Hands-on Space Activities at University of Nottingham

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Abstract— The University of Nottingham launched the aerospace engineering programme in 2016. Four different courses are offered at both BEng and MEng levels with the BEng consisting of three taught years and MEng consisting of four.

Space educational activities at University of Nottingham are mainly concentrated in offering hands-on experiences to students. Students at different levels, starting from the 2nd year, are involved in the design of space systems, mainly CubeSat standard compatible, that will be implemented and boarded in a small satellite.

The main educational project is dedicated to the design and analysis of the first space mission from University of Nottingham. The idea is to use a CubeSat platform and implement a payload of interests for students and researchers at University of Nottingham. At this phase several payloads are under evaluation. The students are supported by a board of staff members involved in different space activities from biomedical research in space to earth observation to the use and application of GNSS. Once identified the mission that will be carried out the student will be involved in all the mission phases, from the design to the launch and in orbit operation. A dedicated ground station will be installed at University of Nottingham in order to be able to track and receive satellites in UHF, VHF and S band.

In addition, to implement student experiences and have soon the opportunity to see the first system designed at University of Nottingham in space, several international cooperation have been made with European partners, such as University of Beira Interior and CEIIA in Portugal, and non-European partners such as, for example, University of Brasilia in Brazil. The goal of these cooperation is not only share knowledge and experiences between teams but also launch opportunities and future opportunities.

As part of the educational project the students are also involved in balloon projects, where the systems will be tested using High Altitude Balloon. Next balloon mission is planned to be launched in November 2019.

The paper gives an overview of all the most interesting space educational activities involving students at University of Nottingham giving particular attention also to the improvement that will be done in the existing facilities in order to have a more effective Space Systems Educational Laboratory.

Keywords—*CubeSats, PocketQubeSats, High Altitude Balloon*

I. INTRODUCTION

In 2016 the University of Nottingham (UoN) launched a new educational programme in aerospace engineering offering four different courses at both BEng and MEng levels.

The four courses offered are a BEng Aerospace Engineering, a BEng Aerospace Engineering including an Industrial Year, a MEng Aerospace Engineering and a MEng Aerospace Engineering including an Industrial Year. A MSc in Aerospace Technology is also part of the UoN offer.

The Aerospace course is a joint project between the Department of Mechanical, Materials and Manufacturing Engineering (M3) and the Department of Electronical Engineering.

All students follow a common programme of study for the first two years, studying material that provides a comprehensive core expertise in aerospace engineering and aircraft technology. In the last two years students have the opportunity to learn and discuss topics related to Space engineering.

The space educational program aims to involve university students in real space projects based on the analyses, design, tests and in orbit operations of space systems, in general, with particular attention to small satellites.

The main system used are High Altitude Balloon platforms, PocketQubeSats, CubeSats.

Similar hands-on activities are conducted overall the world and in Europe are strongly supported by European Space Agency **Errore. L'origine riferimento non è stata trovata.**].

The educational space hands-on program, open also to all M3 students, can be divided in three different phases:

1. Teaching activities
2. Extra curriculum activities
3. Long term projects

The paper will analyse separately the three different phases giving some example of the projects conducted in the last 2 years.

To offer a high-quality hands-on experience University of Nottingham is offering the use of different facilities that are shortly described in paragraph 5.

II. TEACHING ACTIVITIES

The teaching activities section groups all the hands-on activities conducted as part of an existing module. Students get credits and marks accomplishing these activities.

Main characteristic of these activities is a systems approach including an integrating design, make and test project along with laboratory and workshop elements.

A. Group Design and Make

As part of the learning experience, students at M3 have to work as a team to accomplish a specific project in engineering. A specific module, “Group Design and Make”, taught at the 3rd year, involves students in a real hands-on educational activity. The module intends to replicate the challenge and environment encountered when designing as part of a team in industry. Professors from overall the department act as customers requiring a specific product with well-defined technical requirements, a limited budget of 500 £, and a time-frame of one academic year.

