18th International Conference on Space Operations, Montreal, Canada, 26 - 30 May 2025.

SpaceOps-2025, ID # 192

Lessons Learnt From Eyesat as a Starting Point for new French Academic Nanosatellites Projects

Rémi Lapeyre[a]*, Nicolas Verdier[b], Stéphane Fredon[c], Tao Gelati[d], Ewen Kieffer[e]

[a] *Centre National d'Etudes Spatiales, France, remi.lapeyre@cnes.fr*
[b] *Centre National d'Etudes Spatiales, France, nicolas.verdier@cnes.fr*
[c] *Centre National d'Etudes Spatiales, France, stephane.fredon@cnes.fr*
[d] *Centre National d'Etudes Spatiales, France, tao.gelati@cnes.fr*
[e] *Centre National d'Etudes Spatiales, France, ewen.kieffer@cnes.fr*

* Corresponding Author

Abstract

Nanolab Academy is a training program lead by CNES, the French Space Agency. The aim is to train undergraduate students to space techniques through the making of a real nanosatellite, from mission design to in-flight operations.

Building on our first success (Eyesat 2019-2023), We are currently developing Aerosat, a 3U CubeSat with deployable solar arrays. It is based on a flight-proven assembly of commercial and home-made equipment. All technical positions in the project (System Engineer, Flight Software developers, ground segment integration, and other) are held by CNES interns.

We use the know-how acquired on those missions to assist French universities and engineering schools designing their own nanosatellite project. Nanolab Academy already supported several initiatives in the past: They all were academic successes, but not all of them were considered a technical success. To address this issue, we reviewed the reasons why the projects were lacking reliability and proposed a new approach: bringing support by delivering an avionic kit that is identical to our internal project, Aerosat. This CNES project is built on the previous success of Eyesat, taking advantage of flight-proven choices and design. This generic platform has been named SEED, and it will be used in five upcoming missions. On the ground segment end, we offer building bricks to the upcoming academic projects: monitoring and control software, Flight Dynamics software, ground station support from the CNES multi-mission network. As for the flight hardware, the intent is to offer generic solutions on which we have some expertise.

This paper will address the return of experience on Eyesat and past missions, the starting hypothesis we derived from this to design SEED and the implications it has on ground segment design and genericity.
Keywords: Cubesat, Education, Eyesat, Aerosat

Acronyms/Abbreviations

3U	**3-unit**
ADCS	Attitude Determination and Control System
AIT	Assembly, Integration, Tests
AOS	Acquisition Of Signal
CCSDS	Consultative Committee for Space Data Systems
CNES	Centre National d'Etudes Spatiales
EM	Engineering Model
ENAC	Ecole Nationale de l'Aviation Civile
FDIR	Failure Detection, Isolation and Recovery
FDS	Flight Dynamics Software
ISAE	Institut Supérieur de l'Aéronautique et de l'Espace
LEO	Low Earth Orbit
MUM	MUlti Mission (ground stations network)
OS	Operating System
PFM	Proto-Flight Model
PUS	Packet Utilization Standard

SCC	Simple Control Center
SDR	Software-Defined Radio
SEED	Satellite Elements for EDucation
SEU	Single-Event Upset
TTC	Tracking, Telemetry and Command
UHF/VHF	Ultra/Very High Frequency
VPN	Virtual Private Network

1 Introduction

Space engineering requires very specific skills. Each engineering discipline has its own variation when it comes on working on a space project. If academic education generally prepares young professionals to carry out general engineering tasks very well, some of the know-how specific to space systems can only be acquired with hands-on training, on real tasks. It is true for many other engineering domains actually, and the rationale for mandatory internships just before graduation for young French engineers.

In 2023, CNES, the French Space Agency, has published 191 internship and 44 work-study placement offers on its website [1]. Some of those were dedicated to the Nanolab Academy project. Indeed, each year 10 to 20 students are selected to hold key positions on a space mission that only relies on their work. Students are given the System Engineer, Thermal Engineer, AIT Lead, Mission Manager positions for instance. CNES staff is involved only in mentoring these students. We give them such responsibilities because we trust our young engineers-to-be and have confidence in their ability to carry out complex tasks, even before their actual carrier starts. We think this experience will empower them to design new systems, start new companies, create new opportunities. It's our investment for the future.

