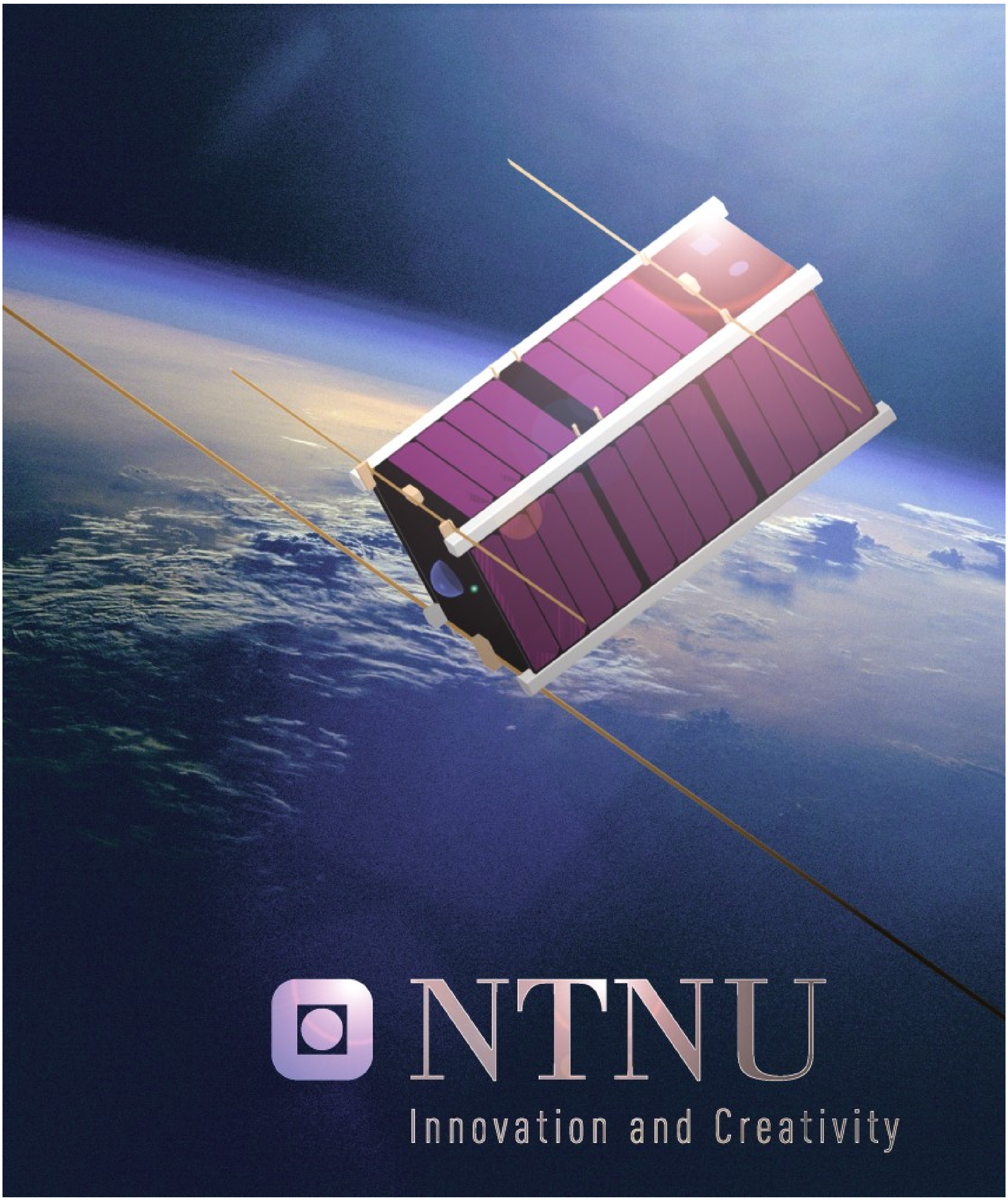
STUDENT SATELLITE PROPOSAL



Elisabeth Karin Blom
Roger Birkeland
Erik Narverud

30. November 2006

NORWEGIAN STUDENT SATELLITE PROGRAM

UPDATE FORM (TRACK OF REVISIONS)

The Table below should be filled in to track the changes done on your proposal. When updating this document, be sure to fill in the revision date and the index for which version of the document is the latest issue.

