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Model Curricula: Umea University

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Space Curriculum Response Form

Name of University	Umeå University
Name of Academic Program	Space Engineering Program
Level of Academic Program	Bachelor/Master of Science
Area of Emphasis	Space Engineering
Names/Descriptions of Courses	1st year: Linear Algebra, Single-Variable Analysis, Multivariable Analysis, Information Techniques, Programming, Classical Mechanics, Circuit Theory, Electromagnetic Fields and Waves. 2nd year: Transform Theory, Spacecraft Technology I, Project Management and Budget, Digital Electronics, Modern Physics and Optics, Analog Electronics, Measurement Techniques, Computer-Aided Electronic Engineering. 3rd year: Space Communications, Space Physics and Astronomy, Spacecraft Technology II, Control Theory, Image Processing and Remote Sensing, Degree Project. Courses at Masters level, 4th year: The Space Environment, Sensors and Instruments, The Observational Platform, Electronics in Space, Data and Signal Processing, Degree Project.
Unique Features	The Department is located in the city of Kiruna in Swedish Lapland, offering the students access to a variety of other space activities such as sounding rocket launches, remote sensing, upper atmosphere research, interplanetary space exploration, control center operations, and spacecraft instrument design, manufacturing & testing.
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TRAINING SPACE ENGINEERING PROFESSIONALS IN SWEDISH LAPLAND

By Carol Norberg, D.Phil. and Peter Berlin, M.Sc.

Abstract

The town of Kiruna, lying 140 kilometres above the Arctic Circle in northern Sweden, has for many years been considered the ‘‘space centre’’ of Sweden. The high latitude makes Kiruna an attractive base for international space research. This paper describes the practical-oriented Space Engineering Program run in Kiruna by the University of Umeå. The students on the program benefit from the expertise of resident and visiting space scientists and engineers. The education is the only one of its kind in Sweden.

1. Introduction

North of the Arctic Circle in Swedish Lapland lies the small mining town of Kiruna. Apart from being the site of one of the largest iron ore mines in the world, it is also the location of the Ice Hotel as well as being a center for international space and environmental research, where researchers from the whole world gather in an exotic environment. The high latitude and temperate climate make Kiruna an ideal location for auroral studies. For that reason a space research institute was established in Kiruna a little more than 40 years ago and today the town has become the ‘’space center of Sweden’’. The number of people involved in space-related activities in the town have increased over the years, and there are now around 500 people working with or studying space topics.

The largest research organization in Kiruna is the Swedish Institute of Space Physics, a governmental research institute that carries out basic research in space and atmospheric physics using both experimental and theoretical methods. Measurements are made from the ground, with balloons, and from satellites. Kiruna is also the location of ESRANGE, a space facility belonging to the Swedish Space Corporation. ESRANGE has three satellite stations, and facilities for launching sounding rockets and stratospheric balloons. Close to ESRANGE is the European Space Agency satellite station at Salmijärvi. At Kiruna’s airport there is a giant hangar called Arena Arctica. It was built to support scientific measurements using aircraft in the region and has become a base for ozone research. The headquarters of the European Incoherent Scatter Scientific Association (EISCAT) are based in Kiruna. EISCAT is an international scientific association using radar to conduct research on the middle and upper atmosphere, ionosphere and the aurora.

The Department of Space Physics of Umeå University is one of the space organizations in Kiruna. The department runs an undergraduate program in space engineering, and is located in Kiruna, 600 km away from the main university campus, in order to take advantage of the local expertise in the space area. The education is located in modern premises on a campus together with the Kiruna Department of Luleå Technical University and the Swedish Institute of Space Physics. On the campus there are about 100 people working with research and education, as well as about 150 university students. This small campus offers an alternative to larger university campuses. Students have the possibility to come in daily contact with teaching staff and to get to know one another well.

2. Space Engineering Program

The University of Umeå has run a bachelor degree program in space engineering in Kiruna for a decade now. The program is popular and graduating students are attractive on the employment market. The program is comprised of 120 points, which is equivalent to 3 academic years of study (1 point corresponds to approximately one week of study.). It leads to a Bachelor of Science in Space Engineering. There is also the possibility to apply for a fourth year of study (additional 40 points) to obtain a Master's Degree in Space Engineering.

Figure 1 shows the program contents and how courses are normally given during an academic year. The program is split into modules that are given over four teaching periods, running between late August and early June each year. The first year of the program is dominated by foundation courses in mathematics and space technology. The courses in the second year begin to give increased competence in electronics and the area of space technology. The third year contains predominantly space applications as well as spacecraft technology, space physics, remote sensing and image analysis. The theme of the fourth, master's year, is ''the space observation platform''. The courses this year deal with the environment a satellite would experience in space, instruments that one would use on a satellite to make measurements in space, the special requirements regarding electronics when equipment is to be used in space and the way in which data is handled once gathered.

