EPFL Spacecraft Team project propositions Spring 2020

The EPFL Spacecraft Team

The goal of the EPFL Spacecraft Team is to run space missions for In Orbit Demonstrations and In Orbit Validations of swiss scientific instruments referred to as payloads. The mission includes to design, build, test, launch and operate a satellite which integrates the scientific instruments.

A satellite can be broken down in two parts. The first part is the platform which is a structure containing all the subsystems that allow the satellite to fly and function (telecom modules, on-board computer, power system, attitude determination and control, etc.). The second part is the payload whose choice is of major importance because it brings scientific objectives to the mission.

There exist countless potential payloads - many people have developed instruments and technologies that they want to fly in space - however there are only very few flight opportunities. The main purpose of the Spacecraft Team is therefore to offer flight opportunities to these organizations, companies while creating the opportunity for students to apply their engineering skills to highly challenging projects.

Our first mission: CHESS

CHESS (Constellation of High Energy Swiss Satellites) was born at e-Space in february 2019. The goal is to launch a constellation of 4 satellites in Low Earth Orbit to study high energy astrophysics. The four identical CubeSats will be loaded with a hard X-ray Compton polarimeter as main payload and will fly around Earth on a low sun synchronous orbit. A strong collaboration at a national-scale with other swiss universities, Hochschulen, and research institutes is to be expected.

The constellation will operate during three years with a triple objective:

- permanent monitoring of the full sky for hard X-ray transient gamma ray bursts
- permanent observation of the sun in hard X-rays energies
- observation of space weather events, electrons protons and heavy ions

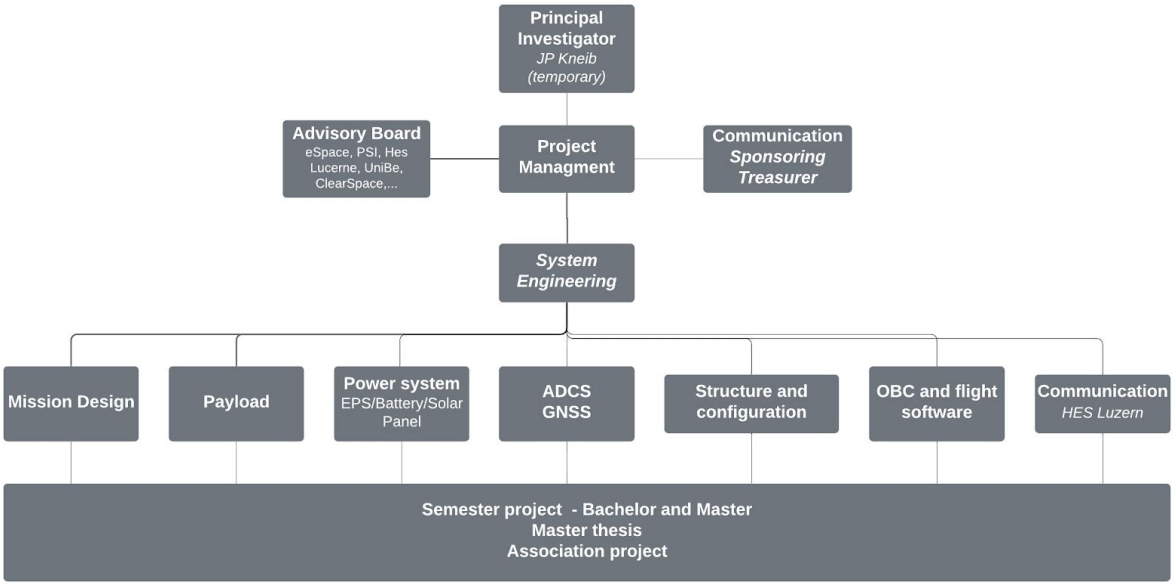
These observations will be used both for space industry applications and for scientific research (data correlation with other missions such as Solar Orbiter and LIGO-Virgo gravitational wave observatories).

Join the Team!

As part of the EPFL Spacecraft Team you will:

- communicate and collaborate with the other members of the project to provide a coherent design of the satellites.
- acquire a comprehensive insight in the conception and development of a space mission.
- be part of a national project involving multiple universities across Switzerland.
- find, meet and ask actors of the space industry in Europe to challenge the key choices you make in your pole.

Organisation chart of the association



Spring 2020 - association open positions and projects

Pole: Communication

Association, 2-3 students

Tasks:

- Set the communication strategy
- Events organisation
- Communication on social networks
    - Write articles for the press and sponsors
    - Posts about news about similar missions
    - Posts about team meetings
    - Posts about conferences/workshops

        - Webmaster (wordpress)
- Communication intern to EPFL (+ partners, e.g. HES Luzern)
    - EPFL magazine
    - Make a video for the team
    - Organize recruitment
- Bring your own ideas (e.g. radio, TV)

Pole: Sponsoring/Partnership coordinator

Association, 3 students

Objectives:
- Design a sponsorship proposal
- Investigate new sponsoring opportunities
- Maintain relationships with external companies who are interested in sponsoring us.
- Eventually, present the association at events and meetings.