Index (*)	Revision date	Chapter number (**)	Short description of modifications

(*): The index indicates the issue number of the proposal form
(**): The number of modified paragraphs should be indicated

Team Number: (will be filled in by NAROM)

INDEX

1 GUIDELINES

The proposal shall be written in English. Additional attachments may be in Norwegian, but preferably in English.

The proposal form should not exceed 20 pages of text, attachments not included.

The proposal shall be divided into three parts:

- *Introduction*
- *Management*
- *Technical*

In each of these parts several issues can be raised and the team should consider these and respond to these issues and answer them in their best ability. These chapters and criteria will be discussed in the expert group and will be considered in the review of the proposals.

2 INTRODUCTION

In this part, the intention of the proposal should be discussed. Also, a short summary of the proposal should be given, including short overall requirements and compliance description.

2.1 Intention

This would describe the idea and plan for what the project would consist of, i.e. scope of work.

The purpose of this project is to design, build, test, launch and operate a student satellite at NTNU. The satellite is intended to be a platform, making it possible to re-use substantial components in future missions, carrying other payloads.

2.2 Proposal Summary

A short summary of the proposal which includes information about all the points described in the management and technical part of the proposal should be described here.

The proposed project aims to develop and build a launch ready satellite within 2 years, and to successfully operate this satellite in space. Project goals include:

- Increase local and national space know-how and expertise
- Develop meaningful and interesting project assignments and master theses for students
- Increase common interest in space technology and exploration.

One project aim is that as much of the development work as possible shall be administered and done by a group at NTNU, consisting of both students and employees from various departments.

This proposal concerns a satellite platform based on the CubeSat standard, in a double configuration. The satellite platform will incorporate two radio transceivers using the 145 MHz and 437 MHz bands, an On Board Data Handling-system (OBDH), an Attitude Determination and Control System (ADCS), a Power Supply and Management System (PSMS), and a colour camera for earth imaging as well as a software-defined radio as initial payloads. There will also be a number of sensors monitoring the on-board environment and satellite status.

As the satellite will be able to support at least 0.5 kg of additional payload, mission goals are preliminary. However, they will include:

- Deliver a satellite ready for launch
- Contact establishment
- Attitude control
- Image caption and transmission

3 MANAGEMENT

In the following chapter the team should think about the organisation of the project, cooperation with other institutions and industry, a budget, a project execution plan, and a documentation plan.

The project will be locally administered by the Radio Group at IET, (Department of Electronics and Telecommunications), NTNU. Local administration and control is important for project success. Decisions will have to be made on a daily basis. However, external coordination with NAROM of verification, test and launch is foreseen.

The Department of Engineering Cybernetics (ITK) and the Department of Computer and Information Science (IDI) have already been engaged in the design process. Other departments will be included for design and implementation as needed. It is also a possibility to cooperate with another university or college on the incorporation of other payloads or mission details. Resources from the industry may also be included if necessary. Such involvements may include companies like Norspace, FFI (Norwegian Defence Research Establishment), SINTEF, Kongsberg Defence & Aerospace, Nordic VLSI, Texas Instruments Norway (formerly Chipcon), Norbit, Atmel Norway, and others.

3.1 Team Structure

In this chapter the team structure and share of workload should be highlighted. It should also consist of how the responsibility is distributed and how industry may be involved.

A doctorate student at IET has been appointed as Project Manager. The role of the project manager is to coordinate the teams and to sustain a continuous dialogue between the departments and development teams.