At Nanolab Academy, our students work on a 3U cubesat [2] project, which is the backbone of our activity. During typically 6 months, they contribute to the project investing their passion for space, and get precious teachings in return. Even if we board scientific experiments on our cubesat, the real payload here is the educative value yield by such a process. In our mission design, the prime system requirement is "Training".

Until now, Nanolab Academy teachings to students have been focused on the space segment and its design. We nevertheless addressed Space operations already during the lifetime of our first mission and would like to go even further, as there is no school which trains specifically for space control centers jobs. It is a unique opportunity to carry out real space operations with students on console, which is quite challenging by design.

Moreover, to multiply the number of students trained each year to space techniques, we rely on Academic Space Centers in France through joint cubesat missions. Opportunity is given to them to be offered hardware, on-the-shelf designs, expertise, launch opportunities and even ground station support in the frame of a cooperation with CNES, through Nanolab Academy. Therefore, their budget is easier to close, and Nanolab Academy gets support in spreading space engineering knowledge across all our national territory.

Our first mission Eyesat, will be addressed in the first section of this paper: this will give the setting to the next section exposing what our current plans are in the frame of Aerosat and SEED new projects. Finally, we'll address our perspectives in the long shot before some closing words.

2 Eyesat, the first success

Eyesat was initiated back in 2012, with one core objective: train students on a real space project, letting them handle every engineering aspect of it. The budget was constrained, and that was the main driver for choosing a nanosatellite as the space segment of the mission. Another rationale was that a nanosatellite is compact enough to be assembled and tested on a table, whereas larger satellite need supporting equipment and larger facilities to be handled.

2.1 Mission Concept

To be true to our commitment of training young professionals on a real space project, the mission could not be only education. It had to have another purpose, a mission-level requirement, that would be declined in system requirements and shaping the final design. In other words, we wouldn't make a spacecraft just to make a spacecraft. Zodiacal light[*] survey was therefore selected as the prime scientific objective of the mission. The payload to achieve this mission was based on a 3DPLUS camera, and a filter-wheel designed by IUT Cachan.

[*] Zodiacal light is the sunlight scattered by interplanetary dust concentrated around the ecliptic plane.

The final design for the space segment ended up to be a 3U cubesat, shared equally in volume between the payload and the platform.

The platform was designed around CNES' joint developments with the French industry (Research and Technology CNES program). Steel Electronique's *Ninano* on-board computer and Syrlink's *EWC31* S-band transponder have since then become best-sellers in the European space market, as well as the *Anywaves'* S-Band patch antennas [3]. The electrical power generation, storage and distribution circuit board was an in-house development by students. The overall avionics concept revolved around the idea of simplicity. On-board autonomy was ensured by a simple strategy: Falling back to sun pointing each time the battery voltage was read below a low threshold. Basically, the spacecraft would enter safe mode should anything affect the power balance, hence the survivability of the spacecraft.

Operations on ground would be shared between CNES and ISAE facilities, with inter-operable topologies (Fig 1.).

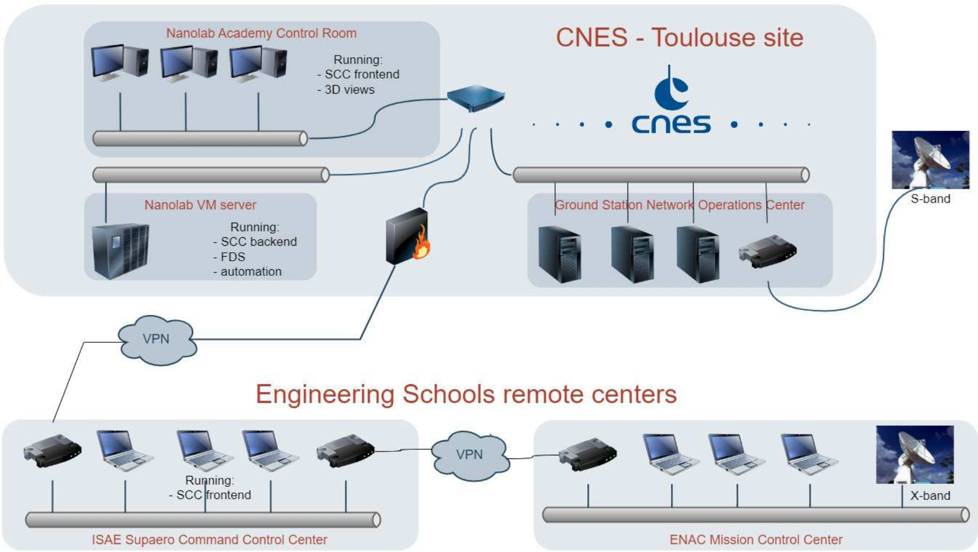

Fig. 1. Eyesat Ground Segment

Control and monitoring of the spacecraft were be carried out using SCC – Simple Control Center, a software developed by students. The Flight Dynamics solution was based on Celestia. Task automation has been carried out using server OS' native features, such as crontab.

