

Norwegian Student Satellite Program – HiNCube

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ABSTRACT

The HiNCube project is a student satellite project where the students build a picosatellite that shall take pictures of the Earth. In this paper, an overview of the project is given from an organizational perspective with lessons learned from the process of initiating and performing a satellite project. None of the members in this student managed satellite project had any practical experience with satellite building when the project was initiated. This paper shows how the HiNCube project is implemented with lacking experience, but with many passionate students who are working hard to complete the satellite. The HiNCube project became member of the Norwegian Student Satellite Program in 2007 after a call for proposals of Norwegian Student Satellites. Through this program the project has gained valuable knowledge, contacts and assets which have been used to enhance the project.

INTRODUCTION

The HiNCube project was initiated by assistant professor Frank R. Vedal and M.Sc. Jøran Antonsen February 2006 at Narvik University College (NUC). The intention of the HiNCube project is to create a satellite platform for future scientific missions as well as increase the interest for science and space technology in Norway. The HiNCube satellite is a cubesat that shall take pictures of the Earth from a Low Earth Orbit (LEO) and provide the students with experience in managing and working in a big multidisciplinary project. The cubesat standard was proposed by Professor Robert Twiggs at Stanford University and is a cube of 10x10x10cm that weighs 1 kg.

HISTORY OF THE NORWEGIAN STUDENT SATELLITES

Before the HiNCube project, there have been two student picosatellites built in Norway, NCUBE-1 and NCUBE-2. Both of these satellites were built by students from four different universities and university colleges, and supported by the Norwegian Space

Centre. Students from the University of Oslo, Narvik University College, the Norwegian University of Science and Technology and the University of Life Sciences contributed in designing, building, launching and tracking the satellites.

NCUBE-1 and NCUBE-2

NCUBE-1 and NCUBE-2 were the first two satellites built by students in Norway. The scientific payload consisted of an AIS receiver that would aid in tracking ships along the coast of Norway. NCUBE-2 was the first satellite that was launched and was piggybacking on SSETI Express on October 27th 2005 from Plesetsk. After the launch, contact with the satellite was lost, and after thorough analyses it is believed that the cubesat was stuck inside the deployment mechanism.

The NCUBE-1 was launched on July 26th 2006 from Kazakhstan with a DNEPR launch vehicle after several delays. During the launch, the first stage was not able to separate in time, and the launch vehicle had to be destroyed. NCUBE-1 and 13 other cubesats were lost in the launch.

THE NORWEGIAN STUDENT SATELLITE PROGRAM

The Norwegian Student Satellite Program (ANSAT) was initiated in the fall of 2006 and is a program that will last until 2011. The foundation for the program was a decision by the Norwegian Centre for Space Related Education (NAROM), Andøya Rocket Range and the Norwegian Space Centre. The overall goal of the program is to facilitate students to build and launch 3 or 4 student satellites following the cubesat standard.

The student satellite program has the intention of stimulating cooperation between educational institutions in Norway and the industry. It also wishes to offer the students the possibility of obtaining hands-on experience with satellite building.

In general, the program pays for the launch of the satellite, while the teams need to pay for the instruments they develop themselves. The program also limits the number of participating institutions building each satellite, which is done to make it easier to follow up the project and aid the development to finish the project in time.

For considerations of project plans, and as a professional review board during reviews, ANSAT uses representatives from the Norwegian space industry. This is done to enhance the overall feedbacks that the cubesat teams get, and to improve the projects to ensure that the cubesats are of high quality.

The first satellite in the program was a result of a call for proposals in a national competition where the HiNCube satellite from NUC was selected. After this method of selection, the program has changed the selection principle to be a targeted search for contractors and subcontractors to build a spacecraft bus and scientific payloads. The second satellite in the program has been selected to be built by the University of Oslo (UiO), and will start during the fall of 2008.

NARVIK UNIVERSITY COLLEGE

At NUC there are two engineering programs in satellite technology; one in bachelor and one in master as well as PhD studies. Through the technical courses the students obtain experience in rockets, satellite technology and design of electronic instruments for space applications.

In addition there are programs in electronics and power technology, mechanical & manufacturing engineering and computer sciences which all help to cover the multidisciplinary competence that is required to build a satellite.

