

IAC-17-E1.4.3

Masters Programs in Space Science and Engineering in Northern Sweden

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Abstract

This review discusses the development of the Masters Programs in Space Science and Engineering at Luleå University of Technology (LTU) in Northern Sweden during the last decade. The space education at Luleå University of Technology started in 1997 with a national Master Program in Space Engineering. In 2005 a new joint two-years Erasmus Mundus Master Program in Space Science and Technology - SpaceMaster was started as a consortium of six European universities from Czech Republic, Germany, Finland, France, Sweden and UK. Luleå University of Technology is program coordinator. Since 2010, the SpaceMaster consortium expanded with American and Japanese universities as well as the External Advisory Board with representative from the space industry and research organizations. The international Master Program in Spacecraft Design and the Master Program in Earth Atmosphere and the Solar System began in 2012. The Master Programme in Spacecraft Design aims to design a spacecraft in a computer environment by a concurrent engineering method and in combination with hands-on experience in instrument building. The Master Program in Earth Atmosphere and the Solar System leads students who have an engineering background to an understanding of the atmospheric and space environments as well as deepens the specific knowledge for students with the scientific background. It also links science and engineering. The review examines conditions and challenges in setting up and running the programs in the areas: choice of themes for the modules; student recruitment; utilization of pedagogical methods and learning outcomes; hands-on learning through the active participation in the international student balloon and rocket projects BEXUS-REXUS that are realized under a bilateral agency agreement between the German Aerospace Center (DLR) and the Swedish National Space Board (SNSB), and the student rocket project SERA, which is part of the PERSEUS programme piloted by CNES in partnership with other organizations; complementarity between formal, informal and non-formal learning; internal and external collaboration with the space oriented organizations, agencies and companies. The review highlights the importance of multicultural awareness and stronger focus on EU added values when working with the international educational programs.

Keywords: space, education, master, engineering, technology, SpaceMaster

Acronyms / Abbreviations

BEXUS Balloon Experiment for University Students

CNES Centre National D'études Spatiales, French Space Agency

DLR Deutsches Zentrum für Luft- und Raumfahrt, German Aerospace Center

EACEA Education, Audiovisual and Culture Executive Agency

ESA	European Space Agency
HSF	Human Spaceflight and Operations
LKAB	Luossavaara-Kiirunavaara Limited Company
LTU	Luleå University of Technology
NRFP	Swedish National Program in Space Technology
IRF	Swedish Institute of Space Physics
OECD	The Organisation for Economic Co-operation and Development
PERSEUS	Projet Étudiant de Recherche Spatiale Européen Universitaire et Scientifique
REXUS	Rocket Experiment for University Students
SNSB	Swedish National Space Board
STINT	The Swedish Foundation for International Cooperation in Research and Higher Education
SSC	Swedish Space Corporation
VHF	Very High Frequency
UHF	Ultra High Frequency

1. Space activities in northern Sweden

Space and atmospheric research in northern Sweden is closely connected to the town Kiruna located 140 km above the Arctic Circle. The town also known for its iron ore mine LKAB and the world famous Jukkasjärvi Icehotel. The first space research institution which was established in this region was the Swedish Institute of Space Physics (IRF) [1]. IRF was opened in July 1957 during the International Geophysical Year. It carries out fundamental research, postgraduate education and observatory activities in space physics, space technology and atmospheric physics in Kiruna, Umeå, Uppsala and Lund. IRF also contributes with teaching and supervision to the graduate space education. In 1966 the rocket and balloon launching range Esrange Space Center [2] was established about 40 km from the town. Close to Esrange the satellite ground stations operated by the European Space Agency (ESA) were established in 1978. The headquarter of the international EISCAT Scientific Association that conducts research on the atmosphere and ionosphere using the incoherent scatter radar technique was set up in Kiruna in 1981 [3]. EISCAT operates a few Ultra High Frequency (UHF) and Very High Frequency (VHF) radar system in Sweden, Norway and Finland. The new EISCAT_3D radar facilities for studies of the solar storms and space weather effects on the upper

atmosphere in the Arctic will be built in Northern Scandinavia - in Skibotn, Norway, near Kiruna in Sweden, and near Kaaresuvanto in Finland and is expected to be operational in 2021. Each site will consist of about 10.000 antennas fed by a powerful 5 MW transmitter at Skibotn and a receiver at each of the three sites. In a wider area of Kiruna municipality there are a few environmental and geophysical research stations. The space educational activities in the northern Sweden are conducted by the Luleå University of Technology (LTU) [4]. LTU combines extensive technical research with areas in the humanities, social sciences, natural sciences, educational sciences, health sciences and art. Cooperation is done across the borders between different disciplines and in multidisciplinary projects. This gives a broad perspective and new insights that make us well equipped to tackle complex research issues such as those in the intersection between art and technology. The university was founded in 1971. It has five campuses around the country with 953 km apart from each the most north and the south ones. LTU's campus in Kiruna is collocated with the head offices of IRF and EISCAT Scientific Association.

