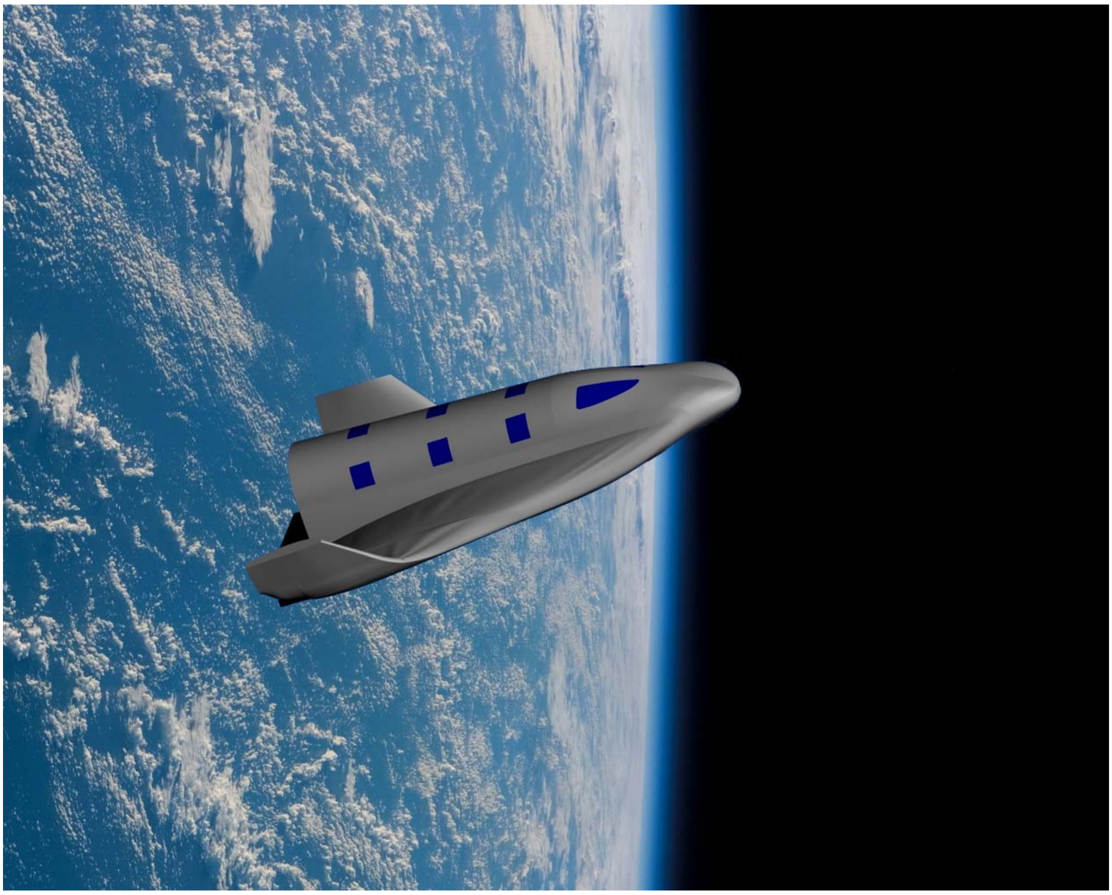
Space Center

EPFL
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Annual Report 2010

Space Center EPFL



http://space.epfl.ch

March 2010

Picture credit to Space Center EPFL. 3D view of the K1000 suborbital plane. This artist's view picture is based on the CAD model of the plane, which was used for aerodynamic calculations as well understanding customer experience.

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Executive Summary

The Space Center EPFL carried out its activities in 2010 mainly thanks to the support of its principal members, RUAG Space (including former Oerlikon Space), SSO and CSEM, and of its academic members, the University of Neuchâtel and the Fachhochschule Nordwestschweiz (FHNW).

2010 proved to be a year of transition after the launch of SwissCube in 2009. In parallel to the monitoring of the satellite, the Space Center team geared towards the future, writing proposals for or developing new projects such as CHEOPS, QB-50 and Clean-mE.

Summer 2010 brought a wind of change to the Space Center with the resignation for 31 December 2010 of its director Maurice Borgeaud, who accepted an offer from the European Space Agency to become Head of the department "Science, applications, and future technologies" in the Directorate of Earth Observation. Following this announcement, the Steering Committee and EPFL set the priority action of finding a replacement to Maurice Borgeaud, a complex mission that is still in process to this date.

This change did not prevent key engineers to continue their projects and further developing the Space Center's network with academies such as University of Bern and Geneva, and industries who share the same interest in the future of space technologies.

In October, EPFL hosted the SECESA conference jointly organized with ESA, in which more than 100 people from all over the world took part. The Space Center was equally very successful with its training course on Dynamic Technical Leadership for Space Projects.

1 Space Center EPFL objectives and organisation

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 which became RUAG Space in 2009), research centres (e.g. CSEM), and universities (e.g. HEIG-VD, University of Neuchâtel, HEVs, FHNW), have decided to become partners of the Space Center EPFL.

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 related 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 company RUAG Aerospace.

These objectives have been approved by the Steering Committee in 2007 and are currently being implemented. A three-year mission plan was issued for the period 2007-2009 for which three main areas were defined as described in Table 1.

With the departure of Maurice Borgeaud at the end of 2010, the mission and role of the Space Center EPFL are being reassessed at high level by the founding members and EPFL Provost Philippe Gillet.

	Main activities 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, which was tacitly pursued in 2010.

For each of these, a list of requirements and needs has been derived based on the knowledge of the needs of the members of the Space Center EPFL. 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)
- 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. For information, the last rows of the table also present the links with the European Space Agency (ESA).

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 Organisation

The overall organisation of the Space Center EPFL, including the Steering Committee is shown in Figure 1 as per 31 December 2010.

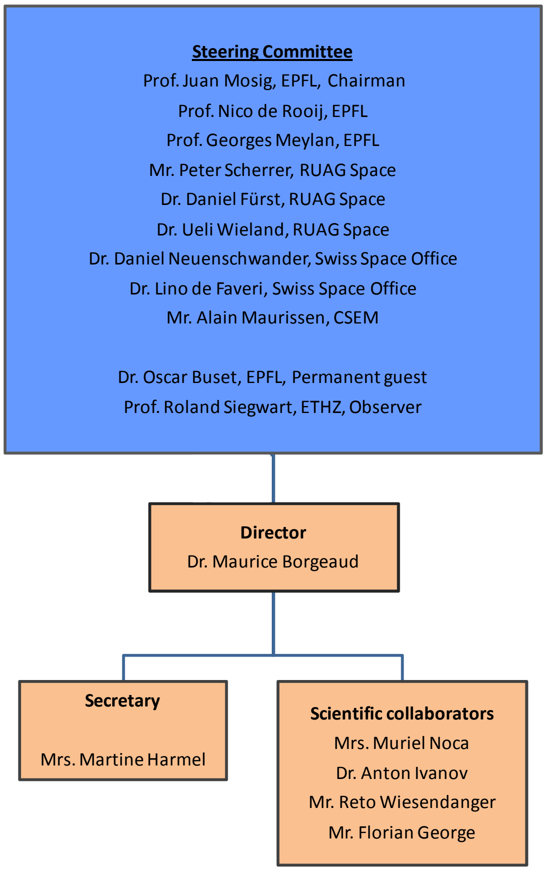

Figure 1: Organisation chart of the Space Center EPFL

1.3.1 Steering Committee of the Space Center EPFL

The Steering Committee met on three occasions in 2010: 10 March (# 25), 26 August (# 26), and 14 December (# 27). It is worth noting that the Space Center accepted to hold bi-yearly meetings (approved by the Steering Committee members in the 23rd meeting) and that the 25th meeting was and extraordinary one to address the future of the Space Center with EPFL President, Prof. Patrick Aebischer, and STI Dean, Prof. Demetri Psaltis.

There have been no changes amongst the membership of the Steering Committee during the year. The seats held by Oerlikon Space positions were kept and transferred to RUAG.

Prof. Juan Mosig, director of the EPFL LEMA (Laboratoire d'Electromagnétisme et d'Acoustique), maintained his position as Chairman of the Steering Committee.

Prof. Roland Siegwart's observer status was renewed in December 2010 for 2 years (2011-2012).

The Space Center EPFL takes this opportunity to thank all the Steering Committee members for their commitment in the development of the Space Center EPFL.

1.3.2 Tasks and responsibilities of the staff in 2010

During 2010, the tasks and responsibilities of the staff of the Space Center EPFL were:

- Dr. Maurice Borgeaud, Director;
  As director of the Space Center EPFL, Dr. Maurice Borgeaud's main task during the year 2010 was to present a strategy which was discussed and approved by the Steering Committee. He was then in charge for the implementation of these decisions. He was also responsible for the daily operations of the Space Center EPFL. Dr. Maurice Borgeaud remained president of the ESA Programme Board on Earth Observation (PB-EO) until the end 2010.
  Dr. Maurice Borgeaud had been hired in 2004 to take over the direction of a very young Space Center. Through hard work and dedication, he managed to ensure the successful development of the Center, taking at heart the education of the students, the launch of the SwissCube, and the relations with members and partners. As already mentioned, Dr. Maurice Borgeaud resigned from EPFL in the summer 2010 with a departure date on 31 December 2010, in order to take up a new challenge as Head of the department "Science, applications, and future technologies" in the ESA Directorate of Earth Observation. The Space Center EPFL Steering Committee and staff wish him all the success he deserves and thank him for his contribution.

- Mrs. Muriel Noca, system engineer;
  Mrs Muriel Noca fulfilled the responsibility of managing the operations phase of SwissCube as described with more details in Chapter 4.1. She also concluded the Space Center's part of the TRP studies on Micropropulsion and participated in proposal activities on that topic. She led the technical work on the Clean-mE project, supported the SSO Mesure de Positionnement selection as well as the QB50 project, and advised the REXUS team. She supervised students and taught one of the Minor classes.

- Dr. Anton Ivanov, engineer responsible of the Concurrent Design Facility;
  Dr. Anton Ivanov was in charge of managing the CDF, situated in room ELD-010 of EPFL. The activities in the Concurent Design Project have included preparatory work for CHEOPS and QB50 projects, and support for the ESA TRP activity on small antenna for a microsatellite. All are detailed in Chapter 4. Dr. Ivanov has also supported mission operations for SwissCube, supervised student projects and taught one of the minor classes. Special activity for the 2010 was to organize a Systems Engineering conference together with European Space Agency.

- Mr. Reto Wiesendanger continued to work part-time for the Space Center in the frame of a civil service until end of August 2010 and was then hired by the Space Center to work on the Clean-mE project until the end of 2010. As of Feb 2011 he will be employed by the University of Bern to work as system engineer on the HiSCI instrument.

- Mr. Andreas Fueglistaler's contract ended in March 2010 with the completion of his study on Biology in Microgravity (Hard-return study 026/2009).

- Mr. Florian George was hired for 1 year as of 1 October 2010 to further develop SwissCube's ground and mission control software. He also participated in the daily mission operations. He will be providing supervision and design for all projects of the Space Center in the area of flight and ground software.

- Mrs. Jelena Stemenkovic is the first Space Center PhD. She was hired on 1 May 2010 for a project on HyperswissNet. With the departure of Dr. Borgeaud, she was transferred at the end of the year to Prof. Thiran's laboratory (Signal Processing Laboratory 5).

- Mrs. Martine Harmel, secretary;
  Mrs Harmel attended all the secretarial and administrative matters as well as the organization of events and newsletter, and in addition is the secretary to Prof. Claude Nicollier until his retirement.

As for the previous year, there was more work to be done than the staff could possibly handle and, for instance, the Space Center had to decline an offer to provide project management and overall system engineering for the QB-50 project (responsibilities that were subsequently taken by the Surrey Space Center).

The Space Center also hosted promising students during 2010 to perform specific tasks such as assist lecturers or work on precise issues:

- Enrique Guzzman, Laurent Hauser, Dimitri Palaz for support to the Minor classes;
- Kim Frank and Jean-Noel Pittet for their support to the Space Center web-site;
- David Lugrin doing his civil service and working on a earth observation project;
- Yann Voumard, in charge of supporting mission operations and analyzing the SwissCube data;
- Federico Belloni, who provided technical tests and support to the SwissCube telecommunication links.

2 Members of the Space Center EPFL

Each member of the Space Center EPFL belongs to a category, which provides tailored contribution and rights.

The **founding members** of the Space Center EPFL are EPFL, RUAG Aerospace, SSO. They participate in the Steering Committee and have veto rights. No more founding members are accepted. Their contracts typically run for 3 years.

Permanent members participate in the Steering Committee and have voting rights. The minimum investment amounts to 125 kCHF/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 kCHF /year (100% soft-return).
- **Industry members**: A yearly contribution of 20 kCHF /year minimum with a 50-50% soft-hard return ratio. However, larger hard-return amounts are allowed with a minimum of 10 kCHF of soft-return.
- **Start-up companies**: 1 kCHF /year for the first two years (100% soft-hard return). The definition of a "start-up company" is at the discretion of the Steering Committee.

The current status of the memberships and contracts is summarized in Table 3.

