ODYSSÉE-S2, A FRANCE-JAPAN EXPERIMENTAL ROCKET PROJECT

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ABSTRACT

International cooperation is essential in today's Aerospace industry. As engineering students at ESTACA (Paris) we were particularly eager to bring this aspect into our training.

Within ESO, the ESTACA rocket club, we started a new experimental rocket project, Odyssée-S2, with the Japanese team TKRC.

We wanted to prove ourselves we could lead this project despite the distance, the language and cultural differences.

The French team would be responsible for the launcher, and the Japanese team for the inboard experiment. Interface and compatibility were the heart of the project.

Odyssée-S2 was launched on August 28th, 2012 at C'Space, the French national student rocketry meeting, and was awarded the CNES prize for a fruitful cooperation.

In this paper, we will introduce how we carried out this project and the key points of a cooperation project, in the hope of inspiring students to throw themselves into such an amazing experience.

1. PROJECT FRAMEWORK

1.1. ESTACA

ESTACA (École supérieure des techniques aéronautiques et de construction automobile) is a French 5-year Engineering school specialized in the design, development and production of transport systems and components.

ESTACA confers a Master's degree in four majors: Aeronautics, Automotive, Railways and Space engineering.

Founded in 1925, ESTACA is now located in Levallois-Perret (Paris) and Laval (Fig.1).

Figure 1. ESTACA is located in Paris (red pin) and Laval (blue pin).

As Space engineering major students, the authors were particularly interested in having a first experience of system engineering, joint project management and international cooperation, which are main challenges for space industries today and tomorrow.

1.2. ESO

The Odyssée-S2 rocket project was carried out within the framework of a student organization, made up of ESTACA students and supported by their school: ESO (Fig. 2).

Figure 2. ESO logo

Estaca Space Odyssey (ESO) is a non-profit student organization, created in 1992 in order to promote space-related activities at ESTACA and with the general public.

Designing, building and flying experimental rockets (Fig. 3) are our main activities. With over 20 years of experience in student experimental rocketry, ESO launches each year between 5 and 10 new projects.

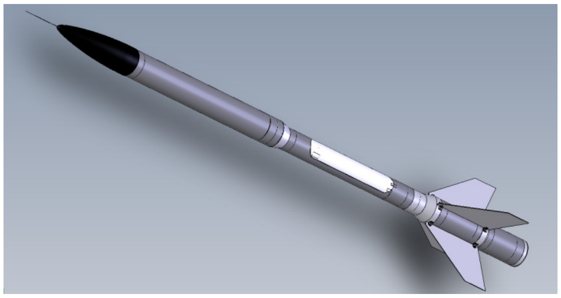

Figure 3. Marianne CAD on DS Solidworks

ESO members are also taking part in stratospheric balloon projects, microgravity experiments aboard the Novaspace Airbus A300-0G, and joining or organizing conferences (the astronaut Jean-Loup Chrétien at ESTACA, Laval, March 14^{th}, 2013) and visits of industrial sites (Snecma, EADS Astrium, MBDA).

1.3. C'Space

C'Space is the French national launch campaign, organized annually by the French space agency, CNES (Centre national d'études spatiales) and Planète Sciences, a non-profit organization promoting sciences education.

It takes place each year during one week, at the end of August, in a French army missile test center in Biscarrosse, near Bordeaux (southwestern France).

C'Space gathers around 20 high school and engineering school rocket clubs (Fig. 4), mainly from France, but also from Russia, Austria, Australia and Japan. In 2012, 22 experimental rockets and 19 mini-rockets were launched.

Figure 4. ESO at C'Space 2011

C'Space is also hosting an annual Cansat competition and stratospheric balloon releases.

Next C'Space will take place from August 24^{th} to August 31^{th} 2013.

2. PROJECT CONCEPT AND ORGANISATION

2.1. First steps at C'Space 2010

In 2010, we went to C'Space with the experimental rocket Marianne (Fig. 3). The atmosphere between the teams attending C'Space is welcoming: teams usually share materials and tools. We met TKRC members (Team Kansai Rocket Club), we helped each other and finally exchanged business cards. A friendship was born!

It was for us a unique opportunity to gain experience in an international project before joining the industry.

2.2. ESO-TKRC Joint Project

One year later, Hugo was welcomed in Japan for a summer internship at Souki Systems. This startup company is supporting TKRC in Osaka. During C'Space 2012, the ESO-TKRC Joint Project (Fig. 5) officially started. The rocket name was also chosen: Odyssée (to celebrate the 20^{th} anniversary of Estaca Space Odyssey) – S2 (the TKRC standard designation).