2. Space education at Luleå University of Technology

Higher education and research in Sweden is under the regulations which are set up by the Ministry of Education and Research. The mission of the universities is to offer education based on academic footing and proven experience, to undertake research and development work, to cooperate with the surrounding communities and to provide information about their operations. "The basic central regulations on the operations of the higher educational institutions are provided by the Higher Education Act, which is enacted by the Riksdag. The Higher Education Act contains basic provisions on the operations of public-sector higher educational institutions and lays down a framework for their organization and governance. The Higher Education Ordinance is linked to the provisions of the Higher Education Act and contains, for instance, regulations on course syllabuses, program syllabuses, grading and qualifications. The Swedish National Agency for Higher Education exercises supervision of the higher educational institutions, which

means ensuring compliance with the statutes and regulations that apply to the higher-education area.” [5]. Universities are entitled to issue first, second and third-cycle general qualifications. It is the Swedish National Agency for Higher Education who gives special permission to the universities to award the specific qualifications and controls their quality, i.e. accreditation of the educational programs in Sweden is done by the governmental authorities. The Swedish system also differs from many other countries in respect that the programs that lead to the award of a professional qualification in the second cycle can be given undivided, i.e. they are not split between the cycles. This means that the program leading to the award of the second-cycle degree, i.e. Master degree, might be also given during the subsequent five years. LTU is a public-sector university and is subject of these legislations.

2.1 National Masters program in space engineering

Space education at LTU started in autumn 1997 with the 4½ years national Master Program in Space Engineering. The students started the education at that time with a three-year study period at main campus Luleå, where after they moved to Kiruna for the fourth year. The last half year was spent with the Master thesis, usually outside of the university. In Sweden these types of programs are named *Civilingenjör* which lead to a professional qualification with the same name. These programs are nowadays 5 years without being divided into Bachelor and Master degree part. Space Engineering at LTU is the only program in Sweden with such a profile for a full program. The Program had been preceded by originally 2 years, later 3 years space engineering program given by Umeå University. That program had later been complemented by one- year Master program, which during a transition period had similarities with the fourth year of the LTU’s Master Program. The Master Program has during the years gone through a substantial deepening and profiling. It had at the start five specializations, but the latest Program syllabus has only two specializations, i.e. (1) Spacecraft and Instrumentation and (2) Space and Atmospheric Physics. The students get a good mathematical, natural science foundation that later on is built on with generic engineering

subjects like circuit theory, electronics, programming, metrology, control technology, and solid and fluid mechanics. Afterwards modules in space are given at Kiruna Space Campus. The specialization Spacecraft and Instrumentation has a clear system perspective. The students learn satellite design, control and communication. They learn to plan and construct instrumentation for satellites, sounding rockets or high altitude balloons. The learning process is supported by the expertise in nanosatellites available at the Division of Space Technology, LTU. These obtained skills are also valuable in other technical domains. The specialization Space and Atmospheric Physics is focused on space plasma physics and the Earth’s atmosphere, with a particular interest to the polar regions. The students have opportunity to participate in the international Rocket Experiment for University Students (REXUS) or the Balloon Experiment for University Students (BEXUS).

The Master Program in Space Engineering has always been popular. During the last years the Program has had the highest number of applicants among all LTU’s Masters programs. It is popular among female applicants whose number increased up to 18% in 2017.

The transfer in the middle of the program from Luleå to Kiruna is a challenge. Campus Luleå is the main university campus with several thousands of students and a rich student life. The number of students at campus Kiruna is around hundred, with some difference between autumn and spring term. This has led to that some students have chosen to change to some other program in Luleå, because of social reason. Once in Kiruna, the students socialize very well with students from other programs, i.e. Space Master, Master in Spacecraft Design and Master in Earth Atmosphere and Solar System. The students are enriched by a very international atmosphere. Not only do they meet students from all over the world, but also the employees at the division as well as the employees at nearby IRF involve people from many nationalities. Come to that, is the space technology sector characterized by collaboration between people from many nationalities.

