# PROGRAMME FOR EUROPEAN COOPERATING STATES (PECS): PROJECT SPACE IMAGE PROCESSING (SIP)

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## Abstract

Lithuania signed the European Cooperating States (ECS) agreement in October 2014 and integrated the accord into the Plan for European Cooperating States (PECS) charter in September 2015. A collaboration of two institutions' educational programmes – Vilnius Gediminas Technical University (VGTU) and the government-run National Paying Agency (NPA) – received funding under the PECS programme in 2019. The aim of the current project was to prepare the study course 'Space Image Processing' and integrate it into the VGTU study programme. The study course was developed following defined requirements and EU higher education standards regarding The European Credit Transfer and Accumulation System (ECTS) and learning outcomes. The programme was also tested, evaluated, and approved by European Space Agency (ESA) and NPA specialists. For the students, this course was as optional subject; for those who chose it, the programme helped them learn about space technologies and their use in various engineering solutions. Last, but not least, the study course 'Space Image Processing' was successfully integrated into the higher education study processes in VGTU; further, it was positively accepted by students who chose it.

Keywords: higher education, space technology, remote sensing, satellite image, Moodle system.

## 1 INTRODUCTION

Satellite imagery, or remote sensing (RS), is a process involving several components that interact with each other. Remote sensing requires a power source. On its way to the earth, solar energy interacts with the atmosphere and objects on the earth's surface. The reflected part of this energy is received by the sensor, encoded by electrical signals, and transmitted to the ground station. The resulting data are then processed, i.e. prepared, corrected, improved, etc. Satellite image data information becomes informative when images are analysed, decoded, described, and so on.

RS systems - the photographic or airborne techniques are normally attached to aircraft and work with the visible range of the electromagnetic spectrum of sunlight. Such sensors are very precise as they are characterised by a very high spatial resolution due to their short distance to the earth's surface. However, they are only able to fly across a small portion of the earth's surface and thus are mainly used for rather specific investigations. It is popular to use aircraft or low-cost drones (unnamed aerial vehicle [UAV]) with different sensors at this time. These systems can be used not only for the creation of high-precision and high-resolution orthophotographic models and digital 3D surfaces mapping, but also for environmental engineers.

Most scientists note that satellite (spaceborne) acquisition systems are very expensive and have a lower spatial resolution than airborne acquisition systems. However, scientists benefit from the fact that these sensors can continually fly across the whole surface of the earth, collecting data over a period of several years [1]. Satellite systems are divided by mass into heavy weights above 1000 kg, medium weights from 500 to 1000 kg, and light weights up to 500 kg. Small cube satellites have increasingly been used in student projects, earth observation missions, and new space technologies for about the last 10 years. The first Lithuanian satellites, CubeSat LituanicaSat-1 (LS-1), were launched on 9 January 2014 [2]. The International Space Station was launched into orbit on 28 February 2014. On 23 June 2017, 06:59 am Lithuanian time, the PSLV-C38 (Polar Satellite Launch Vehicle) rocket, carrying the third Lithuanian satellite (LituanicaSat-2 [LS-2]), took off from the Satish Dhawan Space Centre in India.Meanwhile, the large satellite system, Sentinel-1, was launched in April 2014. The Landsat satellite launched on 23 July 1972. The first commercial satellite sensor – IKONOS – was launched on 24 September 1999 at Vandenberg Air Force Base, California, USA. The IKONOS satellite sensor is a high-resolution satellite operated by DigitalGlobe. Its capabilities include capturing a 3.2 m multispectral, near-infrared (NIR) image, 0.82m panchromatic resolution at nadir. Its high-resolution data make an integral contribution to homeland security, coastal monitoring, facilitating of 3D digital terrain models (DTMs) and digital elevation models (DEMs), etc. The RS system sensor can be divided into: optical; infrared; microwave; radar; satellite; airborne; acoustic and near-acoustic RS. Commonly used RS systems will be explained in lectures; a great deal of information will also be provided in the handbook, *"Remote sensed data characterisation, classification, and accuracies*”, edited by Prasad and Thenkabail [3]. This book is being used to prepare material of a new study subject, 'space image processing'. Remote sensing is used in numerous fields, including geography and most earth science disciplines (e.g. hydrology, ecology, oceanography, glaciology, geology); it also has military, intelligence, commercial, economic, planning, and humanitarian applications. In current usage, the term generally refers to the use of aerial sensor technologies to detect and classify objects on eErth (on the surface as well as in the atmosphere and oceans) by means of propagated signals (e.g. electromagnetic radiation).

