EDUCATIONAL BENEFITS AND CHALLENGES FOR THE NORWEGIAN STUDENT SATELLITE PROGRAM

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This paper will deal with the educational benefits and challenges for the Norwegian student satellite program, ANSAT. The program has been running since 2007 and will end in 2014. The paper will present the main goal and organization of the ANSAT management, the three satellite teams, and the actual program. The three satellites how the different institutions deal with their local project, student organization, staff and resources are presented. The paper also present the status of the three satellites, how they cooperate with each other and with the industry. The lessons learned since the program started in 2007 are presented, especially the challenge of continuity associated with student projects running over long periods.

I. INTRODUCTION

The Norwegian student satellite program, called ANSAT started as a successor to the finished NCUBE student satellite project. The goal of the NCUBE project was to build a student satellite from scratch, and send it into orbit if a launch opportunity came up. This is an important difference from the ANSAT program, were the satellites has a guaranteed launch when the selected university signs the agreement of building it. This will let the students focus more on the satellite, and not worrying about the launch. About 100 students from four universities participated at different levels in the NCUBE project during the five years that it lasted.

II. THE ANSAT PROGRAM

In 2006, The Norwegian Centre for Space-related Education (NAROM), Andøya Rocket Range (ARR) and the Norwegian Space Centre (NSC) decided to initiate a Norwegian student satellite program (ANSAT) as a subsequent program to the NCUBE projects running from 2007 - 2014. This includes the development and launch of three satellites within the CubeSat standard. The main funding comes from the Norwegian Space Centre but also from NAROM, Andøya Rocket Range, the participating institutions and several companies are supporting the program or the individual satellite projects. The organization of the Norwegian student satellite program described in [Antonsen, 2009] presents the organization chart shown in Fig. 1.

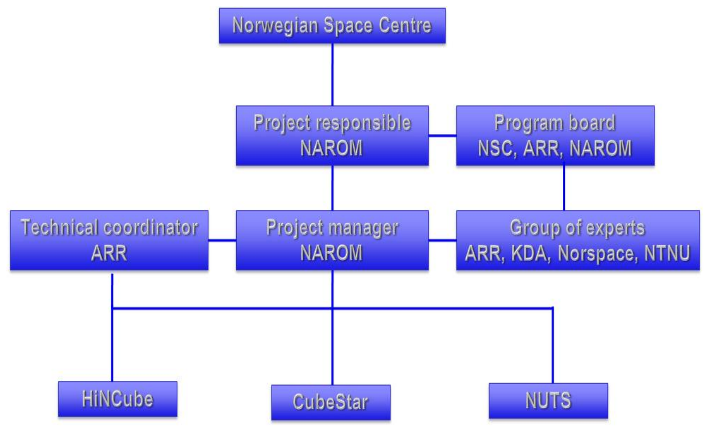

Fig. 1: Organization of the Norwegian student satellite program, ANSAT.

NAROM and Andøya Rocket range has the overall administrative project management in terms of a project manager and a technical coordinator.

III. THE SATELLITES

The Norwegian student satellite program has three participating universities, Narvik University College, University of Oslo and the Norwegian University of Science and Technology (NTNU). Fig. 2 shows illustrations of the three satellites in the program.

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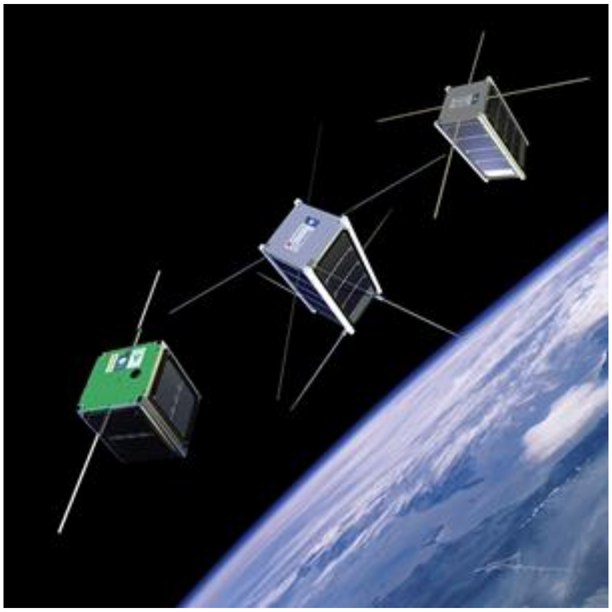

Fig. 2: Illustration of the three cubesats in the program.

