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# OUFTI-1, THE EDUCATIVE NANOSATELLITE OF THE UNIVERSITY OF LIÈGE, BELGIUM.

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*Abstract*—**This article treats the educational aspects of the OUFTI-1 project, whose aim is to build a CubeSat that will carry three payloads. The article addresses the question of maximising hands-on education through such a project. The objectives of the project are presented, and the influence of the first of them (fun and education) on the others objectives is explained. The organization implemented to give as much hands-on experience as possible to the students is also been discussed, as well as the benefits for the students to interact with different people, experts, ham-radios, professors, and colleagues. The involvement demanded to the students, and the gain they could get out of such a project are discussed. The article ends with a presentation of the different lessons learned by the team in general, and concerning the students in particular.**

## I. INTRODUCTION

Design and realization of a whole system is a major part of an engineer's work. However, this competence is rarely and hardly taught during undergraduate studies. The University of Liège wished to improve this aspect, especially in the context of the master in aerospace engineering. The idea of building a satellite appeared and the project received a name derived from a typical local interjection : OUFTI-1. Three elements enabled the project to start at full speed: the CubeSat standard, ideas for innovative payloads, and a flight opportunity aboard the launch vehicle Vega.

The CubeSat is a satellite standard proposed and maintained by Stanford and CalPoly universities. A CubeSat is a very small satellite which has to fulfill a set of requirements [1]. Main features are the 10cm-edge cubic shape and the maximal weight of 1kg. Operational, mechanical, electrical, and testing requirements must be satisfied as well. The CubeSat standard, coupled with the standard deployment system (“ P-POD ”), greatly facilitates the access to space: CubeSats are accepted as secondary payloads aboard many launchers. Moreover, Cubesats allow a shorter development time and a budget smaller than for a regular satellite. These qualities make the CubeSat widely spread among universities and engineering schools all over the world.

Three innovative payloads will fly aboard OUFTI-1. The main one consists in the D-STAR amateur-radio digital telecommunication protocol. One of its main characteristics is the simultaneous transmission of voice and data. The two secondary payloads are high-efficiency solar cells provided by Azurspace and a digitally-controlled electrical power system developed in collaboration with Thales Alenia Space ETCA.

In the very early days of the project, the European Space Agency (ESA) issued a proposal for a free-of-charge flight opportunity aboard the Vega maiden flight [2]. Vega is the new European launcher, developed for Arianespace. It is designed to launch small scientific payloads (300 - 2000 kg) to low Earth orbits. This flight opportunity was intended for educative CubeSats. Nine (+ two backup) were selected, including OUFTI-1. The Vega maiden flight will place OUFTI-1 on an elliptical low Earth orbit ($1447 \times 454$ km, $i = 71$) and is currently scheduled for October 2010.

Those three elements (CubeSat standard, innovative payloads, and flight opportunity) made quickly come true what could have stayed an “ academical dream ”. The question is then: how to maximize hands-on space education through such a project ? The answer appears through different aspects: mission objectives and technical choices, the organization and the different actors, and the involvement of the students.

## II. MISSION OBJECTIVES AND TECHNICAL CHOICES

Well-defined mission objectives are crucial. They lead developments and give priorities in order to take efficient decisions. Success criteria are also needed. They allow the team to measure whether an objective has been reached or not. The different objectives of OUFTI-1 are listed below by order of importance.

1) **Fun and education.** It results from contacts with different teams that having fun while working on a project is the basis of success. However, the OUFTI-1 project aims

at providing hands-on experience, mostly to students. Therefore, both fun and education will be considered as the first objective. There are three criteria to evaluate whether this objective has been achieved. First, we should have a number of students getting good grades for their work on the project. Second, there should be a significant amount of students willing to work on the project each year. Third, the success of a year's work can be measured by the amount of graduate students who, after their graduation, continue to participate, actively or not, in the project.

