An Affordable, Low-Risk Approach to Launching Research Spacecraft as Tertiary Payloads

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Abstract. Rapid and affordable access to space for university researchers and educators has always been a challenge. Despite the availability of lower-cost (e.g. Russian) launch vehicles, launching payloads 20 kg or less typically involves a certain minimum cost that necessitates a cost sharing arrangement among numerous parties and the handling of complex export control issues. In turn, this complicates mission scheduling and increases the risk of missing launch deadlines. The University of Toronto Institute for Aerospace Studies, Space Flight Laboratory (UTIAS/SFL) has taken a leading role in addressing this challenge, and has successfully led a group of international spacecraft developers in manifesting one 1-kg Canadian spacecraft, two 1-kg Danish spacecraft, and one 3-kg American spacecraft on a 2003 Eurockot launch. This paper outlines the approach taken by UTIAS/SFL in negotiating and securing launches for its own spacecraft in collaboration with other spacecraft developers. A summary of how this approach is applied in planning and coordinating the June 2003 Eurockot launch is also presented.

Introduction

Universities want inexpensive and rapid access to space to test-fly new components early before applying them in larger more ambitious missions. Research groups and their industrial partners want to try new system concepts in space for the first time, possibly leading to commercial space activities in the future. Missions such as CanX-1 and QuakeSat are examples of these objectives in action. Because of the risk involved, however, costs must be kept to an

absolute minimum, within tens of thousands of dollars, consistent with university budgets.

One of the most difficult tasks facing university satellite builders is finding an appropriate low-cost launch. Even if orbital requirements for a mission can be relaxed to the point of virtual non-existence, it is extremely difficult to launch even the smallest satellite into space within the budgets common to small university groups. Add to that the complexities associated with launch vehicle separation systems and the lack of experience most universities have at arranging launches, and the university satellite mission remains a dream rather than becomes a reality.

The Stanford/CalPoly CubeSat program is an excellent means to address both the needs of university researchers and the access/cost problem: universities across the world build satellites to a standard form factor and share launches using standard launch tubes known as P-PODs (Poly Picosatellite Orbital Deployers). By sharing a common launch, the unit satellite launch cost is reduced to manageable levels. It has been estimated that a single 1-kg CubeSat could be launched for as little as US$30,000. Recently, the cost has been more realistically quoted to be around US$50,000 per CubeSat.

For the longest time, since the inception of the CubeSat program, there had been little success in organizing and implementing such a shared launch. Various organizations had tried to arrange launches with little or no luck. In June 2003, everything was about to change.

The University of Toronto Institute for Aerospace Studies, Space Flight Laboratory (UTIAS/SFL) initiated Canada's first CubeSat program in 2001. The first satellite of the Canadian Advanced Nanospace eXperiment (CanX) program, CanX-1, was completed in May 2003 by a team of six graduate students. During the CanX-1 project, several attempts were made to subscribe to shared launches without success. Mainly out of frustration, UTIAS/SFL decided to arrange its own launch, partnering with the Technical University of Denmark (DTU), Aalborg University, the California Polytechnic State University (CalPoly), and QuakeFinder LLC. This led to a successful launch arrangement with Eurockot Launch Services. Consequently, four CubeSats have been launched in June 2003, including CanX-1, DTUSat, Aalborg CubeSat, and QuakeSat. This was the first time P-PODs had been tested in space with real satellites and the first time several university CubeSat groups were successfully coordinated onto a commercial launch. This is our story…

UTIAS/SFL Leads a Team that Boldly Goes Where None Have Gone Before

While starting the CanX program, UTIAS/SFL had already been working on the MOST (Microvariability and Oscillations of Stars) microsatellite – Canada's first space telescope for the Canadian Space Agency – as a major subcontractor to Dynacon Incorporated. A launch for MOST had been arranged by the Canadian Space Agency with Eurockot Launch Services in Germany. Eurockot, a joint venture between Astrium and Khrunichev Space Research and Production Center, was providing a launch on board a modified SS-19 ICBM out of the Plesetsk Launch Range. As UTIAS/SFL pondered its options in regard to launching CanX-1, it found it extremely difficult to subscribe to a shared launch via the organizations that were at the time offering to arrange such a launch. As a consequence, UTIAS/SFL thought seriously about piggybacking on the MOST launch. If microsats were considered "secondary" payloads, CubeSats would be "tertiary" payloads – the stowaways of the cosmos.

