



Wojskowa
Akademia
Techniczna

**Resolution
Senate of the Military University of Technology**

No. 10/WAT/2026 of 26 February 2026

**on the establishment of the "Curriculum of Education at the Doctoral School
of the Military University of Technology - 2026 edition"**

Pursuant to Article 201(4) of the Act of 20 July 2018 – Law on Higher Education and Science (i.e. Journal of Laws of 2024, item 1571, as amended), in connection with § 21(1)(21) of the Statute of the Military University of Technology constituting an annex to the Resolution of the Senate of the Military University of Technology No. 16/WAT/2019 of 25 April 2019 on the adoption of the Statute of the Military University of Technology (i.e. Announcement of the Rector of the Military University of Technology No. 2/WAT/2024 of 27 March 2024), the following is hereby resolved:

§ 1

The "Curriculum of Education at the Doctoral School of the Military University of Technology - 2026 edition" *is hereby established*, constituting an annex to the resolution.

§ 2

The curriculum referred to in § 1 is in force from the academic year 2026/2027.

§ 3

PhD students of the Doctoral School of the Military University of Technology who started their education before the academic year 2026/2027 can update Individual Education Programmes on the basis of this programme.

§ 4

The resolution enters into force on the day of its adoption.

President of the Senate

/--/ Brig. Gen. Prof. Przemysław Wachulak

CURRICULUM
AT THE DOCTORAL SCHOOL
MILITARY UNIVERSITY OF TECHNOLOGY
- EDITION 2026

I. General rules

1. The curriculum at the Doctoral School of the Military University of Technology is implemented for doctoral students of the following scientific disciplines:
 - 1) **automation, electronics, electrical engineering and space technologies** - the field of engineering and technical sciences;
 - 2) **technical informatics and telecommunications** - the field of engineering and technical sciences;
 - 3) **civil engineering, geodesy and transport** - the field of engineering and technical sciences;
 - 4) **materials engineering** - the field of engineering and technical sciences;
 - 5) **mechanical engineering** - the field of engineering and technical sciences;
 - 6) **security sciences** - the field of social sciences;
 - 7) **Chemical sciences** - a branch of exact and natural sciences.
2. Learning outcomes take into account the requirements set for level 8 of the Polish Qualifications Framework.
3. Number of semesters: **8**
4. Number of ECTS credits – min. **30 points**
5. The length of compulsory classes is 100 hours and 20 hours of professional practice carried out in the form of teaching or participating in their teaching and corresponds to a total of 10 ECTS credits, and the number of optional classes is at least 200 hours and corresponds to at least 20 ECTS credits. Optional classes may include classes in optional modules of subjects carried out at WAT in the amount of at least 100 hours and 10 ECTS points, subjects carried out at another HEI or scientific institution in Poland or abroad, and other forms of education, e.g. internships, internships in and outside WAT, in particular at another HEI or domestic or foreign institution.
6. Language of the lecture:
 - a. **Polish or English** – only in the case of subjects, internships or other forms of education indicated in the Individual Education Programme (IPK),
 - b. **English** – in the case of education in a scientific discipline in English.
7. The program is valid from **the academic year 2026/2027**.
8. Indication of the relationship between the concept of education and the development strategy and mission of the Military University of Technology:

Education at the Doctoral School of the Military University of Technology, hereinafter referred to as the "Doctoral School", is in line with the development strategy and mission of the Academy, the essence of which is the professional preparation of future personnel in the fields of engineering and technical sciences, exact and natural sciences and social sciences, and in particular in the field of military technology and security technology. The task of the Doctoral School is to ensure that doctoral students are provided with the latest knowledge, skills are shaped and competencies are improved at the highest level, as well as the cultivation of patriotic traditions and responsibility for the Homeland in broadly understood aspects, both military and civilian, in accordance with the

principle of "Omnia Pro Patria" – "Everything for the Homeland". The activities of the Doctoral School correlate with the strategic goals of the Academy's development in terms of strengthening the position of the Military University of Technology in the system of Polish and European higher education, including as the leading educational pillar of higher military education and the expert and research facilities of the Ministry of Defence, as well as other ministries. In addition, it emphasizes the elitism of the Academy as a university conducting innovative teaching and scientific activities, also developing international cooperation in this area.

9. Admission requirements for a candidate for the Doctoral School

The candidate should have a level 7 qualification. Polish Qualifications Framework (master's degree, master's degree in engineering or equivalent) and complete a master's degree in a field related to a scientific discipline conducted at the Doctoral School or have scientific achievements in this discipline. In exceptional cases, justified by the highest quality of scientific achievements, a person who is a graduate of first-cycle studies or a student who has completed the third year of long-cycle master's studies may be admitted to the Doctoral School. Detailed requirements are set out annually by the WAT Senate for the admission to the Doctoral School.

II. Description of the expected learning outcomes

The description of the assumed learning outcomes includes:

- universal characteristics of the first level specified in the Annex to the Act of 22 December 2015 on the Integrated Qualifications System;
- the characteristics of the second level specified in the annex to the Regulation of the Minister of Science and Higher Education of 14 November 2018 on the characteristics of the second level of learning outcomes for qualifications at levels 6-8 of the Polish Qualifications Framework (FFF).

Explanation of markings:

1) In the *Symbol and Effect Number* column:

- a) D - doctoral learning outcomes,
- b) W, U, K (after the underscore) - category: knowledge, skills, social competences,
- c) 01, 02, 03, - learning effect number,
- d) WAT01, ... - number of learning outcomes for subjects for which university learning outcomes apply;

2) in the column *code of the description component* - reference of the assumed learning outcome to the relevant code of the description component of the characteristics of the first and second level of learning outcomes at level 8 of the characteristics of the Polish Qualifications Framework (8 PRK).

A description of the following expected learning outcomes will be achieved as a result of the implementation of the educational programme, including the Individual Learning Programme (IPK) and the Individual Research Plan (IPB)

Symbol number effect	Expected learning outcomes	Code description component
Knowledge: the graduate knows and understands		
D_W WAT01	<i>methods and techniques of conducting didactic classes.</i>	P8S_WG
D_W01	<i>the world's scientific and technological achievements in a given scientific discipline and the resulting implications for practice</i>	P8U_W P8U_WG
D_W02	<i>global scientific and technological achievements including theoretical foundations and general issues and selected specific issues – specific to a given scientific discipline</i>	P8S_WG
D_W03	<i>development trends in the scientific discipline</i>	P8S_WG
D_W04	<i>methodology of scientific research</i>	P8S_WG
D_W05	<i>principles for disseminating the results of scientific activity, including in the open access mode</i>	P8S_WG
D_W06	<i>fundamental dilemmas of modern civilization; economic, legal, ethical and other important determinants of scientific activity; basic principles of knowledge transfer to the economic and social sphere and commercialization of the results of scientific activity and know-how related to these results</i>	P8S_WK
Skills: the graduate can		
D_U WAT01	<i>prepare and conduct didactic classes related to the scientific discipline in a modern way</i>	P8S_UK P8S_UU
D_U WAT02	<i>obtain the necessary information related to the conducted research, using sources, including English-language</i>	P8S_UK P8S_UO
D_U01	<i>analyse and creatively synthesize scientific and creative achievements in order to identify and solve research problems and problems related to innovative and creative activities;</i>	P8U_U P8S_UW
D_U02	<i>create new elements of scientific and creative achievements</i>	P8U_U P8S_UW
D_U03	<i>independently plan and act for their own development and inspire and organize the development of others,</i>	P8U_U P8S_UU
D_U04	<i>use knowledge to creatively identify, formulate and innovatively solve complex problems or perform research tasks , in particular: – define the purpose and subject of scientific research, formulate a research hypothesis, – develop research methods, techniques and tools and apply them creatively, – draw conclusions based on the results of scientific research</i>	P8S_UW
D_U05	<i>critically analyse and evaluate the results of scientific research, expert activity and other creative work and their contribution to the development of knowledge;</i>	P8S_UW
D_U06	<i>transfer the results of scientific activity to the economic and social sphere</i>	P8S_UW
D_U07	<i>communicate on specialist topics to the extent that enables active participation in the national and international scientific community</i>	P8U_U P8S_UK
D_U08	<i>disseminate the results of scientific activity, also in popular forms</i>	P8S_UK
D_U09	<i>initiate a debate</i>	P8U_U P8S_UK
D_U10	<i>participate in scientific discourse, exchange of experiences and ideas, also in the international environment</i>	P8U_U P8S_UK
D_U11	<i>use a foreign language at the B2 level of the Common European Framework of Reference for Languages to the extent that enables participation in an international scientific and professional environment</i>	P8S_UK
D_U12	<i>plan and implement individual and team research or creative projects, also in an international environment</i>	P8S_UO
D_U13	<i>plan classes or groups of classes and implement them using modern methods and tools</i>	P8S_UU

	Social competence: the graduate is ready to	
D_K01	<i>independent research that enhances the existing scientific and creative achievements</i>	P8U_K P8U_KK
D_K02	<i>taking up challenges in the professional and public spheres, taking into account: – their ethical dimension, – responsibility for their consequences and shaping models of appropriate conduct in such situations,</i>	P8U_K P8U_KK
D_K03	<i>critical evaluation of achievements within a given scientific discipline</i>	P8U_K P8S_KK
D_K04	<i>critical assessment of one's own contribution to the development of a given scientific discipline</i>	P8U_U P8S_KK
D_K05	<i>recognising the importance of knowledge in solving cognitive and practical problems</i>	P8U_U P8S_KK
D_K06	<i>fulfilling the social obligations of researchers and creators</i>	P8U_U P8S_KO
D_K07	<i>initiating activities for the public interest</i>	P8U_U P8S_KO
D_K08	<i>think and act in an entrepreneurial way</i>	P8U_U P8S_KO
D_K09	<i>maintaining and developing the ethos of research and creative environments, including: – conducting scientific activity in an independent manner, – respect the principle of public ownership of the results of scientific activity, taking into account the principles of intellectual property protection</i>	P8U_U P8S_KR

III. Method of verification of the assumed learning outcomes

Verification of the assumed learning outcomes, to the extent resulting from the implementation of the education programme, including the individual education programme, is carried out by checking the acquired knowledge, acquired skills and social competences by the doctoral student on the basis of:

- passing the courses included in the Basic Module, including a doctoral seminar in the subject of Research Area Analysis,
- passing courses from the Optional Module of a scientific discipline or disciplines, professional practice and subjects carried out outside the Military University of Technology and other forms of education¹ included in the Individual Education Programme (IPK).

In addition, the verification of learning outcomes is carried out as part of the evaluation of the individual research plan (IPB).

IV. Implementation of the curriculum

1. Education at the Doctoral School lasts 8 semesters.
2. There is one curriculum for all scientific disciplines taught at the Doctoral School.
3. The curriculum includes at least 300 hours of teaching² and at least 20 hours of professional practice carried out in the form of conducting classes or participating in their conduct - a total of at least 30 ECTS credits.
4. The doctoral student's education program consists of:
 - 1) the basic module for doctoral students of all scientific disciplines conducted at the Doctoral School, in the amount of 100 hours with a total of 9 ECTS credits;
 - 2) optional modules related to the scientific disciplines taught at the Doctoral School, in the amount of at least 200 hours each, to which at least 20 ECTS

¹ if they occur in IPK

² didactic classes may include subjects carried out outside the WAT and other forms of education

credits have been assigned,
subject to paragraphs 6, 7 and 8;

- 3) professional practice in the amount of 20 to 180 hours carried out in the form of conducting classes or participating in their conduct from the third to the seventh semester of education, – max. 60 hours per year (in accordance with the individual education programme), to which 1 ECTS point is assigned regardless of the number of hours of practice.
- 4) optionally courses taught outside the Military University of Technology and other forms of education in the hourly amount and number of ECTS credits specified in the individual curriculum.
5. A doctoral student is obliged to complete the basic module and 20 hours of professional practice carried out in the form of conducting classes or participating in their conduct. The doctoral student, in consultation with the supervisor from the optional module for the scientific discipline, selects the courses to be implemented so that the total number of ECTS credits corresponds to at least 20 credits. It is allowed for subjects to come from different scientific disciplines and to be carried out at another university or scientific institution.
6. In the case of planned implementation of courses outside WAT and other forms of education (e.g. internship, internship in and outside WAT), the supervisor determines the number of ECTS credits for them and the expected learning outcomes, assuming that the number of hours of classes in courses carried out at WAT from the optional module may not be less than 100 hours and 10 ECTS credits.
7. In the case of education for foreigners in English, the subjects included in the basic module referred to in Chapter V, concerning the issues of Polish regulations, may be replaced by other subjects. Decisions on the introduction of new subjects are made by the Director of the Doctoral School in consultation with the Chairman of the Council of Scientific Discipline within which the education of foreigners is conducted.
8. By the end of the first semester of education, the doctoral student submits to the Director of the Doctoral School, accepted by the supervisor or supervisors, an individual curriculum.
9. The implementation of the educational programme, including the individual curriculum and the individual research plan, taking into account the provisions of paragraphs 5-7, should ensure that the candidate achieves the expected learning outcomes specified in Chapter II.
10. Classes in the subjects of the basic module are planned centrally for all first-year doctoral students, subject to paragraph 11
11. Classes for foreigners providing education in English may be planned centrally or within the framework of a scientific discipline, taking into account the subjects referred to in paragraph 7.
12. Classes in the subjects of the optional modules are planned according to individual educational programs.
13. Classes in the subjects of the basic module or optional modules can be carried out in a stationary, remote or hybrid form.
14. The decision on the form of conducting classes in the subjects of the basic module is made by the Headteacher of the Doctoral School, and in the case of subjects of optional modules, by the lecturer.

V. Modules of the curriculum

Ip.	Item Name/Module	number of hours	number of credits ECTS	Learning outcomes reference/Annex
Basic module, compulsory for doctoral students of all disciplines³ (I-II sem.)				
1.	Higher education didactics	20	1	<i>D_WWAT01, D_W05, D_W06, D_UWAT01, D_U03, D_K01, D_K02</i>
2.	Rules for conducting classes	10	1	<i>D_WWAT01, D_UWAT01, D_U03, D_U13, D_K01, D_K06</i>
3.	The process of applying for research funding	8	1	<i>D_W05, D_U7, D_K01, D_K03, D_K04</i>
4.	Rules for writing a scientific paper	4	1	<i>D_W05, D_W06, D_U07</i>
5.	Plan your experiment	12	1	<i>D_W04, D_U04, D_K04</i>
6.	Methodology of conducting scientific research	10	1	<i>D_WAT02, D_U01-U05</i>
7.	Ownership rights and commercialization of research	10	1	<i>D_W05, D_W06, D_U06</i>
8.	Scientometry and bibliometrics in scientific activity	6	1	<i>D_W05, D_U08, D_K03, D_K04</i>
9.	Research Area Analysis ⁴	20	2	<i>D_W01, D_W02, D_W03, D_W4, D_U08</i>
Optional modules related to the scientific discipline of the doctoral student (III-VII sem.)				
1	Automation, electronics, electrical engineering and space technologies	min. 200 hours ⁵	min. 20 points	<i>List of items Appendix V.1 - p. 11</i>
2	Technical Informatics and Telecommunications			<i>List of items Appendix V.2 - p. 14</i>
3	Civil Engineering, Surveying & Transportation			<i>List of Items Appendix V.3 - p. 17</i>
4	Materials Engineering			<i>List of items Appendix V.4 - p. 19</i>
5	Mechanical Engineering			<i>List of subjects, Appendix V.5- p. 22</i>
6	Chemical Sciences			<i>List of items Appendix V.6 - p. 25</i>
7	Security Sciences			<i>List of subjects, Appendix V.7- p. 26</i>
Internship (III-VII sem.) - according to the individual curriculum				
1	Professional practice in the form of conducting classes or participating in their conduct	20-180 hours	1	<i>D_WWAT01, D_UWAT01, D_K01</i>
Subjects taught outside the WAT and Other forms of education (III-VII sem.) - optionally according to the individual curriculum				
1	Subjects outside WAT and, for example, internships, internships carried out in and outside WAT at another national or foreign university or scientific institution	<i>The number of hours, ECTS credits and the reference to learning outcomes are determined by the promoter in the individual curriculum</i>		

³ in the case of education for foreigners in English, the subjects included in the basic module, concerning the issues of Polish regulations, may be replaced by other subjects determined by the Director of the Doctoral School.

