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NANOSTAR, A COLLABORATIVE APPROACH TO NANOSATELLITE EDUCATION

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ABSTRACT

The CubeSat standard is today used by many universities and companies as an educational and research tool on space systems. The development of a nanosatellite project requires numerous tools and competences, which makes it an excellent training vector. However, it also requires appropriate experience, facilities and resources, which can be difficult to gather. Hence the need to work in a network. NANOSTAR emerges as a project funded by INTERREG-SUDOE through European Regional Development Fund (ERDF) aiming to develop a network of excellence among universities, the regional industry and the scientific ecosystem in order to create a leading collaborative online platform in Europe for nanosatellites. NANOSTAR aims to provide students with a high level of skills in space engineering and project engineering. In the past year, challenges have been proposed and different education strategies have been adopted. This paper describes the project and gives details about the collaborative online platform and the students challenges. The preliminary mission design challenges are presented, as well as the winner solutions to those challenges. Also, it dis-cusses the methods used to motivate and educate the students. Finally, it draws conclusions based on an analysis of the work development and proposes strategies for the future.

INTRODUCTION

Nanosatellites are today used by many universities and companies as an educational and re-search tool on space systems. The rise of CubeSats, a standardized subclass of small satellites, reduced the costs and complexity of space projects.

The standard was created by Stanford and California Polytechnic State Universities in 1999, and it specifies that form factor of one unit (1U) represents a 10-centimeter cube with a typical mass of up to 1.33 kg. The standardization promotes a highly modular, highly integrated system where satellite components are available as Commercial Off The Shelf (COTS) Moreover, it al-lows CubeSats to be launched as secondary payloads within a standardized deployment system. This simplifies the accommodation on the launcher and minimizes flight safety issues. Due to these features, CubeSats can also be readied for flight on a much more rapid basis compared to traditional spacecraft. This accelerated schedule allows students from universities with a CubeSat program to be involved in the complete life cycle of a mission.[1 2]

THE NANOSTAR PROJECT

Several countries have been strongly investing in small satellites, creating an educational and commercial offer that has become very well positioned in the market. However, despite the numerous benefits of nanosatellites for education, training and research, the Southern Europe has only 14% launched nanosatellites in the European sector (Figure 1).

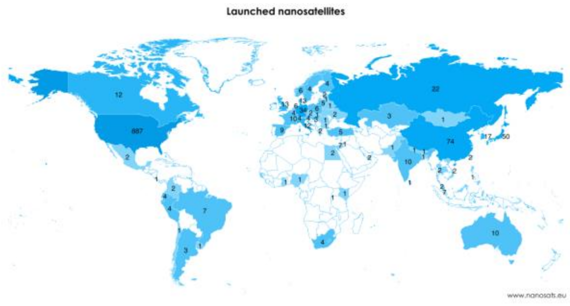

Figure 1 : Launched nanosatellites per country (source: www.nanosats.eu).

In fact, the development of a nanosatellite mission requires numerous tools and competences, which makes it an excellent training vector, but it is also necessary to have the appropriate experience and resources, hence the need to work in a network and exchange experiences.

Thus, the need to create a platform in Europe on nanosatellites by developing a network among universities, the regional industry and the scientific ecosystem. To support it, 7 universities and 2 aerospace clusters from France, Spain and Portugal joined in collaborative project to link their resources, plus 3 ESA-BIC (Business Incubation Centers of the European Space Agency) as associates. The goal is to create a collaborative online platform to provide relevant training on nanosatellite technology through student challenges. The project is funded by the Interreg Sudoe program through the European Regional Development Fund (ERDF).

The main objective of the project is to provide students with the experience of a real space engineering process that includes all stages, from conception and specifications, to design, assembly, integration, testing and documentation. That is, the whole process through a network that combines high-level engineering careers and entrepreneurial ventures in the area of nanosatellites. This will allow to train students with a high level of skills in space engineering and project engineering, so that they become the future main players in the field of nanosatellites. [3]

To do so, the tasks of the project were: to catalog the resources and expertise of the consortium and its environment; to develop the collaborative work tools (the Nanostar Software Suite); to develop the methodology for design, development, integration and testing of nanosatellites based on ECSS standards; to create and manage the competitions between inter-university teams (the student challenges); and to disseminate the results and ensure the continuity of the project.

THE ONLINE COLLABORATIVE PLATFORM

The development of the online collaborative platform is a key within the project. Firstly, it needs to include the methodology and knowledge on how to design of a space mission. Secondly, it will serve as the base for the student work.