Images of the earth's surface, taken from satellites or UAVs, provide various useful information. These photos help to identify not only such surface features as terrain, urban areas, water bodies, forests, and agricultural areas but also more detailed, specialised information which can be adopted in various fields, as well as environmental monitoring. The principle of observations is based on the fact that sensors for different purposes installed in the satellites or UAV measure the flow of electromagnetic waves from the earth's surface. To solve the tasks of environmental challenges and agriculture, multi-spectral cameras are used. Multi-spectral cameras usually fix 5–7 spectral bands for each pixel in a photo of which 1–2 fixes part of the infrared waves (NIR), red and green spectrum and 'red edge interval' by which normalised difference vegetation index, NDVI, is identified. According to Short, *‘Remote Sensing Tutorial’*, orbital platforms collect and transmit data from different parts of the electromagnetic spectrum, which – in conjunction with larger scale aerial or ground-based sensing and analysis – provide information to monitor trends such as El Niño and other natural long and short term phenomena [4]. Other uses include different areas of the earth sciences such as natural resource management, land use planning, and conservation.

RS makes it possible to collect data on dangerous or inaccessible areas and do monitoring of deforestation in areas such as the Amazon Basin, the effects of climate change on glaciers and Arctic and Antarctic regions, and depth sounding of coastal and ocean depths. The example and segmentation processes are in the exercise ‘Threshold, Classification Method on Forest Height Mapping example with Trimble eCognition Essentials’ of this creating course (Figure 1).

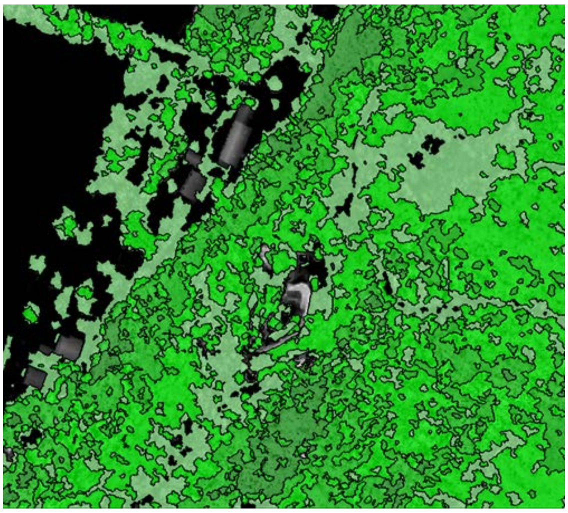

*Figure 1. Example of forest segmentation (source: authors).*

Remote sensing data are used for air quality monitoring. According to the book, ‘Air quality monitoring, measurement, and modelling environmental hazards’, edited by Marco Ragazzy, scientists usually use data from satellite or low-cost calibrated sensors [5].

## 2 METHODOLOGY: PROJECT MANAGEMENT

The team of the 'Space Image Processing' project were members of the prime contractor from VGTU. This team consisted of a project manager, finance manager, administrator, and researcher and as well, the subcontractor from NPA. The team also included the testing supervisor and seven testing specialists. The team composition is shown in the diagram below (Figure 2).

The project manager was the coordinator of all project work; she also served as the meeting organizer. In the meetings, implementation of all work packages (WP) of the project was discussed. The project manager assigned tasks to the project researcher, the subcontractor, and the project administrator; controlled all activities undertaken by the project.

