

SSETI – PAST, PRESENT AND FUTURE

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ABSTRACT: The Student Space Exploration and Technology Initiative (SSETI) was started by the European Space Agency (ESA) Education Department to help students in building and launching satellites. Though originally concentrated around a single satellite project the SSETI programme now encompasses three satellite projects. These projects include over 25 universities from 14 European countries and Canada enabling currently around 400 students from 50 subsystem teams to gain experience in all aspects of satellite design, building, launching and in orbit mission control. Currently three projects are being worked on, well representing the past, the current and the future projects within the SSETI programme. These are the SSETI EXPRESS, the SSETI European Student Earth Orbiter (ESEO) and the SSETI European Student Moon Orbiter (ESMO) satellite projects. This paper will describe the management tools used in the SSETI projects as well as give a technical overview of the three satellites projects and present the results from the EXPRESS project.

INTRODUCTION

The Student Space Exploration and Technology Initiative (SSETI) was created by the ESA Education Department in 2000, in order to actively involve European students in real space missions. The aim is to give students practical experience and to enhance their motivation to work in the fields of space technology and science, this helping to ensure the availability of a suitable and talented workforce for the future.

From work performed so far, it is clear that high levels of academic expertise in specific space-related fields exist throughout European universities. However, these units currently operate independently of each other. The SSETI Programme combines these isolated centres of expertise, offering students access to a powerful network, capable of designing, constructing and operating intricate and interesting student spacecraft and payloads.

The aim of the SSETI Programme is realised through team-based student work on specific satellite projects, under the leadership of the ESA Education Department (which provides technical and managerial coordination) and with support from many ESA and industry experts. A dedicated website has been implemented together with specific Internet-based communication tools, all of which are extremely efficient in facilitating coherence and permanent contact among the student teams.

Since its creation, the SSETI Programme has developed a network of students, educational

institutions and organisations to facilitate work on the various spacecraft projects. More than 1000 European students have made an active, long-term contribution to these spacecraft, either as an official part of their degree or in their spare time. In addition, many hundreds more have been involved with or inspired by SSETI.

The continued interaction of SSETI alumni with the SSETI network will act for the mutual benefit of themselves, ESA, European industry and the SSETI Programme. The experience and knowledge gained by the students will ensure a rich and fruitful recruitment ground for ESA and the space sector in general.

The projects

SSETI students are currently working on three main projects:

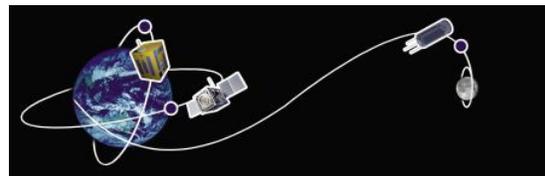


Figure 1 The SSETI Projects, artist's impression

SSETI Express: A low Earth orbit 60kg spacecraft launched on 27th October 2005 by a COSMOS 3M

launcher from Plesetsk on the DMC-3 flight of Surrey Satellite Technology Limited.

SSETI ESEO: The European Student Earth Orbiter, a 120kg spacecraft designed for an Ariane 5 launch. It is planned for launch into geostationary transfer orbit in 2008. By summer 2006, all teams will be in phase C, critical design.

SSETI ESMO: The European Student Moon Orbiter, planned for launch in 2011. It will conduct experiments on its way to the moon as well as when lunar orbit is achieved. ESA is now supporting an ongoing feasibility study on this project.

SSETI Teams

The work performed in SSETI is team based, where each team works on a specific subsystem for a satellite project. This means that each student team is responsible for a specific subsystem or task. This includes designing integrating and building hardware when necessary as well as securing the necessary funds to accomplish this. To help the project teams, several SSETI general teams have been assembled. This includes a legal team who takes care of all legal issues between ESA, the SSETI organization and the universities, a finance team who takes care of the SSETI finances, an infra structure team who has the responsibility of all the internet based tools and a PR team who produces PR material used for team recruitment and presentations. For the individual projects the project teams are led by a project manager or in some cases a project management team. All teams are required to attend weekly chat meetings and file regular progress reports. Currently 52 teams from 30 different universities in 14 European countries (+Canada) are involved in the SSETI Programme. A distribution of the teams across Europe can be seen in Figure 2



Figure 2 The SSETI teams distributed in Europe

MANAGEMENT TOOLS

Due to the distributed nature of the participants, several management tools need to be in place to

facilitate the smooth running of the project. It is vital for the project to have all the persons involved discussing regularly on technical matters as well as global project or programme issues. The physical distance between the students has to be compensated by the ease and comfort of use of appropriate communication tools. Furthermore a system to assure the quality of the work done for a successful mission must be in place. For this several tools are used.

- ESA supervision
- IRC internet chat
- FTP file sharing
- News groups
- Web site
- Workshops

ESA supervision

ESA has several crucial tasks in the running of the SSETI projects. These include:

- Direct supervision
- Expert help and reviews
- Facilities for integration and testing
- Financing workshops and specific parts
- Arranging for launch of the satellite

Direct supervision means that for each of the three SSETI projects ESA provides a full time staff member to manage the project. Furthermore once the project reaches detailed design level, a second staff is attached to the project for technical supervision. A very important aspect of this supervision is to maintain a point of continuity for when the students from the student teams graduate and leave the project. Secondly ESA also provides help in the form of experts in specific fields who aid the students in their design and review the finished designs on a regular basis.

Once the project advances to a stage where hardware is ready the student teams are brought in as appropriate for the integration and testing which is done at ESA's integration and testing facilities in the Netherlands.

Lastly ESA sponsors what is usually showstoppers in a student financed project. This includes the necessary workshops, specific hardware that is too difficult for the student teams to acquire and the launch of the satellite.