The platform's goals are to enable the preliminary design of nanosatellite missions, to support concurrent design engineering and to be pedagogical. Thus, it needs to be informative, flexible, modular, student friendly and easily accessible and/or deployable.[4]

The first step was to create the tools for online collaborative work. These tools are called the Nanostar Software Suite (NSS) and requirements imposed were to be open source (AGPL v3), to use web-oriented technologies (cross-platform), to allow third party application interactions and to share common data representation. To implement such tool, it was decided to use a centralized data base, web service tools (when provided) a Representational State Transfer (REST) API and to follow the standards insofar as possible. The generic architecture of the NSS is represented in Figure 2. New models and interfaces can be developed and added progressively complying with the needs of the users. [4]

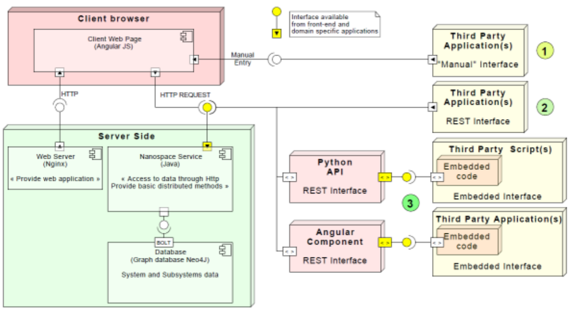

Figure 2 : NSS generic architecture of the first prototype (current). In practice, there are three solutions: manually interacting with NSS web user interface (1), or embedded code to ease interface (2), full compliance with the REST API (3). [4]

It is important to note that NSS is still under update since there are modules that are still in development and/or testing. Figure 3 demonstrates an example of NSS current instance.

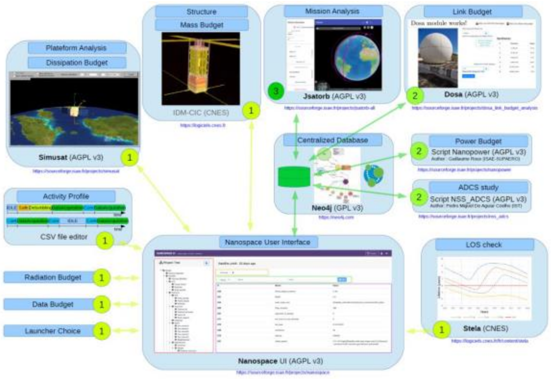

Figure 3: Example of NSS current instance. [4]

Additionally, a Concurrent Design Facility (CDF) was built in all institutions and interconnected. The Integrated Design Model (IDM) suite of tools, from CNES, was installed in all CDFs, which included an editor (IDM-CIC) and a viewer (IDM View) which offer students a powerful way to design and validate space mission concepts during preliminary studies by collaboratively create a technical reference to establish the satellite budgets.

Finally, it is also important to teach the students how to design a space mission, thus the methodology and the educational content was made available online.3 At the Nanostar website, all the material and tools are available to the students. There is also a slack channel where the students, professors and experts can communicate and share ideas and expertise.

THE STUDENT CHALLENGES

The student challenges are specific problems related with the design and development of small satellite missions. There are two types of challenges: the predesign challenges and the detailed design challenges. The first type is more educational, where the second is more about research.

Space mission predesign challenges are competitions in which multidisciplinary teams of students from the Nanostar universities must develop and present their design solutions to satisfy a set of mission requirements while using the NSS. Students are assisted by expert faculty and learn how to create a satellite mission cooperatively in the framework of concurrent engineering. Here, The teams were evaluated based on compliancy with the top-level requirements, project consistency, risk analysis, and physical soundness; maximization of the mission figures of merit; solution innovativeness; document and presentation quality; team management and organization; team size, multidisciplinarity, gender balance, and inter-institution.

Detailed designed challenges are specific research topics about small satellite subsystems that can lead to a final project or even master thesis. They can be addressed in teams or individually.

SPACE MISSION PREDESIGN CHALLENGE FIRST EDITION – MOON OBSERVATION

The search for the presence of lunar water has attracted considerable attention and motivated several lunar missions, largely because of water's usefulness in rendering long-term lunar habitation feasible. Liquid water cannot persist on the Moon's surface, while water vapor is quickly de-composed by the sunlight and hydrogen quickly lost to the outer space. However, scientists have conjectured since the 1960s that water ice could survive in cold, permanently shadowed craters at the Moon's poles. Water molecules have also been detected in the thin layer of gases above the lunar surface. [5]

This challenge consisted in the predesign of small satellite that shall perform a fly-by to the Moon and acquire science data during the periselenium pass (e.g. from altitudes above the Moon's surface lower than 100 km). The science mission shall feature a minimal onboard pay-load consisting of an optical camera to take a few pictures of the lunar soil. Additional payloads that help us achieve the scientific goals shall be proposed and included. A summary of the mis-sion high-level requirements is presented at Table 1.