Operations were carried out on a "best-effort" basis. Meaning there was no on-call service nor operation outside office hours. Eyesat was a demonstrator with no real reliability requirement. It was accepted the mission could be lost in the event of a contingency the on-board FDIR could not handle. There was no guaranteed continuity in its ground monitoring. This unusual setting in the landscape of space operations actually comes from limited funding of the mission and work contract limitations specifics to interns that prevent them to work outside office hours. The budget limit is actually a shared rationale with new space industries, that might choose similar strategies to cut expenses.

This "office-hour" operations scheme is a point to keep in mind to understand the full context of Eyesat end-of-life, later explained in this paper.

2.2 Flight Experience

2.2.1 From late 2019 to early 2023

Eyesat was launched on December 18th 2019 on a Soyuz rocket from French Guiana on a dusk-dawn Sun-Synchronous Orbit. From the start, the spacecraft behaved very nicely, all systems showing good performance. During the four first months, all was nominal and we could even capture some nice deep-sky pictures (Fig. 2).

Fig. 2. The Lagoon Nebula (M8) imaged by Eyesat (credits CNES)

Quite early in the mission nevertheless, reaction wheels' performance started to degrade: a first wheel got stuck 4 months in the mission, leading to patching the flight software to perform control on the 3 remaining wheels. The situation worsened in the following weeks rapidly coming to a total blocking of each wheel, one by one. In these conditions, no fine pointing could be achieved, and the spacecraft remained in safe mode for a while. In this fallback mode, it was actuating the magnetorquers only to achieve attitude control. Soon, the flight software was patched to achieved coarse pointing in nominal mode using no reaction wheel at all. Even with this change, the scientific mission could not resume. In these conditions, the degraded performance of the ADCS was not sufficient for two critical operations:

- It could not stabilize the spacecraft long enough for the camera to be exposed at a stable target during the integration time. Such a faint phenomenon as zodiacal light could not be imaged in these conditions.
- The X-band antenna could not be oriented with sufficient accuracy to beam the images through the hi-rate data downlink. This antenna had an aperture that required the fine pointing system to work, in order to close the link budget.

On the other hand, all other subsystems performed remarkably well. The S-Band data link proved itself to be reliable, and the on-board computer reset itself on SEU detection only 4 times over the satellite lifetime (~46 months). The power system has kept balance robustly until the very last days of the mission.

It was possible to achieve secondary technological objectives. Indeed, we succeeded in imaging Earth with the camera, as the scene was much brighter and requires therefore shorter exposures.

With the X-band link being not usable such pictures where downlinked through S-Band. With a data stream of only 100 kbit/s available, it took between 20 and 30 communication passes to downlink each single full picture. Those efforts proved the payload was actually working very well – even in the very last days of the mission where a last picture was downlinked (Fig 3.)

Operations were at first carried out by CNES and ISAE students and young professionals. As time passed by, new projects were taking shape in CNES and we looked for support for operating Eyesat. The newly founded company U-Space joined us and helped us take care of Eyesat for the 3 last years of the mission. The resources allocated for this were sufficient to keep the ground segment up, and give a decent operational response should the spacecraft enter survival mode.

2.2.2 Orbit decay and end-of-life operations

During spring 2023, we started getting reports from the flight dynamics team that Eyesat's orbit started to decay significantly faster. The first projections showed we could expect reentry on the next year. During summer, this prediction moved even earlier, sometime end of the same year. We had time to carry out some technological experiments, such as trying to start the wheels again (with no luck) and taking a last picture of the Earth. The last scheduled step was to passivate the spacecraft on November 5th as per the French space regulation.

