PERSEUS

A Nanosatellite Launch System Project

Focusing on Innovation and Education

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Abstract

Perseus is a long-term project launched in 2005 by CNES and based on three main objectives:

- To stimulate innovation and advance technologies applicable to launch systems;
- An educational initiative for students and a motivation for the future generations to take up careers in the space sector;
- To realize the design project (phase 0/A) for a nanosatellite launch system (10kg payload on a polar, circular orbit at 250km).

The architecture has not yet been fixed; in fact several concepts are still being studied and we expect that these concepts will converge to a single one by around 2012.

1. Introduction

At the Salon du Bourget two years ago, CNES launched the PERSEUS project (Programme Etudiant de Recherche Spatiale Européen Universitaire et Scientifique – European University and Scientific Space Research Program). The road ahead slowed down the project's initial progress, but these issues have since been identified and the organisation of the project has been updated to ensure its success.

2. Project origins

The beginnings of the project arose whilst Raymond Bec, Head of Advanced Concepts at the Launcher's Directorate of CNES, was wondering how to create truly original ideas with respect to launch vehicle design. His line of thought included trying to avoid solutions which had previously been suggested. He felt that experienced engineers might not be the best adapted to this way of working, having built up notions over the years and no longer being able to see through the problems at the heart of the matter.

So, instead of seeking the help of professionals, he turned to amateurs and it became immediately obvious that students were the ideal candidates (this of course, would add the objective of hopefully inspiring the new generations to take up technical careers, especially in the space sector). So what kind of project could we propose to the universities that would force them to analyse each technical problem involved in a launch system in order to seek out new solutions? The idea of designing from scratch a launcher seemed appealing: they would have the skills and knowledge needed; the project would cover every aspect involved in the design process and the challenge of a professional and not solely academic task would inspire them. Ideas continued to evolve, and it seemed wise to not only look for innovative ideas but to demonstrate certain immature technologies, be it alone on the ground or integrated in a system in flight.

Although an orbiting vehicle should be manufactured by professionals in order to ensure the quality of the vehicle manufacturing and thus the safety during flight, smaller demonstrators could be made by amateurs (under correct guidance of course). It seemed advantageous to design a small launcher: it would be possible to manufacture components at universities and thus the students themselves could get some hand-on experience which would surely encourage them even more to participate in the project, as well as widening their theory-based education. It was agreed that the smallest payload that could reasonably justify a dedicated launch system would be a nanosatellite. Student-driven projects of this sort had already been undertaken, such as CALVEIN by the University of California[1], RVT by the Institute of Space and Aeronautical Science in Tokyo[2], as well as some smaller examples in Europe, notably THG Orbit in Sweden[3] and Atalante by the GAREF in French Guiana[4].

Ideas were starting to set and the Perseus project was born. Based on a reference mission of putting 10 kg on a polar orbit at an altitude of 250 km, CNES would lead a student project that would seek out original solutions and develop promising technologies, hopefully finding some applications on much larger, commercial launchers. In summary of this introduction, the three main objectives of the Perseus project, in order of importance, are:

- To stimulate innovation and advance technologies applicable to launch systems;
- An educational initiative for students and a motivation for the future generations to take up careers in the space sector;
- To realise the design project (phase 0/A) for a nanosatellite launch system.

3. Early difficulties

During the academic year starting in autumn 2005, five projects we organised which increased up to around twenty the following year (that is, the academic year ending this summer). During this period, some interesting challenges and difficulties arose and we have had to adapt our way of working accordingly.

We have observed, as might be expected, a varying quality of work, from excellent execution of certain student projects to others which contributed a very minimum to the overall project. Besides that, we have realised that there is a great need to educate the students specifically in the whole launch vehicle design process, even those who specialise in space systems engineering, as they are mostly taught how certain aspects of a particular vehicle works and not how to start designing a launcher from scratch.

On the whole, they tend to work well in a team, even though it is usually their first experience at this too; perhaps they have not yet the time to build up any grudges. Despite this, the amount of help from the academics at the universities does vary, though it is understandable that certain professors are simply extremely busy characters. Another problem is that students generally find time to work on the project in the evenings and the weekends, the exact opposite of the times that most professionals are available.

On a longer time scale there are further complications: universities do student projects or internships at different times than others; holiday and exam periods can relieve or increase their work load; projects often follow up others so defining precisely the topics some time in advance, as is often necessary, without the previous results is problematic ;. Further again on the scale, few students do projects in their first of a three year degree – a typical Engineering degree in a French "Grande Ecole" involves 2 years of preparatory classes and then 3 years at university – leaving a minimum turnover of two years in a project expected to continue for six more.