With the support of CalPoly, having agreed to provide P-PODs for the launch, UTIAS/SFL approached DTU and Aalborg University, two Danish universities that were nearing completion of their own CubeSats, to share the CanX-1 launch tube (see Figure 1). Within a few weeks, UTIAS/SFL was also coordinating a second P-POD containing QuakeSat, a triple CubeSat built by Stanford for QuakeFinder LLC (Figure 2). Agreements were quickly signed, and UTIAS/SFL was able to convince Eurockot that this was a good idea. Within a few months, the launch was going ahead.

As a non-profit institution, UTIAS/SFL priced the CubeSat launch slots so as to recover the direct costs associated with coordinating the launch, the use of external test facilities, and expected travel and living expenses. There would be some cost savings associated with tagging along with MOST, but not so significant as to preclude similarly priced launches in the future, if suitably arranged.

After sorting out the logistics among its partners, UTIAS/SFL became the main integration site for NLS-1 (Nanosatellite Launch System 1) consisting of a CalPoly P-POD containing CanX-1, DTUSat, and Aalborg CubeSat. UTIAS/SFL arranged for integrated P-POD vibration testing and organized the shipping details to get NLS-1 to Russia. QuakeSat would also be arriving in a second P-POD, and UTIAS/SFL made additional preparations to ship NLS-2 along with NLS-1 and MOST (See Figure 3).

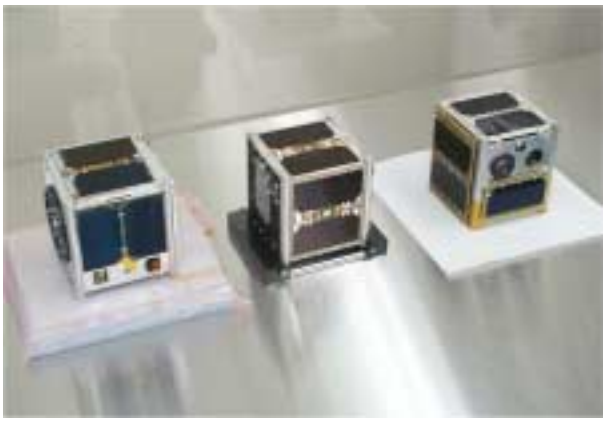

Figure 1 – From left to right, Aalborg CubeSat, DTUSat, and CanX-1

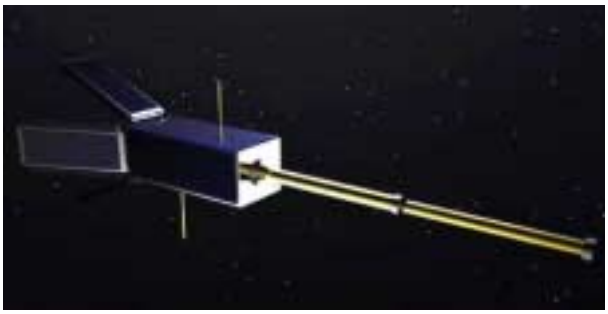

Figure 2 – QuakeSat

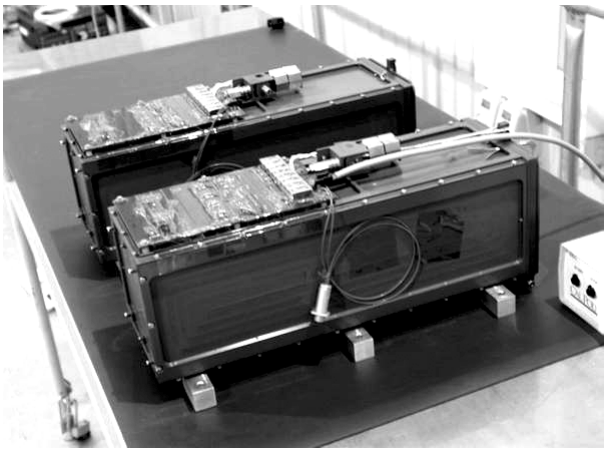

Figure 3 – Integrated NLS-1 (foreground) and NLS-2 (background)

Figure 4 – Payload arrangement on the Breeze-KM Upper Stage

Figure 5 – The Space Head Module undergoing preparation for the MOM launch.