The student satellite program has the intention to stimulate cooperation between educational institutions in Norway and with industry, and to give the students experience in teamwork and hands-on training. The program also aims to increase the interest for science and technology in lower educational levels to secure future recruitment to higher education.

III.I **HiNCube**

The first student satellite in the program called HiNCube is a one unit CubeSat initiated in 2006, partially as a successor of the NCUBE project [Riise, 2003] where Narvik University College (NUC) also participated. The original idea behind the HiNCube project was to transfer the acquired experience and lessons learned among both students and staff to future engineering students. Thus, the main project goal is to increase the learning outcome for students at NUC, give them interesting but challenging tasks along with their theoretical studies with a secondary spin-off effect of making the graduated students more desirable to future employers.

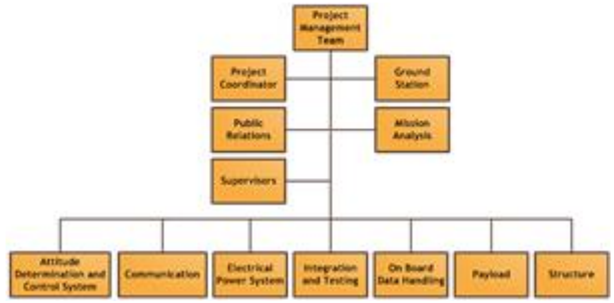

Fig. 3: HiNCube organization chart

The HiNCube team has been working as an all student driven project, with the professor stepping in and guiding. The students worked in different group responsible for the different kinds of subsystems. The students them self also formed a management team to keep control of the other teams, making sure that every team is working with their assign task. The organization chart of the HiNCube project is shown in Fig. 3.

As the HiNCube project has an educational focus, a simple payload consisting of an imaging camera and several thermal sensors were chosen. As the project developed, it was decided that a nonlinear PD+ controller, so-called output feedback controller (without rate measurements) adapted for magnetorquers and single satellites [Kristiansen, 2009], was to be implemented as redundancy for the on-board gyros. The plan is to test this more advanced controller, compared to typically utilized PD/LQ-controllers, providing important experimental results.

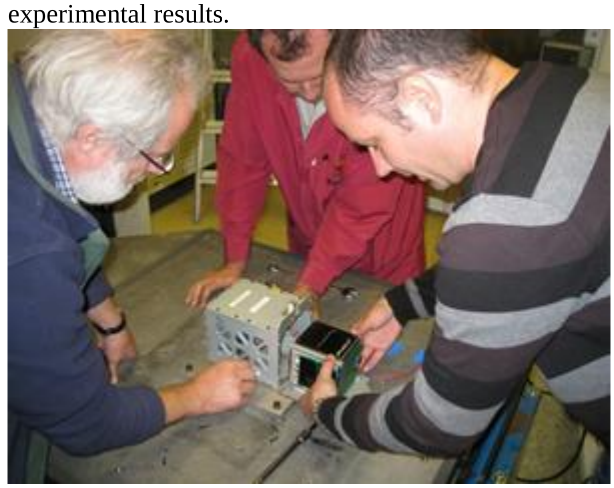

Fig. 4: Inserting HiNCube engineering model in the test pod for the vibration test.

A picture from the vibration test of the engineering model is shown in Fig. 4. The HiNCube flight model was fully integrated and tested by August 2012 and transported to the launch provider Innovative Solutions In Space (ISIS) in the Netherlands waiting for the final integration in the ISISPOD. The launch of HiNCube has been delayed for some time but is currently expected to be launched with Dnepr launcher by the end of 2013 from Yasny, Russia.

So far, 67 students have participated in the HiNCube project. As evidence of the project importance for NUC, the lessons learned have been incorporated into various topics taught to master students at the satellite-engineering group and is the foundation of a new topic on spacecraft systems engineering. The HiNCube flight model inside a thermal vacuum chamber is shown in Fig. 5. Read more about the HiNCube project at http://hincube.cubesat.no.

