A student project as part of an MSc curriculum: Delfi-C^3

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Abstract

The Delfi-C^3 is a university satellite of the Delft University of Technology. The project started in November 2004 and had a dual mission: (no bullets in abstract!)To offer at least 25 students as part of their Master of Science (MSc) study the opportunity to gain hands on experience on a real space project and to provide a platform for fast and low-cost technology qualification in space.

The project was aiming for a launch in the first half of 2007. It was set up two faculties of Delft University of Technology in cooperation with industry partners. With over 60 students that worked on the project and a launch in April 2008, it can, already now, be concluded that the project was a success.

The paper addresses lessons-learned from Delfi-C^3 related to thesis supervision, hierarchy in the project and workforce discontinuity. Also from the side of the university some adaptations are required to enable an efficient, effective and qualitatively satisfactory execution of the project. These adaptations are related to the type of staff required, composition of the student team and, generally, “production-process-mindedness” of supporting university departments.

And, may be most important, the student’s effort as a team member must be valued such that he or she may achieve the same appreciation as his or her fellow students working on an individual, theoretical MSc thesis subject.

Keywords: space development project, Master thesis, lessons learned

1. INTRODUCTION

The faculties of Aerospace Engineering (AE) and Electrical Engineering, Mathematics, and Computer Science (EEMCS) of Delft University of Technology teamed up to set up a satellite project. Use has been made of a standard for small satellites with masses ranging from one to three kg, developed by CalPoly [1] offering an affordable means to build a satellite.

The mission objective was primarily to provide students with the opportunity to be part of a real space project and gain hands on experience in it.

Backed by the MISAT cluster of MicroNed [2] the project started in November 2004 with seven Master of Science (MSc) students. The satellite was officially named Delfi-C^3[3].

Delfi-C^3 measures 10x10x34 cm and has a mass of 2.2 kg. The small size of the satellite enables a short project span at relatively low cost. This attracted industry, which discovered a low-cost and fast means of qualifying new technologies in space. Dutch Space supplied a newly developed solar cell called Thin Film Solar Cell and TNO (Applied Natural Science Research) in Delft supplied two Autonomous Wireless Sun Sensors. These two technologies became the so-called ‘payloads’ of Delfi-C^3 and the satellite is to perform in-orbit performance measurements on them [4]. Figure 1 illustrates the Delfi-C^3 flight model configuration.

Three years have passed since the start of the project and Delfi-C^3 is ready for launch. Delfi-C^3 will be launched from India with the Polar Satellite Launch Vehicle (PSLV). The launch date is currently set for April 11th, 2008.

Section 2 discusses the setup of the Delfi-C^3 project, while project evaluation and lessons-learned are summarized in section 3. Finally, conclusions are given in section 4.

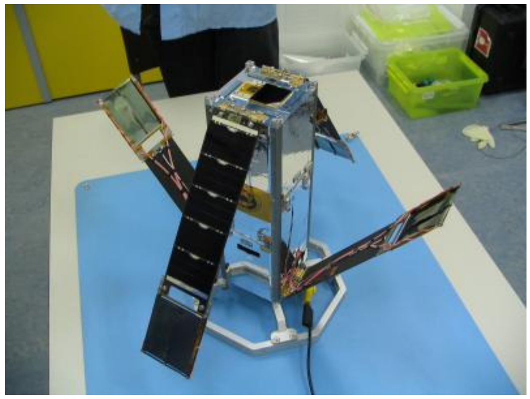

Figure 1 Delfi-C^3 flight model configuration

2. PROJECT SETUP

The complexity of a satellite required a strong commitment by the AE and EEMCS faculties due to the many disciplines involved. This applies as well to staffing as to facilities.

2.1 Team

The project leader and manager positions within the team were filled by staff from the two faculties. MSc students from Delft University of Technology and (Erasmus exchange) students from universities abroad took on the systems engineering and design in the thermal, mechanical, electrical and command and data handling fields. Also quite a few Bachelor of Engineering (BEng) students from colleges in the region graduated on the project in the different fields. To support the students, staff members were selected with expertise in the relevant fields. They performed reviews and supervised students. They also actively supervised and participated in the design, development and verification of the more critical system components, e.g. the TFSC measurement circuitry. The implementation of the payloads was performed in close cooperation with the industry partners. Figure 2 gives an overview of the team structure and shows how it consists out of the two faculties AE and EEMCS with on each side the fields of support each faculty has to offer. The size of the student team varied from about 12 people at the start to over 25 during the full-scale development phase to a small core team of 8 again towards the end.