In May 2003, NLS-1 and NLS-2 were in Russia. By early June, functional checkouts at the launch site were complete and integration with the launch vehicle was underway. On June 30, 2003 the first CubeSats made their way into space history.

Recipe for Success

What contributed to the successful launch of the first CubeSats? Was it the unbridled determination of these fearless university groups to not let anything stop their progress? Was it an unwavering reluctance to see their satellites sit on the shelf indefinitely? Maybe. In practical terms, UTIAS/SFL adhered to the following essential elements to ensure a successful launch arrangement:

- **Limit the endeavor to a small number of CubeSats.** It was very important to keep the number of CubeSats and the number of partners down to a manageable level. Coordinating 18 to 24 CubeSats in a single launch would have been impossible. Some say that such high satellite counts are needed to keep the satellite launch costs down. However, the added administrative nightmare creates countering cost pressure (i.e. drives costs up) because more people have to spend more time coordinating all the different parties. UTIAS/SFL only had to deal with three parties: the Danish Space Research Institute (representing DTU and Aalborg University), QuakeFinder, LLC, and CalPoly, in addition to the launch provider.

- **Decentralize export licensing**. It was important to ensure that each CubeSat developer arranged for their own permits. In the case of QuakeSat, QuakeFinder was responsible for obtaining the necessary export permits and technical assistance agreements from the US State Department. A decentralized approach to licensing was essential to prevent any one CubeSat program from stalling the launch process.

- **Make it real**. There is nothing worse than waiting for a launch arranger to make up their mind as to whether they want to enter into an agreement or not, except perhaps for a launch arranger that enters into an agreement without being sure of the launch or its feasibility. First of all, CubeSat developers should never sign up with a launch arranger that doesn't have a

launch provider sitting on the edge of their chair ready to sign a launch contract. NLS-1 and NLS-2 were successfully arranged because UTIAS/SFL convinced Eurockot to take on CubeSats. Because the number of launch slots was intentionally kept low, UTIAS/SFL was able to find partners to fill the slots quickly. Memorandums of Understanding were signed swiftly with CubeSat partners and the launch contract with Eurockot was signed immediately thereafter. The importance of entering into a complete set of agreements early should not be underestimated. Such action places the onus on the individual CubeSat developers to be ready in time for launch. An essential ingredient is that the launch goes ahead (and the money gets paid) regardless of any one program's state of readiness, even if a team finds they cannot meet the launch schedule at some later date. Sounds mean, but that's the same "real-world" they would face if they were to arrange a launch on their own. When the MOUs and launch contract are signed, things become real really fast.

- **Decouple launch contracts**. The two P-PODs containing four satellites were arranged under two separate but similar launch contracts, corresponding to NLS-1 and NLS-2. The slight increase in administrative load was offset by not having to cross-coordinate between each P-POD group. Separate arrangements allowed decoupling of P-POD manifests, thereby reducing the launch risk for each P-POD group.

- **Provide an independent separation system**. CalPoly's P-POD allowed UTIAS/SFL to keep the interface to the launch vehicle extremely simple, allowing Eurockot to minimize its costs and ultimately resulted in cost savings to each CubeSat developer.

Unfair Advantage?

We know what you're thinking. UTIAS/SFL would not have been able to arrange this launch if it were not for the MOST microsatellite, having had its launch arranged through the Canadian Space Agency. Yes, UTIAS/SFL did benefit in the following ways:

- Less time was spent searching for a launch because the launch was already available.

- Eurockot was already familiar with UTIAS/SFL via the MOST program.

- Shipping arrangements and shipping costs were mitigated by accompanying MOST to Russia.