The project is organized in order to have four major milestones during the year:

- The Requirements and Planning Review (RPR)
- The Preliminary Design Review (PDR)
- The Critical Design Review (CDR)
- Customer Acceptance (CA)

Normally the proposed projects concern area related to M3 research and teaching activity. Regarding Space, the proposed project is the design of a small satellite class PocketQubeSat and test it. In the academic year 2018-19, a team of 4 students designed a 2p PocketQubeSat called PunchSat. PocketQubeSats were initially proposed by Prof. Bob Twiggs in 2009 with the aim to have a satellite standard smaller and cheaper than existing satellites, with dimensions so small that can fit in a pocket. First PocketQubeSats were launched in orbit in 2015 through UniSat-5 platform [1].

PunchSat project aim is to design and fabricate a PocketQube Engineering Model in accordance with the PocketQube Standards [2]. The satellite mission is really simple: to capture one picture with a digital camera.

During the project the students designed the platform, selected the components, integrated the different subsystems, manufactured the structure and the solar panels, designed and tested the software. They used different software available at University such as Solidworks, Abaqus, MatLab and STK to conducted the design and analysis phases.

Due to the limited available budget (500£) and some safety rules constraints the system has not been tested in an High Altitude Balloon (HAB) as planned. In any case the satellite has been designed in order to be launched to a low-Earth orbit (LEO). The satellite CAD model and the internal systems are shown in Fig.1 and Fig.2 respectively.

Fig. 1. PunchSat CAD Model (REF)

Fig. 2. PunchSat Internal systems

B. Introduction to Space

Since the last academic year M3 Aerospace students at the 3rd year can select the Introduction to Space module. The course is organized in two different main activities: theoretical lectures and practical lectures. During the practical lectures the students have the opportunity to learn the use of several software normally used by CubeSat developer team to design their mission. Cubesats are 10 cm cube (called 1U) invented by prof. Robert J. Twiggs and prof. Jordi Puig Suari. This satellite standard was invented with the main purpose of involve students in a real satellite mission. Recently the CubeSat became famous platform used by Space Agencies, Companies and Military to reach space and perform different kind of missions in different orbits, from LEO to Mars. One of the main characteristics of this platform is the relative low costs and flexibility [3].

During this module the practical hands on activity consist on performing an individual project or coursework. During the coursework the student has to think about a space mission that can be performed with a CubeSat (from 1U up to 3U) with a total budget of 2M of EUR and a timeframe of 2 years. If we consider the life cycle of space mission as defined in [4], the students have to conclude phase-0 (Mission analysis/needs identification) and phase-A (feasibility study) up to the PRR (preliminary requirements review) to satisfy the coursework requirements.

To support their activity the student will be have access to several software (3DExperience, Matlab, Abaqus) but also to official documentation coming from previous student satellite missions. In the next academic year students will have also the opportunity to use COTS platform such as the ESAT platform offered by TheiaSpace company to implement their hands-on space experience [5].

C. Spacecraft Systems and Design

Spacecraft Systems and Design is a new module that will be introduced in the academic year 2019-20 for students attending the 4th year of the MEng Course. The course is specifically dedicated to the design of spacecraft systems and, due to its nature, it adopts a hands-on educational approach.

In particular the students enrolled in the module will select, together with the module convenor, a payload and integrate it in an existing platform. The platform is part of the BeeReady program from the company Open Cosmos and includes a mission simulator software (BeeApp) and a 3U CubeSat platform (BeeKit) [6].

In addition, the students will learn how to track and receive a satellite using the UoN UHF, VHF and S band ground station that will be installed before the end of 2019. In the near future, when the first UoN satellite will be put on orbit the students will have also the opportunity to learn how to operate a satellite.

