Space Related Education at the University of Aalborg, Denmark

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The AAU Cubesat student satellite project at Aalborg University was initiated in September 2001 and led to the launch of the satellite from Plesetsk on the 30th of June 2003. The satellite survived three months in orbit and based on the experiences gained the next student satellite project was commenced called AAUSAT II which is due for launch early 2006.

This article presents the experiences gained and lessons learned from the work with student satellite projects at Aalborg University as well as the methodology used to manage these projects.

First an introduction and description of the Problem Based Learning concept used at Aalborg University is given and advantages of applying it to these projects are discussed. The benefits of student satellite projects are also discussed. Finally the specific management methods for the two projects are described and lessons learned from each project as well as a set of recommendations for future projects are given.

For four years since the summer of 2001 student satellite projects have been an integrated part of the education of students at Aalborg University (AAU). The projects have so far been focused mainly around three satellite projects: The AAU Cubesat which was the first cubesat built at AAU, The AAUSAT II which is the successor of AAU Cubesat and is due for launch in Q1 2006 and SSETI Express which is a micro satellite organized by the Education Department of ESA. The first two satellites have been made entirely on an in-house framework at AAU using the cubesat-concept while the latter is carried out as cooperation between students from 12 European universities.

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AAU, Education and Space

Since the foundation of Aalborg University in 1974 education has been based on Problem Based Learning (PBL): The idea is that skills are best obtained by a combination of traditional lecture based education and solving a problem in all phases through project work. Half of the student's time at the University is used for project work. Proper supervision is carried out by a scientific staff member.

This organization of the educational system has been proven to be very rewarding for the graduates who are highly praised by the industry and is very popular with the students them self. This is due to a number of facts: Students prefer real life engineering problems compared to hypothetical, academic problems. This leads to a highly profitable cooperation with the local industry as many student projects are proposed by companies.

AAU has gained high international focus on the PBL paradigm which is copied around the globe, and PBL has for the last decades been a scientific research area at AAU.

For a further elaboration of the Problem Based Learning methods of AAU visit http://www.puc.aau.dk.

PBL and Space

PBL are normally carried out in a 5-7 person group.

This structure of education is a very good basis for a student satellite project as it supports the division of the satellite into subsystems very well. For example for AAU Cubesat the following

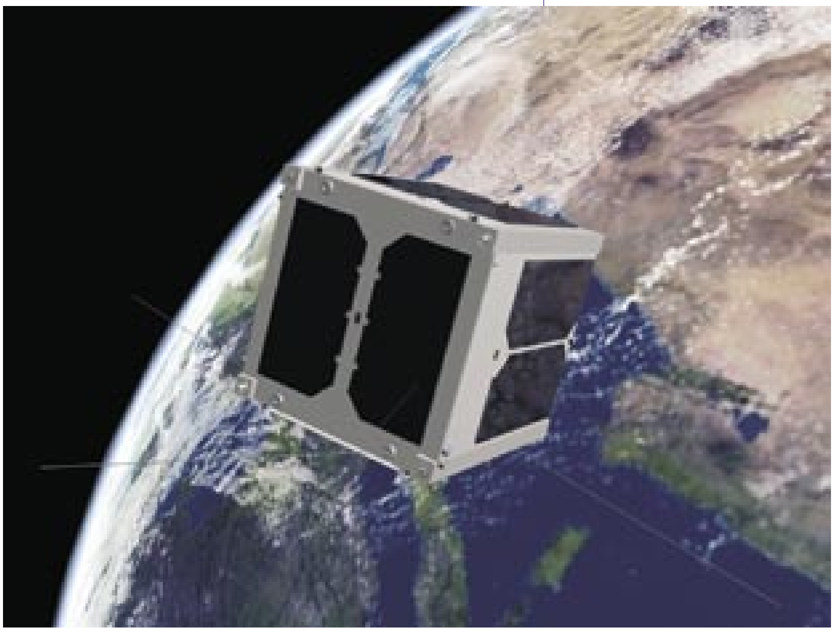
8 subsystems were identified: Power Supply Unit, On-Board Computer, Attitude Determination and Control System, Communication system, Camera, Structure, Command and Data Handling System and Ground Station. All of these systems could all be fitted into a semester theme for a specialization with everything from analysis through design to construction. This means that the work on the spacecraft fit well into the curriculum and the students automatically get academic credit for their work which otherwise could be a problem. Also based on their experiences with combining practical and theoretical engineering work and their familiarity with team work the students are quite ready to take on a large project. Because while a student satellite project certainly contains a lot of technical challenges it most certainly also contains a lot of collaborative challenges and the students need to be able to handle that.