Member	Membership Type	Original contract	Current contract	Remarks
RUAG	Founding	2003	2009-2012	Ongoing
SSO	Founding	2004	2008-2011	Ongoing
Oerlikon	Permanent	2005	2008-2010	Ongoing, to be renewed
CSEM	Permanent	2005	2009-2012	Ongoing
Uni-Neuchatel	Academic	2006	2009-2012	Ongoing
HES-SO/Valais	Academic	2007	2007-2009	Expired
HEIG-VD	Academic	2006	2006-2008	Expired
NWFH	Academic	2008	2008-2010	Ongoing, to be renewed
Almatech	Industry start-up	2010	2010-2011	Ongoing

Table 3: Current status of membership contracts

The following map presents the status of the memberships of the Space Center EPFL.

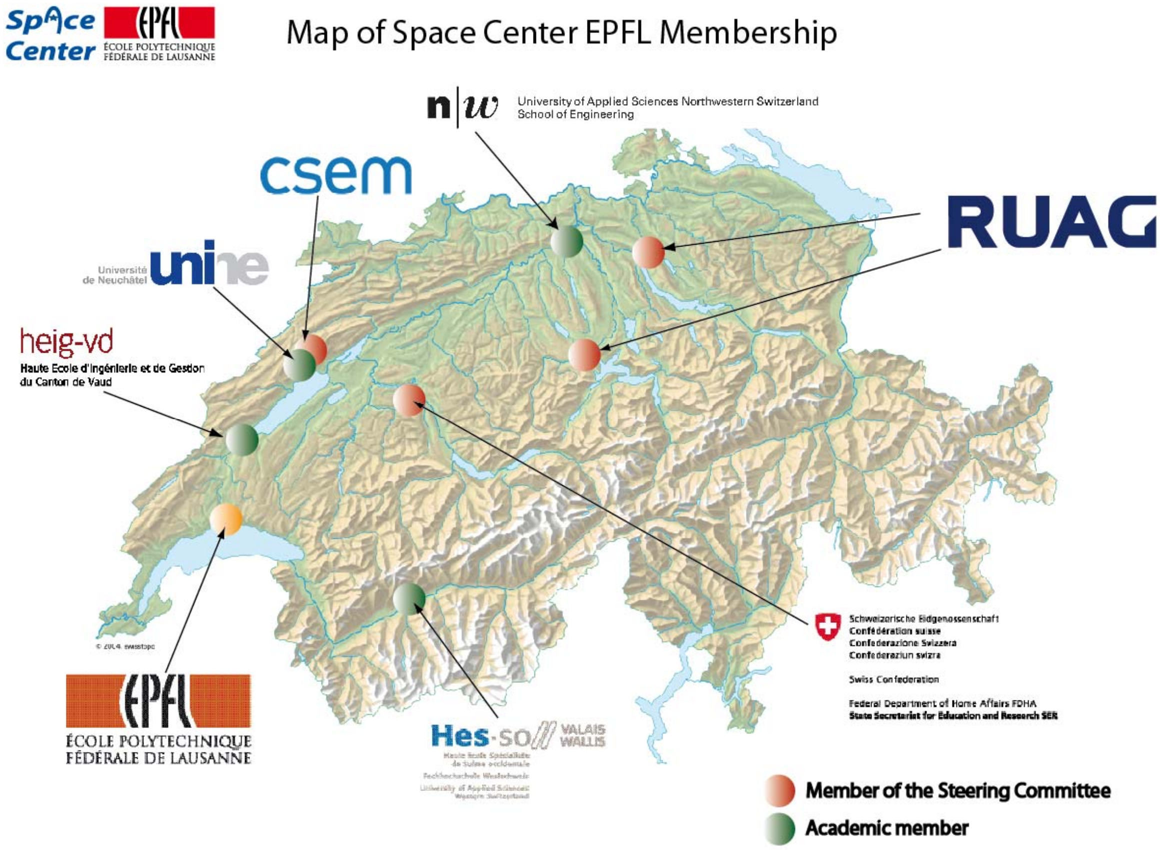

Figure 2: Position of the space Center EPFL in the Swiss Landscape in 2010

2.1 Founding and Permanent Members

In 2003, 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 Bern 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 June 2009, RUAG renewed its cooperation agreement with the Space Center EPFL on the basis of unchanged terms for a period of three years until 31 May 2012.

In April 2005, Contraves Space (which changed names to Oerlikon Space) decided to join the Space Center EPFL thus becoming a permanent member for the period 2005-2007 with voting rights in the Steering Committee. On 4 December 2007, Oerlikon Space and EPFL renewed their agreement for the period 2008-2010. On 1 July 2009, Oerlikon Space was sold to the international aerospace and defence technology group RUAG. The Oerlikon-EPFL contract regarding the Space Center EPFL was nevertheless maintained till its completion in 2010. During the Dec. 14, 2010 Steering Committee meeting, it was announced that the former Oerlikon Space contribution would not be renewed in 2011.

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. In 2009, the CSEM-EPFL agreement was renewed, extending collaboration until 31 December 2012 under the same contractual terms.

The Swiss Space Office affiliated to the State Secretariat for Education and Research in Bern signed a new agreement with the Space Center EPFL on 22 August 2008 for a 4-year period from 2008 to 2011.

In 2010, no renewal of founding and permanent member contracts was necessary.

2.2 Academic Members

The University of Neuchâtel is still an academic member until 31 December 2012.

The Fachhochschule Nordwestschweiz (FHNW) membership expired in December 2010 and should be renewed in 2011.

In 2010, negotiations started with the HES-SO for a global HES agreement. HES-SO space’s strategy is currently being assessed.

2.3 Industrial Members

Almatech is still under contract with the Space Center until 31 December 2011.

3 Management and PR activities

The principal activities of the Space Center EPFL, such as SwissCube or CHEOPS, have a dedicated section further in this report.

In addition, the list of the day-to-day activities during the year 2010 can be found in Appendix 10.1, which provides an exhaustive summary of the main events which took place during the year.

All activities are the results of decisions taken by the Steering Committee addressed in the following chapter.

3.1 Decisions taken by the Steering Committee

The major decisions taken in 2010 by the Steering Committee of the Space Center EPFL are listed in Table 4.

Meeting Number	Date	Major decisions
25	10.03.2010	The income statement 2009 is approved by the members of the Steering Committee.
25	10.03.2010	The 2010 budget is accepted by the members of the Steering Committee.
25	10.03.2010	The annual report 2009 is accepted by the members of the Steering Committee
25	10.03.2010	The Steering Committee accepts the proposal to organize a training course on system engineering in 2010.
26	26.08.2010	Given the current situation, the Steering Committee decides to concentrate on the replacement of MB according to the following procedure: 1. The founding members (EPFL, SSO, RUAG) meet in the coming weeks to suggest names of possible successors to MB. 2. A formal suggestion is transferred to the EPFL direction by JM. 3. The founding members must be involved in MB's succession.
26	26.08.2010	The Steering Committee believes the SwissCube team should now take all the necessary measures to slow down the satellite even if this may yield to lose the control of the satellite.

26	26.08.2010	The Steering Committee decides to hire Florian George for 2 years.
26	26.08.2010	The Steering Committee decides to grant seed money for the Effects of Gravity on Cavitation Bubble Collapse project
26	26.08.2010	The Steering Committee decides to grant seed money for Incubator for simulated microgravity experiments
26	26.08.2010	The Steering Committee decides not to grant seed money to the project Jules Vernes J.V.-SAT
26	26.08.2010	The Steering Committee decides in principle to accept the HES-SO on the committee but would like to see the contract before.
26	26.08.2010	The Steering Committee decides to maintain the training course even if there are financial risks.
27	14.12.2010	The Steering Committee formally approves the interim direction of Prof. Herbert Shea.
27	14.12.2010	The Steering Committee accepts the seed-money proposal LIDAR for JEM-EUSO atmospheric sounding but the decision subject to a financial participation of EPFL in the Space Center budget for 2011.
27	14.12.2010	The Steering Committee accepts the income statement for 2010.
27	14.12.2010	The Steering Committee decides that MB should set up a 2011 survival budget within 6 days without the income from HES-SO and EPFL. The Space Center will start the year with a survival budget.
27	14.12.2010	Prof. Siegwart remains observer of the Steering Committee for the period 2011 – 2012.

Table 4: List of major decisions made by the Steering Committee in 2010

3.2 Workshops and conferences

Table 5 summarises the list of events attended by the Space Center EPFL in 2010.

A classification is made based on 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.

Additional information is provided in Section 5 for some of these activities.

Date	Type	Activity
23 March	Presentation	Presentation of the Space Center EPFL & SwissCube at the VHS (Volkshochschule) Bern
18-20 May	Presentation	Visit BMSTU students from Moscow for 3 days
29-30 May	Exhibition	Booth at the EPFL Open-Day
22-23 June	Conference	Participation to CNES space debris workshop
28 June	Conference	Participation to the ESA Living Planet Symposium
22 September	Presentation	EE industry day at EPFL
5-6 October	Training course	Training course at EPFL “Dynamic Technical Leadership for Space Projects” (more on this in special events)
13-15 October	Workshop	ESA workshop on system engineering, SECESA (more on this in special events)
11 November	Conference	SATW Congress on aerospace, Zurich

Table 5: Workshops and conferences attended and/or organised in 2010

3.3 Media coverage

The Space Center EPFL benefited of intermittent media coverage in 2010, notably due to the operations of the SwissCube satellite. About half a dozen articles were published, and the Space Center participated in a few radio talks. The list in Table 6 presents the dates and titles of all articles and radio/television interviews.

Date	Media	Title
September 2010	L’Hebdo	“L’exploit de SwissCube”
November 2011	Russian TV, Vesti (channel #2 in Russia, 100M people	Russians abroad.

	audience)	
November 2010	Mirco Saner	SwissCube
November 2010	RSR Emission “Impatience”	Point sur les débris dans l’espace
December 2010	Scientific American	SwissCube

Table 6: Press coverage

3.4 Web site

The Space Center website at http://space.epfl.ch was maintained by EPFL student Kim Franck and then Jean-Noel Pittet, during the entire year under the guidance of Dr. Maurice Borgeaud.

The website underwent significant changes in September, as EPFL transformed its entire website layout to present a more dynamic and modern image.

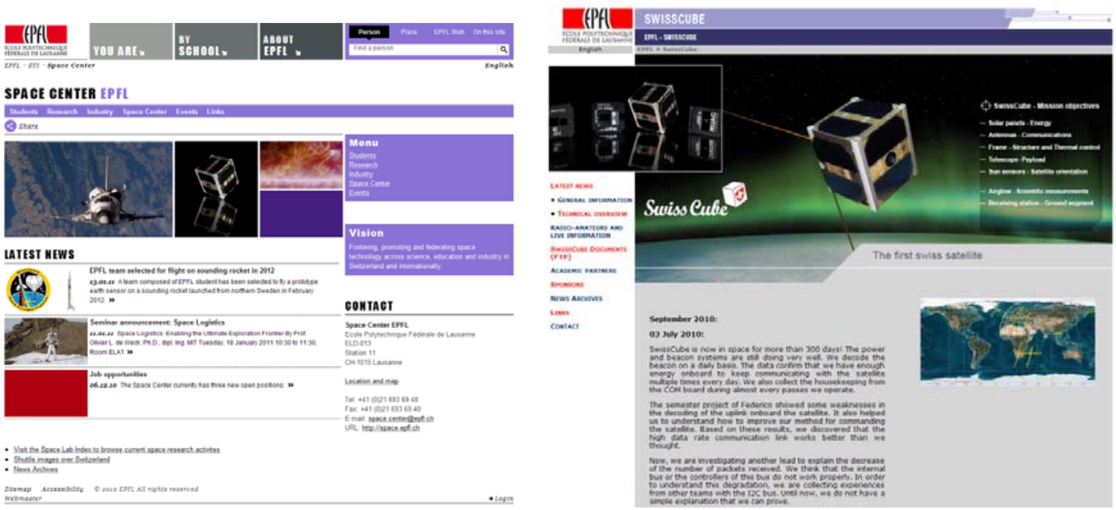

Figure 3: Space Center and SwissCube web sites.

The SwissCube website http://swisscube.epfl.ch was regularly updated with its special SwissCube “live” section (http://swisscube-live.ch) allowing the public and radio amateurs to follow the satellite in real time.

4 Projects

4.1 SwissCube

Figure 4: SwissCube's Windows Phone 7 application for mobile phones

After the launch of SwissCube on September 23, 2009, the mission operations started and spread over the first quarter of 2010. The unplanned high rotation speed of the satellite left the mission operations team with more questions than answers. Several students joined to help but most could only scratch the surface of the issues and could not in such a short term bring significant improvement to the situation. Nevertheless operations were maintained for the first few months of 2010, mostly employed at characterizing the communication link and the health of the satellite. It is to be noted that the whole SwissCube core team of young engineers was employed outside the Space Center by December 2009, which made the operations more and more spurious (on average 1-3 times/week) as the year passed by. However SwissCube continued to work beyond its 4 months of lifetime and continued to slow down its rotation by itself. Also to note the great commitment of the HE-FR as they remained after launch and very often insured communications with the satellite.

By the end of the year, the rotation rates of the satellite had decreased enough that new operation scenarios could be envisaged.

