Master's degree study programme
SPACE ENGINEERING

Level of qualification: 2nd cycle

Study Mode & length of study: full-time, 2 years

Language in which the course is taught: english, slovak

Qualification awarded: inžinier (Ing.)

Employment of graduates

Graduates will gain knowledge and skills in design, development and implementation of smart systems based on electronics, robotics, navigation and communication technologies, which can be used in space applications. The study program is aimed at progressive methods, approaches and technologies developed in electrical engineering, modeling and simulation, electronics, smart sensors, robotics, communication/navigation/information technologies, mechanics and thermo-kinetics, material science, microsatellite construction, and practical astronomy and exploring the Universe.
Employment of graduates is expected in the industrial domain, research and development institutes, or in the education. Graduates of Space Engineering will be educated and skilled in the development of smart systems based on advanced technologies, which can find application in many diverse domains such as embedded systems, robotics, mechatronics, information technologies, automotive industry and transport, power engineering and others.

Graduates may find their job as follows:

- a creative engineer in the development of components, modules and circuits for the space systems and microsatellites,
- a creative engineer in the field of software and information systems development for robotics, automation, space engineering and transport,
- a leader of interdisciplinary and international research and development teams,
- a founder of spin-off companies and a creator of job opportunities,
- a submitter of research and innovation projects.

Study programme guarantor: prof. Ing. Viera Stopjaková, PhD.

Study advisors: doc. Ing. Jaroslav Kováč, PhD.
prof. Ing. Peter Ballo, PhD.

Master's degree study programme SPACE ENGINEERING

1st year – 1st semester (winter):

Code	Name of course	Type[1]	Credits	Teaching methods[2]	Lecturer(s)
I-ADYN	Astrodynamics	C	5	2-2, E	V. Kutiš
I-APE	Applied Electrotechnics	C	5	2-2, E	R. Harťanský
I-RELS	Reconfigurable Electronic Systems	C	5	2-2, E	V. Stopjaková
I-SAC	Sensors and Actuators	C	5	2-2, E	I. Hotový, J. Kováč
I-ROTS	Robotic Technologies for Space	C	5	2-2, E	P. Hubinský
	Semi-compulsory course	*SC*	*5*		
	Total:		**30**		

Semi-compulsory courses

Code	Name of course	Type[1]	Credits	Teaching methods[2]	Lecturer(s)
I-SSPA	Solar System and Practical Astronomy	SC	5	2-2, CFR	P. Ballo
I-PS	Power Sources	SC	5	2-2, CFR	V. Šály

1st year – 2nd semester (summer):

Code	Name of course	Type[1]	Credits	Teaching methods[2]	Lecturer(s)
I-AIDP	Artificial Intelligence and Data Processing	C	5	2-2, E	M. Oravec J. Pavlovičová
I-SDS	Safety-critical Digital Systems	C	5	2-2, E	V. Stopjaková
I-REA	Radioengineering and Antennas	C	5	2-2, E	R. Harťanský
I-MTSS	Mechanics and Thermokinetics of Space Systems	C	5	2-2, E	V. Kutiš
I-DP1-SE	Diploma project 1	C	5	0-2, CFR	V. Stopjaková
	Semi-compulsory course	*SC*	*5*		
	Total:		**30**		

Semi-compulsory courses

Code	Name of course	Type[1]	Credits	Teaching methods[2]	Lecturer(s)
I-EXU	Exploring the Universe	SC	5	2-2, CFR	P. Ballo
I-MDSS	Materials and Design of Space Systems	SC	5	2-2, CFR	Ľ. Stuchlíková

2nd year – 3rd semester (winter):

Code	Name of course	Type[1]	Credits	Teaching methods[2]	Lecturer(s)
I-PRS	Propulsion Systems	C	5	2-2, E	V. Kutiš
I-NS	Navigation Systems	C	5	2-2, E	F. Duchoň
I-COS	Control Systems	C	5	2-2, E	D. Rosinová
I-MSAT	Microsatellites	C	5	1-3, CFR	P. Ballo
I-DP2-SE	Diploma project 2	C	5	0-2, CFR	V. Stopjaková
I-PRS	*Semi-compulsory course*	*SC*	5		
	Total:		**30**		

