Young Engineers' Satellite

Educational Demonstration of SpaceMail

Philippe Willekens*[1]*, Alexander van Dijk*[2]*, Michiel Kruijff*[2]*, Erik van der Heide*[2]*, YES2 Team

[1]ESA Education Office; [2]Delta-Utec SRC, Leiden, The Netherlands

Email: Philippe.Willekens@esa.int; delta-utec@delta-utec.com

The AIR capsule begins deployment on the 30 km-long tether from Foton-M3.

Introduction

In April 2002, the ESA Education Office and the Dutch company Delta-Utec SRC began the development of 'YES2 SpaceMail', the second Young Engineers' Satellite. This first-ever student-built reentry capsule has two prime objectives:

European students are developing innovative tethered and reentry concepts for flight in 2006 ...

– provide European students with spectacular and motivating hands-on experience;

– demonstrate the SpaceMail concept of returning a small capsule from space. This will use two new technologies: a tether rather than a conventional rocket engine for deorbiting, and a capsule that will land in Russia using innovative methods of deceleration and thermal protection.

The YES2 mission is supported by ESA's Human Spaceflight Directorate, and is envisaged to be launched in 2006 as an educational payload attached externally to the Russian unmanned Foton-M3 spacecraft. After 2 weeks in orbit, YES2 will deploy the small reentry capsule on a 30 km-long, 0.5 mm-diameter tether and 'swing' it back to Earth, landing it safely and accurately. Largely developed and built by students and young engineers, YES2 will demonstrate the SpaceMail concept as an innovative route for returning small payloads from low Earth orbit.

SpaceMail Concept

SpaceMail involves a tether system on a spacecraft swinging a capsule into a reentry trajectory, providing flexibility in payload return. This concept could deliver experiment data and other products in small packages like a postal service. Accurate landing can be achieved through the low-complexity, low-cost and lightweight tether deployment hardware in combination with a robust deployment control strategy.

The YES2 team has been designing, developing and testing inflatable technology as one of the reentry options, guided by the principle of 'inherent safety'. The capsule is inflated in space, during a specific phase in the tether deployment, and all in one go. The capsule will function as its own parachute, without the need to change configuration, both in the hypersonic (entry) and subsonic (landing) regimes. With this approach, there is no need for a second-stage inflation or actual parachute to guarantee a soft landing. The overall system is therefore considerably simpler and the number of failure modes is reduced.

Massimo Busetto (Univ. Padova) integrates the YES2 onboard computer as part of the tether test set-up at the Center of YES2 Expertise Krefeld.

Tethers in Space

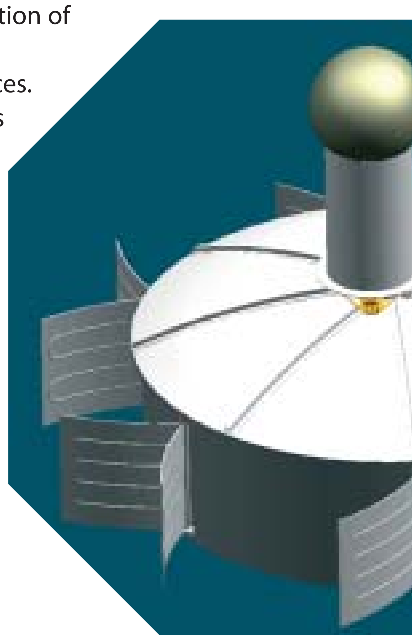
The use of tethers in space is not new. They have been studied for many years and several applications are being considered. Apart from momentum-transfer for sample return (SpaceMail) or orbital transfer, applications include rotating tether systems for inducing artificial gravity on the way to Mars, and electrodynamic tethers as propellantless thrusters for satellite deorbiting or drag compensation. Since 1966, about 15 generally successful experimental tether missions have flown in space, demonstrating the various principles. The YES2 SpaceMail demonstration is the logical next step (most notably to SEDS1 and SEDS2 of 1993 and 1994, respectively) in the development of tether applications. It will be the first European-built tether system to operate in orbit and will also be the first to demonstrate accurate orbit insertion. Following a successful demonstration, the tether system could be used as is with almost any current reentry capsule design.

How Does it Work?

Returning to Earth from a circular orbit at 400 km altitude requires a deceleration of about 120 m/s. A tether can provide this through two effects: the gravity gradient (80 m/s) and the swing of the tether (40 m/s).

During tether deployment, the capsule and spacecraft are forced by their mechanical connection to orbit the Earth with the same period – that of their centre of mass. Gravity is stronger closer to Earth, so the capsule at the lower end of the tether needs a higher speed to remain in a circular orbit. However, while connected to the tether, the capsule is kept artificially below that speed. If the tether is cut, this restriction disappears and the capsule will drop into a new orbit matching its speed. The perigee is lowered by up to 13 times the tether length.