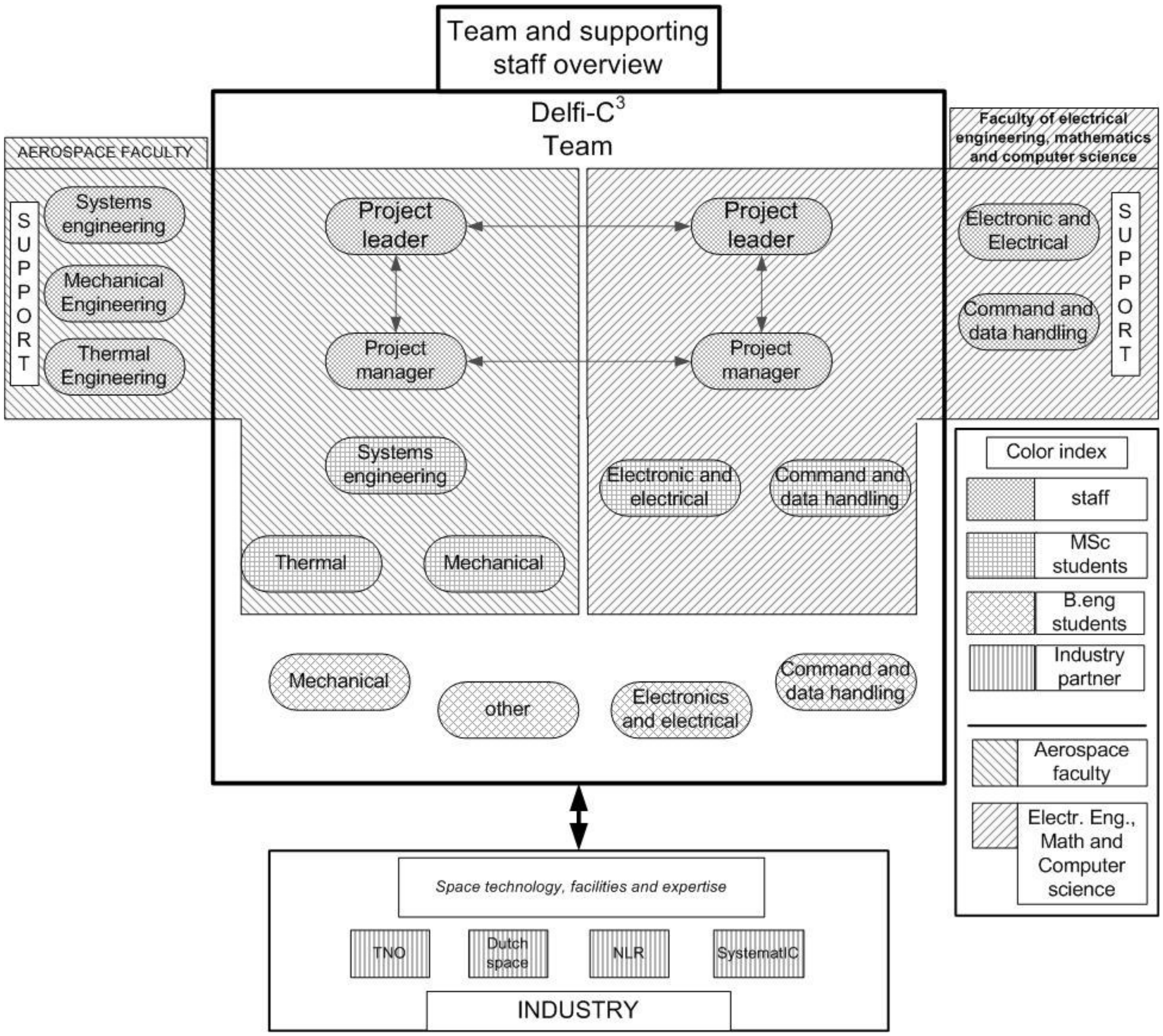

Figure 2 Team and supporting staff overview

2.2 Facilities

The team is split between the two faculties involved; AE has about 15 and EEMCS has about 8 student workspaces (Figure 3). There are also in-house facilities for handling satellite systems for integration and verification such as the class 100,000 clean room, vacuum chamber and climate chamber for thermal testing at the AE faculty.


Figure 3 One of the student rooms at the AE faculty

Facilities of industry partners were used for environmental testing at system level. Thermal Vacuum testing of the integrated satellite was performed at the National Aerospace Laboratory NLR (Figure 4) and vibration test were performed using TNO facilities (Figure 5).