An additional value of the Master Program in Space Engineering is regular student and academic staff exchange with Monash University in Melbourne, Australia. The

collaboration which was initiated in 1996 in the areas of electrical and system engineering as well as in mathematics resulted in signing the Memorandum of Understanding between LTU and Monash University in 1998. The collaboration was also supported by The Swedish Foundation for International Cooperation in Research and Higher Education (STINT). Since 2000 the joint activities have been gradually extended to other areas including space. One of the strongest sides of this collaboration is integration of research, joint graduate and post-graduate education, joint cultural activities into the complete functional system. This has led to a regular and well elaborated student exchange between the national Master Program in Space Engineering at LTU and the international program in Aerospace Engineering in Monash University since 2003.

2.2 International Masters program

2.2.1 Erasmus Mundus Joint Master Degrees Course in Space Science and Technology – SpaceMaster

The Sorbonne Declaration in 1998 and the followed Bologna Declaration in 1999 put grounds for new cooperation processes in higher education. The proposed reforms related to: (1) student and staff mobility, (2) common two-cycle degree system, (3) use of credits, (4) European cooperation in quality assurance and (5) European dimensions in higher education, affected countries within and outside the European Union. The number of official signature countries has risen from 29 in 1999 to 47 in 2015 [6]. In order to support the academic cooperation and increase mobility between the European Union and its partner countries the Erasmus Mundus program was launched in 2004. The program was implemented as joint courses at masters and doctorate levels with award of individual scholarships/fellowships for course participants. During the two editions of the Erasmus Mundus program, i.e. 2004-2008 and 2009-2013, a total of 242 master courses and 43 joint doctorate courses were funded. During the following “Erasmus +” edition in 2014 there have been 102 master and 23 doctorate courses [7]. Management of the courses was delegated to the Education, Audiovisual and Culture Executive Agency (EACEA). The Agency has been fully operational since January 1, 2006 under the supervision of four

Directorates-General of the European Commission: (1) Education and Culture, (2) Communications Networks, Content and Technology, (3) Migration and Home Affairs, (4) Humanitarian Aid and Civil Protection [8].

Following EACEA’s Call-for-proposals in 2004 LTU took an initiative to organise and coordinate a new joint two years Erasmus Mundus Master Course in Space Science and Technology – SpaceMaster [9]. The SpaceMaster was started as a consortium of six European universities:

- Aalto University School of Electrical Engineering (Aalto), former Helsinki University of Technology in 2004, Finland;
- Cranfield University (CU), United Kingdom;
- Czech Technical University in Prague (CTU), Czech Republic;
- Julius-Maximilians Universität Würzburg (JMUW), Germany;
- Luleå University of Technology (LTU), Sweden;
- Université Toulouse III - Paul Sabatier (UT3), France.

The objectives of the SpaceMaster Course were described in the original proposal as:

- to combine the great diversity of space expertise at six European universities to a common platform of competence within the guidelines of the Bologna process;
- to give students cross-disciplinary experience from laboratory and computer simulation environment to concrete situations such as balloon, rocket, satellite and radar control, robotics, sensor data fusion, automatic control and multi-body dynamics;
- to bring together as a core group students from the whole world to share the existing space competence, to develop it together and distribute it to benefit the European space industry and research community.

SpaceMaster is a four-semester Master Course, 120 ECTS. The Course has a common first year for all students. The first semester takes place at JMUW, Würzburg, Germany, and the second semester takes place at LTU, Kiruna Space Campus, Sweden. During the

third semester the students are distributed among the partner universities which have different fields of competence in space science and technology. The different specializations cover almost all branches within the space business. That creates the opportunity for exchange of professional research and teaching experience for the academic staff between the universities and thus, to improve the quality of education on offer. There are six engineering tracks and two scientific tracks. The engineering tracks are:

- Space Robotics and Automation, Aalto University School of Electrical Engineering;
- Dynamics and Control of Systems and Structures, Cranfield University;
- Space Automation and Control, Czech Technical University in Prague;
- Automation, Control and Communication of Space Robotics, Julius-Maximilians Universität Würzburg;
- Space Technology and Instrumentation, Luleå University of Technology;
- Space Technique and Instrumentation, Université Toulouse III - Paul Sabatier.

The scientific tracks are:

- Atmospheric and Space Science, Luleå University of Technology;
- Astrophysics, Space Science and Planetology, Université Toulouse III - Paul Sabatier.