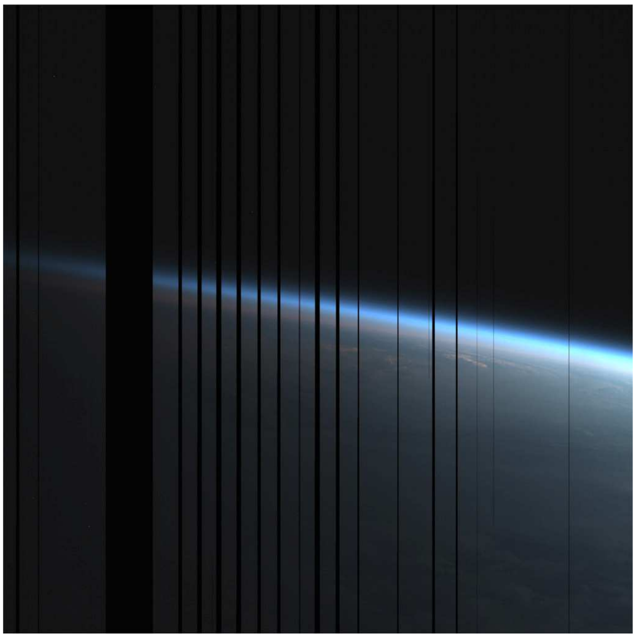

Fig. 3. Last picture of Earth taken from Eyesat (credits CNES)

The downlink of this picture has not been completed, since events unfolding late October caused the mission to end abruptly.

The orbit decay led Eyesat eventually drift outside the flight domain it was designed for: on September 18th, Eyesat altitude was 400 km and rapidly decreasing. We started experimenting trouble on ground stations to catch Eyesat signal at the waiting point, at communication pass start. This was because transponder switch on commands were released on-board later than the geometrical AOS of the ground station. Indeed, the scheduling of these commands was done in advance, based on the Flight Dynamics computation on-ground, itself based on ground station data from previous passes (1-way Doppler and angular measurements). The time-constant of this feedback loop was roughly 12h at first. But the orbit decay rate started to challenge this time-constant, and Eyesat was every day in the sky ahead of where it was expected from ground station perspective… with its transponder not yet on. The ground station pointing being automated on its carrier detection; it was ineffective at the first moments of each com pass.

To mitigate this effect. It was decided to double the daily passes count (making it 4) to lower the FDS loop time constant, and anticipate each transponder switch-on to make sure Eyesat would be broadcasting a carrier when raising over the horizon from the supporting ground station perspective. This made a huge dent in the power budget of the spacecraft, but from the recent readings, it was still believed to be balanced, at least until the eclipse season's start.

On the morning of October 19th, the health checks on Eyesat went green one last time. This was the last time support was active on ground (the subsequent passes were planned in the evening, outside office hours). The next day was a day off for all teams, and happened to be a Friday. Consequently, Eyesat would not be monitored during three consecutive days, and would rely on automated actions taken by the space and ground segments only, which is the operational concept baseline.

On October 20th, A few last frames were received by the supporting ground station of Aussaguel near Toulouse, all other passes having yield no signal from the spacecraft. Back on Monday morning, operational teams concluded the spacecraft had entered safe mode sometime October 19th, on low voltage detection on the battery. This has caused the TTC subsystem to enter the beacon mode, which is power-intensive. One frame of that beacon had been observed on the 20th. Even if the last readings showed the battery cells were at that time on the brink of total depletion and there was little hope to recover the spacecraft, some communications attempts were made during that week… with no success.

It turned out the eclipses had started on the very last day of the previous week. Busy with other tasks, operational teams did not realize the eclipse season start would move forward due to the decay in altitude.

Eyesat reentered the Earth's atmosphere on November 19th 2023.

2.3 Lessons Learnt and Legacy

We estimate around 250 students have contributed to Eyesat, which makes the mission a huge success in regard of its prime objective: training. Young people that have worked as interns on this mission are now skilled engineers, and even successful businessmen. This glowing success has built their confidence in their skills and they started their carrier rocket-fast. Most of our former students start their career in the Space Industry, or in Aeronautics (Fig. 4). Three of our former interns have founded U-Space, a company that designs and builds nanosatellites for their customers. We are very proud at Nanolab Academy to have been part of their inspiring journey.