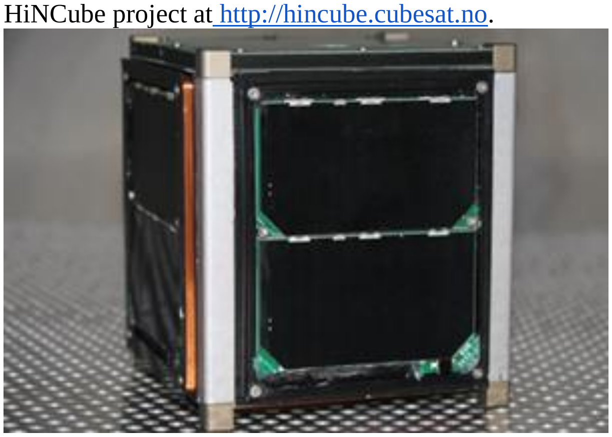

Fig. 5: The HiNCube satellite.

III.II **CUBESTAR**

The University of Oslo (UiO) is building this two unit CubeSat called CUBESTAR. They have finalised all subsystems and are currently integrating the engineering model by the end of 2013. The satellite is to be ready for acceptance testing by June 2014 and expected to be launched by the end of 2014 or beginning of 2015.

Fig. 6: Testing of the CUBESTAR payload in a plasma chamber at ESTEC.

During solar storms, turbulent electron clouds are formed in the ionosphere, causing distortion in satellite signals. The phenomenon of electron clouds is far from fully understood. Research in this area can give knowledge that later can be used to notify space weather, and to improve equipment such as GPS receivers. The CUBESTAR mission at the University of Oslo is to try to measure the structures in the electron clouds and improve the resolution 2000-fold, from today's seven kilometres down to the meter level. The payload, Langmuir probes, has been tested at the plasma chamber at ESTEC as shown in Fig. 6.

CUBESTAR entered the ANSAT program in December 2008 and is organized differently than HiNCube with employees as a project manager, technical manager and a scientific manager. In addition, UiO has several employees supporting the CUBESTAR project. The professors and staff at UiO try to stay ahead of the students and give them support in the design process of the satellite. The students have been divided into different groups where each group is responsible for one or more subsystems. An organization chart for CUBESTAR is shown in Fig. 7.

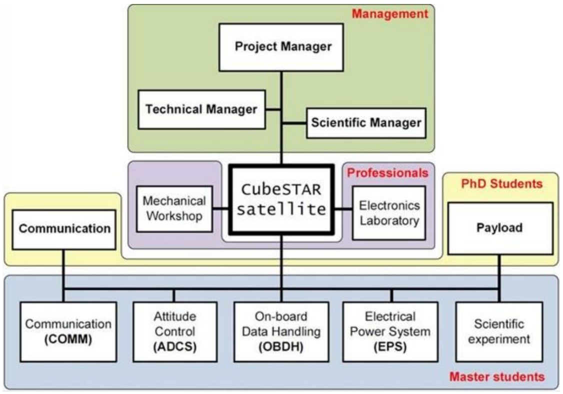

Fig. 7: CUBESTAR organisation chart

The main scientific payload has been successfully tested and flown on several sounding rockets like the IC-2 that was launch from Svalbard, Norway December 2008. It has also been flown on several other rockets, e.g. the ECOMA campaign from ARR 2010, ICI-3 from Svalbard December 2011.

An illustration of CUBESTAR is shown in Fig. 8. A total of 18 students from the University of Oslo has participated in the program. Read more about the CUBESTAR project at http://cubestar.cubesat.no