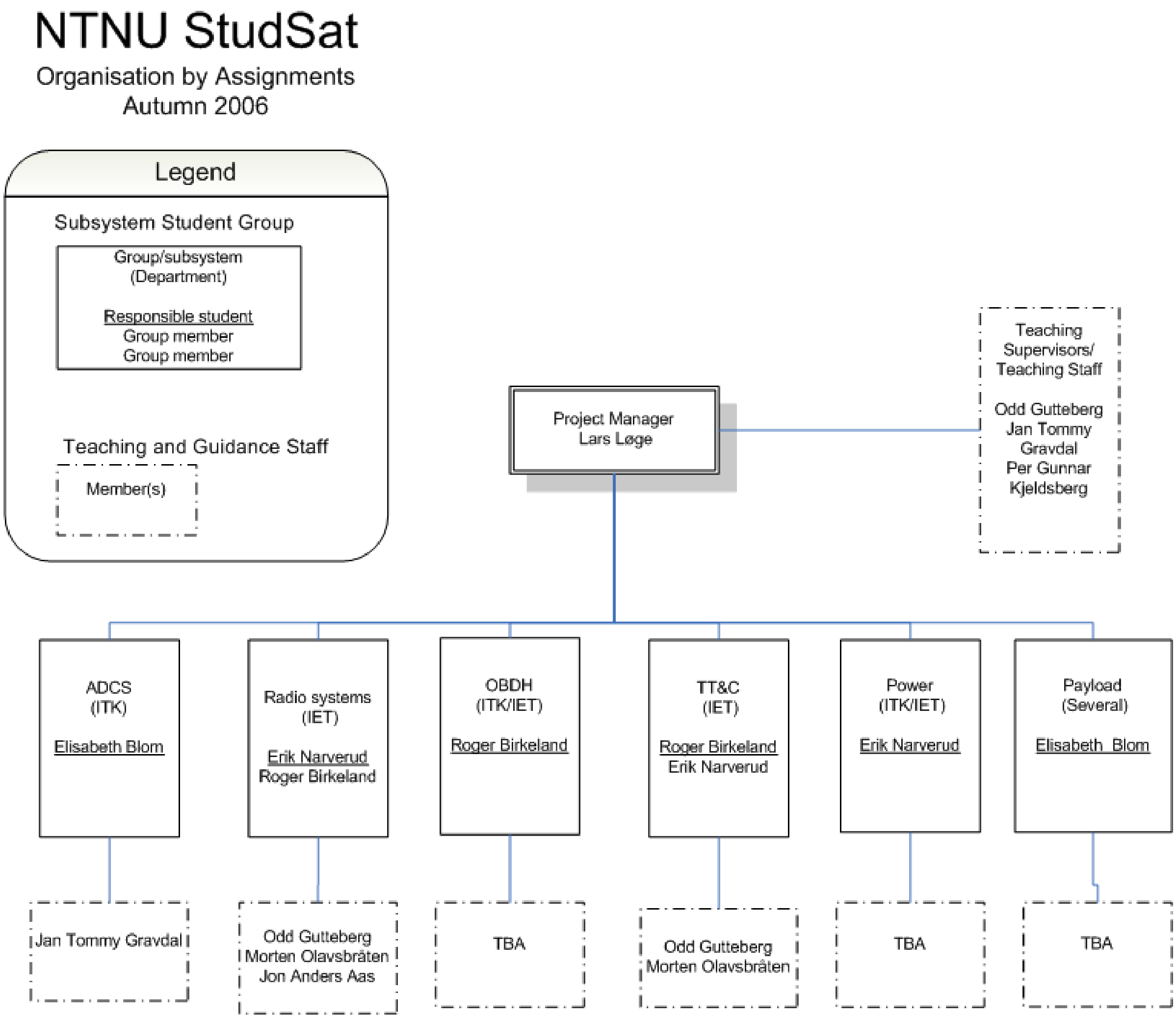
The design teams will mainly consist of 5th year students from various special fields. The workload for each student will be equal to the required workload to complete a 9th semester project and/or a 10th semester master thesis.

