PARTICIPATION OF ULG STUDENTS TO THE SSETI MICROSATELLITE PROGRAMME USING SAMCEF

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Abstract: The objective of this presentation is to discuss the participation of students at the University of Liège to the educational spacecraft project SSETI-ESEO proposed by the European Space Agency. SSETI students are now mainly involved in the ESEO satellite for which the University of Liège is in charge of the *MECH* work package. The students have to propose a design for the structure of the solar panels (including the geometry and materials) and their deployment and pointing mechanisms (including electrical circuits, motors, hinges and actuators). Through detailed finite element computations in the SAMCEF software, they have to verify the structural integrity of the panels during the launch phase and to guarantee a safe deployment once on-orbit. Another task is to ensure an appropriate orientation of the solar panels to collect the maximum power from the sun. An industrial partner specialized in the development of computer-aided engineering solutions, SAMTECH, and a research center, Liège Space Center (CSL), also bring their expertise to the project.

SSETI ASSOCIATION

The Student Space Exploration and Technology Initiative (SSETI, http://www.sseti.net) 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.

In mid 2003, students involved formed the SSETI Association, the ultimate goal of which is to become a support and facilitation network for all student spacecraft-related activity and education throughout Europe, focusing primarily on hands-on involvement of students in real space missions, including micro-, nano- and pico-satellites and various payload opportunities.

From work performed so far, it is clear that high levels of academic expertise in specific space-related fields exist throughout European universities. However, in many cases these units currently operate independently of each other. The SSETI Association has the potential to combine 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.

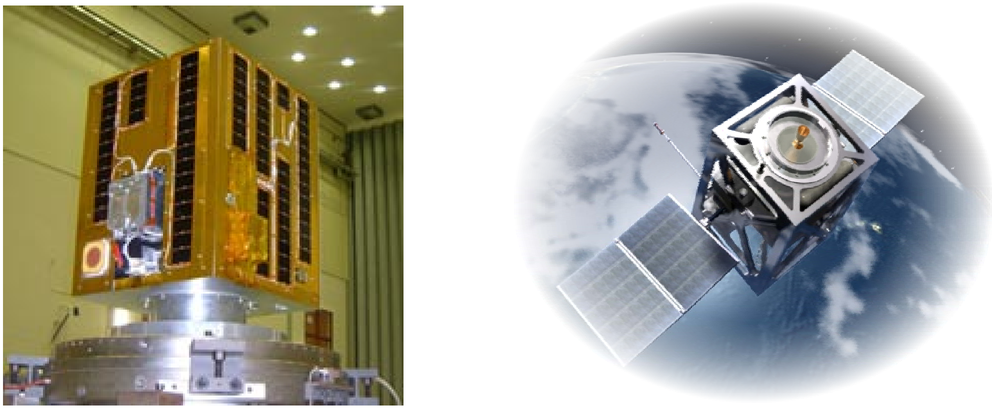
The aim of the SSETI Association is realised through team-based student work on specific satellite projects under the leadership of ESA's Education Department (which provides technical and managerial coordination) and with support from many ESA and industry experts. A dedicated website has been implemented 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 Association has developed a network of students, educational institutions and organisations to facilitate work on the various spacecraft projects. More than 500 European students have made an active, long-term contribution to these spacecrafts, 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 space industry and the SSETI Association. The experience and knowledge gained by the students will ensure a rich and fruitful recruitment ground for ESA and the space sector in general.

Four 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:

1. SSETI Express, a low-earth orbit 60kg spacecraft [see Figure 1(a)], was launched in October 2005 by a COSMOS 3M launcher from Plesetsk. The satellite served as a technological demonstration and as a test bed for some of the hardware that will be used for ESEO.
2. The European Student Earth Orbiter (ESEO), a 120kg spacecraft planned for launch in 2008 [see Figure 1(b)], should be launched directly into an geostationary transfer orbit (GTO) using an Ariane 5 launch vehicle.
3. The European Student Moon Orbiter (ESMO) is now in Phase A. The ESMO spacecraft should be launched in 2011 as an auxiliary payload into a highly elliptical, low inclination 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.
4. The next step would be to land a Moon Rover that would explore the Moon.



(a) (b)

Figure 1: (a) SSETI Express; (b) ESEO (artist rendering)

THE EUROPEAN STUDENT EARTH ORBITER (ESEO)

ESEO is the second ESA student satellite, following SSETI Express; it is also a technical precursor to ESMO. The ESEO technical fact sheet is given in Table 1. This microsatellite will orbit the Earth taking pictures of the Earth and other celestial bodies for educational outreach purposes. It 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. Another ESEO objective is 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.