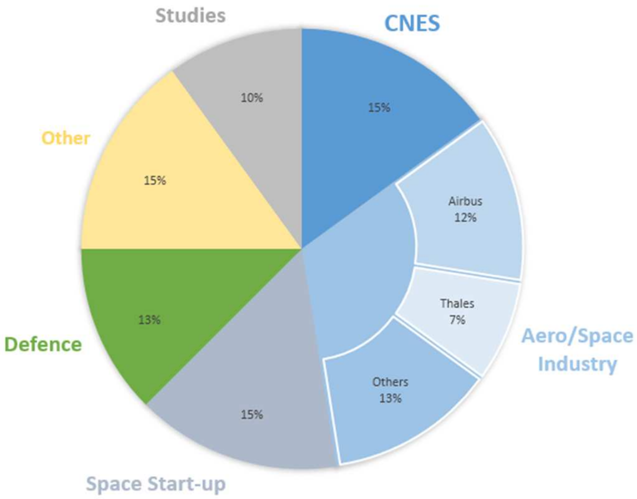

Fig. 4. Results of a survey on the current job our former students are now on
(march 2025, among students that have carried out an internship in the past five years at Nanolab Academy).

The project took 8 years from project kick-off to launch. Obviously, this is not the pace of an industrial project. It's much slower because it is driven by the educative value of the process. We had to manage hand-over between new students every 6-month, facing the challenge of bringing them up to speed very fast. As the project goes closer and closer from launch, there is more and more information to pass, making these hand-overs longer and longer. Having a tidy and synthetic documentation is key to cope with this challenge.

System-wise, the main lesson learnt was the need of implementing a power saving mode to cut off TTC beacon, should the battery hit critical low level.

The last year of operation of Eyesat was the year the new flock of ground stations (5.5 m S-Band diameter antennas) started to integrate the CNES ground station pool. Eyesat was the perfect object to perform qualifications of the first MiniMUM ground station: There was no pressure on link availability, so any test could be carried out with no impact. It is indeed very convenient to have such a mission with a best-effort requirement in quality of service. In the end the ground station support was flawless, even during its qualification phase.

Eyesat very low orbit at its end of life helped test flight domains never tested before with the ground stations, and gain some experience on that.

All in all, the main lesson learnt was that such projects driven by students had great potential. It turned out to be an educative mission only the national agency could lead. Having young motivated and skilled engineering is a common benefit for our industries and labs. Therefore, it is a role CNES is expected to hold in France. We had to give this outstanding success a follow-up.

3 Aerosat and SEED

3.1 Aerosat Mission Overview

During Eyesat operations, it was decided to start another nanosatellite project in-house, to continue to train students to space techniques. The new mission would be a multi-payload carrier, building on the strong points of Eyesat. The new mission was named Aerosat (Fig. 5).

Obviously, Eyesat design was very good. So we decided to keep the Cubesat 3U form factor, and the PC104 assembly architecture. The platform design was adapted to cope with obsolescence: the S-band transponder, not available on the market anymore, was replaced with its new iteration, from the same manufacturer. Electrical interfaces and operability remains the same. The volume was even smaller, which gave room to accommodate more payload. The four reaction wheels were replaced by a single wheel, that would provide only attitude control stiffness. Given the payload selected would not require a fine pointing capability, this choice was simple to make.

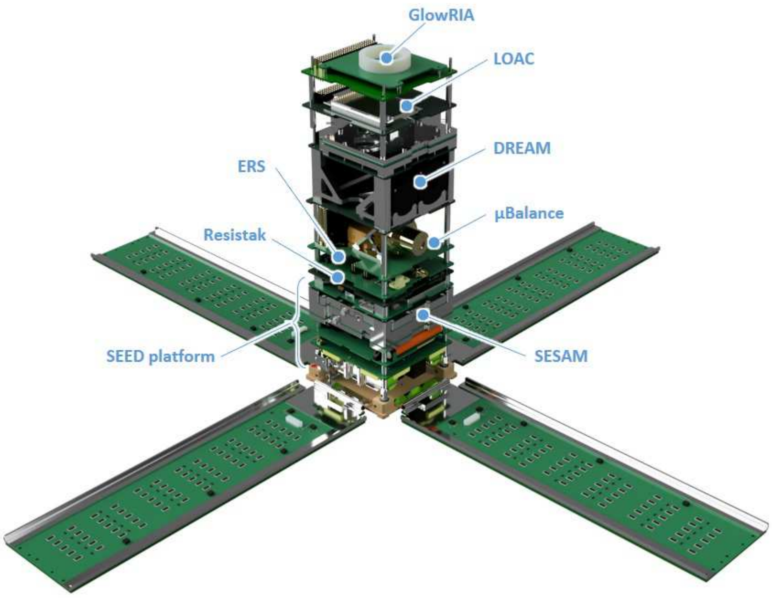

Fig. 5. Aerosat, Nanolab Academy students' current project

Make or buy decision were made on the educative value of making an equipment from scratch versus reliability of on-the-shelf industrial nanosatellite components. Hence, it was decided to in-house design our own power distribution and conditioning units. We had experience on power electronics, so that was considered to be where we could tutor students in electronic at best. On Aerosat, the solar panels, power board and battery are an in-house design. The specificity of the mission lead us to develop our own mechanical parts and hinges. On the other hand, the on-board computer, the S-Band transponder and the magnetorquer boards are the same commercial products than for Eyesat. Flight Software is 100% developed in CNES, by interns.