Internet Relay Chat

For internal communication amongst the teams and the ESA staff, an internet client is constantly running. Chats take place weekly, using an IRC server, to enable all the teams to keep in touch. In this way they can exchange information, discuss problems, solutions and deadlines, and arrange future events. Project leaders are the main moderators of the weekly meetings. The chat also allows private meetings on

Netherlands. Twice a year for each project, 2 students from each team are invited to join a week long workshop. This allows face-to-face meetings of the students, discussions and reviews with experts as well as many project wide discussions and quick decisions. It is also a very good motivation booster for the teams to meet each other and put faces on the otherwise anonymous internet names. Pictures from typical workshops can be seen below in Figure 7



Figure 7 SSETI Workshops in ESTEC

Future tools

Further development in the tools used is being done by the infra structure teams. Chiefly is the work on distributed computing for the use of all SSETI teams and the development of an online concurrent design tool.

MANAGEMENT TOOLS CONSIDERATIONS

Having the right tools does not necessarily make communication straightforward. Students from various study fields, languages, social and cultural backgrounds need to work together in a technical project. Many challenges have been faced by the SSETI teams, and still are daily considerations in their work.

Language

Regarding language two main things are to be considered.

- Only text language used
- Only English used

Most of the communication between the teams is done either on the news or on the chats. For these the only type of language possible is written language. This removes the parts of the communication that are normally done by body language or by voice intonation. Because of the lack of voice and body language in the communication, the written language must convey considerably more than otherwise. Even so it is impossible to convey as much as with the full use of voice and body language. A good example of this is the difficulty of trying to impress on other people the degree of urgency that a certain task has.

Apart from limiting the expression of the people communicating, using only written words severely limits the ability to convey technical ideas. With no possibility of showing with hand gestures it turns explaining a simple thing like orbiting movement into a complex explanation with a possibility of misunderstanding. In many aspects of the technical work discussing a design is very much hampered by the fact that one cannot do quick drawings to show to one another what the idea is. Explaining a drawing with only words is complicated and often leaves possibilities for misunderstanding. These are then not discovered until they are entered in the design and can lead to considerable loss of time.

To overcome these problems, different methods are set in place. To a certain extend participants in chats can write their feelings as comments in the chat, this though is usually only used for strong feelings. To avoid misunderstanding from things said in a joking manner or sarcastically, it must be said in the chat if the words written are not to be taken literally. For technical topics, a good preparation by all participants on that topic will avoid a lot of difficult explanation during the online discussion. To verify that no misunderstandings where made during the discussion, it is necessary for all participants to follow up on the work done afterwards by the other students.

As the project teams come from a large number of different countries, a common language that all can speak had to be found. Since the teams are from all over Europe the language chosen was English. For most teams this is a foreign language. The differences in culture and country politics regarding the teaching of foreign languages mean that the level of English is widely varied from team to team. The level of English sometimes causes misunderstanding. To avoid this patience and repeating things several times in different ways is sometimes necessary. Lastly asking questions when in the slightest doubt must be strongly encouraged. Several misunderstandings have cost time and energy because someone was embarrassed to ask the same question a second time.

These problems do not only occur to non-English teams. The language used will over time be changed by the different nationalities to become a more international version of English that may be very far from the correct British.

An example of this has been seen during a workshop where the only person not understanding what was being talked about at a certain discussion was the native English person.

Economics

A second problem is the economics of different teams. Different teams from different countries have varying access to the equipment needed for the project. This gives problems in older versions of the

same program not being compatible with the newer versions used by other teams. This creates the necessity of extra work on transforming file formats between different versions of a programs, or entirely different programs. The different countries also provide varied access for the teams to the tools needed for the internet communication and thereby restrict the possibilities of internet communication. The chosen communication tools are therefore based on what all teams have access to.

Impersonality and prejudice

Another problem with the internet communication tools is the impersonality of the participants. When the participants have never met one another a certain amount of detachment from the other people is felt. To a certain extent they become just names. Furthermore when only a name and nationality is known prejudice is common. This has a large effect on the work moral of the teams. The workshops help counter this trend by letting the teams meet each other. This helps a lot to counter any previously held prejudice and is a large motivating factor in helping the same people when they later request for information or extra work from each other.

Standards

All the tools used in the SSETI projects are existing tools, very common and available through the internet. They have been chosen due to their wide distribution and easy access for all. As for every tool however, they are only as powerful as the user makes them. A good knowledge of the tools, their abilities and their rules are essential. Even though the students are very familiar with the tools selected through their private use of them, some rules, specific to SSETI, had to be agreed upon in order to facilitate communication. These rules have the sole purpose of avoiding chaos in the discussion or exchange of information.

Defined by the SSETI students themselves rules have been agreed for everybody to follow. The objectives are as wide as avoiding mixed conversation lines in the chat, simplifying information search in the documents, making obvious the changes made in a document and the date of latest update. It is only with this common structure that the work produced can be assembled in a coherent unity.

ADVANTAGES AND WEALTH

Based on the challenges met, the team has grown stronger and has learned how to take profit of its differences and turn them into assets.

National sponsors

With hundreds of students working on the project, and each team using just a little time on finding sponsors, many potential sponsors are reached. Having the teams spread out in many countries means access to many national sponsors. This means that potential sponsors that are interested in encouraging national or even local work in this domain can help individual teams in that region, which will also benefit the project as a whole. Lastly, applications for sponsorship in different countries vary greatly so when applying for sponsorships it is a very large advantage to be familiar with the culture of the area where the potential sponsor is based.

National outreach

Most of the teams have a successful outreach in the form of local media, or even national media. Again it is here important that the teams doing the outreach are knowledgeable about the culture they are reaching out to. That they are local is also important as it shows to the people of that area/country that space is not only reserved for certain countries, but is something that they also could work with.

