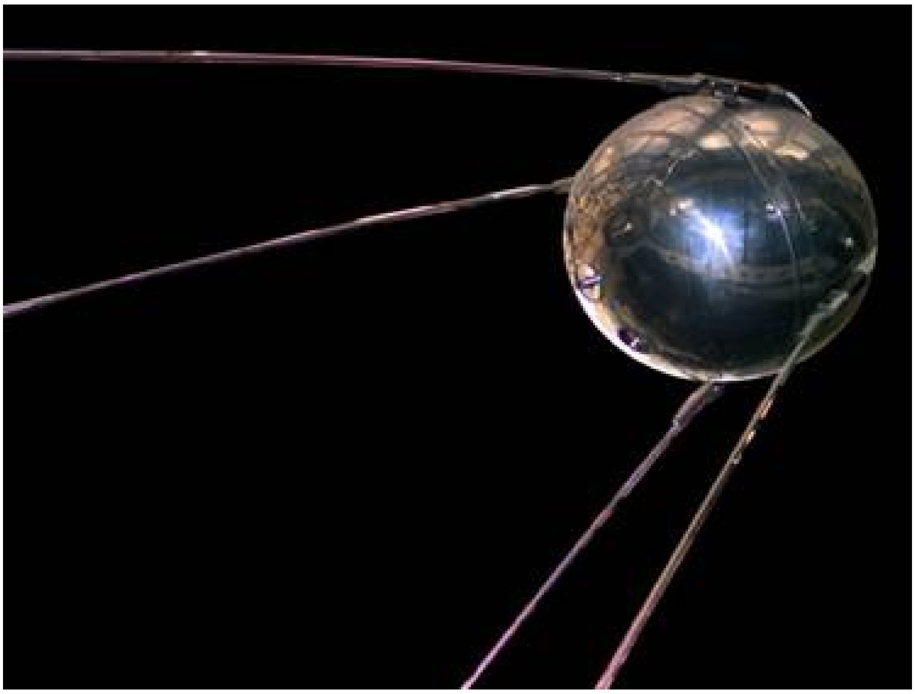
Annual Report 2007

Space Center EPFL



http://space.epfl.ch

25 April 2008

Version for public release

The picture on the cover page shows an image of the Sputnik satellite launched on 4 October 1957. The Space Center EPFL celebrated the 50th anniversary of the launch of the first made-man satellite by using this topic as theme for its traditional EPFL Space Research Day (See Section 3.3).

Table of content

Note: This document is a shortened version of the full report presented and accepted by the Steering Committee of the Space Center EPFL in April 2008.

Executive Summary

This report summarises the main activities carried out by the Space Center EPFL in 2007. The year was very active in all the Space Center EPFL domains of interest, particularly with the links with the industry, research, education, and networking activities.

Extensive contacts took place between the Space Center EPFL and its industrial and institutional members which yielded in several R&D research projects between the industry and EPFL labs. It should be noted that contracts were also placed with the academic members of the Space Center EPFL and the industry.

Among the major events, one should note the partnership renewal with Oerlikon Space for the period 2008-2010 and the new academic membership of HEVs (Haute Ecole Spécialisée de Suisse Occidentale – Valais). Promising discussions also took place with some interested Swiss space industries.

With respect to the projects managed by the Space Center EPFL, the student satellite “SwissCube” phase B was successfully completed during 2007 and phase C was started. More than 70 EPFL and HES students worked on this project during the year in the frame of either semester or Master projects. This project is raising more and more interested on the campus and is becoming an example of cooperation between different academic partners. Worth noting is the EuroNews movie which was produced in July 2007 about the SwissCube project and was aired several times on that TV channel.

The concurrent design facility (CDF) has been set up and additional funding has been secured by EPFL to complete the audio/video equipment of this laboratory. The use of proper system engineering methods was emphasised in the first lectures taught in the CDF to EPFL students. Furthermore, contacts have been established with the ESTEC CDF in order to coordinate efforts in the use of the CDF for the design of small satellites.

In the frame of the EPFL Space Research Programme, a call for PhD research raised a lot of interest at EPFL in 2007. Four proposals were selected for funding out of the many ideas received. Noting this strong interest from EPFL for space, ESA decided to finance at least two extra PhD’s at EPFL in the frame of their Networking Partnering Initiative.

The education duties of the Space Center EPFL were not neglected in 2007 and more and more students are attracted by the Minor in Space Technologies. This Minor is now becoming a very interesting option for the students in the STI engineering faculty at EPFL who wish to complement their education.

In all, the following pages report a positive year 2007 for the Space Center EPFL.

1 Space Center EPFL organisation and objectives

1.1 Origins of the Space Center EPFL

The Space Center EPFL was created in 2003 following a joint decision between RUAG Aerospace and EPFL to set up an organisation for the development of R&D, technologies, and applications related to Space at EPFL. The Swiss Space Office became the third and last founding member in October 2004. Since then, several other industries (e.g. Oerlikon Space), research centres (e.g. CSEM), and universities (e.g. HEIG-VD, University of Neuchâtel), have decided to become partners of the Space Center EPFL.

New members have joined the Space Center EPFL in 2007 as describes a bit further in chapter 2.3 of this report.

1.2 Mission, Objectives and Vision

The mission and the role of the Space Center EPFL can be described with the following motto:

> *"Fostering, promoting, and federating space technology across education, science and industry in Switzerland and internationally"*

The main objectives of the Space Center EPFL are:

- To link Swiss institutions and industries on national and international levels in order to establish focused areas of excellence internationally recognised for both space R&D and applications
- To support implementation for technology demonstration missions and scientific missions focused on areas of interests
- To become a centre for education and training for students and industry:

This set of objectives remains broad to ensure that the Space Center EPFL can undertake numerous space R&D activities and to provide some flexibility. Since the Space Center is hosted at EPFL, some of the objectives are of course linked to research and education. Worth noting is the strong link between these goals and the industrial partnership of the Space Center EPFL with the largest Swiss space companies such as Oerlikon Space and RUAG Aerospace.

The above terms have been determined by a work group constituted of members of the Steering Committee that met on three occasions from 2005-2007. They have been approved by the Steering Committee and are being implemented. Following the last meeting on 16 March 2007, a three-year vision plan was issued, presented and approved at the 16th meeting of the Steering Committee on 29 March 2007. Three main areas were finally adopted as described in Table 1:

	2007-2009
Linking universities and industries	• Facilitate and initiate 5-10 research and technology projects • Create database of university and industry knowledge and capabilities • Network broker on areas of expertise (technology survey)
Support to mission implementation	• Space experience: fly one satellite and plan the second satellite • Focus on very small satellites and planetary robots • Team building: get partner labs on permanent basis
Training and education	• Create an operational CDF (concurrent design facility) • Start offering high-quality training courses (continuing education)

Table 1: Vision 2007-2009 for the Space Center EPFL

For each of these partners, a list of requirements and needs has been derived based on the current knowledge of the partners by the Space Center EPFL. On the other hand, the current expertise available at the Space Center EPFL can be characterised by:

- Development of space technology in partnership with EPFL and other academic partners
- Space system engineering
- CDF (concurrent design facility)
- Knowledge broker and know-how
- Specific domains expertise (e.g. Earth observation, Mars exploration)

As shown in Table 2, the expertise at hand matches well the requirements of the partners, hence their interest in the Space Center EPFL.

Partners	Requirements and needs	Space Center EPFL expertise				
		Development of technology	Space system engineering	CDF	Knowledge broker and know-how	Specific domains
EPFL/ Academia	Education	☑	☑	☑		☑
	Space R&D (PhD)	☑				☑
	Technology demonstrator (SwissCube)	☑	☑	☑	☑	
SSO	Technology monitoring and survey	☑		☑	☑	☑
	Technology cross-fertilisation and expertise	☑	☑		☑	☑
	Proposal evaluation		☑	☑	☑	☑
Industry	Valorisation (technology infusion) of space R&D		☑		☑	
	New business development	☑	☑	☑	☑	☑
	Solutions to specific problems	☑	☑	☑	☑	☑
	Training and networking		☑	☑	☑	
ESA	Studies and projects	☑	☑	☑	☑	
	European networking	☑	☑	☑	☑	
	Student employer (YGT, staff) and training				☑	☑

Table 2: Requirements and needs of the members of the Steering Committee of the Space Center EPFL

1.3 Steering Committee of the Space Center EPFL

The chairman of the Steering Committee is Prof. Juan Mosig, head of the EPFL LEMA (Laboratoire d'Electromagnétisme et d'Acoustique). He has always shown exemplary willingness to advise the Space Center EPFL for management questions, and his help has been strongly appreciated during the year.

The Steering Committee underwent a few changes during 2007:

- Lino de Faveri (SSO) replaced Pascal Vinard as of the 16th meeting of the Steering Committee (26 March 2007). Pascal Vinard left the SSO on 1 April 2007.
- Ana Madrigal (CSEM) replaced Michel Roulet as of the 17th meeting of the Steering Committee (31 August 2007). Michel Roulet retired from CSEM on May 10th, 2007.
- Ueli Wieland (Oerlikon Space) replaced Umberto Somaini as of the 17th meeting of the Steering Committee (31 August 2007). Umberto Somaini retired from Oerlikon Space on 31 July 2007

These changes have not modified the overall structure and balance of the committee.

1.4 Staff of the Space Center EPFL

During 2007, the staff of the Space Center EPFL was composed of:

- Dr. Maurice Borgeaud, Director
- Mrs Muriel Noca, System engineer
- Mrs. Martine Harmel, Secretary
- Dr. Anton Ivanov, engineer responsible of the Concurrent Design facility, starting on 1 March 2007
- Mr. Guillaume Roethlisberger, engineer mostly dedicated to SwissCube, started on 1 April 2007, hired on the basis of a one-year contract.
- Mr. Fabien Jordan, engineer mostly dedicated to SwissCube, started on 15 April 2007, hired on the basis of a one-year contract.
- Mr. Ted Choueiri, engineer mostly dedicated to SwissCube, started on 1 September 2007, hired on the basis of a one-year contract.

Prof. Claude Nicollier continued to give a popular lecture at EPFL during the summer semester, in the frame of the Minor in space technologies (see Section 7.2). He was also closely associated to the work of the Space Center EPFL.

In his final year at EPFL, Piotr Skoczylas, Communication Systems Student, continued to take care of the web site and perform dedicated IT tasks until the end of 2007. He announced his departure early enough and a replacement was found and trained on time to ensure a smooth transition. The Space Center EPFL thanks Piotr for his dedication and excellent work.

A special mention should be given to the work atmosphere which was void of conflicts, allowing a pleasant and definitely enviable environment.

1.5 Organisation

The overall organisation of the Space Center EPFL, including the Steering Committee is shown in Figure 1 as per 31 December 2007.

As director of the Space Center EPFL, in 2007 Dr. Maurice Borgeaud's main task was to present a list of activities which were discussed and approved by the Steering Committee. He was responsible for the implementation of these decisions.