Following the successful model of SSETI Express, the satellite platform of ESEO is being developed by student teams across Europe. More than 200 students, from more than 20 universities in 10 countries take part in this project. Each team is dedicated to a particular subsystem, such as propulsion system, mission analysis, spacecraft structure, attitude control, etc. The University of Liège is in charge of the MECH subsystem (i.e., the design of the spacecraft mechanisms).

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.

Dimensions	600x600x710 mm
Mass	120kg
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 thruster
Orbit Control System	Cold gas
On-board Data Transfer	CAN, RS232, RS242
Telemetry · S-Band · **AMSAT** S-Band	 9.6 kb/s or 128 kb/s 400bps
Power · Average · Peak	Deployable sun-tracking solar-cell panels 150 W 300 W
Batteries	Li Ion, 300 Wh
Propulsion	18 l, 300bar, Nitrogen cold gas
Power bus	15-25V unregulated
Thermal control	active

Table 1: ESEO technical fact sheet

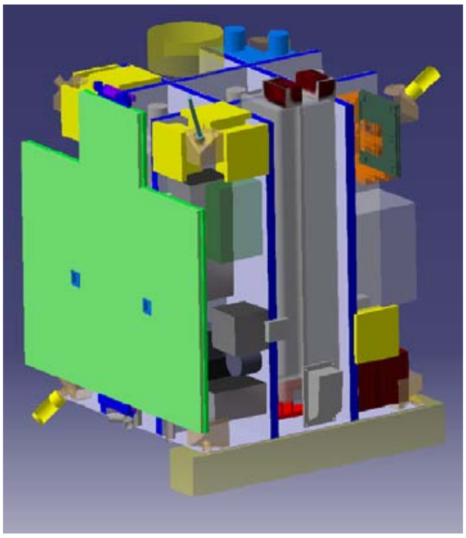


Figure 2: ESEO configuration (CATIA model)

THE MECH SUBSYSTEM

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 theses. 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, 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.

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. A few representative modes are shown in Figure 3. To avoid dynamic coupling between the launcher and its payload, ASAP5 manual imposes that the fundamental frequency of the spacecraft in the longitudinal and lateral axes is above 90 and 45 Hz, respectively.

The spacecraft must also withstand the launch loads which include quasi-static loads, sine vibration, acoustic noise, random vibration and shock loads. The harmonic response of the solar panels was computed using the SAMCEF REPDYN toolbox, and a sample result is depicted in Figure 4. Figure 5 shows that the maximum stress occurs around an excitation frequency of 60Hz and is equal to 25Mpa. This is well below the elastic limit of aluminium.

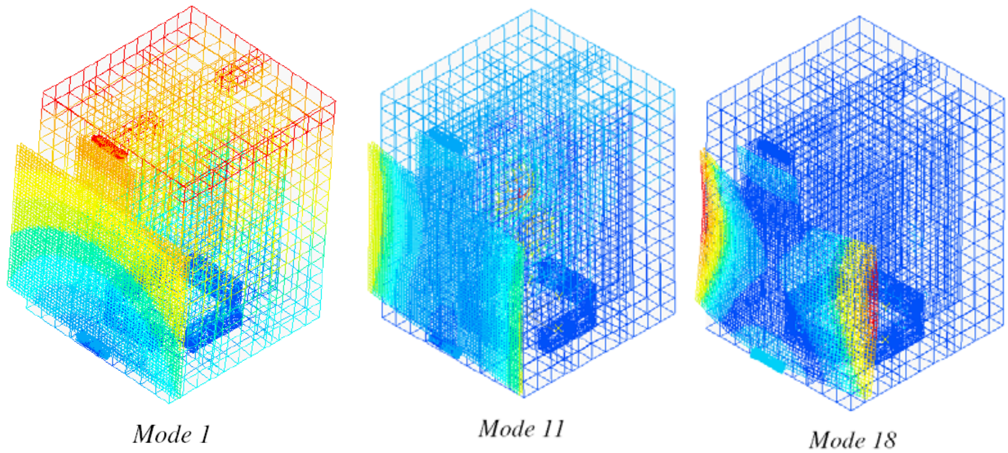


Figure 3: A few representative modes of ESEO spacecraft (SAMCEF DYNAM toolbox)