Figure 5. ESO-TKRC Joint Project patch

2.3. Odyssée-S2 concept

In addition to the international cooperation aspect, we wanted to work with an industrial-like approach, and to be confronted with the compatibility and interface problematic.

The main idea was to separate, as in the industry, the launcher and the payload.

ESO had to design and build the launcher itself, and to offer a "launch service" to its "customer", TKRC. The Japanese team was making the payload, an inboard experiment made up of different PCBs (printed circuit boards).

Thanks to 20 years of ESO rocketry experience, our objective was to build a « ready-to-flight » launcher with simplicity, reliability and functionality as a guideline (Fig. 6).

The fact of assembling the rocket only few hours before launching required a functional architecture and a quick and easy access to the internal structure, holding the inboard experiment devices.

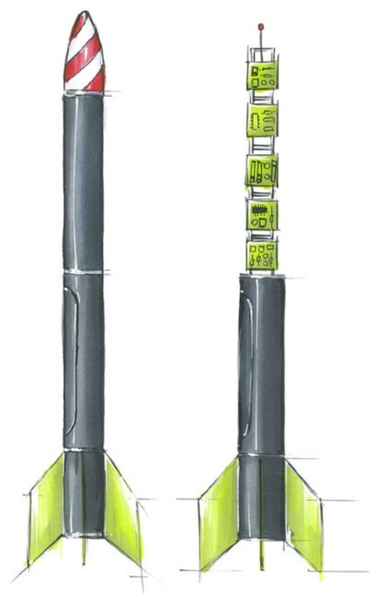

Figure 6. Preliminary sketch showing the general architecture of the rocket

2.4. Teams formation

Once the division of tasks defined, we set up the teams and started to work on the future rocket.

2.4.1. ESO

In France, the ESO team was made up of ESTACA students from the first to the fourth year, with a core group of three people, helped by occasional members at different periods of the year, giving a total of five or six members permanently.

Traditionally, ESO teams are divided in two groups (Fig. 7), the first in charge of the rocket mechanics (architecture, structure, stability) and the other dealing with the inboard electronics (recovery system and experimental devices).

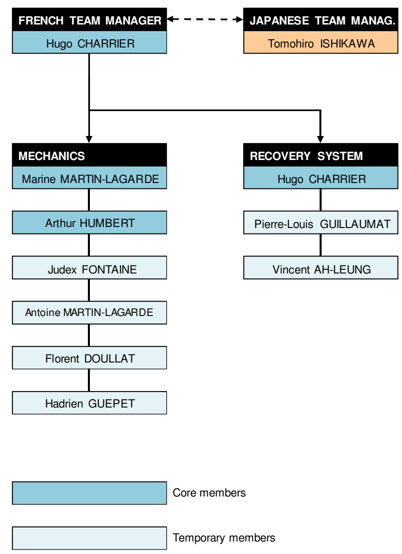

Figure 7. Odyssée-S2 French team organization chart

2.4.2. TKRC

The Team Kansai Rocket Club (TKRC) is gathering university and high-school students and young engineers and technicians from Souki Systems in Osaka.

Souki Systems is a young company, specialized in educational robotics, electronic devices for production system and 4 rotor UAV for observation. Souki Systems also build experimental rockets in cooperation with the Osaka Sangyo University (OSU), within an educational training.

TKRC already used to join C'Space for three years when we started the Joint project.

Made up of five people helped with the other TKRC members, the Japanese Odyssée-S2 team (Fig. 8) designed the inboard experiment, using in particular Souki standard microcontroller PCB.

Figure 8. Core members of the Japanese team

2.4.3. Air-ESIEA

As we will see below, a third team joined the Odyssée-S2 project during spring, 2012: the Air-ESIEA rocket club. ESIEA is another Paris school, specialized in electronics, computer and automatics engineering.

Air-ESIEA was created in 1986 and seeks to promote aerospace activities within ESIEA and to the public.

2.5. Organisation and synergy

At the beginning, it seemed important to us, to write a definition document giving the frame and the broad outlines of the Joint project. We fixed different things in order to work in the same direction and efficiently.

The definition document gathers the objectives and obligations of each team, a global schedule, a weekly skype meeting, and a list of the softwares to be used for each task: schedule, logo, electronic schematics, CAD, reports etc.