While the above is true, UTIAS/SFL believes that future arrangements will be possible, with relatively slight increases (on the order of $10,000 per CubeSat) to the unit satellite launch cost to cover the possible absence of the above conditions.

UTIAS/SFL did benefit from the strong support (and P-PODs) received from CalPoly. Not having to worry about the separation system for the CubeSats was a major advantage.

Cheaper than Cheap?

Was the June 2003 Eurockot launch really that cheap after including all coordination and campaign costs? UTIAS/SFL priced the CubeSat launch slots aggressively at US$40,000/slot. This cost included a portion that went directly to Eurockot, and portion that was used to cover people time, external facilities and travel. In the end UTIAS/SFL broke even.

From Eurockot's perspective, more time was spent coordinating the CubeSat developers than was initially expected. In addition to the four CubeSats UTIAS/SFL had arranged, Eurockot was also independently coordinating with two Japanese teams that were using their own separation systems (not P-PODs). To save Eurockot effort and expense (which ultimately translates into cheaper launches), a single launch arranger and a simplified interface to all CubeSat developers would have been desirable. In the coming years, it will be important to streamline the CubeSat process and reduce the actual cost to the launch provider to prevent launch costs from rising.

This also raises questions related to the specification of CubeSats. Are CubeSats the optimal size and mass to achieve a high ratio of mission return value to launch cost? How much bigger can we make our CubeSats without increasing launch costs? Are we currently at the maximum size/mass or is there room for growth? The answers to these questions depend heavily on the launch provider, and UTIAS/SFL together with its launch partners will be investigating these issues in the near future.

Lessons Learned

UTIAS/SFL believes that the final $/kg cost is still high especially for university projects. In depth review of all costs and potential savings for the future is the subject of current attention. These costs not only include the bare launch provider costs, but also costs associated with supporting coordination meetings, export licensing (if needed), shipping costs, import tax and customs fees, and launch campaign costs.

The CubeSat "standard" can be viewed as a product that needs to be marketed and accepted by the university space community. As with all products, market research, planning and improvements based on experience and customer response are ongoing. A continuing review and impact analysis associated with various launch vehicle specifications are necessary to ensure that the standard is able to meet the loading, thermal, electrical and operational requirements of most launch systems. The CubeSat separation system must gain wide acceptance, not just by satellite developers, but also by launch providers who recognize the standard.

Early and immediate action with respect to long-lead processes and acquisitions is essential to any satellite program. Obviously, export license applications must be submitted early, well in advance of the launch. Having a mentor that has done it before really helps. The most important thing however, is to just do it, and do it early.

Adherence to standards and the implicit need to continually improve and refine the standards is an absolute necessity. To avoid surprises resulting from geographically separated teams building satellites that they hope will fit and work with a common launch tube, implementing a detail standard and inter-team review is essential.

It is also important that the launch arranger have complete and full knowledge of the details of pre-launch activities. The requirements of the launch provider can be quite onerous to the unprepared.

Come Fly with Me

With its partners, UTIAS/SFL successfully arranged the launch of the first CubeSats into space. UTIAS/SFL plans to do it again. CanX-2 has received funding and launch options are already being investigated.

There are obvious advantages to coordinating with a single launch arranger, not the least of which is a simplified interface to the launch provider, which in turn leads to cost savings for everyone.

Now that UTIAS/SFL has had successful experience at arranging launches for CubeSats, it has the advantage of enabling and maintaining collaborative ties with launch agencies such as Eurockot.

Conclusion

With the help of CalPoly, the partnership of the Danish Space Research Institute and QuakeFinder LLC, and thanks to the courage of Eurockot, UTIAS/SFL has successfully led a team of developers to the first CubeSat launch in history.

UTIAS/SFL is committed to its own nanosatellite-based research and development program and to arranging its own launches, as well as helping those interested in sharing a launch with UTIAS/SFL.

UTIAS/SFL is working with Eurockot Launch Services, Khrunichev Space Research Center and other launch providers to streamline the launch arrangement process for tertiary payloads to improve cost savings for all involved. The CubeSat era of space missions is just beginning, and universities can take heart in knowing that future low-cost launches are on the horizon.

We will go to space again!

Acknowledgments

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