Students select the track of specialization for the second year during the second semester. The distribution for the third semester is finalized at the end of the second semester. During the fourth semester students perform their Master thesis projects. They are supervised and examined by academics from at least two partner universities. This leads to two officially recognized Master's degrees issued by LTU and one partner university. The degrees are given below in English and the respective national languages:

- Aalto University School of Electrical Engineering: Master of Science (Technology), Diplomi-insinöörin tutkinto;

- Cranfield University: MSc Astronautics and Space Engineering (SpaceMaster);
- Czech Technical University in Prague: Degree of Master of Science, Study program Cybernetics and Robotics, Inženýr, studijní program Kybernetika a robotika;
- Julius-Maximilians Universität Würzburg: Master of Science (M.Sc);
- Luleå University of Technology: Degree of Master of Science, Major in Space Technology, Teknologie masterexamen, huvudområde rymdteknik;
- Université Toulouse III - Paul Sabatier: Master Astrophysics, Space and Planet Sciences, Master Astrophysique, Sciences de l'Espace, Planétologie; Master Space Technology and Instrumentation, Master Techniques Spatiales et Instrumentation.

During the period 2006-2009 the SpaceMaster Course participated in a specific program organized by EACEA within the Erasmus Mundus frame. The program, named Action 3, aimed to initiate sustainable collaboration and to support systematic staff mobility with other universities outside the European Union. SpaceMaster's partners were: Shanghai Jiao Tong University (China), Stanford University (United States), the University of Tokyo (Japan), the University of Toronto (Canada), Utah State University (United States).

In 2010 EACEA granted the second SpaceMaster Course edition for another five consecutive rounds. For this edition the SpaceMaster Course has expanded with new partner universities, i.e. The University of Tokyo (Japan) and Utah State University (United States), as well as the associated partners, i.e. European Aeronautics Defence and Space Company, Innovation Works Division (EADS-IW) (Germany), EISCAT Scientific Association, Honeywell International s.r.o. (Czech Republic), Swedish Space Corporation (SSC, Sweden), Swedish Institute of Space Physics (IRF, Sweden), which have been organized into the External Advisory Board. The main function of the Board has been to support the academic quality of the Course, work with quality assurance

issues, to provide the relevant information in order to guarantee the development of graduate profiles and to strengthen ties between industry and academia.

The Directorate of Human Spaceflight and Operations (HSF), European Space Agency (ESA) provided financial support and stages at ESTEC for the SpaceMaster students from ESA members states during 2006- 2013.

In 2014 SpaceMaster had successfully passed the EACEA's quality review and was granted another three consecutive rounds. In October 2017 the SpaceMaster Course starts its thirteenth round. The intake for the fourteenth round starts in November 2017.

Today there are more than 455 SpaceMaster alumni around the world. After 12 years of work and experience the main advantage of the Course can be summarized in the phrase 'horizons are broadened'. This broadening applies both to the students and to the staff of the universities involved. The added value of the SpaceMaster Course compared with other courses in the same field can be summarized as:

- structured cooperation between the academic institutions and industry;
- the education is influenced by current advances in research;
- increased intercultural understanding and integration;
- structured cooperation between the universities via the use of the ECTS system, combining together different educational models;
- exchange of experience for both the academic and administrative staff;
- a wide range of specializations improves career prospects of students;
- impact on societies in the locations involved;
- cooperation between countries within and outside the European Union to promote the European space industries throughout the world.

2.2.2 Earth Atmosphere and the Solar System

Since 2005 the Erasmus+ SpaceMaster Course has had a few hundreds applications from international students each year. This confirmed the urgent need and demand for the international Master education in space. Since 2012 an international two-year Master program in Earth Atmosphere and the Solar System has

been offered. Some of the program's modules are given both for the program students and the students from the Space and Atmospheric Physics track within the national Master Program. This allows to offer more modules and to optimise the resources. The Earth Atmosphere and the Solar System program aims at international students with an engineering background, who wish to develop a career related to space and atmosphere instrumentation. It is as also suited for students who have a scientific background within different areas of space science and technology. The program starts with the compulsory modules which introduce the students to physical processes in planetary and interplanetary environments. Modules in remote sensing and image analysis provide fundamental knowledge in observation systems and methods which represent a large fraction of space borne scientific instrumentation. In the second half of the first year, more specific modules in atmospheric dynamics, climate and specific polar atmosphere phenomena lead to a deeper knowledge in the subject. During the second year, two compulsory modules introduce the students to satellite technology and onboard space instrumentation. Additionally, two modules can be chosen depending on the student's professional interest. These modules give much deeper insight into the specific scientific or technological topics. All the scientific modules are related to the on-going research activities in Kiruna with the teachers having a strong research background in these subjects. Practical and theoretical assignments are related to the on-going research projects at the Space Campus and thus, facilitate student contacts with research groups. The program students are embedded into a larger group of about 100 students on the Space Campus in Kiruna with shared modules giving the students an international environment. All students who finished their education proceed to post graduate doctoral education.