Pole: Treasury

Association project, 1 student

Objectives:
- Keep count of all expenses, evaluate costs and organize the budget of the mission.
- He/she will communicate with all the subgroups to understand their needs and how much we can actually allocate on each subsystem.

Pole: System engineering

Association project, 1 student per subpole, i.e. 6 students in total (bachelor or master)

Objectives:
- Follow up all the projects linked to your pole, separate tasks and organize meetings
- Contact other missions to get their input about the part you are managing

Remaks:
- You can be pole manager and do a project inside the pole
- You will get strong support from the core team (Nicolas Martinod, Tristan Trébaol, Alfonso Villegas), at least at the beginning

Pole: Mission design

***Title:* Cubesat Mission Design and Environments Definition**
Supervisor: Bastien Gorret (e-Space)
Type of the project: association and semester project
Resources: 1-2 students (bachelor and master)
Recommended: Minor in Spacetech.

Description:
The goal of the mission design is to define the mission objectives and requirements, assess all possible mission concepts and make sure that nothing that could result in bigger problems in the future development of the mission has been left out. Space mission analysis and design is an iterative process, gradually refining both the requirements and methods. These analyses will impact and support the science investigations, the whole mission plan, and all satellite subsystems requiring environment information. The student will learn about orbital mechanics, mission design, mission planning and space environments.

Tasks:
- Characterize mission concepts and architectures: further define the mission concepts in enough detail to allow meaningful evaluations of effectiveness.
- Identify critical requirements
- Evaluate mission utility: quantify mission performance as a function of design, cost, risk and schedule
- Orbit simulation
- Environment definition
- Precise system requirements
- Allocate requirements to system elements

***Title:* Payload selection**
Supervisor: Bastien Gorret (e-Space)
Type of project: association and semester project (bachelor and master)
Resources: 2-3 students
Recommended: Minor in Space Tech, PHY

Description:
Building a spacecraft is only useful for the payload you want to embark. The selection of those payloads is a crucial step in making a space mission feasible. It is them that make the mission scientifically and financially interesting. Today, we have lots of payload but little embarcation opportunities. By developing a satellite platform, we therefore raise the interest of public and private institutions proposing their payload to be flown. A selection needs to be done.

Tasks:
- Understanding the technical and scientific parameters of a payload
- Mission design (Orbit, power budget, data budget, concept of operation,...) for each payload

- State of the art analysis of the market field

Pole: Structure and configuration

***Title:* Structure design and configuration analysis**
Type of project: association (bachelor and master)
Resources: 1-2 students Bachelor students
Recommended: STI

Description:
The design of the CHESS CubeSats is a very challenging task. Indeed the main payload has an unusual volume of 230x55x55 mm^3 which, in height, occupies almost 80% of the space available. There is therefore very little space to stack the PCBs conventionally and some of the subsystems thus must be placed around the payload. A frame needs to securely hold each component. This frame must be lightweight, yet be robust enough to withstand the high mechanical constraints during launch and keep the keep the satellite (the structure and the electronics inside) intact. A first CAD model of the satellite structure and configuration has already been made. The goal of this project is to precise and finalise the model in order to be able to perform precise vibrational and load tests next semester.

Tasks:
- *Structure*: reiterate structure design with a more precise one: choice of screws, simplification of design (lighter frame, less screws, simpler and cheaper machining, ...)
- *Configuration*: Assess the integration of each subsystem in the platform (spatial configuration, wiring, connectors, ...)

***Title:* Vibration analysis of the CubeSat**
Supervisor: Lili Gu (LAMD)
Project type: semester project (bachelor and master)
Resources: 1 student
Recommended: STI

Description:
During the launch, the CubeSat is subject to high mechanical constraints that can damage or even break the structure. The goal of this project is to test whether the current design is robust enough to withstand launch conditions and if this is not the case, point out what needs to be improved.

Tasks:
- Look for and define the launch conditions for a 3U CubeSat.
- Using the CAD model that has been made of the satellite structure and configuration, the student will use the Finite Element Method and perform free vibrational and buckling load analysis tests to find the deformation of structure at various natural frequencies in order to ensure that the Cubesat could withstand the various conditions while the launch. Propose what could be improved or downsized.

***Title:* Thermal study for CubeSat**
Supervisor: TBD
Project type: semester project (bachelor and master)
Resources: 1 student
Recommended: STI

Description:
The thermal control subsystem is one of the critical systems of almost any spacecraft, as it is responsible to guarantee that all the spacecraft's temperature is within a predefined range. This range is dictated by the requirements and constraints of the individual spacecraft components, considering all operational modes and environments that the spacecraft might be exposed to. Besides respecting a given range of temperatures to operate in, the spacecraft should also limit the temperature gradients. Otherwise, it could lead to reduced efficiencies and/or lifetime of the components, equipment malfunction, structure deformations or even total mission failure.