⁴ a course carried out in an individual mode with a supervisor or supervisors or a supervisor and an assistant supervisor completed with a doctoral seminar

⁵ the minimum number of hours of classes in the Optional Module may be reduced by the implementation of other forms of education, the sum of ECTS credits for the optional module and other forms of education may not be less than 20 points, while maintaining at least 100 hours of classes in the WAT from the optional module

VI. Framework Programme

The framework programme includes the characteristics - curriculum content of all subjects in the compulsory module and optional modules.

Lp.	Name of the subject	Program content
Basic module, compulsory for doctoral students of all scientific disciplines		
1.	Higher education didactics	Basic concepts of contemporary general didactics. Functions of academic education, contemporary models of higher education, principles of higher education functioning. Psychological foundations of the learning process. Principles of curriculum design. Taxonomies of learning objectives. Learning styles vs. teaching styles. Modern methods and techniques of education. Designing didactic classes. Developing the ability to formulate and creatively solve problems; shaping creative attitudes. Evaluation of learning outcomes; assessment methods. Interpersonal communication methodology; relations: student-teacher, moderation of student teams; Contemporary methods of supporting students in the learning process. Social competences of an academic teacher. The ethos of a researcher - an academic teacher. History and evolution of the Military University of Technology.
2.	Rules conducting didactic classes	Methodology of conducting didactic classes; basic forms of didactic classes; problem-based education, project education. Principles of planning didactic classes – constructing detailed outlines using modern methods and techniques of education. Creating teaching materials. Methods of assessing learning outcomes. IT systems supporting the work of an academic teacher. Practical exercises preparing for the implementation of professional practice.
3.	Process inference for funding scientific research	The process of applying for funding for basic scientific research. Statutory activity, financing of domestic and foreign scientific internships for young scientists starting their scientific careers. General characteristics of the rules for applying for funding in domestic institutions (Ministry of Science and Higher Education, National Centre for Research and Higher Education, NCBiR, NCN, FNP) and foreign institutions (European Union and others). Rules on design costs and intellectual property.
4.	Rules for writing a scientific paper	The Law on Higher Education and Science, types of doctoral dissertations, requirements for doctoral dissertations, rules for writing scientific articles, scientific activity of doctoral students. Military University of Technology – scientific potential, education of doctoral students, Doctoral School of the Military University of Technology – concept.
5.	Plan your experiment	Determined and randomized experience plans. Measures of position and dispersion of measurement results. Assessment of the significance of the influence of input quantities on the output quantity. Specify a function that approximates the function of an object. Assessment of the adequacy of the function of the object and the significance of its coefficients. Experimental optimization.
6.	Methodology Guidance scientific research	Analysis of the state of knowledge based on a literature review – creating a synthetic list of what has been done and what needs to be solved. Creating own literature databases in accordance with the citation systems used (American and English). Posing a scientific issue that requires a solution – assumptions (limitations), the required theoretical/technological/experimental apparatus, the expected time and money outlays, the method of verifying the results obtained. Conducting scientific research and its documentation (scientific article as the main element of research documentation). Dissemination of research results: principles of correct oral and poster presentation, conference presentations and scientific publications, principles of citing literature sources, method of self-citation. The rules for determining the contribution to a given study and who should be thanked. Polemics with reviewers – improvement of submitted scientific papers.
7.	Proprietary rights and commercialization research	Basic information on the methods of intellectual property protection, in particular: copyrights, inventions, utility models, industrial designs, trademarks in the field of intellectual property protection. Issues of commercialization of scientific research results and development works.
8.	Scientometry and bibliometrics in the business scientific	Scientometric and bibliometric indicators used in international bibliographic databases (Scopus, WoS), as well as national requirements related to the evaluation of researchers. Dissemination of scientific activities and research results, with particular emphasis on the requirements of the Open Access Policy at WAT regarding the provision of open access to publications and management of research data. The use of bibliographic databases and e-sources in scientific research. Tools supporting the collection of materials supporting the writing of scientific papers.
9.	Area Analysis research	Seminar classes supervisor – PhD student. Analysis of the state of knowledge in the field of research issues selected by the doctoral student. Literature review. Defining the research problem (objective, research questions, subject, hypotheses) and initial

		determination of the methodology. Preparation of a report and presentation for the first doctoral seminar. Preparation of a draft of the Individual Research Plan.
Lp.	Name of the discipline scientific	Program content
Optional modules related to the scientific discipline of the doctoral student		
1	Automation, electronics, electrical engineering and space technologies	<i>Annex VI.1 – p. 28</i>
2	Technical Informatics and Telecommunications	<i>Annex VI.2 – p. 36</i>
3	Civil Engineering, Surveying & Transportation	<i>Annex VI.3 – p. 46</i>
4	Materials Engineering	<i>Annex VI.4 – p. 51</i>
5	Mechanical Engineering	<i>Annex VI.5 – p. 57</i>
6	Chemical Sciences	<i>Annex VI.6 – p. 66</i>
7	Security Sciences	<i>Annex VI.7 – p. 70</i>

VII. Method of organizing apprenticeships and other forms of education

Internships are carried out in the form of conducting classes or participating in their conduct

Detailed rules for the implementation and crediting of professional practice and other forms of education by doctoral students of the WAT Doctoral School are specified by the Director of the WAT Doctoral School:

1. *Regulations of professional practice of doctoral students of the Jarosław Dąbrowski Military University of Technology Doctoral School.*
2. *Regulations for the implementation of other forms of education by doctoral students of the Jarosław Dąbrowski Military University of Technology Doctoral School.*

VIII. Curriculum

The curriculum consists of a general part for all doctoral students of the year and an individual curriculum for each doctoral student. The general part of the plan contains a schedule for the implementation of the basic module.

The individual education plan for a doctoral student for semesters III to VIII is created on the basis of the Individual Education Program.



**PLAN KSZTAŁCENIA W SZKOLE DOKTORSKIEJ OD ROKU AKADEMICKIEGO 2026/2027
WSZYSTKIE DYSCYPLINY NAUKOWE PROWADZONE W SZKOLE DOKTORSKIEJ**

moduły/przedmioty	ogółem godzin/ pkt ECTS		liczba godzin/pkt ECTS w semestrze:																
	godz.	ECTS	I		II		III		IV		V		VI		VII		VIII		
			godz.	ECTS	godz.	ECTS	godz.	ECTS	godz.	ECTS	godz.	ECTS	godz.	ECTS	godz.	ECTS	godz.	ECTS	
Moduł podstawowy, obowiązkowy dla wszystkich dyscyplin																			
Ogółem																			
	100	9	48	4	52	5													
1 Dydaktyka szkoły wyższej	20	1	20	1															
2 Zasady prowadzenia zajęć dydaktycznych	10	1	10	1															
3 Proces wnioskowania o finansowanie badań naukowych	8	1																	
4 Zasady pisania pracy naukowej	4	1			4	1													
5 Planowanie eksperymentu	12	1	12	1															
6 Metodologia prowadzenia badań naukowych	10	1			10	1													
7 Prawa własności komercjalizacja badań naukowych	10	1			10	1													
8 Naukometria i bibliometria w działalności naukowej	6	1	6	1															
9 Analiza obszaru badawczego	20	1			20	1													
Moduły fakultatywne związane z dyscypliną naukową - 315 przedmiotów																			
1 Automatyka, elektronika, elektrotechnika i technologie kosmiczne - 54 przedmiotów	min. 200 godz.*	min. 20 pkt ECTS*																	Zgodnie z Indywidualnym Programem Kształcenia (IPK)
2 Informatyka techniczna i telekomunikacja - 52 przedmiotów																			
3 Inżynieria lądowa, geodezja i transport - 35 przedmiotów																			
4 Inżynieria materiałowa - 40 przedmiotów																			
5 Inżynieria mechaniczna - 78 przedmiotów																			
6 Nauki o bezpieczeństwie - 32 przedmiotów																			
7 Nauki chemiczne - 24 przedmioty																			
Praktyki zawodowe																			
1 Praktyki zawodowe w formie prowadzenia zajęć lub uczestnictwa w ich prowadzeniu	20-180	1																	Zgodnie z Indywidualnym Programem Kształcenia (IPK)
Przedmioty realizowane w innej uczelni lub instytucji naukowej krajowej lub zagranicznej - opcjonalnie zgodnie z IPK																			
1 Przedmioty realizowane w formie bezpośredniej i zdalnej		zgodnie z IPK																	Zgodnie z Indywidualnym Programem Kształcenia (IPK)
Inne formy kształcenia - opcjonalnie zgodnie z IPK																			
1 np. praktyki, staże realizowane w i poza WAT, w innej uczelni lub instytucji naukowej krajowej lub zagranicznej		zgodnie z IPK																	Zgodnie z Indywidualnym Programem Kształcenia (IPK)

* Suma punktów ECTS w ramach IPK musi wynosić min. 21 punktów, min. liczba godzin w Module fakultatywnym może być zmniejszona do 100 godz. i 10 pkt. poprzez realizację przedmiotów poza WAT i innych form kształcenia, którym przyporządkowano liczbę godzin i punktów ECTS

IX. The system of quality assurance of education at the Doctoral School

The Quality Assurance System for Education at the Doctoral School of the Military University of Technology (SZJK SDR WAT) is a set of consciously planned activities providing opinions, analyses and conclusions concerning the functioning of individual elements of the doctoral student education process and indicating the directions of corrective and corrective actions. It is a system subject to constant evaluation and change, constantly adapted to the needs resulting from internal and external conditions.

The SZJK SDR WAT is based on a number of undertakings and activities aimed at ensuring high quality education and research conducted by doctoral students. Quality assurance is carried out through the implementation of processes in the Quality Assurance System of education at WAT and SZJK SDR WAT. The functioning of the system is continuous and systematic, through the continuous involvement in its implementation of the Academy's organizational units responsible for the process of educating doctoral students, internal and external stakeholders. The activities of the SZJK SDR are primarily applied to doctoral students and academic teachers who provide scientific supervision over doctoral students and conduct didactic classes with them.

The Director of the Doctoral School supervises the functioning and improvement of the SZJK SDR.

to the Curriculum at the Doctoral School of the Military University of Technology

Elective subjects**Scientific discipline: automation, electronics, electrical engineering and space technologies**

Ip.	Item Name	number of hours	number of creditsECTS	Reference to learning outcomes	semester of implementation per year academic
1.	Computer network administration	20	3	D_W03	Winter
2.	Acoustoelectronics	30	3	D_W04, D_W05	Winter
3.	Computer-aided analysis of experimental data	30	3	D_W03, D_U06	Winter
4.	Smart antennas	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Winter
5.	Digital Image Processing	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Winter
6.	Optical radiation detectors	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Winter
7.	Electromechanical energy and signal converters	30	3	D_W01, D_U05	Winter
8.	Laser Physics	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Winter
9.	Physics of laser media	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Annual
10.	Photovoltaics	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Annual
11.	Laser fiber optic technology	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Annual
12.	Image Information Engineering	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Annual
13.	Encoding and recognition of radio transmissions	30	3	D_U05	Winter
14.	Laser absorption spectroscopy in gas sensors	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Annual
15.	Laser-plasma radiation sources X-ray and extreme ultraviolet (EUV)	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Annual
16.	Lasers for medical applications	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Winter
17.	Pico- and femtosecond lasers	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Annual
18.	Fiber lasers	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Annual
19.	Mathematical models of electromagnetic fields	30	2	D_W02, D_W03	Annual
20.	Finite Element Method	30	3	D_W02, D_W03	Annual
21.	Data mining methods and tools	30	3	D_W02, D_W04	Winter
22.	Methods of logical synthesis	30	3	D_W02, D_W03	Winter
23.	Minimizing electromagnetic infiltration susceptibility of IT equipment	30	3	D_U05	Winter
24.	Nonlinear laser conversion	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Annual
25.	Scientific and engineering calculations	30	3	D_W04	Winter
26.	Optoelectronics in safety systems	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Annual

Ip.	Item Name	number of hours	number of credits ECTS	Reference to learning outcomes	semester of implementation per year academic
27.	Consistent light optics	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Winter
28.	Plasma in science and technology	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Winter
29.	Basics of remote sensing	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Winter
30.	Fundamentals of Knowledge of Viruses and Other Pathogens for Engineers	30	3	D_W01, D_W02, D_U01, D_U07, D_K01	Winter
31.	Measurements of basic laser radiation parameters	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Winter
32.	Safety system design	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Annual
33.	Programmable and specialized integrated circuits	30	3	D_W01, D_U05	Annual
34.	Acoustic sensors	20	2	D_W04, D_W05	Winter
35.	Microwave sensors in radar	20	2	D_W02, D_U04	Annual
36.	Smart Radio Networks	30	3	D_W01, D_W03	Winter
37.	Digital Systems in Optoelectronic Devices	30	2	D_W01, D_W02, D_W03 D_U07, D_U010, D_K03, D_K05	Winter
38.	Control and measurement systems in the test laboratory	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Annual
39.	Fiber optic technology	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Winter
40.	Terahertz technique	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Annual
41.	Technique of hiding information (steganography)	30	3	D_W01, D_W02, D_U05	Annual
42.	Techniques in Biomedical Engineering	30	3	D_W01, D_W02, D_U01, D_U07, D_K01	Winter
43.	Field theory	30	3	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Winter
44.	Thermal imaging and infrared technology	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Annual
45.	Optical radiation detection systems	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Winter
46.	Laser weapons	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Annual
47.	Modern Physical Quantity Measuring Transducers	30	3	D_W01, D_U05	Winter
48.	Applications of lasers in technology	30	2	D_W01, D_W02, D_W03 D_U010, D_K03, D_K05	Annual
49.	Advanced design of digital systems in FPGAs	30	3	D_W02, D_W03, D_U07, D_U09, D_K05	Annual
50.	Selected problems of statistical theory of radiolocation	30	3	D_W01, D_W02, D_W03 D_U WAT02, D_U05, D_U010, D_K03, D_K05	Winter
51.	Signal processing in radars	40	3	D_W01, D_W02, D_W03 D_U WAT02, D_U05, D_U010, D_K03, D_K05	Winter
52.	Mathematical models of electromagnetic fields	30	3	D_W02, D_W03, D_U01, D_U02, D_K03, D_K05	Annual

