

Engineering and Management of Space Systems (EMSS) - an international joint Master's double-degree program

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Abstract

Dynamic development of the space sector of European, and especially of Polish and German economies results in a necessity for suitable Higher Education Institution graduates. The increasing digitization, distribution and networking of technical systems leads to the necessity of a degree programme teaching “the systems view” and “interdisciplinarity” methods and skills. Furthermore, it is necessary to consider the entire life cycle of the systems starting with the analysis of the requirements, through design, integration, verification, to operation and maintenance, with supplementation of management, social and intercultural skills.

Since interdisciplinarity and internationality are essential for engineering and management of space systems, the international project was launched early last year by two universities – Hochschule Bremen (Bremen City University of Applied Sciences, HSB, Germany) and Politechnika Gdańska (Gdańsk University of Technology, Gdańsk Tech, Poland) establishing an international interdisciplinary joint Master's double-degree program - Engineering and Management of Space Systems (EMSS). It consists of three different fixed three- or four-semester study paths of several mobility schemes, though individual educational pathways adjusted to students' preference are also allowed. Each path includes a joint academic year – first semester is conducted in Gdańsk, the second in Bremen. The remaining semesters can be studied at either of the universities. All of the EMSS curricula meet the highest education standards of both countries.

Several mandatory modules and many elective courses are included in the EMSS curricula. Upon graduation, students of the program are awarded two Master's degrees - in Space and Satellite Technologies, issued by Gdańsk Tech, and, depending on the chosen study path, in Aerospace Technologies, Computer Science, or Electronics Engineering issued by HSB.

Work on the establishment of a new, international, joint field of study - Engineering and Management of Space Systems, run by both universities is currently in progress. The curriculum of the new study programme will be based on the recommendations of the International Council On Systems Engineering (INCOSE) and its German Chapter, Gesellschaft für Systems Engineering (GfSE), and will offer the possibility of certification as a Systems Engineering Professional, Associate Level.

This paper includes the lecturers' and students' perspective on the program and its future development.

Keywords

Engineering and Management of Space Systems, International joint double-degree program

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Acronyms/Abbreviations

Gdańsk Tech *Gdańsk University of Technology (Politechnika Gdańska)*

EMSS *Engineering and Management of Space Systems*

HSB *City University of Applied Sciences Bremen (Hochschule Bremen)*

1. Introduction – the establishment of the EMSS program

To track the origins of the Engineering and Management of Space Systems (EMSS) program one should go back to year 2017, in which 3 Polish universities from the Tri-City region of Gdańsk, Sopot, and Gdynia, joined their forces to run a novel, intercollegiate Master's studies in the field of Space and Satellite Technologies [1][2]. These universities were: Gdańsk University of Technology (Gdańsk Tech, formerly GUT, Fig. 1), Gdynia Maritime University, and the Polish Naval Academy in Gdynia). Gdańsk Tech, the leader and coordinator of this action, is the second-best research university in Poland (in the 'Initiative of Excellence - Research University' competition of the Ministry of Science and Higher Education, currently, Ministry of Education and Science Poland), classified in the most prestigious international rankings, including the Shanghai Ranking. The HR Excellence in Research logo of the European Commission places Gdańsk Tech among the institutions creating the best working and development conditions for researchers in Europe. With over 15 000 students, 37 fields of study, 2 doctoral schools, 13 scientific disciplines, and nearly 1300 academic teachers, Gdańsk Tech is the biggest technical university in the Pomeranian region, most frequently chosen by Polish and international candidates. Its partner, Gdynia Maritime University, is the largest state school of higher maritime education in Poland, and one of the largest universities of this type in Europe. Its programs of study satisfy not only the Polish educational standards set by the Ministry of Education and Science, but also the highest requirements of the International Maritime Organization – IMO. The last party of the initial project, the Polish Naval Academy, is a naval university operating under the Ministry of National Defence of Poland. It educates officer-cadets, commissioned officers and officers of naval forces of the European, North African, Middle and Far East countries, as well as civilian students. Joint studies of these

institutions were supported by the Polish Space Agency and co-financed by the National Centre for Research and Development under the project entitled: Adaptation of the second-degree studies Space and Satellite Technologies to the needs of the labour market.