Semi-compulsory courses

Code	Name of course	Type[1]	Credits	Teaching methods[2]	Lecturer(s)
I-SSI	Space Scientific Instruments	SC	5	2-2, CFR	V. Kutiš
I-SC	Space Communication	SC	5	2-2, CFR	P. Farkaš

2nd year – 4th semester (summer):

Code	Name of course	Type[1]	Credits	Teaching methods[2]	Lecturer(s)
I-RETS	Real-time Systems	C	5	2-2, E	P. Ballo
I-DP3-SE	Diploma project 3	C	10	0-8, CFR	V. Stopjaková
I-DT-SE	Diploma thesis	C	10	0-2, E	V. Stopjaková
I-RETS	*Semi-compulsory course*	*SC*	5		
	Total:		**30**		

Semi-compulsory courses

Code	Name of course	Type[1]	Credits	Teaching methods[2]	Lecturer(s)
I-ABIO	Astrobiology	SC	5	2-2, CRF	M. Musilová
I-TSR	Theory of Special Relativity	SC	5	2-2, CFR	P. Ballo

[1] Type: C – compulsory course
SC – semi-compulsory course

[2] Teaching methods: lecture hours per week – seminar hours per week, mode of completion
E – exam
CFR – classified fulfillment of requirements

Course contents

APPLIED ELECTROTECHNICS – I-APE

Basic terms and laws in electrical engineering. Ideal and real elements of electrical circuits, equivalent circuits of real elements. The concept of technical generator, parallel and serial connection of power sources, efficiency. Harmonic voltages and currents, complex representation of circuit quantities, phasor, complex impedance. Solution of linear circuits in harmonic steady state. Work and power of electric current. Non-harmonic currents. Fourier series. Calculation of circuits feeding by non-harmonic currents. Circuits with distributed parameters. Homogeneous lines, characteristic impedance, maximum power transfer. Methods of adaptation of complex load. Narrowband adjustments, broadband adjustments. Basic microwave circuits.

Supervisor: prof. Ing. René Harťanský, PhD.

ARTIFICIAL INTELLIGENCE AND DATA PROCESSING – I-AIDP

Concepts and principles (artificial intelligence, machine learning, computational intelligence, intelligent systems, knowledge discovery, neural network, deep learning). Conventional and deep neural network architectures and learning. Margins, kernel methods, support vector machines, clustering. 1D and 2D data processing and analysis in time and frequency domain, convolution, Fourier transform, filtering, image reconstruction. Pattern recognition. Big data processing.

Supervisor: prof. Dr. Ing. Miloš Oravec

ASTROBIOLOGY – I-ABIO

Introduction to Astrobiology: latest news, history and direction of the research field. The origin and distribution of biologically important chemicals in the Universe. Initial conditions in the early Solar System and on Proto-Earth. Basic tools for terrestrial life - replication and metabolism. The origin of life on Earth - from abiogenesis to panspermia. History of life on Earth. Limits of the biosphere and extremophiles. Biosignatures and the requirements for life. Looking for life elsewhere in the Solar System. Exoplanets and habitable zones. Search for extraterrestrial intelligence in the Universe. Expansion of humanity into space.

Supervisor: Dr. Michaela Musilová, MSc.

ASTRODYNAMICS – I-ADYN

Two body problem. Motion in inertial frame. Relative motion. Angular momentum. Energy law. Trajectories. Time and position. Three body problem. Orbits in three dimensions. Orbital elements. Calculation of elements. Orbital perturbations. Perturbing forces. Geopotential. Orbit propagation. Variation of parameters. Interplanetary trajectories. Gravity assist maneuver. Orbital maneuvers. Impulsive maneuvers. Hohmann transfer. Non-Hohmann transfer. Plane change maneuvers. Dynamics of rigid bodies. Satellite attitude dynamics.

Supervisor: prof. Ing. Vladimír Kutiš, PhD.

CONTROL SYSTEMS – I-COS

State-space models of dynamic systems and state-space approach to feedback control systems. Modelling approaches for dynamic systems – data driven and first principle ones, nonlinear models, linearization. Design methods in state space: pole placement, linear quadratic regulator, state estimation, Kalman filter, LQG. Basics of digital control systems and digital implementation of controllers. Performance limitations and robustness, extensive use of computer-aided control design and simulation (in Matlab&Simulink environment).

