Federal State Autonomous Educational Institution of Higher Education
Peoples' Friendship University of Russia named after Patrice Lumumba

Academy of Engineering
(name of the main educational unit (MEU) that developed the educational program of higher education)

WORKING PROGRAM OF THE DISCIPLINE

DYNAMICS AND CONTROL OF SPACE SYSTEMS
(name of discipline/module)

Recommended for the field of study/specialty:

27.04.04 CONTROL IN TECHNICAL SYSTEMS
(code and name of the field of study/specialty)

The discipline is mastered within the framework of the implementation of the main professional educational program of higher education (EP HE):

Artificial Intelligence, Machine Learning, and Space Science
(name (profile/specialization) of the educational institution of higher education)

2026

1. THE GOAL OF MASTERING THE DISCIPLINE

The course "Dynamics and Control of Space Systems" is part of the Master's program "Artificial Intelligence, Machine Learning, and Space Sciences" (27.04.04 "Control in Technical Systems") and is studied in the third semester of the second year. The course is offered by the Department of Mechanics and Control Processes. It consists of two sections and seven topics and focuses on developing practical skills in solving design problems involving the formation and calculation of the motion of spacecraft and orbital structures for various purposes, solving specific engineering problems related to orbital launch and maneuvering, and applying mathematical modeling methods to solve these problems using modern computer tools.

The purpose of mastering the discipline is to acquire knowledge, skills, abilities and experience in the field of designing space satellite systems for various purposes, maneuvering spacecraft in orbit, methods of their calculation and optimization, characterizing the stages of the formation of competencies and ensuring the achievement of the planned results of mastering the educational program.

2. REQUIREMENTS FOR THE RESULTS OF MASTERING THE DISCIPLINE

Mastering the discipline "Dynamics and Control of Space Systems" aimed at developing the following competencies (parts of competencies) in students:

Table 2.1. List of competencies developed in students while mastering the discipline (results of mastering the discipline)

Cipher	Competence	Indicators of Competency Achievement (within this discipline)
GPC-2	Able to formulate control problems in technical systems and justify methods for solving them	GPC-2.1 Knows the basic methods of solving control problems in technical systems; GPC-2.2 Able to justify methods for solving control problems in technical systems; GPC-2.3 Proficient in methods of setting control problems in technical systems.
GPC-3	Capable of independently solving control problems in technical systems based on the latest advances in science and technology	GPC-3.1 Knows the basic approaches to solving control problems in technical systems; GPC-3.2 Able to apply basic approaches based on the latest achievements of science and technology to solving control problems in technical systems; GPC-3.3 Proficient in methods of solving control problems in technical systems based on the latest achievements of science and technology.
GPC-4	Capable of assessing the effectiveness of the results of development of control systems using mathematical methods	GPC-4.1 Knows the basic mathematical methods used to evaluate the effectiveness of the results of control systems; GPC-4.2 Able to apply mathematical methods to evaluate the effectiveness of the results of management systems; GPC-4.3 Proficient in methods for assessing the effectiveness of management systems.
GPC-5	Capable of conducting patent research, determining forms and methods of legal protection and defense of rights to the results of intellectual activity, and managing rights to them to solve problems in the development of science, engineering, and technology	GPC-5.1 Knows the methods and approaches to conducting patent research, forms and methods of legal protection and defense of rights to the results of intellectual activity; GPC-5.2 Able to manage rights to the results of intellectual activity to solve problems in the field of development of science, engineering and technology; GPC-5.3 Has knowledge of methods and approaches to conducting patent research, knows the methods of legal protection and defense of rights to the results of intellectual activity.
GPC-7	Capable of making informed choices, developing and implementing in practice circuit de-	GPC-7.1 Able to develop and implement in practice circuit and system engineering solutions for automation and control systems; GPC-7.2 Able to develop hardware and software solutions for