Ip.	Item Name	number of hours	number of credits ECTS	Reference to learning outcomes	semester of implementation per year academic
53.	Advanced antenna design techniques for radio communication systems	30	3	<i>D_W02, D_W03, D_U01, D_U02, D_U03, D_K03, D_K05</i>	<i>Winter</i>
54.	Metrology in electromagnetic compatibility	24	2	<i>D_W02, D_W03, D_U01, D_U02, D_U03, D_K03, D_K05</i>	<i>Annual</i>

Elective subjects**Scientific discipline: technical informatics and telecommunications**

Ip.	Item Name	number of hours	number of credits ECTS	Reference to learning outcomes	semester of implementation per year academic
1.	Quantum Algorithms III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Winter
2.	Algorithm Analysis III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Winter
3.	Analysis and Synthesis of Visual Information III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Winter
4.	Diagnostics of ICT Systems III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Annual
5.	Effectiveness of ICT systems III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Annual
6.	Elements of Forecast Theory III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Annual
7.	Software Evaluation III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Annual
8.	Physical Foundations of Quantum Computing III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Annual
9.	Computer Graphics III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Winter
10.	Cryptology III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Annual
11.	Mathematical methods of decision support III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Annual
12.	Discrete Mathematics III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Annual
13.	Generative and Faceted Methods in Software Development III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Winter
14.	Numerical methods III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Winter
15.	Methods of Multi-Criteria Optimization III	20	2	D_W01,D_W02,D_W03,D_U01,D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Annual
16.	Mathematical Modelling III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Annual
17.	Modeling and verification of ICT networks III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Annual
18.	Modelling Conflict Situations III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Annual
19.	Business Process Modeling, Simulation and Analysis III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Annual
20.	Reliability of Systems III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05,D_U07,D_K01,D_K03	Annual

Ip.	Item Name	number of hours	number of credits ECTS	Reference to learning outcomes	semester of implementation per year academic
21.	Optimization III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05, D_U07,D_K01,D_K03	Winter
22.	Probabilistics III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05, D_U07,D_K01,D_K03	Winter
23.	Stochastic processes III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05, D_U07,D_K01,D_K03	Annual
24.	Image Recognition and Processing III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05, D_U07,D_K01,D_K03	Annual
25.	Neural Networks and Fuzzy Logic III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05, D_U07,D_K01,D_K03	Winter
26.	Smart Radio Networks	20	2	D_W01, D_W03,D_U010, D_K03, D_K05	Winter
27.	Stochastic Exploitation Models III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05, D_U07,D_K01,D_K03	Annual
28.	Computer Simulation III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05, D_U07,D_K01,D_K03	Winter
29.	Database Systems III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05, D_U07,D_K01,D_K03	Winter
30.	ICT Systems III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05, D_U07,D_K01,D_K03	Annual
31.	Decision Support Systems III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05, D_U07,D_K01,D_K03	Winter
32.	Artificial Intelligence III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05, D_U07,D_K01,D_K03	Annual
33.	Theoretical Foundations of Computer Science III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05, D_U07,D_K01,D_K03	Winter
34.	Graph and Network Theory III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05, D_U07,D_K01,D_K03	Winter
35.	Project and Process Management III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05, D_U07,D_K01,D_K03	Winter
36.	Complex Data Structures III	20	2	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05, D_U07,D_K01,D_K03	Annual
37.	5G network application for military	30	3	D_W01,D_W02,D_W03,D_U01D_U02,D_U04,D_U05	Annual
38.	Advanced Cryptanalysis Tools	20	2	D_W01, D_W02,D_W03, D_U01, D_U02, D_U04, D_U05, D_U07, D_K01, D_K03, D_K05	Winter
39.	GNSS – Systems and signals" (GNSS)	20	2	D_W01, D-W02,D_W03, D_U01,D_U02, D_K03, D_K05	Winter
40.	Multidimensional Data Processing (WDP)	20	2	D_W01; D_W02; D_W03; D_U10; DU_04; D_K03; D_K05	Winter
41.	Automated Battlefield Database Systems (SBD-ZPW)	20	2	D_W01; D_W02; D_W03; D_U10; DU_04, D_K03; D_K05	Winter
42.	Hiding data in telecommunications	20	2	D_W01, D-W02, D_W03, D_U01, D_U02, D_K03, D_K05	Winter
43.	AI in Spectral Processing and Analysis	20	2	D_W01, D-W02, D_W03, D_U01, D_U02, D_K03, D_K05	Winter

Ip.	Item Name	number of hours	number of credits ECTS	Reference to learning outcomes	semester of implementation per year academic
44.	Special numbers in cryptology	20	2	D_W01, D_W02, D_W03, D_U01, D_U02, D_U04, D_U05, D_U07, D_K01, D_K03	Winter
45.	Elliptic curves in cryptanalysis of asymmetric ciphers	20	2	D_W01, D_W02, D_W03, D_U01, D_U02, D_U04, D_U05, D_U07, D_K01, D_K03	Winter
46.	Selected elements of lattice theory	30	3	D_W01, D_W02, D_W03, D_U01, D_U02, D_U04, D_U05, D_U07, D_K01, D_K03	Winter
47.	Application of modular gratings in postquan cryptography	30	3	D_W01, D_W02, D_W03, D_U01, D_U02, D_U04, D_U05, D_U07, D_K01, D_K03	Winter
48.	Basis for measuring revealing emissions	20	2	D_W01, D_W02, D_W03, D_U01, D_U02, D_U04, D_U05, D_U07, D_K01, D_K03	Winter
49.	Digital Data Processing Techniques	20	2	D_W01, D_W02, D_W03, D_U01, D_U02, D_U04, D_U05, D_U07, D_K01, D_K03	Annual
50.	Advanced technologies for next generation mobile networks	30	3	D_W01; D_W02; D_W03; D_U10; DU_04, D_K03; D_K05	Winter
51.	Machine learning for telecommunications	30	3	D_W01; D_W02; D_W03; D_U10; DU_04, D_K03; D_K05	Annual
52.	Quantum Communications	30	3	D_W01; D_W02; D_W03; D_U10; DU_04, D_K03; D_K05	Winter

Elective subjects**Scientific discipline: civil engineering, geodesy and transport**

Ip.	Item Name	number of hours	number of credits ECTS	Reference to learning outcomes	semester of implementation per year academic
1.	Safety and reliability of building structures	20	3	D_W03; D_W05; D_U02; D_K02	Winter
2.	Dynamic interaction of building structures with a ground center	20	2	D_W02; D_U01; D_K05	Annual
3.	Environmental Physics	20	2	D_W03; D_U04; D_K02	Annual
4.	Space weather	20	2	D_W03; D_U04; D_K02	Winter
5.	Modeling of heat and humidity processes	20	2	D_W03; D_U04; D_K02	Annual
6.	Identification of loads and structural systems	20	2	D_W02; D_U02; D_K02	Winter
7.	Investment process in construction	20	2	D_W01; D_U04; D_K05	Annual
8.	Mechanics of road and airport runway soil foundations	20	3	D_W03; D_U02; D_U04; D_K03	Winter
9.	Methods of testing the stiffness and bearing capacity of the pavement road and airport	20	2	D_W03; D_U07; D_K07	Annual
10.	Calculation methods of folding bridge structures	20	2	D_W03; D_U01; D_U03; D_K01	Winter
11.	Design methods of the experiment	20	3	D_W02; D_U01; D_K01	Annual
12.	Modeling the behavior of elements and structures reinforced concrete	20	2	D_W02; D_U01; D_K01	Winter
13.	Geometric and physical nonlinearities in mechanics construction	20	2	D_W03; D_U04; D_K05	Annual
14.	Explosive effects on defensive structures	20	2	D_W02; D_U01; D_K05	Winter
15.	Construction Work Scheduling and Estimation Systems	20	2	D_W06; D_U06; D_K08	Annual
16.	Engineering of building materials	20	3	D_W04, D_U04, D_K05	Winter
17.	Cartographic research methods	20	2	D_W02, D_U05, D_U07, D_K03, D_K05	Annual
18.	Spatial data mining	20	2	D_W02, D_U04, D_UWAT02, D_U01, D_U05, D_K03, D_K05	Winter
19.	Methods and technologies in Geospatial Data Science	20	2	D_W02, D_W03, D_UWAT02, D_U01, D_U05, D_K03, D_K04	Annual
20.	Advanced methods of development photogrammetric	20	2	D_W02, D_W03, D_UWAT02, D_U05, D_K05	Winter
21.	Programming in spatial information systems	20	2	D_W02, D_W05, D_U06, D_U10, D_K03, D_K06	Winter
22.	Reference systems in geosciences	20	3	D_W02, D_W03, D_W04, D_UWAT02, D_U05, D_U07, D_K01, D_K03, D_K05	Annual

Ip.	Item Name	number of hours	number of credits ECTS	Reference to learning outcomes	semester of implementation per year academic
23.	Global Geodetic Observing System	20	3	D_W01, D_W03, D_W04, D_UWAT02, D_U05, D_U07, D_K01, D_K03, D_K05	<i>Annual</i>
24.	Modern photogrammetric techniques	20	2	D_W02, D_W03, D_UWAT02, D_U05, D_K05	<i>Annual</i>
25.	Selected numerical methods in geodesy	20	2	D_W02, D_W03, D_UWAT02, D_U05, D_K05	<i>Winter</i>
26.	Parallel data processing methods	20	2	D_W02, D_W03, D_UWAT02, D_U05, D_K05	<i>Annual</i>
27.	Mathematical foundations of digital image processing	20	2	D_W02, D_W03, D_W05, D_U01, D_U02, D_U04, D_U05, D_U07, D_K01, D_K03, D_K04, D_K05	<i>Winter</i>
28.	Numerical methods with linear algebra	20	2	D_W02, D_W03, D_W05, D_U01, D_U02, D_U04, D_U05, D_U07, D_K01, D_K03, D_K04, D_K05	<i>Annual</i>
29.	Finite element methods in Hermite spaces (polynomials of degree 2 and 3). Nonlinear issues.	20	2	D_W02, D_W03, D_W05, D_U01, D_U02, D_U04, D_U05, D_U07, D_K01, D_K03	<i>Winter</i>
30.	Finite element methods in Hermite spaces (polynomials of degree 2, 3 and 5). Linear issues.	20	2	D_W02, D_W03, D_W05, D_U01, D_U02, D_U04, D_U05, D_U07, D_K01, D_K03	<i>Annual</i>
31.	Methods of natural environmental research using GNSS	20	2	D_W01, D_W04, D_UWAT02, D_U01, D_U07, D_K03, D_K05	<i>Winter</i>
32.	Hydrographic studies	20	2	D_W01, D_W03, D_W04, D_UWAT02, D_U04, D_U07, D_K01, D_K03, D_K05	<i>Winter</i>
33.	LiDAR systems in photogrammetry and remote sensing	20	2	D_W02, D_W03, D_UWAT02, D_U05, D_K03, D_K05	<i>Annual</i>
34.	Advanced Fiber-Reinforced Concrete Composite Materials – Design, Mechanisms, and Experimental Research	20	2	D_W02; D_W04; D_U01; D_U04; D_K01; D_K05	<i>Annual</i>
35.	Rules for the creation, verification, control and suitability of databases for means of transport	20	2	D_W02; D_U04; D_K02	<i>Winter</i>

Elective subjects**Scientific discipline: materials engineering**

Ip.	Item Name	number of hours	number of creditsECTS	Reference to learning outcomes	semester of implementation per year academic
1.	Structural studies using X-ray diffraction methods	20	2	D_W02, D_W05, D_UWAT02, D_U04, D_U05, D_U10, D_U03, D_K01, D_K04, D_K09	Winter
2.	Structural studies using scanning microscopy methods	20	2	D_W01, D_W02, D_W04, D_UWAT02, D_U05, D_U06, D_K03, D_K03	Winter
3.	Testing of mechanical properties of engineering plastics	20	2	D_W02, D_W05, D_UWAT02, D_U04, D_U05, D_U10, D_U03, D_K01, D_K04, D_K09	Winter
4.	Physical Basis of Electro-Optical Effects in Liquid Crystals	20	2	D_W01, D_W02, D_UWAT01, D_UWAT02, D_U06, D_U07, D_U10, D_K04, D_K05	Winter
5.	Calorimetric, thermogravimetric and volumetric methods of testing the properties of materials	20	2	D_W01, D_W04, D_U05, D_K03	Winter
6.	Semiconductor Materials for Optoelectronic Applications	20	2	D_W01, D_W02, D_W03, D_UWAT02, D_U02, D_U03, D_U05, D_K01, D_K03, D_K05	Annual
7.	Nano and ultracrystalline engineering materials	20	2	D_UWAT01, D_W02, D_W03, D_W04, D_UWAT01, D_UWAT02, D_U03, D_U05, D_U09, D_K01, D_K05, D_K08	Winter
8.	Nanoporous Anode Aluminum Oxide: Synthesis, Design and Applications	20	2	D_W02, D_W03, D_UWAT02, D_U01, D_U07, D_U03, D_K01, D_K03, D_K05	Annual
9.	Non-telecom applications of optical fibers	20	2	D_W01, D_W03, D_W04, D_U01, D_U05, D_U07, D_K01, D_K03, D_K05	Winter
10.	Measurements of machine and equipment components, parts using coordinate measuring techniques	20	2	D_W01, D_W04, D_U05, D_U06, D_U07, D_K05, D_K08	Annual
11.	Experiment planning and data analysis with Origin and Statistica	20	2	D_W04, D_U01, D_U05, D_U12, D_K01, D_K03	Winter
12.	Basic properties of liquid crystals	20	2	D_W01, D_W02, D_W04, D_W05, D_W06, D_UWAT02, D_U01, D_U02, D_U03, D_U05, D_U06, D_K01, D_K04, D_K05, D_K08	Winter
13.	Keysight Vee and Lab View programs in control and data processing	20	2	D_W02, D_W03, D_W04, D_UWAT02, D_U04, D_K05, D_K08	Winter
14.	Process design for Direct Deposition incremental methods	20	2	D_W01, D_W02, D_W03, D_UWAT02, D_U05, D_U07, D_K01, D_K03, D_K04, D_K05	Winter
15.	Dielectric spectroscopy	20	2	D_W02, D_W03, D_W04, D_UWAT02, D_U01, D_U05, D_U10, D_U11, D_K01, D_K03, D_K05	Annual
16.	Structural determinants of material properties	20	2	D_W01, D_W03-06, D_UWAT02, D_U01, D_U04, D_U05, D_U07, D_U10, D_U11, D_K03-05, D_K09	Winter