The student project SwissCube was managed by Mrs Muriel Noca. Three engineers were each in charge of specific sections of the SwissCube: Mr. Guillaume Roethlisberger for Mechanics, Mr. Fabien Jordan for Electrics, and Mr. Ted Choueiri for Communication System. Without their help, the satellite project would have stagnated and fallen through since the mass of work is so large it cannot be managed by one single person. The SwissCube team was in charge of supervising the assignments of more than 60 students during the year 2007. A detailed report of their work will be exposed in the section dedicated to SwissCube (see Chapter 4).

Mr. Anton Ivanov was in charge of setting up and managing the CDF, situated in room ELD-010 of EPFL. The activities of the CDF are detailed in Chapter 5.

Mrs Harmel took care of all the secretarial and administrative matters.

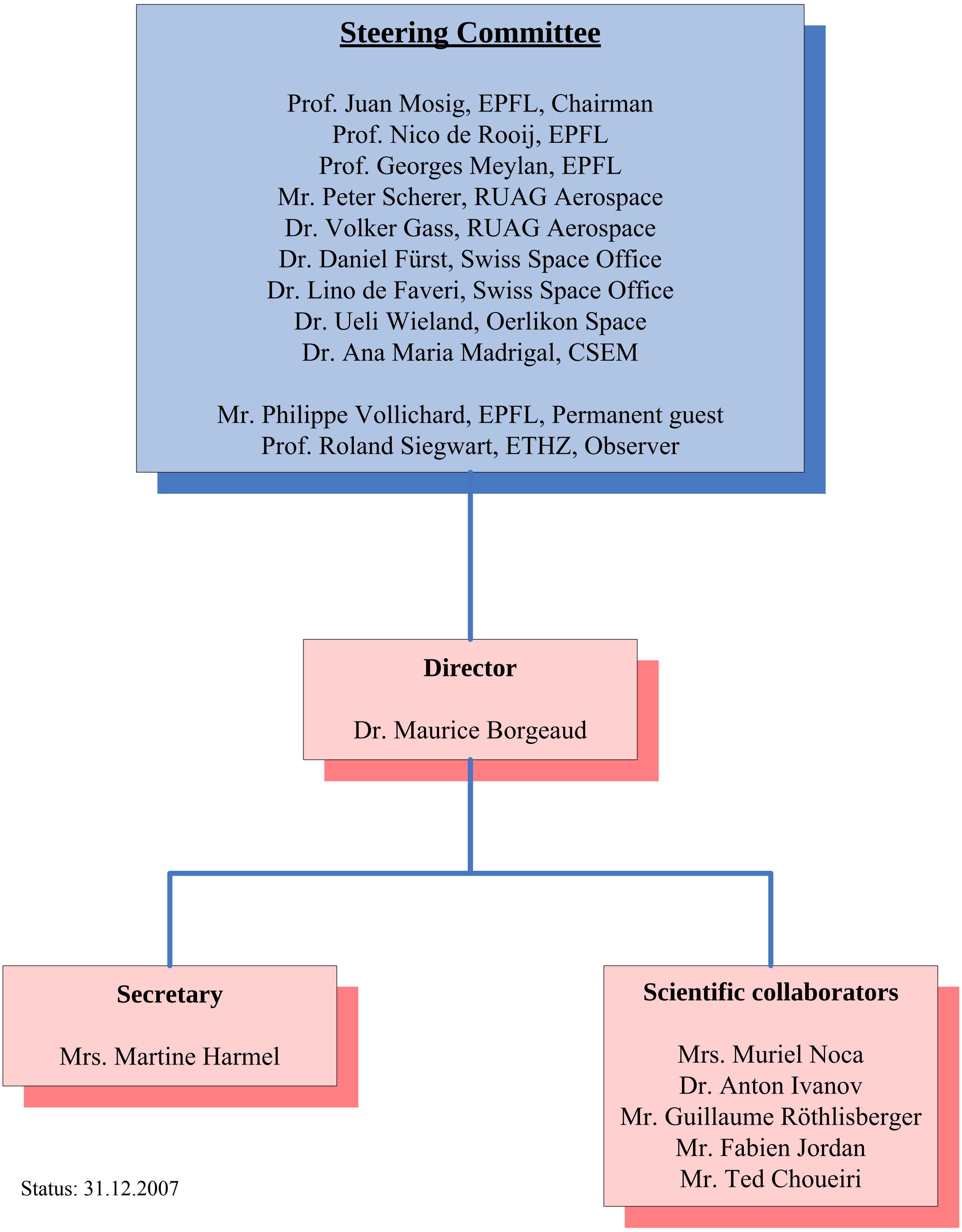


Figure 1: Organisation chart of the Space Center EPFL

2 Members of the Space Center EPFL

2.1 Reminder of Membership Rules

It is recalled that the Steering Committee of the Space Center EPFL has defined the following rules for membership in the Space Center EPFL:

The **founding members** of the Space Center EPFL are EPFL, RUAG Aerospace, SSO. No more founding members are accepted.

Permanent members participate in the Steering Committee and have voting rights. The minimum investment amounts to 125 KFrs/year (50-50% soft/hard-return) for a minimum of three years (multi-year contribution).

Members do not participate in the Steering Committee. There are 3 categories of members:

- **Academia members**. The minimum investment is 5 KFrs/year (100% soft-return).
- **Industry members**: A yearly contribution of 20 KFrs/year minimum with a 50-50% soft-hard return ratio. However, larger hard-return amounts are allowed with a minimum of 10 KFrs of soft-return.
- **Start-up companies**: 1 KFrs/year for the first two years (50-50% soft-hard return). The definition of a “start-up company” is at the discretion of the Steering Committee.

2.2 Founding and Permanent Members

In 2002, EPFL decided to consider Space as a strategic domain and, in partnership with RUAG Aerospace, the Space Center EPFL was created in 2003 to foster and promote space activities at EPFL. In addition, the Swiss Space Office affiliated to the State Secretariat for Education and Research in Berne decided to become a member of the Space Center EPFL in October 2004. The founding members of the Space Center EPFL are therefore EPFL, RUAG Aerospace, and the Swiss Space Office.

In April 2005, Contraves Space (now Oerlikon Space) decided to join the Space Center EPFL and this company become permanent member for the period 2005-2007 with voting rights in the Steering Committee.

In December 2005, the “Centre Suisse d’Electronique et de Microtechnique (CSEM)” became a permanent member for the period 2006-2008 with voting rights in the Steering Committee.

Due to its positive experience, RUAG Aerospace decided to renew on 24 May 2006 its cooperation agreement with the Space Center EPFL for an additional three-year period till mid-2009.

On 4 December 2007, Oerlikon Space and EPFL renewed their agreement for the period 2008-2010. MM. Deich and Wieland came to EPFL for a convivial ceremony with the President of EPFL, Prof. Patrick Aebischer as shown in Figure 2.

Figure 2: Signature of the Oerlikon-EPFL renewal contract on 4 December 2007 by Dr. Axel Deich, Oerlikon Space CEO (left) and Prof. Patrick Aebischer, EPFL president (right).

The renewal of the contract between Swiss Space Office was discussed on several occasions in 2007 and should lead to a new fruitful collaboration for the period 2008 - 2011.

2.3 New Members in 2007

2.3.1 Academic Members

Successful negotiations took place at the end of 2006 between the Space Center EPFL and the "Haute Ecole Spécialisée de Suisse Occidentale – Valais (HEVs)" which yielded to a cooperation agreement as academic partner in February 2007. Prof. Martial Geiser is the official representative of HEVs.

With "Haute Ecole d'Ingénierie et de Gestion du Canton de Vaud", HEIG-VD, that signed in March 2006 and the University of Neuchâtel, UNINE, that signed in June 2006, and now the "Haute Ecole Spécialisée de Suisse Occidentale – Valais (HEVs)", the Space Center EPFL is succeeding in federating a community of academies around Space technologies. This was one of the tasks assigned by the SSO to the Space Center EPFL.

As shown in Figure 3, the Space Center is starting to have numerous relations with other schools and industries while the network of partners of the Space Center EPFL in Switzerland is illustrated in Figure 4.

2.4 International collaboration

Active discussions took place between the Space Center EPFL and two major international key players in the space domain:

NASA-Ames

There have been intensive discussions during Spring and Summer 2007 with NASA. Dr. Butler Hine from NASA-Ames came to visit EPFL on 21-22 June 2007. A MOU is still being considered but is signature depends on NASA-HQ authorisation, presently working on the topic.

Bauman Moscow State Technical University

This university is on the leading Russian institution active in space. Since Russia is considered as a privileged partner during the period 2008-2011 by the Confederation, EPFL is investigating domains of cooperation with that university and space as been identified as a key domain of interest by both parties. A Russian delegation visited EPFL in May 2007 and a Swiss delegation has been invited to Russia in 2008. These preliminary contacts shall yield to new domains of cooperation.

Figure 3: The Space Center is starting to have numerous relations with other schools and industries.