THE HISTORY OF HINCUBE

After the NCUBE project, employees at NUC initiated the HiNCube project with a desire for the students at NUC to build a picosatellite after seeing the positive effects of the NCUBE project. One of the experiences from the NCUBE project where four universities and university colleges cooperated to build a satellite, was that it required much coordination between the schools. In order to counter this challenge, the HiNCube was initiated to be performed only at NUC. Other requirements of the HiNCube project were that it should be a multidisciplinary project where students from all the programs at NUC could join, it should receive professional and financial support by NUC and it should be student managed.

About 40 students joined the project in February 2006 where anyone could join. None of the members of the project had any practical satellite building experience, and those that had participated in the NCUBE project had only ground station experience.

The project members were divided into groups with different responsibilities, ranging from attitude control and communication to managing the whole project. Weekly meetings were initiated where group leaders and the project management team (PMT) attended, where work was distributed between the groups and the satellite mission was discussed.

May 2007, the HiNCube project was selected to be part of the ANSAT project after a call for proposals of Norwegian student satellites. This contributed to inspire the students and gave financial and technical support to the project. This also inspired the industry to support the HiNCube project through funding.

ORGANIZATION

The HiNCube project members are divided into groups as shown in Figure 1. In Figure 2 a system overview of the hardware solution of the HiNCube satellite is shown.

The Project Management Team (PMT) consists of students who are in charge of the whole project with regards to administration and planning. These students are responsible for contact with the ANSAT program, arranging workshops, system engineering and administrative work.

The Project Coordinator is Assistant Professor Frank Vedal at NUC. He contributes with obtaining funding for the project, aids the project with his knowledge of communication and ground station systems as well as serving as the point of contact for the project.