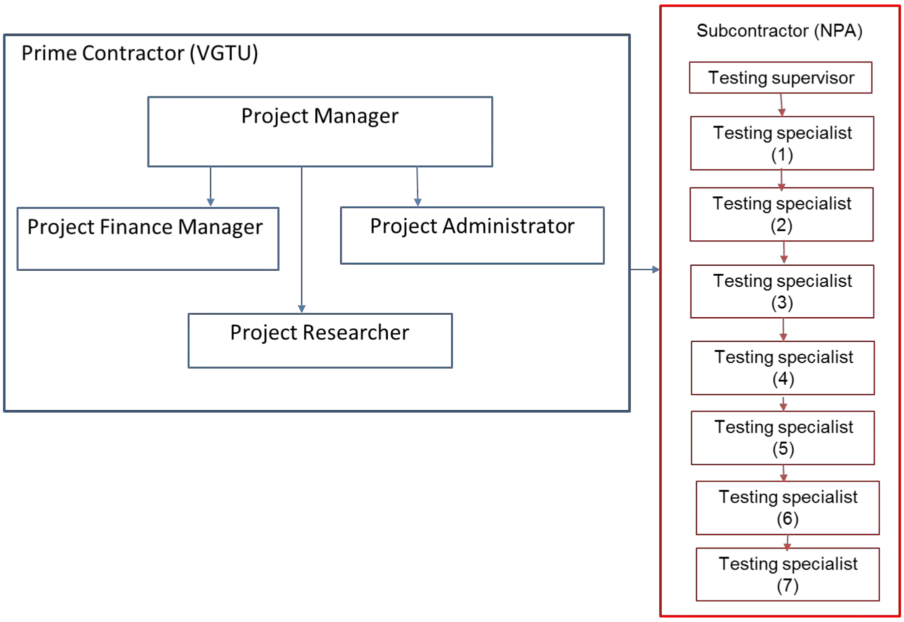


*Figure 2. Team composition of project 'Space Image Processing' (source: authors).*

The Project Manager notified the project finance manager about WPs accomplished. Competencies of the project manager was:

- 2017 - ESA training course on Radar and Optical Remote Sensing and Introduction to Radar Remote Sensing.

The project manager has experience in these projects:

- Creation of system for earth observation by means of unmanned aerial vehicles;
- Researcher in the Erasmus+ projects: International MSc Educational Programme in Environmental Management and Modelling (GeoNetC);
- Erasmus+ project: Environmental Protection in Central Asia (EPCA): Disaster Risk Management with Spatial Methods.

Also, she is coauthor of many publications. She is also a member of the International Photogrammetry and Remote Sensing (ISPRS) workgroup (WG V/7: Innovative Technologies in Training Civil Engineers and Architects) [6]. The Prime Contractor project team was relatively small. The management followed the rules and regulations provided for by the VGTU Statute. The testing supervisor from the subcontractor (NPA) holds a master's degree in photogrammetry and geoinformatics and has more than 15 years of experience in GIS and support management of agriculture and rural development in Lithuania. During her professional career, she was involved in the development of the Lithuanian spatial data infrastructure development project [7]. Her main responsibilities within the project were: development of a Lithuanian national metadata profile, administration of related documentation including technical specifications, metadata quality control, and adoption of the ISO 19115:2003 standard and INSPIRE directive requirements for metadata design. At present, she is responsible for the preprocessing of satellite imagery for controls of declared farmers' fields with remote sensing (CWRS) methods [8]. The subcontractor of the project carried out the project activities in accordance with the NPA administration rules and regulations. Communication between the project's prime contractor and subcontractor on the one hand, and project design units related to project progress, on the other, problems and risks will be carried out on a daily basis. Regular monthly meetings were organised to discuss the issues of common project relevance. The logic of work stages is presented in Figure 3.

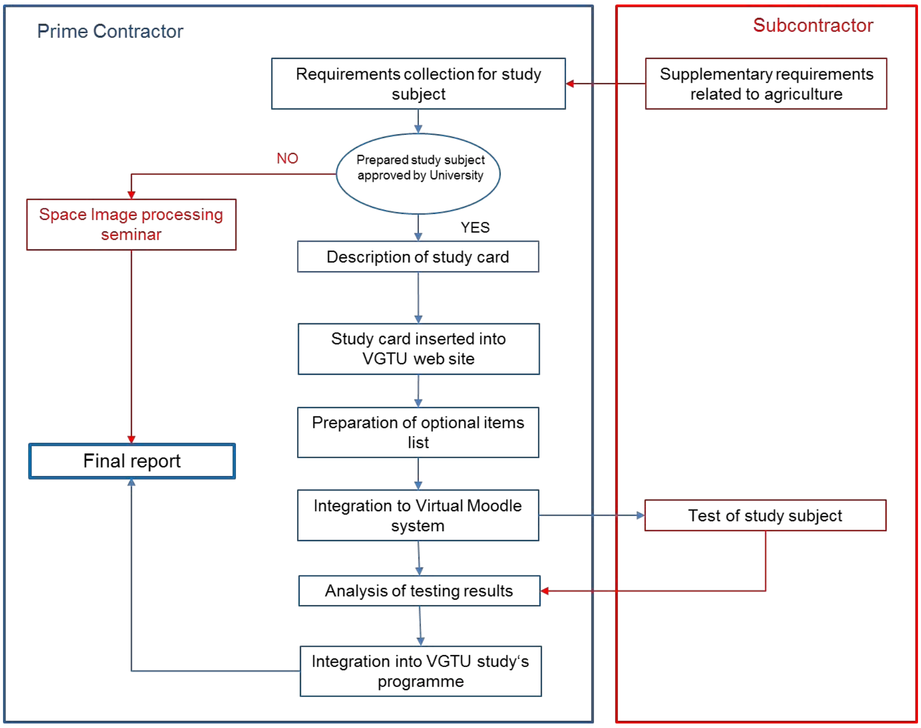


*Figure 3. Programme of work on the project.*

Requirement collection for the study subject consists of the work stages:

- The course syllabus (application) was prepared by academic staff who were teaching the students. In this course, the Project Manager and Researcher were from VGTU.
- A completed course syllabus inserted into VGTU website and approved by VGTU. This stage was successfully done (Figure 3).
- Approved course appeared in students' chosen course lists.
- The number of students depends on the existing technical, computer, and auditorium base. Upon approval of the module by the University Study Committees, the lecturer prepares lecture materials and laboratory work descriptions and provides students with access to the virtual study environment Moodle. Students can preview the material of the chosen module and then use it for learning, doing individual tasks, laboratory work, preparing for the exam. In the Moodle system, each subject is administered by the teacher.

The structure of the new subject material WP is presented in Figure 4.

During integration of “Space Image Processing” into the VGTU studies programme, all the above-mentioned integration steps were successfully completed. The programme was approved; therefore, following the sequence of work (Fig. 4), the preparation of the study programme material has successfully been accomplished. The procedure for preparation of a new study subject is strictly regulated by orders of the higher education institutions; they must harmonise their study programmes with approved descriptions of study group within the field by June 1 of each year [9, 10, 11, 12, 13].

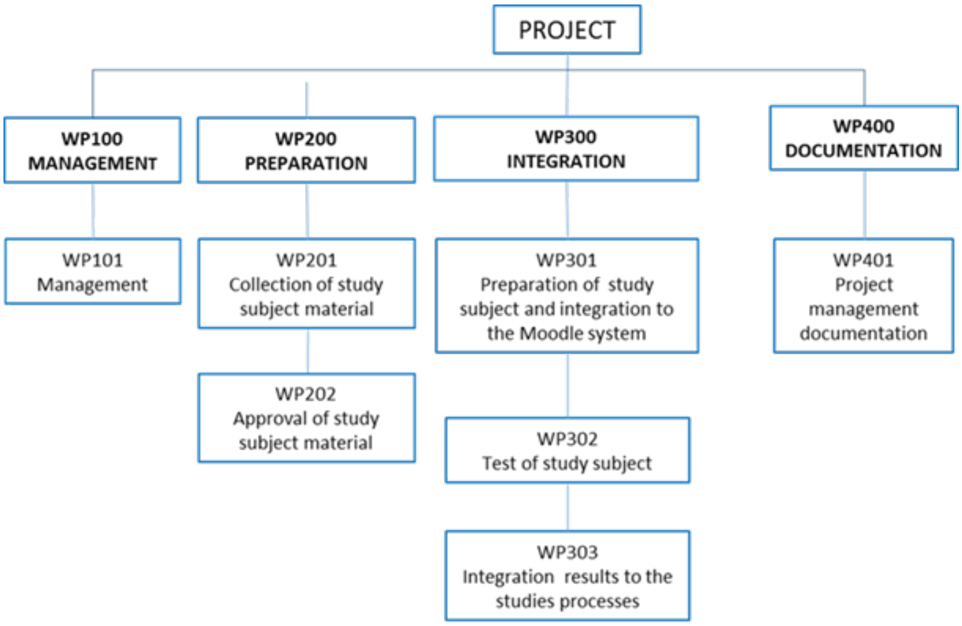


*Figure 4. Work structure.*

# 3 RESULTS

## 3.1 Materials of study subject

The 'Space Image Processing' course is structured in the following topics; materials were preparing by Remote Sensing references:

1. Lectures (30 hours):
   - Remote sensing systems – electromagnetic radiation theories; platforms and sensor characteristics [3, 14 - 22];
   - Remote Sensing Data – MultiSpectral Instrument (MSI) and Operational Land Imager (OLI) Radiometric Performance; Cross Calibration; Sources of Free Remote Sensing Data [23, 24];
   - Space image processing methods and approaches (1) [18, 25-27];
   - Space image processing methods and approaches (2) [28-32];
   - Remote sensing technology for engineering studies – evolution and advances in remote sensing satellites and sensors for the study of different types of environment; remote sensing technology for environmental protection [4, 5, 33, 34, 35].
2. Laboratory works (15 hours):
   - Downloads the Sentinel data (images);
   - Flood plain mapping and simulation with ESA SNAP Toolbox (open source software);
   - Remote sensing for desertification mapping (SNAP software);
   - Land cover classification and accuracy assessment (QGIS open source software).
3. Independent student works (33 hours):
   - Getting started using Trimble eCognition for various remote sensing applications (commercial software);
   - Threshold Classification Method on Forest Height Mapping example with Trimble eCognition Essentials;
   - Building extraction example with Trimble eCognition Developer, with 2 hours of teacher consultation.

## 3.2 Study programme testing activity accomplished by subcontractor

The aim of the testing of the study programme was to evaluate the quality and adequacy of the course material. For testing activity, 7 of the most experienced employees have been selected (having a different engineering background, age, and familiarity with space technologies; see Fig. 4). They all have basic – some of them, advanced – knowledge of processing and management of satellite imagery for control purposes. Testing was performed at the NPA premises with available computer configurations, with additionally installed required SW packages (SNAP, QGIS). Before testing practical exercises, all testing specialists were familiarised with the theoretical lecture material. The testing specialists provided comments about the course based on their own personal experiences. Feedback was collected by respondents completing the questionnaires. The test duration for each practical exercise was planned for a specified time limit. For evaluation of theoretical and practical material, each testing specialist completed a questionnaire comprised of 10 questions.

The main technical objective was to demonstrate to all stakeholders that the study subject, with lectures and practical exercises, reflects the potential need for information and fills the gap in space imagery processing knowledge for the wide range of space-related users – and therefore can further be used as a permanent study subject with yearly updates (considering improvements in technology applications). This objective was achieved by:

- Studying and demonstration through theoretical analysis of lectures and numerical testing iterations;
- Performing practical exercises using SW packages and by following theoretical lecture material;
- Disseminating the lectures and exercises to the corresponding Agency's departments and units to ensure their involvement and permanent qualification improvement;
- Providing feedback and demonstrating effectiveness of the developed study subject and designed structures;

Having evaluated the overall content of the study programme, one can see that it originates from the basic knowledge and experience of the authors, reviewers and contributors who have created, organised, and conducted the training. The material on theoretical lectures and hands-on exercises proved to be informative, adequate, and clearly explained. The training offers many options for meeting NPA daily needs. This study programme will be included in our internal self-learning programme in order to propose it for our employees.

## 3.3 Results of study method

The course teacher involved material to the VGTU open-source learning platform – Moodle. A course in Moodle is an area where a teacher adds resources and activities for his/her students to complete. It was a simple page with downloadable documents of lectures and practise work; these comprised a complex set of tasks wherein learning progresses through interaction [36].

The coursework was done in a mixed way. All information was provided on Moodle and was made available to students. Students could be enrolled manually by the teacher or they could enroll themselves. Students can also be added to groups if they need to be separated from classes sharing the same course or if tasks need to be differentiated.

The course 'Space Image Processing' had an auditorium time for working with students, but most of the students interacted with this course virtually via Moodle. Students also loaded laboratory works results to the Moodle system and received assessment therefrom. The course was completed by an online test at the end of the fall semester.

## 3.4 Results of 'Space Image Processing' study programme

The course was conducted in special classes on the VGTU premises with available computer configurations enhanced by additionally-installed required software packages (SNAP, QGIS, eCognition). Also, the students had the opportunity to work at home using Moodle information. Students uploaded all results of the exercises to the Moodle system and performed the test at the end of the course. All assessments were performed on the Moodle system (are presented in this report) and in the VGTU information system after the course.

The optional study subject, 'Space Image Processing', was included to the VGTU study in the fall semester 2019/2020 (from September). This study subject was chosen by 18 students from various engineering fields:

- Geodesy and cartography;
- Road security;
- City engineering information system;
- Water supply;
- Electronics engineering.

The course was successfully finished by 15 students (Table 2). One student (No 2) started the course later. Student No 7 started the course on time but but completed it later than the deadline. Student No 10 did not start any coursework at all. The assessment of exercises and test results are presented in Table 1.

Six students passed the additional exercises and received the extra grade in the exam result. After completion of the course, each student anonymously answered questionnaire consisting from five questions.). The statistics of results are presented in Table 2.