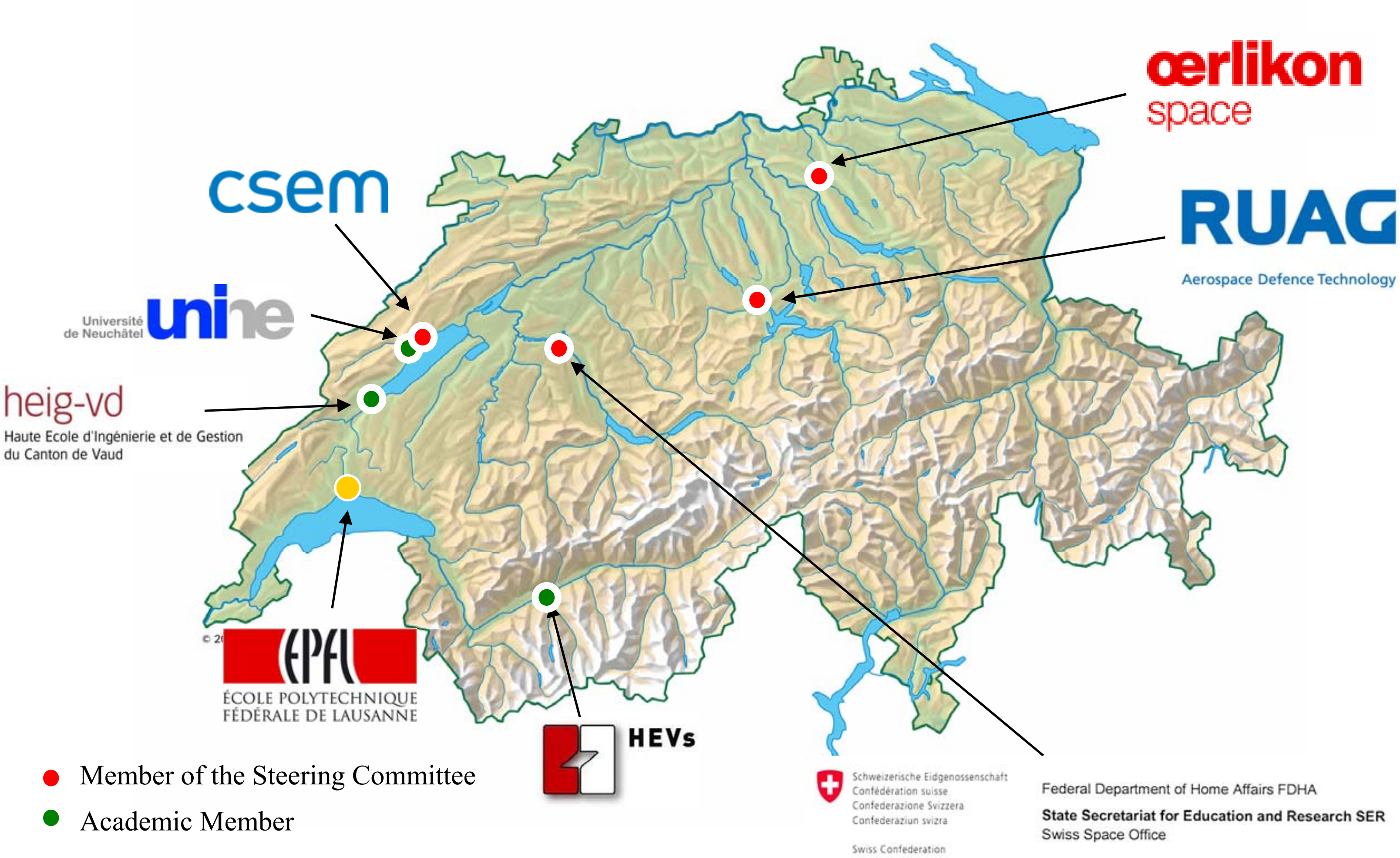


Figure 4: Position of the Space Center EPFL in the Swiss space landscape

3 Activities

3.1 General activities

Most of the activities of the Space Center EPFL in 2007 can be split in the following domains:

- SwissCube student satellite (see Chapter 4)
- Concurrent design facility (see Chapter 5)
- EPFL Space Research Programme (See Chapter 6)
- Minor in space technologies (See Chapter 7)
- R&D activities between industry and EPFL labs (See Chapter 8)

As indicated, these activities are the subject of detailed chapters/sections in this report and are not further developed here.

3.2 Communication activities

Table 3 summarises the list of events attended by the Space Center EPFL in 2007.

A classification is made based on the fact whether the event was organised by the Space Center EPFL, whether a presentation was made by the Space Center EPFL, or whether the Space Center EPFL simply participated in the event.

Some of these events are in addition detailed in Section 3.3.

Date (in 2007)	**Type**	**Event**
18-25 Jan	Newspaper articles	SwissCube articles in « 24 Heures » and « L'Hebdo»
23-24 Jan	Presentation	Meeting with representative of the Tsinghua university (China)
23-27 April	Symposium	ENVISAT Symposium in Montreux (local organiser)
9 May	Presentation	Hyper-Swiss-Net meeting (preparation of a proposal to CUS/CEPF for hyper-spectral data)
14 May	Newspaper article	Article in "24 Heures" related to the

Space Center

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

		EPFL Space Research Programme
30 May	Presentation	Meeting Prof. Federov, Bauman Institute, Moscow
15 June	Presentation	EPFL Erasmus Students
19-20 June	Filmed report	EuroNews video shooting
19-21 June	Presentation	Trinationale Jahrestagung 2007 der SGPBF, DGPF und OVG in Basel.
21-22 June	Discussion	Visit Dr. Butler Hine, NASA-Ames
23-27 July	Symposium	IEEE Geoscience and remote sensing symposium, Barcelona§
1 Sep	Newspaper article	SwissCube article in "Technoscope", publication of the Swiss Academy of Sciences
4 Oct	Conferences	The 3rd EPFL Space Research Day, dedicated to the 50th anniversary of the Sputnik launch, coupled with the Innovation Day in the evening, brought a good publicity upon the activities of the Space Center EPFL.
4 Oct	Interview	Interview by Maurice Borgeaud with "Radio Suisse Romande" related to the 50th anniversary of the Sputnik launch
12 Oct	Newspaper article	SwissCube article in the "Tages-Anzeiger"
3 Nov	Conference and exhibit	Participation of the Space Center EPFL in the "Space Forum 2007" organised by the Swiss Astronautics Association (SRV)
4 Nov	Exhibit	Participation of the Space Center EPFL in the "Claude Nicollier" price organised by the Forum Engelberg

15 Nov	Discussion	The head of the ESA education office, in charge of referencing Space oriented schools in Europe, started his tour by visiting the Space Center EPFL. This person is also in charge of the educational payload on VEGA
29 Nov	Interview	Interview by Maurice Borgeaud with “Radio Suisse Romande” related to the space acitivities

Table 3: Communications activities in 2007

3.3 Special events

3.3.1 ENVISAT Symposium in Montreux 23-27 April 2007

More than 900 scientists from around the world have gathered in Montreux in April 2007 for a five-day symposium to discuss, present and review their findings on the state of our world's land, oceans, ice and atmosphere using data from ESA Earth observation satellites, in particular ENVISAT - the largest environmental satellite ever built by ESA. As local organiser, the Space Center EPFL played a key role in hosting this event in our country and promoting the use of Earth observation data.

3.3.2 Third EPFL Space Research Day

The third EPFL Research Space Day took place in the afternoon of Thursday October 4th, 2007, in celebration of the 50th anniversary of the Sputnik launch (see Figure 5). The topic that had been chosen was “Early days of space exploration and visions for the future”. The event was combined with the 2nd EPFL Innovation Day that was held in the evening.

The **3rd EPFL Space Research Day** had been advertised through an article in the EPFL newspaper “Flash”, EPFL web announcement, posters on the campus and special invitations sent by mail to the members of the space industry and partner academies. It was a public session.

An audience of 60 people, mostly Swiss space industry members, such as RUAG Aerospace, and students, were captured by the exceptional quality of the presentations brought up by distinguished speakers from JPL/NASA, ESA and the Swiss Space community.

Mr. Carl Raggio, 85 years old, made the trip to Europe especially for the EPFL Space Research Day, upon an invitation of the Space Center EPFL. He recalled his work as a scientist active in the development of Explorer 1 at the Jet Propulsion Laboratory (JPL) in 1957. During his extraordinary 30-minute speech he notably reminded the audience of the conditions of Space exploration, at a time where NASA did not yet exist.

Special attention was given to the context of building the first man-made satellites back in 1957 and to how satellites are built today. While the political and economic aspects have drastically changed, the technological challenges remains as scientists permanently strive to push limits further.

Figure 5: Programme of the 3rd EPFL Space Research Day

The **2nd EPFL Innovation Day** was free but registration mandatory. It gathered more than 300 people, amongst which EPFL president, Prof. Patrick Aebischer, EPFL vice-presidents and the "conseillière d'Etat", Mrs Jacqueline de Quattro. Special mention is to be given to the fact that, although the Innovation Day is meant to celebrate innovation at large at EPFL, a substantial part of the event was dedicated to Space.

Dr. Maurice Borgeaud gave a speech about the mission and objectives of the Space Center EPFL.

Mr. Carl Raggio was invited to reiterate his speech of the afternoon, which he did with great ease and more detail, winning the hearts of the audience.

The Space Center EPFL had invited, early 2007, Mr. Oleg Ivanovsky, 85 years old, to attend the meeting. His presence would have been greatly appreciated since he had been one of the early players of man-made satellites on the Russian side. He worked with Korolev on Sputnik, and even closed the door behind Gagarin on the Vostock rocket. Mr. Ivanovsky had warned the Space Center EPFL early enough during the year that he would unfortunately be unable to attend the meeting for health reasons. Mr Anton Ivanov of the Space Center EPFL, organised a trip to Moscow a few months before October 4th to meet Mr. Ivanovsky at his home and interview him with a crew of cameramen. He brought back a filmed report that was presented during the Innovation Day and greatly appreciated.

Finally, Prof. Claude Nicollier made a beautiful presentation on Space and Space technologies, with his unique ability of bringing an entire audience of its feet. After such pictures, everyone would volunteer to become a spacewalker.

The Space Center EPFL acknowledges the excellent upstream preparation work done by Mrs Muriel Noca and Mr Anton Ivanov for finding such distinguished speakers, respectively Carl Raggio and Oleg Ivanovsky. The conference would not have been half the success it was if it had not been for their help. This day was a great resonance chamber for the Space Center EPFL.

3.3.3 ECSS Training course

Following a survey of Swiss industries involved in the Space branch, the Space Center EPFL organised a training course on the space standards developed in the frame of the European Cooperation for Space Standardization (ECSS). The training took place on 27-28 November 2007 at EPFL with lecturers from ESA/ECSS (see Figure 6).

An initial contact with Swiss space industries showed a large interest in the topic (30-40 participants). Two “free seats” were reserved for each member of the Steering Committee and one for each academic member.

There were 34 participants (31 from industries, 3 from universities), with a large participation of RUAG, Oerlikon, and CSEM. People from SpectraTime (ex TNT), Montena EMC, and Realtechnologie AG were also present. In general, participants appreciated the course but a few found it too theoretical and would have preferred a more application-oriented approach.

Though the relatively low fees to attend such a two-day course (500 Frs including lunch and presentation material), the cost to organise such a course were completely covered by the registration feeds.

Figure 6: Picture taken during the ECSS course

3.4 Web site

The web site of the Space Center EPFL (http://space.epfl.ch/) was very regularly updated with news, relevant information and announcements.

In addition, the SwissCube website (http://swisscube.epfl.ch) was totally re-structured and is regularly updated namely with new semester and master projects.

In his final year at EPFL, Piotr Skoczylas, Communication Systems Student, continued to take care of both web sites and perform dedicated IT tasks until the end of 2007.

The home page of the web site of the Space Center EPFL as per December 2007 is show in Figure 7.