Here AAU Space activities have contributed to development of the PBL paradigm as described below:

1. Many groups working together
2. Different educations working together (control theory, mechanical constructions, power electronics,...)
3. Cooperation across semester boundaries (4-10 semester actually working together with respect for every bodies capabilities)

Goals

The overall motivation from the point of view of the university is to let engineering students from various areas of specialization and departments cooperate on a large scale project with a definite goal in mind. They learn to corporate not only within their own groups but also between groups and between completely different specializations, which is very similar to what they will experience when they go out into the industry. It is an excellent exercise in inter-disciplinary work and gives the students good ballast for their future jobs positions as engineers in project-teams.



AAUSAT in orbit.
Figure: AAU

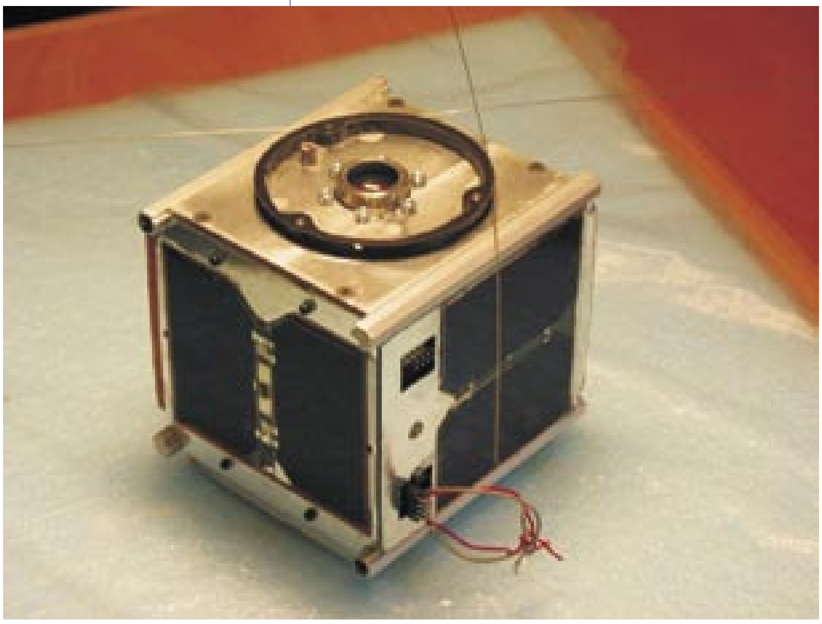
Four fundamental goals can be identified:

1. Giving engineering students more skills than with a traditional PBL project at AAU
2. Motivate Students by constructing and building a satellite
3. Develop the AAU education paradigm
4. Obtaining symbiosis in combining education and space research

The first two goals are obvious seen from a student educational perspective. For the students a satellite project is a fantastic chance to make something that is not only used for a real life product but is actually launched into space. This is a huge motivational factor for the students as space is something many engineering students are very interested in.

The last two goals shall be seen as the continuous development and evolution of our education and research. Skilled master students can join research groups (through their supervisor) - which can encourage research as well as education.

Another benefit is that the students are forced to make a product that is not just a prototype that only works most of the time, but instead they must mature their system into a completed product -- just like in the industry. This means that they must cre-



AAU Cubesat. Flight model. Picture: AAU

ate a system that can be qualified for space and can fit into the satellite and take into account problems like limited volume and limited available power. They must choose components that can withstand vacuum, the temperatures of space and the stress of the launch. Thus the students have already tried all phases of a product development and production when they graduate which makes them very attractive to the industry.

Also by involving the students in the actual management of the projects and the system-engineering work they acquire a, for students, unique experience in actual large-scale project management which is also very valuable to the industry.

Criteria of Success

Construction and launching of satellites is a risky business. Satellites are very complex systems and it is difficult to guarantee a successful launch and operation in space. It is therefore of high importance in context of moral early to define for the students what a success is.

We have a 5 step student success criteria model:

1. Design and construction of the satellite
2. Launch of the satellite and deployment of the satellite
3. Earth contact with the satellite
4. One or more subsystems functioning in the satellite
5. One or more payload functioning in the satellite

Level 2 to level 5 are per our definition characterized as a success.

Management

The management duties fall roughly in three phases: Startup phase, designing/construction phase, finalization/launch phase. The first phase demands visible management. Main purpose is to help the students to define their management procedures and forming a committee of system engineers each with distinct areas of responsibility e.q. mass budgets, power budgets etc.

In the middle phase staff management turns into invisible management where the students are in control of the project. This phase can be difficult to ``implement'' because the scientific staff must let the students be (nearly) on their own. The student acknowledges this very well and acts very responsible.