Ip.	Item Name	number of hours	number of credits ECTS	Reference to learning outcomes	semester of implementation per year academic
17.	Contemporary methods of material characterization	20	2	D_UWAT01, D_UWAT02, D_U01, DU_02, DU_03, D_U04, DU_5, D_U07, D_K01, D_K02, D_K03, D_K05, D_K06	Winter
18.	High-energy ball grinding and mechanical synthesis	20	2	D_W01, D_W01, D_U05, D_K03	Winter
19.	Advanced Hydrogen Storage Materials	20	2	D_W01, D_W03, D_U01, D_K04	Annual
20.	Basics of plasmonics and metamaterials	20	2	D_W01, D_W02, D_W03, D_U01, D_U04, D_U07, D_K03, D_K05, D_K05, D_K09	Winter
21.	Selected materials and functional structures for photonic applications	20	2	D_W01, D_W02, D_W03, D_U01, D_U04, D_U07, D_K03, D_K05, D_K05, D_K09	Annual
22.	Computer Image Analysis in Materials Engineering	20	2	D_UWAT01, D_UWAT02, D_U01, DU_02, DU_03, D_U04, DU_5, D_U07, D_K01, D_K02, D_K03, D_K05, D_K06	Annual
23.	Additive manufacturing of functional materials	20	2	D_UWAT01, D_W02, D_W03, D_W04, D_UWAT01, D_UWAT02, D_U03, D_U05, D_U09, D_K01, D_K05, D_K08	Winter
24.	Methods for amplifying light emission from broadband semiconductor nanostructures	20	2	D_W01, D_W03, D_UWAT02, D_U04, D_U05, D_U07, D_U10, D_K01, D_K03, D_K04, D_K09	Winter
25.	Electrochemical synthesis of anti-reflective, super-hydrophobic coatings and photonic crystals	20	2	D_W01, D_W03, D_UWAT02, D_U04, D_U05, D_U10, D_K03, D_K04, D_K05, D_K09	Winter
26.	Modeling of semiconductor instruments.	20	2	D_W01, D_W02, D_W03, D_UWAT02, D_U02, D_U03, D_U05, D_K01, D_K03, D_K05	Winter
27.	High Entropy Alloys – Synthesis, Structure, Research and Properties	20	2	D_W01, D_W01, D_U05, D_K03	Winter
28.	Additive manufacturing of alloys based on intermetallic phases	20	2	D_W01, D_W02, D_W03, D_UWAT02, D_U05, D_U07, D_K01, D_K03, D_K04, D_K05	Winter
29.	Combinatorial Fabrication and Research of Engineering Materials	20	2	D_W01, D_W02, D_W03, D_UWAT02, D_U05, D_U07, D_K01, D_K03, D_K04, D_K05	Winter
30.	Reactive mechanical grinding as a method of synthesis of modern materials for solid-phase hydrogen storage.	20	2	D_W01, D_W01, D_U05, D_K03	Winter
31.	Additive techniques with reverse engineering elements	20	2	D_W02, D_W04, D_UWAT02, D_U03, D_U07, D_K03, D_K05	Winter
32.	An overview of the additive techniques used in modern technology	20	2	D_W01, D_W03, D_UWAT02, D_U10, D_K03	Winter
33.	Selected issues from 3D printing	20	2	D_W01, D_UWAT02, D_U01, D_U08, D_K04, D_K05	Winter
34.	Researcher's Workshop 1 – Tools for Writing Scientific Texts	20	2	D_W04, D_U01, D_U05, D_U12, D_K01, D_K03	Winter
35.	Researcher's Work Workshop 2 – Writing Scientific Articles	20	2	D_W04, D_U01, D_U05, D_U12, D_K01, D_K03	Winter

Ip.	Item Name	number of hours	number of creditsECTS	Reference to learning outcomes	semester of implementation per year academic
36.	Researcher's Workshop 3 – Writing Scientific Articles	20	2	<i>D_W04, D_U01, D_U05, D_U12, D_K01, D_K03</i>	<i>Winter</i>
37.	Quantum mechanics in examples	20	2	<i>D_W02, D_W03, D_W04, D_UWAT02, D_U01, D_U05, D_U10, D_U11, D_K01, D_K03, D_K05</i>	<i>Winter</i>
38.	Corrosion testing in materials engineering	20	2	<i>D_W01, D_W02, D_W03, D_W04, D_U01, D_K05</i>	<i>Winter</i>
39.	Anodic oxides of copper and its alloys – production, characteristics and applications	20	2	<i>D_W01, D_W02, D_W03, D_UWAT02, D_U01, D_U04, D_K03, D_K04, D_K06</i>	<i>Winter</i>
40.	Anodizing Aluminum Alloys	20	2	<i>D_W01, D_W02, D_W03, D_UWAT02, D_U01, D_U04, D_K03, D_K04, D_K06</i>	<i>Winter</i>

to the Curriculum at the Doctoral School of the Military University of Technology

Elective subjects**Scientific discipline: mechanical engineering**

Ip.	Item Name	number of hours	number of creditsECTS	Reference to learning outcomes	semester of implementation in a year academic
1.	Numerical analyses in load-bearing structures	40	4	D_W01, D_W02, D_W03, D_U05, D_K01, D_K03, D_K05	Annual
2.	Autonomy of mobile robots	30	3	D_U04, D_W03, D_K01	Winter
3.	Non-destructive testing of aircraft	30	3	D_W02; D_W05; D_U01; D_K05	Winter
4.	Biomechanics of human body movement during a road accident	20	2	D_W03, D_W05, D_U02, D_U05, D_K04	Annual
5.	Construction and operation of industrial robots	30	3	D_W01, D_W02, D_U04, D_U06, D_K01, D_K03	Winter
6.	Digital signal processing	30	3	D_W01, D_W02, D_U04, D_U06, D_K01, D_K03	Winter
7.	Dynamics of mechatronic system design	30	3	D_W03, D_W05, D_U02, D_U05, D_K04	Annual
8.	Car dynamics	30	3	D_W03, D_W05, D_U02, D_U05, D_K04	Annual
9.	Dynamics and modeling of hydrostatic systems	30	3	D_U04, D_W04, D_K01	Winter
10.	Dynamics of multi-part systems	30	3	D_W01, D_W02, D_W03, D_U05, D_K01, D_K03, D_K05	Winter
11.	Impulse loads of motor vehicles – selected issues	20	2	D_W04, D_U04, D_K09	Winter
12.	Computer-aided machine operation	20	2	D_W02, D_U05, D_K05	Annual
13.	Shaping a safe car body	20	2	D_W01, D_U04, D_K01, D_K05	Annual
14.	Composite materials in mechanical engineering and operation	30	3	D_W01, D_W01, D_U04, D_K01, D_K05	Annual
15.	Finite Element Method	30	3	D_W01, D_W02, D_W03, D_U05, D_K01, D_K03, D_K05	Winter
16.	Methods of analysis of numerical and experimental research results	30	3	D_W01, D_W02, D_W03, D_U05, D_K01, D_K03, D_K05	Annual
17.	Methods of testing the condition of machines	30	3	D_W03, D_U05, D_K01, D_K03	Winter
18.	Experimental methods for investigating thermophysical properties of solids	30	3	D_W03, D_W04, D_U04, D_U05, D_K01, D_K03	Annual
19.	Methods and techniques of testing the mechanical properties of materials	30	3	D_W03, D_W04, D_U04, D_U05, D_K01, D_K03	Winter
20.	Numerical Methods in Engineering Applications	30	3	D_W01, D_W02, D_W03, D_U05, D_K01, D_K03, D_K05	Winter
21.	Numerical Methods in Mechanical Engineering	30	3	D_W01, D_W02, D_W03, D_U05, D_K01, D_K03, D_K05	Winter
22.	Methods of design and optimization of aeronautical structures	30	3	D_W01, D_W03, D_U04, D_U05, D_K01, D_K03	Annual
23.	Constitutive Models of Materials in FEM Analysis	30	3	D_W01, D_W02, D_W03, D_U05, D_K01, D_K03, D_K05	Winter
24.	Modelling of heat transfer processes	30	3	D_W01, D_W03, D_U01, D_U05, D_K01, D_K03, D_K05	Winter
25.	Modeling and simulation of mechatronics issues	30	3	D_W04, D_U04, D_K01	Annual

Ip.	Item Name	number of hours	number of credits ECTS	Reference to learning outcomes	semester of implementation in a year academic
26.	Modeling and simulation of nonlinear mechanics	40	4	D_W01, D_W02, D_W03, D_U05, D_K01, D_K03, D_K05	Annual
27.	Parametric modeling and structural optimization using FEM	30	3	D_W01, D_W02, D_W03, D_U05, D_K01, D_K03, D_K05	Annual
28.	Flow modeling	30	3	D_W01, D_W02, D_W04, D_U05, D_K01, D_K03, D_K05	Winter
29.	Machine Motion Modeling	20	2	D_U04, D_W04, D_K01	Annual
30.	Modeling composite structures	30	3	D_W01, D_W02, D_W03, D_U05, D_K01, D_K03, D_K05	Winter
31.	Contact Modeling in Structural Mechanics	30	3	D_W01, D_W02, D_W03, D_U05, D_K01, D_K03, D_K05	Winter
32.	Modelling and research of wheel-road cooperation processes	30	3	D_W01, D_W02, D_W03, D_U04, D_U05, D_K01, D_K03, D_K05	Winter
33.	Modeling of car movement and control	30	3	D_W01, D_W02, D_W03, D_U04, D_U05, D_K01, D_K03, D_K05	Winter
34.	Modern technologies for joining construction materials	30	3	D_W01, D_W02, D_U05, D_K01, D_K05	Annual
35.	Modern design and manufacturing systems CAD\CAM\Additive Manufacturing	20	2	D_U04, D_W03, D_K01	Winter
36.	Renewable energy sources	30	3	D_W06, D_U04, D_W02, D_K07	Winter
37.	CAE Engineering Software	30	3	D_W01, D_W02, D_W03, D_U05, D_K01, D_K03, D_K05	Winter
38.	Experiment planning and mechanical object optimization	30	3	D_W04, D_U04, D_K05	Winter
39.	Road safety basics	20	2	D_W03, D_W05, D_U02, D_U05, D_K04	Winter
40.	Basics of Intake Air Filtration for Internal Combustion Engines in Partition Filters	30	3	D_W04, D_U04, D_W02, D_U07, D_K02, D_K03	Annual
41.	Basics of Intake Air Filtration for Internal Combustion Engines in Inertial Filters	30	3	D_W04, D_U04, D_W02, D_U07, D_K02, D_K03	Winter
42.	Fundamentals of Continuous Media Mechanics	30	3	D_W01, D_W02, D_W03, D_U05, D_K01, D_K03, D_K05	Annual
43.	LabVIEW in experimental studies	30	3	D_W01, D_W02, D_W03, D_W04, D_U05, D_K01, D_K03, D_K05	Annual
44.	Starting processes for internal combustion engines	30	3	D_W04, D_U04, D_K01	Annual
45.	Programming control systems for unmanned working machines and robots	30	3	D_U04, D_W03, D_K01	Winter
46.	Mechatronic sensors	30	3	D_W03, D_W04, D_U06, D_K01, D_K04	Winter
47.	Condition monitoring systems	30	3	D_W02, D_W03, D_U02, D_U05, D_U07, D_K01, D_K03, D_K05	Annual
48.	Aircraft Operation Systems	30	3	D_W03; D_U01; D_K03	Winter
49.	Control systems in mechanical engineering	30	3	D_U04, D_W03, D_K01	Annual
50.	Technologies for the production and processing of composite materials	30	3	D_W01, D_W02, D_U04, D_K01, D_K05	Annual
51.	Selected solutions in the field of automotive technology and vehicle movement	20	2	D_W01, D_W03, D_U04, D_K01, D_K05	Annual

Ip.	Item Name	number of hours	number of credits ECTS	Reference to learning outcomes	semester of implementation in a year academic
52.	Theory and organization of machine operation	30	3	D_W04, D_U06, D_K03	Winter
53.	Thermomechanics of materials and thermophysical properties research	30	3	D_W03, D_W04, D_U01, D_K03	Winter
54.	Tribology	30	3	D_W03, D_U04, D_K05	Winter
55.	Durability of aircraft structures	30	3	D_W02, D_W03, D_U02, D_U05, D_U07, D_K01, D_K03, D_K05	Annual
56.	Introduction to Mathematical Physics Equations	30	3	D_W01, D_W02, D_W03, D_U01, D_U04, D_K01, D_K03	Annual
57.	Modern machine and vehicle drive systems	30	3	D_W03, D_U04, D_K05	Winter
58.	Modern methods of testing internal combustion engines and vehicles	30	3	D_W04; D_U01; D_U02; D_U03; D_U04; D_U05; D_UWAT01;	Winter
59.	Selected methods and techniques of temperature measurement	30	3	D_W03, D_W04, D_U04, D_K05	Annual
60.	Selected problems of rocket technology	30	3	D_W03, D_U04, D_K05	Winter
61.	Selected issues of waste gas treatment from motor vehicles	30	3	D_W01; D_W02; D_W03; D_K03; D_K05; D_U010;	Annual
62.	Selected issues of simulation of combustion processes and working processes of internal combustion engines.	30	3	D_W01; D_W02; D_W03; D_U05; D_K01; D_K03; D_K05;	Winter
63.	Selected issues of contemporary programming - an introduction to modern programming languages.	30	3	D_W01, D_W02, D_W03, D_U05, D_K01, D_K03, D_K05	Annual
64.	Fatigue strength and fracture mechanics of materials and structures	30	3	D_W01, D_U04, D_K01	Annual
65.	Advanced methods for manufacturing products from sintered powders	30	3	D_W04, D_U04, D_K01	Annual
66.	Advanced ballistics, modeling and simulation departments	30	3	D_W01, D_U04, D_K01	Annual
67.	Advanced Math Departments	40	4	D_W01, D_W02, D_W03, D_U05, D_K01, D_K03, D_K05	Winter
68.	Advanced modeling in structural dynamics	30	3	D_W01, D_W02, D_W03, D_U05, D_K01, D_K03, D_K05	Winter
69.	Advanced Measurement Systems	30	3	D_W04, D_U04, D_K01	Winter
70.	Advanced Materials Testing Methods	30	3	D_W01, D_W02, D_W04, D_U02, D_U04, D_U05, D_K01, D_K05	Annual
71.	Application of experimental mechanics in scientific research 1	30	3	D_W01, D_W02, D_W03, D_W04, D_U05, D_K01, D_K03, D_K05	Winter
72.	Application of experimental mechanics in scientific research 2	40	4	D_W01, D_W02, D_W03, D_W04, D_U05, D_K01, D_K03, D_K05	Annual
73.	Application of the Finite Element Method in Mechanical Wave Propagation Analysis	30	3	D_W01, D_W02, D_W03, D_U05, D_K01, D_K03, D_K05	Annual
74.	Selected issues of vibration theory	20	2	D_W02, D_W03, D_U04, D_K01, D_K03, D_K05	Winter
75.	Selected issues in acoustic electronics	30	3	D_W02, D_W03, D_U04, D_K01, D_K03, D_K05	Annual
76.	Numerical methods	30	3	D_W01, D_W03, D_U04, D_K01, D_K03, D_K05	Winter
77.	Electromagnetic field theory	30	3	D_W01, D_W03, D_U04, D_K01, D_K03, D_K05	Winter
78.	Quantum mechanics	30	3	D_W01, D_W02, D_W03, D_U04, D_K01, D_K03, D_K05	Winter

to the Curriculum at the Doctoral School of the Military University of Technology