Local expertise

In addition to the skills of the individuals, the field of expertise of the universities can also be combined. Each university in Europe has a stronger side, whether be it communications, computer science or mechanics. A spread team, like the SSETI one, allows each university to join a technical project, doing what they are best at and using it in a bigger purpose. It is very difficult for one single university to support a satellite project (nano-, pico-, micro-) from end to end. The structural setup of the SSETI projects allows these universities to take part in a full scale space missions by bringing the best skills of the individual universities to the project. This is positive both for the project, who gets each part built by people with high focus on specific tasks, but also for the individuals who learn from others and gain experience in working on a large project.

International cooperation

As a consequence of this melting pot of expertise from various universities, coherent exchange of knowledge can be organised. This is done in two main ways. In the frame of the project, where teams help each other by sharing information and skills, but also in a wider frame: students exchange programmes.

By identifying universities working in their field of interest, students can target their selection for a host university when planning an internship. This is in the mutual interest of the student and the host.

SSETI – PAST, PRESENT AND FUTURE

With the above mentioned model of project management, three projects have been placed under the umbrella of the SSETI. These represent the past, the current and the future projects within the SSETI programme.

- SSETI Express
- SSETI ESEO
- SSETI ESMO

SSETI EXPRESS

History

The SSETI Express project was started in January 2004 when it was realized that many of the teams from the ESEO satellite project were very far ahead, while some of the teams still had a long way to go. This would result in several qualified teams not getting to fly their hardware in their time on the project. It was therefore decided to build and launch a precursor to the ESEO by gathering these teams into an Express team. The missing subsystems on this Express team were then found amongst other European university projects of a sufficient maturity to keep pace with the rest of the team. This mix of old ESEO teams together with new teams managed to finish designing, building integrating and flight testing the Express satellite in less than 18 months after conception of the project. So though not the first satellite project to be started under the SSETI programme, it became the first to be launched.

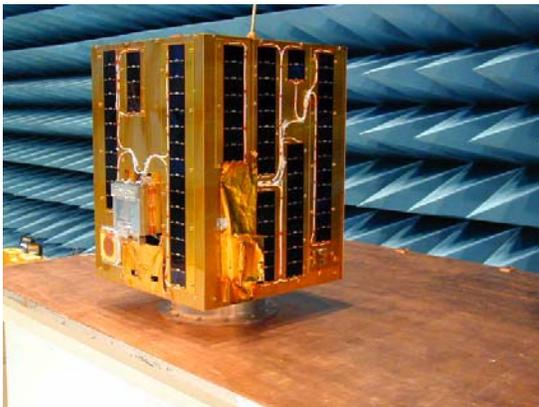


Figure 8 SSETI Express during testing

Mission statement

SSETI Express is an educational mission that shall deploy CubeSat pico-satellites developed by universities, take pictures of Earth, act as a test-bed and technology demonstration for hardware of ESEO, the European Student Earth Orbiter, and function as a radio transponder for the global amateur radio community.

Mission objectives

- To demonstrate the successful implementation of ESA's pan-European educational initiative, SSETI, and therefore encourage, motivate and challenge students to improve their education and literacy in the field of space research and exploration.
- To carry as passengers, and subsequently deploy, three educational Cubesat pico-satellites.
The primary payload of SSETI Express is therefore a set of three deployment tubes to eject the passengers once in orbit, after which they will embark on their autonomous missions.
- To demonstrate and test the hardware and technology being developed for the European Student Earth Orbiter (ESEO).
The secondary payload of SSETI Express is the ESEO cold-gas attitude control system. Other hardware related to ESEO consists of the structure, the electrical power system and the patch antennas.
- To take pictures of the Earth.
The tertiary payload of SSETI Express is a visible-light camera developed specifically for low-Earth orbit.
- To involve the amateur radio community in the downlink of housekeeping and payload data, and support this community by acting as a transponder once the main mission objectives are complete.
The SSETI Express UHF and S-Band communications systems can be combined to form a voice transponder that will be freely available, along with the mission data downlink, to the global radio amateur radio community.

Role of SSETI Express

SSETI Express is the first ESA Student satellite to be launched and is:

- a technical pre-cursor to the SSETI ESEO micro-satellite, several essential ESEO subsystems being flown on-board
- a logistical pre-cursor to the future SSETI micro-satellite projects
- hugely motivational and has enhanced the enthusiasm and dedication of the students involved in the SSETI Programme

- a pilot project for the SSETI student community, a demonstration of how ESA experts can support student initiatives and an inspiration for other educational satellite programmes developed by students in Europe
- bringing together several educational and related programmes, academic institutions and commercial industries, therefore expanding the SSETI Network for the mutual benefit of all

Technical description

Below in Table 1 is shown the core technical data on the Express satellite.