Seven payloads are boarding Aerosat:

- LOAC, a laser-based aerosol counter which electronics have to be qualified in orbit before deployment to planetary atmosphere in-situ mission for Mars or Venus
- DREAM, a High-energy particle detector [4]
- GlowRIA, an optical-fiber-based dosimeter
- Microbalance, a contaminant detector
- ERS, to study Earth infrared radiative properties (as in UVSQ-SAT NG [5])
- Resistack, an atomic-oxygen detector
- SESAM, a machine-learning engine to detect incoming on-board failure weak signals.

The spacecraft will be ready for launch in 2026.

3.2 SEED, a common avionics

Nanolab Academy spends over 75% of its budget to help Academic Space Centers in France. Engineering Schools, Universities and even research labs have set up ventures during the past decade or two, and are eager to orbit their own mission. We have an history of helping these Academic Space Centers through the former JANUS program. Looking back at the performance of this program, it comes that even if there were some glowing examples of success, most of the students' spacecraft failed early in their mission, or didn't make it to the launch pad. There are mainly two reasons for that, in our opinion:

- Lack of technical support. Because these projects had total control over the choice of the flight hardware from which they will build their nanosatellite, they tended to design their own PCBs or to buy equipment CNES have no or little knowledge own. The choices were very diverse, and we could not embrace the full variety of them with the limited resources we had.
- A focus on the payload, detrimental to the platform reliability. This is especially true when a research lab is involved in the project. Platform engineering is not a detail of a project, and a strong motivation is required to carry out a project with this task.

Consequently, for the next iteration of our support to Academic Space Center, we had to tackle the reliability issue. We could have provided ready-to-go platforms to the Academic Space Center, as some industries offer on the market, but it would have nullified the technical training value for students.

We had to find a trade-off between reliability, and training value. We came up with the idea of providing a hardware kit to the Academic Space Centers. From this kit, they would build their own spacecraft. The hardware selected to be part of this kit would be the same as for Aerosat, which would put us in a position to provide excellent technical support.

On top of these two hardware platform kits (one EM, one PFM), CNES backs the project for finding a launch opportunity and support the mission with its ground stations for the first year in orbit, at not cost for the university.

This is as well a very convenient way to support Academic Space Center without funding them directly. We do not fund the projects to close their budget, we are providing hardware and services that will ease the budget. SEED objective is to enhance the academic space center focus on the human resources needed to tutor the students efficiently.

3.3 Ground segment design

Aerosat Ground segment design inherits directly from Eyesat, with some evolutions, driven by the lessons learnt and obsolescence.

The Flight Dynamics solution is now SIRIUS [6], a CNES software suite. This in order to merge efforts with other control centers in CNES using this solution. By doing so, we ensure the mission will benefit from the expertise of our Operation Directorate, which masters this tool.

The task automation engine is still in design and decision has not been made yet to re-use similar techniques as for Eyesat (where everything was based on shell scripts and crontab tasks).

For the space-to-ground link, we can count on CNES Ground Station Network and its S-Band capacity. The same interfaces as for Eyesat are foreseen. More *small* stations will be available to support the mission, on a one-pass per day scheme. We decided to use this frequency band (and not the very popular UHF/VHF radioham bands) on purpose. As the objective is to train students to work for the industry, it makes sense to choose a professional frequency band for the mission. This choice lead as well to use standard CCSDS and PUS packets, which is a great way to introduce these standards to students.

The core of the ground segment will be SCC (Simple Control Center). This monitoring and control software has been initially developed for Eyesat and has supported the mission during four years. This software is now jointly developed and maintained by U-Space and CNES. Operations will be carried out from our dedicated control room (Fig. 6), the same that has been used for Eyesat last year of operations.