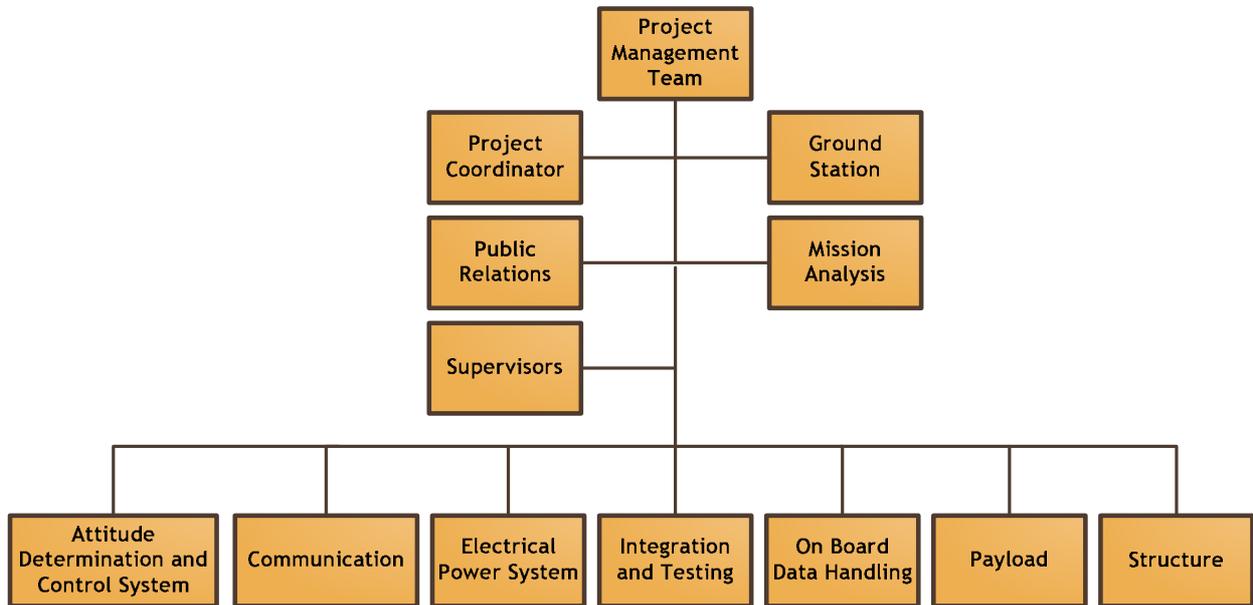


Figure 1: The HiNCube Organization

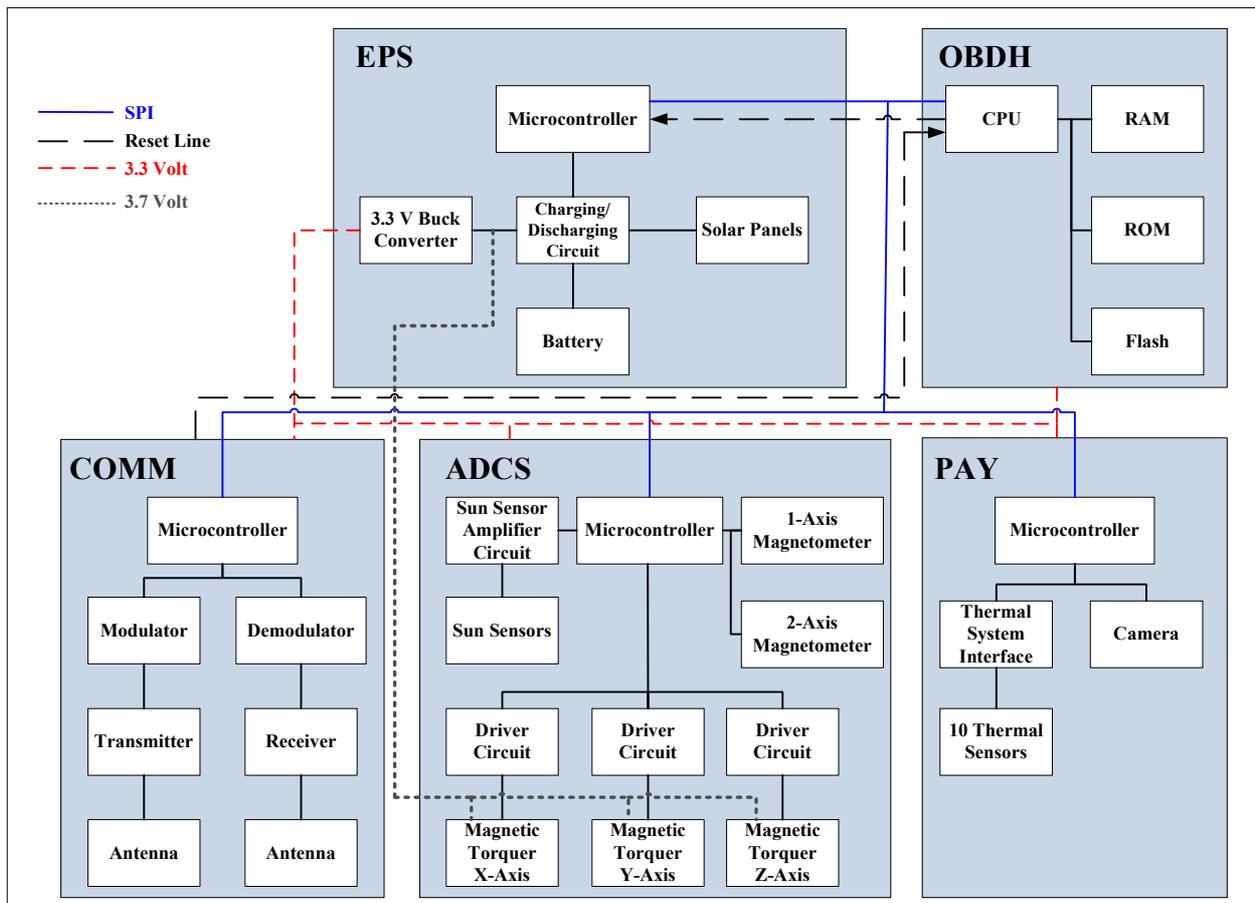


Figure 2: System Overview

The Ground Station team (GROUND) is responsible for maintaining the ground station at NUC in Narvik as well as one that is located at Svalbard. They will be responsible for communication with the HiNCube after launch. Currently NUC possesses two antennas that enable communication with the UHF and VHF frequency bands.

Public Relations (PR) is a group that is responsible for promoting the project and maintaining the web page¹² and the FTP. In addition, this group is responsible for social activities that are used to create cohesion within the HiNCube project.

Supervisors are part of the staff at NUC who contribute by sharing professional knowledge in satellite technology, electronics and communication and guides the students in creating a robust system.

The Mission Analysis (MIAS) group is responsible for analyzing the project and make sure that the requirements that are defined for the satellite are met. They are also responsible dividing the available space between the subsystems and plan the mission in detail.

Attitude Determination and Control System (ADCS) is responsible of determining the attitude and change it according to the mission requirements. The actuation solution that has been selected is to use magnetic torquers³ and use three-axis magnetometer and analogue sun sensors to determine the attitude of the satellite¹.