Each student, or group of students, is responsible to design and/or develop a specific module. A student from each group will be appointed as group manager, required to meet with the project manager on a regular basis. The industry can be involved in several ways, as suppliers of components such as radio development kit, suppliers of test facilities or guidance. It is desirable to develop most of the hardware at NTNU. However, components like solar cells, batteries and electronics must be delivered by the industry. It can be desirable to produce PCBs at a professional supplier. Circuits can be assembled by FFI or Alphatron, ensuring high quality construction.

3.2 Organisation

An organisation chart should be under this chapter. This chapter should also include a list of participants with contact info. The follow up by the faculty should also be acknowledged under this point. In addition, the future plans for the project should also be discussed, i.e. full life cycle considerations including pre launch follow up in case of launch delays beyond students education periods.

A tentative organisation chart is shown below. Names are included where known, but all names and groups are subject to change. A complete contact list is available in attachment 7.



The Project Manager will be responsible for project coordination at NTNU. The project manager will meet with the group managers every week, and provide continuous follow-up at an administrative level. A group of teaching supervisors, consisting of professors/associate professors from each special field, will follow the project work and meet with the project manager once a month. Each group of students will have one or more supervisors to assist their work. These supervisors might or might not be a part of the teaching supervisors group.

The purpose of the supervisor group is to have a group of professionals following the work on a superior level, not on day-to-day basis. The guidance teacher(s) will be responsible to periodical follow-up the students and their work. Together with the project manager, they will also provide the needed continuity for the project, as no student can be expected to take an active part of the project throughout its entire lifespan. This implies that the project manager and the supervisor group will be responsible for handling post-development issues regarding operational tasks and pre-launch follow-up, possibly by creating suitable student assignments.

3.3 Facilities (lab/construction/test)

In this point the team should mention the availability of facilities offered from the institution, as well as possible needs for external resources from industry. This will include lab facilities during the design, construction and test phases. This will also include a classroom for the project. The final testing of the satellite will be taken care of by the program.

All 5th year students have access to their own study room. Students working together in a group will be located in the same room for easier cooperation.

All the different departments, IET, ITK and IDI, possesses laboratory and workshop facilities available for students. These include computer labs with sufficient software, radio and antenna lab with network analysers and other measuring equipment, and mechanical workshops for structure and details production. There is a workshop run by students at NTNU with equipment for PCB prototype production. Laboratory and workshop equipment for design and construction is considered sufficient for successful development.

Facilities for thermal, vacuum and vibration testing, must be acquired externally.

3.4 Outreach program

In this chapter, a plan for an outreach program should be mentioned. This includes how the project may involve and create spin-offs to other parts of the educational system, i.e. elementary schools, middle schools, high schools, and so on. A media plan should also be mentioned in this point.

There are several possibilities to include other institutions, as well as the general public, in this program. As the satellite will carry a camera, it can be possible to download pictures, as well as housekeeping data, from the satellite via the Internet.

In the early phase, a naming contest can be launched for secondary schools in the Trondheim region. Prototypes accompanied with a presentation, as well as signal or image reception, can be used in the quite substantial PR campaigns already in operation by NTNU. One of these is the “Teknolos” project, where students from NTNU visit high schools all over the country in an effort to make them choose a technical or scientific education.

When a radio and camera prototype is operational, it will be desirable to demonstrate this in TV programs like “Newton” or “Schrödingers Katt”, giving an even further boost to common national interest concerning the project.

As mentioned earlier, this program has already given birth to several tasks involving many different departments on NTNU. Project assignments and master theses may also deal with alternative subsystem solutions, subsystem or mission analysis, or future missions and payload projects, aiming at both technical education and scientific space research. All areas can potentially produce a vast amount of meaningful, inspiring work for pupils, students and scientists, provided that the project manages to produce a certain level of enthusiasm.

3.5 Credits

A plan on how the institution will give the students credit for the work they do in the project should be discussed in this chapter. This may be credits from elective subjects, project subjects or other ways of giving credit.