Fig. 6. Nanolab Academy Control Room

The idea behind SEED and providing Academic Space Centers technical resources extends as well to the ground segment. We offer free non-commercial license of the monitoring and control software (Simple Control Center) and the Flight Dynamics suite (SIRIUS). We push a TC authentication solution that is easy to deploy yet strong, stressing the importance of securing the space-to-ground link. On top of that, we provide one year of S-band ground station support to the sudents' missions.

3.4 Students hands-on training

Space operations is not something one can learn at school. At best, our students had a 4-hour introductory lecture on it. It is then of great interest to train the students holding key positions in a control center, during space operations, on opportunities like Aerosat.

The most convenient way to do this is to rehearse operations on a simulator, during office hours. This is easy to setup, at least for nominal scenarios. Every mission, even regular ones, operated by professional staff, rely on training in simulation. Nevertheless, training does not feel quite the same if there is no real deal at the end. On-console training on a simulator is fine, but it needs the perspective of a real flight to have a meaning. We need these students on-console as well, for real-time space operations.

For the regular mission phase, Eyesat has shown it is feasible during office hours, provided a trade-off in mission reliability. Making student work on this phase is easy, nevertheless, it is not the most active phase of the mission. Consequently, educative value, even if real, is limited.

Obviously, the Launch and Early Operation Phases is the phase our student need to have their hands on, as the emotional bond with the mission is built during this phase mainly. This is our students' project, so they deserve their seat in the control center on launch day.

CNES has no experience yet in making interns work night shifts or on the week-end. Nevertheless, we need to come up with a way doing so, to offer our student the true experience of space operations. We are working with human resources to find a way to enable them living these unique moments on console.

4 Other projects and perspectives

One of the main drawback of working on a nanosatellite project and taking the time of making it worth - in terms of educational value - is that the project spans over several years. This is true for Eyesat, Aerosat, and pretty much every student spacecraft ever built. It's not a deterrent as such, but one has to put such long-time experience in perspective with the academic life rhythm. Indeed, student involvement of such project rarely last over one year. Most of them will not see the beginning and the end of the project, which are key events to build motivation. We decided in Nanolab Academy to offer other activities that can be lead in parallel (and even sometime synergize) with a nanosatellite project. The last part of this paper will expose some of them, and what they can bring to the Space Operations training we can offer, at CNES and in French Academic Space Centers.

4.1 UHF/VHF Ground station

A very popular asset in Academic Space Centers is a ground station you can afford and operate easily. The vast majority of the Academic Space Center in France have a UHF/VHF ground capability in radioham bands. One of our work-study trainee in CNES is designing and building one, to support complementary activities (AEROSAT uses S-Band only, so this ground station is not design to support this mission). The process of making such a stations yields great academic value over radiofrequencies, Software-Defined Radio solutions, Station automation, Satellite tracking on ephemeris, Digital signal processing and decoding, control center interface design. With such and active station at hand, a student can take the grasp on how time-constrained is a LEO satellite communication pass. There are already a large set of orbiting spacecraft that broadcast packets in those bands, so the variety of available data makes good material for future educational events, even for younger audiences.

The station we build at CNES will as well support High Altitude Ballons campaigns, which is the next point to discuss.

4.2 High Altitude Balloons

A high altitude balloon mission is a totally affordable mission, even for Academic Space Centers with almost no budget. Yet, there are great perks coming with such initiatives.

This kind of mission can be carried out in months, from design to launch, which makes it very easy to accommodate in an academic year. It is a perfect exercise in electronics and wireless communication [7]. The high altitude environment at 30 km provides negative temperatures, and an atmospheric pressure of ~1% of the one at sea level. Not quite space yet, but still enough of relative vacuum and adverse temperatures to challenge home-made electronics.

On operational aspects, a High Altitude Balloon project is a gold mine: It is the perfect way to introduce students to negative chronology planning. It's as well the true experience of launching a remote system – and realizing you cannot fix it while in flight! Ground station aspects can be addressed with reception stations and decoding of the on-board transponder. Last but not least, recovery of the gondola need team coordination. The ground station reception team has to give directions to the recovery team to drive them in the vicinity of the landing prediction, updated in real-time. There is so much to do in education on operational aspects with a High Altitude Balloon, that it should be the first project of every newly established space student initiative.

We plan to support 5 Academic Space Center flights a year with Nanolab Academy resources, ramping this up if needed, and get the according resources.