Figure 1. Gdańsk University of Technology

Under the umbrella of the Space and Satellite Technologies program, several related fields of study, namely the Information and Telecommunications Technologies in Space and Satellite Engineering (offered by the Faculty of Electronics, Telecommunications and Informatics of Gdańsk Tech), Mechanical and Mechatronic Technologies in Space Engineering (run by the Faculty of Mechanical Engineering of Gdańsk Tech), Marine Satellite and Space Systems (organized by the Faculty of Electronics of Gdynia Maritime University), and Space and Satellite Applications in Security Systems (of the Faculty of Command and Naval Operations of Polish Naval Academy) were merged to offer a truly interdisciplinary branch of graduate studies. As a result, not only a highly professional program with the best input of all the universities involved was launched. Another unquestionable benefit of such a collaboration was turning the institutions that used to be competing for graduate students into partners, sharing their knowledge, good practice, and efforts in recruiting the best candidates. Thanks to the financial support of the external bodies, experts from the space industry were invited to deliver part of the courses. In such a partnership, side by side with the Polish Space Agency, the universities were able to face the challenges of a new innovative industry sector of space exploration and utilization technologies emerging in Poland, and Pomerania - a manifold of companies and other related entities. These new entities were both Polish branches of well-established

international corporations, along with smaller local firms offering various services, including satellite telecommunication, satellite navigation, Earth observation, as well as the Geographic Information Systems (GIS).

However, rapidly-growing European and global markets set high demands that could be met only under international collaboration. Since similar issues were faced by the German Higher Education Institutions, another partnership strengthening the Space and Satellite Technologies program was made. Seeing great potential of international collaboration and complementarity of the institutions within the field of space sector, the City University of Applied Sciences Bremen (Hochschule Bremen, HSB, Fig. 2) and Gdańsk University of Technology decided to launch a joint interdisciplinary double-degree Master's program, supported by the expertise of the old members of the Space and Satellite Technologies alliance.



Figure 2. City University of Applied Sciences Bremen

The Bremen City University of Applied Sciences is the largest university of applied sciences, the second largest Higher Education Institution in the federal state of Bremen. It offers almost 70 degree programs in engineering for about 8,500 students. The HSB offers a reliable framework for all students to gain international experience during their studies. A cornerstone of internationality at HSB are the more than 360 cooperation agreements with universities and diverse companies and organisations worldwide. The partnership with the Gdańsk Tech is especially valuable, since Bremen and Gdańsk are twin cities. Thanks to long-standing contacts with industrial partners, enabling strongly practice-oriented teaching and research, HSB offers a broad spectrum of future-proof and innovative study programs. Thus, it is regarded as driver of innovation for the surrounding region. Having so much to offer, HSB entered the agreement with Gdańsk Tech with three fields

of study, i.e. Aerospace Technologies, Computer Science, and Electronics Engineering, giving rise to 3 possible branches (study paths) of the initial Space and Satellite Technologies program, collectively called the Engineering and Management of Space Systems program. The first pilot run of the program was started in April 2021.

2. Program details

2.1. Program management

Dr. Marek Chodnicki for the Polish part and Prof Jasminka Matevska for the German part are responsible for the management of the program. Along with Prof Zbigniew Łubniewski (Gdańsk Tech) they are local coordinators of the program. Supported by a team of academic teachers from both of the universities, they are responsible for all the program curricula, course contents, learning outcomes, supervision of students, and all other matters related to the quality of education, and organization of the program.

2.2. Student admission

Candidates eligible to apply to the program are the holders of Bachelor's or engineering degrees meeting the admission criteria of both universities. Students are recruited separately by both institutions into respective fields of study: Aerospace Technologies, Computer Science, and Electronics Engineering at HSB, or Space and Satellite Technologies at Gdańsk Tech. The university that recruited students becomes the Home University for these students. Next, each institution selects highly motivated candidates that are evaluated by local coordinators from HSB and Gdańsk Tech, i.e. by Prof Jasminka Matevska (HSB), Dr. Marek Chodnicki (Gdańsk Tech), and Prof Zbigniew Łubniewski (Gdańsk Tech), heads of the program. Positive evaluation of candidates results in their nomination to the international double-degree EMSS program, and their enrollment at the second university that becomes the Partner University for these students.

2.3. Program structure and curricula

The EMSS program is a joint interdisciplinary international Master's double-degree program of an Erasmus Mundus type. It is designed for completion in three or four semesters of full-time study, depending on the chosen study path and study pace. All students enrolled to the program follow one of a predefined two-semester joint study paths. The first semester is conducted in Gdańsk, the second semester in Bremen. The place of study for the



remaining one or two semesters is the Home University, unless decided otherwise by students and coordinators of the program.