Tasks:
- Determine the operational conditions.
- Analyse thermal behavior of all subsystems.
- Use the Finite Element Method and constitute a thermal model of the whole satellite.
- Propose solutions to control the temperature of the CubeSat (design of the thermal control subsystem).

Pole: Payload

***Title :* Design of a LiDAR camera for satellite tracking in space**
Supervisor *:* Pr. Charbon (AQUA)
Type of the project: association and semester project
Resources: 2-3 students (master and bachelor)
Recommended: STI and PHYS

Description:
The need for LiDAR camera in space is growing. They became essential for both for space rendez-vous and debris removal. But only few solutions are available, and they often come at a great financial cost. This project is investigating the feasibility of a CubeSat mission with a LiDAR as a payload.
This project will follow the feasibility study currently going-on.

Tasks:
- Design of an experimental setup
- Mission design and concept of operation
- System engineering of a LiDAR

Pole: ADCS/GNSS

***Title:* Attitude determination and control system**
Supervisor: Philippe Müllhaupt (LA - Automatic Control Laboratory)
Project type: semester project, master thesis
Resources: 2 master or bachelor students
Recommended: STI

Description:
The attitude control is a challenging problem due to power, mass and size limitations of the actuators and sensors. In fall 2019, students characterised the requirements of the subsystem and came up with a first solution. Your objective will be to come up with a working solution which will be presented at the Preliminary Design Review in September 2019. If everything goes well, the ADCS will be bought for fall 2020 in order to start the test phase.

Tasks:
- Improve the control algorithm :
    - In precision: integrate the current control algorithm on the simulation tool (GNCCsim) to model standard perturbation.
    - In robustness: the ADCS should work even if some actuators/sensors are down.
- Software and hardware redundancy analysis to improve the current version
- Create a timing budget for the transient states (with the concept of operations as main input)
- Interface hardware and software inside the satellite (in close relation with other projects and the supplier)
- Assess the quality of V1 (discussion with the supplier)
- Plan the test phase

***Title:* Spacecraft formation flying with CubeSats using differential drag on LEO**
Supervisor: TBD
Type of project: association (bachelor and master)
Resources: 1 student
Recommended: Minor in Space tech, STI, MATH, PHYS

Description:
Nowadays, more and more constellation of satellites are launched into orbit. Usually spacecraft formation flights are done when the satellites are equipped with a propulsion system. Since CHESS CubeSats won't have any, their speed will be modulated by taking advantage of the remaining atmosphere in Low Earth Orbit to apply different drag forces on the satellites.
Since all the satellites will be launched at the same time from the same rocket, they will fly near one another on the same orbital plane. Due to the science objectives of the mission, the constellation will be operational only when the satellites are in a specific formation where they are equidistantly placed over the orbital plane. Your

objective will be to study how to put and then maintain the satellites in their formation.

Tasks:

- Model the separation of the satellites over the orbit:
    - Determine the desired relative ordering of the satellites (referred to as their slotting).
    - Generate an optimal sequence of control input to acquire the slotting.
    - Simulate the separation different scenarios with orbit altitudes and satellite's cross sectional area as variables
- Study how the formation flight will impact the control algorithm and the actuators of the ADCS (in close collaboration with the ADCS project)

Pole: Power system

***Title:* Design and integration of the Electrical Power System on a CubeSat**
Supervisor: Drazen Dujic or Olatz Arriana (Power Electronics Laboratory - PEL)
Type of project: association and semester project (bachelor and master)
Resources: 1-3 students for association or 2 students for semester project
Recommended: STI

Description:
The role of the EPS is to gather the energy from the solar panels and redistribute it to the different subsystems (ADCS, OBC, GNSS, transceiver, payloads, antennas, EDU, battery, thermal system) in the most robust and energy-efficient way. In fall 2019, three students came up with a first choice for the EDU, battery, solar panel. The objective is now to interface the different components of the EPS together and integrate them inside the satellites, while looking at the power budget.

Tasks:

- Battery dimensioning
- Present a final power budget (with the concept of operation as main input)
- Suggest an architecture for the redundancy of the EPS:
    - latch up protection
    - robustness in case some solar panels are down
- Draw the flat-sat for the Preliminary Design Review
- Plan the test phase of all the electronics of the satellite

Pole: OBC and Flight Software

***Title:* Characterization of the On Board Computer and its Flight Software**
Supervisor: TBC
Project type: association and semester project
Resources: 2 students for association or 2 students for semester project
Recommended: Computer and communication science

Description:
The OBC is the brain of the satellite. It has a central role to control the other subsystems, grant or deny their access to power, create the log report for the

mission operations, prepare the data transmitted from and to the communication subsystem. You will face constraints linked to reliability, maintenance, sizing and power delivery. Since it is the first project concerning the OBC at EPFL Spacecraft Team, the objective is to characterize the needs of this subsystem and suggest a version 1 in June. It is likely that the OBC will be bought and adapted to our mission.

Tasks:

- Explore and determine the requirements for the OBC software in order for it to meet the requirements for the CHESS mission.
- Search for different types of software, hardware architectures, evaluate their strengths and weaknesses, and present a first choice for the CHESS mission