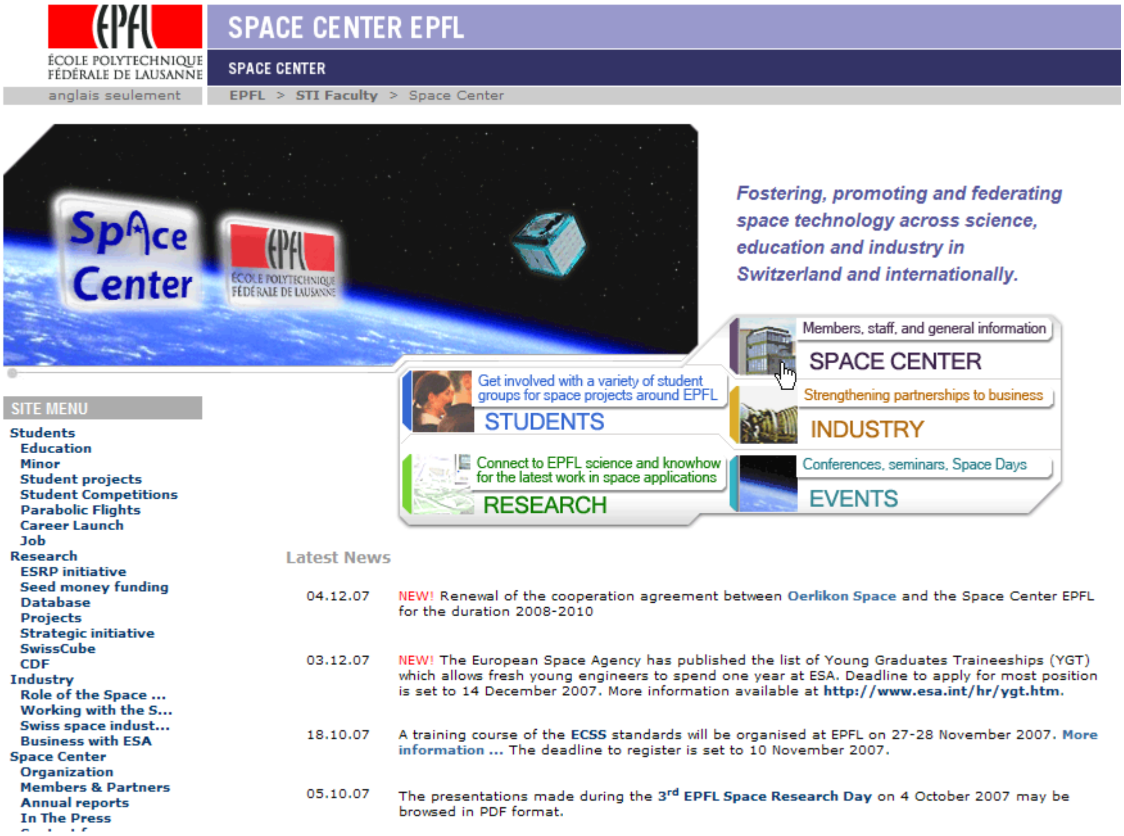


Figure 7: Home page of the Space Center EPFL, status December 2007

4 SwissCube

The year 2007 was filled with major milestones for the SwissCube Project. The sections below address the management, technical, and PR accomplishments and status for 2007.

4.1 Management Significant Accomplishments

4.1.1 Project schedule, reviews and workforce

The project has made progress and has seen in 2007 the end of Phase B and the beginning of Phase C in the development of the satellite (see Figure 8). Phase B was concluded for part of the satellite's subsystems during the Preliminary Design Review (PDR), held on March 5-6, while the rest of the subsystems concluded their Phase B activities during the Delta-PDR on Sept. 3-4.

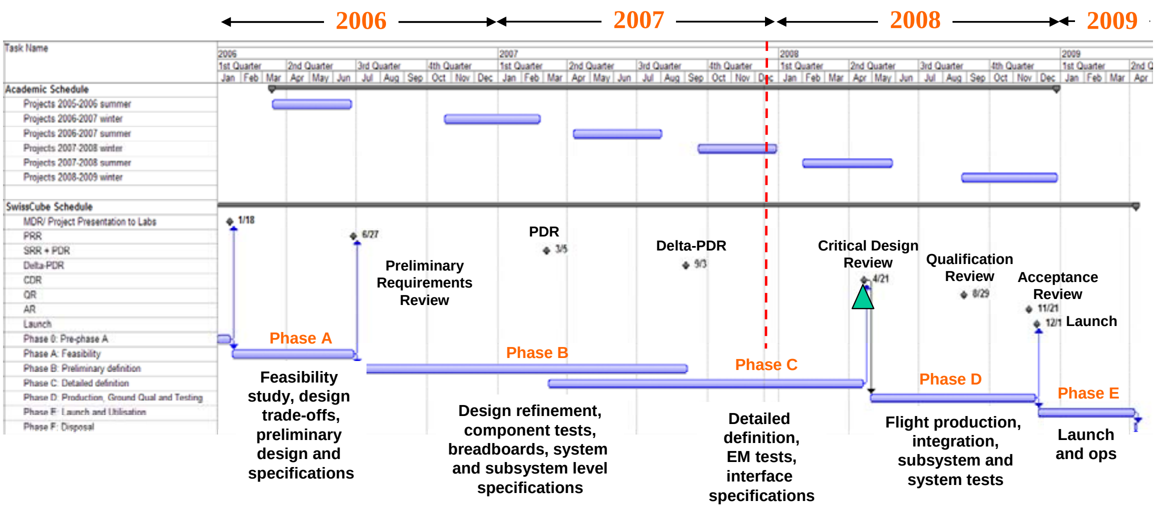


Figure 8: SwissCube Schedule

About 10 reviewers attended PDR (see Figure 9) including: Neil Melville (ESA-ESTEC), Christoph Steiger (ESA-ESOC), Abe Bonnema (TU Delft, Delphi C3 Cubesat), Karl Laursen (Aalborg University, AAU Cubesat), Peter Wild (RUAG-Aerospace), Mikael Sjöholm (RUAG-Aerospace), Pasquale Lombardi (Syderal), Christophe Bianchi (HES-SO/HEV) and Maurice Borgeaud (EPFL). The first day assessed the status of development of the satellite and second day of the flight software and ground system. About 120 review comments were combined in a database, with associated action items. The major management comments were that the project is lacking system engineering coherency, and that a full time job on verification of the interfaces is needed.

In response to this lack, the decision was taken to hire 3 system engineers (one to supervise all mechanical work, another to supervise all electrical work and a third to supervise all data related interfaces). Their job is to coordinate the work done by the laboratories, verify and apply consistency of design at the system level, review subsystem documentation, write system documentation and plan for and perform system level tests. Two of the system engineers started in April 2007, and the third one in September 2007. Soon after PDR, the project created the System Engineering Team (SET), which is composed of 8 students and engineers that ensure consistency of the project at the system level.

The Delta-PDR assessed the remaining items from PDR without any major problem and the decision was taken to move to Phase C (Figure YY). The reviewers were: Christoph Steiger (ESA-ESOC), Pierrik Vuilleumier (ESA-ESTEC), Karl Laursen (Aalborg Univ., AAU Cubesat), Youssef Belgued (ELCA), Ernest Kopp and Maurice Borgeaud (EPFL).

About 35 students per semester (above and beyond the SET) participated in the activities. About 1/3 of them continued over from one semester to the other to perform their Master project (diploma work).


Figure 9: Delta-PDR, Sept. 3-4, 2007

The project officially became an EPFL-HomoFaber project. The mechanical section at EPFL has in 3rd year a mandatory project in Mechanical Engineering, called HomoFaber. SwissCube was added to the list of options offered to the students. About 8 students worked their 4 credits on SwissCube.

4.1.2 International activities

The project also attended International technical interchange meetings. Two engineers presented the project to the CUBESAT Community Workshop on April 27-29 at Cal Poly in San Luis Obispo, California. Very valuable information was brought back regarding the design of cubesats. The project attended the Kaiser-Threde 2nd KAP Costumer Day meeting November 19-20, to start preliminary contacts with KAP (see Figure 10). Kaiser-Threde is responsible for finding secondary payloads on the ESA VEGA launch vehicle qualification flights (VERTA flights). The project looked at flight option and interface requirements.

The project also had several contacts with ESA experts on batteries and solar cells.

Figure 10: Kaiser-Threde 2nd Costumer Day

To get expertise in the domain of radio-amateurism and help in setting up of the EPFL ground station, the project contacted the Radio Amateur from Vaud and established a plan for cooperation. The radio-amateur of the Fribourg canton were also contacted and participate in the HE-Fr ground station. Both communities are very active in the project now.

4.1.3 International Registration

Regarding the legal aspects of the project, we started the registration procedure with OFCOM, ITU, and IARU in order to obtain the proper satellite international registration and frequency allocations. The frequencies are now allocated for SwissCube. International registration is pending.

4.1.4 Launch Provider

The project also nailed down the Launch Provider to 2 launch options: either on the ESA VEGA Maiden Flight or on an Indian PSLV vehicle. The ESA VEGA maiden flight is, according to ESA, scheduled for December 2008. The Indian PSLV offer a launch end 2008 and beginning 2009. This launch is coordinated by ISIS, a spin-off company of Delfi C3 in the Netherlands. The details still need to be worked out for both launch options. The CalPoly negotiations with DNEPR did not reach agreement for 2008, and they now propose a launch in 2009 with DNEPR.

4.1.5 New industry ties

New industry ties were created with Dynatec, which will provide the Antenna Deployment System material and fabrication. We visited the Physics Institutes in Basel to discuss Latch-up protection strategies. And a small company located near Fribourg provided mentoring and EMC expertise for 2 full days with a preliminary review of all the electronic design and also tests of critical areas. Further EMC testing will be done with Montena EMC on the Qualification model of the satellite.

4.2 Technical Significant Accomplishments

2007 was a year of design and verification at subsystem level. Several functional tests, critical element thermal and vacuum tests, outgassing tests were performed. Several critical elements such as batteries, RF quartz and power amplifier, solar cells were also tested in various environments.

2007 was also a year of catching up with delays accumulated in 2006, especially in the area of Flight software and Beacon design. A tested integration model of the beacon board was delivered to the Space Center EPFL in November 08 by the HES-Fribourg, after just 2 semesters of work.

And finally, 2007 was a year of redesign of some subsystems. The Antenna Deployment System was redesigned as tests showed that the design ended up not being redundant (see Figure 11). The communication board had to be partly redesigned as the modulation implemented in the first place required a signal over noise ratio too demanding for the rest of the system to accommodate (from AFSK modulation to FSK-SSB). After the PDR review, there was also a significant change in the attitude determination sensors, more specifically the gyroscopes and magnetometers. These had been previously selected for power and operating voltage reasons but their performances appeared to be not sufficient as shown by the simulations. New sensors were selected and implemented. The control algorithms were also greatly simplified, work perfectly and now allow a low rotation rate of the satellite, as required. Early in the year, a selection between the SPAD and a regular CMOS payload detector had to be made in favour of the CMOS as the SPAD development was experiencing significant delays.

A new technique of solar cell soldering on the PCB faces of the satellite was tested in depth. Several layout for the solder mask were fabricated. Each of these design was tested by thermal shocks at the LMTS Laboratory and then verified in detail with non-destructive tests at the HEIG-VD END laboratory (see Figure 12).

New developments also had to be made for the kill switch, as the type proposed by industry had material not compatible with space standards. Thus a new design was built and tested, and does fit within the specifications.