Cipher	Competence	Indicators of Competency Achievement (within this discipline)
	sign, system engineering and hardware-software solutions for automation and control systems	automation and control systems; GPC-7.3 Possesses approaches for making a well-founded choice and implementing in practice circuit, system engineering and hardware-software solutions for automation and control systems.
GPC-9	Capable of developing methods and performing experiments at existing facilities with processing of results based on information technology and technical means	GPC-9.1 Possesses modern information technologies and technical means for conducting experiments at operating facilities; GPC-9.2 Has skills in developing methods and performing experiments at operating facilities; GPC-9.3 Has the skills to develop methods and perform experiments at existing facilities with processing of results using information technology.
PC-2	Able to apply modern theoretical and experimental methods for developing mathematical models of objects and processes under study in the field of aerospace systems management	PC-2.1 Knows modern theoretical and experimental methods used to develop mathematical models of studied objects and processes of professional activity; PC-2.2 Able to determine the effectiveness of the methods used to develop mathematical models of the objects and processes under study; PC-2.3 Has mastered modern theoretical and experimental methods for developing mathematical models of objects and processes of professional activity in the field of study.
PC-4	Capable of participating in scientific research and development of design solutions in the field of ballistics, dynamics and flight control of spacecraft	PC-4.1 Familiar with the basic methods and approaches used to solve problems in the field of artificial intelligence and robotic systems; PC-4.2 Proficient in methods for solving professional problems in the field of artificial intelligence and robotic systems; PC-4.3 Able to apply mathematical methods and modern information technologies when conducting scientific research.

3. PLACE OF THE DISCIPLINE IN THE STRUCTURE OF THE EDUCATIONAL EDUCATIONAL INSTITUTION

Course "Dynamics and Control of Space Systems" refers to the mandatory part of block 1 “Disciplines (modules)” of the educational program of higher education.

As part of the higher education program, students also master other disciplines and/or practices that contribute to the achievement of the planned results of mastering the discipline "Dynamics and Control of Space Systems".

Table 3.1. List of components of the educational program of higher education that contribute to the achievement of the planned results of mastering the discipline

Cipher	Name of competence	Previous courses/modules, practical training*	Subsequent disciplines/modules, practices*
GPC-2	Able to formulate control problems in technical systems and justify methods for solving them	Virtual Reality and Computer Vision; Numerical Methods for Solving Mathematical Modeling Problems; Information Technology in Mathematical Modeling; Programming Technology;	Undergraduate Training;
GPC-3	Capable of independently solving control problems in technical systems based on the latest advances in science and technology	Research work / Scientific research work; Virtual Reality and Computer Vision; Advanced Methods of Space Flight Mechanics;	Undergraduate Training;

Cipher	Name of competence	Previous courses/modules, practical training*	Subsequent disciplines/modules, practices*
		Programming Technology;	
GPC-4	Capable of assessing the effectiveness of the results of development of control systems using mathematical methods	History and Methodology of Science; Advanced Methods of Earth Remote Sensing;	Undergraduate Training;
GPC-5	Capable of conducting patent research, determining forms and methods of legal protection and defense of rights to the results of intellectual activity, and managing rights to them to solve problems in the development of science, engineering, and technology	Research work / Scientific research work; Machine Learning and Big Data Mining;	Undergraduate Training;
GPC-7	Capable of making informed choices, developing and implementing in practice circuit design, system engineering and hardware-software solutions for automation and control systems	Advanced Methods of Space Flight Mechanics; Research work / Scientific research work;	Undergraduate Training;
GPC-9	Capable of developing methods and performing experiments at existing facilities with processing of results based on information technology and technical means	Virtual Reality and Computer Vision;	Undergraduate Training;
PC-2	Able to apply modern theoretical and experimental methods for developing mathematical models of objects and processes under study in the field of aerospace systems management	Research work / Scientific research work; History and Methodology of Science; Virtual Reality and Computer Vision; *Artificial Neural Networks (Deep Learning)* **; *Artificial Neural Networks (Deep Learning)* **; Information Technology in Mathematical Modeling; Advanced Methods of Space Flight Mechanics;	Undergraduate Training;
PC-4	Capable of participating in scientific research and development of design solutions in the field of ballistics, dynamics and flight control of spacecraft	Research work / Scientific research work; History and Methodology of Science; Advanced Methods of Earth Remote Sensing;	Undergraduate Training;

* - filled in accordance with the competency matrix and the SUP EP HE

** - elective courses/practices

4. SCOPE OF THE DISCIPLINE AND TYPES OF EDUCATIONAL WORK

The total workload of the course “Dynamics and Control of Space Systems” is 8 credit units.

Table 4.1. Types of educational work by periods of mastering the educational program of higher education for full-time education.

