in the space domain, by allowing them to work hands-on to ultimately design, develop and build space-related hardware and software systems capable of functioning successfully as required in their operational environments has proven to be a very powerful engineering education tool. The ‘learning by doing’ approach has been underpinned and reinforced by a number of formal education methods, introduced as a result of lessons learned on the student project activities, which have led to increased success in the educational and operational/mission outcomes.

A. Mentoring by senior technical experts

Where possible within the scope of the project, the work of the students has been closely followed by a senior expert in the relevant technical field. This has been done both remotely (expert and students not co-located, communication by phone or internet) and locally (student and mentor co-located, communication largely through daily face-to-face meetings). Remote mentoring has had limited effectiveness, whereas local mentoring has proven to be highly effective in all cases. It has been most effective when students are embedded in the core system team of the project on internships. Such a daily contact with expert advice has led to strong motivation, deep understanding, high quality work output, and resulting engineering products either meeting or exceeding requirements and expectations. Quick progress is made due to mentors allowing students to explore the trade space whilst properly bounding it and guiding them towards the best solution to the problem, often based on their past experience with the appropriate rationale behind.

B. Training courses to increase practical skills

For the majority of the project activities, regular workshops are held either at ESTEC or the prime contractor (in the case of the micro-satellite projects). These are one week events where representatives from each team of students working on the particular project gather together to coordinate their interfaces/dependencies with each other, and to complete group tasks required by the project team (ESA or prime contractor) to make significant progress on project milestones. Whilst this is also an occasion for the students to meet their mentors (typically for half a day or more), additional education is given to students in the form of training courses. This has been particularly useful in increasing practical skill levels in advance of upcoming relevant project work. Courses in such areas as requirements definition, structure/electronics/thermal design & analysis techniques, and manufacturing of PCBs/cables through soldering and crimping have benefited the overall quality of workmanship achieved by the students. This is also foreseen to reduce the number of defects that need to be remedied later on, saving time and effort.

C. Immersion in the project environment

Considerable effort and investment has been made to allow students to be fully involved in the project activities, through regular contacts, meetings and internet-based tools for the exchange of key information, particularly technical data. System engineering tools are accessible to all students and capture all requirements and design data at all levels and all originators on the project. Licences for industry standard analysis tools (e.g. NASTRAN/PASTRAN for structural analysis) are provided to participating student teams in order to facilitate design decisions down to the lowest level. Furthermore, project management related aspects such as schedule, work breakdowns and task descriptions are provided at the start of the project activity (or phase of the activity) in order to give a clear path ahead to follow. A web portal is used to clarify points of uncertainty and to track tasks and project events on a continuous basis.

D. Independent reviews of design

All project activities undergo formal project reviews at key milestones in the project lifecycle, such as requirements reviews to agree on the requirements for students to follow, or preliminary or detailed design reviews to check that their designs comply with the requirements agreed. Later on in a project, post-test reviews are conducted in order to qualify the design or accept student-built flight hardware for system/platform integration. These reviews involve ESA technical experts not directly participating in the project, and have been an extremely useful learning experience for the students (as they learn more about quality standards and trying to meet those standards), as well as raising overall quality levels. It is also an important verification of their work if it passes an ESA review.

IV. KNOWLEDGE/SKILLS TRANSFER TO STUDENTS

Across the different project activities, the knowledge transfer to the students varies according to the strategy of the Education Office to meet the needs of a well qualified workforce.

A. Micro-satellites

These larger projects involve tens of different universities working on different subsystems of the overall system over typically 3 or 4 years in the development cycle. Here, students gain significant specialist experience and deep insight into a particular subsystem, and learn to define and adhere to interfaces with other subsystems. This satisfies the needs to produce specialists in Europe in particular competency areas known to be in short supply in the workforce. Student system engineers are also trained and a knowledge of complex space systems is developed. However, due to the long duration, students typically only experience part of the engineering process (either design, development or manufacture/testing), and knowledge transfer between generations of students in each team is crucial. This continuity must be provided by the supervising professor locally at the university. The involvement of space industry is expected to also give students a working knowledge of how to apply and meet minimum product assurance standards.

B. Nano-satellites

Being contained within a single university and short enough in duration to have the development cycle fitting within one generation of students, these smaller projects produce specialist engineers and system engineers with a working knowledge of space systems with moderate complexity, but with stronger system engineering process and full project lifecycle understanding than the micro-satellite projects. Students appreciate a high degree of interdisciplinarity due to the vertical integration of the project team in one location, but as a result they tend not to strongly experience interface definition activities which are relevant to larger space projects. A moderate level of innovation is enabled where students can explore and demonstrate new concepts/technologies.

C. Student experiments

As these are highly focussed short-term activities where the full development cycle lasts for a year or less, they are an excellent introduction to the space project lifecycle and an opportunity to gain excellent and relevant hands-on practical skills in a less challenging flight environment than Earth orbit. These opportunities offer students the possibility to be creative in design, perform scientific/technology research and test their ideas/concepts with a specific experiment development. They still gain experience of interdisciplinarity (to a lesser extent) since structural, electronics and software engineers need to work in the same team to achieve their objectives. Engineering as well as science students benefit from these programmes, and the experience gained can lead to a career path suited to instrument/payload engineering.

D. Ground segment

The GENSO project in particular is targeted at producing the ground segment, software and operations engineers of the future workforce. Students gain knowledge in ground station networks, mission control centre functions, real-time communications links and mission planning/data exploitation activities. Whilst specific protocols are not widely used in ESA missions, the underlying principles remain the same, so the students can gain a deep understanding of the ground segment elements.

E. High school hands-on activities

These activities, with CanSats in particular, give children their first contact with the space domain and serve to attract the next generation of youngsters into engineering faculties at university where they can then build satellites and flight experiments prior to graduating and entering careers in ESA or industry. The opportunity to build, program and fly a CanSat under the supervision of their teacher, then compete against other schools to win a prize can give inspiration to children and spark their interest in space, thus leading to increased take-up in science, technology, engineering and mathematics subjects at school and an increase in the pool of potential (space) engineers.

V. Conclusions

Over 3,500 European students have been involved in the various hands-on activities announced, managed and funded by the ESA Education Office to date. They have been able to visit ESTEC and participate in workshops, project reviews, integration and test campaigns. They have prepared the required documentation according to professional standards, followed formal engineering processes and participated in communication and outreach activities. They have developed flight and ground hardware and software, benefited from the support by ESTEC/industry staff on these projects, and from detailed discussions with these experts. Throughout all these processes they have met fellow students from other European countries, learned how to work successfully as a team, and established valuable contacts at ESA and in the space industry. Several hundred Masters and PhD theses have resulted from these projects, and the active involvement in one of the projects of the Education Office has often been the first step towards a successful career in space.

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