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Fly a Rocket Campaign! A Unique ESA Academy Hands-on Project

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***Abstract*— The *Fly a Rocket! Campaign* is an ESA hands-on project in collaboration with the Norwegian Space Agency and the Norwegian Center for Space-related Education (NAROM) which allows university students at their first or second year of Bachelor degree to build, launch and operate their own first sounding rocket from the Andoya Space Centre located in Northern Norway. This paper gives a general overview of the second edition of this programme, as it took place throughout winter 2018 – spring 2019. Being selected to be member of the *Telemetry and Data Readout team*, the author's task was to set up and operate the telemetry station, including manually tracking the rocket and downloading its data, making sure that the students received and collected data from the rocket. For this reason, this paper will focus particularly on the activities followed by the Telemetry and Data Readout team members.**

***Keywords*— sounding rocket; education; Andoya; ALOMAR**

I. Introduction

The project was designed to offer University students early in their studies the chance to learn about rocketry and launch their own rocket from Andoya Space Center.

Through their participation in the programme, students were meant to gain experience in how to:

- Reproduce a scientific project: scientific objective, building and testing instrumentation, retrieve telemetry data, analysis, and conclusions;
- Work on a real rocket project as a team and interact with industry experts and other students from several different nations.

Students taking part in the *Fly a Rocket! Campaign* also learn about:

- How a rocket engine works using solid, liquid or hybrid propulsion technology;
- Basic rocket theory – be able to derive the rocket equation;
- Rocket aerodynamics and stability – the physics behind a sounding rocket and know the forces acting on a rocket;
- The use of rockets, balloons and ground based instruments as a technology platform to study processes in the atmosphere;
- Sensors and basic electronics;
- Orbital mechanics and use of satellite navigation.

II. The Rocket

The student rocket is a version of the Mongoose 98 optimized for didactic purposes. The Mongoose 98 has a length of 2.708 metres and a width of 102.8 mm. It is mostly made of carbon and glass fiber. Its total weight is 18.762 kg, of which:

- 1.3 kg is payload;
- 4.812 kg is the Pro98-N2501-P Cesaroni solid propellant motor, which burns for 6.09 seconds, giving an average thrust of 2,501.8 N;
- 8.496 kg is solid propellant;
- 4.154 kg is the dry weight of the rocket.

An electronic plate is mounted along the elongated axis, and on this plate the encoder, the transmitter, 2 S-band antennas, the battery and the sensors are mounted.

The suite of instruments flown on the rocket included an external and internal temperature sensors, a pressure sensor, a magnetometer, a two-axis accelerometer, a light sensor, a GPSIMU for latitude, longitude, altitude, velocity and three axis acceleration, an array mounted on the inside of the nosecone, counting 10 different temperature sensors.

III. Teams Overview

The 23 students involved in the project were split into four different working teams, each composed by an appropriate number of people, with different and peculiar tasks.

A. *Telemetry and Data Readout*

The Telemetry and Data Readout team was in charge of preparing the Student Telemetry Station (NAROM TM) to receive, visualize and record sensor and housekeeping data transmitted from the Student Rocket.

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The team worked both on the hardware and the software part of the Telemetry Station. The hardware part was composed by:

a. A horn antenna;

b. Two receivers;

c. A combiner, which took the best signal from the receivers;

d. A bit-synchronizer, which reduced the noise;

e. The decoder.

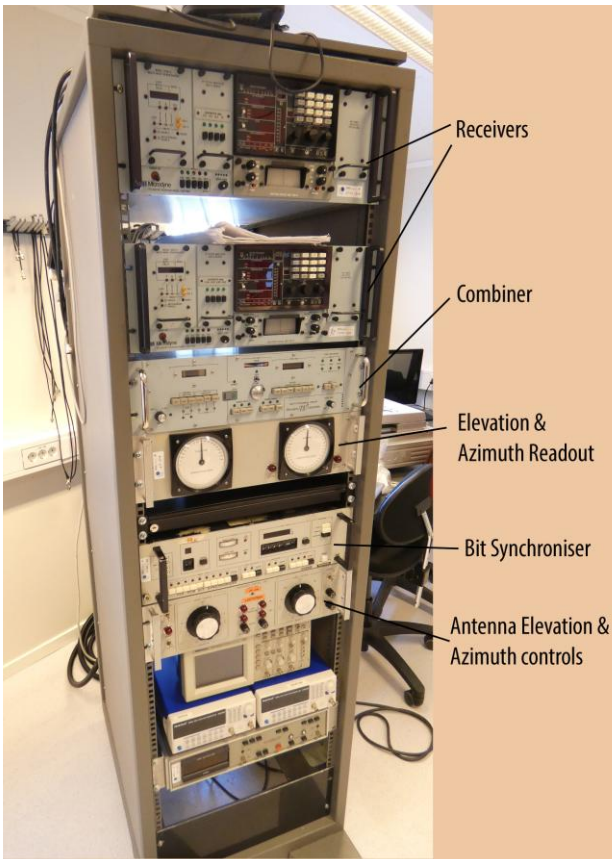

Figure 1. NAROM Telemetry Tower

While the software used were Matlab, to export data collected into format suitable for plotting, and DEWESoft, to tell the telemetry station what data were of interest and how it should have arranged them in displays. This was also the phase of more overlapping between groups: the Payload and Sensor teams members shared with the Telemetry team the equations to implement in DEWESoft. Those equations represented the calibration of the sensors, thus related the voltage sampled by the instrument to the physical value measured during the flight.