Elective subjects

Scientific discipline: chemical sciences

lp.	Item Name	number of hours	number of credits ECTS	Reference to learning outcomes	semester of implementation per year academic
1.	Analysis of warfare poisonous agents	20	2	D_W03, D_W04, D_UWAT02, D_K02, D_K03	Winter
2.	Chemistry and technology of liquid crystal materials	20	2	D_W01, D_W03, D_U06, D_U02, D_K01	Annual
3.	Chemistry and technology of high-energy materials	20	2	D_W01, D_W03, D_U01, D_U04, D_K01, D_K02	Annual
4.	Polymer chemistry	20	2	D_W02, D_W03, D_UWAT02, D_K01	Annual
5.	Chemistry of heterocyclic compounds	20	2	D_W01, D_W03, D_W04, D_UWAT02, D_U01, D_U04, D_K01, D_K05	Annual
6.	Chemical Basis of Environmental Pollution	20	2	D_W02, D_W03, D_UWAT02, D_K01, D_K03	Annual
7.	Chemoinformatics	20	2	D_W02, D_W03, D_UWAT02, D_U04	Annual
8.	Chiral and polar liquid crystal functional materials	20	2	D_W01, D_W02, D_W03, D_UWAT02, D_U02, D_K01	Annual
9.	Physicochemical properties of carbon materials	20	2	D_W01, D_W02, D_W03, D_U04, D_UWAT02, D_U01, D_K03, D_K05	Annual
10.	Physicochemical aspects of the explosion	20	2	D_W01, D_W02, D_W03, D_U04, D_U06, D_K01, D_K05	Annual
11.	History of chemistry	20	2	D_W02, D_W03, D_UWAT02, D_K01	Winter
12.	Ionization methods in analytics	20	2	D_W03, D_W04, D_UWAT02, D_K01	Winter
13.	Methods for preparing samples for analysis	20	2	D_W02, D_W03, D_UWAT02, D_K01	Annual
14.	Spectroscopic methods	20	2	D_W02, D_W03, D_UWAT02, D_K01	Winter
15.	Modeling and simulation computer programs in chemistry	40	4	D_W01, D_W02, D_W03, D_W04, D_U04, D_U05, D_K01, D-K03, D_K04	Winter
16.	Modern nanoporous materials	20	2	D_W02, D_W03, D_UWAT02, D_U01, D_K01, D_K03	Winter
17.	Modern methods of synthesis of functional organic compounds	20	2	D_W01, D_W02, D_W03, D_UWAT02, D_U02, D_K01	Annual
18.	Biomedical polymers and biomaterials	20	2	D_W02, D_W03, D_UWAT02, D_U09, D_K01	Winter
19.	Field detection and analysis of hazardous materials	20	2	D_W02, D_W03, D_UWAT02, D_K01, D_U04, D_K05	Annual
20.	Practical tools and concepts of modern organic synthesis	20	2	D_W01, D_W03, D_W04, D_UWAT02, D_U01, D_U04, D_K01, D_K05	Winter
21.	Liquid crystal synthesis	20	2	D_W01, D_W02, D_W03, D_UWAT02, D_U02, D_K01	Winter
22.	Advanced pyrotechnics	20	2	D_W02, D_W03, D_UWAT02, D_K01	Annual
23.	Advanced spectroscopic methods	20	2	D_W02, D_W03, D_UWAT02, D_K01	Annual

24.	Applications of Organic Chemistry in Health and Functional Products	20	2	D_W01, D_W03, D_W04, D_UWAT02, D_U01, D_U04	Annual
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Annex V.7

to the Curriculum at the Doctoral School of the Military University of Technology

Elective subjects

Scientific discipline: security sciences

Ip.	Item Name	number of hours	number of ECTS credits	Reference to learning outcomes	semester of implementation per year academic
1.	Social Research in Security Sciences	40	4	D_W WAT01; D_W01; D_W06; D_U03; D_K03;	Winter
2.	Statistical methods in social research	40	4	D_W04; D_U03; D_U04; D_KO1; D K03;	Annual
3.	Risk and Business Continuity Management in Security	30	3	D_W01; D_W03; D_U03;	Annual
4.	Security systems project management	30	3	D_W03; D_U04; D_K05;	Annual
5.	Safety Systems Engineering	30	3	D_W03; D_W02; D_U06; D_U10; D_K05;	Winter
6.	Safety propaedeutics	30	3	D_W02; D_W05; D_U01; D_K05;	Winter
7.	Strategies and concepts of state security management	30	3	D_W02; D_U04; D_K05;	Winter
8.	Crisis management in public administration	30	3	D_W01; D_W03; D_U03; D_U12;	Annual
9.	Civil Protection and Civil Protection	30	3	D_W02; D_W03; D_U01; D_U03; D_K09;	Annual
10.	Homeland Security	30	3	D_W02; D_W03; D_K05; D_K07;	Annual
11.	Threat Intelligence	30	3	D_W03; D_W06; D_U05; D_U07; D_U10; D_K04; D_K05;	Annual
12.	Designing an energy security strategy as a safety measure subjective	30	3	D_W03; D_W06; D_U05; D_U06; D_K04; D_K05	Winter
13.	Survey Data Analysis	20	2	D_W04; D_U04; D_KO1;	Winter
14.	Forecasting and simulations in safety	20	2	D_W03; D_W04; D_U WAT01; D_U05; D U13; D_K03; D_K04; D K05;	Annual
15.	Multivariate analyses	20	2	D_W04; D_U04; D_U05; D_KO1; D_K03; D_K04;	Winter
16.	Evaluation Study Procedures	20	2	D_W04; D_U04; D_U05; D_KO1; D K03	Annual
17.	Logic and Theory of Argumentation	20	2	D_W04; D_U01; D_U04; D_U05; D_KO1; D_K03; D_K04;	Winter
18.	Modern technologies in security	20	2	D_W01; D_W02; D_U WAT01; D_U06; D K03;	Annual
19.	Philosophy of Security Sciences	20	2	D_W02; D_W03; D_U01;	Winter

Ip.	Item Name	number of hours	number of ECTS credits	Reference to learning outcomes	semester of implementation per year academic
				D_U05; D_KO1; D_K03;	
20.	Modern terrorism	20	2	D_W03; D_W06; D_U05; D_U08; D_U09; D_KO1; D_K06;	<i>Winter</i>
21.	Morale and Security Culture in National and International Relations	20	2	D_U WAT01; D_U WAT02; D_U05; D_U13; D_K03; D_K04; D_K05;	<i>Annual</i>
22.	Security history	20	2	D_W02; D_W03; D_U WAT02; D_U05; D_K03; D_K09;	<i>Winter</i>
23.	Strategic communication	20	2	D_W01; D_W03; D_U06; D_U10; D_K01; D_K05	<i>Annual</i>
24.	Political security sector	20	2	D_W02; D_W03; D_U08D_U12; D_K02;	<i>Winter</i>
25.	Shaping military security in the 21st century	20	2	D_W04; D_U WAT01; D_U WAT02; D_U05; D_U13; D_K03; D_K04; D_K05;	<i>Winter</i>
26.	Information security	20	2	D_W06; D_U01; D_K05;	<i>Winter</i>
27.	The economic dimension of safety	20	2	D_W03; D_U WAT02; D_U05; D_K03; D_K04; D_K05;	<i>Winter</i>
28.	Energy security in the face of socio-economic transformation	20	2	D_W04; D_U WAT01; D_U WAT02; D_U05; D_U13; D_K03; D_K04; D_K05;	<i>Annual</i>
29.	Social determinants of the security of modern states	20	2	D_W03; D_W06; D_U04; D_U05; D_K05; D_K07;	<i>Winter</i>
30.	Environmental security on a global, regional and national scale	20	2	D_W03; D_W04; D_U WAT01; D_U WAT02; D_U05; D 1.113; D_K03; D_K04; D_K05;	<i>Winter</i>
31.	Geopolitical determinants of the security of countries and regions	20	2	D_W02; D_W06; D_U02; D_U10; D_K05; D_K06	<i>Annual</i>
32.	Security policy of the Republic of Poland of the 21st century	20	2	D_W04 ,D_UWAT01,D_UWAT 02,D_U05,D_U13,D_K 03	<i>Winter</i>

Curriculum content for elective subjects

Scientific discipline: Automation, Electronics, Electrical Engineering and Space Technologies

Ip.	Item Name	Program content
1.	Computer network administration	Human-machine relations. Socio-technical system. Communication of network devices. The basics of Windows and Linux administration. Configuration of network and multimedia service devices in wired (Ethernet) and radio (5G) networks. Security, reliability and quality of ICT networks.
2.	Acoustoelectronics	Technical applications of elastic waves. Elastic waves in solids and their types. Elastic waves in confined media. Ferroelectric materials. Piezoelectricity. Electrostriction. Excitation and detection of acoustic volumetric waves. Filters and resonators with acoustic volumetric wave. Construction and properties of interfinger pickups. Filters and dispersion lines with acoustic surface wave. Acoustic convolutors and Fourier processors. Acoustoelectronic sensors of mechanical quantities. Acoustoelectronic activators. Remote identification systems. Basics of synthesis of acoustic surface wave systems. Matching Acoustoelectronic Systems to External Circuits
3.	Computer-aided analysis of experimental data	Selected issues in the field of confirmatory and exploratory data analysis, including the estimation of parameters of various data models, issues of graphical representation of one- and multidimensional data, processing of multivariate experimental results using linear transformations, issues of discrimination including methods of minimum distance classification, nearest neighborhood, k-means and hierarchical grouping.
4.	Smart antennas	Basic properties of smart antennas. Construction of antenna arrays. Applied solutions for shaping the characteristics of smart antennas. An overview of algorithms for use in smart antennas. The principle of operation of adaptive arrays, the properties of their components and the configurations in which they are used in practice. Simulation models of the adaptation process.
5.	Digital Image Processing	Digital representation of images. Intensity transformations and spatial filtration. Spatial frequency processing. Image correction. Wavelet analysis. Morphological Image Processing. Segmentation of images.
6.	Optical radiation detectors	Physical basics of optical radiation detection. Thermal detectors: thermocouples, bolometers, pyroelectric detectors, thermal detector matrices. Photon detectors: photoresistors, p-n, pin, APD, Schottky barrier photodiodes, UV, VIS, IR detectors, THz detectors, photomultipliers, MCP microchannel wafers. CCD and CMOS sensors. Hybrid matrices. Signal reading circuits. Architecture of read circuits for CCD and CMOS arrays. Direct detection systems. Noise models of photoreceiver input stages. Type II supergrid detectors. QWIP detectors. Barrier detectors.
7.	Electromechanical energy and signal converters	Electromechanical systems with rotational motion - mathematical description. Generalized theory of electromechanical energy processing in relation to Euler Lagrange's formalism. State functions, magnetic coenergy function, and generalized external forces. Dissipative elements.
8.	Laser Physics	Heisenberg's uncertainty principle, operators and operator equations, Schrödinger's equation. Harmonic oscillator, electromagnetic field quantization. Radiation of a perfectly black body. Interaction of radiation with the medium: probabilities of forced transits, form of spectral line. Laser medium, three- and four-level and quasi-three-level systems, laser material equations. Gain saturation effect, a condition for stationary laser generation. Laser output power. Laser resonators. Laser beam parameters. Types of non-stationary laser generation. Structure of energy levels of active ions in solid media, levels of ions of rare earth elements, metal ions of the transition group.
9.	Physics of laser media	Interaction of the electromagnetic field with the medium (quantum description). The effect of a harmonic perturbation on a quantum object. Electron energy levels of free ions. Terms and multiplets of rare earth elements and transition group metal elements. Elements of group theory and their matrix representations. Splitting the energy levels of ions in the crystalline field. Electron-phonon interaction. Energy levels of transition group metal ions. Phenomena of energy transfer between ions in active media.

Ip.	Item Name	Program content
10.	Photovoltaics	Quantitative and qualitative characteristics of solar energy. Semiconductor theory in the aspect of photovoltaics. Structures of modern photovoltaic cells. Technology for the production of photovoltaic cells, modules and panels. Photovoltaic modules. Photovoltaic installations.
11.	Laser fiber optic technology	Basics of optical fibers; fibre optic fabrication techniques; single-walled, double-walled and three-walled optical fibers used in laser technology; basics of high-power lasers and fiber optic amplifiers (doped with ytterbium, thulium, erbium, holmium ions); basic components of lasers and fiber optic amplifiers; welding of optical fibers, including special optical fibers; dispersion and nonlinear phenomena occurring in optical fibers during radiation propagation; examples of lasers and fiber optic amplifiers with continuous and pulse operation; high-power fiber optic supercontinuum radiation generators; selected applications of high-power lasers and fiber optic amplifiers.
12.	Image Information Engineering	Machine vision systems, analysis of fast-changing phenomena and processes, interpretation of 2D and 3D scenes, recognition and identification of objects. Fusion of images and data in information systems: analyses and fusion of images in spectral bands UV, VIS, NIR, IR, THz, analysis of image material based on metadata. Imaging technology in virtual and augmented reality systems: imaging technology in Virtual Reality (synthesis of 3D models, capturing the movement of objects), Mixed Reality – key system components, application solutions.
13.	Encoding and recognition of radio transmissions	Data transmission protection against errors in the SERIAL TONE (MIL-STD-188-110A) system operating in the shortwave range. Protect data transmission from errors during automatic connection establishment (ALE) in a shortwave channel. Analysis of selected radio communication protocols and corresponding coding algorithms for binary information sequences. Transmission error generation algorithms for binary strings corresponding to selected radio communication protocols. Determination of distinctive features enabling automatic recognition of transmission protocols. Algorithm for recognizing selected transmission protocols. Algorithm for recognizing block and convolutional codes.
14.	Laser absorption spectroscopy in gas sensors	Methods of gas detection and defining parameters of gas sensors. Laser absorption spectroscopy. Optical spectra of gas molecules. Basics of optoelectronic gas sensors. Methods to improve the limit of detection. Measurements of concentrations in samples of gas mixtures using optoelectronic sensors.
15.	Laser-plasma radiation sources X-ray and extreme ultraviolet (EUV)	Methods of X-ray and extreme ultraviolet (EUV) production, basics of laser-generated plasma physics and X-ray and EUV optics, principles of operation and construction of laser-plasma X-ray and extreme ultraviolet (EUV) sources, examples of the use of these sources in science and modern technology.
16.	Lasers for medical applications	Description of optical properties occurring in biological centers. Physical phenomena and their application in optical therapy and diagnostics. Selected methods of forming radiation distributions in laser systems for medical applications. Laser systems for biostimulation, selected optical diagnostic systems, therapeutic kits – planned effects of the laser beam interaction with tissues and selected methods of implementation. Medical applications of sources with pico- and femto-second pulse durations. Examples of design solutions for sets with lasers for medical applications and the therapeutic and diagnostic effects obtained.
17.	Pico- and femtosecond lasers	Characteristics of ultrashort laser pulses. Description of ultrashort pulse propagation in optical fibers. Mod synchronization as a method of generating ps and fs pulses, description in the domain of time and frequency. Active and passive mod synchronization, examples of passive mod synchronization implementation. Dispersion and methods of its compensation. Selected elements of nonlinear optics. Modern solutions of fs. Amplification of ultrashort pulses of laser radiation. Examples of applications of ultrashort pulses in practice.
18.	Fiber lasers	Optical fibers, selected geometries, eigenvalue for the fiber, propagation of E-M radiation in optical fibers. Bicos fibers vs. photonic fibers. Construction solutions for pumping systems, lasers and fiber amplifiers. Semiconductor pumping lasers used. Fiber laser resonators – structure and properties. Selected methods of shaping the radiation spectrum – co-doped media. Structure of energy levels of active ions in solid media, levels of ions of rare earth elements, transitional group metal ions - selected issues.
19.	Mathematical models of electromagnetic fields	Analytical and numerical methods of computational electromagnetic field. Differential dependencies. Distribution. Orthogonal functions in wireless