Dimensions	560x560x900 (maximum envelope)
Mass	62kg
Mass of payload	24kg
Expected lifetime	Minimum 2 months, extended mission until end of life
Attitude Determination System	Sun-sensors and magnetometer
Attitude Control system	Semi-passive magnetic stabilisation, plus a cold-gas payload
On-board Data Transfer	CAN, RS232
Telemetry <ul style="list-style-type: none"> ▪ UHF ▪ S-Band 	437.250 MHz, 9.6 kb/s, AX25 2401.84 MHz, 38.4 kb/s, AX25
Power <ul style="list-style-type: none"> ▪ Average ▪ Peak 	Body mounted solar panels 12 W 20 W
Batteries	Li Ion, 90Wh
Propulsion	6l, 300bar, Nitrogen cold gas
Camera	~100m/pixel, 1280*1024 pixels, CMOS
Power bus	28V regulated
Thermal control	Passive
Launcher	COSMOS 3M
Orbit type	Low-Earth sun-synchronous
Altitude	686km
Inclination	98deg
Eccentricity	0
Date	27 th october 2005

Table 1 Technical data on the SSETI Express

Satellite subsystems

Below is a description of the individual subsystems as well as an figure of their individual placement in the satellite as seen in Figure 9

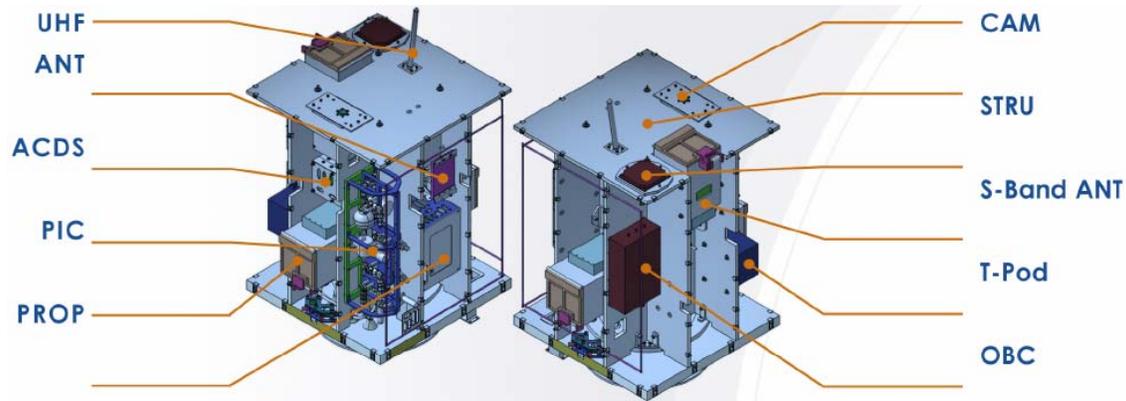


Figure 9 SSETI Express subsystem positioning

ADCS (Aalborg, Denmark)

The Attitude Determination and Control System (ADCS) has two parts. The Attitude Control System uses semi-active magnetic stabilisation. A pair of magnetorquers provide detumbling functionality and actively damp any subsequent vibrations, while a passive magnet ensures alignment of the spacecraft's z-axis with the Earth's magnetic field. The attitude of the spacecraft is therefore stabilised about two axes with one remaining, but fully characterised, degree of freedom about the z-axis. The pointing error is expected to be lower than five degrees. The Attitude Determination System consists of a pair of sun-sensors and a three-axis magnetometer, allowing determination of the attitude with respect to the magnetic field lines of the Earth and the sun.

CAM (Aalborg, Denmark)

The on-board camera (CAM) is based on a colour complementary metal oxide semiconductor (CMOS) sensor and an instrument control unit. In order to adjust for varying brightness, the camera can be fully calibrated in orbit. It is adapted from the AAUSAT-1 pico-satellite mission. The optical section of the camera consists of a specifically designed and manufactured lens system constructed of radiation-hardened glass. The ground resolution of the camera is about 100m per pixel, with an image size of 1280 by 1024 pixels.

EPS (Naples, Italy)

The Electrical Power System (EPS) is based on the concept of power generation by body-mounted photo-voltaic cells. The energy is stored in a rechargeable Lithium-ion battery to ensure power is available during eclipse phases or during low sunlight periods, when there may be insufficient power input from the solar cells. Each of the other subsystems is supplied by dedicated power lines from a regulated 28V power bus.

Ten separate strings, each of fifteen triple-junction Gallium-Arsenide (Ga-As) photo-voltaic cells with an estimated efficiency of around 22%, are used.

They are mounted on the four lateral sides of the spacecraft, each of which is covered by approximately 100cm of solar-cells.

MIAS (Zaragoza, Spain)

The Mission Analysis team (MIAS) are responsible for identifying the possible communication sessions with the spacecraft, and making sure that they are adequate to retrieve the mission data and progress through the mission objectives. They also analyse the eclipse and sunlight phases for thermal and power considerations, and have performed a detailed 'Collision Avoidance' study to ensure the safe deployment of the Cubesat passengers.

OBC (Aalborg, Denmark)

The On-Board Computer (OBC) controls the spacecraft during nominal and payload operations. It collects all telemetry and payload data for subsequent transfer to the ground. Commands can be uplinked into the computer's flight plan from the ground stations via the UHF radio communication system. At its core is an AMTEL ARM 7 processor. The surrounding hardware and software architecture was entirely student-designed.

PIC (Lausanne, Switzerland)

The Propulsion Instrument Control (PIC) unit is affectionately referred to as the "MAGIC" box. This subsystem processes commands related to the propulsion system, controls the thruster valves and performs data acquisition from the various thermistors and pressure transducers. It is also designed to provide a high current pulse to detonate the pyrotechnic valve.

PROP (Stuttgart, Germany)

The propulsion (PROP) payload is an attitude control cold-gas system with four low-pressure thrusters, fed by a pressure regulation system. The tank (derived originally from fire-fighter air tanks) contains six litres of gaseous Nitrogen at a pressure of 300bar. The pressure is managed by a series of valves and

regulators and secured for safety during the launch by a pyrotechnic valve. These components are connected by stainless-steel high-pressure tubing.

S-Band ANT (Wroclaw, Poland)

The S-band patch antennas (S-Band ANT) are adapted from the ESEO microsatellite. A set of three directional patch antennas are used, outputting a total of 3 watts of circularly polarised radiation at 2401.84 MHz. The half-power beam width is approximately 70 degrees. The main lobes are directed along the spacecraft's z-axis, which will face nadir during transit of most of the northern hemisphere, and along the spacecraft's positive and negative x-axis.