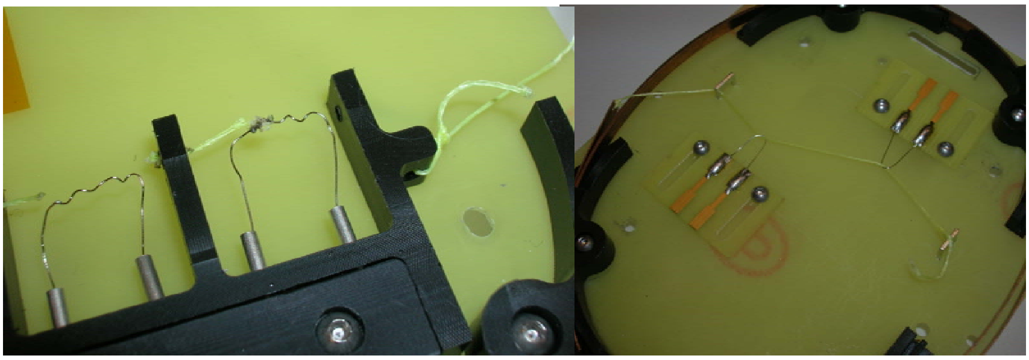


Figure 11: Antenna Deployment System redesign.

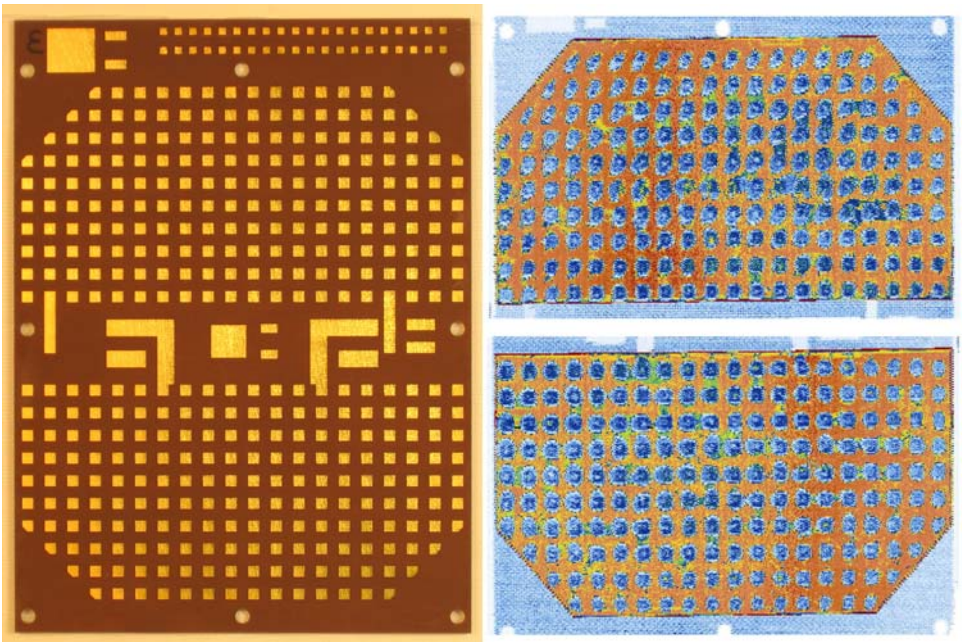


Figure 12: Non destructive tests on a solar cell layout

4.2.1 Structural Verification

The structural verification of the STM was performed at Astro- und Feinwerktechnik Adlershof GmbH, DLR, Berlin, in Aug. 07 (see Figure 13). This verification included vibration and shock tests at qualification levels. These tests were organized and financed by RUAG-Aerospace. The STM survived as specified the environment.

Figure 13: Structural verification at Astro- und Feinwerktechnik Adlershof GmbH.

4.2.2 Thermal cycling and shock verification

Thermal vacuum cycling tests were performed at RUAG-Aerospace in Nyon, in September 07 to verify the thermal design of the STM and battery box (see Figure 14). This test showed that additional measures had to be taken to ensure that the STM would see the full range of qualification temperatures. It was followed by several other smaller tests that helped with the characterization of the performances and thermal behavior of critical components. All of these tests were done in Nyon.

Thermal shocks were also performed on solar cells in November 08 at the LMTS with 900 cycles reached, about half of the mission time. Other components were tested such as sun sensors and solder joints.

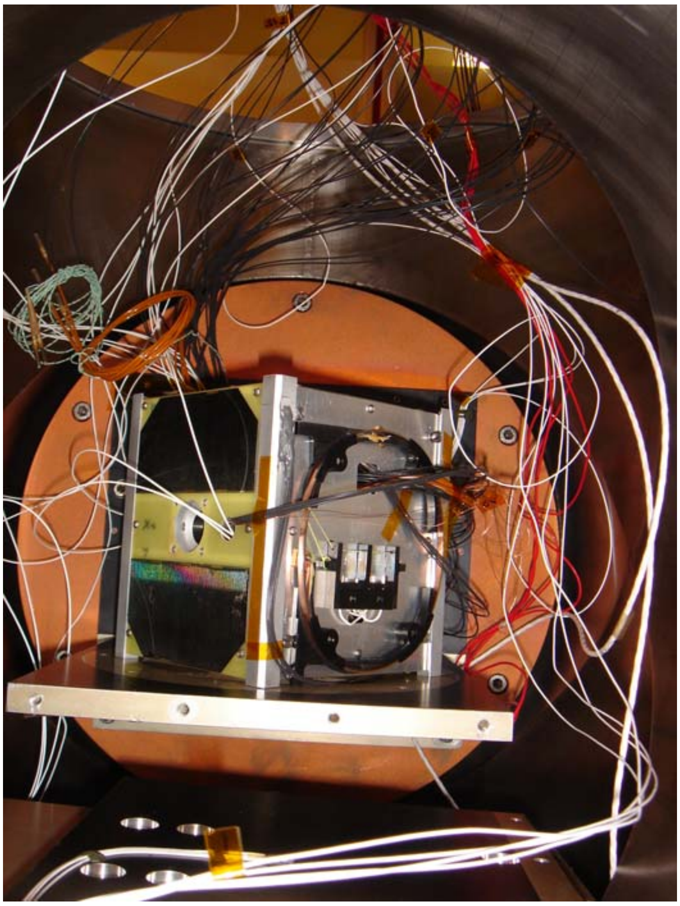


Figure 14: STM thermal testing at RUAG-Aerospace Nyon.

4.2.3 Software developments

Too catch up with some delays in the area of ground and flight software, two (excellent) students were sent to ESA/ESTEC for 4 months. They worked with EGSE team and developed the core of the Mission Control System, databases, and router (see Figure 15). The core is based on a simple MS .net product. The EGSE team at ESA wants to continue development of this approach as an option to simplify current software.

In 2007, the on-board flight software architecture was also defined (see Figure 16). It is based on a very simple approach, where knowledge is on the ground. Most of the functions are defined, as well as most housekeeping parameters. The software functions were installed on the Electrical Power System micro-controller and developed for the Command and Data Management subsystem.

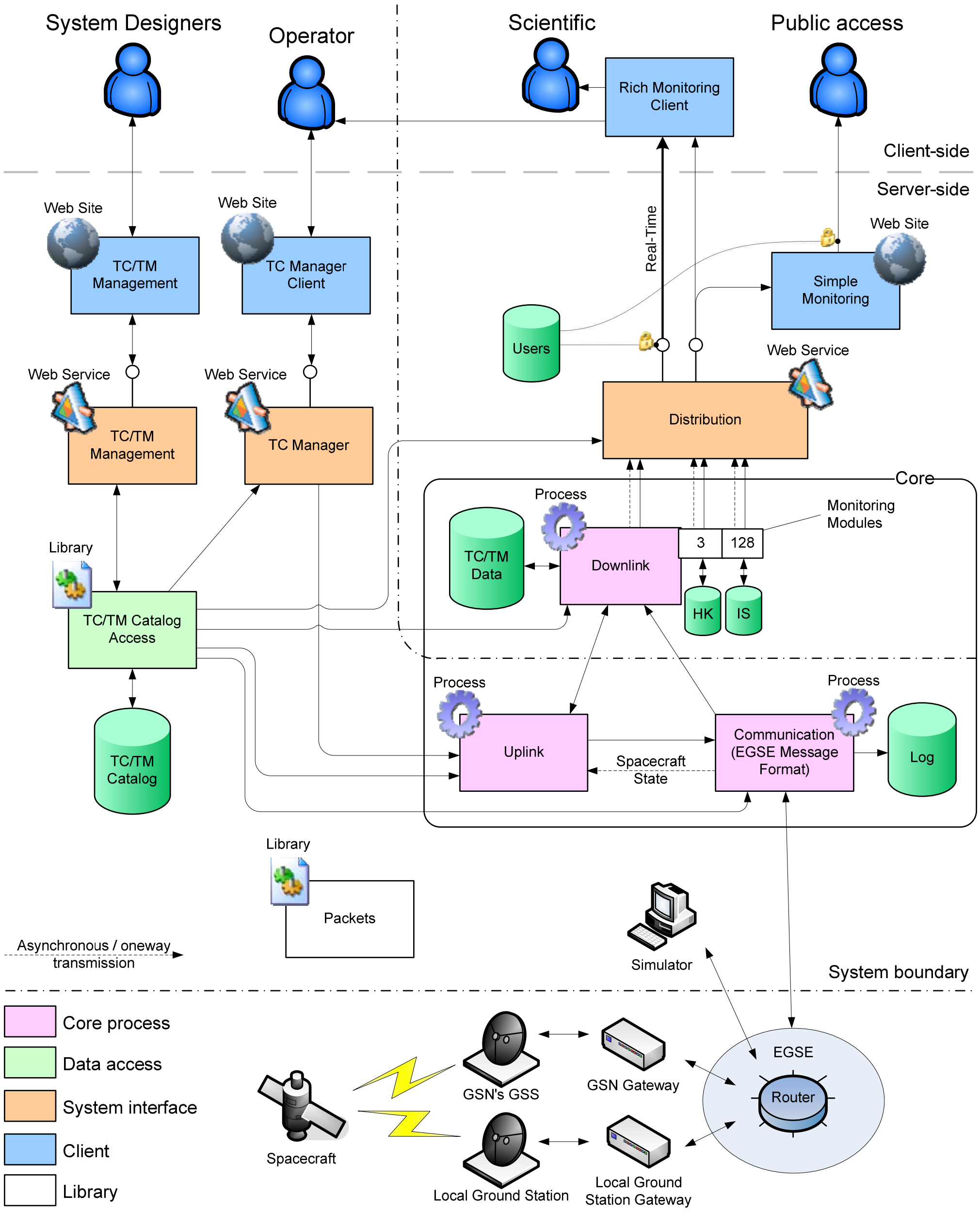
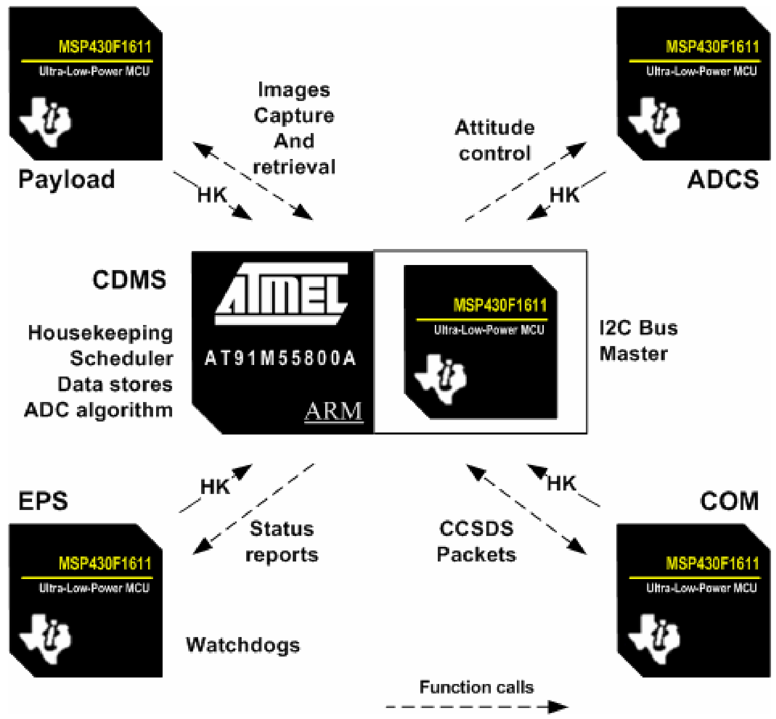


Figure 15: SwissCube ground software architecture.



