LEODIUM project and student space activities at the University of Liege

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Abstract
The University of Liege together with Liège Espace tries to promote space to the students. They are at the origin of the LEODIUM project which stands for Low Earth Orbit Demonstration of Innovations in University Mode. This project aims to create student pico- or nano-satellites. There is a strong motivation coming from the students and from the academic members to promote space. Being unexperienced in complete satellite design, as a first step in this direction, we started working with the ESA funded SSETI association.
At the moment, two teams of students are working on SSETI satellites. One is working as the MECH team which is in charge of the design of the sun-pointing solar panels of the European Student Earth Orbiter (ESEO) satellite mechanisms, the other team is working on the phase-A studies of the Narrow Angle Camera (NAC) which will be the core payload of the European Student Moon Orbiter (ESMO) satellite, both in collaboration with local industrials.
The students are mainly working on ESEO and ESMO as part of their master thesis. In addition to that, two PhD students are in charge of the coordination of the teams (one for the ESEO team and another for the ESMO team). They will also be the link between previous and new students every times an overlap will occur and ensure that information is not lost during the transition.
In this paper, we will describe the current design and the achievements on the ESEO solar panels and the ESMO NAC camera. Explanation will also be given on how the collaboration between the local student and the SSETI association is managed. Finally, we will briefly introduce the prospective for the LEODIUM project.

1. Introduction

The University of Liege together with Liège Espace tries to promote space to the students. They are at the origin of the LEODIUM project which stands for Low Earth Orbit Demonstration of Innovations in University Mode. This project aims to create student pico- or nano-satellites. There is a strong motivation coming from the students and from the academic members to promote space. Being unexperienced in complete satellite deisgn, as a first step in this direction, we started working with the ESA funded SSETI association.

1.1 SSETI association

The Student Space Exploration and Technology Initiative (SSETI) was created by ESA's 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, thus helping to ensure the availability of a suitable and talented workforce for the future. This association gathers more than 500 students from more than 15 universities located in European countries and Canada.
The SSETI association was created in 2003 in order to gather the participants of the SSETI programme by providing a common and legal structure for the projects within the programme. The purpose of the association is to work as an umbrella for international student space projects and create, develop and support a network of students that will work together do design, build, launch and operate satellites or spacecraft. By providing this, the association take part in fulfilling the aims of the SSETI programme itself.
The aims of this association are:

— to involve and educate students about space and to develop and promote interests in space technology and space-related topics.

— to promote autonomy of young people by giving them the tools to develop an educational space project.

— to promote exchange of ideas and cross order collaboration between European students.

Three missions have been defined in the framework of the SSETI Association. The missions are part of a layered structure that could lead to a Moon landing and are defined as follows:

0. **SSETI Express**, the first SSETI satellite, launched in October 2005 by a COSMOS 3M launcher from Plesetsk, is a 60 kg low-Earth orbiting (LEO) spacecraft. It has acted as a technological test-bed, a logistical precursor, and, most importantly, a demonstration of capability.
1. The **European Student Earth Orbiter** (ESEO) currently in design study (Phase B), planned to be launched into geo-stationary transfer orbit (GTO) using an Ariane-5 launch vehicle at the end of 2008.
2. The **European Student Moon Orbiter** (ESMO) currently in feasibility study (Phase A), planned to be launched in 2011. From GTO, the 200 kg spacecraft will use its own propulsion system for lunar transfer, lunar orbit insertion and orbit transfer to its final low altitude polar orbit around the Moon.

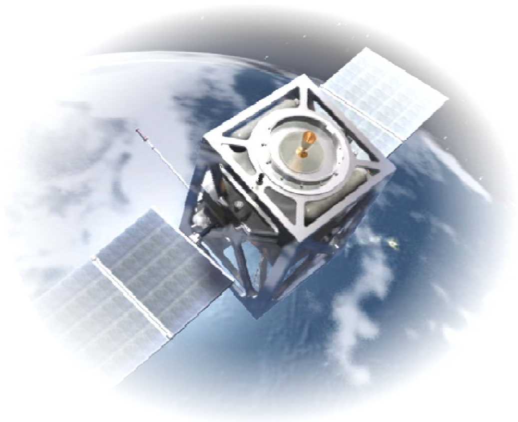


Figure 1: ESEO spacecraft (artist rendering).