The tether is deployed downwards at a large forward angle with respect to the vertical owing to a combination of inertia, coriolis and gravity-gradient forces. When deployment is completed, gravity-gradient forces will pull it back to the vertical, causing it to swing. So cutting the tether near to the vertical means the backward swing adds another 40 m/s of deceleration to the capsule.



The current layout of YES2 on the Foton battery pack. The canister (red) holds the tether, which is connected to the MASS cylinder (Mechanical and Data Acquisition Support System) via the 'barberpole' tether breaking system (yellow). The MASS cylinder interfaces with the inflatable AIR capsule (not shown) and is mounted on an ejection system derived from a Swedish Space Corp. design. The Fotino capsule is on top of the MASS cylinder.

YES2

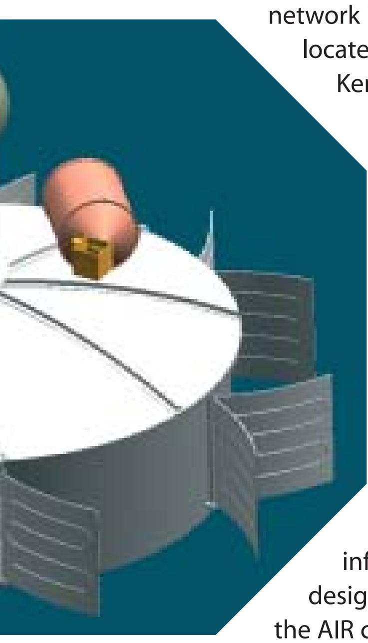
YES2 has its origins in the TeamSat cooperative venture between Delta-Utec SRC and ESA's Education Office, in which the Dutch company was responsible for the first educational YES satellite aboard the Ariane-502 test flight in 1997.

The YES2 mission is being developed by students from Europe, Russia and Canada with support from ESA. The project started in May 2002 (Phase I), with a focus of involving students from all over Europe in setting up a network of participating universities. Some 400 students from 25 universities were involved at this stage in studying the technical feasibility of the mission and coming up with concepts for inherently safe capsules. Many hands-on projects were initiated, such as a tether-deployment test rig, parabolic aircraft flight deployment testing, capsule mock-ups and drop tests, flexible heatshield development and high-temperature inflatable manufacturing technology. At the end of Phase I, a winning concept for the 'AIR' (*A*n *I*nherently-safe *R*eentry) capsule based on inflatable technology was chosen from a wide variety of

Early samples of the inflatable beams for the AIR capsule were made by YES2 student Matteo Benetti at the Italian company Aerosekur. The high-temperature beams consist of an inner layer of Kapton (transparent beam at left) with a high-strength Zylon outer layer.

innovative and interesting concepts. The phase was officially closed with a successful YES2 Preliminary Design Review at ESA/ESTEC in December 2003.

During Phase II, recently started, the detailed design of the satellite systems and the manufacturing and testing of the components are under way. For this purpose, five YES2 Centres of Expertise (CoE) have been set up with the support of the Education Office. They have been chosen from the established network in Phase I and are located at five universities: Kent (UK), Krefeld (Germany), Patras (Greece), Reggio Emilia (Italy) and Samara (Russia).



As a baseline, the YES2 mission currently involves the simplified 40 cm-diameter, 1.5 kg spherical 'Fotino' capsule to demonstrate the flexible heatshield developed for the AIR inflatable capsule. The design and development of the AIR capsule itself continues under supervision of the CoEs, who are seeking active support from European industry to have the fully-fledged inflatable capsule included on the YES2 mission. Last April, the YES2 students made a successful Critical Design Review presentation to ESA experts at ESTEC. It was the conclusion of an intense workshop in which students exchanged their design work and interacted with experts from the different ESTEC departments.

In early 2003, the YES2 team at Reggio Emillia performed drop tests of the inflatable 'GARLIC' capsule mock-up from a 100 m cliff near Reggio, Italy. Similar tests were performed with the 'LEPTON' capsule mock-up.

Russian and European students gathered in Russia for the Summer Space School Samara 2003 where YES2 was a major theme. Teams from Toulouse, Munich, Cranfield and Reggio brought mock-ups of their inflatable capsule designs for subsonic windtunnel tests (the LEPTON capsule can be seen).

Conclusion

The 'YES2 SpaceMail' project is providing an exciting opportunity for students to participate in the design, construction and flight of an actual space experiment. The tether and reentry technologies being developed are highly innovative and of broad interest to the space community. In parallel, the project has created a network of European universities where students can participate in real space projects. Some 400 students were involved during the initial phases, whereas some 30 students are now actively engaged in the detailed design and manufacture of the flight hardware. The eventual success of the mission could give a boost to tether applications in general and would show that the tethered reentry system is a viable technology for a future LEO payload-return system. It also shows that young people can be challenged with daring questions, have an innovative approach, and can provide Europe with a talented workforce for the future. ■

YES2 students tested their tether test-rig design in 2003 during an ESA parabolic flight campaign.