Applications to various aerospace-motivated control problems, including basic DC motor (positional and speed servo) , satellite attitude control, and navigation guidance (reference tracking).
Supervisor: prof. Ing. Danica Rosinová, PhD.

DIPLOMA PROJECT 1 – I-DP1-SE
Study of the problem, investigation of resources. Problem analysis. Written presentation of the project results.
Supervisor: prof. Ing. Viera Stopjaková, PhD.

DIPLOMA PROJECT 2 – I-DP2-SE
Study of the problem, investigation of resources. Problem analysis. Draft solutions. Verification of selected parts of the solution. Written presentation of the project results.
Supervisor: prof. Ing. Viera Stopjaková, PhD.

DIPLOMA PROJECT 3 – I-DP3-SE
Detailed problem solution. Revision and critical evaluation of decisions from previous stages. Complex verification of the solution. Written presentation of the project results.
Supervisor: prof. Ing. Viera Stopjaková, PhD.

DIPLOMA THESIS – I-DT-SE
Elaboration of master thesis. Preparation of thesis presentation and defense. Thesis defense in front of examination committee. Responding to reviewers questions and comments. Discussion related to thesis subject in the wider study field context.
Supervisor: prof. Ing. Viera Stopjaková, PhD.

EXPLORING THE UNIVERSE – I-EXU
Basic principles of space exploration. Technology used in space exploration, refractors, reflectors, radio telescopes, spectroscopic methods. Experimental methods used on satellites. Research of the Sun, nearby and distant planets of our System. Research of distant stars, measurement of distance, type and position of a star. Research of black holes. Research on exoplanets. Methods of data processing.
Supervisor: prof. Ing. Peter Ballo, PhD.

MATERIALS AND DESIGN OF SPACE SYSTEMS – I-MDSS
The materials used in space systems. Physical principles of processes in materials, requirements for material properties, characterization and testing of properties of materials and basic elements. Trends in material research, fabrication technologies and quality criteria. Fundamental construction of space systems. The effect of external conditions on the properties of the materials. Proposal of selection of suitable materials and constructions of simple space systems.
Supervisor: prof. Ing. Ľubica Stuchlíková, PhD.

MECHANICS AND THERMOKINETICS OF SPACE SYSTEMS – I-MTSS
Satellite structures and materials. Satellite subsystems. Satellite structural design. Strength analysis of space systems. Static strength analysis. Modal analysis. Harmonic response analysis. Thermal deformation analysis. Spacecraft structural analysis using finite element method. Heat transfer mechanisms. Conductive heat transfer. Fourier's law of heat conduction. Convective heat transfer. Newton's law of cooling. Radiative heat transfer. Stefan-Boltzmann law. Heat generated by the spacecraft electronics. Passive and active thermal control. Spacecraft thermal analysis using finite element method.

Supervisor: prof. Ing. Vladimír Kutiš, PhD.

MICROSATELLITES – I-MSAT

Mechanical construction, analysis of mechanical properties, load and stiffness, elasticity, vibration, choice of materials, structural analysis. Thermal construction, heat sources, thermal equilibrium, thermostatic elements, thermal design and realization. Design of electrical systems, production, storage, regulation and monitoring of electrical energy, EMC, shielding and grounding, protection. Communication and data manipulation, surveillance, radio systems, antennas, telemetry and command systems, boardcomputer, operating system. Guidance and navigation systems, path determination and control, positioning and control algorithms. Design and testing of payload, detailed design, production, environmental testing, payload.

Supervisor: prof. Ing. Peter Ballo, PhD.

NAVIGATION SYSTEMS – I-NS

Introduction to the mobile systems used for space exploration. Kinematics, dynamics, control. Localization (GNSS systems, odometry, IMU, natural landmarks, triangulation and trilateration, localization on the basis of visual system, KF, SLAM, EKF SLAM). Navigation (visual systems, distance measurements by visual system, reactive navigation methods – histogram methods, velocity methods, planning navigation methods – A* and modifications, probabilistic roadmaps and RRT). Specific properties of navigation systems in cosmic space.

Supervisor: prof. Ing. František Duchoň, PhD.