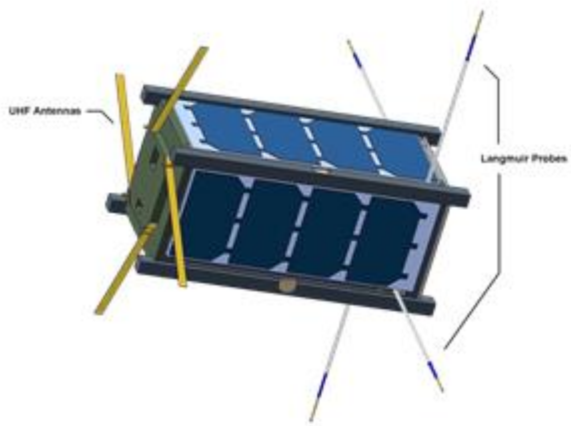

Fig. 8: Illustration of CUBESTAR

III.III NUTS

The NTNU Test Satellite (NUTS) project is a student satellite project at the Norwegian University of Science and Technology (NTNU). The NUTS project aims to design, develop, test, launch and operate a double CubeSat by 2014. Students from different study programs will do the main part of the work, supported by project management and technical staff. The work will be performed as part of the students' project- and master thesis. The design has been chosen to be generic and modular, so the satellite-bus can support different payloads. As a payload for this satellite, an IR-camera will be implemented. Recruitment and education of skilful students constitute a main part of the project's goals. Through hands-on experience, the students will be able to master different skills needed in their jobs after graduation. NTNU offers a wide range of technological studies. Accordingly, a strategy to develop all subsystems "in-house" has been chosen. This means that if problems and delays in the project were experienced, this could not be "repaired" by buying missing sub-systems. The internal layout of the satellite electronics is different from most CubeSat projects. A backplane layout where cards for other systems can be slotted in, will be implemented. The main structure will be made of composite material instead of using aluminium, and to our knowledge, be unique to NUTS [Birkeland 2013-2]. An early version of the Carbon Fibre frame is shown in Fig 9.

Currently, the NUTS project is starting construction of an engineering model of the satellite to start functional testing and qualification testing. To better secure the final construction and testing stages of the project, we have strengthened our team with one hardware engineer and one apprentice from August 2013. This will enable us to better support the master students in the project, and relieve much of the hardware construction from the students. One PhD-student will also work in association with the project.

A new production method for the carbon fibre frame has been developed [Nomme 2013] and a new model is made. NUTS will use aluminium corners to avoid introducing an unknown interface between the rails in the launch pod and the satellite. Further investigation on how to use a reinforced plastic also for the corners will be needed. This will save additional weight. The NUTS team are still in the process of acquiring a suitable camera for the payload. We have identified a few camera alternatives. Unfortunately, the camera type needed has a huge cost compared to the rest of the satellite hardware.

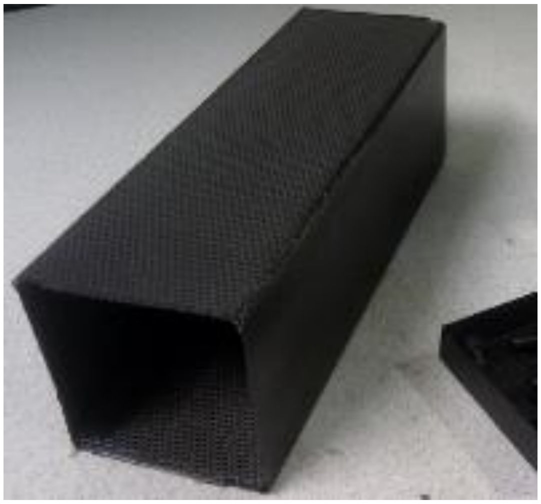

Fig. 9: Carbon Fibre prototype structure

IV. Student conferences and workshops

Some funding in the student satellite program is for an annual ANSAT workshop. A total of seven workshops has been arranged for the participating universities. This is an annual event were the students from the different projects get to meet and discuss their ongoing work and share their experience with other students. Every year industry partners are invited to hold highlight lectures within a specific topic dependent on the focus of the workshop. In addition, guest lectures with long experience within the CubeSat community outside of Norway have participated giving lectures about their lessons learned.

The institutions also get funding for students to have the opportunity to attend CubeSat workshops and conferences to present their work and learn more from other CubeSat communities. Every year since the beginning of the ANSAT program several students have participated at various CubeSat conferences and workshop. Mainly master and PhD students have participated by presenting their ongoing project work or results from their thesis. This is something that have been very popular and motivating for the students. More than 50 students have presented their work at international conferences.

V. Contact with industry

The student satellite program has gotten a lot of support through the group of experts consisting of representatives from Kongsberg Defence & Aerospace, Kongsberg Norspace and NTNU. Everything from support on design reviews and workshops to environmental testing and support has been given to the ANSAT program. The HiNCube engineering model and flight model performed vibration tests at NATECH. The Thermal vacuum tests and out-gassing were done at Kongsberg Defence & Aerospace. The companies are also very positive to also support and testing of the other satellites in the program as well.