Thus 2011 will see the continuation of the mission operations, with the de-tumbling procedure of the satellite and picture downloading. The project results will also be presented at the AIAA/Small Sat Conference in Utah, USA in August. The management part of the project will be summarized in a report, including lessons learned.

The next sections will summarize the technical lessons learned while operating the satellite a little bit more than 1 year. Figure 5 shows the main SwissCube satellite subsystem which will be discussed.

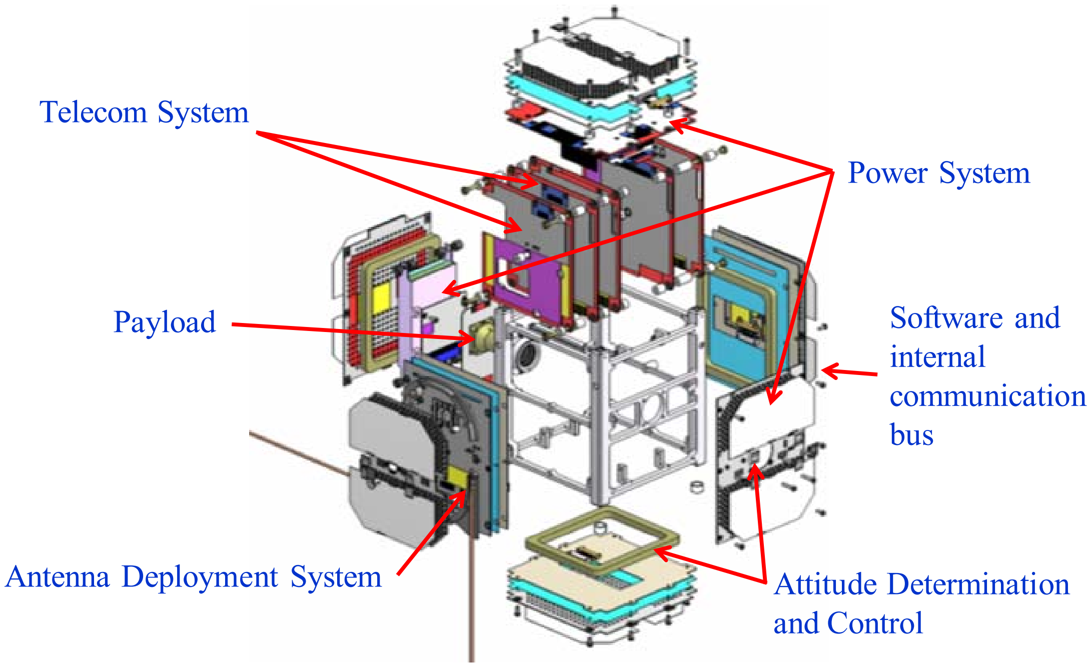

Figure 5: Main SwissCube subsystems.

4.1.1 Power System

After more than 450 days, the Power System has still been working perfectly. Composed of a set of redundant (COTS) batteries, solar panels, and a distribution system providing a regulated 3.3 V bus, the power system has been very reliable. Its micro-controller, which hosts the satellite's main flight software, has seen no reset or performance degradation.

Batteries and power bus voltages are also within performance expectations. Batteries have seen an equivalent of about 3000 cycles since launch. Figure 6 shows the stability of the regulated bus over time. The battery heating system has also worked as planned as the batteries temperature never went below -5^{o}C.

Solar panels currents indicate that all solar panels are functional and within performance expectations. The total current under sunlight is on average ~ 800 mA, thus producing about 2.6 W. The maximum current seen per solar panel is on the order of 500 mA. This confirms solar cell efficiencies on the order of 24-26%.

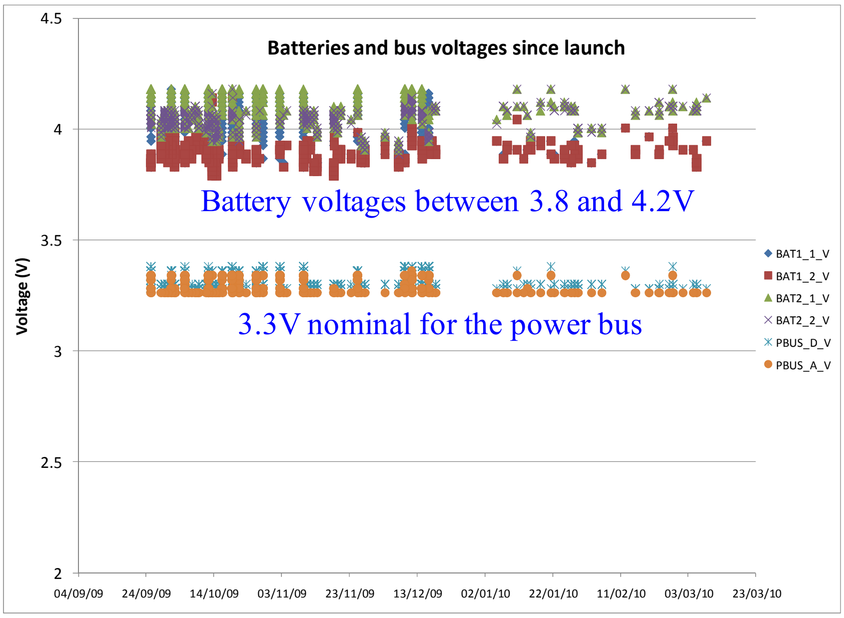

Figure 6: battery and bus voltage measured in flight.

4.1.2 Payload

The payload subsystem is composed of an infrared telescope, a detector and associated electronics. This subsystem was checked after launch and worked nominally. The detector could take a picture, store and download it under command from the ground. Since the rotation of the satellite was too high to get any meaningful airglow measurements, the payload subsystem was shut down until further use. It remained off for the rest of the year.

4.1.3 Software and internal communication bus

Although communications with the satellite were abundant early on, the capacity of downloading data became more and more difficult as time went by, as shown in Figure 7. After several analysis and counter intuitive discoveries, the root cause of the communication difficulties was found to be the internal communication bus (I2C). The I2C communication link became unstable for long frames (early on) and eventually unstable for short frames. It became thus difficult to communicate with other subsystems besides the com and power systems. This problem drastically reduced the total number of packets received on the ground. Reflecting on how to improve the design for the next satellite, it was proposed to start developing the CAN bus as a more reliable option.

All software developed on SwissCube has been very reliable. Although not rewritable, the software has been flexible enough to adapt to various non-nominal operations. The on-board time distribution has proven correct and reliable. The TI-MSP 430, SwissCube main microcontroller, has been also very reliable. There has been no reset on the main power system microcontroller, and no obvious radiation degradation has been seen.

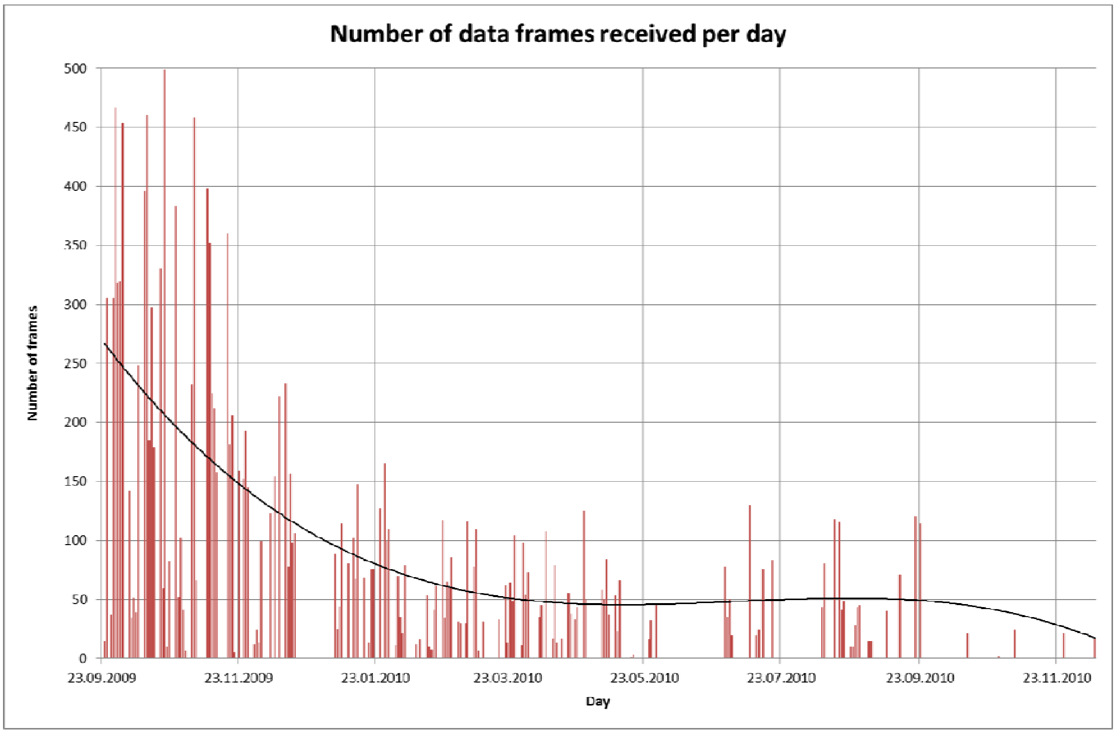

Figure 7: Number of housekeeping data frames received on the ground per day.

4.1.4 Antenna deployment system (ADS) and attitude control

After several investigations, it is believed that the antenna deployment system is a likely cause for the high rotation rates of SwissCube. It is very difficult to reproduce on the ground or even model the high dynamic behaviour of this deployment system. Several tests reproduced the vibration environment inside the CubeSat deployer and concluded that deployment during was very unlikely. Other tests analyzing the deployment dynamics showed that a part of the deployment energy remained in rotational energy. Thus the deployment system should be re-designed for future application. However the wire heating system that released the antenna proved a good and robust solution.

SwissCube's rotation started at around 300 deg/s (state early 2010) naturally slowed down to about 70 deg/s in one year. The rotational rates were determined using the RF signal observations as shown in Figure 8 and Figure 9 show the RF measured rotation rates (in rad/s) as a function of time.

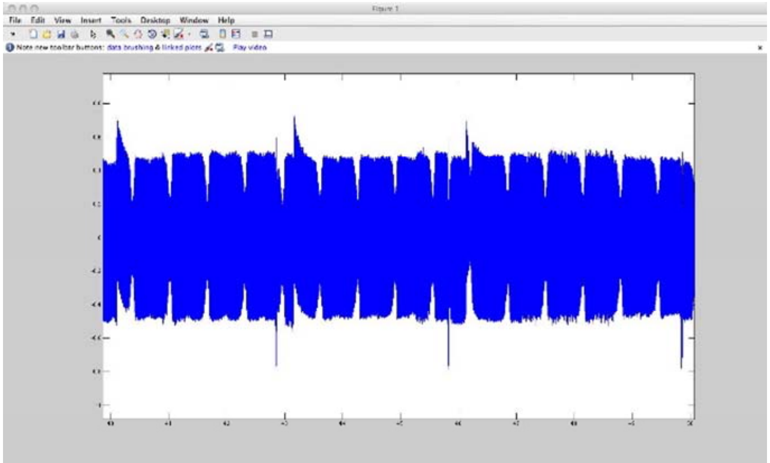

Figure 8: RF signal pattern showing the rotation of SwissCube

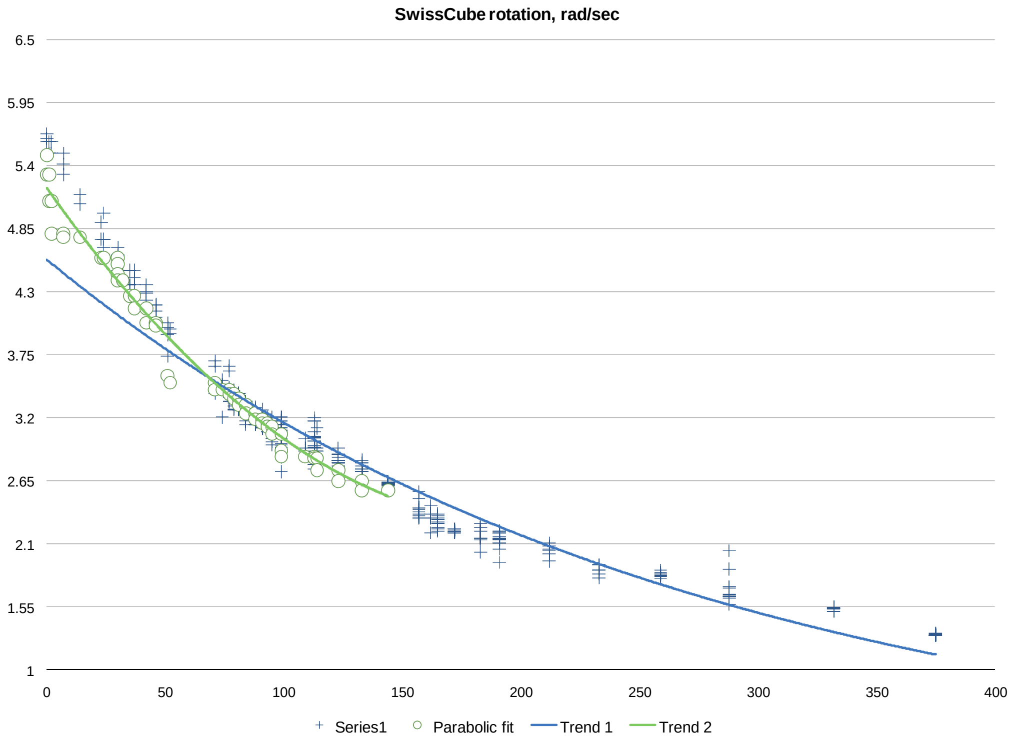

Figure 9: SwissCube's main rotation rates (in rad/s) as a function of time (days).