S-Band TX (AMSAT-UK)

Radio Amateurs from the United Kingdom have developed the S-Band transmitter (S-Band TX). It serves a dual-function; providing both high-speed mission data downlink at 38400bps and also, in combination with the UHF system, a single-channel audio transponder which will be freely available to the global amateur radio community whenever the other payloads are not in use.

STRU (Porto, Portugal)

The primary load-bearing spacecraft structure (STRU) consists of honeycomb panels configured in a similar way to the famous "tic-tac-toe" game. The secondary structure consists of 1mm aluminium outer lateral panels, serving as mounting surfaces for the solar cells, sun-sensors and other lightweight equipment. A titanium ring inside the structure ensures proper load distribution onto the launch adapter. Aluminium inserts glued into the honeycomb panels provide mounting points. The structure team is also in charge of designing the configuration of all subsystems with respect to balance, mass distribution, harnessing and thermal issues.

T-PODs (Toronto, Canada)

The Tokyo Pico-satellite Orbital Deployers (T-PODs) will be used to store three passenger CubeSats during the launch and then deploy them from SSETI Express once orbit is achieved. They have an interface to the ground support equipment for charging the passengers and arming the release mechanisms.

TCS (Stuttgart, Germany)

The Temperature Control System (TCS) is essential for ensuring that the spacecraft subsystems are not exposed to extremely hot, or cold, temperatures which could impair their functionality. It consists of passive elements such as reflective foils, thermal coatings and thermo-optic paint. There are several sensors on-board to monitor the thermal situation at all times.

UHF (Radio amateur, Hohhenbrunn, Germany)

The Ultra-High Frequency (UHF) unit contains a radio and a Terminal Node Controller (TNC) and is the primary communications system of the spacecraft. It provides uplink of telecommands from the ground station, audio uplink from amateur radio users, and downlink of mission data at 9600bps, all via a top-mounted rigid monopole antenna.

The cubesat passengers

Ncube II (Norway)

The main payload of Ncube II is an Automated Identification System (AIS), which is a system used onboard ships to receive GPS signals and return, by certain AIS frequencies, information such as the ship's current location, heading and expected time of arrival. These AIS signals of Ncube II will be detected, stored and forwarded to the Ncube ground stations, allowing them to track the satellite. To test this technology, a reindeer, named Rudolf, will be equipped with a collar containing a complete AIS transmitter and tracked as it walks around the Hardangervidda national park of Norway during the mission.

This CubeSat was developed and constructed by:

- Narvik University College
- Norwegian University of Science and Technology
- Norwegian University of Life Sciences
- University of Oslo

The work was coordinated by Norwegian Space Centre and Andøya Rocket Range.

UWE-1 (University of Würzburg's Experimental satellite 1)

The main objective of UWE-1 is to conduct telecommunication experiments, related to the optimisation of an Internet related infrastructure for space application. Various Internet protocol variants will be tested, analyzed and optimized in space during the mission of UWE-1. In particular, typical space environment characteristics such as delays, noise, interruptions, low bandwidth and high packet loss rates will be taken into account.

The second objective is to establish and efficiently interlink a network of ground control stations via terrestrial Internet. In this context a ground control station has been set up in Würzburg, as well as the software infrastructure for the coordination of several ground stations. This infrastructure will be tested and further optimized during the UWE-1 mission.

Finally, the key educational aspect of UWE-1 is to learn about system design approaches in interdisciplinary teams of students by addressing the motivating and challenging project tasks of implementing a pico-satellite. Here modern miniaturization techniques for electro-mechanical components provide essential contributions to an

efficient implementation of such small satellites of 1 kg mass within the framework of the international CubeSat programme.

Xi-V (Tokyo University, Japan)

Xi-V is the second nano-satellite built by the University of Tokyo's Intelligent Space Systems Laboratory (ISSL). Its primary mission is the demonstration of newly-developed Cu(In,Ga)Se₂ (CIGS) solar cells in space. Other than CIGS cells, GaAs cells are also tested on Xi-V, which will be used on ISSL's next remote-sensing nano-satellite "PRISM". Other mission objectives include the acquisition of Earth images by a commercial off-the-shelf digital camera and the operation of a message transmission service, using an amateur radio frequency.

Ground segment

Furthermore the ground segment was build up of the following teams:

MCC (Aalborg, Denmark)

The Mission Control Computer (MCC) is the interface between the human Operations team and the two ground stations. It is capable of controlling the uplink of detailed flight plans to the spacecraft and has a database in which all downlinked telemetry is stored. The MCC can be remote controlled.

OPER (Warsaw, Poland)

The Operations (OPER) team is responsible for defining the flight plans and commanding the spacecraft via the MCC and ground stations. All contingencies have been considered and responses defined in advance, so that analysis of real-time telemetry always leads to a clear and concise course of action to further the mission objectives.

Primary Ground Station (Aalborg, Denmark)

The main mission ground station consists of tracking antennas, an Ultra-High Frequency (UHF) radio, an S-Band to Very-High-Frequency (VHF) down-converter, a VHF radio, a Terminal Node Controller (TNC) and a controlling computer. It is the primary command station for controlling the spacecraft and for downlink of mission telemetry on both radio frequency channels.

Secondary Ground Station (Svalbard, Norway)

The secondary ground station provides a redundant UHF uplink and downlink support for telecommand uplink and mission telemetry downlink. Its extreme latitude ensures fourteen passes of the satellite per day, therefore allowing for a high data return during the mission. This station is entirely remote-controlled from the primary ground station in Aalborg.