Ip.	Item Name	Program content
		connectivity (LTE and 5G) and radar. Wave propagation in materials and metamaterials. Simplified analytical models for the calculation of the radiation field. Techniques of calculation using potentials. Radiation field analysis. The field of the Hertz elementary dipole. Morphology of the electromagnetic field. Mathematical-physical determinants of the far zone criterion. Numerical computational electromagnetism - differential methods.
20.	Finite Element Method	Mathematical foundations of MES. Generation of 2D and 3D meshes. Implementation rules. Libraries supporting FEM programming. Commercial simulation tools.
21.	Data mining methods and tools	Basic concepts of "data mining", Optimization methods and algorithms used in data mining. Linear and logistic regression methods. Bayesian classifiers. Decision trees. MLP and RBF artificial neural networks. Generalization abilities of neural networks. A network of vectors supporting SVM and its applications in data mining. Classifier and predictor teams. Methods for assessing the quality of classifiers and predictors. Deep neural networks and deep learning Transformations and methods of reducing the dimension of data. Selected methods of generation and selection of diagnostic features. Sharp and fuzzy methods of grouping data. Multidimensional data visualization Examples of applications of data mining methods.
22.	Methods of logical synthesis	Logical synthesis tasks. Two- and multi-level synthesis. Algorithms of the ESPRESSO method. Selected SIS and Demain procedures. Principles of multivalued and symbolic minimization. Functional decomposition of combination systems and its models. Sequential chip decomposition: ROM address modification chips and ROM content modification chips. Use university design tools to improve the efficiency of enterprise systems. The issues discussed in the lectures will be practiced practically as part of calculation and laboratory exercises, and the main effect of the education will be the acquisition of the ability to consciously use logical synthesis methods in digital device designs.
23.	Minimizing electromagnetic infiltration susceptibility of IT equipment	Electromagnetic perturbations as revealing emission. Measurement of the emission level of electromagnetic disturbances. Uncertainty of measuring the level of electromagnetic disturbance emissions. Evaluation of the quality of the results of measurements of the emission level of disturbances. Protection of IT devices against electromagnetic penetration of information in the form of shielding and filtration. Factors affecting the required shielding performance and insertion attenuation of power filters. Methodologies for measuring parameters affecting the level of electromagnetic safety (shielding efficiency, insertion attenuation of power filters and signal filters, absorption losses and material scattering). Examples of applications of protection of IT devices against electromagnetic penetration of information.
24.	Nonlinear laser conversion	Elements of crystallography and crystal optics. Properties of uniaxial and biaxial crystals (KDP, LiNbO ₃ , KTP, BBO, LBO, etc.). Electromagnetic wave in a crystal. Frequency mixing in a three-wave approach. Phase matching, scalar and vector synchronism. Generation II of harmonic light and summation and differential frequencies in uniaxial and biaxial crystals. Parametric light generators and amplifiers, tuning methods. Generation threshold and conversion efficiency. Quasi-phase matching. Nonlinear crystals with periodic domain structure. Design and application of Optical Parametric Chirped Pulse Amplification systems
25.	Scientific and engineering calculations	An overview of basic numerical methods in the context of implementation. Engineering Calculation Tools. Parallel programming. Processing and presentation of calculation results.
26.	Optoelectronics in safety systems	Propagation of optical radiation in the atmosphere, reflectance, safety of eyesight. Laser Rangefinder, Operation Basics, Flowchart, Range Equation Improve signal-to-noise ratio, timing, detection probability and false alarm probability. Discussion of the principle of operation of lidars: scatter, DIAL, fluorescent, Raman and Doppler. Flame detector, laser scanner.
27.	Consistent light optics	Preliminary Stochastic Processes. 1st order statistics of thermal and laser light. Partially polarized radiation, coherence matrix, degree of polarization. 2nd order statistics, temporal and spatial coherence function. Propagation of the function of time-spatial coherence, boundary forms of the time-space function, i.e. Van Cittert – Zernike. Radial temporal coherence, coherence path measurement in Michelson interferometer, Spatial coherence of radiation, coherence radius

Ip.	Item Name	Program content
		measurement in Young's interferometer. Measurements of radiation coherence parameters.
28.	Plasma in science and technology	Introduction to plasma physics, basic concepts. Motions of charged particles in electric and magnetic fields. Plasma in terms of fluid mechanics. Atomic processes in plasma. Magnetic and inertial maintenance of plasma. Plasma diagnostics. Plasma applications in technology.
29.	Basics of remote sensing	The interaction of electromagnetic radiation (from microwaves to cosmic rays) and corpuscular radiation and acoustic fields with matter. Physical foundations of spectroscopic methods – absorption, scattering, radiation emission. Energy forms of an atom and a molecule. Nuclear magnetic resonance NMR (radiospectroscopy). Electron paramagnetic resonance EPR (microwave spectroscopy). Rotational and oscillating spectra (infrared spectroscopy). Electron spectra (VIS-UV spectroscopy). Active and passive methods of electromagnetic radiation detection and image recording and analysis. Spatial, temporal, radiometric and spectral resolution. Multispectral remote sensing. Laser remote sensing systems. Application of laser spectroscopy methods in lidar systems. Spectroscopic methods in the analysis of environmental contamination and pollution. Sensors for security systems and for military applications.
30.	Fundamentals of Knowledge of Viruses and Other Pathogens for Engineers	Presentation of selected issues of microbiology, epidemiology and public health in the light of the latest scientific discoveries. Using the achievements of bioinformatics to describe the world of microorganisms. Discussion of contemporary threats to human and animal health, basic groups of pathogens and ways to prevent infections and contagion. Zoonotic diseases. Gene and genome engineering, biotechnology, threats to ecosystems. One Health concept. Basics of immunoprophylaxis and hygiene. Pathogens are particularly dangerous in states of war and natural disasters.
31.	Measurements of basic laser radiation parameters	Measurement methods of radiation spectrum, radiation power and energy, pulse duration and pulse repetition frequency, radiation beam divergence angle. Familiarize yourself with the basics of laser safety
32.	Safety system design	Protection strategy and principles for creating technical protections. Normative principles and a set of good industry practices. The range of technical protection measures that can be applied. Specificity of protection devices intended for outdoor and indoor applications. A general overview of the solutions used. Characteristics of a set of protection devices for indoor and outdoor applications. Working conditions and restrictions on this account. Structure of the technical executive design. Scope of technical executive design in the security industry. Characteristics of hazard analysis and technical design concept. Rules of detailed design and cost estimation. Design study in the field of technical detailed design. Required resources that define the basis for project implementation. Threat analysis. Technical protection concept of the safety system. Rules for conducting a threat analysis for example objects. Characteristics of numerical determination of the scale of threat of the facility. Rules for describing the area of the facility. Attack scenarios and verification of the possibilities of technical technical protection to counteract them. Technical description of the detailed design. Characteristics of the principles of alarm system design. Ways of describing and graphically representing a technical design. The way documentation is organized. Examples of technical detailed designs of critical infrastructure facilities. Documents related to the technical detailed design. The rules for developing an investor's and "blind" cost estimate. The need to compile technical catalogs and technical data sheets of devices.
33.	Programmable and specialized integrated circuits	Classification of integrated digital circuits, in particular specialized circuits (ASICs) and programmable gate arrays (FPGAs). Manufacturing technology and design methods of ASIC and FPGA chips. Basic digital CMOS (OAI) systems: schematics, parameters, topographies, design styles. Selected functional solutions. Principles of designing the topography of digital circuits, ways of distributing power and distributing clock signals, I/O buffers, IP blocks and design tools.
34.	Acoustic sensors	Features and parameters of modern acoustic sensors. Mechanical structures. Piezoresistive sensors. Magnetolectric and electromagnetic transducers. Capacitive transducers. Acousto-optical transducers. Magnetostrictive transducers. Piezoelectric transducers. Systems with acoustic surface waves.

Ip.	Item Name	Program content
35.	Microwave sensors in radar	Microwave sensors in radar. Broadband microwave sensors with noise signals. Sensors in medical diagnostics. Anti-collision sensors.
36.	Smart Radio Networks	Smart radio network concept. Architecture of the Czech Republic. The Semantic Context of CR. Problems of teaching in the CR system. Dynamic spectrum management. Problems of reception in CR. Ad-hoc CR networks, collaborative MIMO. Standards for CR networks. Security problems in CR. Current research programs in the CR area.
37.	Digital Systems in Optoelectronic Devices	Digital system architecture. Principles of digital system design. Basic control and digital signal processing. Design of digital modules for control and signal processing. Design of microprocessor systems. Embedded systems design. Information exchange between digital system modules and with external systems
38.	Control and measurement systems in the test laboratory	Signal conditioning systems. Control and measurement systems. Measurement signals and their processing. Measuring instruments and platforms. Interfaces of measurement systems. Automated control and measurement systems in practice.
39.	Fiber optic technology	Optical fibers and optical elements. Studies of optical fibers and optical elements. Lasers and optical transmitters. Photodetectors and optical receivers. Optical signal modulators. Optical signal amplifiers. Digital optical links. Measurements of characteristics and parameters of fiber optic links. Multiplexing and demultiplexing. Coherent transmission. Studies of the characteristics of fiber optic interferometers. Optical analogue links. Radio-fiber optic systems. Optical links in free space.
40.	Terahertz technique	Introduction to THz radiation. Sources of THz radiation – semiconductor and photonic. THz radiation detectors. Photoconducting switches. Time domain spectrometry. Imaging and tomography. Sensors, waveguides, metamaterials THz. Applications of THz.
41.	Technique of hiding information (steganography)	Glossary of data hiding techniques. An overview of practical applications for data hiding applications in multimedia, speech, radio signal, and network protocols. Distinguishing between basic types of algorithms: watermarking and steganography. Classification of data hiding methods. Basic data embedding and extraction algorithms and their properties. Development of assumptions for the designed system. Selection of the method of embedding and extraction of hidden data. Perceptual models for the Human Auditory and Visual Model. Additional signal correction. Methods of evaluating perceptual transparency. Methods of evaluation of resistance and steganoanalytical susceptibility. Examples of software and hardware implementation of data hiding systems. New methods of hiding data – cases and scenarios of action.
42.	Techniques in Biomedical Engineering	Fundamental issues and research techniques in biology and biomedicine will be discussed, including the main points of bioengineering and biotechnology. Thus, the skills necessary to undertake interdisciplinary research in these areas of science will be developed. The principles of construction of essential research equipment will be presented, including measurements based on fluorescence excitation. The possibilities of bioinformatics analysis and international databases will be discussed. In addition, the principles of good laboratory practice and safe work in biomedical laboratories will be presented. Requirements for conducting reliable measurements and elaborating results in biomedical research and medical bioengineering will also be discussed.
43.	Field theory	Basic concepts and equations of electromagnetic field theory. Maxwell's equations, Properties of mediums and boundary conditions. Fields at the boundary of the separation of media, Energy of the electromagnetic field. Types of electromagnetic phenomena, Electrostatics and magnetostatics. Stationary and quasistationary electromagnetic fields, Maxwell's equations in complex form for harmonic waveforms, Electromagnetic waves. Wave equation for a sourceless area, Homogeneous flat wave. Propagation parameters of a homogeneous flat wave, Propagation of a homogeneous flat wave in a lossless dielectric, Propagation of a homogeneous flat wave in lossy dielectrics, Propagation of a homogeneous flat wave in a good conductor, Structure of a homogeneous flat wave, Reflection and refraction of a homogeneous flat wave at the flat boundary of two different media. Reflection and refraction of a homogeneous plane wave at the boundary of two different dielectrics, Reflection of a homogeneous plane wave propagating in a dielectric from a flat surface of a conductive medium Electromagnetic potentials and radiation, Potentials of alternating fields, delayed

Ip.	Item Name	Program content
		potentials. Hertz Vector Potential, Field of Elementary Oscillator, Electromagnetic Field at Small Distances from Oscillator, Electromagnetic Field at Long Distances from Elementary Oscillator, Phase of Wave, Wave Type, Phase Velocity, Propagation of Waves in Parallel Conductor Systems and in Waveguides, Transverse Electromagnetic Wave TEM, Transverse Magnetic Wave TM in Rectangular Cross-Section Waveguide, Transverse Electric Wave TE in Rectangular Cross-Section Waveguide, Basic Type, Rectangular Cavity Resonator
44.	Thermal imaging and infrared technology	Methods of correcting heterogeneity of matrix detector characteristics in thermal imaging devices. Radiometric calibration of a thermal imaging camera and its impact on the accuracy of remote measurement of temperature and radiation power. Thermal imaging methods of recognizing chemicals and minerals are based on spectral emissivity analysis. Multi and hyperspectral infrared systems. Active thermal imaging, measurement capabilities and prospects for its application. Infrared image polarimetry.
45.	Optical radiation detection systems	Signal processing systems for detectors and matrices. Lock-In detection. Detection systems with synchronous signal integration. Signal averaging detection systems. Coherent detection (heterodyne, homodyne). Advanced methods of optical signal processing in practice.
46.	Laser weapons	Aims, tasks and functional diagrams of laser weapons (BL) The basic limitations of the BL, including the optical range, the range of the effective impact of the BL. Basics of laser beam optics and methods of measuring their parameters. Laser beam propagation in the atmosphere, including the effect of extinction, scattering, and turbulence on beam parameters on the target. Physical mechanisms of laser beam interaction with the target, including thermo-optical effects occurring in the BL effector, nonlinear propagation effects, and the processes of absorption, heating/tearing of the surface and volume of the target. An overview of high-power laser effectors for BL and information available at the time on practical BL systems.
47.	Modern Physical Quantity Measuring Transducers	The concept of a measuring transmitter and their classifications. Static and dynamic properties of transducers. Resistance strain gauges. Capacitive, piezoelectric, inductive, magnetoelastic, thermoelectric and piezometric transducers. Conductivity transducers. Flow meters. Fiber optic converters, their specifics and classifications. Optoelectronic and acoustoelectronic transducers. Photoacoustic and photonic transducers. Integrated transducers.
48.	Applications of lasers in technology	Types of lasers, components and optical systems used in material processing – an overview. Examples of lasers in macro and micro machining. Interaction of radiation with materials, Lorentz-Drude model, optical and thermal parameters of materials, reflection, absorption, energy transport, phase changes, plasma shielding, interaction ranges, equation of thermal conductivity. Lasers in surface engineering – polishing, engraving, texturing, cladding, impact hardening, cleaning, direct interference lithography in micro- and nanotechnology. Application examples. Lasers in volumetric processing of materials – hardening, welding, cutting, drilling and other applications of lasers in industry. Application examples.
49.	Advanced design of digital systems in FPGAs	The course of advanced digital systems design techniques in FPGAs discusses, among other things, issues related to, m.in the development of integrated digital systems in FPGAs, topographic design, effective use of design constraint attributes, preparation of functional tests and good design practices. The course is divided into theoretical (lectures) and practical (laboratories and design), and the results of the project work are discussed at the seminar. Before taking the course, it is advisable to know the hardware description languages (HDL) and the architecture of FPGA chips.
50.	Selected problems of statistical theory of radiolocation	Detection (detection) of signals and mathematical statistics, optimization criteria (Bayesian criterion, Neyman-Pearson criterion, SNR maximization criterion, min-max criterion). Signal detection rule, relationship of the reliability quotient (decision statistics) for basic signal models with the receiver structure. Bayesian synthesis of TES systems. Bayesian estimation of signal parameters – radar echoes. The relationship between the radar uncertainty function (Woodward function) and the synthesis of complex signals. Distinguishability and accuracy of measurements over time and frequency. Cognitive radar vs "silent" radar.