During the end of the summer of 2010, the first satellite in the program, HiNCube, went through qualification testing. This testing was performed in close cooperation with Norwegian space industry. Students did the final assembly of the qualification model at Andøya Rocket Range supported by staff from ARR and NAROM. For the integration of the HiNCube engineering model, two students were hired by Narvik University College to do their summer jobs for the program. Their place of work was at Andøya Rocket Range (ARR), and they got support by staff from ARR during the integration. The summer Students received salary from the NUC and NAROM covered the accommodation of the students at the hotel at the ARR.

Several other companies has supported some of the satellite projects directly in terms on guest lectures, hardware samples and even funding for hardware and travel support.

The ANSAT program has not only gotten support from industry but also given something back to the industry in terms of well-trained students. Several students who have participated in the ANSAT program has gotten their first job in one space related companies such as Kongsberg Defence & Aerospace, Kongsberg Norspace, Kongsberg Satellite Service, Radionor, Andøya Rocket Range, NAROM, Kongsberg Seatex, European Space Agency, Atmel, EIDEL and more . This is also one of the goals for the program as well.

VI. Ground stations

The student satellite ground station at Andøya was built in August 2008. The technical coordinator for ANSAT, as well as six students from the University of Oslo, built the station during a one-week workshop. A picture of the students is shown in Fig. 10. The station is a typical ground station, utilizing amateur radio frequencies in UHF and VHF for communication with student and amateur satellites.

For future use, the station is aiming to be GENSO compatible. The station is located at 69° 18′ 55″N, 16° 7′ 50″E, and is able to track 12 (download data from 10) of 14 daily passes of a polar orbiting satellite at 900km altitude [Mathisen, 2012]. This station is available for NAROM activities, as well as support for satellites in the ANSAT program and possibly other satellite projects as well.

Fig. 10: Students who participated in setting up the ground station at Andøya.

In addition to the ground station at Andøya, all of the institutions have built their own ground station located in Narvik, Trondheim and Oslo. This gives a unique opportunity for tracking and downloading data from the Satellites since the program has four ground stations from 60 - 69 degrees north.

VII. Educational benefits and challenges

The individual projects started up at different times where the goal was that some of the lessons learned from the first satellites could be an advantage for the coming satellites. This has to some extend been the case, however since each of the three satellite project are run differently at each participating university it has also been a challenge.

The former NCUBE project involved a lot of work done by the student on the side of their studies. Very few got any credits for their work. For the ANSAT program the institutions were encouraged to find ways to provide credits for the work done by students. The institutions have looked into possible ways of doing this. Everything from setting up a new course for CubeSat project work, master and PhD thesis and even a master program. A total of 4540 ECTS credits related to ANSAT have or are currently being produced by a total of 227 students. A total of 106 of these students have participated in the annual ANSAT workshop. Over 50 students have had the chance to attend international conferences and present their work.

VII.I HiNCube

So far, 67 students have participated in the HiNCube project. Now, the current members are preparing the ground station for the launch event and in-orbit operation of the HiNCube. Some of the students have contributed to the work as a part of their studies; either as a part of some project work or their bachelor or master thesis, producing 325 ECTS credits although, most of the work has been performed on the students' spare time in parallel with their studies. As evidence of the project importance for NUC, the lessons learned have been incorporated into various topics taught to master students at the satellite-engineering group and is the foundation of a new topic on spacecraft systems engineering.

VII.II CUBESTAR

The University of Oslo have been a long time user of scientific sounding rocket from Andøya Rocket Range. A few years back they took the challenge of recruiting new students to their main research field serious by choosing a bottom up approach. Through the collaboration program between Norway and Canada called CaNoRock, the University of Oslo are sending students in the beginning of their studies to attend a one-week student rocket course at NAROM. This course is meant as introduction to rocketry and the space industry. The students get to know about some of the opportunities to study space science and be a part of the CUBESTAR project. The best students who are interested then have the opportunity to continue on as a PhD student and to do research by the use of sounding rocket from Andøya Rocket Range and Svalbard.

The ICI series rocket and the upcoming Maxidusty have and will fly and test subsystems intended to later fly on the CUBESTAR satellite. A lot of subsystems and payloads can be tested out with the use of sounding rockets at a lower cost before they are put on a CubeSat.