The group also operated the Student Telemetry Station and assisted the operations of the Main Telemetry Station (a second telemetry station which the students where just in charge of operating, not building), according to the Countdown Procedure handed out at the Pre-flight meeting.

In addition to this, the team studied how they could measure the slant range using phase shift, measured with a phasemeter. Which is to say, how is it possible to exploit doppler effect due to the movement of the rocket in respect with the ground station to measure the length of the trajectory flown.

B. *GPS and Simulations*

The GPS and Simulations team was responsible for building the GPS sensor and running simulations including the rocket's trajectory and the position of the Centre of Gravity and the Centre of Pressure.

C. *Payload*

The Payload team accounted for the final assembly of the rocket's payload. Additionally, the Payload team built the umbilical (for power and transmission at the launchpad), assembled the wiring for the encoder and transmitter boards, and built two of the temperature sensors.

D. *Sensors experiments*

The Sensor team made all the sensors (except the two of the Payload team). In addition, they prepared and launched two weather balloon PTU probes prior to the rocket launch.

IV. PRE-COURSE

Before the launch campaign, the students were expected to complete two individual assignments. In order to do so, they had been strongly recommended to attend the online course offered by NAROM. The pre-course taught the students about:

- Rocket engines: the rocket principle, the rocket equation, total impulse, the nozzle, rocket motor efficiency, the engine types (solid, liquid, hybrid, ion thruster);Basic rocket theory – be able to derive the rocket equation;
- Rocket dynamics: aerodynamics and forces acting on the rocket, simulating a rocket launch;
- Satellite orbits: Kepler's laws, six basic orbital parameters, orbit equations in a plane, examples of orbits.

Those assignments, especially the second one, were challenging on purpose, as to promote cooperation between the participants through online platforms.

V. LAUNCH CAMPAIGN

The launch campaign took place at the Andoya Space Center, one of the most popular facilities worldwide for sounding rockets and aerostatic balloons, with an illustrious history, counting over 1,200 sounding and sub-orbital rocket launches in its 57-year lifespan.

The students stayed at the Space Centre from the 7th to the 13th of April 2019.

Day 1 – travel day, welcome and practical information; Day 2 – introductions, rocketry lectures, tour of the Andoya Space Center, start of the student rocket work; Day 3 – lectures on balloons and radiosondes, continue

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working on the rocket, MATLAB lecture;
Day 4 – payload testing, whale museum;
Day 5 – presentation of data from simulations, pre-flight briefing and safety brief, rocket operation, post-flight meeting, evaluate data, prepare for presentation, Gala dinner;
Day 6 – presentations of data collected;
Day 7 – travel day.

A. *Lectures*

During the week in Andoya, the students attended a number of lectures, given by experts, regarding technical aspects such as rocket physics, transmitting data, balloons, radiosondes and ALOMAR Observatory but also some others aimed at raising students' consciousness of how wide the spectrum of Space activities is, for instance how is like to work at an operative rocket range, or to be an operator in Kourou (French Guiana).

Most of the lectures were in common for all the teams. Some of them were specifically shaped for tasks peculiar of each team.

B. *Labs work*

The teams worked on their tasks in near rooms so that they could interact when they had to. The labs work on the rocket started the day after the students arrived at Andoya. Each of the four groups was followed by one or more NAROM experts.

A key factor characterizing the labs work was the attitude "The students take the work": they were really pushed to work on the rocket, make it ready to fly with all the sensors working and being able to have data back on the ground. The students believed that all was their responsibility, even though the technicians from NAROM tended to correct their mistakes without giving the feeling that the rocket would have flown because they oversaw the students' activities.

C. *The day before the launch*

The day before the launch, the students used NAROM telemetry station to verify the health of the payload, in order to be sure that each sensor was working and they received data from it. It was a critical moment, since some issues occurred with the temperature sensors on the nose of the rocket, but eventually, checking each connection, the Sensors team solved the problem.

D. *Launch day*

Before the launch, the students attended a safety brief in which Andoya experts explained in detail all safety matters.

The launch was at first one hour delayed due to a plane transit above the launch area.

All the students were provided with a countdown procedure, nominally 1 hour long. As a matter of fact, the countdown stopped at minus 15 minutes because the telemetry stations didn't receive data from the payload, while the rocket was at the launchpad.

The reason was that the rocket experienced connection issues with the umbilical cords. The problem took half an hour to be solved, by removing the rocket from the umbilical cords, restarting the power system and attaching the rocket to the cords again.

E. *PTU sondes*

Prior to the rocket launch, the students launched two PTU sondes (aerostatic balloons with pressure-temperature-humidity sensors) to verify the weather conditions were good enough to go for the rocket launch.