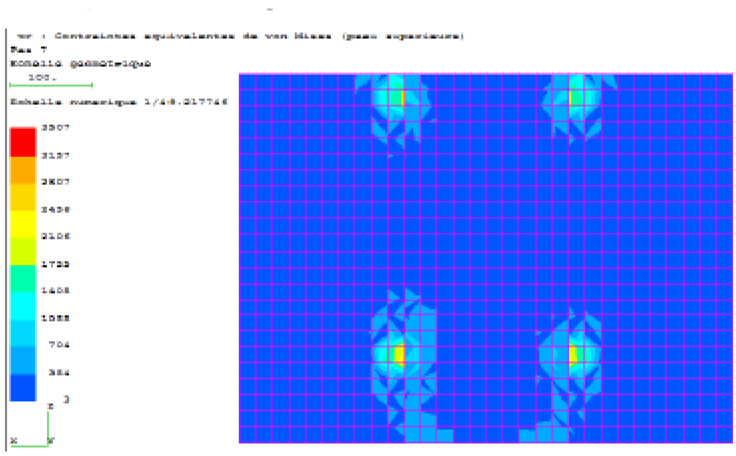


Figure 4: Harmonic response (50 Hz) of a solar panel (SAMCEF REPDYN toolbox)

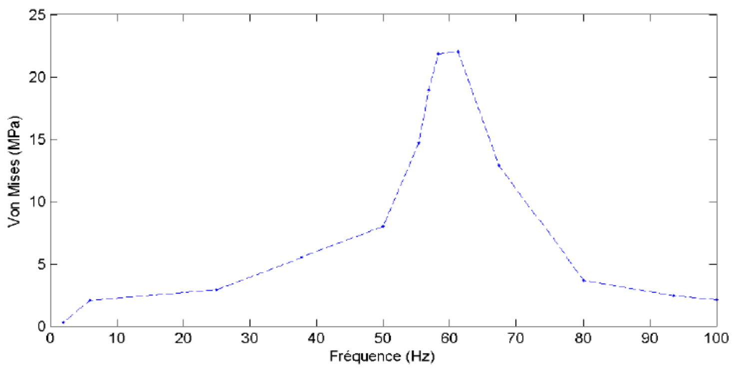


Figure 5: Maximum stress vs. excitation frequency (harmonic response, SAMCEF REPDYN toolbox)

Taking into account the shock response and random vibration spectrum for Ariane 5 (given in terms of power spectral density), the random response of the solar panels was computed using the SAMCEF SPECTRAL toolbox. The maximum stress is around 170 MPa, as illustrated in Figure 6.

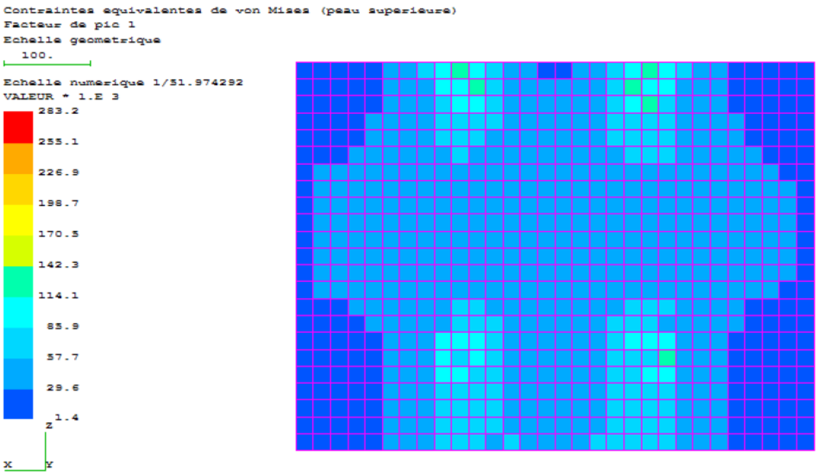


Figure 6: Mechanical stresses (random response, SAMCEF SPECTRAL toolbox)

Another verification is to guarantee a safe deployment once on-orbit. The solar panel deployment was simulated in the SAMCEF MECANO environment. For instance, Figure 7 shows the mechanical stresses in one solar panel after 0.4s. Figure 8 shows the kinematics of the deployment and displays the angular position and velocity of the two hinges.