2.2.3 Spacecraft Design

A new international Master program named Spacecraft Design started at LTU in 2012. There are not many programs on a bachelor level that might give necessary prerequisites for the program. In order to allow students from a broader category of programs, the education starts with a module Introduction to

Space Mechanics and Electronics. During the first year of the program the students acquire knowledge about the spacecraft environment and its effects on the spacecraft and mitigation methods from harmful effects. The other modules treat spacecraft orbits, attitudes, subsystems and communication aspects. The modules in space electronics and on-board computers provide a deep insight into the on-going technological developments. The main part of the modules in the program during the first year is studied together with the fourth year students from the national Master Program in Space Engineering. The marginal cost for the program is therefore optimized. The autumn term of the second year focuses on the principles of spacecraft design in a computer environment, in parallel with the hands-on experience of design and building onboard instrumentation. It is optional for students from other programs in Kiruna to choose the spacecraft design project module. In order to speed up the learning process, the working method of concurrent engineering is adopted to the design process. The program focuses on the on-going development in space industry towards smaller satellites, with shorter lead times and increased employment of commercially available subsystems, thereby opening up for a more entrepreneurial approach. The students have opportunity to participate in the international rocket project REXUS or the balloon project BEXUS.

2.3 Postgraduate doctoral education

The third-cycle of space education in Luleå University of Technology is represented by the Graduate School of Space Technology. The School was started in 2002, as one of the government's appointed 16 national research schools. The studies lead to award of a Licentiate degree after two years of full-time studies or a PhD after four years of full-time studies. During the first round totally 33 postgraduate students from Chalmers University of Technology, Lund University, Meteorological Institute at Stockholm University (MISU), Umeå University and the IRF were enrolled. The Graduate School second round with 15 postgraduate students and the on-going third round with 18 students are carried out in close collaboration with the academic and industrial partners. The research areas represented in the on-going round are space technology, atmospheric science,

material engineering, applied physics, machine elements and product innovation. The Graduate School is also an integrated part of LTU's Structural Funds Project Space for Innovation and Growth (RIT) with 37 MSEK. Some of the projects are performed in close collaboration with SSC, GKN and OHB Sweden and are funded by the Swedish National Program in Space Technology (NRFP). The Graduate School is supported by the Board with members from the Swedish National Space Board (SNSB), RUAG Space, SSC, GKN Aerospace and IRF.

3. Student recruitment

LTU's international Masters programs are open for all applicants around the world. For the applicants from EU/EEA, Swiss citizens and persons who have permanent residency in Sweden, or temporary residency for a reason other than studies, there are no application or tuition fees. Other applicants are required to pay fees. This financial constraint identifies different recruitment strategies for applicants from the countries inside and outside the European Union. The strategy development has been initiated on a few levels, i.e. program, university and the national education agency. The majority of the enrolled international master students at LTU are from the European countries. However, the number of self-paid students increased by 59% in 2016 [10]. The Erasmus Mundus Joint Master Degrees Courses are in favoured position, because of their higher attractiveness due to the possibility to receive double diploma from two European universities and structural mobility, i.e. possibility to study at two or three different European universities. The supporting factor is availability of the Erasmus Mundus scholarships with amount of 49,000 EUR for two study years which cover participation costs, travel, installation and subsistence costs. The number of such scholarships is limited, so only the students with the highest grades may receive the scholarship. Moreover, the number of available scholarships has been constantly reduced by the EACEA since the Course start, i.e. 23 scholarships were available in 2005, 8 scholarships in 2014 and 3 scholarships in 2016. This led to a decrease of participation of citizens from outside the European Union from 67% in 2005 to 31% in 2014. Despite this fact, the number of applicants per each study place increased from 3.6 in 2005 to 11.5 in 2014, and

11.3 in 2016. This indicates a strong sustainability and attractiveness of the SpaceMaster Course. The average number of the enrolled students during the last intakes varies between 57 in 2014 and 44 in 2016. This temporal drop was closely related to visa processing issues during the refugee situation in Europe.

The average age of the students at the national Masters programs is below 24 (85%), for the international Masters programs the age varies between 24 and 28. The female participation rate at Masters programs in space is about 22% that is still unsatisfactory, considering that females constitute above 50% of persons possessing higher education. Following the mission "Equality in the Academy" from the Swedish government LTU elaborated a working plan for improvement actions for the period 2016-2019.