Due to this very high rotation rate after launch, the attitude control subsystem could not be verified. It was turned on, and a check that each sensor worked could be done. However no performance assessment could be performed. The on-board controller, based on the "bdot" algorithm, was designed to handle rotation rates on the order of 10 deg/s. A few parameters in this controller could be changed by upload of new values. At the beginning of 2010, no stable solution had been found that would prove that the bdot could be used at high rotation rates.

However, new simulations done by a TU-Delft student in cooperation with ISIS (NL) showed there may be a strategy for actively slowing down the satellite (Bdot controller may be stable even at high rotation rates). This work was performed during the student's 9-month master project. Figure 10 shows the path for detumbling by uploading new values of the bdot parameters. This strategy will be applied as soon as internal communication in the satellite resumes.

OHM:	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6	1.8	2	2.2	2.4	2.6	2.8	3
Lambda:															
0.1	K-	K-	K+	K+	K+	K+	K+	K+	K+	K+	K+	K+	K+	K+	K+
0.2	K-	K-	K-	K+	K+	K+	K+	K+	K+	K+	K+	K+	K+	K+	K+
0.3	K-	K-	K-	K-	K+	K+	K+	K+	K+	K+	K+	K+	K+	K+	K+
0.4	K-	K-	K-	K-	K+	K+	K+	K+	K+	K+	K+	K+	K+	K+	K+
0.5	K-	K-	K-	K-	K-	K+	K+	K+	K+	K+	K+	K+	K+	K+	K+
0.6	K-	K-	K-	K-	K-	K-	K+	K+	K+	K+	K+	K+	K+	K+	K+
0.7	K-	K-	K-	K-	K-	K-	K+	K+	K+	K+	K+	K+	K+	K+	K+
0.8	K-	K-	K-	K-	K-	K-	K-	K+	K+	K+	K+	K+	K+	K+	K+
0.9	K-	K-	K-	K-	K-	K-	K-	K+	K+	K+	K+	K+	K+	K+	K+
1	K-	K-	K-	K-	K-	K-	K-	K+	K+	K+	K+	K+	K+	K+	K+

Figure 10: Strategies for detumbling even with high rotation rates.

4.1.5 Ground station and telecommunications

Early ground-satellite communication difficulties were thought to be related to the RF link, but in fact were related to I2C. Both the uplink and downlink frequencies and board design turned out to be very stable over time. The only default found was the power needed to start the main communication board. Further analysis and tests were done on the ground and found a mismatch between the communication board connector and its antenna. That mismatch is the cause of the high power needed on the uplink. However the sensitivity remained good.

Decoding of the RF signal on the ground turned out to be more challenging than expected. The decoding is done by a radio-amateur decoder, which can be improved. It is thus proposed to develop a custom decoding software for the next iteration. It is also proposed to use a better communication protocol than the AX.25.

Over 2010, regular hardware problems on the ground station at EPFL (both azimuth and elevation rotor failed, several connecter on the antennas got wetted...) and in Fribourg (problems with the hardware AX.25 decoder) prevented us from a reliable link quite often, but all these problems were fixed. A lesson learned is that the project should have spent time on more reliable mechanical and software design for the ground station.

In the middle of the year, the EPFL Electricity section, which had proposed one of its room for hosting the ground station electronics, claimed back its room and proposed another one, one floor below. About 20 m of cable were added, making it about 50 m till the end of the antenna mast. Additional amplifier and a filter at the ground station mast improved the signal quality. This addition was proposed by a radio-amateur in Switzerland, many from which the project got very good support (advices as well as hardware). Also note that the project got very valuable support from the EPFL-LEMA laboratory for the assessment of the ground station performances. We do thank all these contributors.

The project also hosted in June a special meeting of about 30 radio-amateurs (JITIM) from France. Figure 11 shows the location of all the radio-amateurs who registered to the SwissCube website to participate.

Figure 11: Location of participating radio amateurs early 2010.

4.1.6 Mission control software (MCS)

The mission control software proved very well designed and reliable. It supports not only the 2 SwissCube ground stations but also the inputs from the radio-amateurs in the world. The only one glitch found was due to a counter not wrapping correctly at its upper limit of 2^{14} (16384) commands sent, which was eventually reached. This flaw was quickly identified and easily solved.

ESA-ESOC has shown great interest for the MCS, as it has been developed using Microsoft's .NET technology. It is a very light ground segment, yet compatible with the ECSS, easily used for tests with the satellite. ESA's interest lays in small satellites applications. Interaction with ESOC will continue for improvements on MCS.

In addition, a company the Dutch, EATOPS, has contacted us to upgrade the current mission control software to provide a multi-satellite capability. This is being subject to an external contract for the Space Center, which negotiations will be continuing in 2011. The specific application is to perform real time operations of constellation of satellites, typically for fleet surveillance.

Figure 12 shows the component included in the MCS.

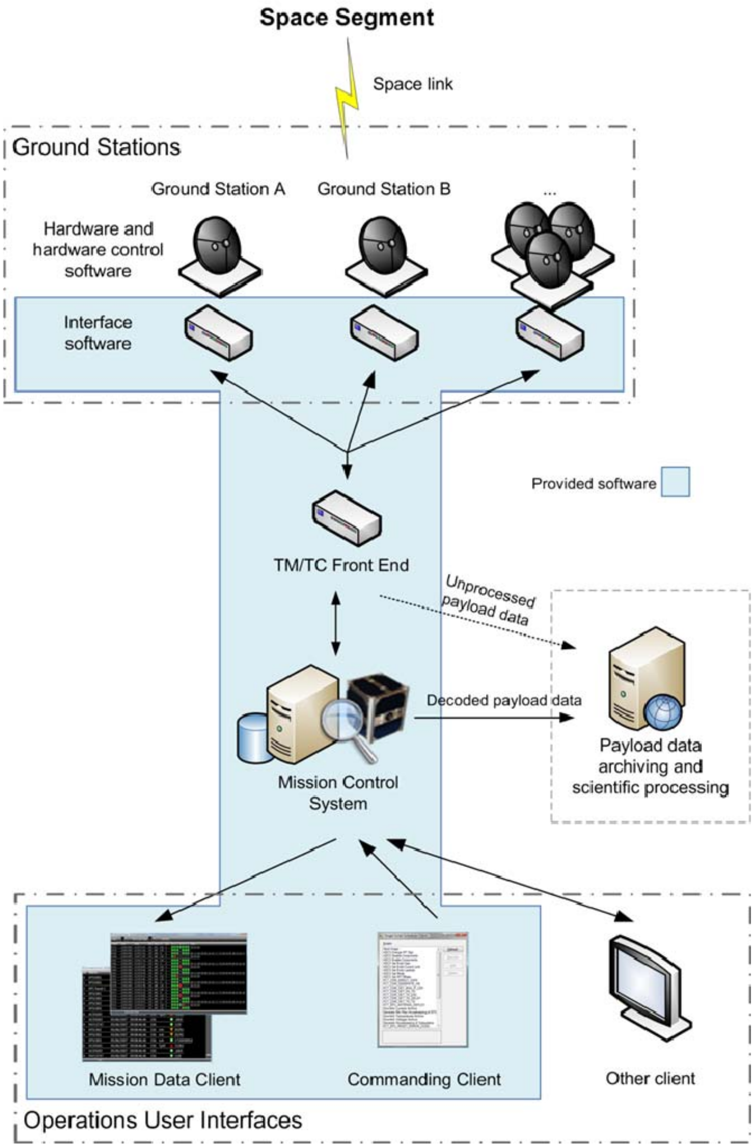

Figure 12: SwissCube high level diagram of the MCS.

4.1.7 Satellite temperatures

There are 21 thermal sensors aboard SwissCube. Most of them are accurate to within 1 degC. The collected temperature data shows that the design margins were generous during qualification and acceptance tests. The qualification temperature on the outside frame were between -50/+70 ^{o}C, while flight data show variation between -30/+45 ^{o}C: Internal board temperatures vary between -30/+35 ^{o}C.

4.1.8 Encounter with orbital debris

SwissCube has seen in 2010 seven (7) close encounter with orbital debris, as predicted by the United States Joint Space Operations Center (JSpOC). Most encountered debris are remains from the IRIDIUM/COSMOS collision in 2009. Typical encounter distances varied from 200 m to 600 m.

4.1.9 Plans for future operations

To solve the I2C internal communication issue, it is proposed in 2011 to implement a total reset of the satellite. Keeping in mind that the satellite was not designed for it, verification of the strategy on EQM will be done before implementation (EQM's communication switch had to be replaced). If successful this reset should allow for implementation and test of the detumbling scenario followed by the download of pictures. Mission operations and findings will be documented as well. An extension of 1 year for continued telecommunication to OFCOM and ITU has been asked.

4.2 Concurrent Design Facility

4.2.1 CDF improvements

Concurrent design facility (CDF) is an environment where engineers of different specialties come together to perform system engineering study for a project. Key elements for a CDF are team, process, environment (including A/V and software) and knowledge management. Benefits of a CDF for industrial implementation include faster design of new products, shorter time to market, overall quality improvement, knowledge re-use, fast implementation of trade studies. For the academic environment goals have to be completely different because there is no commercial product delivered at the end and product lines do not exist. This paper will describe the process of setting up a facility in a university and will try to answer a question of where CDF concept can fit into education.

We have also implemented a system to assist with tracking of the requirements. All requirements are entered into a database (MySQL) via a specialized interface on an Excel sheet. The interface allows initiating, editing, confirming or validating requirements. User level access is controlled; hence subsystem engineers only have access to requirements from their subsystem. External systems can be used for tracking requirements and understand dependencies between different levels.

One of the problems in concurrent design is to back track to a particular decision point, or understand why a particular decision was taken. A simple version control system is implemented, based on the Subversion (open-source version control system). Before committing a design or design change the engineer needs to enter a simple log, which can be later retrieved together with the spreadsheet. It requires a certain discipline in the team, but it allows keeping the history of design evolution.

In the near future, we are planning to evaluate use of the Open Concurrent Design Server for projects carried out in academic environment. This will require a major software change and redesign of existing interfaces. We also plan to improve handling of requirements and design logs. Migration to OCDS will allow development of models, which can be exchanged with ESA CDF and possibly other universities.

4.3 Clean-mE

4.3.1 Clean-mE activities in 2010

The seed-money activity initiated in September 2009 on Clean-mE continued over the first two quarters of 2010. During that time, the Space Center established first contact with industry regarding this project. It organized a visit of CSEM in January 2010, and of RUAG-Space in May 2010. A final report was provided in May 2010 that included:

1) A preliminary design (Phase 0) of the Clean-mE satellite, mostly elaborated to get smarter on the systems issues ;
2) A draft version of an R&T roadmap :
3) And a list of the identified existing technologies in CH that have synergies with what is needed for rendezvous and proximity operations (RPO).

The team attended the first European workshop on orbital debris removal, workshop organized by the CNES in June 2010. This workshop provided a good overview of orbital debris removal (ODR) technologies in Europe.

The Space Center also co-wrote a StarTiger Proposal and submitted it to ESA in June 2010. The goal of this proposal was to design and perform a ground demonstration of an integrated vision and capture system. Several partners were included and responsibilities were spread as such (see Figure 13):

- RedShift: Project management, SE, electronics
- CSEM/ABB: 3-D (high resolution) camera
- EADS Astrium: Net capture system
- EPFL: Image processing and ground simulator

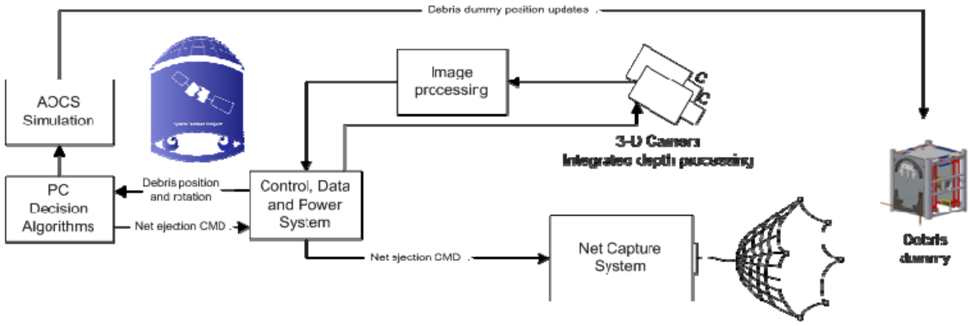

Figure 13: Proposed Star Tiger demonstration.

The debrief for the StarTiger proposal is still to date to be expected, as the proposal was not selected.

The Space Center also responded to an Ariadna call for ideas (ITT AO/1-1-6411/10/NL/CBi), which purpose was to address key aspects of a multi-debris storage deorbiting system. This proposal was not selected.