*Table 1. Assessment of results, optional study subject 'Space image processing' in 10-mark system.*

| Students | | Exercises | | | | | |
|---|---|---|---|---|---|---|---|
| ID | Test | 1 | 2 | 3 | 4 | Addl.* | Total |
| 1 | 10 | 10 | 10 | 10 | 10 | - | 10 |
| 2 | 8 | 8 | 8 | 8 | 8 | - | 8 |
| 3 | 9.62 | 10 | 9 | 10 | 8 | 8 | 9 |
| 4 | 9.62 | 10 | 10 | 10 | 10 | - | 10 |
| 5 | 10 | 10 | 10 | 10 | 10 | - | 10 |
| 6 | 8.85 | 10 | 10 | 10 | 8 | - | 9.5 |
| 7 | 9.62 | 10 | 8 | 8 | 7 | - | 9 |
| 8 | 10 | 10 | 10 | 10 | 9 | 10 | 9.8 |
| 9 | 9.62 | 10 | 10 | 10 | 8 | - | 9.5 |
| 10 | - | - | - | - | - | - | - |
| 11 | 9.23 | 10 | 9 | 10 | 8 | - | 9.25 |
| 12 | 10 | 10 | 10 | 10 | 10 | - | 10 |
| 13 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| 14 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| 15 | 9.62 | 10 | 9 | 10 | 10 | 10 | 9.8 |
| 16 | 9.23 | 10 | 10 | 10 | 8 | 10 | 9.6 |
| 17 | 10 | 10 | 10 | 10 | 10 | - | 10 |
| 18 | 10 | 10 | 10 | 8 | 9 | - | 9.33 |

* Addl. – additional exercises.

*Table 2. Questionnaire.*

| No | Question | Average Answer |
|---|---|---|
| 1 | How do you rate the course (1–10)? | 9.31 |
| 2 | Was there enough time to absorb the material (1–10)? | 9.77 |
| 3 | Was it interesting (1–10)? | 9.31 |
| 4 | Would you recommend this course to another student (1–10)? | 9.33 |
| 5 | Can you write a comment about this course? | |

| | |
|---|---|
| | • It was interesting and the information was easy and clear to process. |
| | • The course was clear, all the material was uploaded, exercises were useful. |
| | • I really like this study course, especially because it was online. It was easier to combine my studies with my work. |
| | • The course was interesting because I really like image-processing projects and related topics. I learned so much with this course; thank you so much, Professor, for helping me with my all questions about this course. |
| | • I think it would be better to have more work in classes with the lecturer, because It's quite difficult to absorb and understand all the information studying remotely. |
| | • I learned a lot in processing of space images with this course component. The material provided in the Moodle system was appropriate. |
| | • Everything was fine, I like the option of taking an exam via the internet. |

## 4 CONCLUSIONS

Space activities have a future in Lithuania, Europe, and the world – as they are associated with the economic impact of satellite communications and broadcasting, satellite navigation, earth observation from space. The development of new space technologies has been driven by advances in information technology, nanotechnology, and materials science. Small satellites are being developed that can only carry out functions and tasks previously performed by large satellites. The first steps in the formation of Lithuania's space policy were made in 2008. The Lithuanian Space Association (LSA) was established and the Government of Lithuania signed a cooperation agreement with the ESA in 2010. Objectives and tasks of the LSA are [37]:

- To promote and support educational, innovative, and other public activities in space-related fields;
- To seek favourable conditions for actors in this field in order to enhance Lithuanian science and business competitiveness in Europe and the whole world;
- To play a role of experts for business and governmental institutions dealing with space-related issues;
- To develop independently educational, science, and business activities in space-related fields.

The innovative educational project, 'Space Image Processing', is a first step toward expanding students knowledge and understanding regarding satellite imagery. The course was completed finished by students from a range of engineering fields. They were able to use the data from the Sentinel satellite and Landsat data sets from the ESA Copernicus Open Access Hub (ESA SciHUB) and the U.S. Geological Survey (USGS) archives. Students successfully created land surface temperature, vegetation cover, soil moisture thematic maps, and mode land-cover classification with open source SNAP, QGIS, and commercial software eCognition. The assessment grades for the student’s laboratory work were 8, 9 and 10. The theory knowledge results (as reflected on testing) were 8, 9 and 10 also. After the “Space Image Processing” course, students left good feedback about the material. Overall, the created course ‘Space Image Processing’ quality was rated to be high. The material could be used for seminars if students do not select it next year.


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