2. Participation in ESEO

ESEO is a technical precursor to the 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. Each team is dedicated to particular subsystems, such as the on-board computer, the propulsion system, the communications antennas, etc. The ESEO platform will carry a number of interesting payloads to achieve its objectives. The ESEO technical fact sheet is given in Table 1.

Table 1: ESEO technical fact sheet.

Dimensions	600x600x710 mm
Mass	120 kg
Expected lifetime	Minimum 1 month, 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 thrusters
Obrit Control System	Cold gas

On-board Data Transfer	CAN, RS232, RS242
Telemetry - S-Band - AMSAT S-Band	 9.6 kbps or 128 kbps 400 bps
Power - Average - Peak	Deployable sun-pointing solar-cell panels 150 W 300 W
Batteries	Li Ion, 300 Wh
Propulsion	18 l, 300 bar, Nitrogen cold gas
Power bus	15-25V unregulated
Thermal control	active

Currently, ESEO is at the end of phase B (i.e., definition of the system and subsystem designs in sufficient detail; production of subsystem requirements and design specifications; initiation of advanced activities such as ordering of long-lead items and detailed design of critical parts). The ESEO configuration is shown in Figure 2. In the near future, Phase C, which encompasses development, manufacture, integration and test, will begin by the end of this year.

2.1 ESEO mission objectives

The ESEO mission objectives are summarised as follows:

- 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.
- To involve the amateur radio community in the downlink of telemetry and payload data from the satellite to enable them to contribute to the mission and to provide a UHF/S-Band linear transponder until the end of the mission.

2.2 MECH sub-system & Liege student participation in ESEO

Students at the University of Liège are responsible for the MECH subsystem. They are in senior year of Aerospace Engineering and participate in the SSETI project through graduation thesis. The SSETI project is supervised by professors and researchers from the University. Two industrial partners, SAMTECH (specialized in the development of computer-aided engineering solutions) and DUTCHSPACE, and a research center, CSL (Liège Space Center), also bring their expertise to the project. ALSTOM sponsors the project by offering licenses of ESARAD-ESATAN softwares. Finally, ESA experts at ESTEC (Noordwijk, The Netherlands) carefully review the design proposed by the students.
The objective of the MECH team is to design the solar panels (including the geometry and materials) and their deployment and pointing mechanisms (including electrical circuits, motors, hinges and actuators). The mission requirements are as follows:

- Solar panels shall be kept in folded configuration during launch;

- Solar panels shall be protected against accidental release;
- Deployment mechanism shall be designed such that vibrations and shocks transferred to the spacecraft during panel deployment stay below certain limits;
- Pointing mechanism shall provide equal pointing angles for all solar panels controlled by MECH;
- MECH shall provide a solar panel pointing accuracy of 10 degrees;
- MECH shall provide telemetry data on panel status.

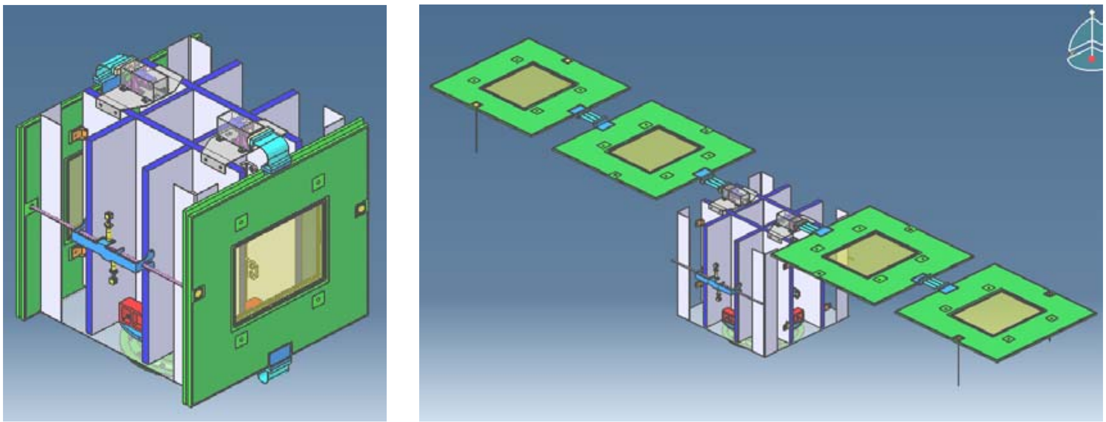


Figure 2: CATIA model of ESEO solar panel mechanisms in launch configuration (left) and in deployed configuration (right).