F. *The excursions*

During the week in Andoya, the students could take part into several exciting excursions:

1) The whale museum;
2) The lighthouse;
3) The near city of Andenes.

They could also use their spare time to go hiking to the mountains surrounding the Space Centre.

G. *Post flight analysis*

The data collected thanks to telemetry (the rocket was not recovered) were immediately worked by the students. Each of them was given a particular case study, which related two aspects of the flight, for instance altitude vs velocity, battery vs temperature, light vs altitude and so on.

The rocket reached an altitude of almost 8 km, a maximum velocity of 2.0 Mach, and a peak in the acceleration in the travelling direction of 17g.

After the first moments, in which the rocket spun on its axis many times per second, the rocket spin reached its minimum soon after apogee.

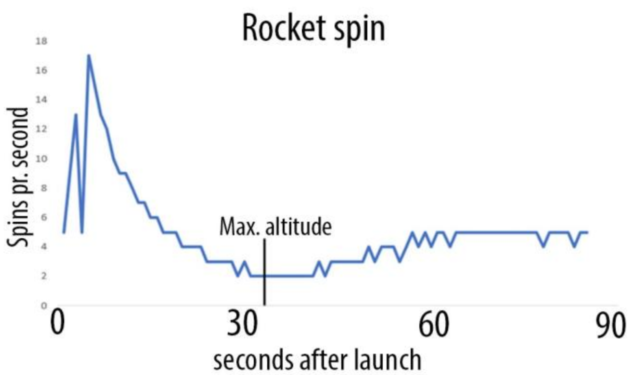

Figure 2. Spin vs time

The case study the Telemetry Team was expected to analyse was the difference in signal received by NAROM Telemetry station (the one set up by the students) and, instead, the MAIN Telemetry station (the one the students just operated). The outcome was that more powerful antennas

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locking automatically on the rocket (MAIN Telemetry station) are able to maintain a more stable telemetry link than smaller, manually pointed ones (NAROM Telemetry station).

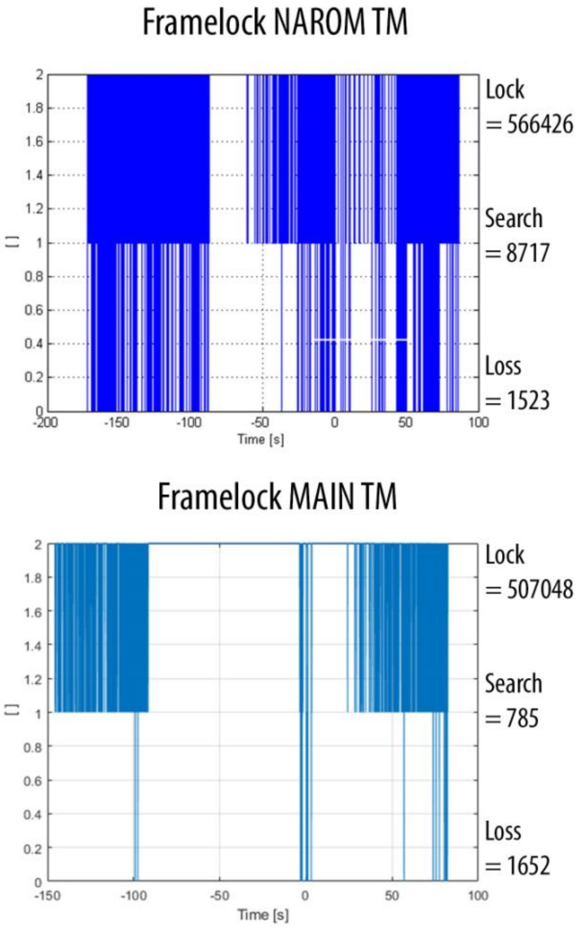

Figure 3. Telemetry case study

Indirectly, thanks to the light sensor but also the study of the launch video frame by frame, the students found the clouds to be at an altitude of 1100m.

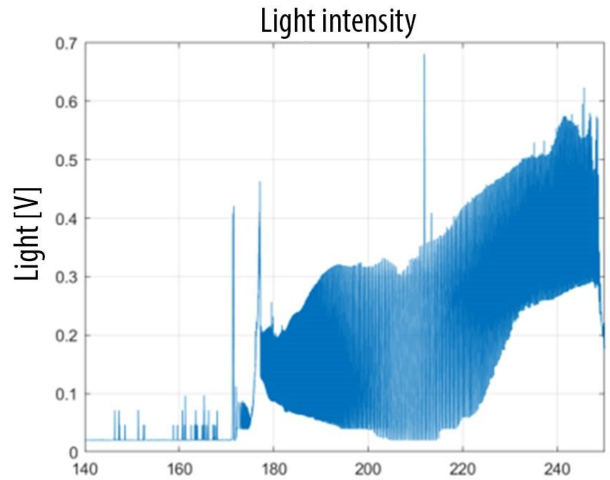

Figure 4. Light vs time

Drag calculations allowed to derive the drag coefficient of the rocket, which was obtained to be 0.7.

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