D. Individual Projects

As part of all the M3 courses, the student has to work individually in a project and produce at the end a scientific paper (MEng) or a technical paper (BEng and MSc). One of the opportunities give to engineering students at UoN is the possibility to perform a hands-on project where they have to solve a real problem. Normally project proposals are coming from small companies, research teams inside and outside the university or even institutional organizations such national foreign companies. This will give them not only the opportunity to be involved in a real project but also the chance of discussing problems and find solutions with real “customers”, researchers and experts coming from other institutions.

Last academic year for example students from MEng, BEng, and MSc where involved in projects concerning the design, analysis, prototype manufacturing and preliminary tests of space system of interests of different institutions as reported in table 1.

Some of the projects will be continued by future students and implemented in real satellite or mission. For example, the de-orbiting systems designed are going to be launched next year.

Other projects will be continued inside external companies by the students themselves and will become real products.

III. EXTRA-CURRICULUM ACTIVITIES

The general and strong interest among the students about space activities pushed them to be organized in team and associations with the common goal of performing additional hands-on experiences. Differently from the teaching activities described in paragraph II, in this case the students do not receive any credit or mark but get economical and technical support from M3 department. In some special case, as for example when the team are able to be involved in the ESA educational office program, parts of the work can be presented as individual project, but this is not always the case of this kind of activities. In this paragraph we will introduce only the most active student project called Ophelos and its results up to now

A. Ophelos Project

The OPHELOS (Orbital Platform Helping Experiment on Living Organisms in Space) project is being developed by a group of 4 students at the University of Nottingham and it focuses on developing an affordable CubeSat able to carry various biomedical payloads.

OPHELOS is split into different phases:

- *Initial testing phase – Phase 0*

The project is actually completing the initial phase or phase 0. The main goal of this step is to test a student-made scintillator and the thermal control system on a high-altitude balloon (HAB) with a mockup payload and a required power supply unit (PSU). The HAB launch was planned for June 2019 but postponed to October 2019 for some restriction related to the University safety rules. All the structural components have been manufactured by the students using existing facilities. Fig. 3 shows the 1U CubesSat structure with some subsystems before the integration.

- *First orbital test – Phase I*

First orbital platform is planned to be a standard 1U CubeSat (100x100x113.5mm). OPHELOS-1 will be a platform mainly focusing on testing the main satellite subsystems. The main payload is proposed to be the scintillation detector, consisting of 3 types of crystals: BiGeO, CdWO₄ and PbWO₄. A preliminary test of the thermal control system (TCS) will be conducted with the biological sample at 37°C ± 0.5°C.

Fig. 3. Ophelos Phase-0 system before the assembly

- *Final orbital system – Phase 2*

The second phase of the project will be carried out by a 3U CubeSat, allowing for bigger payload and more sophisticated subsystems. This part of the project will focus on a long-term observation of glioblastoma cancer cells, with an observation module inside the satellite. The project is a development from the GlioSat and GlioLab experience, both designed to observe the behavior of Glioblastoma cancer cells in extreme environments, and expanding their capabilities by being able to carry a wide array of payloads [7]

IV. LONG-TERM PROJECTS

The long-term initiatives have the main goal of establishing a complete program where students, in a time frame of approximately 2 years, will be involved in a real complete space mission. The full 2 years program will involve the students in different phases and at different levels. Basically the full program includes design, analyses, tests and in orbit operations of a satellite, normally CubeSat standard based. Similar hands-on activities are conducted overall the world and in Europe are strongly supported by European Space Agency [8].

To achieve these important goals and to get the chance to have interesting missions every two years the proposing team proceeded establishing an UoN Space group and several international cooperation.

A. UoN Space Group

Established in 2018, the UoN Space group aims to bring together existing expertise from across the University of Nottingham to focus on capturing research income around the technologies and sciences needed by the growing UK space sector. In coalescing this expertise, the team also anticipate training undergraduate, graduate, and post-doctoral researchers in the skills in demand by the space sector.

