ESA and NAROM student rocket program Fly a Rocket!

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***Abstract*— The Fly a Rocket! programme is a hands-on programme which gives students the chance to learn more about space science and technology, and to launch their very own student rocket from the Andøya Space Center in Northern Norway. The programme was initiated as an ESA Academy program in collaboration with the Norwegian Center for Space Related Education (NAROM) and the Norwegian Space Agency (NSA) as a pilot in 2017 [1]. The aim was to give students in the early years of higher education the possibility to work on a real rocket project and learn about space physics and space engineering and thereby to inspire and motivate the students to consider careers and further study in space and space related disciplines. The pilot cycle was a huge success hence a second cycle was initiated in the fall of 2018, and the rocket launch campaign was in the spring of 2019. This paper will present the ESA and NAROM student rocket program Fly a Rocket! and its objectives together with the experiences and lessons learned from the two cycles of program.**

Keywords*— *Student rocket, launch campaign, space physics, education, hands-on, fly-a-rocket

I. Introduction

The ESA Education Office has a long experience inspiring young people with their portfolio of activities, both for Primary and Secondary school level and for University students. Maybe the two best known are the REXUS/BEXUS programme for university students and the CanSat competition for high school students. Previously there had been a limited offer for students that had just started their university studies, however, with the Fly a Rocket! student rocket program it is possible to fill this gap. NAROM has since 2000 had a student rocket program that fits this gap very well to give students that have recently started on their university studies an introduction to a "real" rocket project.

The program is a collaboration between ESA, NAROM and the NSA, and all the three parties provided funding for the pilot and subsequent cycle.

The Fly a Rocket! Programme [2] offers a unique opportunity aimed at bachelor's level students early in their studies and will give them an introduction into space science and technology. While an understanding of some higher-level mathematics is required, candidates need not necessarily be from an aerospace background, however they should show, and demonstrate a strong interest in the space industry, space science or technology.

The programme is divided into three parts, in addition to the application process, which are described further in the next section. Students take part in an online pre-course, learning about rocket engines and dynamics, satellite orbits and details about NAROM's student rocket remotely. After the pre-course students are invited to participate in their own launch campaign at Andøya Space Center (ASC) in Northern Norway, where they will, as part of a team, build, verify and launch their own student rocket! After the launch at Andøya, participants will work together to analyse the results of the flight and to produce a final report to deliver to ESA.

II. The Programme

Through the student's participation in the programme the students go through exactly the same procedures as in a professional scientific sounding rocket campaign at ASC, but on a more condensed time scale. The students gain experience on how to work as a team with other students from several different countries on a real rocket project and build experiments using different kinds of digital and analogue sensors. The students do all the work, including manning all stations during the countdown before launch, with supervision from NAROM and ASC professionals.

During the student rocket campaign, the students' practical work is mixed with lectures from experts. The lectures cover topics such as rocket physics, space physics, satellite engineering, and telecommunication. Following campaign the students will be able to set up a model in rocket simulation software, describe the principle of the sensors on-board the rocket and analyse and interpret the data from the sensors. In addition, during the course, the students will make, and release two stratospheric weather balloons used for monitoring the state of the atmosphere prior to launching their rocket.

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A. Programme objectives

A very important part of the Fly a Rocket! programme is a practical approach. From experience, we find that mixing some lectures/theory in the classroom with practical work works great and is very encouraging for the students involved. This is also important for showing the students how an actual scientific project is, and at least the campaign period is very similar to an actual, "real" rocket campaign in every aspect, only condensed.

Students who take part in the student rocket programme will 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.
- Build experiments using different kind of digital and analogue sensors, and to learn how these works
- Be a part of a student rocket operation at Andøya Space Center
- Analyse scientific and technical data and compare this with models
- Set up a model in a rocket simulation software and perform several simulations and analysis

In addition, students will also learn about:

- How a rocket engine works using solid, liquid or hybrid propulsion technology.
- Basic rocket theory
- 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 – A/D conversion, Encoder/Decoder, Telemetry, radio communication
- Describe the principle of the sensors on-board the rocket and weather balloon and be able to analyse and interpret the data from the sensors.
- Basic understanding of orbital mechanics and the principle and use of satellite navigation

International cooperation across different languages and cultures is also an important part of the learning outcome of the program. In addition, the student rocket programme is perfect for getting experience and learning abilities such as working in groups, communication, interdisciplinary communication, presentations and reports.