Communication (COMM) is responsible for creating a transmitter and a receiver that will enable the GROUND to communicate with the satellite after launch. The uplink will work on the VHF band, while the downlink will work on the UHF band.

Electronic Power Supply (EPS) is responsible for delivering power to the subsystems in the satellite, and charge the batteries by using solar panels. Each of the subsystems will receive 3.3 V for their circuits, while the magnetic torquers will receive 3.7 V. Much of this design is based upon the work by Cederblad et al.⁴.

Integration and Testing (INT&TEST) is responsible for putting the satellite together and make sure that all the interfaces are intact. They are also responsible for testing the satellite, both for specific subsystems as well as the whole satellite. One of the members became the leader of this group that consist of one member from each of the subsystem groups, and is one of the most important positions in the HiNCube project.

On-Board Data Handling (OBDH) is responsible for the dataflow inside the satellite. Depending on the

mission mode, and commands from the GROUND, it will command the subsystem to perform required tasks. The subsystem is using the motherboard from Pumpkin, which enables this group to focus on the software. As the overall bus system, Serial Peripheral Interface (SPI) has been chosen.

Payload (PAY) is responsible for creating a camera that will take pictures of the Earth, as well as thermal sensors that will be used to perform measurements to study the propagation of temperature inside the satellite.

Structure (STRUCT) is responsible for the mechanical structure of the satellite. This group works with the mounting mechanisms, thermal isolation and the antenna deployment method and is using the structural model from Pumpkin.

LESSONS LEARNED

Student Managed Project

In the HiNCube project, students were in charge of the project from the beginning. They lead the project, plan the project, design the satellite, build the satellite, test the satellite and will track the satellite during its flight. The project coordinator contributes in support and serves as the point of contact for external parties.

At the beginning of the project, none of the members possessed basic space management or system engineering skills. These are skills that the members have obtained through the project, and the students are now working to incorporate these areas into the satellite technology bachelor or master programs.

Since the HiNCube project is a voluntary project, it has not been easy to get all the members to contribute. From the beginning of the project, several methods have been employed in order to increase the productivity of each member, some with more success than others. As the project was initiated, the team leaders of each group were responsible for the work that had to be done until the next leader meeting. This worked with some success, but led to some groups contributing while others did not. The main reason for this was that the members did not feel obliged to contribute since this is a voluntary project.

During the autumn 2006 in phase A, workshops were initiated as a means of performing a lot of work in a short time. After much trial and error, the best workshop times have been shown to be on Friday evenings, and on Saturdays as a two day workshop. This leaves time free for the members on Sundays, and leaves them revitalized for continuing working with their studies the following week.

Arranging workshops has worked very well, and has been one of the main methods that make the project progress. During the autumn 2006 only two workshops were held, something that led to a discontinuity between the workshops. This was due to the fact that some members did not do anything related to the project between the workshops, something that resulted in a loss in potential contribution.

During the Phase C of the project from October 2007, the time to a ready flight model was near. Initially, the plan was to have a ready flight model by April 2008, which led to an increase in the frequency of workshops. This led to a workshop being arranged every other weekend. The quantity of work became taxing on the members, and resulted in loss of some members, but most members stayed with the project. At the end of the semester, many members were tired of the work, which resulted in low productivity. The deadline of April 2008 has been postponed until the 1st of October 2008.

With these experiences in project management, it was decided to combine the workshops with an evening every week where the members could work. Every Wednesday evening the members have the option of working at NUC with the project, and in addition one workshop is held every month. As have been seen during the spring of 2008 the productivity has been good and the project obtains a good continuity between workshops.

Project Schedule

During Phase 0 when the mission and the HiNCube project were defined, the project was estimated to be finished by April 2008. Initially this seemed like a reasonable time requirement for the project, but has turned out to be difficult to meet. An overview of the

actual timeline of the HiNCube project is shown in Figure 3.

The project has been divided into phases as according to the ECSS documentation⁵. During the first half of 2006, the mission of the HiNCube satellite was defined and the project members got an introduction on how space projects were performed. The last half of 2006 the project advanced into phase A, where a feasibility study was performed on the satellite as well as defining the requirements for the satellite. Phase B was initiated in January 2007 where a preliminary design was created. The limited space of a cubesat was divided between the subsystems and solutions to the requirements from phase A was planned. After a Preliminary Design Review was held in September 2007, the project advanced to Phase C where a detailed design is being performed. In this phase the end product will be an engineering model with all the prototypes for the different subsystems connected together representing a working satellite.