One of our interns coupled the use of our VHF/UHF station with the high-altitude balloon activity. He designed the backend and frontend of a monitoring software (Fig. 7.) that can track signal from flights embedding the Kiwi, an emitter designed for educative balloon flights. It interfaces with the station's SDR to decode Kiwi frames and display the content on a nice-looking display. Thanks to his work, our control center can support this additional activity, along with UHF/VHF spacecraft communications, making our Aerosat control center truly multi-purposed.

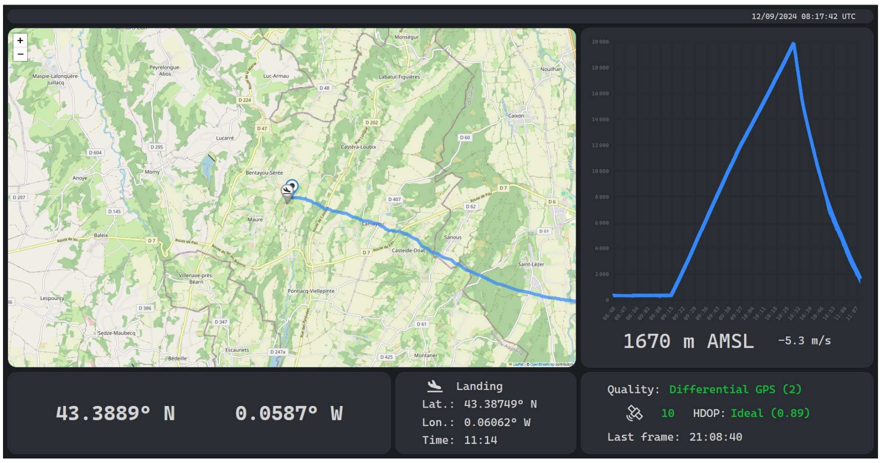

Fig. 7. "KiwiLoc" Interface, as displayed on one of the main wall screens of the control room.

4.3 Perspectives

Nanolab Academy will close a loop in 2026, with the end of the initial funding plan. We will need to come with a new plan for the next years. That means both a new internal project, subsequent to Aerosat, and another way to support Academic Space Center activity, like we did with SEED.

We think we have reached a point where supporting other single nanosatellite initiatives in Academic Space Center makes no more additional value. One strong motivation of the Academic Space Center to fund a space project is the public relation's potential of it. Having a spacecraft with the name of the university on it is viewed as some kind of achievement, demonstrating the university is one of the few with the ability to carry out complex projects. Past this first mission, this motivation fades out.

This view seems to be shared by French Universities and Engineering schools: At least one initiative called COMETES has started, federating several Academic Space Centers around a single project. It's still several spacecraft, but unified in a constellation, which is a first step to project collaboration on the same system.

We intend to follow and support that trend, by proposing another ambitious space project (different from COMETES), led by CNES. Every Academic Space Center would be given a work package in accordance with its expertise domain and/or simple preference. Nanolab Academy would lead project and system aspects. Such a mission has not yet been selected, but obviously we would have to focus on topics dear to students.

5 Conclusion

Nanolab Academy has one goal: offer opportunities to students to develop their skills in space techniques. We believe it is crucial to let them face the real challenges by letting them lead every key aspect of a space mission, including operations. For us at CNES, it is the perpetual seek of balance between a mission that is reliable enough and the liberty to experiment and try things that might fail. We want them to be prepared to the industry, so we turn to professional solutions, that sometimes comes already packaged. There are trade-offs to make to keep the academic value in a domain where you could just buy every solution and assemble them. We want our young engineers to experience the lab and the tools because their academic knowledge is overwhelmingly made of abstract concepts and numerical simulations.

Nanolab Academy heavily relies on CNES experts in various technical domains: they tutor students over their internship. We could not teach as much without their support. They actually like to spend some time on Nanolab Academy related topics, because working with students is mind refreshing, and help them zoom out from their other day-to-day duties. It's a great source of motivation within the agency.

We cannot do much difference alone: that's why our partnership with Academic Space Centers is crucial. Our SEED platform is declined in various ways by students all over France, and it's a pleasure to see them make this platform theirs. It builds a community that will hopefully last for the years to come.

Nanolab Academy is an initiative only a governmental agency could lead: by taking the time and money to train the next generation, we invest in our future. The students we have trained will build space systems better than ours, start successful companies, explore space as never before. Our only role is to pass over to them the tools and knowledge. It's not a matter of letting them the floor only, but letting them the sky as well.

Acknowledgements

We would like to thank all students that have ever contributed to any French cubesat project. We salute their motivation for space-related jobs and desire to show what they're capable of.

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