The Space Center visited EMPA in November 2010 as their compliant material system could be used for a gripper mechanism.

Figure 14: EMPA gripper mechanism (courtesy EMPA)

The Space Center also held a focused technical Interchange Meeting with Astrium Satellites (in Nov. 2010) specifically on the vision and robotic systems.

Further plan (roadmap) for activities will be done early 2011.

4.3.2 Student Activities in 2010

Several students (about 8 of them) worked on the Clean-mE project in 2010. The project focused mostly on the vision system (target shape and attitude reconstruction algorithms development, new video test set-up), on satellite control simulations (for target approach), on robotic arm survey and conceptual design and on the telescope design for a "Debris Inspector" instead of a debris remover, working closely with University of Bern.

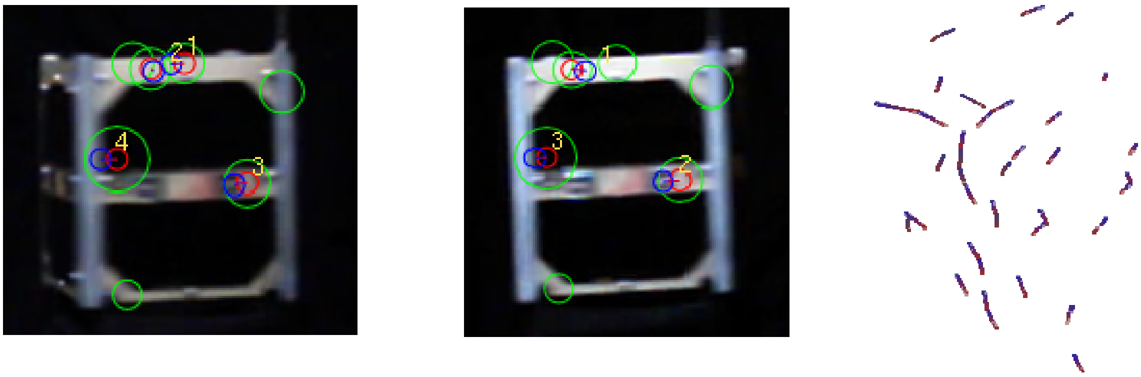

Figure 15: Example of a visual texture independent methods tested for Clean-mE (partially satisfying). The last picture shows the trajectory of the selected points on the test model.

4.3.3 Next steps

2011 will see the continuation of student projects in the area of the vision system, robotic system, and telescope inspector. An effort will be done on the identification of target conditions and test set-up. The Space Center will also write an R&T plan for 2011-2015 and will continue its search for funding.

4.4 Small Exoplanets Observatory (CHEOPS)

Building on the recognized scientific excellence of Swiss scientists in the area of detection and characterization of planets inside and outside the solar system, we proposed a mini-satellite that will make follow-up measurements of known exoplanets in order to characterize their structure. Originally proposed within the framework of the NCCR project PlanetS, the mini-satellite provisionally called CHEOPS (CH ExOPlanet Satellite) is envisioned to be a small spacecraft (< 100 kg) carrying a telescope (of order 40 cm) that will perform ultra-precise optical photometric observations within two wavelength bands. The science goal of CHEOPS is to measure transit signals from stars with planets (see Figure 16) in order to accurately determine the radius of the latter. A wavelength dependence of the signal will provide some characterisation of the atmosphere of the planets.

The Space Center is participating in a feasibility study, which is carried out under the overall leadership of the University of Bern (UniBE) in close collaboration with the University of Geneva (UniGE). The studies will cover all aspects of the development of a mini-satellite (satellite, payload, and ground segment) as it is customary at the major space agencies for these phases of development. In addition, a consortium of national and international partners will be set up in order to carry out the project beyond feasibility studies should the conclusion be positive. At this point EPFL Space Center carries responsibility for the Satellite System, which includes the Space Segment (satellite itself, except for the payload) and the Ground Segment (receiving sations, mission control).

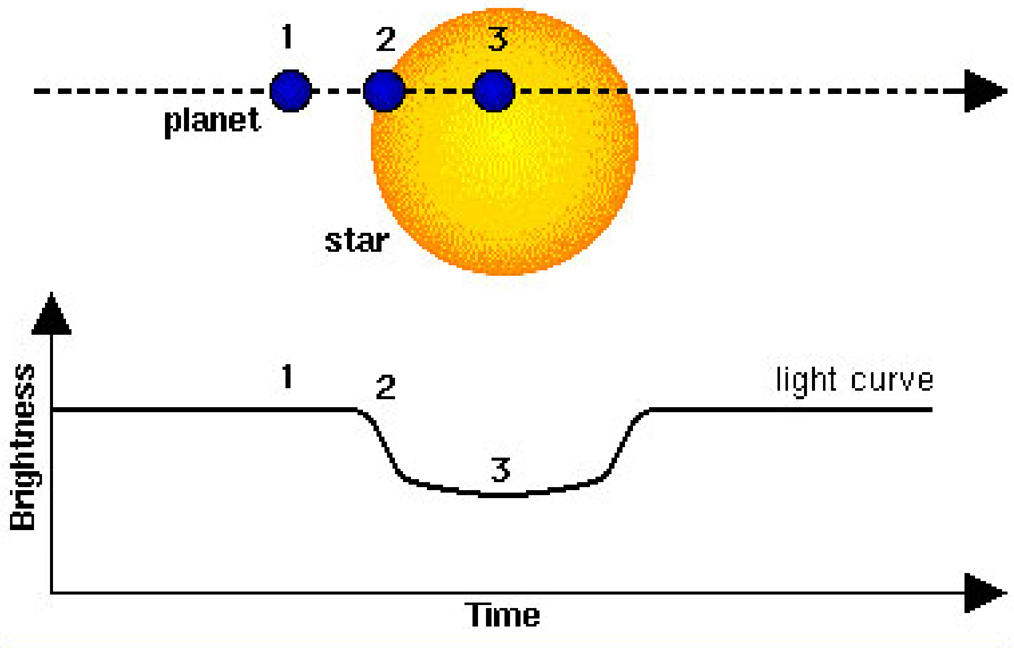

Figure 16. An illustration of the transit method for observations of exoplanets. As a planet comes in front of the host star, it blocks a portion of the flux coming from the star. Apparent brightness drops by a very small amount (less 1%), which requires a very sensitive photometer to be flow on our microsatellite mission.

4.5 Other projects

4.5.1 MicroThrust

The Space Center completed its deliverables for the ESA TRP activity on micro-propulsion, activity lead by TNO and with major participants the EPFL-LMTS, QMUL and NanoSpace. It presented its results at ESA during the final review on 30 March 2010.

The Space Center EPFL also participated in an FP7 MicroThrust proposal lead by EPFL Professor Herbert Shea. This proposal was selected and funding came at the end of 2010. This proposal also involves TNO, QMUL, NanoSpace and Systematics.

The Space Center is leader of Work Package WP1: Mission Analysis. It will provide support to the team in the area of mission analysis and system engineering (9 WM on WP1 spread over 3 years). It is also supporting the Propulsion Systems Engineering WP with 2 WM. The main goal is to infusion the mission requirements into the propulsion system design. It is also to understand the limits of the propulsion system (in terms of capability and performances) and its benefits to future ESA or university missions.

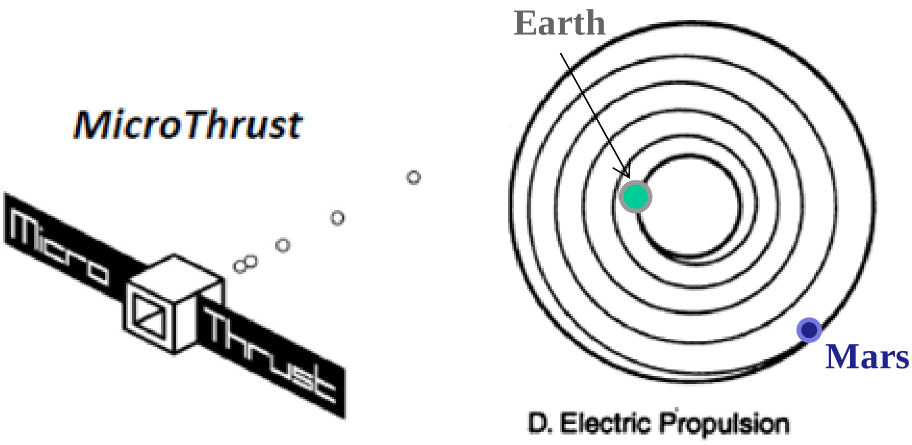

Figure 17: MicroThrust satellite on its way to Mars

4.5.2 MAST: Miniature antenna for small satellites.

We performed a feasibility study in the frame of an ESA TRP on a compact antenna system to be integrated within a small spacecraft and able to provide three different modes of coverage working in the S- band with circular polarization: a) omnidirectional full- coverage, b) one directive beam, and c) four tracking-lobes at a time. The key items for the design of this antenna system are not only the multifunctional aspect and the concurrency of the three modes, but also the achievement of a high integration degree providing the best performances. For the construction of a mock-up satellite, a typical satellite size within the small satellites range (cubic shape of 250x250x250mm ~ 1.8λx1.8λx1.8λ @ 2.16GHz, which is the center frequency of the band 2025-2300 MHz usually allocated for space applications) has been chosen. This project was led by LEMA and JAST

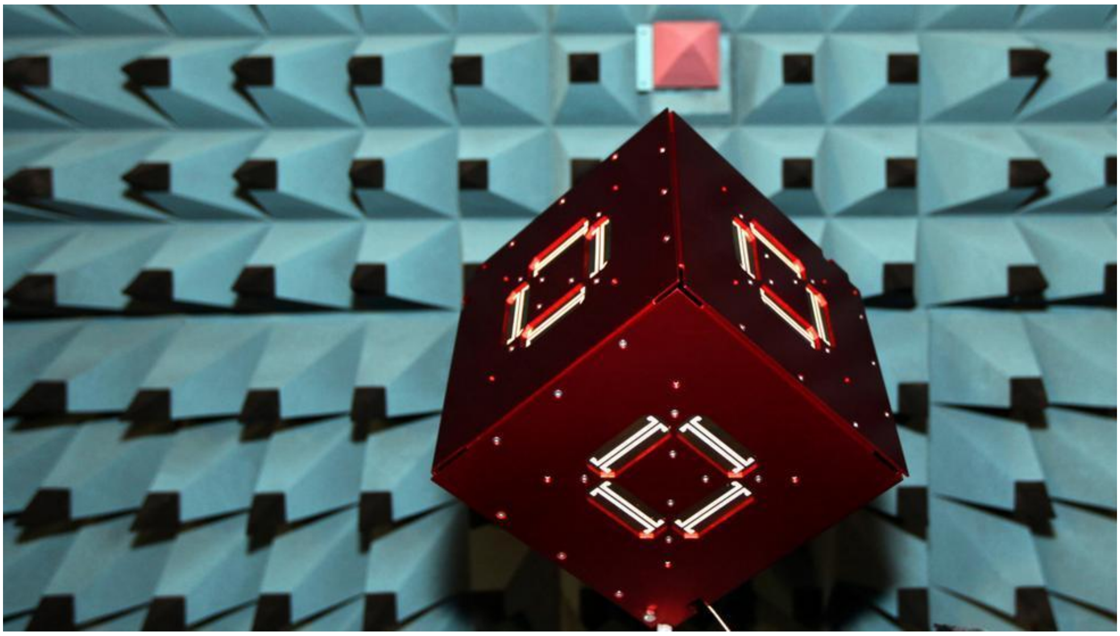

Figure 18: Breadboard model of the MAST antenna in the LEMA acoustic chamber. ©Alan Herzog, EPFL. Full version of the report can be found at http://actu.epfl.ch/news/epfl-antennas-chosen-by-esa-for-nano-satellites/

Using facilities at the Space Center EPFL, we have performed a systems engineering study to formulate basic telecom requirements and functional requirements. We have computed key antenna system parameters for evaluation of antenna performance. Two key reference scenarios have been evaluated: Direct to Earth (DTE) link and satellite-to- satellite communication for a Mars Ascent Vehicle (MAV) capture. For the Direct to Earthlink we have assumed a narrow beam antenna to maximize downlink data volume. Both scenarios were evaluated for the designed small satellite mock-up in order to obtain realistic estimations of the power budget available. For the DTE scenario, antenna patterns and link budgets were calculated for various antenna sizes and facilities available on the ground. Even in the most constrained cases, we were able to achieve speeds up to 512kbit/sec, which satisfy some of the Earth Observation or Debris Capturing missions. For the Mars Ascent Vehicle scenario, we were able to show that in the foreseen orbit, MAV stayed in contact for approximately 3 hours per day with the Earth Return Vehicle (ERV).

Final review for the project was held in November 2010. Satellite and antenna models have been shipped to ESTEC.

The MAST consortium is now investigating possibilities to continue this work with a hardware implementation of the S-band subsystem, which can possibly be used on the future minisatellite missions designed at the Space Center EPFL.