The most important aspect of this cooperation was to understand cultural differences, and respecting them even in case of disagreement (e.g. corporate hierarchy).

The more we could understand about the way the other team worked, the more we could anticipate possible issues and mistakes. It was a real improvement of our management skills and it remains as a very important part of our engineering training.

3. BUILDING THE ROCKET

3.1. French team work

The French team had two main targets: first, designing and making a functional and simple body structure; then, to design and make a reliable recovery system.

Moreover, the challenge was to put together different systems, made in France and in Japan. Interface and compatibility were the heart of our job.

3.1.1. Rocket structure

Thanks to ESO members' experience, we worked on making a « ready-to-flight » launcher with simplicity, reliability and functionality as a guideline.

The Odyssée-S2 CAD (Fig. 9) was made with DS Solidworks. This software is studied at ESTACA from the first year, and it was important since we had students from the first to the fourth year; it was also used by TKRC.

Figure 9. The rocket CAD

Careful attention was paid to the access to inboard electronics, in order to be able to solve any issue in few minutes.

The rocket we designed is 2.40 m high with an external diameter of 140 mm. It required several materials and processes. Skin and fins were made of carbon-fiber-reinforced polymer (CFRP). Rings and internal structure were made of machined aluminum, and nose cone of polymer.

ESO characteristic is our capacity to make almost every part of our rockets ourselves, in our workshop at ESTACA.

The CFRP tubes are hand-made, using a PVC pipe as a mold (Fig. 10). Aluminum parts could be machined at the ESTACA workshop, with the help of our teacher.

Figure 10. The French team manufacturing the CFRP tubes

3.1.2. Recovery system

The recovery system mainly includes:

- a timer PCB;
- a take-off detector;
- an electromagnet setting off the parachute door opening;
- a parachute.

The timer PCB (Fig. 11) includes a microcontroller processing data and making the orders.

In addition, keeping in mind the objective of our team (to offer a reliable and functional launcher), we added extra components such as a 7-segment displaying the countdown during tests; a buzzer indicating the parachute door opening, in order to warn an untimely activation; a setting mode to program the timer without connecting the computer etc.

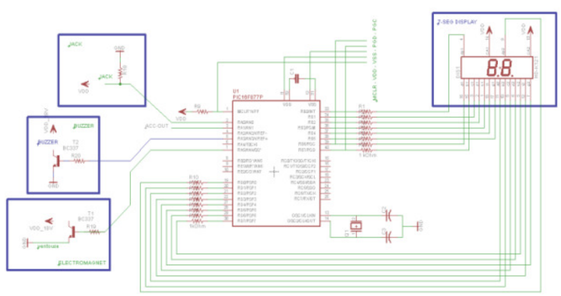

Figure 11. The timer PCB schematic on Eagle

In the context of a school project, third-year students worked on a reliability study. They studied different schematics thanks to a fault tree analysis (Blocksim7) and made recommendations.

The recovery electronics were also made at the ESO workshop, from the computer (schematics and layout on Eagle) to the PCB.

3.1.3. Interface

A large part of our work consisted in preparing the assembly and to ensure compatibility between all the components.

The interface was limited to a ladder-shaped internal structure (Fig. 12) with a standard width, fitting the Japanese PCB. We made our own PCB with the same width and, later, we checked it would also fit the Air-ESIEA devices.

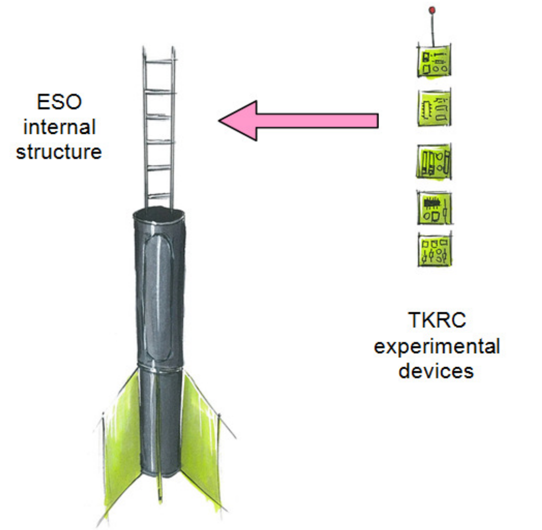

Figure 12. Integration of the inboard experiment on the internal structure

3.2. Japanese team work

TKRC worked on different experiments using Souki Systems standard PCB, including microcontrollers (Fig. 13): GPS coordinates, 3-axis acceleration measure, telemetry and data storage. Finally, the system had to be revised due to the company schedule and was composed of accelerometers, a GPS receiver and inboard storage.