TIDB (France)

The Telemetry Interface Database (TIDB) is a web-based application facilitating the dissemination of all mission telemetry from the MCC to the distributed SSETI Express teams, radio amateurs and the general public. Radio amateurs may also submit downlinked mission data to the TIDB.

Express post launch results

After launch of the Express satellite contact was quickly established and subsystems started to be tested. Already at the second pass over the primary ground station it was evident that the battery voltage had dropped. The satellite continued working flawlessly but only on the battery power, the power from the solar cells never reached the batteries. After approximately 12 hours the satellite went silent. Below is a step by step description of the express flight:

06:52:26 Launch
 06:54:37 First stage separation at 63.7 km altitude
 06:54:52 Fairing jettison at 81.2 km altitude
 06:59:56 Second stage shut-off at 240.4 km altitude
 07:26:40 Second stage re-ignition at 689.2 km altitude
 07:26:53 Second stage shut-off at 689.2 km (orbit injection)
 07:27:09 Tilting of TSINGHUA and SINAH-1
 07:27:13 Tilting of SSETI Express and MOXHAETS
 07:27:18 Separation of TOPSAT
 07:27:20 Separation of TSINGHUA
 07:27:21 Separation of SINAH-1
 07:27:23 Separation of SSETI Express and start of coast phase
 07:27:24 Intended separation of MOXHAETS (failed)
 07:45:00 SSETI Express leaves eclipse and is exposed to full sunlight for the first time, but has yet to be activated
 08:26:51 SSETI Express comes in range of the primary groundstation
 08:32:23 Activation of SSETI Express, including Cubesat deployment pods
 08:33:33 First nominal mode beacon received on schedule by primary groundstation and several radio amateurs Two-way communication established Operation nominal Battery voltage 23.7V
 08:40:27 SSETI Express goes out of range of the primary groundstation
 Various radio amateurs around the globe receive nominal beacon
 09:14:00 First contact is made with Cubesat Xi-V by the groundstation in Tokyo
 10:04:37 SSETI Express comes in range of the primary groundstation

- Copenhagen ground station receives nominal beacons (primary has problems)
 Battery voltage dropped to 23.2V which causes concern about a possible problem with the solar arrays or a power drain
- 10:14:00 First contact is made with Cubesat UWE-1 by the groundstation in Würzburg
- 10:18:02 SSETI Express goes out of range of the secondary groundstation
 Various radio amateurs around the globe receive nominal beacons
- 11:46:07 SSETI Express comes in range of the primary groundstation
 Two-way communication is re-established with primary groundstation
 Battery voltage dropped to 22.6V, so operators invoke emergency power saving precautions (turn off ACDS and S-BAND)
- 11:54:31 SSETI Express goes out of range of the primary groundstation
 Various radio amateurs around the globe receive safe-mode beacons
- 20:16:52 SSETI Express comes in range of the primary groundstation. Two-way communication is re-established with primary groundstation
 Battery voltage 14V (the PCU is assuming the battery is broken)
 A significant amount of housekeeping data is downloaded
- 20:25:27 SSETI Express goes out of range of the primary groundstation
 Unconfirmed weak beacons are received by two radio amateurs
 No other signals from SSETI Express are received
- ~21:00:00 The mission effectively ends when the battery is fully discharged.

All times are given in UTC, 27th October 2005.

The most likely cause for the failure is according to the Flights analysis summary¹ the following:

Following separation from the upper stage of the Cosmos 3M launch vehicle, the hardware timers in the Electrical Power System (EPS) of SSETI Express prevented, as designed (for the safety of the other passengers on the launch vehicle, mainly regarding the deployment of the Cubesat passengers), activation of the satellite until 65 minutes later. Of these 65 minutes the satellite was in sunlight for 47 minutes, which is believed to be the environmental cause of the main failure, exposing a design flaw in the EPS.

Before activation the satellite was entirely off (with the negligible exception of the timers) and therefore consumed no significant power. In this case the excess power requiring dissipation was all the power generated by the solar arrays.

The estimated peak power output of the four solar arrays is 25W at 28.7V, therefore sourcing 0.87A which needed to be dealt with by the shunt system. The voltage drop across the shunt resistor was 8.7V, since it is a 10 Ohm resistor, and therefore it needed to dissipate approximately 7.5W of heat. Since it has a high thermal capacity and is mounted directly to the thermal mass off the +y lateral panel, this heat flux is not problematic.

However, the remaining 17.5W must have been split between the two redundant MOSFETs, at 8.75W each. These components are mounted on a heat sink which did not have sufficient radiative or conductive dissipation to provide a high enough heat flux to prevent the MOSFETs from overheating. The flaw was not detected during verification because, unfortunately, although ground-based tests of the timers, of the solar array inputs and of the EPS in vacuum were all carried out, they were not carried out simultaneously.

This heating over a period of time led to a short circuit of one of the MOSFETs, effectively shorting the solar arrays to ground through the shunt resistor. This prevented significant power to be supplied to the bus and battery charge regulator for the duration of the mission and the satellite therefore shut down due to a bus under-voltage when the battery reached zero capacity, approximately 14 hours and 8 minutes after launch.

Mission achievements

Despite the early ending of the mission, the mission was counted as a huge success 20th

The Primary Mission Objective was fulfilled many times over during the design, construction, verification, launch campaign and operations of the spacecraft: *To demonstrate the successful implementation of this pan-European Educational initiative and therefore encourage, motivate and challenge students to improve their education and literacy in the field of space research and exploration.*

- All the students involved have reaped huge educational benefits from the hands-on practical approach and the chance to experience *all* phases of a real satellite mission.
- Several spin-off and related projects have directly benefited and are progressing well.
- Many educational opportunities have been created, such as students performing specific PhDs and internships which would not have been possible otherwise.