B. Application and selection process

Over 200 applicants applied for the total of 24 places for the 2018/2019 cycle. The selected students represented 14 ESA member states and Canada. The application from the students consisted of a single document where the student would describe his/her motivation for joining the programme, what outreach would be done if accepted, a tie-breaker with a suggestion of the name of the rocket, and a technical task were the student had to suggest an additional payload on the rocket. The selection process was done by ESA.

Figure 1 The Fly-a-Rocket! Students 2018/19

C. Online pre-course

For the programme, students from all fields are invited to apply. Since the students are not necessarily from a closely related subject, an online pre-course was developed for the pilot cycle of the programme and further developed for the second cycle of the programme. The pre-course was made to bring all participating students to a given academic level to make it easier for everyone at the campaign period to start with the same background information. For some students already at a high academic level in the related subjects the online pre-course was expected to be quite easy and for others it would probably be more difficult and demand more work/time to complete. The pre-course consisted of two parts: an online portal openly available for the public [3], and two exercises based on the content of the online portal that the students needed to write a report of and hand in to NAROM. Answers to both exercises needed to be delivered to NAROM to be invited to the rocket campaign at Andøya. All students got individual feedback on both their reports.

The subjects for the second cycle pre-course was:

- Rocket Engines
    - The rocket principle
    - The rocket equation
    - Total impulse
    - Nozzle

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    - Rocket Motor Efficiency
    - The Engine types: solid, liquid and hybrid, ion
- Rocket Dynamics
    - Aerodynamics and forces acting on the rocket
    - Simulating a rocket launch
- Satellite orbits
    - Kepler's laws
    - Introduction to the six basic parameters
    - Orbit Equations in a plane
    - Examples of Orbits
- NAROM Student Rocket
    - Encoder, transmitter and the sensors
    - Encoder Frame
    - Mongoose 98 student rocket

D. Rocket campaign

The most important part of the project is the student rocket launch campaign at Andøya Space Center. The students arrive on day 0, and over the next five days the students will have introductory lectures for the week and group work to prepare for the rocket launch. The NAROM student rocket is a 2.7 meter long Mongoose 98 sounding rocket with a carbon fiber body with an apogee of approx. 8.5 km altitude and a flight time of 90 seconds. The rocket is spin stabilized and is not despun during flight. The impact area is at sea, and there is no recovery attempted.

The students are divided in to four teams which have specific responsibilities for preparations prior to the rocket launch as explained below:

1. Payload team: make sensor cards, make custom cables in the rocket, install all sensors in the rocket. Prepare the rocket itself before launch and test it in collaboration with the telemetry group
2. Telemetry team: Setting up all the telemetry equipment and decoders and test this prior to launch receiving signal from the rocket in collaboration with the payload group. Do the first pre-analysis of the flight data and present this at the post-flight meeting
3. Sensor Experiment team: make several different sensor boards and discuss with the payload group where to place the specific sensor boards in the rocket. Develop sensor digital-to-analogue conversion equations and hand them over to the telemetry group for use in the decoder setup. The sensor experiment group also build two PTU sensor packages and release these under two weather balloons prior to the rocket launch, analyse and present the weather balloon data.
4. GPS team: Make, configure and test GPS sensor card including data cabling made in collaboration with the sensor experiment section and perform macro scale rocket simulations (position (trajectory), velocity, acceleration and other derived parameters during flight)

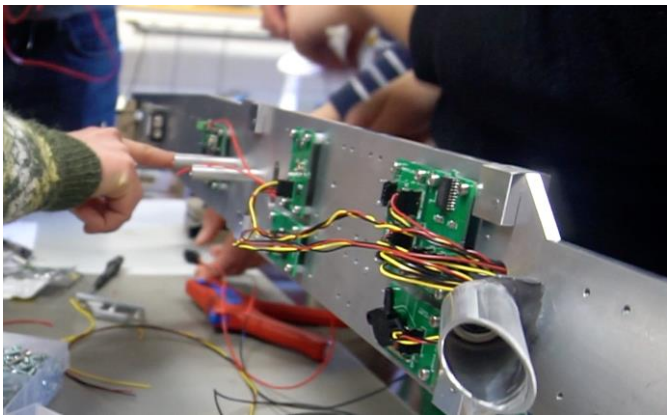

Figure 2 Sensors in the rocket

Together, these team go through all the preparations the same as before a large scale rocket campaign, but again on a more condensed scale. It was emphasized to the students that all the students in the teams were part of one large group and thus were encouraged to collaborate to finish the rocket in time prior to the launch window. The students do all the work of the campaign but are assisted by professionals from NAROM and ASC.