The student work will, as stated before, be done through 5th year projects. Dependent on the student's involvement, this can yield a total of 45 sp (study points, credits) for a student attending one year. The nominal number of study points for one year is 60 sp.

The reason for involving 5th year students only, is that there is no current possibility for crediting lower class students. Although all students able to produce relevant contributions are welcome to join the project, the concrete workload has been divided as project assignments and/or master theses.

Because of the long lifespan of the project, it may, however, be possible for teachers to give project-related assignments to students engaged in related courses. This is a good opportunity to involve lower-level students which will be followed up. As such student assignments will be part of a course; students will receive credits for their work.

Another problem concerning work crediting is that most courses held at NTNU focus on science or technical development, not manufacturing. Therefore, there is no official way to give a student credit for production related work, unless it is specifically tied to his/her assignment or thesis. E.g. there is no such thing as a "soldering course" held on NTNU. Students involved in the project must therefore be prepared to do some volunteer work regarding assembly.

The work carried out by the current student group of 3 students developing the satellite preliminary specification and this proposal, will be included in their 9th semester project report. This project report, giving each student 15 sp, will mainly consist of this proposal and specification in addition to a closer investigation on radio and antenna systems.

More assignments to be given will be to design, produce, implement and test the ADCS-system, OBDH-system (hardware and software), integrate the chosen TT&C-protocol software and payload systems. In addition, subsystem tests, system integration and system test has to be carried out.

During the 2007 spring semester, assigned tasks for master theses are design of radio hardware, software radio and preliminary design of ADCS and OBDH-systems. The radio assignments will be carried out by students at the radio group, ADCS and OBDH-systems will be solved by ITK-students. IDI has also published master theses, but it is not known at the moment if any students will pick up on this.

3.6 Budget

This chapter will contain the Rough Order of Magnitude (ROM) budget for the project. The budget should contain the costs of the hardware the institutions will develop, and the expected man hours put into the project by the students and the faculty at the institutions.

Development costs will be covered by the institution, as they will be charged as student assignment expenses. It is desired that test and launch costs, travel expenses as well as ground segment operation other than the station located at NTNU, will be covered by NAROM.

Two Rough Order of Magnitude budgets have been worked out, see attachment 5. They are based on current available student assignments within the project as well as coarse estimates of future tasks. The man-hours budget accounts for student man hours to be put in by the 5th year students expected to take part in the project. This is done on the basis of the number of weekly work hours for students in the Master of Science in engineering program as specified by NTNU. The costs budget accounts for estimated expenses related to the completion of the 5th year projects. For faculty members, the man hours covers the project manager's involvement as well as staff providing student guidance.

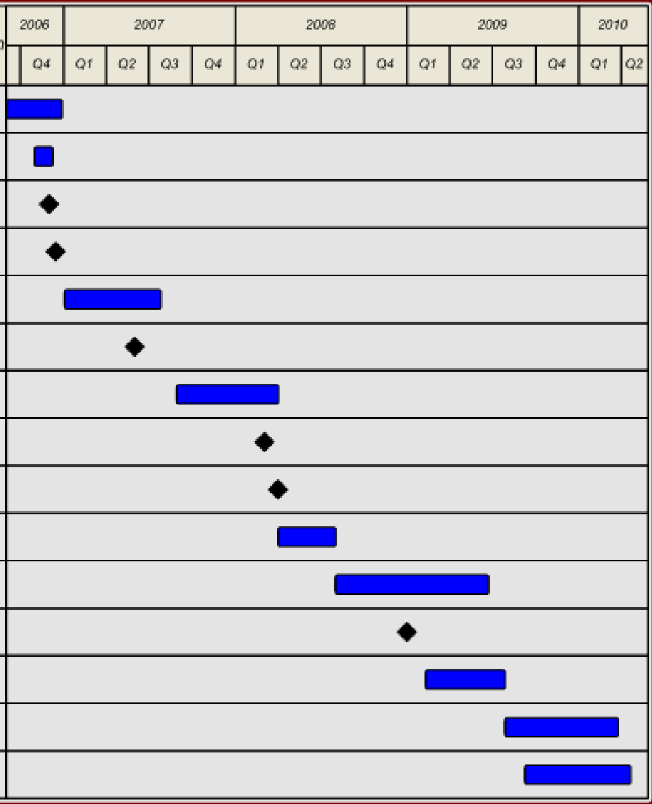
The ROM concerning man hours is valid only if a sufficient number of students chooses assignments in the satellite project. The work outlined cannot be undertaken by a smaller group of students.