POWER SOURCES – I-PS

Energy systems for space applications. Sun as a source of energy, sunlight in terrestrial and extraterrestrial conditions. Semiconductors, photovoltaic transformation, photoelectric and photovoltaic phenomena, solar cells and modules, specific requirements of space applications, photovoltaic systems in space. Degradation processes. Thermal energy, heat loss. Fuel cells and batteries for satellite equipment. Photo-electrochemical generation of hydrogen. Electricity transport, wires and cables for space applications. Nuclear energy systems in the cosmos. Power systems for interplanetary missions. Radioactive decay. Radioisotope thermoelectric generators (RTG). Nuclear fission. Nuclear reactors for space applications.

Supervisor: prof. Ing. Vladimír Šály, DrSc.

PROPULSION SYSTEMS – I-PRS

Fundamental equations of fluid flow. Thermodynamics of gases. Speed of sound. Isentropic flow. Nozzle fluid flow. Chemical rocket propulsion. Performance characteristics of rocket motors. Heat transfer in rocket motors. Liquid-propellant and solid-propellant rocket motors. CFD simulations. Electric rocket propulsion. Physical principles of operation and reasons for using electromagnetic propulsion systems. Major categories of electromagnetic rocket engines. The main design elements of electromagnetic rocket motors. Examples of practical deployment of electromagnetic propulsion systems. Rocket motion in vacuum. Multi-stage rocket. Ballistic missile trajectories. Rocket motion in atmosphere.

Supervisor: prof. Ing. Vladimír Kutiš, PhD.

RADIOENGINEERING AND ANTENNAS – I-REA

Maxwell equations (differential and integral form), boundary conditions, power and energy of EM field. Wave equation and its solution for no source; for no loss environment; for loss environment in various coordination systems. Wave propagation and polarization; wave transition into the second environment, wave reflection, perpendicular impact, oblique

impact. Diffraction - on the cylinder; on the edge. Elementary EM field sources, elemental dipole, elementary loop. Finite length dipole, half-wave dipole. Pocklington integral equation. Indoor and outdoor antenna task. Antenna systems. Radio-communication equation.
Supervisor: prof. Ing. René Harťanský, PhD.

REAL-TIME SYSTEMS – I-RETS
Automated Data Capture System (ADCS), from theory to practice. ADCS algorithms, sensor data processing, interface, mechanical and non-mechanical drives, on-board computer. Real-time operating system, task types and execution time, accelerating algorithms in hardware for real-time systems.
Supervisor: prof. Ing. Peter Ballo, PhD.

RECONFIGURABLE ELECTRONIC SYSTEMS – I-RELS
Motivation for reconfigurable electronic systems towards space applications. Field programmable gate arrays (FPGA). Hardware description language (HLD) methodology of digital reconfigurable system design. Design of digital systems at different level of abstractions - logic level, register transfer level (RTL) and system level. Design flow. Introduction to verification of digital systems. Logic synthesis to FPGA, technology mapping. Optimization constraints. Reconfiguration. Physical implementation. Design example of a control unit.
Supervisor: prof. Ing. Viera Stopjaková, PhD.

ROBOTIC TECHNOLOGIES FOR SPACE – I-ROTS
Robotics - basic definitions, historical milestones. Robot and his subsystems, autonomous and remote controlled systems, robot classification according to different criteria. Mobile robots - design principles of robots moving on solid surface, on and below (water) level and in a gas atmosphere and a cosmic space. Position and orientation control. Methods of landing on cosmic bodies of different types. Robotic manipulators and other mechanical structures for use on the mobile platforms and manned spaceships. Exoskeletons. Drive systems for use in robotics, motors and gear mechanisms. Sensor systems for use in robotics. Sensors of internal variables, localization sensors. Sensors for remote and in situ survey the physical properties of cosmic bodies. Power sources for mobile robots, energy management, internal temperature stabilization, protection systems against adverse environmental effects. Human-robot interaction - basic ways of control and programming robots. Visual and haptic feedback. Augmented and virtual reality. Current and upcoming applications of robotic technologies in remote exploration of the Earth and other cosmic bodies. Robotics in manned cosmonautics. Sample gathering and transporting them to Earth. Mining and building the bases on other cosmic bodies using robots.
Supervisor: prof. Ing. Peter Hubinský, PhD.