4.5.3 QB50

QB50 is a VKI lead activity, which purpose is to fly a network 50 CubeSats on one launch and operate them all at the same time. QB50's scientific objective is to study in situ the temporal and spatial variations of a number of key constituents and parameters in the lower thermosphere (90-320 km). QB50 will also study the re-entry process by measuring a number of key parameters during re-entry and by comparing predicted and actual CubeSat trajectories and orbital lifetimes. Given the short development time and low cost of CubeSats, a network of such satellites developed each by an institution seems to be an interesting and justifiable possibility to provide multi-point in-situ measurements. The satellites will be provided by universities across the world. The 50 CubeSats are planned to be launched in 2014 by a Shtil-2.1 into a circular orbit at 320 km altitude. The selection of the 50 2U/3U CubeSats is supposed to be done in 2011.

The Space Center's participated in the QB50 FP7 proposal with a Work Package for 100 k€, and will deliver the Mission Control Software for the project.

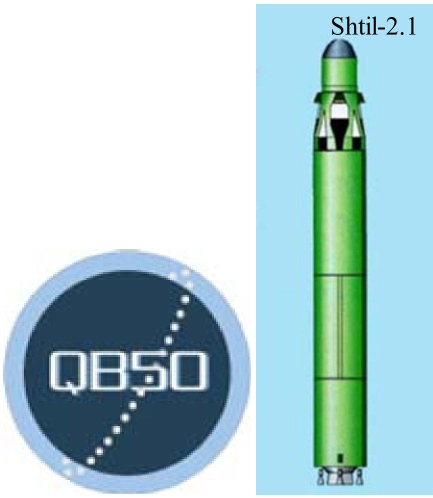

Figure 19: QB50 logo with Shtil2.1 rocket

The Space Center will also provide support to the science working group. Preparation work has been carried out on science and mission objectives for QB50 program. This work was to answer the following question: how to put scientific goals of QB50 into context of the global observing programs? We have collaborated with the World Meteorological Organization (Space Division). This work done to explore possible avenue within the task 3.16 of the Global Atmospheric Watch program which states: "Specify the requirements for new generation air chemistry satellite observations and surface-based measurements associated with calibration and validation of existing satellites. (WMO Space lead, GAW partners CEOS, IGACO Offices-ongoing)".

Some preliminary results of this work have shown some short comings of such a mission based on Cubesats. For example, lifetime of proposed QB50 mission is quite short (40 to 60 days). In this may be an issue to organize a coordinated observation campaign across many universities and properly start operations of the satellite. In terms of science payload, it might be possible to fly a spectrometer on a Cubesat in which case it might be coordinated with the Global Observing program. One of the possible instruments that was considered is Argus 1000 spectrometer was flown on Canadian CanX-2 mission, however its science performance is unknown. The final conclusion of this work is that it is important to student satellite missions in the range of 10-15 kg, with payload which would satisfy requirements of the world Earth observation community. This includes satellite lifetime requirements as well as quality of science measurements. Small satellites may lead the path to shorten development cylcle and improve responsiveness of climate observations.

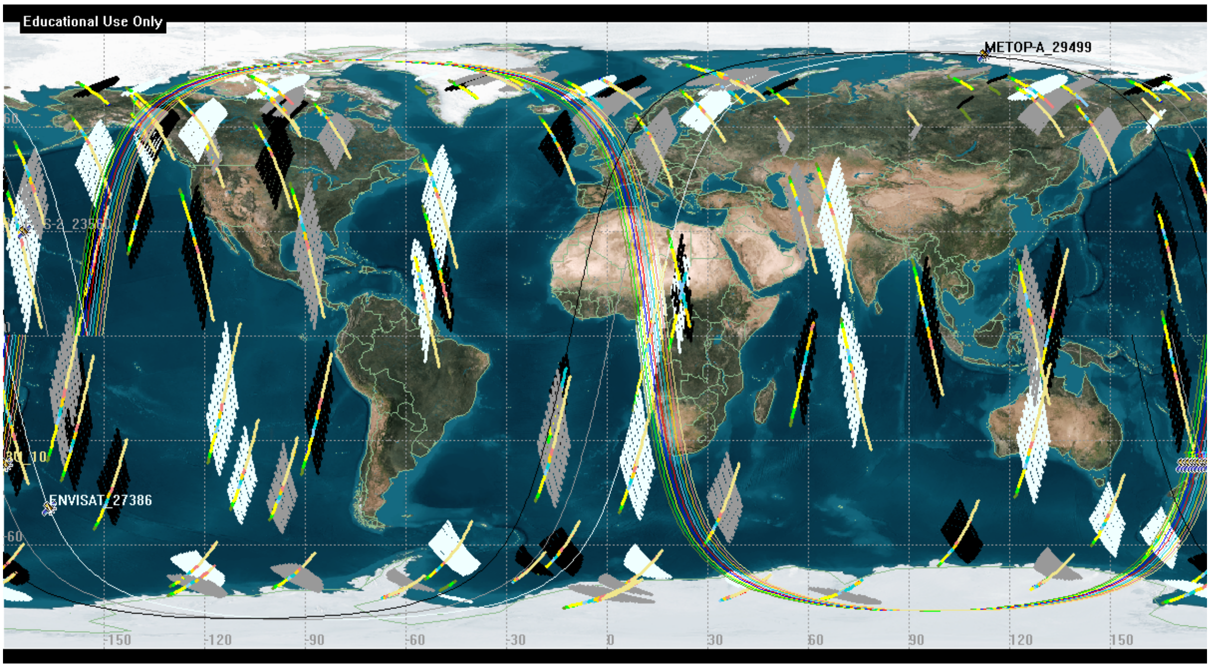

Figure 20: Possible cross-calibration opportunities with the Global Observing System (GOS) satellites for the QB50 mission over period of its lifetime. We have found that this coverage depends greatly on the RAAN parameter of the of the orbit. This coverage allows possibilities for joint observations of QB50 with GOS program space and ground assets.

4.5.4 Rexus GGES Flight experiment

This project was initiated by a group of EPFL students, who quickly got support from the LMTS laboratory and the Space Center. They prepared for and attended the selection workshop at ESA on Nov. 30 - Dec. 1. Out of 8 teams, the EPFL team got selected and is now under a stringent schedule to deliver the experiment to ESA by the end of November 2011. The flight test will be done in March 2012 aboard the REXUS sounding rocket, and launched from the EuroLaunch facility in northern Sweden.

The objective of this REXUS experiment is to perform a flight test of a MEMS Gravity Gradient Earth Sensor developed over the last three years by the EPFL – LMTS Laboratory (among funding sources - ESA contract 21053/07/NL/CB). The test will measure the gravity gradient torque with changing angles with respect to the Earth Vector in low ambient pressure, and study the performance of the sensor as the booster shuts off. This test cannot be performed under normal gravity conditions, under which the displacement due to the gravity gradient torque is negligible, compared to the effect of gravity.

According to the regulations for these types of flights, students only can be part of the flight. However, this schedule for this experiment is extremely tight and this team (~ 6-8 students) will need support from the Space Center to maximize chances of success. The Space Center will ensure correct implementation of the project, and provide electronics, software and mechanical support in 2011.

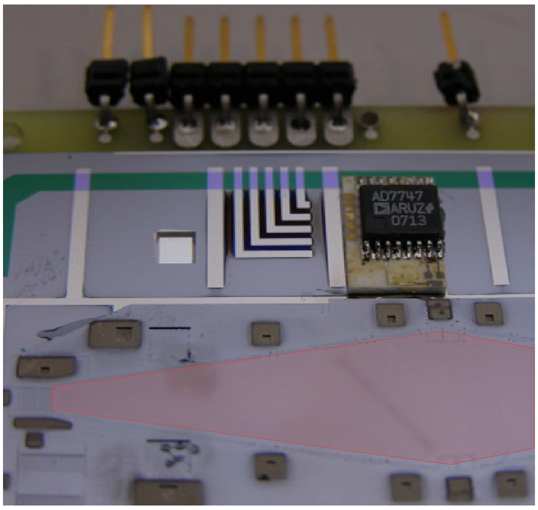

Figure 21: Rexus rocket at the ESRANGE Space Center (Sweden) and microfabricated Earth sensor.

4.5.5 Suborbital plane project (K1000).

This project was to design a sub-orbital plane, in which passengers can experience 0g environment. The plane is deployed from a commercial plane at the altitude of 10 km and then uses its own engines to climb up to altitude of 100 km. After a few seconds of microgravity environment the plane glides to a safe landing. This project consisted of a mechanical, aerodynamics and propulsion subsystems. General view of the plane is shown in Figure 22. Overall plane and mission parameters were all collected in a system sheet. The team has computed aerodynamic properties of the space plane and validated primary requirements of the project.

During this study we have implemented a centralized model approach for the Concurrent Design. In contrast with classic modeling, where subsystems models are implemented independently, we employed a central model for the system written in MATLAB/Simulink environment. Each of the subsystem engineers was responsible for contributing a submodel block to the system and the role of systems engineer was to integrate all inputs. We have found that for clarity all of the important parameters shall stay in the Excel sheet, which was used as input table. Excel sheets were also used to summarize model results. This approach allowed very efficient implementation of complex design loop, which included some very demanding computations of aerodynamic properties of the vehicle. Structural shape of the plane was designed by mechanical engineers. Using this shape, aerodynamic coefficients were computed on a cluster system. Results of aerodynamic simulation were then used for control algorithms and mission design.

Once model was established we performed studies on secondary propulsion system (for improved security of the descent and landing), some aspects of vehicle and passenger safety, prepared examples of the flight failure tree and possible outcomes. Through extensive use of visualization tools linked to the model we have also made recommendations for improvement of customer experience.

The final report has been submitted to Dassault. Future of the whole program depends on the commercial experience of the competitors (e.g. Virgin Galactic), as well as funding available for initiate a new large scale project.

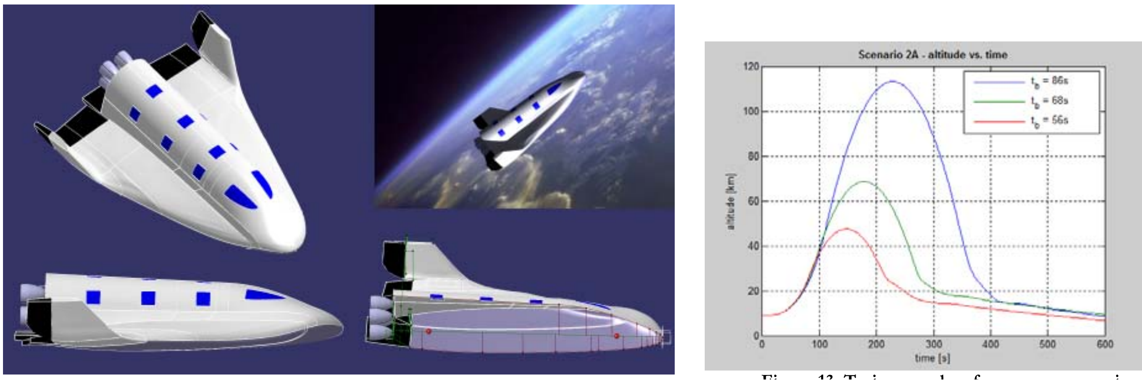

Figure 22: Snapshots of external view of the sub-orbital space plane (left panel) and an example of aerodynamic flow simulation. Shape of the airplane was used in flow calculations to determine a set of aerodynamic coefficients.

5 Special events

5.1 International cooperation with BMSTU

In the frame of the partnership with several Russian universities and in response to the space camp followed by several EPFL students in 2008-2010, a delegation of the Bauman Moscow State Technical University (BMSTU) came to visit EPFL from 18 to 21 of May 2010. List of the delegation is shown in Table 7.

	Members of delegation from BMSTU		EPFL Students to Space Camp 2010	
№	Name	Status	Last Name	Name
1	Mayorova Vera	Professor	Cabello	Alan
2	Zelentsov Victor	Senior Teacher	Madi	Mohammad Reza
3	Zelentsova Ekaterina	Senior Teacher	Bhargava	Saurabh
4	Gavrilovich Irina	Student	Raghavan	Santosh
5	Ivanova Yulia	Student	Gattiker	Cyrille
6	Deeva Daria	Student	Peric	Oliver
7	Lyubchenko Mikhail	Student	Belloni	Federico
8	Kuchina Yulia	Student	Python	Quentin
9	Leonov Victor	Ph d Student	Perrin	Lucas
10	Gladysheva Maria	Student	Semmler	Patricia

Table 7: List of the students and stuff of the Bauman Moscow State University visited the Space Center EPFL (left panel) and list of EPFL students, who went to the BMSTU Space Camp in 2010 (right panel)

After a visit of the Space Center EPFL, they were invited to see the labs of Prof. Clavel, Dr. Mondada and Prof. Ispeert. It was also important for the EPFL students, who were selected to attend the BMSTU Space Camp, to meet with Russian students before the trip. The official visit was followed by a highly appreciated tour in the Swiss Alpes with typical Swiss delicacies. The visit was mostly organized and hosted by Anton Ivanov of the Space Center EPFL with the enthusiastic participation of Pierre Wilhelm and Andreas Hofstetter.

EPFL students attended the BMSTU Space Camp in July 2010 (list of the delegation is shown in Table 7). This visit has been reported as one of the best to date. Program has included technical project on a project of manned Lunar Base, visits to many space industry facilities near Moscow.

