A Danish Perspective on Problem Based Learning in Space Education

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Abstract:

This paper describes the goals of the Student Satellite Program at Aalborg University (AAU), and the means for implementing it, namely a concept called Problem Based Learning, which is the cornerstone in the education at AAU. AAU has within the last decade chosen to focus strongly on education in space technology, not because the country lacks aerospace engineers, but because space projects require the students to think about systems rather than individual modules, while providing problems that are technically challenging for the students to solve. This combination makes the graduates very attractive for the industry in general, and not only for the space industry.

1 Introduction

This paper describes a selection of the educational activities in Denmark within the field of space technology with emphasis on the activities at Aalborg University (AAU). Danish space activities were boosted in 1992, when the design phase of the first Danish satellite Ørsted began. The Ørsted satellite was a professional co-operation between AAU, The Danish Technical University (DTU), and several Danish companies. AAU was responsible for developing the attitude control system. As part of the participation of AAU, several Ph.D.s were educated. The satellite was successfully launched in 1999.

Following the success of the Ørsted satellite, AAU and DTU both launched initiatives to allow students to design, build, and launch small 1kg cubesats. The Danish initiatives took their start in August 2001, when the AAU CubeSat and DTUsat student satellite projects were initiated. At AAU the AAU CubeSat satellite, under Assoc. Prof. Rafal Wisniewski, became the initiator for an educational program within space engineering. Amongst many activities under this program, students have participated in the pan-European student satellite SSETI-Express and parabolic flight campaigns, both organized by ESA, and are now developing a second cubesat AAUSAT-II.

1.1 Problem Based Learning

The Problem Based Learning (PBL) paradigm is an integrated part of the curriculum at AAU. In fact, the entire educational structure of the university is based upon project organized PBL. In PBL the students have an increased responsibility for their own learning, and working in project groups requires that the students communicate the curriculum between them. The key element is that the students spend about half of their time working in groups focusing on a specific problem, and the other half on traditional lectures. Each semester the students form groups of typically 3 to6 students, and in the group they must select a project from a pool of proposals from teachers, industry, and students, which they will then work on during the semester under the supervision of a scientific staff member. Each of these groups get an office assigned, and the philosophy is that the students spend almost all their time in these groups. This means that both the problem based project work as well as preparation to lectures and assignment work is done in these groups, where the students can aid and support each other. The final result is an 80 to200 pages report and, for the engineering students, a prototype of the system they have developed.

Through PBL, the students acquire a large experience in applying the theoretical elements in practical engineering problems, besides a thorough theoretical insight. The group based teamwork teaches the students how to professionally present their own proposals and how to be constructively critical to other proposals, i.e. not take solutions for granted. Furthermore the students urge themselves on in the groups and almost always set much higher standards for their work than the university does, thus producing results of very high quality on top of high level of learning.

The combination of the PBL approach and space applications tailor the student with strong technical skills combined with equally strong skills in collaboration and management. Another interesting beneficial side effect of the PBL approach to education is that students at AAU tend to complete their education much faster than students from universities with more traditional education systems. At AAU, 75% of the engineering students finish on time.

2 Past and Present Space Education Projects

After the Ørsted satellite was launched in 1999, groundwork for implementing the Student Satellite Program at AAU began. To this date, the program has led to participation in two satellite projects that have been launched already, and further two projects that will be launched in 2006. This section will briefly describe the various projects. For details and updated information of the Student Satellite Program, the reader is referred to [4].

2.1 AAU CubeSat

The AAU CubeSat project began in September 2001 with the goal to let students build and launch a pico-satellite, and thereby provide hands-on education and gained experience within pico-satellite technology. The satellite was launched on the 30th of June 2003 from Plesetsk in Russia atop of the Rockot Launcher. The main payload was a CMOS imager.

Following launch, the satellite was active for three months, until the battery had lost too much capacity to continue operations. During this time only a limited amount of data was successfully down-linked from the satellite due an antenna deployment problem resulting in very weak signals being transmitted from the satellite. AAU CubeSat, however, as a first step into pico-satellite technology and student built satellites is considered a great success. A total of around 70 students contributed to the project, which had a total budget of around EUR 180.000. A picture of the AAU CubeSat flight model is shown in Figure 1.