Tab.1 Detailed curriculum of one of the study paths is shown in Tab.1. Space and Satellite Technologies (Gdańsk Tech) + Electronics Engineering (HSB)

MODULE NAME	ECTS
First semester, Gdańsk Tech	
Mechanics and mechatronics in space technologies (includes: Robotics for human health and performance, Gravity-related research, Heat and mass transfer in lack of gravity)	6
Satellite technologies (includes: Satellite navigation, Satellite remote sensing, Spatial data processing technologies)	6
Interdisciplinary project – part 1 (includes: Interdisciplinary project, Management in space industry)	6
Law and security in space (includes: Space law, Cybersecurity, Crisis management)	6
Electronics Engineering – elective (Choose 3 from 4: 1. Antenna technique in space applications, 2. Autonomous (systems) vehicles control, 3. Objective programming, 4. Electric drives)	6
Polish as a foreign language – only for German students	1
Second semester, HSB	
Space Systems Engineering (includes: Systems engineering foundations, Systems engineering methods and processes, competences and roles, Classical and agile approaches, Requirements engineering, Technical realisation processes, Operational aspects)	6
Project Management (includes: Project management activities and methods, Classical vs. agile project management, Project management in the space application domain, Teambuilding and communication)	6
Interdisciplinary project - Part 2 (includes: CubeSat development, Engineering and management)	6
Metrology and Instrumentation	6
Laser systems and applications	6
Electronics Engineering – elective modules (Choose 1 from 6: 1. Satellite Communications, 2. Unmanned Aerial Vehicles, 3. Image Processing and Pattern Recognition 4. Fundamentals of Machine Learning, 5. Non-Chemical Space Propulsion Systems, 6. Optical Communications)	6
German as a foreign language - only for Polish students	1
Third semester, HSB or Gdańsk Tech	
Master thesis (includes: Diploma seminar, Master thesis)	30

The EMSS curricula include various mandatory modules, such as Mechanics and Mechatronics in Space Technologies, Satellite Technologies, Interdisciplinary Projects, Law and Security in Space, Space Systems Engineering and Project Management. Additionally, many elective courses depending on the chosen specialty, like Design and Modelling of Space Propulsion Systems for Aerospace Technologies, Methods for Development of Complex Software Systems for Computer Science, Metrology and Instrumentation for Electronics Engineering are available to adjust to students' individual interests and preference. A detailed curriculum of one of the offered study paths is shown in Tab.1. Individual study plans may also be taken into account, if appropriately motivated, and verified in terms of the diploma

requirements and approved by both institutions. Students enrolled to the program choose their specialization by signing a proper Learning Agreement stating the program of their studies and degrees awarded.

Apart from regular classes, students of the program may also participate in traineeships, language, adaptation, and intercultural trainings. Such course diversity should result in highly skilled specialists that will meet the demands of the European as well as the global job market related to various space programs.

2.4. Graduation criteria, Master's thesis, degrees awarded

All of the curricula offered within the EMSS program meet the most rigorous higher education standards of both countries. They are consistent with Polish, German and European Qualification Frames, as well as, with internal study regulations of both universities. As it is not a trivial issue, all of the actions of the local coordinators of the program are supported by Dr. Justyna Szostak, a specialist in international multiple-degree programs from Gdańsk Tech.

A minimum of 30 ECTS credits has to be collected at each of the institutions. Credits acquired at one university in accordance with the Learning Agreements are recognized by the other university. The International Offices of both universities are offering support considering the organizational aspects. To confer both of the final qualifications, students have to meet the graduation criteria of both universities - both fields of study they are enrolled in. They have to collect the minimum number of ECTS credits and learning outcomes specified for a chosen study path, write and defend a Master's thesis.

To make sure that the Master's thesis follows the standards of the two fields of study and both universities the student is going to graduate from, each Master's thesis has to be co-tutored by professors from both institutions. In addition, a reviewer validating the quality of the submitted thesis has to be assigned. If the main supervisor of the thesis is from HSB/Gdańsk Tech, a Gdańsk Tech/HSB professor has to be chosen as a reviewer, respectively. The defense of the thesis, run in accordance with the internal regulations of both universities, will take place only once if the Examination Board includes the representatives of both partners. Otherwise, the defense will be organized separately at each of the universities. If necessary, the



defense may be conducted on-line or in a blended form.

Graduates of the EMSS joint program will be awarded a Master in Engineering Degree in Space and Satellite Technologies issued by Gdańsk Tech, and a Master's Degree in Aerospace Technology, Computer Science, or Electronics Engineering, depending on the specialization, issued by Bremen University of Applied Sciences.

2.5. *Language policy*

During the first, joint year of study, all of the classes, exams and trainings of the EMSS program are held in English. To this purpose students are required to prove a satisfactory (minimum B2, according to C.E.F.R.) level of both spoken and written English. Master's thesis has to be written in English, that is the language of the defense as well.