PERIOD 1	PERIOD 2	PERIOD 3	PERIOD 4
Year 1			
Linear Algebra, 5 p	Single-variable Analysis, 5 p	Multi-variable Analysis, 5 p	Circuit Theory, 5 p
Information Techniques, 5 p	Programming, 5 p	Classical Mechanics, 5 p	Electromagnetic Fields & Waves, 5 p
Year 2			
Transform Theory, 5 p	Project Management & Budget, 5 p	Modern Physics & Optics, 5 p	Measurement Techniques, 5 p
Spacecraft Technology I, 5 p	Digital Electronics, 5 p	Analog Electronics, 5 p	Computer-Aided Electronic Engineering, 5 p
Year 3			
Space Communications, 5 p	Spacecraft Technology II, 10 p		Degree Project, 10 p
Space Physics & Astronomy, 5 p	Control Theory, 5 p	Image Processing & Remote Sensing, 5 p	
Year 4			
The Space Environment, 5 p	Sensors & Instruments, 5 p	Electronics in Space, 5 p	Degree project, 15 p or 20 p.
Data & Signal Processing, 5 p	The Observational Platform, 5 p		

Figure 1. Space Engineering Program schedule in each academic year (p=point, i.e. 1 week of academic study in the Swedish system)

2.1 International Character

The majority of the program is currently given in Swedish however a number of the courses are given in English, and even when the spoken language of a course is Swedish much of the course literature is often in English. The Department of Space Physics employs seven lecturers of various nationalities and in addition has a number of visiting lecturers from Sweden and abroad who participate in the program for periods of time varying from a few hours per year to several months per year. Many lecturers are local and are involved in space research or industry in Kiruna. The program like the space business has an international character. The disciplines of space science and engineering bring together professionals from many countries. Scientists and engineers frequently work abroad, and most spend at least a part of their working week discussing with foreigners. To help the students during their studies and prepare them for working with colleagues of different nationalities they are given a short course in cross-cultural awareness within the course ''Information techniques'' in the first year. The course enables the students to examine their own cultural makeup. Armed with this understanding, they are in a better position to probe the logic behind foreign behavior, thereby replacing their natural knee-jerk reaction with a more tolerant approach.

The course is based on research by the Dutch social anthropologist Fons Trompenaars. The students are given an opportunity to recognize his 7 cultural dimensions in real-life situations through a case study, which is analyzed in parallel working groups and subsequently discussed in plenary session.

2.2 The Space Theme / Teaching Philosophy

The basic mathematics, physics and electronics within the Space Engineering Program are the same as would be found in standard engineering or technical physics university programs, so that the students are qualified to work in non-space related technical positions when they complete the education if they want to do so. However, the students are also given knowledge of space technology both through the use of space applications in their basic courses and by studying courses which deal exclusively with space technology, e.g. space physics and astronomy, spacecraft technology I and II. The program contains many practical elements. Documentation of laboratory exercises by the use of a logbook is taken up in the course in information techniques. Throughout the program emphasis is placed upon fine tuning the students' report writing skills and ability to give oral presentations. Learning to work on projects as part of a team is also an integral part of some courses.

Great effort has been put into tying all of the courses in the program together so that the students have a sense of continuity as they progress through the program. A disadvantage with the way that the program is set up today is that there are no optional courses. However, this problem is being addressed through collaboration with Luleå Technical University which has a program in space technology given partly in Kiruna and also one in geographical information technology given entirely in Kiruna.

2.3 Learning to Work in Project Form

In many of the courses in the Space Engineering Program students are required to work in small teams to carry out both practical and theoretical work. For instance in the course in classical mechanics, in the first year, the students build model rockets in groups of 2, carry out stability calculations, and make predictions of the maximum altitude that their rockets will reach. The whole class must then work together in order to carry out a rocket launch campaign lead by a campaign manager which they themselves select.

A common problem in large space programs is the tendency among engineers to isolate themselves from their commercial, financial and contractual colleagues. The perception seems to be that engineering is what

makes a project happen, whereas marketing, budgeting, planning, contracts and administration are mere "frills."

Most of the students who embark on a career in the space business are likely to find themselves in a project team – "project" being defined as an activity with a clearly defined beginning and end over a specified time span. For a project to be managed efficiently, it is essential that isolationistic tendencies be discouraged, so that the engineering staff actively participates in a broader, non-technical context.

To achieve this, the students on the Space Engineering Program are offered a 5-week course in Project Management where they learn how to draw up Gantt and PERT planning charts, establish program budgets, seek external financing, negotiate legal contracts, build up project teams, and establish their own latent management style. The students spend the first half of the course attending lectures, and the second half in working groups writing a business plan. The plan is subsequently presented to a panel of simulated external financiers, with a view to obtaining program funding in terms of equity and debt. Here again, the panel members query the students about their business strategy before "committing" themselves to supply part or all of the necessary funds.

Experience with this course has shown that most engineering students are highly motivated to acquire non-technical management skills. The students also display admirable – and sometimes astounding – creativity when it comes to inventing commercially viable space projects. Recent ideas include a small satellite radio terminal to be installed in vehicles to enable rapid detection of accidents and theft; a television game show based on satellite imagery whereby viewers are invited to identify geographical locations; and a matrix of 80 satellites in sun-synchronous orbit, each equipped with a steerable sun-reflecting mirror, for displaying commercials in the dawn/dusk sky.