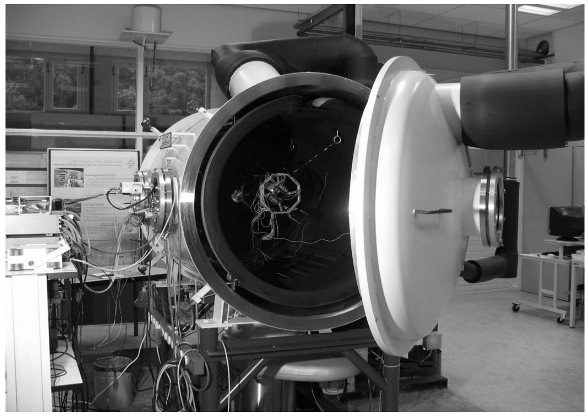

Figure 4 Thermal vacuum testing at NLR

Figure 5 Vibration test at TNO

3. PROJECT EVALUATION

The primary mission of the project was to provide students the opportunity to apply acquired knowledge on a real space project and gain hands-on experience. Over 60 students have worked on Delfi-C^3, 20 of which were MSc students graduating on the project. Given the fact that the satellite has been built and is ready for launch it can be said that the primary mission has been successful. Some 24 conference papers have been published on the project, so also from the scientific aspect the project was successful.

An overall project review, looking at the project stand-alone and as part of the curriculum, revealed that the following items are of particular importance.

3.1 MSc program structure

Executing a project in an MSc program requires a setup different from the traditional setup of MSc graduation work. The traditional setup addresses research and the scope of it is often limited to proof of principle. It focuses on individual work and does not necessarily match with industrial engineering demands and needs. A project however requires the student to involve himself also in more practical work, even work, which might be considered menial for the level of education, as the objective is to deliver a working system meeting the (user) requirements set initially. Teamwork and coordination between the many different disciplines play a big role and the overall work resembles the demands and needs of the industry more closely.

3.1.1 *Staff and university infrastructure*

The type of staff required to run such a project is different from the staff normally hired for teaching and research tasks. To properly run a project as part of the curriculum, staff with industry experience and knowledge beyond their field of expertise is required.

University workshops, facilities and support departments are used to operate in a context where time is not a very scarce commodity. A project, and especially a space project, requires timely delivery and anticipation on future events based on uncertain information (planning and scheduling). The university infrastructure must get used to this more "industrial" business process.

3.1.2 *Student supervision*

The introduction of the project into the curriculum may cause a conflict of interest between the student's thesis progress and project progress. Committing to the project might mean a delay in the thesis progress and not committing might mean missing a project deadline. To protect the student from only working for the project and losing grip on his thesis in such a case, it is required that he has thesis supervision which is independent from the project, unbiased supervision which allows him to give priority to his thesis when thesis progress conflicts with project progress. The student should however still have the freedom to give the project priority if he desires.

Supervision within the project should focus on the deliverables of the student with respect to a successful project, keeping in mind the inexperience of the student and the required training and learning that it might involve. Whereas thesis supervision is done by only one person, project supervision could be more than one person depending on how project management wants it.

	Thesis supervision (1 person)	Project supervision (1 or more)
Main focus	*Get student to complete thesis successfully*	*Have the student deliver work as to complete project successfully*
Relation to student	• *Advisor in relation to thesis* • *Reviewer of work (thesis grading)*	• *Boss, colleagues* • *Reviewer of work (project success)*

Table 1. Student thesis supervision vs. project supervision

It is also important to clearly and accurately state the expected deliverables of a student in the thesis assignment and to be aware that a slipping project planning might delay a student's thesis progress as well so alternative deliverables might need to be considered.

Ways shall be devised to balance the opportunity of learning by making mistakes and delivering the product (satellite and ground system) on time.

3.1.3 *Thesis reporting*

The student will have certain project deliverables as set in the thesis plan. These deliverables are accompanied by project documentation. A thesis report according to traditional standards would mean the student needs a couple of months to write it, which means less time on the project and lower project efficiency. Instead many students of the Delfi-C^3 team bundled their project documents in the appendix, and added an introduction and a chapter on lessons learned. Scientific staff members do not universally appreciate this approach, as they are used to a self-supporting, complete and individual report of the work performed for the thesis.

The student's effort as a team member to deliver (part of) a product fit for use by an external customer must be valued in such a way that he or she may achieve the same appreciation as his or her fellow students, who select an individual, theoretical MSc thesis subject. This requires an objective method to evaluate the design and development effort performed by the student within the project team.

3.2 Internal Project structure

3.2.1 Hierarchy and discipline

One of the challenges of working with students is to get discipline and some form hierarchy within the project. Amongst each other there is little hierarchy, which makes it difficult to delegate work by one student to the other. There is a sort of "peer" atmosphere, which is pleasant but not always productive.