During the nominally 60 minutes long countdown the students take an active part, including filling the positions as Head of Operation, Payload Manager, Pad Supervisor, Principal Investigator and all other positions, but again with the assistance/help from NAROM and ASC.

After launch, the students are again divided into groups as for the pre-launch work and analyze the rocket data. On the last day of the campaign, the day after launch, the students have presentations for each other and NAROM/ASC to present the data analysis they have completed the day before.

E. Student pilot cycle end report

After the launch campaign, the students start work on a single, large project report which they all have to contribute on with one student taking the lead on the work.

F. Improvements from the pilot cycle

Though the pilot cycle student feedback and evaluation from ESA and NAROM were very positive, it showed some parts that could need improvements, which is discussed in more detailed in this section.

The first assignment during the online pre-course phase, which focused mostly on rocket physics, was a success and all students performed well. However, the second assignment, which focused mostly on orbital mechanics, was a bit harder by design, and many of the students performed below par on their assignments. The assignment has a subject which most students do not know very well, and they were meant to collaborate with each other on a social media group to solve this assignment. The

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students did not use this opportunity, and hence it quickly got difficult to answer all the questions on the assignment since they did not help each other. For the 2018/2019 cycle, NAROM were not a part of the social media group to help to try to make a "friendlier" environment. This and a mix of students that worked well together helped very much and the second assignment on this cycle was a huge success, with all students performing very well. Working together on the social media group also help to create a group feeling even before they met each other physically for the first time at Andøya during the launch campaign.

During the group work at the launch campaign during the pilot cycle, the students were divided into five distinct group that collaborated little with each other. During the 2018/2019 the students were part of one large group with many areas of responsibility. The students were expected to help out wherever help was needed. To make it easier for the students to get an overview of where their assistance or help was needed during the rocket launch preparations in order to meet the campaign deadline, a check-list of tasks was printed and hung on a central wall in the laboratory where the students worked on the rocket and sensors. Each student marked a task as "started" when starting a task and as "finished" when completed the task. In that way it was easy for everybody to follow the progress. The workload was also bigger with more sensors flown, so it was essential that all students helped each other to complete all the tasks before the deadline. This means that all students took an active role with working with the preparations for the launch, which really helped with their understanding on a detailed level and on a system level.

Another initiative that helped to give the students a feeling that they were part of a real rocket or space mission campaign is the introduction of a verification document that should be filled for every sensor going to be launched in the rocket. The verification document stated the type of sensor, test method and -results and the wanted spot to be placed in the rocket together with signatures of both the student that build and tested the sensor board and of a representative from the payload team stating approval of this specific sensor board.

III. After the campaign

An extensive survey was done by ESA after the end of the pilot cycle, which showed that the students was very satisfied. Some improvements were noted from the survey and by ESA and NAROM throughout the cycle. Some of the results are discussed in [4]. Another survey was done for the 2018/2019 cycle also showing that students was very satisfied. Suggestions for improvement from the survey has been noted and to be taken into account in the case of any future Fly a Rocket! Programme.

Many of the student participants choose to present their participation and flight results at international conferences, and nearly all completed some kind of outreach (as per their application), to promote space, science and STEM in general.

Figure 3 3, 2, 1, 0, ... Lift off

IV. Conclusion

The second cycle of the Fly a Rocket! ESA Academy program in collaboration with the Norwegian Center for Space Related Education (NAROM) and the Norwegian Space Agency (NSA) was initiated in the fall of 2018, and the rocket launch campaign was in the spring of 2019. The Fly a Rocket! programme which is a hands-on programme giving students the chance to learn more about space science and technology, and to launch their very own student rocket from the Andøya Space Center in Northern Norway was a huge success and had some new initiatives compared to the pilot cycle which enhanced the students learning further during the pre-course and their sense of working in a group with other students on a real rocket project. The new initiatives included a more collaborative setup both during the online pre-course and during the rocket launch campaign.

References

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