From our experience in management and teaching at Masters programs in space engineering and science at LTU we can state that, for the successful international recruitment it is very important to combine joint efforts of a few actors, i.e. academic staff, admission and international offices, alumni and current students, into a cohesive network for maximizing the outcome of the outreach activities. This joint network is crucial for the student application decision making. Since the first graduation in 2007 the SpaceMaster has more than 455 alumni around the world. Many of the SpaceMasters alumni are also thesis supervisors for the current students. This natural cycle of competence transfer assures the program sustainability and facilitates the student recruitment. The program and university websites are the mostly common used information source for the prospective master students. However, during the last years a proactive online and social media outreach activities have become the second important factor for successful recruitment. Taking into account Master's student digital proclivity the mobile ready recruitment strategies become actual. For students with limited financial resources scholarship availability is vital and might have the same importance as faculty research expertise. Application decision-making within this group is strongly influenced by availability of family support. This factor must also be taken into the account during the marketing and recruitment. The students with high academic preparedness are mostly

interested in program related information than the experiential aspect of studying abroad. One of the key decisive factors is employability after the graduation. LTU's Carrier Center regularly performs surveys among alumni. Recent results from 2017 showed that nearly 92% of LTU's graduates are employed within one year after the graduation.

4. Choice of modules, utilization of pedagogical methods and learning outcomes

Following the LTU's regulations the syllabus of the Masters programs are elaborated by the program leader in close collaboration with the academic staff. Afterwards the syllabus is examined by the Faculty Board that approves, rejects or suggests the modifications in the syllabus. The approved syllabus is a legally binding document that is open for the public. The choice and design of individual modules is steered by the program theme and is governed by current research and needs in the professional sector. The academic staff from the Department of Computer Science, Electrical and Space Engineering who is in charge of the Masters programs are involved in research related to atmospheric physics and onboard space systems. The Department has good contacts with scientists and engineers from IRF, EISCAT Scientific Association and Esrange Space Center. The modules content is strongly influenced by the on-going research projects in these organisations as well as their staff scientific experience and competence. The researcher's international professional network also becomes available for the students.

At LTU the academic year lasts from late August until early June and is divided into autumn and spring semesters. Each semester is further split into two study periods. During each study period the student shall follow at least two parallel given modules of 7.5 ECTS each. The first semester of the Masters programs is dedicated to the introductory modules in order to bring up the students having different academic background, i.e. scientific or engineering, to the same level. Moreover, in order to optimise the university resources some of the introductory modules have been offered to students from different master programs. The learning outcomes were very promising. Parallel to the knowledge

acquisition the modules develop professional skills in scientific writing, presentation techniques and scientific project management. The training for these skills is embedded in the modules on different stages with the following feedback which supports the process. During the second and third semesters core specialised modules should be taken together with the project modules 15 ECTS. In order to be at the frontline of innovation and excellence the module content is adopted to the latest research and technological achievements. The scientists and engineers from the European Space Agency and other space organizations are invited for lecturing on a systematic basis. The modules include study visits to space research and industrial organizations. Within the modules “Special Studies in Space Engineering” and “Special Studies in Space and Atmospheric Science” the student can deepen her/his insight into a specific field and the scientific work methods. This module has been developed in collaboration with researchers as an individual study. This type of individual studies creates the basis and facilitates the entry for the Master thesis at the later stage.

The project modules in the Masters programs are designed to give the students first-hand and hands-on experience in a real space project. To carry out these projects and provide the launch opportunities, LTU relies on collaborations directly with Esrange Space Center or collaborations with other organizations such as CNES or DLR/SNSB’s REXUS/BEXUS program who collaborate with Esrange Space Center. The fact that Kiruna’s Space Campus and Esrange Space Center are close to each other is crucially important in making the first-hand experience of the students as close as possible to a real space projects. It enables meetings of students with experts at SSC Esrange and using testing facilities at Esrange Space Center. A student team carries out a complete project, from the idea to the results and analysis. Following the student academic results and learning outcomes related to knowledge, skills and social competence, the project modules with this hands-on learning approach are considered to be one of the most effective tools in space education.

The fourth semester is dedicated to the compulsory Master thesis of 30 ECTS. In order to strengthen the links to the professional

sector, to enrich practical skills and thus, to increase student competitiveness at the labour market, all Master students are encouraged to perform their internships and Master thesis outside the university. The student is supported by the internal supervisor from the company and the supervisor-examiner from the university. For the SpaceMaster course the thesis examination is done by the academic staff from two partner universities.