The varying geographical location of the participants who all work on the Perseus project is an additional factor to be accounted for. What's more, the specialists in a given particular field are not necessarily in the same region as the students, who generally do not have the time nor resources needed for 'business' trips. Universities in France, where degrees are not ranked by students' marks but by the reputation of a given "grande école", are particularly competitive and it can be difficult to encourage them to work together. Understandably but unfortunately, some universities are much more keen to take on the project when financial aid is available for their own research purposes, instead of trying to help give the students an enriching experience.

As for the launchers, despite the initial efforts a few decades ago, there simply does not exist any similar, modern rockets from which initial assumptions and validation can be made, except perhaps for certain missiles of which the design parameters are not available. Finally, the reduction of the size of a launcher does not necessarily make it more feasible, in fact as we reduce the payload mass, the take-off mass does not diminish linearly and so we fear that manufacturing costs may increase.

4. Improved approach

Clearly, as is the nature of many projects, the initial ambitions of the project were not as easy to obtain as one might have hoped. Fortunately, following careful consideration, we have found various solutions to these afore-mentioned problems.

The majority of student projects are done as a part of their degree, either by their own initiative or as directed by the university following an agreement with us. This acts somewhat as a guarantee that the students will at least try to obtain some reasonable results; if the idea of the project is not inspiring enough then at least passing your degree is motivating. We are also trying to write, collect, filter and summarise various launch vehicle design course notes to be sure that we give clear and concise information on the problems to be solved whilst trying not to offer the classic solutions available.

A successful initiative has been our annual seminar, the second and most recent one taking place at the beginning of February at the Air and Space Museum in Bourget, Paris (Figure 1). We see this as an opportunity for the different participants to expose and to become aware of all the various student projects, which in turn creates debate and encourages different teams to cooperate and integrate their work with other teams. The timing of this event is important, it is late enough to allow a large number (but not all) of projects to have some meaningful results, and early enough to allow new subjects to be defined by the summer so that they can be agreed to before the following academic year (as certain universities require).

Figure 1: Participants of the second Perseus project seminar in February 2007

In order to further encourage the teams to take an interest in and cooperate with the other projects, a web portal is being developed from modified open-source tools which we hope to further enhance according to the needs of such a program (Figure 2). This will be online before the beginning of the next academic year. As with any other project, we have divided the subjects into several work packages: groups of complementary student projects around a given theme. These have become known as macro-projects. Tools and organisation alone are not enough, so we are currently matching regional specialisations with one or several macro-projects and seeking out macro-project leaders, preferably acquainted with the topic but at the very least enthusiastic to guide and organise various student teams. We thus have the beginnings of a network of macro-projects and respective coordinators.

Figure 2: The web portal will allow a greater exchange of information between the project's participants

The involvement of associations and university clubs is a way to guarantee that the project can proceed beyond the limits of the turnover of students. Equally, these volunteers are often suitable candidates for leading certain macro-projects. Where candidates are not available, small and medium enterprises can fill the spot as long as they show a willing to work for more than just a profit. We work hard to create partnerships with the various participants – whether academic, associative or professional – so that they are fully involved in the evolution of the project. The partnerships are an important element of federating the diverse actors around a common and worthwhile goal. Although we still strongly encourage cooperation between different teams, we have observed in elsewhere that when students compete against each other they are likely to come up with innovative concepts. Our difficulty with this is to find a suitable isolated problem that can be achieved by students in a competition.

Having a certain number of collaborators does incur its own difficulties, notably a problem of reaching agreement in lengthy meetings to the satisfaction of the whole. In response to this need, an open-space project ("plateau projet" in French) is being set up where the leading partners can all pool their resources into a single entity at a given location. This streamlines the management of the project, speeds up decision-making and offers a universal leadership to the macro-project leaders and their student teams.

5. Preliminary technical results

Reorganising is not the only outcome of our initial studies; interesting technical results have come through and will be continued and extended. To put the students on the right track, consultants were initially asked to come up with simple reference concepts assuming little or no innovative improvements to today's state of the art. In addition, some more optimistic target concepts have been elaborated. These preliminary studies enabled us to define certain topics worth consideration.