2.4 Spacecraft Technology

The flagship course of the Space Engineering Program is the third year course on spacecraft technology in which the students are familiarized with the functionality and interdependence of the classical spacecraft subsystems. They attend lectures and collaborate in working groups to prepare a technical specification. The level of technical depth corresponds to the specifications that an industrial bidder might include in his proposal to a customer.

The course is divided up into a 5-week period of theoretical studies, followed by another 5 weeks of hands-on satellite construction.

During the first half of the theoretical course the students follow seminars on each subsystem. In the second half they meet in working groups to develop the specifications as well as the orbital parameters, the reliability requirements and the test program. The course culminates in the students' presentation of their work to a panel of simulated customers. The panel members include senior space program executives who listen to the students' presentation and offer constructive critique, before formally "accepting" the proposal. The presentation event is held in the large conference hall of the nearby Institute for Space Physics in an atmosphere of great formality, so as to instill in the students a sense of realism and a healthy dose of stage fright. Sometimes a panel member is brought in from abroad, in which case the students have to make their visual as well as verbal presentations in English.

In the practical portion of the course, the students work in groups of 4, whereby each group designs and builds a "nano-satellite," typically a 7-inch cube-shaped spacecraft. The satellite is made up of a basic structure, a power supply subsystem including solar panels, an onboard data handling subsystem, and thermal control as required. Each group is given a fairly tight budget for ordering the requisite components from industrial suppliers. Once built, the satellites are exposed to shock tests as well as thermal vacuum testing to check for survival and to compare predicted and measured performance results. In all cases the groups have to record their activities in logbooks and test reports. Whenever performance anomalies are detected, the students perform failure analyses until the cause of the faults is isolated.

2.5 Degree Project

The Space Engineering Program ends with a degree project that is normally carried out at a company or university. An increasing number of students are choosing to do their degree projects outside Sweden, in for example the United Kingdom, Germany, the United States, Australia. In order to obtain a degree, students must also carry out 6 weeks of job experience while registered on the program.

3. Employment market

Graduating students can work as engineers in both national and international space projects. Many general engineering courses are included in the program. This makes it possible for them to work in a large number of companies that develop or produce general electronic products, measurement and control systems, or equipment for telecommunications. At the moment

there is an abundance of positions for graduating students, and typical employers for students who have completed the education have been ESRANGE, Ericsson and Saab Ericsson Space. Another alternative for the students is to go on to a research education in Kiruna or elsewhere.

4. Who studies on the Space Engineering Program?

Each year 30-35 new students are enrolled on the Space Engineering Program. The age of 1st year students is in the range of about 19 to 35. The students come from the whole of Sweden, the majority from southern Sweden, and also from abroad. The students are about 70% male and 30% female. Non-program students may apply to study individual program courses provided that they are suitably qualified to fulfil the course prerequisites.

5. The Future

The Space Engineering Program is under constant development to keep pace with the developments in space science and technology. The aim is to introduce optional courses for students and provide opportunities for the students to work on space projects alongside their studies. In 1995 the students had the opportunity to put their own payload onto a rocket that was then launched from ESRANGE. They were also able to participate in the building of the Swedish nanosatellite Munin that was launched into Earth orbit in 2000. Such opportunities give students an unique opportunity to participate in ‘’real’’ space projects while still undergraduates. We would also like to form an exchange program with one or more foreign university to enable our students to study abroad and to attract foreign students to study on our exciting program.

PERSONAL RESUMÉS

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Carol Norberg (née Nairn) studied for a joint honors degree in mathematics and physics at University College London. She then moved to the University of Oxford where she took a master’s degree in the science and applications of electric plasmas

followed by a doctorate in theoretical space plasma physics. She has worked as a research associate at the Rutherford Appleton Laboratory, held research fellowships at the European Space Science and Technology Centre in the Netherlands and at the University of Oxford, carrying out research related to measurements made with Langmuir probes in both space and laboratory plasmas.

Dr. Norberg is now a reader in space physics and Head of the Department of Space Physics at the University of Umeå in Sweden.

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Peter Berlin obtained his Master's Degree in Aeronautical Engineering from the Royal Institute of Technology in Stockholm, Sweden. His career includes 30 years in international space organisations, primarily ESA and Inmarsat. During 15 of those years he held senior management positions as Meteosat Operations Manager, Sirio-2 and Inmarsat Satellite Program Manager, Inmarsat Deputy Director of Satellite Programs, and Director of Contracts at the Euro African Telecommunications Satellite Ltd.

In 1996 Mr Berlin changed his professional orientation to concentrate on writing. In parallel he carries out consultancy and teaching assignments at international corporations and universities. He is the author of many newspaper and magazine articles, as well as of three books, including "The Geostationary Applications Satellite" (Cambridge University Press 1988).