EPS microcontroller board temperature						
HK id	TBD		**Subsystem**		EPS	
Name	HK_EPS_PCB_MC_TP		**Unit**		Degree Celsius (°C)	
Description	EPS microcontroller board temperature					
Sampling minimum	0.1 Hz		**Type**		Sensor	
Raw parameter code	**PTC**	Signed integer	**PFC**	4	**Bit size**	8
Engineer parameter code	**PTC**	Signed integer	**PFC**	4	**Bit size**	8
Calibration type	None					
Calibration	-					
Danger Low	-30		**Danger High**	60		
Warning Low	-20		**Warning High**	50		
SID	SID_EPS_RT SID_EPS_AR SID_EPS_COMPLETE_RT SID_EPS_COMPLETE_AR					
Remark	Chip type : LM94022 GS = 01 Gain: 1V/V Tmesured-min = → Umsp-min = 1955mV Tmesured-max = → Umsp-max = 301mV					

Set the ADC algorithm frequency				
Function id	0x44		**Subsystem**	CDMS
Name	FCT_CDMS_SET_ADC_FREQUENCY			
Description	Set the ADCS algorithm execution frequency			
Application data				

FunctionId	Frenquency
Enumerated (1 octet)	Unsigned integer (1 octet)
FCT_CDMS_SET_ADC_FREQUENCY	

Parameters	**Name**	FunctionId	**Bit size**	8
	Description	The id of the function.		
	PTC	Enumerated (2)	**PFC**	8
	Value	FCT_CDMS_SET_ADC_FREQUENCY		
	Name	Frequency	**Bit size**	24
	Description	Count of ticks between two ADC algorithm execution		
	PTC	Unsigned integer (3)	**PFC**	4
	Value	Any count of ticks. A tick is 62.5ms as per [N4]		
Execution condition	None			
TC verification errors	**Subtype**		**Error code**	
	Acceptance		ERR_MISSING_PARAMETER	
Remark	The CDMS cannot guarantee that it can respect the exact frequency if the chosen one is higher than it's currently available processing power. A value of 0 indicates that it must execute the ADC algorithm with the higher frequency possible. The minimum frequency is 0.063hz (delay of 15.9375s with 255 ticks).			

Figure 16: SwissCube Flight Software architecture.

4.2.4 Ground Stations

The radio-amateur ground station at HE-Fribourg was refurbished and tested. Communication FM with the radio-amateur satellite OSCAR 27 was successful in uplink and downlink. The digital part of the communication remains to be tested. The link margin is good but not 10 dB at low elevations as required, and we will evaluate possibility of enhancing the reception part in 2008.

4.2.5 New Technologies associated to SwissCube

New technologies in development for Pico-Sat platforms were started this year. The first area is in inertia wheels. No off-the-shelf motor could drive SwissCube's inertia wheel, due to efficiency and size constraints. Permanent magnet synchronous motors have been developed due to their high efficiency. This was done by the LAI Laboratory of Prof. Perriard.

Lead free soldering has also been investigated. This is a new technique that has no space heritage. Thermal shock tests were done with lead and lead free to compare both options.

As discussed previously, the solar cell soldering technique is also a new development for space applications.

And finally, it was seen over the course of the year that SPAD detectors and flexible PCBs are technologies that could be tested on the next satellite but would not be ready for SwissCube.

4.3 Public Relation (PR) Significant Events

The project organized several student presentations at EPFL Polydome in January and June, to RUAG apprentices in October, in Luzern in November, and at all HES in November. The students also organised a booth at VIVA Poly at EPFL in June.

Two movies were also produced. The first one was a part of the EPFL movie for "La Magistrale", which started and ended with SwissCube animations. The second one was produced by EuroNews and stayed for 6 weeks on the first page of their website (see Figure 17).

Figure 17: SwissCube on EuroNews.

5 Concurrent Design Facility

5.1 Introduction

The concurrent design facility (CDF) is an environment where engineers of different specialties come together to perform system engineering studies for a project. The design process is facilitated by the co-location of specialists in one room with access to all necessary information and tools, and special software that enables instantaneous data exchange during the design process. CDFs have been founded at ESA and NASA research centres as well as in the industry. These facilities are widely used to conduct preliminary design studies to estimate costs, consider trade-offs and review proposals. One of the main goals of the CDF at EPFL is to give students the opportunity to tackle complex projects and develop their skills in system engineering, thus enhancing their level of education.

5.2 Funding and personnel

In the frame of the EPFL "Fonds d'Innovation pour la Formation (FIFO)", the Space Center EPFL made a proposal in March 2006 to build a Concurrent Design Facility (CDF). The board of directors gave a good reception to this new idea and decided to fund it for the period 2007-2008. This funding mainly meant to cover the salary of a CDF engineer for two years. In parallel, a request to purchase the necessary infrastructure and the computer equipment was also approved by EPFL in the frame of a "Crédit hors-enveloppe". Additionally, the STI faculty has approved in 2007 purchase of additional audio/video equipment.

With the arrival of Dr. Anton Ivanov in March 2007, the setting up of the room could begin. Dr. Ivanov was chosen mainly for his proficiency in CDF environments since he came directly from JPL where he was part of the very successful CDF team.

5.3 Perceived relevance of CDF

The primary direction for development of the CDF at EPFL is to improve of quality of student education and give them unique experiences that are not available at other institutions. Students will receive experience in working in a group in addition to working on their own assignment. They also acquire important communication skills (speaking in front of the group, preparing a presentation, listening to others). CDF is also used to support SwissCube project and will be used extensively for design phase of future satellites. This facility can be used as a project design centre for large education and industry projects. We foresee cooperation with other CDFs, especially the one at ESTEC. We are aiming to be compatible with ESA facilities and standards to allow design studies for ESA in our facility.

5.4 CDF implementation

All of the computer equipment has been installed during 2007, connected to EPFL network and authentication services as shown in Figure 18. CDF contains 10 desktop computers, 3 powerful workstations (mainly for CAD applications and complex calculations) and 2 servers (can be used for extensive calculations and data storage). There are also facilities for connecting laptops to the network and projectors. 2 more projectors, SMART boards are purchased and will be installed in early 2008 using EPFL funding.

All computers have a standard set of software installed, which includes Microsoft Office, Matlab, STK (satellite visualization kit), LabView and other engineering suites that are necessary to perform calculations for satellite design. Through EPFL licensing CDF has access to CATIA and COMSOL software suites. In addition to the above, we have installed a student version of the CDF that has been developed at ESTEC. This version has been significantly improved by Dr. Ivanov to allow more efficient exchange of data. CDF software allows efficient interfaces with Matlab, STK and CAD applications as well data sharing between different stations with Microsoft Excel interface.

Figure 18: View of the CDF EPFL during the first phase of installation.

5.5 CDF utilisation

Immediately after computers were installed they were employed by the students working on the Swiss Cube project. The environment becomes immediately active. The first use of CDF in curriculum was by Mrs. Muriel Noca in her system engineering class followed by Dr. M. Borgeaud in his remote sensing class (see Figure 19). This class had approximately 46 students, which were split into 6 different groups. The first test was very successful and there were plenty of lessons learned from this exercise. Considerable changes were implemented and allowed efficient preparation for new projects coming into CDF in 2008. Tasks that have been carried out during 2007 are shown in the Gantt chart (Fig. 3). CDF Computer Setup task has been completed, with the remaining task of setting up new Video equipment. Support for Space Center project has been provided starting in summer of 2007 and new projects have been initiated in the fall.

Figure 19: First session at the CDF for Dr. Borgeaud's remote sensing class.

5.6 Near future plans

It became clear at the end of 2007, that the CDF would not only attract space projects, but also other complex EPFL projects such as HomoFaber projects Faux Dufaux (the replica of a 1910 plane that will be flown by Claude Nicollier) and Hybrid MotoBike (an highly economical motorcycle), and an ENAC project "Life support system for a Manned Mars Mission". Preparatory talks have been held in November of 2007 and these projects are now expected to conduct their studies in the CDF during the spring semester of 2008. Video equipment that will allow efficient switching of computer screens and SMART boards will be installed early in 2008 and this will complete hardware installation of the CDF. Towards the end of 2008 we plan to support study for one of the Space Center's industry partners as well attract new classes taught at EPFL into the facility. The schedule of these activities is shown in Figure 20.

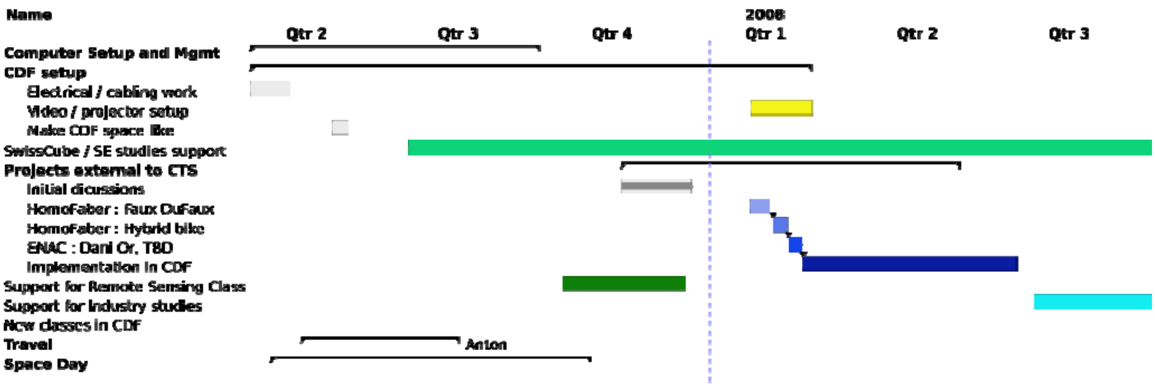


Figure 20: Tasks and schedule for the EPFL Concurrent Design Facility.