The teaching approaches vary from module to module. However, they are all gathered into one common platform, i.e. Pedagogical Idea LTU. The purpose and goal of the Pedagogical Idea LTU [11] is to ensure effective student’s learning and progress through:

- developing tasks and activities that motivate the commitment;
- to constructively plan tasks and activities for sustainable work;
- to support students' skills so that they can work independently within their competence.

The Pedagogical Idea shifts focus from the teacher to the student. Learning strategies, methods and techniques which contribute to development of competences and skills among different individuals become more important. Traditional way of thinking is that, during the education process the student should reach a predefined program goal. The question arises about what competences and skills should be developed by the student in order to be able to reach this goal, e.g. the educational milestones on the way to the program final goal should be determined. Therefore, the educational process is represented as a stairs with three steps, i.e. from the independent student to the participating actor and further to the independent actor. The independent student is an individual who can make use of university resources and has responsibility for her/his own learning. The participating actor enriches the activities and tasks with her/his own knowledge, skills and experiences and make use of them for own development in collaboration with others. The independent actor shows her/his high professional competence through her/his actions. After successful completion of the program the graduating student should have changed self-image and acquire qualifications in the following areas [12]:

Knowledge and Understanding

- within the main field, i.e. space science and technology, with considerably deeper knowledge within certain parts of the field,
- that give deep insight into current research and development work,
- to show deep knowledge of methods within the main field of the Course.

Proficiency Skills and Capacity

- that demonstrate the capability to critically and systematically integrate knowledge, to analyse, evaluate and handle complex phenomena, problems and situations even with limited information,
- to critically, independently and in a creative way identify and formulate problems, to be able to plan and with adequate methods to carry out qualified tasks within the given time frames, and thus to contribute to the knowledge development as well as to evaluate this work,
- to make oral and written presentations during national and international events, to discuss problems and use arguments suitable for dialogs with different target groups,
- for participation in research and development work or for independent work in another qualified area.

Evaluation Skills and Viewpoint

- to make evaluations with regard to the relevant scientific, social and ethical aspects for research and development work,
- about scientific possibilities and limits, their roles in society and humanity's responsibility for the way of their use,
- to identify their own needs for further knowledge and to take the responsibility for their own lifelong learning.

The educational process for the joint Masters programs with a few different universities, e.g. the SpaceMaster Course, has additional special features. They result mainly from the national legislations and university legal procedures, and are related to the differences in structures and time schedules of

the academic year, implemented educational models with different examination processes, forms and grading systems.

5. Collaboration with the space organizations, complementarity between formal, informal and non-formal learning

LTU's research and education are traditionally oriented towards industry and possess a broad professional network. According to the university policy and regulations each Masters program has a Board consisting of a person responsible for the program, teaching staff and student representatives. The Board very often includes the representatives from the external organizations. The External Advisory Board for the current edition of the Erasmus+ SpaceMaster Course, i.e. 2015-2019, consists of both scientific organisations and the industrial companies:

- EISCAT Scientific Association, Sweden;
- Evolving Systems Consulting s.r.o., Aerospace Company, Czech Republic;
- Honeywell International s.r.o., Czech Republic;
- Swedish Space Corporation (SSC) Sweden;
- Swedish Institute of Space Physics (IRF) Sweden;
- Utah State University, USA.

The representatives guarantee the exchange of information necessary for joint research and educational activities, discussion on modules content and structure, proposals of topics for Master theses and their supervision, recruitment of outstanding graduates. This facilitates the access of university Master students to the professional sector. Complementary funding might be provided by the external partners where the students are integrated during their study projects or Master thesis. European industrial companies might provide financial support to the students during their Master thesis. However, this possibility depends on the internal policy of the company.

Space Campus in Kiruna unites LTU, IRF (Head office) and EISCAT Scientific Association (Head office). The researchers from these organizations contribute to the formal education by lecturing, supervision of

the projects and master thesis Students have access to the scientific data from the satellite and ground based instruments. Another important aspect of this immediate positional proximity to the active research institutions is that the students may participate in the scientific seminars, lectures and workshops organized by these institutions for its own academic staff, and have daily contacts outside the lecture rooms between the experienced senior researchers, post graduate and master students. This secures the non-formal and informal learning processes as an important complement to the formal learning, and facilitates the implementation of the “lifelong learning” strategy which was agreed by The Organisation for Economic Co-operation and Development (OECD) in 1996.