2) The Secondary Mission Objective was mostly fulfilled with the deployment of the Xi-V Cubesat from the University of Tokyo, Japan, and the UWE-1 Cubesat from the University of Würzburg, Germany. These two spacecraft subsequently embarked on their own successful missions. (The deployment of the NCUBE-2 Cubesat from the Andøya Rocket Range, Norway, was problematic. It is possible that NCUBE-2 remains attached to SSETI Express because of either a malfunction in the NCUBE-2 antenna deployment mechanism, or in the SSETI Express T-Pod.)

3) Several important mission milestones were met successfully:

- a. Hand-over of the spacecraft to the launch authority
 - b. Reception of the first beacon from the spacecraft precisely on schedule
 - c. Quickly establishing reliable two-way communication with the spacecraft
 - d. Downlinking significant amounts of housekeeping telemetry from orbit
 - e. Flight verification of several subsystems for future missions
- 4) Unique cooperation between the SSETI community and the Amateur Radio community, enabling
- a. the inclusion of flight hardware for the mutual benefit of both parties
 - b. extensive educational input to SSETI teams
 - c. a virtual global groundstation (proven invaluable during the mission)
 - d. the honour of having an OSCAR number, "X0-53", assigned to SSETI Express by AMSAT
 - e. future, highly beneficial, cooperation of a similar nature

5) Unusually fast mission development: less than 18 months from kick-off in January 2004 to flight-readiness. This is highly indicative of the motivation and enthusiasm in the SSETI community and is a timescale that fits well with student degrees.

6) Lessons learned, both positive and negative, are being collated from all phases and at all levels of description. These will be collated into a SSETI Knowledge Base made freely available for use in all future European educational satellite projects.

7) SSETI Express attracted a huge amount of media attention

- a. The launch was broadcast on over 100 European TV stations and probably watched by over 100,000,000 people
- b. Fourteen national events took place, organised by SSETI students, at which local media was welcomed and direct interaction with the teams was possible
- c. The student-run SSETI website served more than 1,000,000 hits during the month of October

d. During launch day the *Google* search engine reported over 800,000 web pages referring to "SSETI Express"

ESEO

History

SSETI ESEO was started in 2000 to be the first ESA student satellite, but will after the Express launch in 2005 be the second to be launched. ESEO is also a technical precursor to the SSETI ESMO micro-satellite and will test hardware in a hard-radiation environment for future SSETI exploration missions beyond Earth's orbit. Following the successful model of SSETI Express, the satellite platform of ESEO is being developed by student teams across Europe. The ESEO platform will carry a number of payloads to achieve its objectives. Integration and testing of the subsystems and payloads will take place throughout 2006-07, with a view to launching ESEO in 2008. The preferred launch vehicle is Ariane 5 or the Soyuz launch vehicle which will place the satellite into Geostationary Transfer Orbit. All the results from the mission will be made widely available to the public and used for educational outreach purposes.

ESA and industry experts have offered considerable guidance during the design phases and the students will continue to benefit from their experience and know-how in the future.

Mission statement

The European Student Earth Orbiter (ESEO) shall be a micro-satellite, designed, built and tested by a network of European students as part of ESA's educational SSETI Programme, which will orbit the Earth taking pictures, measuring radiation levels and testing technologies for possible future missions.

Mission objectives

- To demonstrate the successful implementation of ESA's pan-European educational initiative, SSETI, and therefore encourage, motivate and challenge students to improve their education and literacy in the field of space research and exploration.
- To take pictures of the Earth and other celestial bodies for educational outreach purposes.
ESEO will therefore carry three cameras: the Narrow Angle Camera will photograph Europe; a micro camera will capture images of the satellite in space; and a star tracker will provide images of the stars.

- To provide measurements of radiation levels and their effects throughout multiple passes of the Van Allen belt.
A series of sensors will measure the total radiation dose received at different points on the satellite as well as the instantaneous radiation. Furthermore a series of dedicated memory chips will indicate the effect of radiation on the on-board electronics. Lastly a Langmuir probe will in parallel measure the plasma flow.
- To act as a test bed for advanced technologies for future SSETI missions
ESEO will carry a small high gain antenna, as well as a large inflatable high gain antenna. Further two technologies will be tested on the orbit control thruster: The nozzle movement control system and the nozzle material.

Technical description

Below in Table 2 is shown the core technical data on the Express satellite.

Dimensions	600x600x710 mm
Mass	120kg
Orbit	GTO (250 km x 35500 km, inclination of 7 degrees) (TBC)
Launch vehicle	Soyuz from Kourou (TBC)
Expected lifetime	Minimum 1 months, extended mission until end of life
Attitude Determination System	Sun-sensors, horizon sensors, magnetometers and a star tracker
Attitude Control system	Momentum wheel, cold gas attitude thrusters and a vector thrust control main thruster
Orbit Control System	Cold gas
On-board Data Transfer	CAN, RS232, RS242
Telemetry	world ground station coverage through the radio amateur community
▪ S-Band (low gain)	9.6 kb/s
▪ S-Band (high gain)	128 kb/s
Power	Deployable MPPT, sun-tracking solar-cell panels with body mounted backup cells
▪ Average	150 W
▪ Peak	300 W
Batteries	Li Ion, 150Wh
Propulsion	18 l, 300bar, Nitrogen cold gas
Power bus	15-25 V unregulated
Thermal control	Active

Table 2 Technical data on the SSETI Express

Satellite subsystems

Below is a list of the subsystem and teams working on the ESEO as well as the current number of students in the team (in brackets)

- Assembly Integration and Verification (30)
- Attitude and Orbit Control System (16)
- Communication system 1 (30)
- Communication system 2 (5)
- Configuration (4)
- Electrical power supply (7)
- Ground station 1 (6)
- Ground station 2 (5)
- Harness (6)
- Langmuir probe (8)
- Mission Control Centre (14)
- Mechanical system (5)
- Memory board (8)
- Mission analysis (3)
- Data management (5)
- Narrow Angle Camera (8)
- On Board data handling core (12)
- On board data handling node (12)
- Operations (5)
- Propulsion interface control unit (5)
- Propulsion (25)
- Radiation memory (10)
- Risk management (7)
- Simulation (7)
- Star tracker (4)
- Structure (7)
- System engineering (5)

- Technical management (8)
- Thermal control system (6)
- Micro camera (2)

Below in Figure 10 is shown the satellite in its current configuration, though this is still not fixed and therefore still changing.