In order to support and implement the multilingualism policy of the European Union, it is advised for non-native students to acquire a basic level of proficiency in the Polish/German language (A1, according to C.E.F.R.) before the end of the joint semester of study held in Gdańsk/Bremen, respectively. In order to implement this recommendation, language courses are offered to students.

2.6. *Financing*

The first run of the EMSS program was supposed to be financed from a KATAMARAN grant awarded to the partners by Polish National Agency for Academic Exchange. Unfortunately, due to COVID-19 pandemic, and other related issues, it was impossible to make use of these funds. Nevertheless, HSB and Gdańsk Tech decided to run the program despite the lack of additional funds. Both universities will apply for national and international, e.g. DAAD or Erasmus Mundus funds, to support the realization of the program in the future.

Students participating in the EMSS program, though enrolled at both institutions, pay tuition fees, and any other fees but HSB semester contribution, to their Home University only. They are also required to cover any personal expenses incurred by them during the exchange period, including travelling and lodging. Their international mobility is supported by the Erasmus+ program funds. Within the frame of this program, Home University of the EMSS program is considered as the Sending Institution, and is responsible for the financing of the Erasmus+ mobility of that student.

3. **Discussion – the results of the first pilot run**

3.1. *Teachers' perspective*

The first batch of students, consisting of 13 international participants of the EMSS program, has just started their 3rd semester of study, while 13 best candidates out of 47 applicants have been selected for the second pilot run.

At the end of the second semester at HSB a retrospective session was organized by Prof. Matevska. All the students, many lecturers and supporters of the study program participated actively. A very honest and open discussion took place and very valuable information considering the experiences on both sides could be collected.

As a summary, it can be stated that the first run of this international interdisciplinary study program was a great experience for all involved parties. This is the right direction and way to follow during the establishment and accreditation of the new joint study program. The very good availability, friendly communication, good team work and helpful lecturers / organizers were much appreciated. Also, the accompanying guest presentations held by experts from the space industry organized during the winter semester at HSB were a great opportunity to get an inside of the actual practical work.

Nevertheless, there is some improvement that can be done for the second run and considered for the new study program. For example, the better coordination of the contents of the first and the second part-module for the interdisciplinary project shall be achieved. Furthermore, the specialization of each single student shall be checked in more detail and if necessary, some additional specific modules shall be defined as mandatory, so everybody can follow the lectures in the best effective way.

3.2. *Students' perspective*

The offered program, with its designed learning outcomes spanning from engineering domain to management, soft skills and intercultural competences is very attractive for students choosing their master studies. Experience gained during the first pilot run of the EMSS project proves the real interdisciplinary character of the studies, what is very well backed not only by the offered subjects and study paths, but is also supported by very diverse background of students from their

bachelor studies, what could be best observed utilized during the interdisciplinary project classes. As the pioneers of the pilot run, students were aware of possible imperfections of the implementation of that ambitious program, willingly sharing their remarks, ideas and conclusions during the retrospective session, to make future editions an even better experience. What was perceived by students among the best that they experienced during the program, was the work in a big interdisciplinary team on the research cubesat project and submitting it the ESA Fly Your Satellite! program, as well as the international experience of cooperation with people from different backgrounds and living abroad, which unfortunately was a bit limited due to the COVID pandemic. What could be developed in the future, would be the possibility of building a prototypes of developed designs. Finally, the studies are very demanding and time consuming, but students were aware of that upon matriculation.

3.3 Future plans

After a very intensive and successful first year of educational and organizational collaboration, HSB and Gdańsk Tech decided to further strengthen their partnership regarding the "Engineering and Management of Space Systems" (EMSS) program. A novel, joint interdisciplinary field of study at both institutions shall be established. The existing study paths on HSB side shall be combined under one main master's degree EMSS including three different specializations according to the three already established paths. The final curriculum will be adapted accordingly. The accreditation of the new study program is planned for the year 2023 and will be performed on both universities in parallel following the accreditation and quality requirements of each country. The final result is subject to approval of the different boards and committees. The INCOSE certification will be the next step upon successful accreditation.

Students in the new field of study will be able to carry out many joint projects, including those organized by ESA Education.

4. Conclusions

The new international interdisciplinary study program of Engineering and Management of Space Systems is a very promising approach. It is strongly supported by both partner universities and by the local space industry partner companies.

The successful first run has shown, that the team is on the right way. Furthermore, the necessary improvements could be recognized so they will be considered for the second run and for the establishment the final new joint study program. We are happy to continue our cooperation work and very confident that it will result in a successful accreditation of the new study programme.

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