6 EPFL Space Research Programme

The need for funds to finance PhDs was met in 2007 by two parallel grants: one coming from EPFL with the Strategic Initiative and one originating from ESA with the Networking-Partnering Initiative.

6.1 EPFL Strategic Initiative

Prof. Roland Siegwart, former Chairman of the Space Center EPFL Steering Committee was the first to mention the possibility of proposing a strategic initiative to EPFL board of Directors in 2005. This idea was carried out in 2006 by the Space Center EPFL. The Strategic Initiative was officially presented by Prof. Juan Mosig and adopted by the EPFL board of Directors in December 2006.

The main goals of this program of work would allow the Space Center EPFL to focus and expand its research activities in a few emerging domains of key importance for which EPFL expertise does already exist such as:

- Micro/nano/pico satellites
- Space sciences and planetary exploration
- Earth observation

6.2 ESA Networking-Partnering Initiative (NPI)

In parallel to this, ESA launched the « Networking-Partnering Initiative » (NPI) with the goal of co-sponsoring PhDs in the space domain in European universities.

ESA expressed strong interest in the outcome of the EPFL strategic initiative in favour of the Space branch and was willing to provide EPFL with additional funding for some5 PhD theses through a frame contract. The ESA NPI theses conditions were set as follows:

- 30 K€/year for max. 3 years (90 K€ per thesis)
- A mandatory 6-month training at ESTEC during the studies
- IPR owned by EPFL but a RTU granted to ESA

6.3 Ph.D. Call for Proposals and Evaluation

A joint ESA/EPFL call for PhD research proposals in the Space domain was published on 5 April 2007. 23 proposals were received before the deadline which had been set to 1 June 2007. The proposals ranged from robotics to informatics, physics, mechanics, and system engineering. 22 different labs wrote a proposal, one lab proposing two PhD's.

The evaluation committee was made up of 10 people:

- 1 ESA representative: Jörg Wehner

- 3 Representatives of the Swiss space industry: Volker Gass from RUAG Aerospace Michel Roulet from CSEM and Umberto Somaini from Oerlikon Space.
- 1 Swiss Space Office representative: Lino de Faveri
- 5 persons from EPFL: Juan Mosig, Jacques Jacot, Bertrand Merminod, Muriel Noca, and Maurice Borgeaud

The Committee met on 9 July 2007 and ranked the best proposals using a list of criteria mentioned in the call. The committee submitted a recommendation to ESA and EPFL. The final decision was taken by ESA and EPFL and the official announcement was made on 30 October 2007.

The selected theses are shown in Table 4 and are split according to the EPFL-ESRP or ESA-NPI schemes:

PhD title	Professor	EPFL labs	Type of thesis
3D Optical Imaging of Living Cells in Microgravity: Application to Study Dynamic Changes of the Cytoskeleton	Depeursinge - Egli	Advanced Photonics Laboratory	EPFL/ESRP
Investigation and Modelling of Solid-Propellant Combustion in Miniaturised Devices for Space Applications	de Rooij - Favrat	Institute of Microtechnology	EPFL/ESRP
Broadband True Time Delays Using Microwave Photonics	Thévenaz	Laboratoire de Nanophotonique et de Métrologie	EPFL/ESRP
Advanced solar antennas for Exomars mission	Mosig	Laboratoire d'Electromagnétisme	EPFL/ESRP
Novel Composite Materials for Control of Vibration and Deformation of Space Structures	Manson	Laboratory of Composites and Polymer Technology	ESA/NPI
Planetary Exploration Aerothermodynamics, Radiation Effects and Innovative Structure Coupling	Leyland	Laboratory Ingénierie Numérique	ESA/NPI

Table 4: Selected theses in the frame of the EPFL-ESRP programme (in red) and ESA-NPI programme (in green)

The final selection was slightly different with the recommendations of the evaluation committee because, according to EPFL internal rules, some people were unfortunately not in the position of supervising PhDs. That is why some good projects were not accepted after all.

This research initiative, funded by both EPFL and ESA, will therefore allow six PhD theses linked to space to start early 2008. ESA is currently evaluating the possibility of funding two additional theses and should be announcing their decision in 2008.

It is planned to issue a similar call for proposals in 2010, assuming funding can be obtained from EPFL, and hence assuring a continuity of PhDs related to Space at EPFL.

7 Education and Teaching

7.1 Master and semester projects

The Space Center EPFL offered a substantial number of Master and semester projects in 2007 in the frame of the SwissCube and Earth observation (remote sensing) activities. Most of the 70 SwissCube projects were directed by professors in the relevant EPFL labs though a few were directed by Maurice Borgeaud. All the SwissCube projects were however coordinated by Mrs Muriel Noca. The 7 proposals in the Earth observation domain were directed by Maurice Borgeaud. In addition, one semester project related to robotics was guided by Prof. Auke Ijspeert (EPFL) and Maurice Borgeaud.

7.2 Minor in space technologies

In 2005, the Space Center proposed to the EPFL board of directors to set up a minor in Space Technologies in order to develop space education at EPFL and make up or the lack in that domain.

The goal of the minor in Space Technologies is:

- To offer students the possibility to strengthen their knowledge in the space domain
- To promote space applications, technology and science based on the large interest raised by space
- To foster a strong teaching in the space sector in parallel to the development of academic and research projects at EPFL (e.g. SwissCube)
- To teach new lectures and adapt existing courses to include a space component

The minor in Space Technology courses include fascinating fields such as experimental research in our solar system using spacecrafts; near-Earth space, research on the Sun and planets to the limit of our solar system and beyond; spacecraft architecture from microelectronic vulnerability to space radiations environment; satellite communication systems and networks; satellite localization; remote sensing of the earth by satellite.

In order to successfully pass the Minor, a student has to acquire 30 ETCS (European Credit Transfer System) made out of:

- 22 ETCS for courses
- 8 ETCS for a project

Table 5 shows the list of courses available to the students in October 2007. The students have to choose among a list of courses which are strongly encouraged due to the fact they are entirely dedicated to space (shown in the top part of the table) and a list of existing EPFL courses which are slightly adapted to emphasise some space aspects (shown in the bottom part of the table).

It should be noted that 14 EPFL students were registered in 2007 in the frame of the Minor in Space Technologies.

SEL - SMT - SGM - SMX   Mineur en Technologies spatiales

Les enseignants, les crédits et la période des cours sont indiqués sous réserve de modification.
Le projet en Technologies spatiales de 8 crédits est obligatoire.

Matières	Enseignants	Livret des cours	Crédits	Période des cours
Mineur en Technologies spatiales			**61**	
"Bases spatiales" (cours vivement recommandés)				
Introduction to space science	Blush	EL	2	A
Lessons learned from the Space Exploration	Toussaint	EL	2	P
Localisation par satellite	Gillieron	SIE	3	A
Remote sensing of the Earth by satellites	Borgeaud	EL/MT/SIE	2	A
Satellite communication systems and networks	Farserotu	SC	3	A
Spacecraft data processing and interfaces	Storni	EL	2	P
Spacecraft design and system engineering	Noca	EL	2	A
Strategic technology management : the space case	Bertschi	EL	2	P
Technologies et opérations spatiales	Nicollier	EL/GM/MX/MT	2	P
Compléments				
Aerodynamique	Leyland	GM	2	A
Astrophysique I: Introduction à l'astrophysique	Courbin	PH	3	P
Astrophysique III: Cosmologie observationnelle	Meylan	PH	4	A
Conception mécanique I+II	Giovanola/Schorderet + Giovanola/Schorderet/Hoover	GM	4	P
Fundamentals of radiation damage and effects	Baluc/vacat	MX	2	P
Instabilité et turbulence	Monkewitz/Deville	GM	4	A
Lever aérien	Vallet	SIE	3	A
Rayonnement et antennes	Mosig	EL	3	A
Reliability of MEMS	Shea	MT	2	A
Technologies des capteurs et des actionneurs intégrés	De Rooij	MT	2	A
Transfert de chaleur et de masse	Ursenbacher	GM	4	P
Projet du mineur				
Projet en technologies spatiales	Divers enseignants	EL	8	A ou P
Légende :	A = automne, P = printemps 1 semestre comprend 14 semaines.			

Table 5: List of courses offered in the frame of the Minor of Space Technologies in 2007

8 Research projects

This chapter only handles "seed-money" projects. As a reminder, these are studies or pre-studies of innovative ideas which could, in the long run, be useful for the industry. "Seed-money" projects are financed by a pool of funds brought together by the Members of the Space Center EPFL. As such, the members of the Steering Committee decide which project is worth developing or not.

As opposed to this, "Hard-return" projects are mandated by one company. They remain confidential and are treated bilaterally between the relevant industry partner and the Space Center EPFL.

8.1 Vade-Mecum for requests related to "Seed money" activities

Based on discussions during the Steering Committee of the Space Center EPFL, it was decided in August 2007 to issue a Vade-Mecum with a list of detailed questions that the author of a "seed money" request has to answer so that the Steering Committee can decide upon the validity and the relevance of the proposal. In order to focus space research performed at EPFL, seed-money proposals dealing with the following requirements will be privileged:

- Be in line with the themes of the EPFL strategic initiative for space
  or
- Be in line with the technology priority axes identified by the Swiss Space Office.

8.2 "Seed money" studies executed in 2007

Based on this new tool to evaluate the seed money requests, the Steering Committee approved four projects as described in Table 6. For completeness, the table also indicates all the studies that were either completed or started during this year.

For the two studies completed in 2007, the corresponding executive summaries are included in Appendix 10.1.

Title	Reference	EPFL partners
Solid-propellant development and filling in micro-machined cavities for space micro-propulsion modules	009/2005	IMT (Briand)
Collaborative conceptual design support system for a satellite design	012/2006	LICP (Xirou-chakis)
Effects of gravity on cavitations bubble collapse	014/2007	LMH (Farhat)
Innovative microscopy technique for life science investigations in space	015/2007	LOA (Depeursinge)
Design of innovative antennas for airborne and spaceborne ice sounder radars	016/2007	LEMA (Mosig)

Table 6: List of projects approved by the Steering Committee in 2007

9 Outlook for 2008

The year 2007 was very productive and we believe 2008 should be the straight continuation of the core activities of the Space Center EPFL.