2) **Design of the OUFTI-1 system.** Besides the educational objectives, OUFTI-1's first goal is to design and build a satellite, which implies designing and building both a space and a ground system. The success criteria is to have a functional satellite and its corresponding ground system working properly.
3) **Launch of OUFTI-1.** Once the satellite will be built, the next step will be to launch it. Having a proper launch is the success criteria.
4) **Having the satellite alive in space.** After launch, the satellite's life will start. The success criteria is to receive a signal from the satellite, indicating that it is alive.
5) **Operating the satellite.** The success criteria is to upload telecommands and download telemetry.
6) **Having the D-STAR functional.** The D-STAR payload will be the first to be operated, as it is the main payload. The goal is to demonstrate the use of the D-STAR protocol in space. A single D-STAR contact via the satellite is enough to considerate the D-STAR payload as a success.
7) **Operating the secondary payloads.** The two secondary payloads, which are high-efficiency solar cells and a digital power system, will then be operated. The success criteria is to receive telemetry from those two payloads.

It can be seen that education takes the first place amongst mission objectives. The educational purpose will then be considered and kept in mind while working to accomplish the other objectives. It leads, for example, to the choice of designing all subsystems (except the structure and the on-board computer) instead of buying commercial parts. We also decided to develop our own ground station, even if it is sometimes considered as less attractive than designing the satellite. Although being the main payload, operating the D-STAR only appears as the sixth objective. Such a gradation of objectives means that launching the satellite is already a partial, but great, success of the mission.

## III. Organization of the project

To accomplish all the objectives, a adequate organization is needed. This was one of the first lessons learned. Without a well-organized team, the project could not work. Even though it sounds obvious, it is not a familiar way of working in the academic world.

The project has been structured as follows. A project manager is in charge of all the aspects of the project: visibility, achievements, technical coherence, financial safety and people management. The project manager is a former student who did her MS thesis on CubeSats. Managing the OUFTI-1 project enables her to gain experience not only in technical management, but also in all the aspects of a project, such as visibility, contacts with inside and outside partners, time management, team building, budget keeping, etc.

Besides, a system engineering team deals with the interfaces between the different subsystems. It guarantees that a change in one of the subsystems will either not affect any of the other subsystems or that the subsystems affected by this change can deal with it. Otherwise, new interfaces must be defined. The system engineering team is composed of four graduate students, three of them having previously realized their MS thesis on the OUFTI-1 project. Each member of the system engineering team has a transversal topic in his competencies: communications, mechanics, computer science, and electronics. Nevertheless, each one has to remain aware of the entire technical state of the project. Each one can then at the same time gain experience in technical management, and in a specific domain, but also acquire advanced knowledge in other domains.

The technical tasks are divided into subsystems. Each subsystem is then splitted into workpackages. A workpackage consists in a particular technical problem that has to be solved by a student. The work is supervised by an advisor and a technical expert. Technical experts come from the industrial world or are ham-radio operators. Their goal is to give to students, in addition of the theoretical college formation, an industrial pragmatic and practical point of view on a technical problem and on the feasibility of the solutions envisioned. As long as technical solutions remain inside the interfaces defined by the system engineering team, the student works with his advisors. In case it is proved the interfaces specifications cannot be met, the student addresses the issue to the system engineering team that will evaluate the solution for the entire system and give back to the student new specifications. In any case, regular reports stating the student's advancement must be sent to the project manager.

However, several topics involve more than one workpackage, and therefore more than one student. In this case, students must work together to provide a feasible solution. The solution proposed is then evaluated by both the advisors at the particular level of workpackage and by the system engineering team at the system level.

The way OUFTI-1 project is organized is a unique occasion for students to submit innovative solutions to technical experts and to work together with team-mates of different backgrounds.

## IV. Deep involvement of the students

Most of the students in the OUFTI-1 team work in the framework of a MS thesis. The project is however relatively different from a classical MS thesis, in the sense that it implies some unusual features. The main one is probably the importance of teamwork. This is closely linked to the high multidisciplinarity of the project, and the numerous interactions between subsystems and thus between students. Another particularity is the similitude with a real industrial project: the team is structured and has a project manager, schedule and deadlines must be respected, industrial tools and softwares are used. Moreover, the work performed will lead up to a real satellite and not only to academic reports. The project also involves some constraints for students, such as monthly reports for ESA or public presentations. Last, it was chosen to involve students in investigation and choices of technical solutions. It can create an unusual situation with professors and advisors when investigating complex issues. Students must show independence of mind in those " as equals " discussions.