Insert Figure 1 here

2.2 SSETI-Express and Baumanetz

SSETI-Express is a student satellite built by students from 14 different universities across Europe. The project was coordinated by the European Space Agency (ESA). The project was initiated in January 2004, and the satellite was launched on the 27th of October 2005 from Plesetsk in Russia. The SSETI-Express flight model is shown in Figure 2. AAU participated with around 20 students who, for the space segment, contributed with the on-board computer, flight software, attitude control system, and a camera payload. For the ground segment, AAU provided the full physical primary ground station and mission control software situated in Aalborg.

Insert Figure 2 here

SSETI-Express was acquired during the first pass over Aalborg, but the mission was severely shortened due to a thermally induced fault in the power supply. However, during the operational period of 11 hours all AAU subsystems were operated successfully, except for the camera, which remains untested. An on-board computer, similar to the one on SSETI-Express, has been delivered by AAU students to the Baumanetz student satellite, developed at the Bauman Moscow State Technical University, Russia. This satellite is awaiting launch in June 2006.

2.3 AAUSAT-II

The AAUSAT-II satellite is the successor of the AAU CubeSat. The project was started in September 2003, and a launch is being negotiated for Q4 2006. It is built solely by graduate and under-graduate students, and has involved about 80 students so far. The satellite will be equipped with all the necessary sub-systems, including an attitude control system with tiny reaction wheels, as well as magnetorquers. The scientific payload is a miniature gamma ray burst detector, which consists of a single CdZnTe detector crystal, equipped with a developed pixel electrode structure. The technological objective of the mission is to study the performance of this novel detector in the space environment, including detection of gamma ray bursts. The payload is developed by the Danish National Space Center in co-operation with a student group at AAU. The satellite is designed for a mission lifetime of at least 0.5 years.

2.4 Parabolic Flights

AAU has also frequently had students participating in the parabolic flight campaigns for European students, which are organized by ESA each year. In fact, each time an AAU team has submitted a proposal, they have been accepted. In 2002, 2004, and 2005, teams have participated with experiments relating to attitude control of pico-satellites, i.e. projects that have directly supported the satellite program. In 2003, a student group flew with a system for active vibration isolation of experiments on the International Space Station, and subsequently got elected to re-fly the experiment on another campaign for professional researchers.

3 PBL in Student Satellites

Within the Student Satellite Program, it is a requirement that a satellite is built and launched, which introduces a number of problems when implementing a satellite project within PBL. A single group cannot be expected to design and build an entire satellite within one semester. It is necessary to involve several groups from different semesters and institutes for the duration of a number of semesters. Some groups are expected to be involved in parts of the project only, as tasks are finalized, or new tasks are proposed to new groups. This method requires extensive work in management of the projects, maintained jointly by the students and staff members.

The system engineering tasks of the satellite project (see [5] for details on these tasks) are handled by the steering committee. The steering committee consists of one systems engineer from each group involved in the project at the time. A second seat in the committee is given to each group, occupied round-robin amongst the remaining group members. This ensures consistency and continuity in the steering committee and ensures that all students are included in the management tasks, whilst limiting the number of people present at meetings.

The finalization of a satellite, i.e. implementation, integration, and testing, are not tasks which semester projects can be based on within the curriculum. Hence these tasks are typically done by students in their spare time, motivated by the prospect of launching the satellite into space. From an educator’s point of view, this is an important benefit of PBL in space education, as the extra work put in by the students also gives the students relevant hands-on experience, without compromising the scope of the curriculums.

From the experience of the AAU CubeSat and AAUSAT-II projects, the importance of the system engineering documents from the beginning of the project has been clear, due to the large number of groups. However, it should also be noted that it is very difficult to ensure proper updates of the documents. As the number of groups decrease towards the project finalization, the management documents become less critical, since the students still involved are limited in number and have a better overview of the entire system. For this reason staff will monitor the work process and push for updates when it is found to be necessary. Less management and more hands-on work increases the motivation of the students, and also ensures that the project does not get stuck in the documentation process without progress in actual hardware design and implementation.