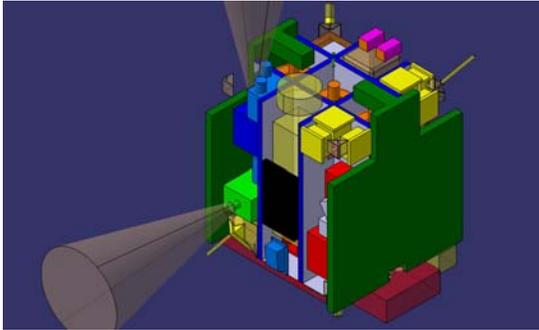


Figure 10 SSETI ESEO configuration

Timeline of ESEO

Below is shown the timeline of the ESEO project

- 2000 Started as a concurrent design facility exercise
- 2003 Some sub-systems ready for Phase C/D → SSETI Express
- 2005 all teams in Phase B with several technically in phase C or further
- 15-19 May 2006 PDR Workshop
- 21 July 2006 PDR final review board meeting → Phase C critical design
- Jan 2007 CDR
- early 2007 - mid 2007 EM integration and testing
- end 2007 - early 2008 FM integration and testing
- mid 2008 - end 2008 Launch campaign
- end 2008 - early 2009 Mission operations

As can be seen this constitutes one major difference to the Express project as it includes the construction and testing of a full flight worthy engineering model. As can be seen the current status of the project is final preparations for the preliminary design review, where after the teams will start building and testing prototype hardware and perfection their designs.

ESMO (the future)

In March 2006, the Education Department of the European Space Agency approved the European Student Moon Orbiter (ESMO) mission proposed by the Student Space Exploration & Technology Initiative (SSETI) association for a Phase A Feasibility Study.

If found to be feasible, ESMO will be the third mission to be designed, built and operated by European students through the SSETI association, and would join many other contemporary missions to the Moon such as ESA's SMART-1, the Chinese Chang'e-1, the Indian Chandrayaan, JAXA's SELENE and Lunar-A, and NASA's Lunar Reconnaissance Orbiter.

The ESMO mission objectives are summarised as follows:

- Education: prepare students for careers in future projects of the European space exploration and space science programmes by providing valuable hands-on experience on a relevant & demanding project
- Outreach: acquire images of the Moon and transmit them back to Earth for public relations and education outreach purposes
- Science: perform new scientific measurements relevant to lunar science & the future human exploration of the Moon, in complement with past, present and future lunar missions
- Engineering: provide flight demonstration of innovative space technologies developed under university research activities

The ESMO spacecraft would be launched in 2011 as an auxiliary payload into a highly elliptical, low inclination Geostationary Transfer Orbit (GTO) on the new Arianespace Support for Auxiliary Payloads (ASAP) by either Ariane 5 or Soyuz from Kourou. From GTO, the 200 kg spacecraft would use its on-board propulsion system for lunar transfer, lunar orbit insertion and orbit transfer to its final low altitude polar orbit around the Moon. A 10 kg miniaturised suite of scientific instruments (also to be provided by student teams) would perform measurements during the lunar transfer and lunar orbit phases over the period of a few months, according to highly focussed science objectives. The core payload would be a high-resolution narrow angle CCD camera for optical imaging of lunar surface characteristics. Optional payload items being considered include a LIDAR, an IR hyperspectral imager, a mini sub-surface sounding radar for polar ice detection, and a Cubesat subsatellite for precision gravity field mapping via accurate ranging of the subsatellite from the main spacecraft.

Two different spacecraft designs are being studied in parallel and traded-off by the students during the Phase A: one based on a hybrid solid/liquid propulsion system, and one relying upon solar electric propulsion. The former would allow a rapid transfer to the Moon within a few days, but with a

reduced payload, whereas the latter would take up to 12 months for the lunar transfer phase with the benefit of giving greater payload accommodation and wide launch window flexibility. Other technologies include miniaturised avionics, and lightweight structure and solar array. The mission would need to be supported by a Global Educational Ground Station Network for TT&C, a single large ground station for payload data downlink from lunar orbit, and several student-run Mission Control Centres. The mission would end in 2012 with a targeted impact of the spacecraft into a polar region at around 2 km/s, and ground-based telescopes would observe the impact ejecta plume for traces of water ice, as planned for the retirement of many lunar spacecraft including SMART-1.

Preparations for the Phase A include a Call For Proposals to European student teams for the spacecraft subsystems, ground segment, and scientific payload. The deadline for submission of proposals to the SSETI association is 15th August 2006. A team selection process will be made by Education Department and the SSETI association during September 2006, closely followed by a study on ESMO in the ESTEC Concurrent Design Facility (CDF). Student workshops will take place at ESTEC in October 2006 and January 2007, with the latter performed in the CDF accompanied by training of the students in concurrent design methods and tools. The go/no-go decision to implement the ESMO mission and proceed to launch will be made following the Phase A study review to be conducted by Education Department, ESA technical experts and the SSETI association in July 2007.