Type of academic work	**TOTAL,**academic hours		**Semester(s)**
			3
Contact work, academic hours	*72*		*72*
Lectures (LC)	36		36
Laboratory work (LW)	0		0
Practical/seminar classes (SC)	36		36
Independent work of students, academic hours	*180*		*180*
Control (exam/test with assessment), academic hours	*36*		*36*
Total complexity of the discipline	**academic hours**	***288***	*288*
	credit	***8***	*8*

5. CONTENT OF THE DISCIPLINE

Table 5.1. Content of the discipline (module) by types of academic work

Section number	Name of the discipline section	Topic Title		Topic Contents	Type of academic work*
Section 1	Methods for optimizing orbital structures of satellite systems	1.1	General principles of satellite system design. Methods for constructing systems for global, continuous coverage of Earth's regions. Ballistic design of systems for zonal, continuous coverage of the Earth's surface.	General principles of satellite system design: purpose, composition, structure, accuracy and performance requirements. Methods for constructing global continuous surveillance systems: low-orbit constellations, geostationary systems, Molniya orbits. Ballistic design of zonal continuous surveillance systems: selection of orbital parameters (altitude, inclination, eccentricity), determination of the number of satellites in the constellation, coverage area analysis.	LC, SC
		1.2	Determining the time gap in observations by a single frontal group of the entire Earth's surface. Methods for constructing satellite systems for periodic coverage of the Earth's surface. Designing ballistic structures for systems for covering the entire Earth's surface with small gaps in observations. Designing systems for periodic coverage of a region on the Earth's surface. Ballistic design of probabilistic spacecraft systems.	Determining the time gap in observations by a single frontal group. Methods for constructing periodic surveillance systems: using multiple orbits, phase shifts. Constructing ballistic structures for global coverage with a given periodicity: optimizing satellite placement, taking into account the latitude belt.	LC, SC
		1.3	Spacecraft communication systems. Satellite radio navigation systems. Design features of meteorological satellite systems. Design of space surveillance systems. Ballistic design of systems using ballistically coupled spacecraft groups.	Satellite communication systems: geostationary and low-orbit systems (Iridium, Globalstar, Starlink). Satellite radio navigation systems: GPS, GLONASS, Galileo, BeiDou – design principles, orbital structures. Features of meteorological satellite systems: geostationary (GOES, Meteosat) and polar-orbiting (NOAA, Meteor). Space surveillance systems: detection and tracking of space debris and hazardous objects. Ballistic design of systems with highly elliptical orbits.	LC, SC
		1.4	Space tether systems. Orbital operation of tethered space objects. Space rendezvous using tether systems. A method for developing optimal controlled motion modes for tether systems when solving practical problems.	Space tether systems: purpose, design, and physical principles. Orbital operation of tethered objects: the dynamics of the satellite-tether-cargo system. Rendezvous using tether systems. Method for developing optimal controlled motion modes for tether systems: minimizing energy consumption and stabilization.	LC, SC
Section 2	Numerical and analytical methods for optimizing	2.1	Equations of spacecraft motion during deviations from a reference circular orbit.	Equations of spacecraft motion during deviations from a reference circular orbit. Single-impulse maneuvers: changing the orbital	LC, SC

Section number	Name of the discipline section	Topic Title		Topic Contents	Type of academic work*
	orbital maneuvers		Single-impulse maneuvers. Orbital shape change due to the application of a velocity impulse. Estimating the magnitude of maneuvers, choosing the initial deviation along the orbit at spacecraft launch. Necessary optimality conditions. Main types of optimal spacecraft maneuvering problems.	shape and orientation. Estimating the characteristic velocity. Selecting the initial deviation to minimize costs.	
		2.2	Optimal maneuvering in the space debris problem. Spacecraft collision avoidance maneuvers against space debris. Evaluation of maneuvers performed by an active space object.	The space debris problem: sources, scale, and threats. Avoidance maneuvers: proximity detection, impulse calculation, and optimization of direction and magnitude. Maneuver evaluation: fuel consumption, execution accuracy.	LC, SC
		2.3	Optimal maneuvering in space servicing. Planning optimal servicing for a constellation of spacecraft in non-coplanar orbits. Evaluation of maneuvers performed by active spacecraft when transferred to the vicinity of serviced objects.	Space servicing tasks: refueling, repairs, and deorbiting. Constellation servicing planning in non-coplanar orbits: optimization of rendezvous sequences, minimization of fuel consumption. Active spacecraft maneuver assessment: insertion accuracy, remaining fuel.	LC, SC

* - to be completed only for FULL-TIME education: LC – lectures; LW – laboratory work; SC – practical/seminar classes.