The University of Nottingham has wide ranging experience and research interests in Space Exploration, Space Technology and Manufacturing, observing the Universe, Space Biology, Space Pharmacy, Navigation and Earth observation.

The UoN Space group in particular is proposing several CubeSat missions in the different areas of research that will be developed in the near future by students and researchers at UoN.

B. International Cooperations

In the last two years several international cooperation have been established by UoN and international partners such as INPE (Instituto Nacional de Pesquisa Espacial), CEiiA, University of Beira Interior (UBI), University of Brasilia (UnB). The cooperation will allow students at UoN to get the chance to cooperate with foreign people and to put their own system in space starting from the second quarter of 2020.

- Cooperation with INPE-Brazil

The cooperation with INPE is actually based in two different projects: RaioSat and UbatubaSat-II. The RaioSat joint project aims to develop a 3-axis attitude determination and control

subsystem (ADCS) for the nanosatellite RaioSat, a 3-U CubeSat designed by INPE/Brazil. The satellite's primary mission is to detect intra-cloud and cloud-to-ground lightning flashes simultaneously, specifically to provide complete lightning detection covering Brazil. This information is useful for predicting extreme weather phenomena that require high-resolution numerical weather prediction (NWP) models and high amount of observational data [9] Students at UoN will be involved in the design of both software and hardware to guarantee the three-axis stabilization needed to accomplish the mission.

The UbatubaSat-II cooperation involves also the Associação Ubatubasat (Ubatubasat Association) in Ubatuba (SP, Brazil). The association is the responsible of the Ubatubasat program who allowed students aged 9-16 years from the school Tancredo Almeida Neves, in Ubatuba (SP) to launch the picosatellite Tancredo-1, one of the two first TubeSats ever launched[10]. In this second edition the young students will use a 1U platform to integrate their new payload and UoN students will support them designing the deorbiting mechanism. The launch is scheduled for the end of 2020.

- CEiiA and University of Beira Interior- Portugal

UoN is cooperating also with institution in Portugal with the aim of having a first space system in orbit with Soyuz in the second quarter of 2020. The CEiiA and UBI satellite, a 1U CubeSat, will test a new algorithm for ADCS magnetic stabilization developed in cooperation with Keldysh Institute of Applied Mathematics (KIAM). UoN will cooperate in the payload and in the system to guarantee the satellite deorbiting.

- Univeristy of Brasilia-Brazil

UoN is an active partner of UnB in particular with the Laboratório de Simulação de Controle de Sistemas Aeroespaciais (LSCSA) in different space activities such as LAICAnSat, the ADCS simulator and the Alfa Crux mission.

LAICAnSat is a platform for testing several payload using a HAB and a 3U CubeSat shape platform [11]

The ADCS simulator consist in an Helmholtz cage and airbearing table designed by students with the main goals of testing new algorithm and hardware for ADCS [12]

Alfa crux mission main goal is the design of narrowband communication satellites, compatible with defence tactical radios, and able to provide critical communication beyond radio targeting, and enable an M2M / IoT data network in remote regions with little infrastructure. The first technological demonstrator will be launched in the second quarter of 2020.

V. FACILITIES

Mechanical, Manufacturing and Materials Department has all the equipment needed to help the students to manufacture their own system starting from the 3D printer prototyping to laser cutting, water cutting and CNC machines.

M3 is also investing in acquiring new facilities and software to implement the hands-on student experience. In the academic year 2019-20 a UHF, VHF, S band ground station provided by AlenSpace company will be installed. As told in the previous paragraphs also two different cubesatt simulators will be available for the students one provided by TheiaSpace and the other by OpneCosmos.

The setting facilities are not completed yet but shakers, anechoic chambers and vacuum chamber are yet available.

VI. FUTURE ACTIVITIES

Future activities at UoN are mainly based on the idea of establish the CubeSat UoN program, The program will offer the student the unique opportunity to work in a real space program from the beginning of their university career with some preliminary design up to the end of their academic course with the in orbit operation.

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