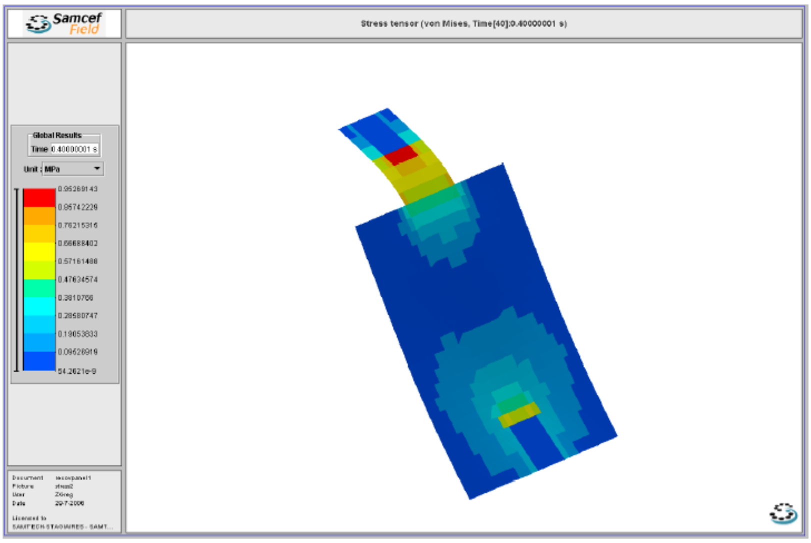


Figure 7: Mechanical stresses (solar panel deployment after 0.4s, SAMCEF MECANO toolbox)

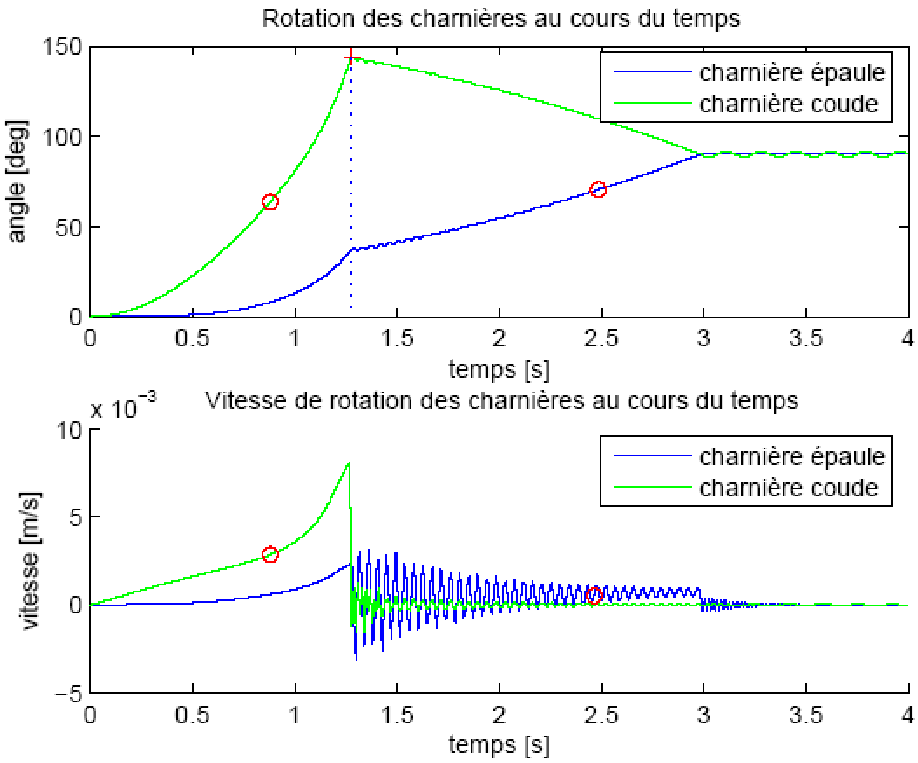


Figure 8: Angular position (top plot) and velocity (bottom plot) of the two hinges SAMCEF MECANO toolbox.

CONCLUDING REMARKS

Students at the University of Liège participate in the educational spacecraft project SSETI-ESEO proposed by the European Space Agency (ESA). It is definitely a unique experience for them, as they are involved in the design of a real space mission. An interesting feature of this project is that the students must follow the standard ESA rules and guidelines, that is those that are currently used for the design of industrial spacecraft.

The next steps in the project are (i) to perform thermo-elastic analysis by a combined use of SAMCEF and ESARAD-ESATAN software, developed by ALSTOM; and (ii) to build a prototype and test it (e.g., vibration tests, thermal and vacuum tests). The long-term objective at the University of Liège is to involve students in the design of a cubesat.

ACKNOWLEDGMENTS

The authors P.V., G.K., O.B. and L.N. would like to acknowledge the Belgian National Science Foundation (FNRS) for its financial support. The authors would also to acknowledge ALSTOM for offering licenses of ESARAD-ESATAN softwares.