6. LOGISTIC AND TECHNICAL SUPPORT OF DISCIPLINE

Table 6.1. Material and technical support for the discipline

Audience type	Equipment of the auditorium	Specialized educational/laboratory equipment, software and materials for mastering the discipline (if necessary)
Lecture	A lecture hall equipped with specialized furniture, a whiteboard (screen), and multimedia presentation equipment.	
Computer class	A computer room for conducting classes, group and individual consultations, ongoing monitoring and midterm assessment, equipped with personal computers (in the amount of ____ units), a board (screen) and technical means for multimedia presentations.	
Seminar	An auditorium for conducting seminar-type classes, group and individual consultations, ongoing monitoring and midterm assessment, equipped with a set of specialized furniture and technical means for multimedia presentations.	
For independent work	A classroom for independent student work (can be used for seminars and consultations), equipped with a set of specialized furniture and computers with access to the Electronic Information System.	

* - the classroom for independent work of students MUST be indicated!

7. EDUCATIONAL, METHODOLOGICAL AND INFORMATIONAL SUPPORT OF THE DISCIPLINE

Main literature:

1. Averkiev N.F., Vlasov S.A., Bogachev S.A., Zhatkin A.T., Kulvits A.V. Ballistic principles of designing launch vehicles and satellite systems: textbook. - St. Petersburg: A.F. Mozhaisky Air Defense Academy, 2017. - 300 p.

2. Baranov A.A. Maneuvering of spacecraft in the vicinity of a circular orbit. - M.: Publishing House "Sputnik+", 2016. - 512 p.

3. Bordovitsyna T.V., Avdyushev V.A. Theory of motion of artificial Earth satellites. Analytical and numerical methods: a tutorial. - Tomsk: Publishing house of Tomsk. University, 2007. - 178 p.

4. Beletsky V.V. Essays on the motion of cosmic bodies. Issue No. 4. - M.: URSS Publishing Group, 2017. - 432 p.

Further reading:

1. Vlasov S.A., Kulvits A.V., Skripnikov A.N. Spacecraft flight theory: textbook. - St. Petersburg: A.F. Mozhasky Space Academy, 2018. - 412 p.

2. Ivanov N.M., Lysenko L.N. Ballistics and navigation of spacecraft: textbook. 3rd edition. - M.: Drofa, 2016. - 528 p.

3. Sazonov V.V., Barbashova T.F. Lectures on space flight mechanics. Special course. - M.: Moscow State University Publishing House, 2018. - 152 p.

4. Mechanical Engineering. Encyclopedia. Editorial Board: K. V. Frolov (chairman) et al. - Moscow: Mechanical Engineering. Rocket and Space Technology. Vol. IV-22 / A. P. Adzhyan, E. L. Akim, O. M. Alifanov et al.; editors V. P. Legostaev, editors E. A. Akim, Yu. P. O. M. Alifanov, V. V. Vakhnichenko, G. N. Zaslavsky, A. A. Dyadkin, V. V. Ivashkin, B. I. Katorgin, Yu. N. Razumny, Yu. P. Ulybyshev, Book 1. 2012. Section 2.5. Satellite Systems. Pp.

5. Razumny Yu.N., Shkolnikov D.O. Basic integrals of unperturbed motion and the Kepler equation: a tutorial. - Moscow: Publishing house of Bauman Moscow State Technical University, 2011. - 38 p.

Resources of the information and telecommunications network "Internet":

1. RUDN University Electronic Library System and third-party electronic library systems to which university students have access based on concluded agreements

- RUDN University Electronic Library System – RUDN University Electronic Library System https://mega.rudn.ru/MegaPro/Web
- Electronic Library System "University Library Online" http://www.biblioclub.ru
- EBS Yurayt http://www.biblio-online.ru
- Electronic Library System "Student Consultant" www.studentlibrary.ru
- EBS “Knowledge” https://znanium.ru/

2. Databases and search engines

- Sage https://journals.sagepub.com/
- Springer Nature Link https://link.springer.com/
- Wiley Journal Database https://onlinelibrary.wiley.com/
- Scientometric database Lens.org https://www.lens.org

Educational and methodological materials for independent work of students in mastering a discipline/module:*

1. Lecture course on the subject "Dynamics and control of space systems".

* - all teaching and methodological materials for independent work of students are posted in accordance with the current procedure on the discipline page in TUIS!

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