The solar panels are equipped with solar cells that bring electrical power to the whole satellite. The higher the size, the more available power. The size of the array is limited by the space allocated by the launcher. So there is a trade-off between the two constraints. In this context, a deployable system composed of 4 solar panels (two on each side of the satellite) was conceived. To maintain the solar panels in folded configuration during launch, two cables that go throughout the spacecraft bus retain the panels. Once on-orbit, thermal knives will cut the two cables.
One important part of the project is to validate the design through detailed finite element computations in the SAMCEF software. Among other things, the students had to verify the structural integrity of the panels during the launch phase. To this end, they built a finite element model of the complete spacecraft (bus and solar panels) and computed the resulting modal parameters (i.e., natural frequencies and damping ratios) using the DYNAM toolbox of the SAMCEF software. To avoid dynamic coupling between the launcher and its payload, ASAP-5 manual imposes that the fundamental frequency of the spacecraft in the longitudinal and lateral axes is above 90 and 45 Hz, respectively.

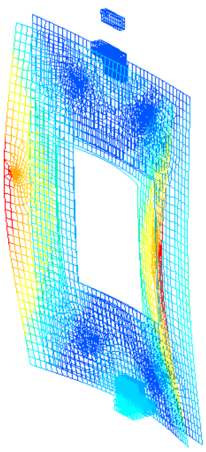


Figure 3: First vibration mode of the solar panels of ESEO.

3. Participation in ESMO

The ESMO spacecraft will 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 will 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) will 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 will be a high-resolution Narrow Angle Camera (NAC) for optical imaging of lunar surface characteristics developed by University of Liege. Optional payload item being considered include a Cubesat subsatellite for precision gravity field mapping via accurate ranging of the subsatellite from the main spacecraft developed by Canadian students.
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 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.
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.

3.1 ESEO mission objectives

The ESMO mission objectives are summarised as follows:

- **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

3.2 NAC instrument & Liege student participation in ESMO

The University of Liege is responsible for the design of the NAC camera. Students working on this project are in senior year of Physics Engineering and participate in ESMO through graduation theses, followed by experts from GDTech and CSL (Liège Space Center). The main mission requirements of the NAC sub-system are as follows:

- The NAC shall map lunar surface characteristics for education outreach purposes.
- NAC shall take at least 5 pictures per day of the lunar surface for a period of at least 4 weeks.
- The images taken by the NAC shall have a spatial resolution of 10 m at 200 km.
- The total power consumption shall be less than 10 W.
- The NAC shall have a maximum mass of 2.5 kg.

The camera is composed of a tube made in titanium alloy encapsulating the 6 lenses grouped in 3 doublets (see Figure 4). Titanium alloy has been chosen for its thermal behaviour which is close to the thermal behaviour of the lenses, therefore maximizing the tolerable thermal range of the camera. An optical baffle is situated at the external extremity of the tube, to decrease parasite optical rays entering the tube to increase the signal-to-noise ratio. At the opposite extremity, the tube is fixed to a cleat supporting the CMOS detector and the proximity electronics (see Figure 5.a). The detector and the proximity electronics are covered by a 3-mm thick box that acts as an additional radiation protection (see Figure 5.b).