As mentioned before, the structure ratio does not decrease linearly with respect to the payload mass and so the take-off mass of the launch vehicle concepts was larger than desired. As suggested by experts, we have decided to study ways to improve a liquid oxygen tank, notably to see if it could be made out of a composite structure[5]. We have also held creativity sessions on stage separation mechanisms leading to original ideas such as an interstage made of petals retained by a strap which is not broken by pyrotechnics but by a bar that hits a piece of cooled metal at critical structure points[6]. The electrical sub-systems are also being studied, especially as the reduction of the avionics' mass is crucial[7]. To list some examples, we are studying the feasibility and problems related to wireless internal data transmission[8].

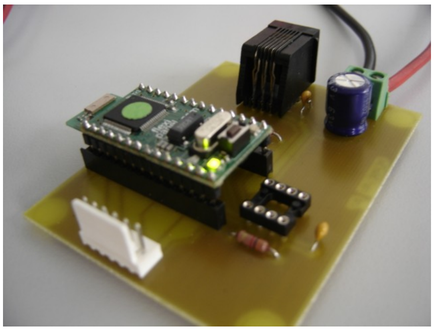

Figure 3: Toothpick, Bluetooth wireless communication

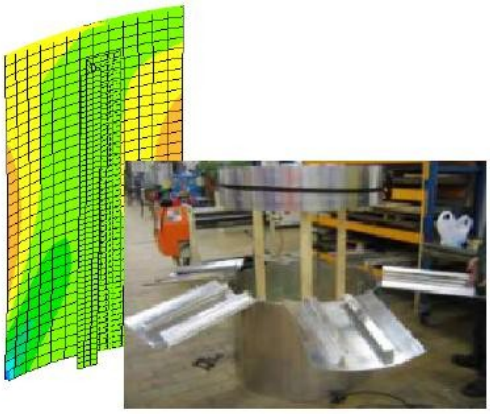

Figure 4: Separation system with petals

Hybrid propulsion is very appealing to our project as it offers better a structure ratio and is simpler to develop than a liquid engine. Solid propulsion has been ruled out for the moment due to strict safety legislation. All the same, a liquid methane / liquid oxygen engine will be developed. We intend to investigate innovative nozzle designs including a spiked-nozzle and an expansion-deflection nozzle. One student project has decided that the reciprocating system could become an alternative to pressure-fed and turbopumps[9].

Save perhaps the liquid engine which will take some time to develop, the results from these sub-systems projects shall be integrated into our system level effort. A Multidisciplinary Design Optimisation tool dedicated to launch vehicle analysis is under development that will help students to understand the design process and allow engineers to investigate different concepts at both a system and sub-system level[10]. We aim to demonstrate different launch vehicle concepts which, individually, will not reach have the performances necessary to achieve the ultimate goal of reaching orbit but will serve as flight tests of the various sub-systems as well as the concepts themselves. Currently, this translates to a sub-orbital launch with a few minutes of weightlessness, an air-launch from an unmanned air vehicle and a final stage which could be launch in a piggyback configuration. One association has already built a drone that should launch a model rocket this summer (Figure 3). It should be noted that we still consider the Perseus project to be in phase 0/A despite these demonstrators which serve to validate immature technologies in flight as well as giving some real goals to the students.

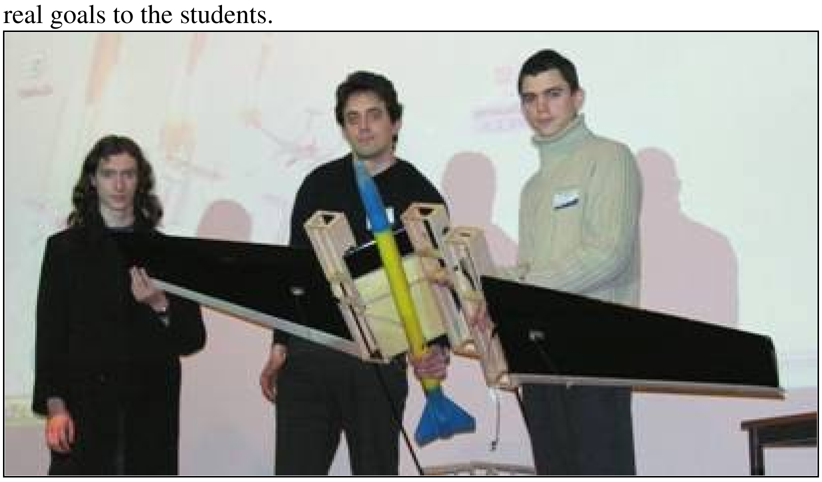

Figure 5: The association STS has constructed a drone that will hopefully launch a model rocket during the summer 2007