Ip.	Item Name	Program content
51.	Signal processing in radars	Presentation of basic and advanced techniques for processing radar signals. Types of probing signals. Filtration matched. Doppler filtration. Eliminate interference. Detection of radar echo signals.
52.	Mathematical models of electromagnetic fields	Analytical and numerical methods of computational electromagnetic field. Orthogonal features in modern wireless connectivity (LTE and 5G) and radar. Wave propagation in materials and metamaterials. Analytical models for the calculation of the radiation field. Techniques of calculation using potentials. The field of the Hertz elementary dipole. Numerical computational electromagnetism, differential methods, FDTD. Radiation models of modern intelligent and adaptive antennas in mobile telephony systems. Relativistic electrodynamics in satellite communications.
53.	Advanced antenna design techniques for radio communication systems	<p>The course covers theoretical and practical issues related to modern antenna design, with particular emphasis on computer modeling and simulation in the CST Studio Suite environment.</p> <p>The lectures discuss basic and advanced antenna parameters, methods of analysis and synthesis of radiant structures, matching and power supply techniques, methods of bandwidth expansion and miniaturization of antennas, as well as the design of multiband and broadband antennas used in radio communication systems.</p> <p>The laboratories are dedicated to the practical implementation of antenna designs in CST, including the creation of geometric models, the selection of solvers and boundary conditions, the analysis of S-parameters and radiation characteristics, the optimization of design parameters and the assessment of the impact of materials used in the production of antennas and production tolerances on the properties of antennas, and the whole ends with an independent design of an antenna that meets the set application requirements.</p>
54.	Metrology in electromagnetic compatibility	<p>The course covers issues related to the principles of EMC measurements and the methodology of ensuring the reliability of results in emission and immunity tests of electrical and electronic equipment.</p> <p>The lectures discuss the basics of metrology and measurement uncertainty theory, requirements for measurement consistency, calibration and calibration of instruments, characteristics of measurement paths and their parameters relevant to EMC, as well as sources of errors and disturbances in measurements and ways to reduce them, taking into account the requirements and test procedures resulting from the EN 55022 and NO-05-A500 standards, including the classification of devices, emission limits, measurement conditions and conformity assessment criteria. The principles of organization and validation of test stands, procedures for measuring radiated and conducted emissions and methods of resistance testing, as well as the selection and application of apparatus and measuring equipment in accordance with normative requirements are also presented.</p> <p>The laboratories focus on the practical implementation of EMC measurements in accordance with EN 55022 and NO-05-A500, including the configuration of measuring stations, performing preliminary and full-compliance measurements, analyzing the impact of instrument settings on the results, determining the uncertainty budget, interpreting the results in relation to standard limits, and developing complete documentation and test reports confirming the fulfillment of electromagnetic compatibility requirements.</p>

Curriculum content for elective subjects

Scientific discipline: technical informatics and telecommunications

Ip.	Item Name	Program content
1.	Quantum Algorithms III	Mathematical foundations of quantum computation: operators in Hilbert spaces, tensor product of Hilbert spaces and vectors in this space, Hermitian and unitary operators. Description of a quantum system and its states. Description and properties of measurement in quantum systems. Forms of information recording. Information Processing. Quantum gates. Synthesis of quantum circuits. Detect entanglement and estimate its level. Algorithms: Deutsch-Jozsy, Bernstein-Vazirani, Simon, Grover, Shor and hybrid algorithms. Quality of quantum computing in terms of time and memory complexity.
2.	Algorithm Analysis III	Algorithms and algorithmic problems. Preliminary concepts. Algorithm definition, algorithm quality criteria, algorithm complexity and task complexity, numerical stability of algorithms, principles for designing effective algorithms. Computational complexity of combinatorial algorithms. Types of tasks, sequential computational models (DTM and NDTM), problem transformations, computational complexity classes, NP-completeness, time and memory complexity of algorithms (pessimistic and expected), sensitivity of algorithms (pessimistic and expected), examples of complexity estimation. Approximate algorithms Methods for estimating the accuracy of algorithms. Polynomial Approximation Schemes (PTAS), Fully Polynomial Approximation Schemes (FPTAS), examples of approximation algorithms for computationally difficult problems. Heuristic search methods. Techniques for designing effective algorithms Recursion vs. iteration, divide and rule techniques, parallelization techniques, advanced data structures and algorithm complexity. Advanced models and methods of graph and network theory. Examples of the use of effective algorithm design methods.
3.	Analysis and Synthesis of Visual Information III	Weierstrass' theorem and orthogonal expansion of the signal state space. Basics of function approximation theory. Orthogonal span transformers with an unlimited carrier. Laplace and Fourier transforms. Orthogonal bases with limited carrier. Wigner, Wannier and Wavelet functions. Wavelet transform – definitions and examples. Applications of the wavelet transform. Peculiarities of the process as extreme points and/or singular points of the signal. Search for extreme points and peculiar points of the signal in wavelet spaces.
4.	Diagnostics of ICT Systems III	General theory of functional tests. Types and properties of tests. Error and control effectiveness of the test. Test Setting Methods. The use of tests in the recognition (condition of the object), in technical diagnostics and in data processing. Test Determination Methods for Digital Devices and Logical Networks. Ways of propagating unfitness. Conditions for the transmission of the effects of unsuitability. Masking unsuitability. Roth's algebra. Random methods of testing digital devices. Methods for compressing test results. Compression spectrum. Signature analysis and its application. Diagnosis procedures. Insight in diagnosis. Methods for determining optimal procedures. Models and methods of systemic diagnostics. Self-diagnostic systems. Diagnosing the system using the method of diagnostic dialogue between its elements. Diagnostic dialogue structures and their properties. Diagnosing the system by means of diagnostic assessment of its elements. Structures of diagnostic opinions and their properties. Determination of diagnostic structures with specific properties. Diagnosing software. Properties of the program control transfer network.
5.	Effectiveness of ICT systems III	Indicators of the effectiveness of ICT networks. Stochastic models of event streams. Models of local and wide area computer networks. Wireless and cellular network models. Stochastic and deterministic problems of task ordering.
6.	Elements of Forecast Theory III	Basic concepts of forecast theory. Linear and non-linear trend models. Naive models, moving average, and exponential smoothing models. Forecasting based on econometric models. Forecasting of qualitative phenomena.
7.	Software Evaluation III	The essence of software evaluation. The concept of software quality. Factors shaping software quality: design quality, implementation quality. Software quality assessment criteria: computational complexity, reliability. Methods for assessing the computational complexity of algorithms. Computational complexity of algorithms: time complexity, memory complexity. Methods for estimating the time complexity of algorithms. Asymptotic complexity of iterative recursive algorithms. Methods for evaluating software reliability. Software reliability models: time-domain

Ip.	Item Name	Program content
		models, data-domain models, phenomenological models. Methods of practical use of software reliability models. Software quality assurance methods. Inspections and inspections. Rules for conducting inspections and reviews in the software development process. Testing. Types and methods of software testing. Design test datasets. Criteria for completing the testing process. Formal methods of constructing and verifying the correctness of programs. Hoare's logic. Inference rules. Description of the program through states and operations. The concept of implicit specification of operations. Proving the correctness of the operation. Proving the correctness of programs. The role and importance of standards in the process of ensuring the required software quality. Characteristics of standards in the field of software engineering. Software quality standards. Use of standards.
8.	Physical Foundations of Quantum Computing III	Introduction to quantum mechanics. The uncertainty principle and its consequences. Schrodinger's cat and the superposition of states as an image resulting from the diffraction of the electromagnetic field. Introduction to quantum electrodynamics – operators of creation and annihilation on a selected energy state. Hilbert space and L2 space. Bell's inequality. Superposition and entanglement of states. Q-bit and its physical implementations. Mathematical representations of q-bit. Mixed states and entangled states in the description of the state density matrix. Seal Space. Fermions and bosons and entanglement. Physical realizations of entangled states in optics – examples. State teleportation. Dense coding. Operating q-bit, quantum gates.
9.	Computer Graphics III	Introduction to computer graphics, basic applications - computer animation, visual simulation, AR and VR systems. Vector graphics, raster graphics - representation of image data. Basic graphics standards - GKS, PHIGS, OpenGL. Raster algorithms - Bresenham, anti-aliasing, HLHSR. Geometric modeling - curves and surfaces, 3D objects. Geometric transformations - translations, rotations, scaling, projections. Color modeling - color perception, color models CIE, RGB, HLS, HSV(B), transformations in color spaces. Lighting modeling - lighting models, shading algorithms, raytracing, radiosites. Texture modeling - defining, mapping, and filtering textures.
10.	Cryptology III	Basic concepts and history of cryptology. Modular arithmetic. Classic cryptosystems. Cryptanalysis of ciphers. Stream ciphers. Block ciphers. AES and NESSIE competition. Asymmetric cryptosystems. Shortcut functions. Cipher security. Cryptographic protocols. Applications of cryptography
11.	Mathematical methods of decision support III	Process and decision cycle. Mathematical modelling of decision-making processes. Optimal and approximate decisions. Modeling the Decision-Maker's preferences. Analysis of the sensitivity of optimal solutions. Usability features. Making decisions under conditions of uncertainty. Methods for determining the representation of sets of irreparable decisions. Methods for determining "approximate sets of optimal solutions". Examples of modeling decision support processes.
12.	Discrete Mathematics III	Relationships and features. A relationship of equivalence, order, good order. The principle of abstraction. Maximum, minimum, largest, smallest, majorant, minorant. Surjections, injections and bijections. Permutations. Generalized activities on harvests. Recurrences. Counting sets and functions. Counting techniques. Binomial and multiary ratios. Stirling numbers. Counting surjections, injections, and bijections. Bell numbers. Euler numbers. Catalan numbers. Division of a number into components. Asymptotics. Creating functions. Asymptotic notations. Universal recursion. Asymptotic approximations. Operations on the authoring functions. Creating functions for selected strings. Determination of the number of solutions of Diophantine equations. Recursion Resolution. Collections with repetitions. Divisibility of integers. Operation modulo. Partitioning algorithm. Euclid's algorithm. The basic theorem of arithmetic. Congruences. Fermat's little theorem. Solving congruences and congruence systems. The Chinese Residue Theorem. Functions and Euler's theorem. Elements of graph theory. Counting graphs. Coloring vertices and branches of graphs. Associations in graphs. Transversals and matroids. Capacity networks.
13.	Generative and Faceted Methods in Manufacturing Software III	Advanced modeling in UML: diagrams of classes, use cases, sequences, states, activities. UML usage methodology: application field and consistency rules. Metaprogramming and metamodeling. Generative techniques: generating state and test machines. Contract specification on the example of the OCL language. Elements of AspectJ AspectJ Aspect-Oriented Programming: Junction Points, Intersection Points, Hints, AOP Applications

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14.	Numerical methods III	Basic concepts of numerical analysis: vectors, matrices and norms; rounding errors in computer calculations; conditioning of the calculation task; algorithms that are numerically correct and numerically stable. Solving linear systems of algebraic equations: conditioning the problem; Gaussian method with full and partial selection of the main element; the Cholesky-Banachiewicz method; the Householder method; the impact of rounding errors on the result; poorly conditioned tasks. Linear problem of least squares: distribution of matrices by special values; generalized inverse matrix and generalized solution of a system of linear equations; algorithm with normal equation; algorithm with Householder transformation; conditioning of the task; regularization. Finding the roots of nonlinear equations: the secant method and its properties; tangential methods, sphere and convergence exponent; Fishing method.
15.	Methods of Multi-Criteria Optimization III	Mathematical foundations of optimization. Formulation of a multi-criteria optimization task. Dominant and non-dominant solutions. Optimization in the Pareto sense. A perfect and anti-ideal point. A compromise solution. Methods of objectifying rankings. Hierarchical optimization. Optimize for multiple goals. Examples of formulating multi-criteria optimization tasks.
16.	Mathematical Modelling III	Principles of mathematical modeling. Mathematical model. Decision-making variable data and indicators. Analysis of the information level. Correct data. Admissible decisions. Possible values of indicators. Goal achievement assessment functions. Optimization task. The task of extremization. Multi-criteria and game models. Criterion space. Domination relation in the Pareto sense. Lexicographic order. The method of compromise. Ideal point and nadir point method. Satisfactory solutions. Methods of analyzing game situations. An extensive character of the game. A normal game character. Dominated strategies. Iterative elimination of clean strategies. Best answer. A point of equilibrium in the sense of Nash. Reverse induction method. Coalition games. Multiple games. Probabilistic models Decision-making under risk conditions. Replacement of a random variable with its characteristics: expected value, quantile, probability of favorable and unfavorable events, variance. The principle of not taking into account small probabilities. Application of multi-criteria methods. Dominance of indicator efficiency. Decision trees. Lottery. Usability feature. Fuzzy Models Fuzzy Sets. Optimal decisions in fuzzy conditions. Purpose, constraints and decision blurred. Activities on fuzzy harvests. Cartesian product. Fuzzy numbers. Fuzzy relationships. Fuzzy logic elements. Fuzzy: negation, conjunction, alternative, implication, and equivalence. Models with uncertainty Maximin, maximax, Hurwitz, Laplace, Savage criteria. Confidence indicator. Uncertain variables. Making decisions with uncertain data. The relationship of indistinguishability. Lower and upper approximation of the set. Approximation accuracy. Optimal decisions under conditions of approximate knowledge of data. Decision boards. Deterministic and non-deterministic rules. Uncertain variables.
17.	Modeling and verification of ICT networks III	Basics of verification of ICT systems (ICT) based on formal models: model verification, models of parallel systems, linear-time properties, safety and lifetime. Elements of Petri Network (SP) theory: model properties, problems of marking reachability and network life, constructing a reachability tree and a state diagram. Basic types of Petri nets: temporal, stochastic, colored (CPN). Hierarchical models of SP. Modeling of time-conditioned STs: analysis of simple and interval time SPs, analysis of time-based stochastic networks. Elements of the theory of time machines. ST modeling with time machines. Examples of modeling and verification tasks of ICT systems: testing the properties of the system based on the model using the following tools: PIPE-2, CPN Tools, UPPAAL.
18.	Modelling Conflict Situations III	Modelling of conflict situations. Quality criteria in conflict situations. Game models. Strategy games. Balance points. Balance in the Nash sense. Cooperative games. Modeling of group decision-making processes. Optimization task for multiple goals. Compromise solutions in game models.
19.	Business Process Modeling, Simulation and Analysis III	Modeling of business functions and processes. Principles of designing the processes of the functioning of the organization. Models and methods of business process design. Function hierarchy diagrams. Business process diagrams. Diagrams of service processes. Workflow systems. BPMN notation. BPMN notation properties. Objects in BPMN notation. Events, simple and complex activities, logic gates, and control flows in BPMN notation. Description of roles in BPMN notation. Process patterns in BPMN notation. Workflow modeling and analysis environments. Overview of BPMN-compliant modeling and analysis environments for Workflow systems. The ARIS environment of Software AG. IBM's