Figure 23: EPFL students at the Space Camp 2010 together with all other students who participated in the program (left side). Students near the Museum of Cosmonautics in Moscow (right panel)

5.2 Dynamic Technical Leadership for Space Projects

A training course on "Dynamic Technical Leadership for Space Projects" was held on 5-6 October 2010 at EPFL. 41 participants attended the course with a strong participation of the industry (RUAG, Maxon Motors, ABB), CSEM, and academia (EPFL, UniBE, HES).

This course gave the audience an understanding of how and why current systems engineering and management processes commonly used in the space business often fail to deliver innovation, cost or schedule control, or technical excellence. Several fascinating systems engineering concepts were presented including a useful and interesting definition of what systems architecture really is and why it is important for enabling innovation; how effectively-stated requirements are critical to the success of large programs (but often drive innovation out of small programs); and why parametric cost models are often incorrectly blamed for a failure of programs to deliver on cost (and what the real culprits are). A review of the state of space project management and systems engineering methods was provided with an eye toward what works and what doesn't work. Attendees learned that when it comes to management and systems engineering practices, a one size fits all approach often leads to failure. These lead into a presentation of a unique model called D2S (Depth, Disruption, and Scope) for assessing individual programs to determine which management and systems engineering methods should be used for each program. The D2S model is used as a foundational construct to walk through the space of different types of space projects and for each archetypical type of project, best practices and methods of systems engineering and management are taught. Three canonical projects types including small and highly innovative, large and highly disciplined, and deep technology were addressed. Hybrid project types which require dynamic leadership were discussed.

The presenter, Joel C. Sercel, PhD, is President and Founder of ICS Associates Incorporated a California-based U.S. consulting firm. Dr. Sercel has 25 years experience developing and utilizing advanced technology to increase cost effectiveness of technical enterprises. During a 17-year career at NASA's Jet Propulsion Laboratory (JPL), Sercel made important contributions in diverse areas including space technology development, systems engineering, software development, and management. He led the conception, proposal, and definition of the NSTAR ion propulsion system, the first deep space application of ion propulsion technology to reduce the cost of solar system exploration in the 21st century. Software and processes designed by Dr. Sercel are in use at JPL, Boeing, Raytheon, among many and are credited with having increased team productivity by a factor of four for complex systems engineering tasks. Dr. Sercel has consulted for with dozens of organizations and has received multiple awards for innovations in areas ranging from support space mission projects to engineering team productivity tools and advanced space propulsion technologies.

According to the satisfaction survey, the course was well appreciated by the participants.

Figure 24: “Dynamic Technical Leadership for Space Projects” training course.

5.3 SECESA Conference

ESA and the Space Center organized the 4th International Workshop on System & Concurrent Engineering for Space Applications (SECESA), held on 13-15 October 2010 at EPFL. Over 100 participants participated including key ESA and NASA speakers (Michel Courtois, Franco Ongaro, and David Nichols). All of the big European space industries were present (Thales Alenia, Astrium) along with many SMEs. In the framework of the Workshop demos of the recent software for design studies were organized in the Space Center CDF facility. Many participants have reported new contacts and the excellence in meeting organization.

The 2010 budget had allocated a total of 5000 CHF for the organization of the conference, but the Space Center only spent 4400 CHF.

A social event was organized in the Olympic museum on the Thursday evening and participants had dinner within the museum among the exhibited historical sport items.

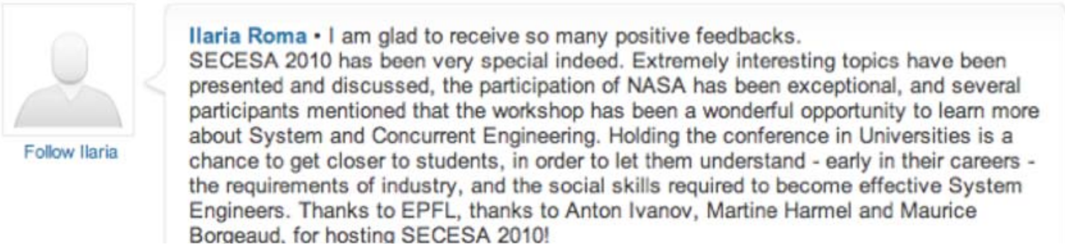

Figure 25: Positive feedback from participants of the conference on the professionals' social network LinkedIn.

Figure 26**:** Participants of the SECESA 2010 Workshop during the social event at the Musee Olympic in Lausanne.

6 Education and Teaching

6.1 Master and semester projects

Due to the fact that the Space Center EPFL resides at EPFL, many students interested in space applications are doing part of their required curriculum with the Space Center EPFL. A total of 31 projects under the responsibility of the Space Center EPFL were offered in 2010. These projects can be categorised in the following main applications, namely:

- SwissCube, 5 students
- Remote sensing of the Earth, 3 students
- System engineering and CDF related studies, 2 students
- Clean-mE, 5 students
- CHEOPS, 4 students
- Other (QB50, SPL, Micro-propulsion, Aerothermodynamics), 7 students.

The list of all student projects is provided in Appendix 10.2. Table 8 summarises the number of students for each project types.

Type of projects	Number of students
Master	3
Minor	13
Semester	10
Summer jobs	5
Total	31

Table 8: Number of registered Space Center projects

6.2 Minor in space technologies

The Minor in Space Technology courses include fascinating fields such as experimental research in our solar system using spacecraft; 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:

- 18 ETCS for courses
- 12 ETCS for a project.

Figure 27 shows the number of newly registered minor students per year. As the Minor spreads over 2 years, on December 2010 there were 30 students registered in the minor.

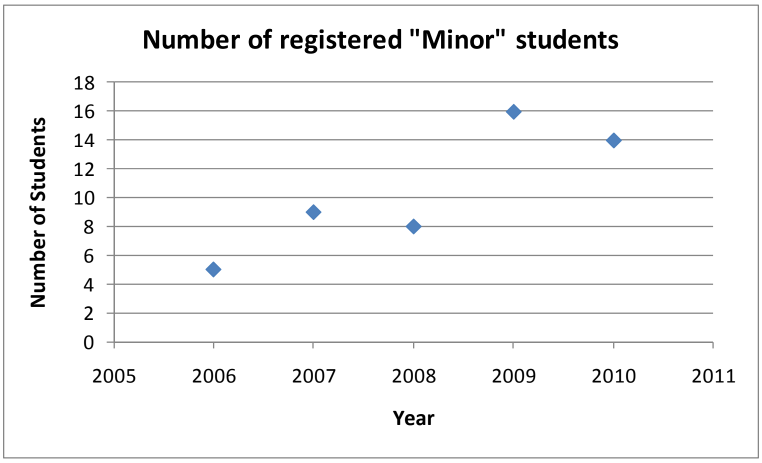

Figure 27: Newly registered students to the Minor in Space Technologies.

The main courses of the minor in space technologies were attended by the following number of students:

Class	Lecturer	Credits	Semester	# students
Introduction to Space Science	Blush	2	Autumn	21
Remote sensing of the Earth by Satellite	Borgeaud	2	Autumn	46
Satellite Communication systems and networks	Farserotu	3	Autumn	38
Spacecraft data processing and interfaces	Storni	2	Spring	14
Lessons Learned from Space Exploration	Toussaint	2	Spring	18
Spacecraft design and system engineering	Noca	2	Autumn	16
Space mission design and operations	Nicollier	2	Spring	76
Introduction à la conception de mécanismes spatiaux	Mäusli	2	Spring	8
Introduction to planetary science	Ivanov	2	Autumn	23

Table 9: Attendance of the "strongly encouraged" minor classes

Table 10 shows the list of courses available to the students in 2010. 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).

Mineur en Technologies spatiales								
	Title	Lecturer	Section	Credit	Semester		Schedule	Exam type
Space Courses (Strongly encouraged)	Space Courses (Strongly encouraged)							
	Introduction to space science	Blush	EL	2	A		Weekly	written
	Remote sensing of the Earth by satellites	Borgeaud	EL/MT/SIE	2	A		Weekly	written
	Satellite communication systems and networks	Farserotu	SC	3	A		Weekly	written
	Spacecraft data processing and interfaces	Storni	EL	2		S	Bi-Weekly	written
	Lessons learned from the space exploration	Toussaint	EL	2		S	Bi-Weekly	oral
	Spacecraft design and system engineering	Noca	EL	2	A		Weekly	written
	Space mission design and operations	Nicollier	EL/GM/MX/MT	2		S	Five modules during the semester	oral
	Introduction à la conception de mécanismes spatiaux	Mäusli	EL	2		S	Weekly	oral
	Introduction to planetary science	Ivanov	EL	2	A		Weekly	written
Additional Courses	Additional Courses							
	Lever aérien	Vallet	SIE	3	A		Weekly	tbd
	Localisation par satellites	Gillieron	SIE	3	A		Weekly	oral
	Techniques de navigation	Skaloud	SIE	4		S	Weekly	written
	Astrophysique I: Introduction à l'astrophysique	Courbin	PH	3		S	Weekly	oral
	Astrophysique III: Cosmologie observationnelle	Meylan	PH	4	A		Weekly	oral
	Conception mécanique	Schorderet	GM	5		S	Weekly	oral
	Fundamentals of radiation damage and effects	Schäubin/Spätig	MX	2		S	Weekly	oral
	Instabilité et turbulence	Gallaire/Deville	GM	4	A		Weekly	oral
	Rayonnement et antennes	Mosig	EL	3	A		Weekly	written
	Reliability of MEMS	Shea	MT	2	A		Weekly	written
	Technologies des capteurs et des actionneurs intégrés	De Rooij	MT	2	A		Weekly	oral
	Heat and mass transfer	Thome	GM	4		S	Weekly	oral

Table 10: List of courses offered in the frame of the Minor of Space Technologies in 2010

6.3 PhD research

Since 2007, the EPFL Space Research Programme (ESRP) was created and enabled the sponsoring of 4 PhD theses in the space sector. In addition, two ESA Networking-Partnering Initiative (NPI) funded thesis started at approximately the same time as shown in Table 11. These PhD theses are still running.

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 11: List of ESRP and NPI theses at EPFL linked to the Space Center EPFL

In addition to these 6 theses in the space domain, M. Valentin Longchamp was pursuing his PhD at CSEM-Alpnach in the frame of the hard-return contribution of the CSEM to the Space Center EPFL. His thesis dealt with the integration of CSEM Sensor-Technology in state-of-the-art robotics with a special focus on cooperative and distributed systems applied to space exploration. M. Valentin Longchamp stopped his PhD in Oct 2010.

6.3.1 HyperSwissNet

The Space Center EPFL secured in 2008 to the funding for a PhD student in the frame of the HyperSwissNet project, a joint collaboration with several Swiss academic partners interested in hyperspectral imaging for Earth observation applications. Using its expertise in this domain, the role of the Space Center EPFL in this project was to develop new retrieval algorithms to derive bio- and geo-physical parameters from remote sensing data for land applications. A special emphasis is put in the study of the synergy of hyperspectral data acquired by the APEX airborne sensor and SAR (Synthetic Aperture Radar) satellite data over vegetated (forestry, agricultural areas) and bare soil areas. Ms Jelena Stamenkovic started the PhD in May 2010 under the supervision of Dr. Maurice Borgeaud. With the departure of the latter, Ms Stamenkovic was transferred in December 2010 to the laboratory of Prof. Philippe Thiran, Signal Processing Laboratory 5.

7 Research and development projects

7.1 "Seed money" studies executed in 2010

As a reminder, "seed-money" projects 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 a specific member of the Space Center EPFL. They remain confidential and are treated bilaterally between the relevant industry partner and the Space Center EPFL.

In 2010, the Steering Committee approved two new projects as described in Table 12. For completeness, the table also indicates all the studies that were either completed or still running during this year.

Title	Reference	EPFL partners	Type	Amount [CHF]	Comments
Light-Weight RF Cables	025/2009	LEMA (Mattes-Mosig)	Soft-return	50'000	Completed
Clean-Me feasibility study	029/2009	Space Center EPFL (Borgeaud)	Soft-return	36'000	Completed
Effects of gravity on cavitation bubble collapse	031/2010	LMH (Farhat)	Soft-return	40'000	Running
Incubator for simulated microgravity experiments	032/2010	NWFH (Sekler)	Soft-return	50'000	Running

Table 12: List of projects approved by the Steering Committee, completed or running in 2010.

7.2 SSO Mesures de positionnement

The SSO organized a Swiss call to foster and promote Swiss scientific and technological competences. The Space Center provided support to this new initiative in 2010. It drafted and issued the call under SSO guidance. It also organized the technical and management evaluation for SSO, which happened in July. Several experts from ESA and retired Swiss space industry engineers were invited. The recommendations were provided to SSO in September. After final selection by the SSO, the Space Center organized the kick-off of the selected proposals during November.

Table 13 shows the title and institutions of the selected proposals.