Table 1: Summary of high-level requirements.

R01	The minimum payload on-board shall be an optical camera (1kg, 1U, 5W, 10Mb/flyby, 0.5 pointing accuracy, 20 deg half cone angle).
R02	At least one flyby on the moon shall be performed (altitude of periselenium less than 100km)
R03	The maximum satellite volume shall be less than 27U
R04	The mission lifetime shall be less than 5 years
R05	The data shall be transmitted to the ESA ground-station network
R06	The satellite starts in a GTO with free inclination

The challenge counted with 103 registered students (15 teams) that proposed different mission objectives, designs and innovations. The first prize went to Moon Invader team from Univer-sidade da Beira Interior (Portugal) and Universidad Politécnica de Madrid (Spain).

The Moon Invaders mission consisted of a 6U CubeSat with 14kg presented at Figure 4. The mission goal was to identify different forms of water on the

Moon's South Pole. For that, they used two additional payload: a neutron spectrometer system able of measuring the total water volume present up to one meter below the surface; and a near-infrared volatiles spectrometer sys-tem that can check whether the hydrogen found on a specific crater on the Moon is in the form of water (H2O) or Hydroxyl (OH). [6]

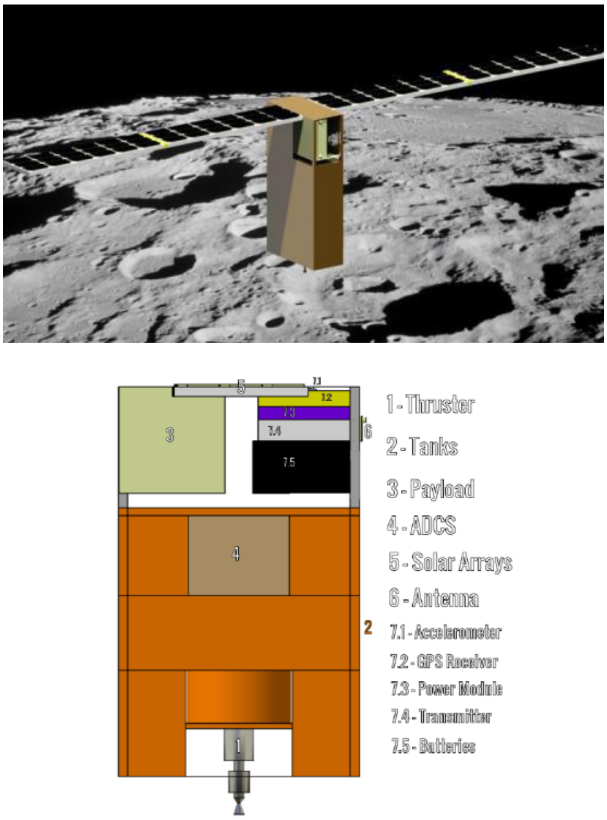

Figure 4 : The 6U nanosatellite from Moon Invaders team.

Space Mission Predesign Challenge Second Edition – Science Research in LEO

This challenge consisted in predesigning a small satellite scientific mission. The goal of the mission is to verify the survivability in space of a marine photosymbiotic species of worms (Ros-coff worms), which may one day play an essential role in the creation of artificial ecosystems for deep space exploration missions. The scientific payload will monitor the metabolism of the worms and their efficiency for urea and air recycling via video observations and measurements. A summary of high-level requirements is presented at Table 2.

Table 2 : Summary of high-level requirements.