SwissCube as flagship project of the Space Center EPFL shall undergo the end of Phase C, pass successfully the CDR (critical design review), and the flight hardware shall be produced and assembled so to deliver a working flight model by the end of 2008. A choice will have to be made for the launcher and it is hoped that SwissCube will be selected on educational payload to be flown on the VEGA maiden flight as long as this first launch is not delayed too long. Alternative solutions for a launcher shall be considered if VEGA is delayed in the second half of 2009. Several PR activities and fund raising events are planned in order to secure the funding of the project.

All necessary computer hardware and software of the concurrent design facility have been set up and the facility is now in operation. This environment has provided support to classes that are taught by the Space Center staff as well as to the SwissCube Engineering Team. 2008 shall be the first year during which we can take advantage of this advanced system engineering tool. Not only space projects shall be considered for use in the CDF but also complex non-space activities that can be split in several sub-systems (e.g. aircraft, modelling of climate change). International contacts will be sought, particularly with the ESA CDF implemented at ESTEC. One of our major goals is to create an operational facility for conception and design of pico- and nano-satellites in collaboration with ESA.

Contacts and joint research activities between industry and academia shall be also privileged in 2008. Not only the aspects of valorisation of R&D results by the industry shall be developed but also how the labs can better support the industry when they have specific R&D problems. Dedicated workshops are planned with the labs and the industry on specific problems in order to foster the development of solutions.

An important role of the Space Center EPFL as coordinator of space R&D at national level shall be pursued in 2008. Partnerships with new academic members shall be promoted in order to build a network of all the key players in our country in the space sector. Of course, this network will be built in cooperation with the Swiss space industry and its capabilities.

The EPFL research activities in the space domain shall be fostered in 2008 by the start of 6 doctoral theses financed in the frame of the EPFL Space Research Programme and by the ESA Networking Partnering Initiative. In addition, a substantial number of students at bachelor and Master levels will be supervised by the Space Center EPFL staff in the frame of the SwissCube, Earth observation, and system engineering activities. Very close to research is the domain of the space education of students. It is planned to add new classes to the Minor in space technologies in order to teach all the basic domains of space activities. This shall make the Minor even more attractive to the students and ensure that EPFL students get the necessary knowledge in the space domain before graduating.

The Space Center EPFL shall also be active in promotion of space activities at national level and plans to organise with SSO an information day on the new ESA astronaut recruitment campaign.

We personally look forward to work in 2008 with the Steering Committee and all the members of the Space Center EPFL.

Finally, as director of the Space Center EPFL and chairman of the Steering Committee, we would like to express my special thanks to the team working with us since none of the achievement described in this report would have been possible without them.

Lausanne, 25 April 2008

Maurice Borgeaud

Director, Space Center EPFL

Juan Mosig

Chairman, Steering Committee of the Space Center EPFL

10 Appendixes

- List of R&D projects managed by the Space Center EPFL in 2007

10.1 List of R&D projects managed by the Space Center EPFL in 2007

A short summary of the R&D projects performed with the "seed-money" budget of the Space Center EPFL and which were completed in 2007 is presented in the following pages:

- Study 009/2005: Solid-propellant development and filling in micro-machined cavities for space micro-propulsion modules
- Study 012/2005: Collaborative conceptual design support system for a satellite design

Solid Propellant and Igniting Technologies for Space Micro-propulsion Modules

Space Center EPFL study # 009/2005

Executive summary

Nowadays, the use of commercial solid propellants has lead to major concerns in terms of reliability of miniaturized pyrotechnical systems. Most of them are not adapted to operate in very small dimensions. In many cases the propellant was combined with micro-igniters available on the shelves and not specifically developed for the proper ignition of the given propellant. The lack of a robust technology to ensure the reproducibility of the ignition is recognized to be one of the main reason checking the exploitation of the micro-pyrotechnical systems, for instance in micro-propulsion modules for space applications. The present project aimed at the development of a high performance propellant coupled with a reliable ignition technology based on microsystems. The project consisted in formulating a solid-propellant and an ignition concept adapted to ignition and combustion at the micro-scale level.
Compared to the standard igniting concepts, the approach used in this project was to go back to an ignition happening underneath of the propellant, but with an ignition concept allowing a complete and controlled combustion of the propellant. It eliminates the problems associated with the other ignition techniques used so far such as the lost of the contact between the igniter and the propellant due to gas generation, particles generation and combustion of propellant outside the thruster. Moreover, it simplifies the design and processing of the thrusters reducing the number of parts to two (Figure 1).

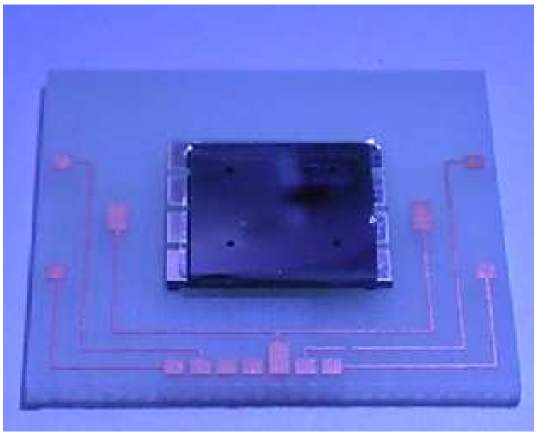


Figure 1: Picture of the 2×2 micro-thrusters array demonstrator on the printed circuit board for testing.

Optimization of the igniter design was performed via FEM simulations. A propellant with an extensive gas production and a fine grain distribution was produced to suit the requirements of the ignition concept and of the application. The formulation of the propellant was optimized with the incorporation of a binder to improve its adhesion on the igniter and the use of safe and easy to manipulate solvent. Due to the smart design of the igniter and the adapted filling procedure developed to coat the propellant, the structure of

the micro-thruster becomes and its realization become a lot simpler. The thruster structure is composed of only two parts: a micromachined part to include the chamber and nozzle and an igniting part made of glass or silicon. The ignition of the solid-propellant coated on the micro-igniting chips has been evaluated using a high speed camera. The ignition concept has been validated and data have been generated on the ignition characteristics of the propellant. Preliminary experiments have been conducted on the ignition of thrusters under vacuum and at different temperatures. Thrust measurements were performed showing the high efficiency of the propellant developed with a very interesting specific impulse and thrust characteristics that could potentially lead to the realisation of digital micro-thrusters. A typical thrust characteristic obtained is presented in Figure 2. A demonstrator composed of a 2×2 array of micro-thrusters (see Figure 1 above) has been made and successful ignition recorded at low-power.

The developed propellant and igniting system enables the realization, with simplified processing and assembling procedures, of solid-propellant micromachined thrusters with reliable ignition for space applications. It represents a tremendous progress compared to the state-of-the-art in this field and a major break through for the commercial exploitation of micro-pyrotechnical systems.

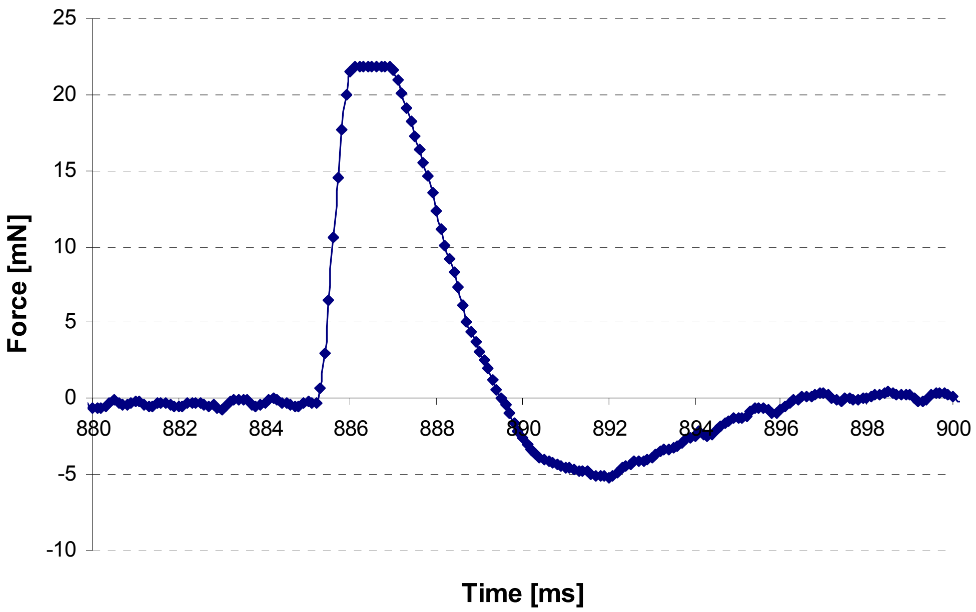


Figure 2: Typical thrust force as a function of time for a micro-thruster filled in with the propellant developed within this project: F_{thrust} > 22 mN (saturation of the thrust balance), combustion time: 5 ms, total impulse > 110 µN.s and specific impulse > 62 s.

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Collaborative Conceptual Design Support System for a Satellite Design

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Collaborative Conceptual Design Support System for a Satellite Design

Executive summary

Since satellite design requires a large body of multidisciplinary knowledge such as thermodynamics, electronics, mechanics, space environmental engineering, manufacturing, reliability engineering, it should be performed collaboratively by a group of specialists, usually called design teams. Design teams design their sub-functions according to their own local criteria even though they take into account the overall functionality and global criteria.

Furthermore, a specific model of satellite is not usually intended to be mass-produced, but to accomplish the special mission objectives, such that the new satellite development process should be carefully planned and systematically executed from the conceptual design stage. Decisions made at the preliminary design phase are of great importance because the result of those decisions becomes a seed for all optimization processes at the subsequent design stages. Therefore, a robust generation and selection method of satellite design concepts is required to minimize the need for critical refinement and serious modifications of the design at the subsequent design phases.

Conceptual design is a transformation process of the system specification into functional structures and engineering constraints of the overall function of a system; it involves two main steps: (1) generation of design concepts and (2) selection of the best one.

The selection process of design concepts is achieved by the integration of two main activities: verification and evaluation. The former involves checking that a design concept satisfies functional and other specifications (feasibility), whereas the latter focuses in comparing the relative strengths and weaknesses of the design concepts and selecting the best design concept against specified global criteria (optimality).

This project deals with how to generate the set of compatible combinations of design principles (design concepts) and to select the best design concept by considering design constraints and designers’ preferences. First, a systematic method to quantitatively evaluate the compatibility of a design principle with the other design principles and the other sub-functions is defined (filtering). Subsequently, in order to select the best design concept, Multiple Criteria Decision Aiding (MCDA) methods are adapted to the conceptual design phase (selection). In particular, they take into account the uncertainty in the values of design parameters and criteria evaluations during the conceptual design phase.

By using the proposed conceptual design support system, it is expected that:

- designers can easily explore different design principles for alternative design concepts
- designers can integrate design verification (feasibility check under design constraints) and design evaluation (optimality check against design criteria)
- each design team for a sub-function (e.g. payload system design team or electrical power system design team) can focus on their own design problem
- the overall satellite design process can be accelerated by reducing design iterations