Domain	Prime	Partners	Title
Applications	SAPHYRION	UniTI-ALARI	TENCIA-1: RF module for space borne GNSS receivers
Applications	SARMAP	ETHZ	Generation of Digital Elevation Models based on the Fusion of Optical Stereo and SAR Interferometry Techniques
Applications	Gamma Remote Sensing	ETHZ	Gamma Portable Radar Interferometer
Avionics	Syderal	EPFL	FOCS: Floating Point Operation Controller IP Core for Space Applications
Avionics	Maxon Motor	CSEM	Reaction Sphere for Attitude Control Rotor Optimization
Mechanisms and structures	RUAG Space	HEIG-VD	Contactless Power and Data Transmission
Mechanisms and structures	ABB	CSEM	Advanced High Precision Encoder AHPPE
Optics	UniNE	SpectraTime	Compact and stablized laser head for innovative Rubidium atomic clock
Optics	CSEM	Leica, UniNE, ABB	Space QUalified Assembly Technique for Optical System (SQUATOS)

Table 13: Title and institutions of the selected proposals for SSO mesures de positionnement

8 Outlook for 2011

The year 2011 will be a transitioning year with the nomination of a new operational director and the revision of the foundation of the Space Center EPFL toward a more national role. In parallel, the future of the Space Center will be secured with the renewal of the SSO contract and agreement with the HES-SO. The new person hired with SSO funding will definitely increase the visibility of the Space Center EPFL as a technology partner.

2011 will see the continuation of the SwissCube mission operations, possibly with the de-tumbling procedure of the satellite and picture downloading. The project results will be presented in conferences and the project will be summarized in a report, including lessons learned.

2011 will also see the elaboration in Phase A of the CHEOPS satellite and consortium. Activities in that regard have started at the end of 2010, and momentum is building to make this satellite and mission a real opportunity for Switzerland. Several new positions are opening up to perform the Phase A work, which will consolidate the Space Center's role and breadth of expertise.

Concurrent Design Facility activities will be focused around Phase A study for the CHEOPS project and support of the REXUS project if required. CHEOPS study will allow to start work on models, which can be re-used on other satellites of similar size. For example, we will look into whether parts of the Energy and Power Subsystem, Telecom subsystem, can be re-used in other projects such as Clean-mE.

The initial concepts proposed in 2009 and 2010 for a space debris-removal mission and a constellation of small satellites in the frame of an international mission will be further developed. The educational thread will be continued with the support to the REXUS GGES flight experiment team.

We anticipate that there will be an increase in the number of students working on these exciting projects. Research activities in planetary exploration will focus on preparation for the HiSci mission and necessary developments to complete objectives in this project. Activities in international projects are extremely important for teaching as well, as they allow students to learn current state-of-the-art and possibly participate in data planning and analysis.

The success of the Space Center's activities, quite largely depends on the dedication of its team, students and young engineers who have, together, demonstrated their ability of dealing with very complex and bold projects such as launching the very first Swiss satellite. As interim-director of the Space Center EPFL and chairman of the Steering Committee, we would like to express our special thanks to the team working with us, and especially to Dr. Maurice Borgeaud, former director of the Space Center EPFL, since none of the achievement described in this report would have been possible without them.

Lausanne, February 29, 2010.

Herbert Shea
Ad Interim Director
Space Center EPFL

Juan Mosig
Chairman, Steering Committee of the
Space Center EPFL

9 Appendixes

The following appendixes are presented in the following pages:

9.1 List of detailed activities in 2010

The following table shows the detailed list of the activities performed in 2010 by the Space Center EPFL.

Date	Activity
19 Jan 2010	Visit & discussions CSEM on future collaboration
28 Jan	Visit & discussions RUAG on SwissCube-2
10 Mar	25th meeting of the Steering Committee (Extraordinary meeting)
17 Mar	Preparation meeting for the SATW workshop on 11 Nov. 10 entitled "Luft und Raumfahrt: Herausforderungen und Chancen für die Schweiz"
23 Mar	Presentation of the Space Center EPFL & SwissCube at the VHS (Volkshochschule) Bern
16 Apr	Telecon with Thales-Alenia (Torino & Cannes) => visit on 7 Sept. at EPFL
19 Apr	Meeting & discussion HEVs Sion on future collaboration
5 May	Visit & discussions RUAG
6 May	FP7 proposal dealing with "MEMS-based micro propulsion" submitted last November selected by the EC
18 May	Visit BMSTU students from Moscow for 3 days
29-30 May	Booth at the EPFL Open-Day
11 Jun	Meeting HES-SO
17 Jun	Submission of StarTiger pre-proposal to ESA with CSEM
21 Jun	Submission of Ariadna proposal to ESA (education)
22-23 Jun	Participation to CNES space debris conference

28 Jun	Participation to the ESA Living Planet Symposium
4-14 Jul	Participation of 10 EPFL students in the Russian space camp, Moscow
6-7 Jul	Technical evaluation of the SSO proposals submitted in the frame of the Call to foster and promote Swiss scientific and technological competences
14 Jul	QB50 teleconference
15 Jul	Meeting prof. Schildknecht, UniBE, on space debris
25 Jul	Signature of the contract with EATOPS for SwissCube ground station
9 Aug	Resignation of the Director of the Space Center EPFL
11 Aug	Discussion with Daniel Neuenschwander, SSO
12 Aug	Visit & discussions RUAG Space
12 Aug	Discussions with Roland Siegwart, ETHZ
25 Aug	Meeting Juan Mosig with EPFL Direction
26 Aug	SwissCube for more than 11 months in space. Still operating and still tumbling...
26 Aug	26th meeting of the Steering Committee
27 Aug	Visit & discussions SSO
26 Aug	26th meeting of the Steering Committee, RUAG, Emmen
27 Aug	Meeting with SSO about strategy of the Space Center EPFL
10 Sep	1st meeting of the working group to find a new Director of the Space Center EPFL
21 Sep	Visit Thales-Alenia at EPFL
22 Sep	EE industry day at EPFL
5-6 Oct	Training course at EPFL "Dynamic Technical Leadership for

	Space Projects”
7 Oct	Meeting with P. Gillet on the future of the Space Center EPFL
18 Oct	Negative answer received from ESA for StarTiger
13-15 Oct	ESA workshop on system engineering
3 Nov	Meeting ALCAN at EPFL
11 Nov	SATW Congress on aerospace, Zurich
17 Nov	Visit EADS-Astrium linked to CleanMe
23 Nov	Meeting P. Gillet, R. Siegwart, and D. Neuenschwander
26 Nov	FP7 QB-50 proposal submitted to EC
3 Dec	Meeting between A. Deich (CEO of RUAG) and P. Gillet at EPFL
7 Dec	KO of FP7 MicroThrust study
14 Dec	27th meeting of the Steering Committee, EPFL
14 Dec 2010	2010 Annual Meeting of the Space Center EPFL

Table 14: Detailed list of events in 2010

9.2 List of Master, Minor, and Semester projects during 2010

The following table presents an exhaustive view of the projects carried in 2010 at the Space Center EPFL. They are categorised by activity type corresponding to either Master (30 credits ETCS equivalent to 4 month of full time), semester (12 ETCS), or Minor (12 ETCS) projects:

Firstname	Lastname	Semester	Project	Title	Type
Pierre	Deleglise	Spring 2010	Clean-mE	Clean-mE vision system	Master
Federico	Belloni	Spring 2010	SwissCube-next	S-band telecom system analysis and trades	Minor
Julien	Ston	Spring 2010	Propulsion	Design of a carbon composite tank for SPL	Minor
Jorge	Vincentservera	Spring 2010	SwissCube	ADCS reaction wheel control algorithm	Master
Christophe	Meerts	Spring 2010	Aerothermodynamics	Design of an atmospheric entry model	Semester
Sylvain Gallay	Gallay	Spring 2010	CDF	Systems engineering and requirements modelling	Semester
Arthur	Triguero Baptista	Spring 2010	CDF	CDMS model for a nanosatellite	Semester
Francisco	Bedmar	Spring 2010	CHEOPS	Thermal environment for the CHEOPS satellite	Master
Grigori	Chevtchenko	Spring 2010	Earth Observation	Joint analysis of ENVISAT ASAR and MERIS satellite remote sensing data	Minor
Hervé	Meyer	Fall 2010	Micro-propulsion	Test of high-voltage converters	Minor
Benoit	Chamot	Fall 2010	Micro-propulsion	Test of high-voltage converters	Semester
Lucas	Perrin	Fall 2010	Micro-propulsion	Test of high-voltage converters	Minor
Yannick	Bastin	Fall 2010	SwissCube	Ground antenna dynamics simulation	Semester

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Jean-Francois	Labrecque-Piedboeuf	Fall 2010	SwissCube	Test of SwissCube Antenna Deployment System	Semester
Federico	Belloni	Fall 2010	SwissCube-next	Design of an S-band telecom system	Minor
Sylvain	Gallay	Fall 2010	Clean-mE	Clean-mE robotics arm design	Minor
Yves	Buntshu	Fall 2010	Clean-mE	Clean-mE vision system	Semester
Vincent	Kuenlin	Fall 2010	Clean-mE	Telescope design for Clean-Me Inspector	Minor
Manuel	Klein	Fall 2010	Clean-mE	ADCS simulator for ODR	Semester
Leila	Mirmohamadsadeghi	Fall 2010	QB50	Science requirements QB50	Minor
Ioana	Josan-Drinceanu	Fall 2010	QB50	QB50 systems	Minor
Christian	Günther	Fall 2010	CHEOPS	CHEOPS thermal design	Semester
Vladan	Popovic	Fall 2010	CHEOPS	CHEOPS power design	Minor
Marco	Parisi	Fall 2010	CHEOPS	CHEOPS attitude control	Minor
Benjamin	Currat	Fall 2010	Earth Observation	Satellite constellation for Earth observation	Minor
David	Lugrin	Fall 2010	Earth Observation	Cominbed use of spaceborne optical and radar data to derive environmental parameters for land applications	Semester

Table 15: List of students in 2010 at the Space Center EPFL

9.3 Newsletters of the Space Center EPFL

The Space Center's newsletter was published in May 2010 and is shown in Figure 28.

Newsletter
N° 3 - May 2010

EDITORIAL

The main event since the last newsletter has been the successful launch of SwissCube on 23 September 2009. This project was able to attract not only 200+ students since 2006 but was also a fantastic networking opportunity between our industrial (RUAG Space), institutional (SER-SSO), research (CSEM), and academic partners (HES-SO, FHNW, University of Neuchâtel). It allowed also fostering space education and promoting system engineering, topics which are very close to the heart of the Space Center EPFL. Enjoy the reading!

Maurice Borgeaud
Director
Space Center EPFL

ANNUAL REPORT 2009

The Annual Report of the Space Center EPFL, summarizing the activities performed in 2009, has been published and an electronic copy is available at http://space.epfl.ch/page64669.html in PDF format.

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Fostering, promoting and federating space technology across education, science and industry in Switzerland and internationally.

SWISSCUBE

Since its launch in September 2009, the satellite has been operating very well and contacts between SwissCube and the ground stations in Lausanne and Fribourg are established on an almost daily basis. Due to a high tumbling rate, it is not possible at the present time to operate the telescope to map the airglow phenomena but the rotation rate is slowing down and we are hopeful to acquire the first images soon. In the meantime, thanks to telemetry data, plenty of information is obtained on the health of the satellite.
More at http://swisscube.epfl.ch and http://swisscube-live.ch.

CALL FOR PROPOSALS

A "Positioning Measure" to reinforce the technological and scientific capabilities of Swiss entities in the space sector has been issued by the Swiss Confederation to promote education, research and innovation. Responsible for this activity, the Swiss Space Office of the State Secretariat for Education and Research (SER/SSO) has decided to initiate this Call for proposals and has entrusted the Space Center EPFL to implement it. The deadline to submit proposals has been set to 1 June 2010.
More information at http://space.epfl.ch/page72041.html.

ESA SYSTEM ENGINEERING WORKSHOP

As local organizer, the Space Center EPFL will host the 4th International Workshop on System & Concurrent Engineering for Space Applications (SECESA-2010) on 13-15 October 2010 at EPFL. SECESA-2010 aims at providing agencies, companies, organizations, universities, and institutes with a forum of excellence in the area of System Engineering (SE) and related techniques and methodologies. Concurrent Engineering, SE innovative approaches, enabling methodologies, latest tools and techniques will be presented so as to promote the creation and exchange of ideas and the identification of new trends and required developments for complex applications not only related to space. Deadline to submit papers has been set to 4 June 2010.
More information at http://www.congrex.nl/10C08/.

TRAINING COURSE

The Space Center EPFL will organize on 5-6 October 2010 a training course entitled "Dynamic Management and Systems Engineering of Space Projects" for members of the Swiss space industries and academic institutions. Based on the successful courses organized in the past on ECSS standards and space radiation, the topic for the 2010 course will be dedicated to space engineering and fostering space innovation. The deadline to register has been set to 31 August 2010 and more information may be browsed at http://space.epfl.ch/page70568.html.

FUTURE PROJECTS

Based on the tremendous SwissCube success obtained by the Space Center EPFL together with its academic and industrial members, three future space projects are being considered for possible implementation. Initial concepts for a space debris-removal mission, a small telescope to monitor exo-planets, or a constellation of small satellites in the frame of an international mission will be further investigated. Preliminary studies are being currently performed to assess the technical requirements and feasibly of these missions that will require spacecrafts substantially bigger and more powerful than SwissCube but still remaining in the nano-satellite class.

Please end an email to martine.harmel@epfl.ch if you wish to sign in or opt out of this newsletter.

Figure 28: Newsletter of the Space Center EPFL published in 2010