ESMO will also be launch with ASAP. In the case of the camera, its first eigen frequency has to be higher than 100 Hz, which is fulfilled with the current design. As the spacecraft configuration is still quickly involving, no precise vibration input can be used, so we have been recommended to use a factor of 1.5 to the ASAP vibration levels.
The current design of the camera provide a mass budget of 2.6 kg, including 5% margin for COTS element and 20% margins for the other parts. Further analysis will be carried in order to decrease the mass of the tube by cutting holes in sections of the tube between the lens-doublets. We therefore expect possibility to decrease the mass of ~ 10%.
This feasibility study (Phase-A) will be reviewed in July 2007 by ESA experts

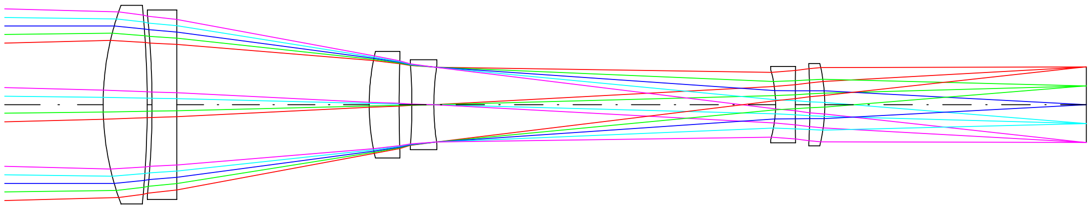
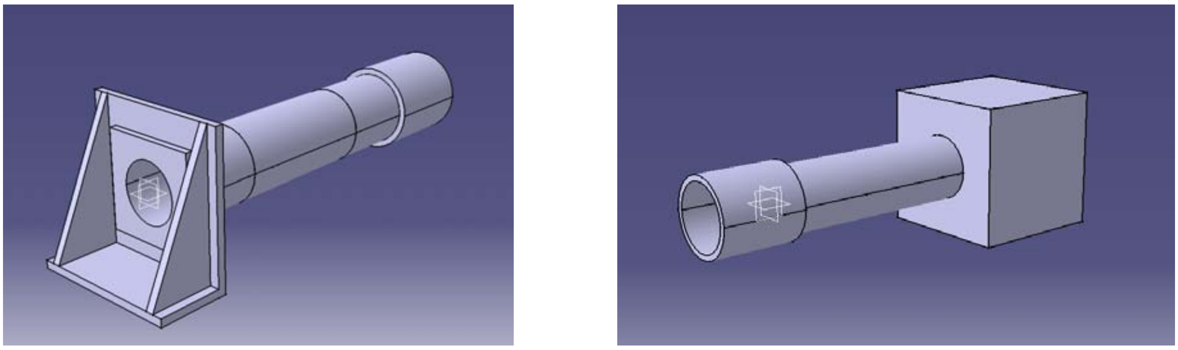


Figure 4: Optical design of the NAC camera.



(a) (b)

Figure 5: Mechanical design of the NAC camera

5. LEODIUM project

The aim of the LEODIUM project is to realise pico- or nano-satellites with students at University of Liege in collaboration with local industrials from Liege Espace. This project could in the long term provide a reliable low-cost platform for small scientific payload and new technology validation.
A master thesis prospecting current available technologies and looking at other realisations in Europe and Canada has been realised this year. In this work four objectives have been proposed for the project:

- **Education objective:** to increase students skills, improve their experience in the space-related fields and prepare them for high-tech industries thanks to the global management of an ambitious and motivating interdisciplinary project.
- **Communication objective:** to increase public awareness of Liege space sector, the scientific studies and space related industry in general.
- **Scientific objective:** to allow scientists (researcher or students) to design and realise new experiment and orbital measurements at low cost.
- **Technologic objective:** to provide a test bed for new technologies and equipments developed by the industry or the university.

The LEODIUM project is only at its start for the moment, most of the work is yet to be done. We hope to achieve such an ambitious project thanks to the solid collaboration started and the experiences acquired with the SSETI ESEO and ESMO projects. Those projects have permitted us start efficient collaboration between different professors from different domains of the university, some industrials like SAMTECH, GDTech and DUTCHSPACE. In our search for talented electronic students, collaboration has also been achieved with the Haute Ecole Rennequin Sualem, which offers master theses in electronics for both ESEO solar panel and ESMO camera. All these put together constitute a solid frame that will increase our chances of success in the long term of the LEODIUM project.

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