In the last phase much student work is on a voluntary basis due to unforeseen delays, unknown time of launch etc. In this phase the scientific management ``joins'' again the project on a equal level to the students helping to troubleshooting technical and other problems.

It is important to stress out that scientific staff do not do any construction or design of the satellite.

The scientific staff and management are all the time responsible for financial issues, launch negotiations and proper integration into the education plans at the university.

AAU student satellites and satellite projects

AAU students has constructed and launched AAU Cubesat, participated in ESA Educations SSETI Express and are now (May 2005) in the end of the detailed design phase of AAUSAT II.

AAU Cubesat

AAU Cubesat was designed and built from the summer 2001 to the spring 2003 and included students from five different departments:

Mechanical department, control department, electrical department, power electronics department and computer science. At the beginning of the project 70 students divided into 11 groups were involved with the different subsystems and this number was then reduced as the project progressed until the end where 5 students conducted the final integration and checkout.

The mission of AAU Cubesat was to take pictures with a camera in the visible range of light. Pictures taken of the earth had a resolution of 100x100m with a camera specially developed for this mission. The pictures should then be transmitted to AAUs own developed and operated ground station.

Cubesat was launched successfully. The radio link to our ground station was of such a bad quality that picture transmission was not possible. It is estimated by simulation and measurements that it was due to an antenna deployment failure.

SSETI EXPRESS

In January 2004 a group of students met at the European Space Technology and Research Center (ESTEC) in Holland to discuss the feasibility of building a micro-satellite, dubbed SSETI-Express, from parts derived from other student satellite projects and launch it within one and a half year. The project is an initiative under the ESA Education Department and the Student Space Exploration and Technology Initiative (SSETI), an European student organization. The satellite is currently scheduled for launch on the 30th of June 2005 atop a ”Cosmos” launch vehicle from Plesetsk in Russia.

The design relies heavily on its sister project SSETI-ESEO (European Student Earth Orbiter), which is a much more complex satellite that has been developed by students since the year 2000. From the current SSETI-ESEO design SSETI-Express has derived the mechanical design, Electrical Power System and Propulsion System. It is a key objective of the mission to evaluate these systems prior to the launch of ESEO. The envelope of the satellite is 60x60x80 cm and weighs 80kg.

In addition the satellite carries a small camera, which will be able to take color pictures of the Earth as well as celestial targets. The camera is the original engineering model from the AAU-Cubesat project.

Mission Statement

The following mission statement has been adopted:

“The SSETI Express mission is an educational mission that shall deploy CUBESAT pico-satellites developed by universities, take pictures of Earth, act as a test-bed and technology demonstration for hardware of the complementary project: the European Student Earth Orbiter, and function as an radio transponder for the rest of it’s mission duration”

Mission Objectives

To accomplish SSETI Express’s mission statement, the following objectives have been developed:

1. To demonstrate the successful implementation of this pan-European Educational initiative and therefore encourage, motivate and challenge students to improve their education and literacy in the field of space research and exploration.
2. To demonstrate and test the hardware and technology being developed for the European Student Earth Orbiter.
3. To take pictures of the Earth.

Space Segment Teams

The following tables list the teams, their name, task and location, which are involved with work on the space segment of the mission. This illustrates very well the scale of the international cooperation.

Attitude Control & Determination	AAU, Denmark
Camera Payload	AAU, Denmark
Electrical Power System	Napoli, Italy
Onboard Computer and Datahandling	AAU, Denmark
Propulsion Payload & Stuttgart	Stuttgart, Germany; Laussanne, Switzerland
Thermal Control System	Stuttgart, Germany
S-band payload transceiver	Warsaw, Poland
UHF Transceiver	Hohenbraun, Germany, Vienna Austria

The main ground station is located in Aalborg in Denmark, but the mission also has limited access to a ground station placed at Svalbard in Norway.

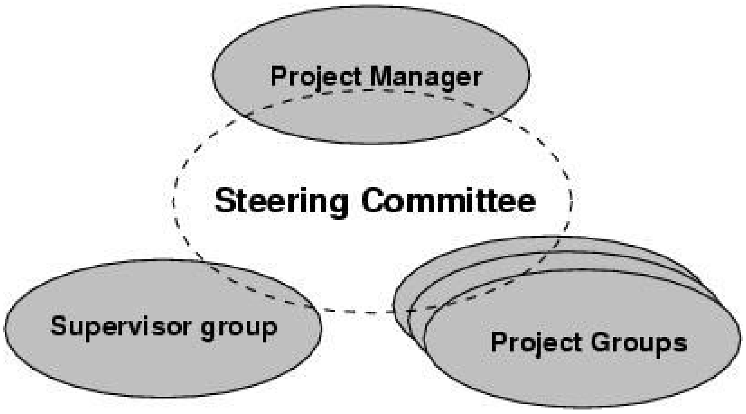
The operations center is also placed in Aalborg for the initial operations, hereafter it will relocated to Wroclaw in Poland.