Establishment of a hierarchy should be promoted by making the team members aware of the different project disciplines in the project. In the Delfi-C^3 project the discipline was often lacking in case of systems engineering tasks such as documentation management, reporting and change or version control. The students not involved in systems engineering did not seem to understand the importance of these systems engineering activities[1]. Future projects should have new team members take an introduction to systems engineering so it is better understood what is expected from them.

3.2.2 Workforce discontinuity

There are different types of workforce discontinuity within a student project. A change of the old student generation for the next is the most difficult workforce discontinuity to overcome. To ensure complete and swift information transfer, good documentation is required and preferably an overlap period in which the new student is shown the ropes by his predecessor. Such an overlap has rarely been implemented, as project work pressure was too high.

One of the problems the Delfi-C^3 team encountered after the change of the alumni team to the new team was that the documentation system structure was not transferred properly. Individual formats appeared and the original documentation structure was lost. It must be said however that time pressure also played a big role in the strong reduction in documentation output in the final phase of the project. Documenting is not very popular and quite time consuming, so it is one of the first activities to go in case time pressure increases.

A last problem is caused by the tradition at our University, that a student is free to choose the subject of his MSc thesis. It is difficult to build a student team with the required expertise, when project participation is based on such voluntary choice of the student alone.

3.2.4 Communication

The partnership of the faculty of Aerospace Engineering with the faculty of Electrical Engineering, Mathematics and Computer Science promoted knowledge transfer. The two geographically separated sites did mean that the team would be split up in two. This was not optimal for the communication; preferably all team members should be co-located on the same floor or at least in the same building.

Delfi-C^3 used a peer-to-peer chat server to promote communication between the two sites. Such a communication system has no positive feed-back mechanism, hence does not guarantee effective communication. Structured communication of essential information was also hindered by a lack of hierarchy and the absence of an official information (change) control system. The information flow structure is partly incorporated in the documentation system, which was not being used properly anymore. The result was, especially during hectic periods, that not everybody was aware of the latest changes or baseline.

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[1] This even applies to Aerospace Engineering students, which receive one or two Systems Engineering courses during their education.

4. CONCLUSIONS

The Delfi-C^3 project is a great success. Over 60 students were part of the project in the form of internships or graduation assignments. The faculty of Aerospace Engineering and the faculty of Electrical Engineering, Mathematics and Computer Science demonstrated that, with the help of industry, they are able to provide the know-how and the facilities to run projects as complex as a satellite project. The success of the Delfi-C^3 has resulted in a second satellite project, Delfi-n3Xt, which has started in October 2007. There are however a few areas that will need attention in the next project.

Experienced staff with broad knowledge outside their field of expertise and with experience not limited to the academic community is required. University recruiting rules should allow hiring such staff.

Evaluation of an MSc thesis executed within a project should, in addition to the classic aspects of quality of the research and written and oral presentation of the results, take the specifics of that project into account. In the case of Delfi-C^3 that is at least the student's role(s) in the team, in development and verification activities and external (customer) contacts. Well-structured evaluation criteria and a regular peer evaluation may provide valuable inputs to that process.

Student supervision should put the interests of the student above that of the project and should therefore be independent of the project.

Hierarchy is often lacking among students, which is particularly difficult for systems engineers whose tasks are often misunderstood. New team members should be informed about the different roles within a project and the purpose, methods and tools of systems engineering.

The workforce discontinuity when the old student group is replaced with the next generation students is the hardest to deal with. Documentation needs to be complete and accessible. Having the predecessor supervise the successor to teach him the ropes is ideal, and sufficient time should be allocated to do this.

Co-location of the different disciplines within the team is highly desirable. This promotes the communication between disciplines and increases the visibility of all aspects of the project.

Establishment and maintenance of a well-structure documentation (change) system is essential, also for a relatively "informal" student satellite project.

Co-operation with industry, which has a direct stake in the success of the project, has a very positive influence on the project and promotes knowledge exchange between university and industry. It seems natural that such an initiative is rewarded in the academic environment.

Abbreviations and acronyms

AE	Aerospace Engineering
AWSS	Autonomous Wireless Sun Sensor
BEng	Bachelor of Engineering
EEMCS	Electrical Engineering, Mathematics and Computer Science
MSc	Master of Science
NLR	National Aerospace Laboratory
PSLV	Polar Satellite Launch Vehicle
SE	Systems Engineering
TNO	Toegepast Natuurwetenschappelijk Onderzoek (Applied Natural Science Research)
TFSC	Thin Film Solar Cell

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