The work on the pan-European ESA SSETI-Express satellite demonstrated that students from AAU have excellent skills in problem solving, when it comes to complex projects that require high theoretical knowledge, practical engineering tasks, developed skills in project management, and collaboration on an international level. Although PBL has been found to be very suitable for large scale projects with multiple groups, some difficulties still arise. Since the curriculums are semester based only, the continuity across semesters is a major challenge. For a detailed description of the PBL model and the project organized PBL implementation at AAU, see [1] and [2, 3].

3.1 Strategy of Upcoming Satellite Project at AAU

In planning the strategy for the next student satellite project, the experiences from students and staff from the previous student satellite projects are taken into consideration. An important lesson learned from the previous satellite projects is that the continuity over semesters is the most difficult challenge. It is seen as an important goal to build the satellite within two years, so the students can see the result of their work. The projects have started with project proposals within each of the satellite sub-systems, i.e. mechanical, power, communication, command and data handling, attitude control, etc. From the groups assigned to each proposal, the steering committee was formed, and the systems engineering work was initiated. Due to iterations of design and top level requirements, this resulted in major design changes, requiring a number of iterations of the sub-systems. As a result, the work of a single group in one semester may have been written as a new proposal for a new group on the following semester, introducing delays in the project development, since new students in the project needed time to get an overview of the overall project.

In order to improve on the above problems, a strategy has been chosen, where the first semesters are dedicated to preparation of the students through classes in systems engineering, and introduction to general design techniques for each of the sub-systems. This ensures that the students have insight into the challenges and limitations of each sub-system. Through the lectures in systems engineering, the management documents will evolve, hence giving a much tighter lock down of the design prior to the detailed design phase. Preliminary designs will be prepared through classes and study groups, rather than project groups. The goal is to prepare the students for the detailed design phase, which is planned to be concluded within two semesters. Within this period integration and testing must commence, leaving final integration and testing only. The detailed design is conducted in project groups, and the finalization is done during the summer holidays as summer school course activities. The major change in this strategy is reducing the detailed design phase to one year through a package of courses to prepare the students, which also will involve them in the planning and preparation of the project. The intention is well defined requirement documents on sub-system level, which will ensure efficient, goal-oriented project work during the detailed design phase.

4 Conclusion

During the last 5 years, education within the field of space technology has evolved a great deal in Denmark and especially at AAU, which has been deeply involved in three student satellite projects as well as other space related student projects. The success and quality of the space education at AAU is attributed to the PBL paradigm of education, which focuses on a solid theoretical background applied in problem based project work. When combining PBL with the multidisciplinary challenges of a student satellite project, a very high level of theoretical and practical skill is achieved by the students. Some problems, like ensuring continuity in the project, still remain, and a revised management approach to challenge these has been presented. The revised strategy emphasizes the structural approach preceding the detailed design phase, in order to minimize the number of semesters required for design, integration, and test. The strategy will be implemented on the next AAU student satellite project AAUSAT3, which will be used to evaluate the efficiency of the proposed method.

5 References

[1] Biggs, J., Teaching for Quality Learning at University, The Cromwell Press, 2003