These characteristics could be seen as constraints for students. They are on the contrary consequences of choices and give rise to the most interesting learnings in the project. Students develop qualities and skills such as team spirit, initiative spirit, autonomy, and critical mind. They also get familiar with industrial approach and tools. Through the multidisciplinary team, students learn to adapt their speeches to engineers from a different specialty, while learning from other disciplines. Presentations and travels are great opportunities to meet people and practice a foreign language. Above all, OUFTI-1 is an exceptional and highly motivating project that gives the students a way to reach space.

## V. Lessons learned

Based on the experience from the first fifteen months, the OUFTI-1 project has derived several lessons. Those lessons concern both the project in general and the students in particular.

1) **Full-time project manager and well-defined organization chart are needed.**
   At the beginning, the project was managed by three persons (two university professors and an industrial). Due to this division of responsibilities and also because all these three persons were working part-time on the project, decision process was not efficient.
2) **Technical issues are not the most time-consuming.**
3) **A multidisciplinary team is not easy to manage, but really enriching.**
   In fact, getting the people to work together is by far the hardest task and the most time-demanding one, but it is necessary to achieve the objectives.
4) **There are strong interest and support from academics, ham-radio community, industrial, and general public.**
5) **There is a real and great CubeSat community spirit.**
   The different contacts established by the team with all the industrial partners, the ham-radio community, and the other CubeSats teams turned out to be really interesting. The students have been able to exchange information with experts and also with colleagues from other teams. Moreover, the general public has been very receptive to the OUFTI-1 project, with many articles and interviews in local and national newspapers and radio-stations. Everybody wants the project to succeed !
6) **There is a crucial need for rigorous documentation.**
7) **Everybody, and not only students, learns.**
   This kind of project is a unique opportunity for every member of the team to learn, both in his own domain and about other technical matters, as no pre-existing solution is possible. In order to make everybody able to learn on any aspect of the project, but also to guarantee knowledge transfer from one generation of students to the other, rigorous documentation is a must. Otherwise, loss of information or, even worse, misinterpreted information, appears, leading to non-sense and inappropriate decisions.

   As far as the students are concerned, the following points must be underlined:
8) **Interfaces can not be managed by students**
9) **Autonomy and initiative spirit must be learned**
   At the beginning of the project, the idea was to let the students manage the interfaces. Experience has proved that even though they were and are still highly motivated, students lack the benefit of both hindsight and experience. Furthermore, autonomy and initiative spirit are not inborn. However, it can be acquired, especially through this kind of project. But the most important characteristics about students, and they were all unanimous about it, is the numerous discoveries and encounters the project made them make. This concerns obviously the technical aspects, but also soft skills such as making presentations, networking and exchanging information, speaking a foreign language, and dealing with " real " technical materials and problems.

## VI. Conclusions

This article treated the educational aspects of the OUFTI-1 project, whose aim is to build a CubeSat that will carry three payloads. The objectives of the project have been presented, and the influence of the first of them (fun and education) on the other objectives was explained. The organization implemented to give as much hands-on experience as possible to the students has also been discussed, as well as the benefits for the students to interact with different people, experts, ham-radios, professors, and colleagues. The involvement demanded to the students, and the gain they could get out of such a project have been discussed. The article ends with a presentation of the different lessons learned by the team in general, and concerning the students in particular. The motivation each generation of students shows from year to year, for three years now, makes everyone confident to succeed in such a hard work as to put and operate a satellite in orbit.

## References


[1] *CubeSat Design Specification*, Revision 11, The CubeSat Program, Cal Poly SLO, October 2008.

[2] *Educational payload on the Vega maiden flight - Call for CubeSat proposals*, Issue 1, Revision 1, European Space Agency, February 2008.