3.7 Project execution plan

Activities, milestones, time frame and risk handling should be described here. The activities that make up the project and a time frame for these activities should be shown here, together with a milestone schedule. When it comes to risk handling the team must go through a risk assessment that will guarantee that the satellite will not interfere with other satellites on a shared launch.

The pre-launch phase is predicted to last approximately two years. This time line is considerably longer than the one asked for by NAROM, there are several reasons for this decision. Firstly, to gain a substantial amount of creditable student work related to the project, the departments have to distribute the entire workload as assignment and thesis proposals. Secondly, as no student can be expected to produce more than one assignment/thesis per semester, work had to be distributed over a minimum of two whole years. It is of no interest to assemble a satellite based on already finished work, as the main goal for NTNU is to offer the students attractive engineering assignments.

ID	Task Name	Start	Finish	Duration
1	Preliminary studies and planning.	01.09.2006	28.12.2006	85d
2	Application	31.10.2006	08.12.2006	29d
3	Submit application	01.12.2006	01.12.2006	0d
4	Spesification Review	15.12.2006	15.12.2006	0d
5	Structure and Radio System Construction	03.01.2007	26.07.2007	147d
6	Preliminary Design Review	01.06.2007	01.06.2007	0d
7	Design of Subsystem Engineering Models	30.08.2007	01.04.2008	154d
8	Preliminary System Function Test	03.03.2008	03.03.2008	0d
9	Critical Design Review	01.04.2008	01.04.2008	0d
10	Fligth Model Subsystem Design and Production	01.04.2008	01.08.2008	89d
11	Flight Model Assembly and Testing	01.08.2008	22.06.2009	232d
12	System Function Test	31.12.2008	31.12.2008	0d
13	Launch preperations and launch	09.02.2009	27.07.2009	121d
14	In-Orbit Operations	28.07.2009	24.03.2010	172d
15	Review	08.09.2009	20.04.2010	161d



Furthermore, it is a common and advantageous arrangement that students at NTNU continues their autumn project work in their master thesis, and it is not likely that many will leave their current occupation for a satellite related theses spring 2007. As a result, main design work of many modules are delayed until the autumn of 2007.

As mentioned above, the time line will only be valid if a sufficient number of students are available. The focus in this project must be to complete the mission in orderly conditions not compromising quality of work or exploiting the students hours.

It should also be mentioned, it will of course be possible to build a simpler satellite, for example not much more than a radio, in a shorter amount of time. With future missions and the academic gain in mind, this is considered to be of less benefit both to the students and NTNU.

3.8 Documentation plan

The team should also take into consideration that the work done has to be documented. A plan on how this could be done should be discussed at this point. The documentation should be design and review reports, test reports, and a final report. The team should also document the developed software and hardware, together with a report on lessons learned. The project management of the satellite program are developing routines for documentation and document control together with industry.

A document database and a group file system will be used for document publication and storage. All students involved in the project will have access to a shared file system. All involved project members, students and teachers alike, will have access to published documents through the database. The general public will have access to a web page containing general information about the project.

The database will be divided into logical sections following the hierarchy of the satellite, subsystems, units and components. Documents can be linked to the elements in the hierarchy where they belong. A system for revision control will be included.

A general list of all documents will be included. Project guidelines state that all documents written in relation to the project must be registered in the database as soon as they are finished. It will be a requirement that all pre-study documents, design plans, reviews, drawings, schematic layouts, data sheets and reports are published through the database. This ensures good document supervision.