They assembled the PCBs with the sensors and the GPS receiver, and programmed the microcontrollers to communicate together and store data safely.

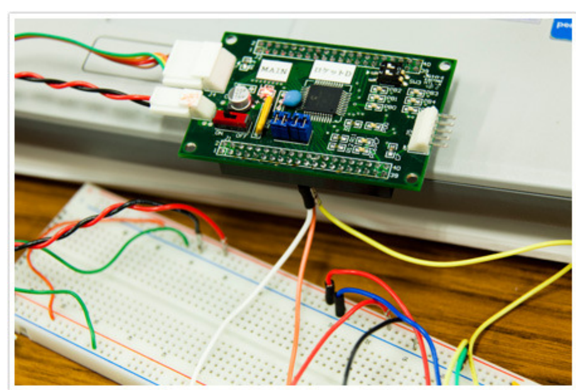

Figure 13. Standard Souki Systems PCB used for the inboard experiment

3.3. Air-ESIEA additional experiment

During spring 2012, we were confronted with a common industrial issue: due to the experiment revision, the launcher and the payload did not fit exactly.

We had to adjust the payload size (the rocket was too voluminous) and we offered Air-ESIEA, another French student organization, to join the adventure.

They proposed to set up their Cansat electronics into the rocket, in order to proceed tests and to supply the landing GPS coordinates by telemetry. We had to check compatibility between their components, the rocket structure and the Japanese systems: mechanical, radio and electrical compatibility.

4. LAUNCH CAMPAIGN

4.1. Rendezvous at C'Space 2012

The three teams, ESO, TKRC and Air-ESIEA, met finally at C'Space 2012, in order to put all the systems together and proceed tests before the launch (Fig. 14).

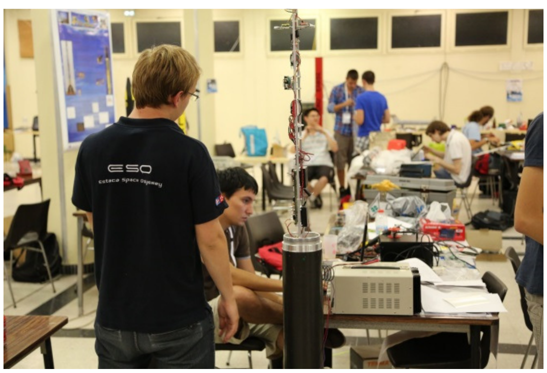

Figure 14. ESO and Air-ESIEA students finalizing details before the flight

We had three days to prepare the rocket, before the first day of experimental rocket launches.

4.2. Assembling the rocket

The fact of assembling the rocket only few hours before launching required a meticulous preparation.

Thanks to a constant communication, we shared the essential information to assemble the rocket quickly and to avoid unpleasant surprise: PCB and internal structure dimensions, wiring schematics, batteries volume, and finally an outline (schematics, chronology) of how the electronics would be integrated.

Every step was supposed to be written. However, something unexpected is always to be expected…

Before and during C'Space, several ESO members joined the team to help us. Finally, the preparation went off without major issue and Odyssée-S2 was the second rocket to pass successfully the technical controls, and to reach the launch pad.

4.3. Technical controls

Each rocket to be launched during the C'Space national launch campaign must fit to the Planète Sciences specifications, both concerning the mechanics and the electronics.

To acquaint ourselves with these specifications since the beginning of the project is essential to start in the good way.

During the pre-flight controls, our architecture and system choices were confirmed: all the tests were passed without significant problem.

4.4. Flight

Odyssée-S2 was launched on August 28th, 2012, in Biscarrosse. (Fig. 15 and 16).

Figure 15. Odyssée-S2 is placed into the launchpad

The rocket reached an altitude of 1100 m and a maximum speed of 530 km/h. The rocket was stable and the parachute opened right after the apogee (12.5 seconds after take-off). All of our « passengers », the inboard experiments, could reach the ground safely under the rocket parachute. The rocket landed on the beach, around 2 km far from the launch pad (Fig. 20).

Figure 16. Lift-off (Julien Franc, Planète Sciences)

4.5. Flight data

TKRC and Air-ESIEA flight data could be recovered safely during flight, thanks to the telemetry system, or stored inboard and recovered after landing. We will introduce shortly their measures.