Management of AAU Cubesat and AAUSAT II

Managing the AAU Cubesat Project

When the AAU Cubesat project was initiated it was done by gathering into one room about 70 students from the different necessary specializations who was interested in working with space technology. The project manager then outlined which subsystems were needed and what the expected functionality and responsibility of each subsystem were and then he announced that it was up to the students to find out who would do what and how and then he left the room. The students then spend the rest of the day dividing the responsibilities between them and discussing how to run the project. This story is very symptomatic for how the management of the AAU Cubesat project was carried out. It was from the start the intension that as much as possible should be left up to the students in a kind of controlled Laissez-faire management style. The management took care of finding funds, negotiating launch and dealing with legal issues while the students were responsible for the day to day management.

A project structure containing three bodies was defined: A steering committee, a supervisor group and the various project groups.



The supervisor group consisted of the supervisors of the different project groups and the responsibility of this group was to monitor that the technical standard required for the project were maintained. The steering committee was the actual management group of the project with weekly meetings and it was run by the students with representative from each project group and the professor acting as project manager. Members of the supervisor group were represented at the meetings when appropriate for the particular discussion. The committee had the following objectives to oversee at the meetings:

1. Define mission and payload.
2. Discuss and determine interface specifications
3. Ensure that loose threads were picked up

This structure worked quite well throughout the project but a number of problems presented them self as the project progressed. It soon became apparent that the supervisor group did not function as intended as some of the supervisors were more interested in getting their groups to make interesting theoretical projects instead of producing a product that was worthy of the satellite. In other words they were more interested in their field of work than the satellite which made it difficult for some of the groups to participate 100% in the project.

Also there were initially a lot of internal support from the various departments of the university but as some departments began to complete some systems while others were still working on more time demanding systems the commitment declined. This was unfortunate as it lead to the problem that when the time for integration came the students responsible for that had to take over the work performed by many of the departments -- these had not made provisions to ensure proper backing for final integration and testing of their systems. A possible solution to this could be draw formal contracts at the project definition that commits the different involved parties to their responsibilities.

Another closely related problem was that during the project some students completed their education and left the university while others simply started on other student projects. This meant that some students with key information were often not available during the integration and testing phase which was prolonged due to that fact. This is a very important issue that the management can handle by identifying the different key persons and keeping then involved in the project e.g. by out-sourcing smaller tasks to them as spare-time work. This is particularly easy if there are adequate funds to employ these students to do some to of the work that cannot be categorized into the on-going student projects.

Early in the project the ``seeing is believing'' idea was used when the mechanical structure was produced as a early prototype to allow the students to actually see the satellite (see figure proto at the next page).

This was a huge success as it made the students believe that their work would eventually turn into a satellite.

While the minimum-involvement management did work quite well for the AAU Cubesat project it was afterwards concluded by the students that a larger amount of top-management was needed at the next project. This was due to two things: It sometimes put too large a work pressure and responsibility on the students which made some leave the project before the end. Secondly for it to be successful the right students with the right resources are needed and these are not always available.

Finally two other important lessons was learned from the AAU Cubesat project: The perhaps most important thing is that the interface specifications must be kept updated at all times and changes in interfaces must be discussed in the steering committee. Another important lesson was the Keep It Simple Stupid (KISS) principle is very important to remember when building satellites, complex systems simple consume much more time in the integration phase.

Managing the AAUSAT II Project

Following the relative success of AAU Cubesat in the summer of 2003 then it was promptly decided that Aalborg University should build a new student satellite called AAUSAT II. Work on this began in the autumn semester 2003 and continued in the spring of 2004.

However it quickly became apparent that the project was running astray for two reasons; Firstly no economical means had been secured before the new project was initiated and secondly no clear direction for the new satellite existed, but it was mainly motivated by the high spirits following the launch AAU Cubesat.

A key lesson was learned here: Before a project is committed there must exist a clear picture of the objectives and means to reach them. This does not mean that every detail should be planned in advance, but there must be a clear idea about how the project is funded and hence an idea of a budget, a clear idea idea of what kind of satellite is to be built (envelope and complexity) and finally a schedule leading to a realistic launch date.

AAUSAT II lacked the above for the first year of its development.