In phase D, the circuits will be manufactured professionally and a test model and a flight model of the satellite will be built. Both models will be thoroughly tested before one is selected for flight. Finally, the flight model will be launched in phase E and the satellite will be utilized and the scientific mission will be performed. After its lifetime in space, it will enter a phase F, which means that it will be disposed. Since there are no thrusters onboard, the satellite will not be able to enter a parking orbit. This will lead to an orbit that will deteriorate, and the satellite will eventually burn up in the atmosphere.

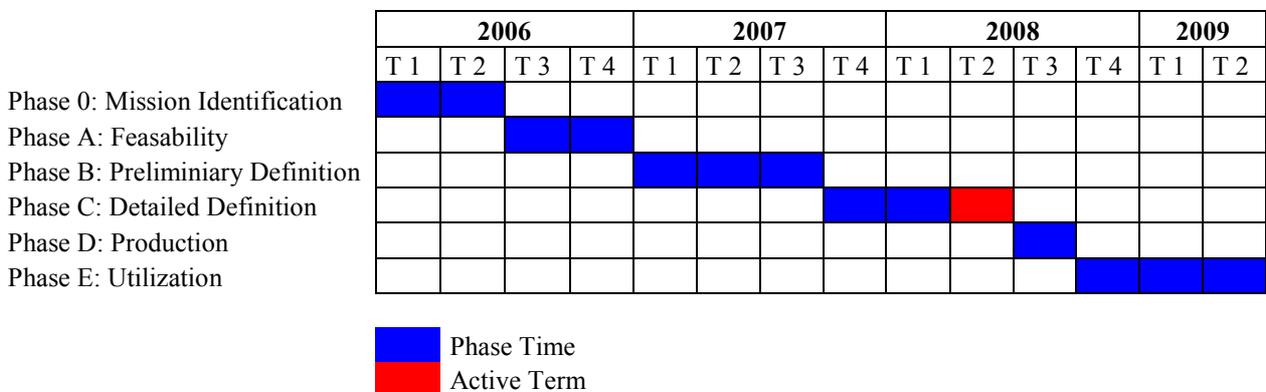


Figure 3: HiNCube Schedule

Human Resources

As the project was initiated, the 40 members were divided into different groups that work in parallel to develop the satellite. During the initial period of the project, much of the work that had to be done by the PMT was to administrate the human resources and make sure that everyone contributed. With an open invitation for everyone to join, it led to many free riders that had to be booted to ease the administration work. In addition to free riders, there were many members that did not like the fact that the HiNCube mission had to be planned through documentation who eventually quit the project.

One of the challenges with human resources is to get new members into the project. Recruitment has been done throughout the project. But as people with expert knowledge in one of the fields with regards to the HiNCube quit due to job or studies elsewhere, they leave a gap which must be filled by other members. One of the methods that have been used to counter this challenge and contain the continuity of the project is through documentation. Another important method is to perform internal training of new members when experienced members are going to leave the project, as well as recruit key personnel into research fellow assistant positions at NUC.

In order to increase the work that is being performed, the members have the option of working with the project as a summer job. This is financed through the HiNCube project and has shown good results, and has played an important factor in meeting the milestones of the project. It has also motivated the students to be able to work with the project at fulltime.

Another motivate power is the possibility for the students to attend conferences to meet other students in the same situation to exchange experiences. These experiences has been gathered through these conferences and brought back to NUC where it is shared with the rest of the project and thus improve the skills of the members with regards to satellite building.

One of the biggest challenges with human resources in a voluntary student project is that it has to compete against the compulsory education which has led to delays in the schedule. This problem has been reduced by introducing an elective subject, as well as to create compulsory subjects related to the HiNCube project. There have also been written several theses related to HiNCube. Among them are a bachelor thesis written on the attitude determination system¹, a master thesis with focus on the mission analysis of HiNCube⁷, a bachelor thesis on the camera subsystem², a master thesis on the magnetic torquers for attitude control³, a bachelor thesis

on the antenna system⁸ and a bachelor thesis on the thermal sensor system⁶.

One of the choices that were made to maximize the contribution from the members was to create a distributed system with regards to microcontrollers as can be seen in Figure 2. Each of the subsystems has their own microcontroller, and receives commands from the OBDH which controls the satellite. This has worked well throughout the project since there is little dependability of others with regards to development of subsystems.