TKRC could draw the acceleration profile of the rocket during the flight (Fig. 17) and store data. A problem occurred with the GPS receiver and the signal couldn't be acquired.

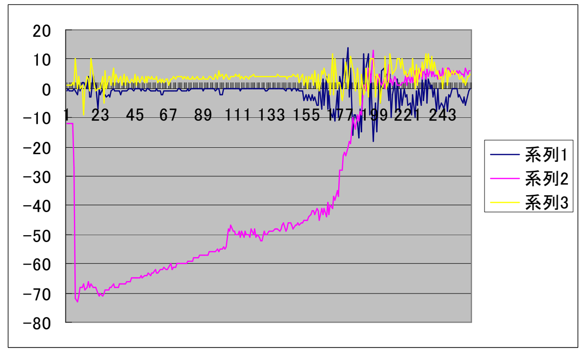

Figure 17. 3-axis acceleration raw data (TKRC)

Air-ESIEA devices transmitted a telemetry signal with the GPS coordinates and hygrometry measures (system designed initially for a Cansat competition).

Thanks to this telemetry system, we could obtain the landing coordinates (Fig. 18) in few minutes and find the rocket easily.

Figure 18. Flight under parachute, GPS coordinates (red path)

4.6. CNES Award

Each year, three prizes are awarded at C'Space: the CNES, Planète Sciences and French army (DGA) Awards.

Our team was awarded the CNES prize for a perfect flight: stability, parachute opening at the apogee, safe recovery of the rocket and data; and a fruitful international cooperation programme.

We were invited by CNES to join the 21st ESA Symposium on European Rocket and Balloon Programmes and Related Research (9-13 June 2013, Thun, Switzerland), in order to present the Odyssée-S2 rocket project and to attend the conferences.

5. PROJECT BENEFITS

The ESO-TKRC Joint Project was an important part of our engineering training, and prepared ourselves to join the Aerospace industry as system engineers.

This programme was also fruitful for ESO and ESTACA, since a total of 3 students have flown to Osaka, for summer internships at Souki Systems, in 2011, 2012 and 2013. ESO-TKRC cooperation will probably go on under different forms, in the next years.

At ESO, Odyssée-S2 was the first international rocket built.

In September, 2012, few weeks after the launch, a new team was formed within ESO, to build the experimental rocket Esther. This rocket will take on board experimental devices made by several other clubs, from France or abroad.

Taking advantage of the experience acquired making Odyssée-S2, ESO is once more designing a launcher and offering the other teams a "launch service" for their experimental devices. Esther is to be launched during C'Space 2013, from August 24th to August 31th.

CONCLUSION

Understanding cultural differences is absolutely necessary to anticipate related problems, check we understand each other and make sure the project will be carried out successfully.

Making use of our previous experiences, of synergy between teams (Fig. 19), and preparing carefully the interface between the launcher and the inboard systems, we passed the technical controls without problem and the rocket flew perfectly.

This project remains for us a rewarding experience of international cooperation, project management, and will keep a great importance in our engineer training.

At the end of our presentation at the Symposium, and of this paper, we hope we could encourage young people to throw themselves into a rocket or scientific cooperation project.

Figure 19. ESO, TKRC and Air-ESIEA with Odyssée-S2

ACKNOWLEDGEMENT

First of all, we would like to express our sincere thanks to Mr Nicolas Pillet (CNES Education) and Mr Thierry Stillace (CNES/DLA), who awarded the Odyssée-S2 teams the CNES Prize at C'Space 2012.

Thanks to Planète Sciences, CNES and DGA (French army) for giving us such opportunities to live out our passion for rocketry; to Christophe Scicluna (Planète Sciences), Mr. Faux (ESTACA) and Junpei Maruo (OSU) for their personal support and to Alix Charrier (Strate Collège) for the sketches.

And finally, this project could not have been carried out without the great help of all ESO, TKRC, Air-ESIEA and PV3e members, and the constant support of ESTACA through years.

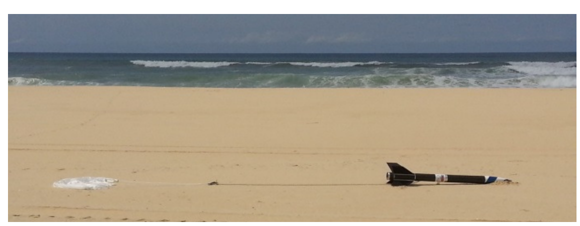

Figure 20. Odyssée-S2 on the beach after landing