YES2:

An innovative space experiment

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YES2

The faculty of Electrical Engineering of the Delft University of Technology is involved in several satellite projects, such as MiSat and Delfi-C3. Somewhat lesser known is the 2nd Young Engineers' Satellite (YES2), which is due for launch in 2007 on the Foton-M3 mission. YES2 is now a full project of the European Space Agency (ESA), and is the first student satellite to follow professional ESA standards at all levels of design. YES2 has just passed the final design milestone, CDR. The integration and test phase of this 35 kg satellite for innovative technology demonstration is about to start. We are inviting several students from the Electrical Engineering faculty to join in this effort to deliver a complete satellite by the end of this year.

YES2 SpaceMail

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 firstever student-built re-entry system has two prime objectives: provide European students with spectacular and motivating hands-on experience and demonstrate the SpaceMail concept of returning a small capsule from space. This will use two new technologies: a tether (thin cable) rather than a conventional rocket engine for deorbiting, and a capsule that will land in Kazakhstan using innovative lightweight structure and thermal protection.

The YES2 mission is supported by ESA's Human Spaceflight Directorate, and is envisaged to be launched in 2007 as an educational payload attached externally to the Russian unmanned Foton-M3 spacecraft. After 12 days 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. Developed and built by students and young engineers, YES2 will demonstrate the SpaceMail concept as an innovative route for deorbiting small payloads from low Earth orbit (or Mars, for that matter).

SpaceMail is a concept that was developed in 1995 by Delta-Utec engineers for Delft's Faculty of Aerospace Engineering and involves a tether system on a spacecraft, swinging a capsule into a re-entry 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 involved 250 students from over 40 universities, from Europe, Russia and beyond in project work leading to the YES2 design, and nearly 40 master thesis works to date. About 40 students are working at any given time. Much work went into development of several re-entry capsule concepts and manufacturing and test of prototypes, including a complex inflatable capsule, that was inspired by a project assignment from Delft's Aerospace Faculty (SPRINT). The result of the trade-offs was a small spherical capsule, Fotino, with parachute and recovery system as well as a science package. Fotino is strongly supported by ESA ESTEC as an experimental laboratory and is currently undergoing plasma chamber re-entry tests in the Von Karman Institute. Fotino's final test will be a drop from a high-altitude (30 km) balloon, later this year.

The new approach for high-quality student space projects and innovative technologies have sparked several spin-off projects within ESA and European universities.

Tethers in space

The idea of tethers in space is still innovative but not fully 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 re-entry 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).

Figure 1: The 30 km of YES2 tether, a total of 5.5 kg only. The material is Dyneema, a Dutch invention and the same material that is used for kite-surfing.

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 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.

History of YES2

YES2 is managed by the Dutch company Delta-Utec SRC, in Leiden, founded in 1996 by young Delft engineers.

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 building 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 beyond 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. The phase was officially closed with a successful YES2 Preliminary Design Review at ESA/ESTEC in December 2003.

From PDR to CDR (Critical Design Review), the detailed design and analysis of the satellite systems and the manufacturing and testing of breadboards were performed. For this purpose, 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 were located at four universities: Krefeld (Germany), Patras (Greece), Reggio Emilia (Italy) and Samara (Russia). These centers served as focal points for the activities, although YES2 continued to welcome other student groups and individuals.

The YES2 mission involves the 40 cm-diameter, 5 kg spherical 'Fotino' capsule to demonstrate the lightweight structure and heatshield, and perform scientific measurements of the unknown aerothermodynamic regime it will enter on its way through the atmosphere.
In April 2005, a Design Review was held with ESA experts at ESTEC. It was concluded that the satellite is of so much interest and impact to ESA that it was upgraded to an official ESA project, including the requirements to follow the ESA design & management standards for small projects, as much as possible. This design upgrade to CDR was completed successfully in April 2006, with additional analysis and test, added redundancy, increased reliability measures and further documentation demonstrating not only the design but also its quality level.

The work was performed by interns at Delta-Utec and ESTEC near Leiden, supported by the Centers of Expertise and various other European student groups. For the final phase (manufacturing and test) small European companies and institutes like IMTsrl (Italy),

Figure 2: Promotional balloon inflated by André Kuipers on the International Space Station during his one-week trip.

Andoya Rocket Range (Norway), Emxys+Valencia team (Spain), Von Karman Institute (Belgium) are providing additional sponsorship to YES2, especially in electronics, by offering internships, facilities etc.

Delta-Utec houses the system engineering activities, management, software and tether deployment tests. The hands-on work in ESTEC is increasing as it is the center of the YES2 integration.

Electronics in YES2 today

YES2 in fact contains three largely independent satellites: FLOYD, MASS and Fotino. A ground system is built in support of design, test and mission.

FLOYD (Foton Located YES2 Deployer) is mounted to the large Russian Foton-M3 research satellite, and is the interface for telecommand, power and telemetry (by our robustly designed Power Distribution Unit that connects to the Russian infrastructure). FLOYD furthermore contains the tether and the deployment control (a PC104 running QNX, combined with optical measurement electronics, stepper driver -based on Atmega 64- and tether friction brake control mechanism), as well as a UHF receiver and antenna (receiving data from MASS). Finally it contains the ejection system using pyrotechnics and springs, which initiates the deployment by ejecting MASS away from the Foton-M3.

MASS is the tethered subsatellite (Mechanical and data Acquisition Support System), and contains a GPS/GLONASS unit, tensiometer, dynamic sensors (MEMS), battery power, power distribution and a Data Handling System using Atmega 64 microprocessors, as well as the UHF transmitter.

The re-entry capsule Fotino is released from MASS by a timer, using pyrotechnics that hold together a belt-system. Fotino contains a parachute system, with ignition system and ARGOS recovery beacon. Secondly, it contains the scientific payload, including GPS, thermocouples, pressure sensors, MEMS dynamics sensors, storage and telemetry, which can be used as an independent recovery system.

The ground system includes a tether deployment test rig and an advanced full mission simulator, as well as testing electronics and software. It also includes a portable ground station with tracking capability of the Fotino capsule.

Pim Tamerus en Peter Bruintjes from the Faculty of Electrical Engineering are two of the four Delft students that have joined YES2 to date. So far they have worked on the selection of the space qualified parts for the electronics from ESA's Preferred Part List, and the FMECA (Failure Mode Effects and Criticality Analysis) of the FLOYD PDU circuits, as required by ESA. We like our students to be able develop their position through the course of the project and hope to offer them increasingly responsible tasks. In general, the tasks within YES2 are challenging, educational and fun. Pim: "I stepped into a world that I could never have dreamt of. Not only are we learning about norms and requirements for electronics in space, it is especially unique to be able to discover first-hand that such kind of project can also be done by the combined force of students."

The YES2 electronics is now being manufactured and tested, with system integration and tests mostly at ESTEC. Subsystems are built in the various supporting centers around Europe, as well as in ESTEC. Also Delft facilities may be involved here.

Conclusion

You are invited to join one of the most exciting space projects for students to date, at its most exciting time.

The 'YES2 SpaceMail' project is providing an exciting opportunity to participate in the design, construction and flight of an actual space experiment. The tether and re-entry 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 40 students are now actively engaged in the manufacture and test 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 or planetary surface delivery system. It also shows that young people can be challenged with daring questions and can produce innovative space technology.

Further info

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Background: Fotino re-entry capsule heatshield test in the Von Karman Institute plasmatron.