6. Conclusions so far

As we have seen, innovation is not just some jargon in this project, it really is key to its success: without creating new ideas our ambitious objectives may never be reached. We hope equally to drive forward some promising technologies that may not otherwise be investigated in larger, more expensive programs. Participants are encouraged by CNES to patent their ideas and self-sustaining start up companies will hopefully spin-out of the project. Federating the different actors of European universities (such as undergraduates, postgraduates, lecturers), as well as fostering relationships with other institutions, associations, companies and public agencies, all makes the project more rewarding to CNES and the members of the Perseus community.

There’s no doubt that the project provides some novel challenges (and will continue to do so) both technically and in terms of project management, but it’s surely these difficulties combined with the determination and hard work of many individuals that will ensure substantial progress in several aspects of launch vehicle technology.

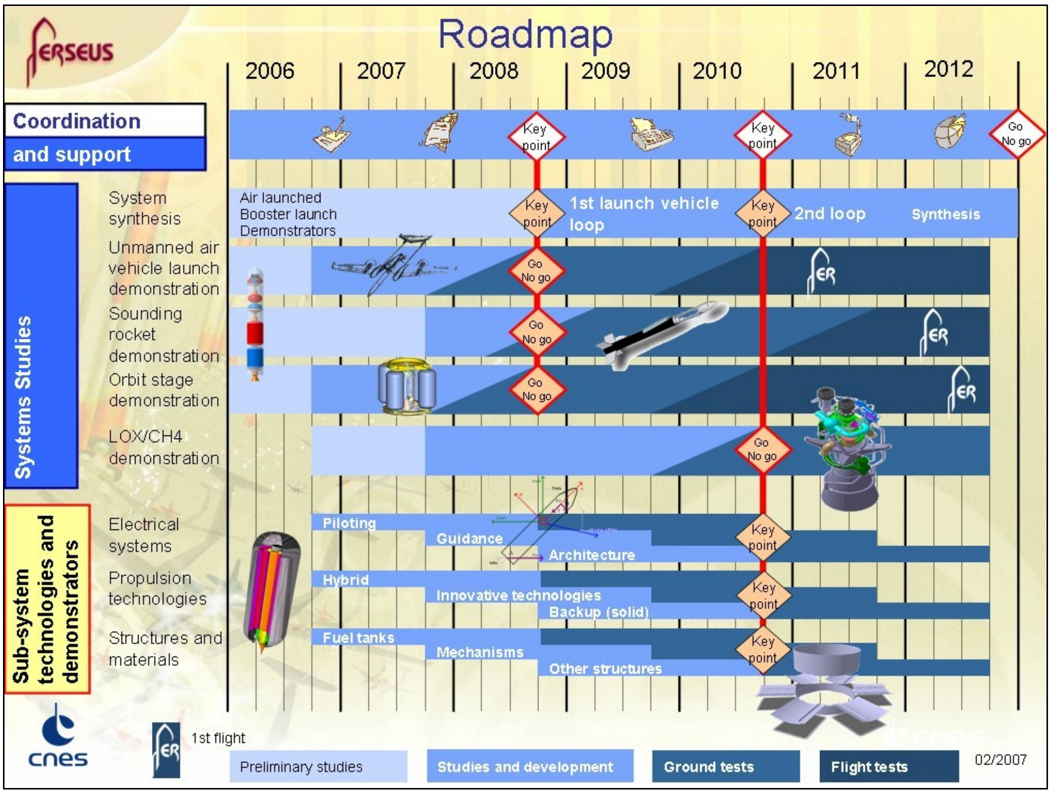

Figure 6: Perseus project roadmap

References

The student projects involving several teams and numerous reports are thus referred to below by the names of the respective universities and collaborating companies.

[1] CALVEIN by the University of California

[2] RVT by the Institute of Space and Aeronautical Science in Tokyo

[3] THG Orbit in Sweden

[4] Atalante by the GAREF

[5] ENSAM, IUT and IMA of Bordeaux

[6] Ecole Centrale at Lille

[7] Supelec at Gif-sur-Yvette

[8] Ecole Centrale at Lille

[9] INSA at Rouen

[10] HADES project by BERTIN, CNES, ONERA, SIREHNA and Ecole Centrale at Nantes

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