R01	The minimum payload on-board shall guarantee the survivability of the worms (7kg, 3U, L-shape, 1 pic/min, 10s HD video per hour, 0.5 pointing accuracy).
R02	The maximum satellite volume shall be less than 8U
R03	The mission lifetime shall be between 2 weeks to 3 months
R04	The data shall be transmitted to the ESA ground-station network
R05	The satellite shall have a kill button for the worms

The challenge counted with 82 registered students (12 teams) very multidisciplinary that pro-posed different designs and innovations. The first prize went to UC3M StarWorms from Univer-sidad Carlos III de Madrid (Spain). The UC3M StarWorms mission consisted of a 6U CubeSat with 16kg, presented in Figure 5. [7]

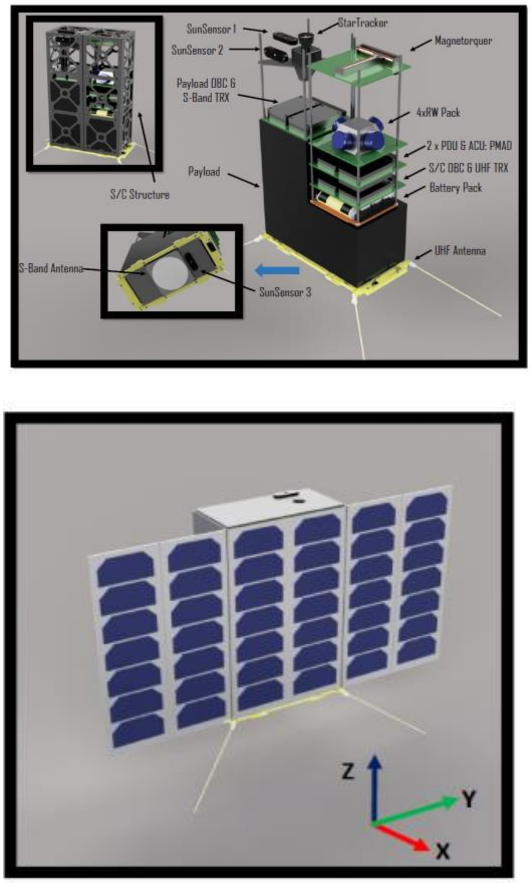

Figure 5 : The 6U nanosatellite from UC3M StarWorms.[7]

Detailed Design Challenges

The detailed design challenges are research based. Each institution will be offering specific challenges on the detailed design, development and testing of nanosatellite components. The main objectives are to increase hands-on education for students, research and development within the universities, instill collaboration and mobility of students and researchers and allow to buy equipment and other resources.

Some of these challenges were related to specific subsystems, others to nanosatellite testing facilities and there will also be a challenge on the detailed design of a Roscoff worms' payload, considered in the second edition of the preliminary design competition.

Up to now, there have been a total of 68 registered students in 22 different challenges. The challenges will start soon.

FUTURE WORK

Nanostar consortium is focused on building an inter-university network to provide satellite hands-on education. The goal is to create a multi-level network:

- Level 1 - Administration: It consists on the governance. Provides the framework and manages the funds for the network to be sustainable. It contains the legal documentation.
- Level 2 - Network of Resources: It gathers all the equipment necessary to design, build, test and operate a nanosatellite in a collaborative approach. It contains also the open-source tools developed for students and researchers.
- Level 3 - Network of Knowledge: It gathers all the experts and skills from different entities necessary to provide support and education on small satellites.
- Level 4 - Network of Students: It consists on the students that worked on small satellite projects and their work that can be published.
- Level 5 - Network of Research: It gathers a network of companies and research centers that want to develop nanosatellite projects. They can provide funding for specific research pro-jects and provide a work environment for students.

This multi-level network would be very beneficial in the European space field since it allows institutions to work together and help each other mutually. It can add benefit to all the actors either in the development of skills or in the advancement of research.

CONCLUSION

NANOSTAR is developing an online database of knowledge, a network of expertise and re-sources, and collaborative open-source tools that are pushing forward space education in Europe.

It is important to understand that Nanostar project deals with different types of actors with different interests and perspectives.

From the point of view of the universities, the project is having a positive impact in two fronts. On one hand it motivates students to work on specific space research projects at the university, giving them funds, resources and the knowledge required. On the other hand, it helps re-search units to disseminate knowledge and opportunities among students, researches and professionals. This is very useful to recruit, share ideas and develop new projects and partnerships.

From the point of view of the students, the project is providing them with space education, and they seem very interested in having more resources available to learn. However, they would like to get some hands-on practice and not only theoretical. Therefore, it would be beneficial to have projects where they could go beyond design phases and participate in production, qualification and even operation. Also, the students were motivated to participate on the student challenges just because the project was insert on an international level. By knowing that they had the possibility of interacting and competing with students from other universities, they felt the need to show their value and put effort on their work.

Therefore, Nanostar project developed a formula that can be used in a larger scale to motivate students to enroll on space sector while doing relevant space research at the same time.

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