A total of 18 master and PhD students have participated in the CUBESTAR program producing a total of 2940 ECTS credits in total. The high number of credits is achieved through the ELDAT master study program that has been adapted to the CUBESTAR program. In addition, several PhD students have their main work on related to the CUBESTAR satellite and the ICI sound rocket series. The ANSAT program and CUBESTAR has increased significantly the amount of students to instrumentation/electrical engineering at the physics department at the University of Oslo.

VII.III NUTS

More than 50 students, both final year master students and volunteers from six different departments have participated or are currently involved in the project. 1275 ECTS credits have been produced as project and master theses, including credits through a 4th year project (30 students each year for the last 3 years). In addition to the students, staff at mechanical and electronic workshops support the project.

The biggest challenge the NUTS project has faced is the turnover in the team. A new team must be implemented every autumn, and most students graduate after an involvement period of one year. This leads to very difficult project planning, as the project management never knows in advance what resources the team will have. This situation has led to lack of staff in some disciplines and the consequence is that work is put off for an indefinite amount of time.

The NUTS project has also experienced some challenges while finding a way to define the student projects in a way that both cover the necessary academic level of a master's thesis and covers the need for practical work to be carried out in the project. The solution to this is to involve volunteer students and technical staff. This solution still pose some challenges, technical staff may have limited capacity due to other tasks, and it is hard to predict the involvement of volunteer students. [Birkeland 2013-1]

VIII. Conclusion and future opportunities

The Norwegian student satellite program will continue to offer students the possibilities to attend workshops and conferences, both international and national arranged. I it important for the ANSAT students to come together and discuss their ideas on design and solutions and to exchange valued experience. It is also important continue the cooperation with experts from industry that have years of experience on designing and building spacecraft so that the students can learn from them. The students who participate in the ANSAT program also get to know more about the job opportunities in the space industry were also several of the former students now are working.

The main challenge for all institutions is the turnover in students finishing their studies and new coming in. Another important part is that the projects rely on funding to continue on. If the funding stops, then the project also stops. It has also been shown that to have a completely student driven satellite project has it challenges and needs to have more project management and technical support to function well.

Finding a launch opportunity for Cubesats has the latest years been more and more challenging. Also the cost of launching a CubeSat has increased a lot the latest years. It seems to be growing a significant market for launching Cubesats and small satellites. At the moment most of theses satellites are launched as so called "piggy back" together with several other larger satellites. Nammo and Andøya Rocket Range are working together to develop a new series of scientific rockets within the North Star program. The North Star family will consist of three configurations, North Star 1, North Star 2 and the North Star Launch Vehicle, all using hybrid propulsion technology. Hybrid rocket motors have several advantages compared to solid fuel motors. A hybrid motor does not contain explosives, which means it is easier to transport. Hybrids are environmentally friendly and the liquid oxidizer is not toxic. The hybrid motors will initially be used to power the proposed North Star 1 and 2 sounding rockets, both carrying the ARR developed Hotel Payload. After gaining experience with them on the sounding rockets, they will be used on the proposed three stage North Star Launch Vehicle (NSLV). The NSLV will be a fully hybrid powered vehicle for pico-, nano- and small microsatellites up to 20kg, launched into Polar VLEO and Polar LEO from Andøya Rocket Range about 2017.

Rather than what is happening to most of the Nano-satellites these days, when they are intermittently piggy-backed into too high orbits, the NSLV is intended to serve a growing market of these small satellites in need for a launch at a specific time, and into a specific orbit and altitude. With its location at Andøya in Northern-Norway we can offer a launch environment that is very flexible due to low air and sea traffic, and short time spans from notification of launch until lunch (approx. 6 weeks).

The NSLV is a green alternative, both in its hybrid rocket configuration, but also when it comes to orbital limitations. Future legislation will put limits on the orbits small scientific payloads can utilize. The NSLV will be the first and only launcher specifically tailored to serve those polar low altitude orbits. The maximum altitude for regular Cubesats is set to 350km, but for special purpose launches higher orbits will be available as well. The favourable latitude of ARR is another factor positively influencing the size of the launcher needed to carry these scientific payloads into their desired orbit. Together, this will be a milestone in the process of limiting the growing amount of space debris caused by satellites launched into too high orbits for both their own needs and their technical capabilities.

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