All 5th year project work are documented and evaluated in a final report. Those taking part in the development process as volunteers are expected to provide good documentation of their work on the same level as students doing credited work. In addition, care must be taken to ensure individual systems are compatible. To enable a smooth system integration process, subsystem designers are required to provide a document specifying their system's interface with other systems.

4 TECHNICAL

Under the technical section of the proposal the team should describe the technical aspect of the project. This will include an overview of the project, a discussion of the ground and space segment, a requirements review and a technical description. A test and verification plan should also be made together with an overview of the deliverable hardware for the project. The team must focus on the technical demonstration on the housekeeping functions of a satellite.

4.1 Scope/mission

In this chapter an overview of the mission, its target and what it will involve should be discussed.

The scope of the project is to design, build, test, launch and operate a small satellite. The work will be done by students at NTNU. The satellite is to be made with platform-design in mind, ensuring a possibility for easy re-configuration and adaptation to subsequent missions carrying other payloads.

4.2 Ground segment

The ground segment of the mission should be taken into consideration in this chapter. This will include telemetry ground stations, pre-launch Electrical and Mechanical Ground Support Equipment (E/MGSE), publication of data and also all the activity on the ground. Currently, Narvik University College (NUC) has a ground station, built for NCUBE, in their possession. A ground station at Svalbard which Kongsberg Satellite Services (K-Sat) owns is also available. Radio Amateur Clubs are also present at the Norwegian University for Science and Technology (NTNU) and at Vestfold University College. European Space Agency (ESA) is trying to develop a global network of student ground stations for educational purposes. However, this project is in its very early stages.

In the early phase after launch, NTNU wishes to use ground stations at Svalbard and Narvik. The station at Svalbard will be able to track more passes than a ground station further south, given a polar orbit. This will be useful when establishing communication.

At NTNU a local ground station will be build by the radio students at IET cooperating with ARK ("Akademisk Radio Klubb"), a student amateur radio club in Trondheim. This is desirable to be used for later in-orbit operations. A local ground station will provide the students at NTNU with easier access to downloaded data, and learn how to operate a satellite in orbit. This will also free resources at the Svalbard or Narvik stations.

The ground stations should be able to upload satellite data and images to the Internet as soon as possible after reception, preferably automatically, in order to gain even further outreach effects.

4.3 Space segment

All technical solutions linked to the satellite should be presented in this chapter. The space segment will consist of all the parts in the satellite, as structure, power supply, solar cells, communication link, and so on. The communication link is going to be in amateur radio frequencies. The NCUBE used a downlink at 437.305 MHz and an uplink at 145.980 MHz. It may be possible to reuse these frequencies, assuming approval from the Norwegian Post and Telecommunication Authority (PT) and The Radio Amateur Satellite Corporation (AMSAT).

A 145 MHz transceiver will be designed as a TT&C-radio, able to communicate with a ground station regardless of the satellite orientation, i.e. even if the ADCS-system fails. Additionally, a 437 MHz transceiver will be implemented, primarily intended as a payload downlink. A morse beacon will also be incorporated on one of these frequency bands. Having two independent radios on-board gives the project redundancy and more reliability. The 437 MHz radio will be implemented using an antenna with optional directivity, meaning that it can transmit omnidirectionally in case of initial ADCS failure. The 145 MHz antenna will be near omnidirectional at all times. The ACDS system will most likely incorporate magnetic coils for controlling attitude. There will be no gravity boom for nadir stability, as this will hamper mid-mission attitude control. A full technical review of the space segment is given in the Technical Specifications, see attachment 1.

4.4 Requirements review

The team must in this section state the requirements of their satellite and demonstrate that they have understood the concept of the requirements for a Cubesat, and that they are compliant with these requirements in their proposal.

All physical dimensions, design details and mission tasks will be in compliance with the CubeSat Standard Specification Document, revision 9, which is attached to this proposal as attachment 8. The team is aware that it is responsible for noticing changes to this specification, and that the completed satellite must be approved by Cal Poly personnel prior to launch.