The Space Campus is located about 40 km from the Esrange Space Center, a rocket and balloon launching site operated by SSC. This neighbourhood gave birth to a very close and fruitful collaboration between Esrange and the students who studied space science and engineering at Kiruna Space Campus. In 1995 the Kiruna space students together with other organisations in Sweden have been offered an opportunity to perform a rocket experiment [13]. The design and construction of the payload was done by the students during their free time with support from IRF and SSC. REXUS-1 was successfully launched December 4, 1995. The nose cone of REXUS-1 was later on mounted on a sounding rocket and placed at the Division of Space Technology in Kiruna. In 2002 SSC offered a place on a stratospheric balloon and the first BEXUS-1 was realised. These project names have lived since then until 2007, when during the ESA’s 17th PAC symposium, held in Visby, Sweden, REXUS and BEXUS programmes became truly international through the cooperation agreement between the German Aerospace Agency (DLR), the Swedish National Space Board (SNSB) and the European Space Agency’s (ESA’s) Education office [14]. The programs realise the EuroLaunch project via collaboration between the SSC’s Esrange and DLR’s Mobile Rocket Base (MORABA), and give access to space on a regular basis for a wider student audience in Europe. The students at Space Campus have been regularly participating in these projects. 2016 became a very successful year when the students have participated in a few projects at

the same time, i.e. REXUS-21 with SALACIA (Saline Liquids and Conductivity in the Atmosphere) experiment, BEXUS-24 with EXIST (Examination of Infrasound in the Stratosphere and Troposphere) and BEXUS-25 with IRIS (Infra-Red albedo measurements In Stratosphere).



Fig. 1. Helen Hellmark Knutsson, Swedish Minister of Higher Education and Research, visited Kiruna and together with Prof. Johan Sterte, Vice Chancellor of LTU, met SpaceMaster student Jonas Burgdorf, who showed the projects students have been working on during their education in Kiruna, Sweden. Photo: Lars-Göran Norlin, May 9, 2015.

The students have been also involved in the rocket project SERA, part of the PERSEUS (Projet Étudiant de Recherche Spatiale Européen Universitaire et Scientifique) programme that is piloted by CNES in partnership with other organizations [15]. SERA rockets are performance demonstrators for supersonic rockets developed by French students. For launching these rockets, CNES collaborates with SNSB. As part of this collaboration, Swedish students provide payloads for SERA rockets. So far, SERA-1, SERA-2, and SERA-3 with payloads provided by LTU students have been launched from Esrange Space Center. The student teams were composed of students from the various Master programs at LTU campus Kiruna. The collaboration with CNES means that the students experience communicating with this external partner to define and discuss their requirements. In addition they get to travel to a workshop and review process in France. Similarly, during REXUS or BEXUS projects students communicate with ESA and DLR and travel to Netherlands and Germany. Now, SERA-4, to be launched April 2018, has

selected another payload proposed by LTU students.

6. Multicultural awareness

There is a multicultural environment both in the student group and in the academic staff group at the Division of Space Technology. The Masters students come from the countries all around the world and from all continents. The class with 50 Masters students might be represented by 20-25 different nations. The Erasmus+ SpaceMaster program is the best example of such diversity. Gathered together into one program the students meet new cultures, languages and attitudes. The learning styles the students inherit from their cultures and particularly the style of student-teacher communication have also distinct differences. The understanding of this allows the teachers to exploit the student strength and effectively assist her/him in their learning process. The importance of specially organised joint cultural activities becomes evident. During the studies the international students become an integrated group. After the graduation these students are spread through space organizations around the world, but continue to keep contacts with each other and are even involved in joint space projects. A special role in this belongs to the Erasmus+ projects which support and facilitate the people networking with a stronger focus on EU added values.

7. Conclusions

The education aspect is a basic activity and a strategic goal in the Europe 2020 Strategy. Education in space particularly supports all other objectives including employment, innovation, social inclusion and climate/energy that should be reached by 2020. The Masters programs in Space Science and Technology, and in Space Engineering inspire and motivate young people to pursue careers in science, engineering and technology and thus, to achieve the strategic objectives of the European development. Since 1997 LTU designed and actively developed a few international Masters programs in space engineering in close collaboration with the space institutions in Kiruna, national and international partners. We are very grateful for all the help and support that we have received from them.



Fig. 2. Round 10 SpaceMasters celebrating their graduation at the Cité de l'espace in Toulouse, France, Photo: Anette Snällfot-Brändström, October 28, 2016.

Acknowledgements

The Erasmus Mundus Joint Master Degrees Course in Space Science and Technology – SpaceMaster has been funded with support from the European Commission. This publication [communication] reflects the views only of the authors, and the Commission cannot be held responsible for any use which may be made of the information contained therein.



Co-funded by the
Erasmus+ Programme
of the European Union

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