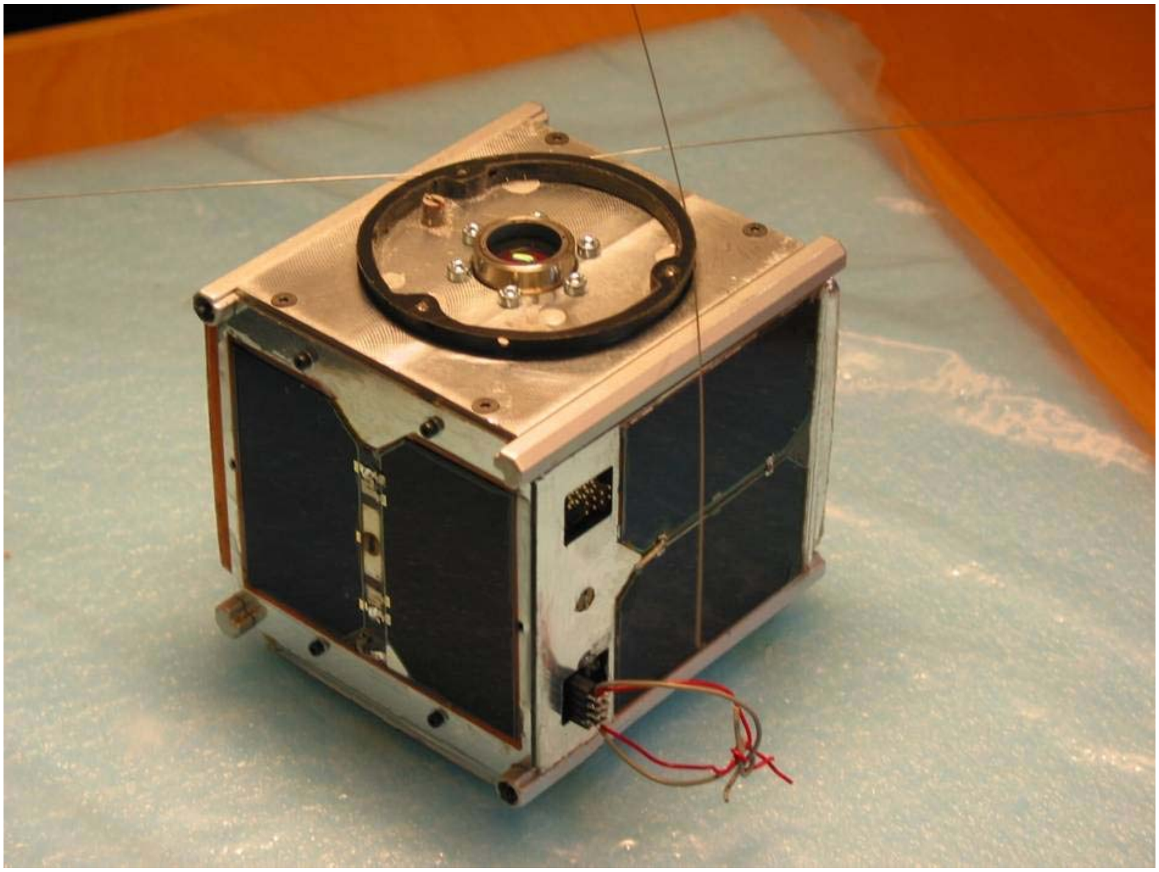
[2] Fink, F. K., Integration of Engineering Practice into Curriculum – 25 Years of Experience with Problem Based Learning, 29th IEEE Frontiers in Education Conference, 1999

[3] Kjærsdam, F. and Enemark, S., The Aalborg Experiment – Project innovation in university education, Aalborg University Press, 1994

[4] Student Space Program, http://www.studentspace.aau.dk, Aalborg University, 2006

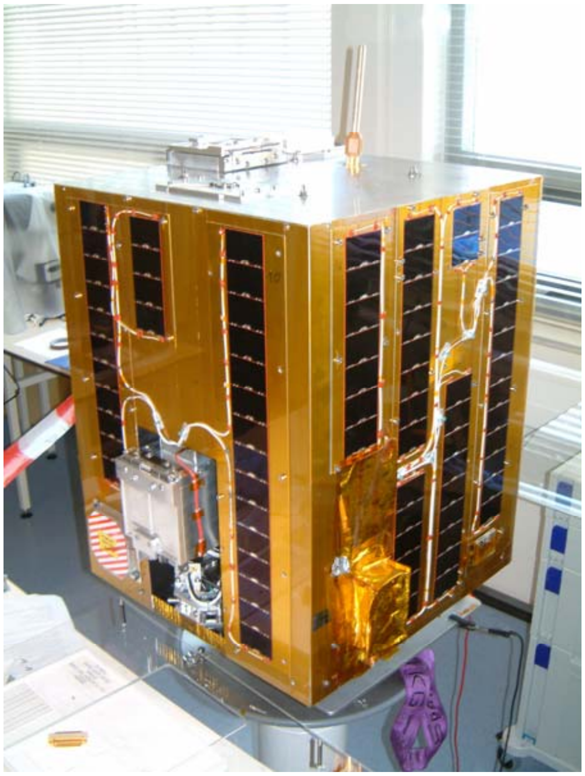
[5] Wertz, J. R., Space Mission Analysis and Design, Space Technology Series, 1999

Figure 1



Caption: **Figure 1**. The AAU CubeSat flight model.

Figure 2



Caption: **Figure 2**. The SSETI-Express flight mode