4.5 Technical description/mission statement

The mission statement will be mentioned in this point. The team must describe what their satellite will be doing when flying. The communication link is in this project very important to establish.

The mission goals are:

- Deliver a fully functional and tested satellite in time for launch
- Transmit a beacon signal from the satellite receivable for radio amateurs.

- Capture an image
- Transmit the image to the ground.
- Establish two-way communication.
- Testing attitude control, consisting by magnetic coils.
- Take a picture of Earth and transmit the picture to the ground.

For further explanation, see the tentative mission statement and System Specification in attachment 1.

4.6 Test and verification plan

A plan for testing and verification should be prepared in this chapter. The testing will consist of communication, vibration, vacuum and thermal testing, and the satellite will have to qualify in all these test to fly.

A working engineering model of each subsystem must be developed prior to the final product, in order to test system functionality and communication, internally and externally. It is also desirable to expose these subsystem prototypes to thermal, vibration, and vacuum testing to identify environment problems at an early stage. However, such testing is expected to be difficult to carry out due to lack of resources and facilities. An engineering satellite consisting of the prototype subsystems will be tested and verified before the final flight model is to be built. The engineering model may not include solar panels.

Before final assembly, each subsystem shall be tested to see if it complies with specification, and that its function is similar to that of the working prototype. The internal communication will then be tested and verified after the satellite has been partially assembled. After initial function tests have been accomplished, vibration, vacuum and thermal testing will be carried out according to CubeSat standards. See attachment 6 for a detailed description.

4.7 Deliverable hardware

In this chapter the team must report what kind of hardware they will deliver to be launched, and possibly ground support and test hardware, as well as any specific satellite ground telemetry.

The hardware delivered will include all modules needed for an operational satellite, assembled and ready for testing. The satellite chassis will either be bought from CalPoly, or designed by the students and manufactured at the workshop at IET.

From NTNUs side, the goal is to design and build as much of the hardware as possible using only in-house resources. However, the student group at IET would still like to consider payload contributions from other national institutions, as long as these payloads do not seriously complicate the mission. Such a payloads in total would be limited to a mass of 0.5 kg and a volume of less than 1 litre. If a payload from another institution is included, NTNU must have the final word regarding specific requirements, to avoid incompatibility and delay issues.

4.8 Support/Assistance

In this chapter we want the team to explain if any assistance or support is needed. This may be on the technical parts, space and ground segment.

As mentioned earlier, use of ground stations at Svalbard and Narvik is desirable due to their advantageous geographical position during in-orbit operations.

NTNU must offer the students good engineering assignments, so the project will strongly benefit if a lab engineer is appointed to support the students, for example as a 50% position. The founding for this position must be discussed. A lab engineer could the be able to follow the design and manufacturing of the satellite and its systems closely during the whole project life. Some work would require supervision by a practical skilled professional. Some work regarding assembly and testing are tasks not suitable for student assignments. A lab engineer could do this work. NTNU considers this a better solution than buying hardware from a 3rd part.

It would be of great advantage if the participating students were able to attend national and international conferences and meetings relevant to their projects. It is desirable that NAROM founds and supports fees and travel expenses for such arrangements.

Costs regarding to test execution and launch are expected to be covered by NAROM. Access to test facilities and and administration must also be supported. An approval of an orbital debris mitigation plan as specified by the CubeSat Design Specification might be needed, as well as obtaining licenses for frequency use. This is expected to be arranged by NAROM.

To successfully test the structure and antenna implementation, it would be of great use if NAROM could supply a P-POD for use by the students in their developing work.

5 ATTACHMENTS:

1. Technical Specification Document
2. Link Budget
3. Power Budget
4. Mass Budget
5. Rough Order of Magnitude Budgets
6. Project Execution and Verification Plan
7. Contact List
8. CubeSat Design Specification
9. Signature Form
10. Words of Wisdom