Therefore in the summer of 2004 the whole project was re-staged by addressing the mentioned areas above and recruiting a large number of new students to increase the level of activity. The management group was also strengthened to four persons in this period by incorporating former AAU Cubesat students, now PhD students at the university, in the group. The final organization was formed as two parts: The management team, which also acted as supervisors for almost all groups, and the students groups. These two parts then joined in the steering committee called the system engineering group where all four managers and one fixed student for each group which acted as responsible system engineer for his subsystem. However there is one extra seat per group in the system engineering group which the students then take turns at occupy -- this system was introduced to ensure that all students got a feeling of the system engineering work while the fixed student from each group ensured continuity.

This reorganization put the project back on track, but the eagerness of the managers to get things going led to a situation where the project was over managed with the effect that the students were too little involved in the system engineering side of the project, which clearly contrasted the first objective. Talking about it at the weekly meetings did little to put the responsibility back on the students, who used the extra resources on their subsystems instead. In the end the management group walked out on the group at a scheduled review to kick-start things - This gave the student the sensation that it in fact was their project and they stepped up and took the responsibility.

Early prototype of AAU Cubesat. Picture: AAU

The example, contrasted with AAU Cubesat, clearly demonstrates the major challenge of managing a student satellite; It is a very fine line between under managing and over managing. As we have learned then the good student satellite manager has a very large overview of the project and communicates a lot with the students about their problems and solutions, but does not jump in any time he thinks the students are walking a bit away from the straight path - most times the students find back themselves and learn from it.

The main management tasks, as it has been exercised on the AAUSAT II project since the mentioned design review, is to keep a cool overview and manage the budget, perform the launch negotiations and communicate with the students as one engineer to his peers. However, a from time to time situation arises were the management group sees important problems that must be solved. These problems can be communicated to the students which in many cases can handle them when aware, other times the management group may lend its manpower to help solve a specific problem alongside the students - manpower is often the most scarce resource in this kind of project.

At times during the AAUSAT II project it has been hard for the students to maintain focus, and specifically, and not surprisingly, in periods with many exams. One effective tool that have been employed here is to refocus the group after the last exam in a period by making a long weekend workshop with scheduled discussions on key areas and practical work in the laboratory. Such workshops bring students together, strength the team spirit and all in all give a large step forward to the project.

The Constraints of Student Satellite Projects

At the beginning of the AAU Cubesat project a number of important constraints were identified and generalized mission success criteria was formulated in an incremental way:

1. Educating engineers with theoretical as well as practical experience in spacecraft design and construction.
2. Acquire signal from the satellite.
3. Acquire comprehensive housekeeping data for system evaluation.
4. Satellite and payload operations.

Thus it was defined that the most important aspect of a student satellite project is to educate the students participating in it which means that a project can still become a partial success even though no signal is ever received from the satellite. The formulation was done this way in order to keep focus on the fact that the project is there for the students and not vice versa.

The constraints that were identified were used to steer and structure the project:

1. Short project (<2 years)
2. Designed, implemented and operated by students
3. Low budget

It was identified that it was very important to keep the duration of the project very short. When the students start on the project they must be able to see the end is within the time frame of their own studies and before the students can contribute technically to the project they need some years of prior studies in the basics of their field.

Another important aspect that was identified is to allow the work of designing and building the satellite to be done entirely by students. While it is not always desirable or possible to adhere to this it is nevertheless an important point corresponding with the first success criterion.

It is also important to keep the project at a low budget for several reasons: The most important is of course that only limited funds exist at most universities for such educational projects and it is easier to find small an amount of money than a large. This also justifies the way of formulating the success criteria as the financial investment is kept low enough to accept the possibility of a failure of the satellite.

Conclusion

In this article the evolution of the organization and management of the two student satellite projects at Aalborg University have been discussed. This included a presentation of the two satellites and an introduction to the Problem Based Learning method used at Aalborg University. Among other things an overall conclusion the following set of recommendations can be summed up:

1. Ensure that a large part of the needed funds are available before project start.
2. Ensure that the different involved parties will support the project even through difficult times.
3. Keep the interface specifications under a very tight leash.
4. Force the students to keep them updated and all changes should be discussed in the system-engineering group.
5. Allow the students to make mistakes; do not over manage the project.
6. Start launch negotiations from the start of the project as this provides the project with needed realism. It makes the students (and managers) believe in the project.
7. Use workshops where as many as possible of the students are gathered at one time, e.g. over a weekend.
8. Remember the KISS principle and adhere to it.
9. Integration always takes more time than anyone expect.
10. Transpiration always follows inspiration.
11. It must be fun to build satellites.

SELECTED REFERENCES

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page with many links to pages like:

http://www.aausatii.aau.dk
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