Reviews

December 2006, a phase A review was held where Dr. Jens Dahlgaard Nielsen from the University of Aalborg participated. He shared his experience from the AAU cubesat project⁹ and pointed out weaknesses of the planning and asked questions that pushed the project in the right direction.

During the Preliminary Design Review (PDR) that served as an end of phase B in September 2007, several experts attended. Among them were:

- **Aleksander Marthinussen** the prior project manager of the ANSAT project¹⁰
- **Torbjørn Houge** the technical coordinator of the ANSAT project¹⁰
- **Kjell Paulsen** from Kongsberg Defense and Aerospace
- **Eystein Sæther** the prior leader of the NCUBE project¹³
- **Supervisors** from NUC

In addition, two external experts, Dr. S. Rao from the Indian Space Research Organization (ISRO) and Dr. Z. Sun from the University of Surrey in England performed the review remotely by reviewing the documentation. Both possess much experience from space projects and gave many good advices.

Both reviews contributed greatly to enhance the project with regards to creation of subsystems, documentation, test planning and to point out the weaknesses in the design, which enabled the project to create safeguards to avoid fatal errors. It enabled an arena for discussion, where possible solutions could be discussed with the experts who all gave feedbacks that have shaped the project.

IMPACT ON EDUCATIONAL PROGRAMS

As a result of the HiNCube project, some new subjects have been created at NUC as the practical aspects of the project highlights where more education are needed. One of the elective subjects that have been created as a

direct result of this project is the Technical Project, where students obtain 5 ECTS for participating in a technical project arranged by NUC. In addition, the need for subjects in system engineering and space management has become obvious.

SUPPORT

As a heritage from the NCUBE project, NUC possesses two ground stations that will be used to track and communicate with the HiNCube satellite. One ground station is located at NUC and another is located at Svalbard. As a result of joining the ANSAT program, the HiNCube project will be able to obtain use of another ground station that is being built at Andøya Rocket Range. All these ground stations are part of the Global Educational Network for Satellite Operators (GENSO)¹¹, which means that when the GENSO program is operational these ground stations will be available for other amateur satellites.

Another result of joining the ANSAT project is the network that the project obtains. Through them, the HiNCube project has obtained contacts with the Norwegian space industry which has led to support in reviews and testing of the satellite.

June 2008, the HiNCube project learned that they had been selected as a backup team after a call for proposals for the Vega Launch Vehicle. This means that the HiNCube satellite will get a free launch through the European Space Agency (ESA). If one of the primary teams does not meet the time schedule, the HiNCube may be launched by Vega. If HiNCube on the other hand is not launched by Vega, NUC has been promised that they will obtain a launch at a later date. In addition to a free launch, the HiNCube will receive professional assistance through ESA as well as test pods for the testing phase of the satellite.

FUTURE VISIONS

Satellite Platform

One of the mission objectives of the HiNCube project is to create a satellite platform that can be used for future scientific missions. The NCUBE project contributed greatly through documentation of how to build a satellite, but as first time builders, the HiNCube project sees a need for a satellite platform that can be used by other Norwegian student satellites. This will enable more scientific missions, test new technologies and increase the knowledge of satellite technology as well as an increased scientific output.

Formation Flying

Formation flying is one the major research areas at NUC where multiple satellites can serve as one satellite instead of using one large satellite. Multiple small satellites is cheaper than one large satellite, and enables the possibility of creating 3D models of atmospheric plasma, in-flight maintenance and 3D SAR imaging. With the strong theoretical background that exists at NUC within formation flying, it is desirable to perform practical experiments to test the algorithms and models that have been derived. In order to create a satellite platform that can be used for this goal, the cubesat will be used as a first step to validate the current technology. Then at a later stage, a satellite platform will be created that is large enough to carry thrusters in order to perform translatory motion to be able to perform formation flying missions with reconfiguration possibilities.

CONCLUSION

In this paper, an overview of the organizational aspects of the HiNCube project has been discussed. The HiNCube project is part of the Norwegian Student Satellite Program and is being built at Narvik University College. Many of the challenges of initiating a student satellite project have been highlighted as well as a discussion of the countermeasures to reduce these challenges. The ambition of the project to create a satellite platform to facilitate more research in the area is also mentioned as well as the possibility of creating a platform for formation flying missions.

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