SAFETY-CRITICAL DIGITAL SYSTEMS – I-SDS
Reliability issue of electronic systems for space applications. Faults in digital systems induced by cosmic rays. Fault-tolerant digital systems. Basic architectures of fault-tolerant redundant systems: double modular redundancy (DMR), triple modular redundancy (TMR), quadruple modular redundancy (QMR). Metrics of reliability. FPGA technologies for space engineering (Rad Hard FPGA). Advanced methods of system verification (OVM, UVM) and debugging in FPGA (JTAG, logic analyzer). Error mitigation techniques for FPGA. Built-in self test (BIST). Mixed systems-on-chip (SoC).
Supervisor: prof. Ing. Viera Stopjaková, PhD.

SENSORS AND ACTUATORS – I-SAC

Technical and technological requirements for sensors and actuators for aerospace as well as for non-standard and harsh environments. Motivations from the standard conditions of preparation to the microsystems and MEMS elements. Design rules, technical parameters, required properties, utilized physical and chemical effects and the specifications of sensors and actuators for aerospace as well as for non-standard and harsh environments (high temperature, large range of the pressures, gravitation, aerospace radiation). Modern trends in the development of sensors and actuators: smart materials, material structures and progressive technologies of their fabrication. Selected types of sensors: pressure, position, temperature, acceleration, vibrations and chemical composition. Optoelectronic elements and photonic structures (cameras, displays, LEDs and lasers, optical fiber sensors, micromirrors, Bragg gratings). Selected types of sensors and actuators as the components of miniature smart measuring platforms and the functional microsystems for aerospace applications.

Supervisor: prof. Ing. Ivan Hotový, DrSc.

SOLAR SYSTEM AND PRACTICAL ASTRONOMY – I-SSPA

Introduction to solar system mechanics. Sun, properties and physics. List of solar systems: names and definitions of planets, asteroids, moons, comets and objects of the Kuiper belt. Earth's planets, the four inner planets of the solar system. Giant planets, differences between gas giants (Jupiter and Saturn) and ice giants (Uranus and Neptune). Kuiper belt, Pluto, Eris, Quaoar. Special lecture: Exoplanets, properties, their location and how we find them.

Supervisor: prof. Ing. Peter Ballo, PhD.

SPACE SCIENTIFIC INSTRUMENTS – I-SSI

The reasons for the placement of observation and measuring devices in space. Major categories of instruments operated in space. Optical astronomical space telescopes (their focus and main characteristics). Astronomical space telescopes observing beyond the optical wavelengths (their focus and main characteristics). Apparatuses designed for basic research (detectors and other special devices). Earth observation instruments (the main characteristics of telescopes and radars). Optical and near infrared Earth observation instruments. Earth observation instruments operated in microwave and UV bands. Synthetic aperture radars.

Supervisor: prof. Ing. Vladimír Kutiš, PhD.

SPACE COMMUNICATION – I-SC

Satellite, deep space and terrestrial communication systems and bandwidths for wireless communication. Channel models and signals applicable in space communication and their interaction with systems. Optimal receiver. Space communication from Information theory perspective. Channel capacity and why transmission codes are inevitable in space communication in AWGN channel. Convolutional codes-first transmission codes in applied in space; From first block codes applied in space- Golay codes to Reed Solomon codes; Up to date space codes. Link budget. Satellite systems. Multiple access in telecommunications satellites. Bandwidths, signals and transmission codes for satellite communication, navigation and sensing.

Supervisor: prof. Ing. Peter Farkaš, DrSc.

THEORY OF SPECIAL RELATIVITY – I-TSR

Physics before Einstein, dynamics and electrodynamics. Transformation concept, Galilee and Lorentz transformation, the concept that distant simultaneity and its dependence on the reference system. Great Experiments with Light, Michelson Morley (MM) Experiment.

Einstein's explanation of the MM experiment, the principle of relativity. Postulates of special relativity theory. Speed folding and other differential transformations. Four-vectors and their transformation properties. Relations between mass and energy, particles of zero mass. New concept of space-time according to H. Minkowski. Geometry of space-time, space-time interval, light cone. Four-dimensional form of Maxwell's equations. Lagrange formula of electrodynamics.

Supervisor: prof. Ing. Peter Ballo, PhD.