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		WebSphere Business Modeler Advanced. Sybase's Power Designer environment with Simul 8. Testing the effectiveness of WorkFlow systems. Ways to examine the properties of WorkFlow systems composed of business process diagrams. Time and cost characteristics of business processes. Efficiency indicators of WorkFlow class systems. Use of WorkFlow modeling and analysis environments.
20.	Reliability of Systems III	Basic concepts of reliability theory. The generalized state of the object. Assessment of the condition of the facility. Structural function. Reliability states. Reliability of the technical facility. Reliability model. Reliability indicators. Classification of objects from the point of view of reliability tests. Reliability of Non-Renewable Facilities Reliability Model of a Non-Renewable Facility. Definitions of non-renewable object reliability indicators. Basic properties of reliability indicators of a non-renewable object. Methods for determining reliability indicator values for non-renewable objects. Selected suitability time schedules. Reliability of renewable facilities with zero renewal. Facility reliability model of zero-renewables. Definitions of reliability indicators for zero-renewables. Basic properties of reliability indicators of zero-renewal renewable facilities. Methods for determining reliability indicators for zero-renewal facilities. Reliability of non-zero renewables. Reliability model of a non-zero renewable. Definitions of renewable object reliability indicators with non-zero renewal. Basic properties of reliability indicators of a non-zero renewal renewable facility. Methods for determining reliability indicators for non-zero renewables. System reliability. System reliability model. Reliability structure. Structural system reliability function. Examples of reliability structures. Probabilistic system reliability model. The process of changing the reliability states of the system. Redundancy in the system.
21.	Optimization III	A general optimization task. Classification of optimization tasks. Convex tasks. Methods for solving linear problems. Discrete tasks. Relaxations, restrictions. Algorithms for solving PCL, PCLM, PLB problems. Evolutionary algorithms of discrete optimization. Non-linear tasks without limitations. Methods for solving nonlinear constrained problems. Parallel calculations in optimization. Probabilistic algorithms. Evaluation of the quality of optimization algorithms.
22.	Probabilistics III	Multivariate random variables. Parameters of multivariate random variables. Examples of one- and multivariate distributions. Functions of random variables. Use of characteristic and creating functions. Boundary theorems. Asymptotic properties of distributions. Parametric and non-parametric estimation. Parametric tests. Non-parametric tests. Randomness Study. Partial and multiple correlation analysis. Multivariate Regression Analysis.
23.	Stochastic processes III	Random sequences and their properties. Probabilistic description of the stochastic process. Examples of processes. Markov trials. Ergodicity. Counting processes. Queuing systems and characteristics. The Semi-Markov trials.
24.	Image Recognition and Processing III	Introduction to digital image recognition and processing. Frequency methods in digital image processing. Image acquisition, spatial methods in image processing. Improving image quality with the use of filtration. Frequency methods in digital image processing, basics of the use of transforms in digital image processing and analysis. Introduction to image recognition methods. Segmentation algorithms using the following methods: thresholding, edge separation, area growth, divisions and links, point classification. Application of the Hough transform for analytical curves and irregular objects. Application of neural networks, including deep learning methods, for image recognition (models, applications).
25.	Neural Networks and Fuzzy Logic III	Neural network as an approximation of functions. Multilayer neural networks and algorithms for learning them. Self-organizing networks (SSNs). Sierci GAN. Transformers and LLN components. Fuzzy sets and approximate inference. Fuzzy-neural control and approximating. Fuzzy controls with rule learning. Fuzzy neural networks.
26.	Smart Radio Networks	Smart radio network concept. Ad-hoc CRAHN networks. CR hardware and software architectures. The Semantic Context of CR. Problems of teaching in the CR system. Policies in the CR network. Dynamic spectrum management. Sensing and Spectrum Sharing. Collaboration and rivalry in CR networks. Security problems in CR. Standards for CR networks and CR solutions in NG (Next Generation) networks

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27.	Stochastic Exploitation Models III	Introduction to stochastic modeling of systems. Complex technical systems. Operating conditions. Modeling goals. Homogeneity and stationary functioning and operation of technical systems. Efficiency of technical systems. Models of Markov of the operation of technical systems. Application of Markowa DD class models for modeling the functioning and operation of systems. The use of Markowa DC class models for modeling the functioning and operation of systems. Momentary and marginal probabilities of the system staying in states. Boundary probabilities of the system being in subsets of states. Estimating dwell times in subsets of states. Presentation of the functioning of the selected computer system in the form of the Markov model. Semi-Marek models of the operation of technical systems. Application of semi-mark models to model the functioning and operation of systems. Momentary and marginal probabilities of the system staying in states. Boundary probabilities of the system being in subsets of states. Estimating dwell times in subsets of states. Presentation of the functioning of the selected computer system in the form of a semi-mark model. Queue models of technical systems operation. Simple queue systems. Open systems. Closed systems. Marków Railway Systems. Niemarkowska queue systems. Queue networks. Modeling systems with queue systems. Queue models of basic computer system structures. Computer network models. An example of the operation of a technical system. Presentation from assumptions to implementation of the stochastic model of the functioning or operation of a computer system. The impact of the development of design assumptions on the form of the stochastic model of functioning and operation. Study of the properties of a computer system based on the study of its stochastic model.
28.	Computer Simulation III	Models and methods of formal description of complex processes subject to experimental study. Determination of the simulation model, advantages and disadvantages of simulation methods, types of research problems. Basic laws and theorems used in computer simulation. Methods of generating numbers and random processes, testing random generators. Continuous and discrete simulation systems, the issue of time elapsed in computer simulation, basic principles of simulation experiment design, statistical analysis of simulation results. Methods of testing the adequacy of simulation models. Parallel and distributed simulation, general characteristics of simulation languages. Presentation of simulation systems and environments. Computer simulation trends.
29.	Database Systems III	Basic concepts, database systems and information systems. Data models: hierarchical, network, relational, object-oriented. Database system architecture, levels of data description, the essence of central data management and independence, definition and processing languages, database management system tools. Data modeling and normalization, practical data modeling. Security and protection of data, in classic and statistical databases. Methodological foundations of database design. Database Applications: Databases vs. Application Systems, Commercial Database Systems, Warehouses and Data Mining. Formulation and discussion of selected research tasks in the field of databases.
30.	ICT Systems III	Control of route and link availability in the LAN environment: control of LAN availability using the STP protocol, - HSRP protocol and control of the availability of default gateways, control of link load using access control lists. High-performance routing protocols for LANs: VLSM, route aggregation using VLSM, default routes – broadcasting, classless routing problems, characteristics of link state routing protocols, characteristics of EIGRP and OSPF protocols. Translation of NAT and PAT addresses. DHCP protocol: the principle of operation of the address translator, forms of NAT and PAT implementation. Technologies and protocols in WANs: characteristics of selected protocols used in WANs, packet switched networks, and channel switching. Basic concepts related to QoS systems: architecture of quality assurance systems, DiffServ model, IntServ model. Packet classification: IP Precedence and DSCP – structure and interpretation of IP header field values, marking and classification of packets by switching devices in layer 2 and layer 3 of the reference model. Methods of managing bandwidth, congestion and packet queuing: characteristics of queuing methods – FIFO, WFQ, PQ, CQ, LLQ, congestion avoidance using the RED and WRED gateway algorithm. MPLS protocol – integrating MPLS with the QoS system: MPLS protocol characteristics, principles of operation of MPLS border and internal domain routers, traffic management and congestion avoidance in MPLS VPNs, configuration of switching devices using labels. Private VPNs: VPN concept,

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		VPN implementation methods and protocols, examples of VPN implementation using GRE tunneling and IPSec, MPLS-based VPNs.
31.	Decision Support Systems III	Methods of identifying decision-making processes in management and control systems. Basic concepts of decision analysis. Models of decision-making processes in a selected class of systems, formulation of decision-making tasks based on adopted models using optimization methods and artificial intelligence. Forecasting models. Introduction to the design of decision support systems. Principles of designing a decision support system for a specific management or management system, developing a language system, knowledge system and task processing system, formulating project tasks for SWD. Use of IT tools to construct algorithms and decision support systems for specified decision-making tasks. Principles of using simulation games in the process of evaluation and decision support. Methods of verification of decision support algorithms. Presentations of environments and decision support tools.
32.	Artificial Intelligence III	Paradigms of artificial intelligence and areas of its applications, limitations of artificial intelligence – Gödel's theorem and Church-Turing's thesis. Formal systems – alphabet, formulas, axioms and rules. Calculus of propositions and predicates. Herbrand and Skolem's Theorem, Introduction to Artificial Intelligence Languages. Techniques of searching space (classical, evolutionary, taboo search, simulated annealing). Machine learning, approximate sets, neural network elements. Knowledge bases and knowledge representation – ontologies and semantic networks. Inference methods (classical, fuzzy). Pattern recognition algorithms in data mining.
33.	Theoretical Foundations of Computer Science III	Algorithmic information theory. Accuracy and correctness of algorithms. Computation models, deterministic and non-deterministic Turing machines, probabilistic machines, non-uniform calculations. Complexity of algorithms in the Turing sense. Types of complexity. Decision-making and optimization problems. Polynomial transformations of problems. The complexity of the problems. Classification of problems: classes P, NP, NP -complete and strongly NP -complete, Co-NP, PSPACE. Complexity hierarchies. Models for defining and recognizing character patterns. Language, grammar, languages designated by grammars. Deterministic and non-deterministic finite state machines. Languages accepted by finite slot machines. Regular expressions. Languages generated by regular expressions. Context-free grammars. Normal grammar forms. Contextual grammars. The generative power of grammars, regular expressions, and finite automata. Parallel Computing Models.
34.	Graph and Network Theory III	Graph definition. Graph as a system model. Characteristics of the graph and elements of its structure, measures of centrality of vertices. Types of graphs. Graph parts, subgraphs, and partial graphs. A complex graph as a special type of graphs. Graph coloring. Stable subsets of graph vertices. Graph databases. Graph chromatics. Graph coloring models. Algorithms for accurate and approximate graph coloring, on-line graph coloring. Computational complexity of coloring algorithms. Routes, chains and roads in graphs. Definitions of route, chain, road. Consistency and strong graph consistency. Cyclomatics and graph carcasses. Computational complexity of the algorithms discussed. Berge charts. Definition and types of Berge graphs. Components of strong digraph coherence. Leifman's algorithm. Roads in digraphs. Layered representation of a digraph. Euler's and Hamilton's paths in graph. Computational complexity of the algorithms discussed. Graph similarity. Measures of exact graph similarity: graph isomorphism, graph homomorphism, largest common subgraph, smallest common supergraph. Measures of approximate similarity of graphs: editorial distance of graphs, iterative measures. Methods of pattern recognition using graph similarity measures. Networks. Network definition. Economical casings. Extreme roads in cyclic and acyclic networks in the sense of roads. Network methods of analysis of complex projects (CPM, PERT, GERT). Stochastic networks and the basic problems defined in them. Computational complexity of the algorithms discussed. Flows in networks. Flow in a standard network. Splitter cross-section and its throughput. Algorithm for determining the maximum flow. Edge and vertex consistency. Vertex and edge roads. Menger's theorem. Satisfying flow at minimal cost. Computational complexity of the algorithms discussed. Optimal quotas Specify an assignment as a two-part network association. Hall's theorem. Algorithm for determining the most numerous allocation, the most numerous allocation with a minimum cost. Computational complexity of the algorithms discussed.

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35.	Project and Process Management III	<p>Functional and process management concepts: definitions and classes of operating systems, place and classes of processes, identification of system features, organizational structures, essence of process management, management strategies.</p> <p>The essence and role of projects in organization management: definitions and classes of projects, management functions and the project management cycle, systemic aspects of the subject of design, formal project structures, basic design cycle, identification of project needs, areas of project management, complexity of processes and projects. Identification of the life cycle of projects and products: product life cycle vs. project life cycle, needs analysis and definition of requirements, definition of project assumptions and constraints, models of artifacts according to systems engineering, construction and prototyping, verification, documentation and closure of the project, implementation and implementation, improvement, annihilation of the design, process and product. Planning of project processes: planning the scope and effects of the project, analysis and planning of project and process costs, evaluation of projects and processes, analysis of the value of projects and processes, planning the usefulness and functionality of project processes, planning the reliability of project activities, planning the control and verification of results, project risk management.</p> <p>Quantitative and qualitative analysis of design processes: analysis and evaluation of the effectiveness of design processes, defining project quality, measures and methods of estimating project quality, process and project quality management, project logistics management. Time and cost validation of design processes: project process budgeting, functional and task structures of processes, project time evaluation, project scheduling, project improvement and development processes, change management, project integration management. Innovation process management: the concept of innovation, classification of innovative processes, organization of requirements and planning of innovation processes, evaluation of innovative processes and systems, product design, design of technological processes, principles and methods of innovation management. Organization of the project entity: the place of the entity in the organizational structure of the enterprise, organizing and planning the structure of project teams, hierarchical and flat organizations, network and virtual models, hybrid models, tasks and selection of project teams, institutional forms of project management, control and evaluation of project teams, project communication management, methods and techniques of process improvement, models of process management development. Project and process management using benchmarking: methods, techniques and tools of design support, computer aided design systems of the CAD/CAISE class, management of the design process through a project repository, X-engineering strategy in design processes based on utility models, functionality of packages supporting the management of design processes, temporal, spatial and cost conditions. Development trends in project management: the essence of the rhomboidal model of project management, principles and foundations of good projects, innovation, technology, complexity and pace of project implementation, implementation of the rhomboid model in project organizations, conditions for the implementation of process models in project organizations, implementation costs and limitations.</p>
36.	Complex Data Structures III	<p>Letter structures. One-way and two-way lists. Implementation of lists. Basic operations. Applications of letter structures. Binary trees. BST trees: properties, implementation, basic operations and their temporal complexity. Methods for balancing BST trees. An overview of the uses of BST trees. AVL trees: properties, implementation, basic operations, uses. Red-black trees: properties, implementation, basic operations, uses. RST trees: properties, implementation, basic operations, uses. Trees partially ordered. Properties of partially ordered trees. Binary mounds: properties, types, basic operations. An overview of the uses of semi-ordered trees. Connectable mounds. Binomial trees and mounds: properties, basic operations, applications. Fibonacci Mounds: Properties, Structure, Basic Operations, Applications. Multidirectional trees. B-trees: properties, implementation, basic operations and their time complexity. Types of B-trees. Applications. Data structures for disjoint sets. Representation of disjoint sets. Basic operations on disjoint sets. Applications.</p>
37.	5G network application for military	<p>5G network technologies. 5G use cases and system concept. 5G Network Architecture. 5G architecture elements and functionalities/roles. Millimeter wave communications. Device-to-device (D2D) communications. The 5G radio-access</p>

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		technologies. Machine-type communications. Massive multiple-input multiple-output (MIMO) systems. 5G Network Military Gaps. Sensors and effectors. Military scenarios (use cases). 5G network Military Application and use cases: 5G network in Spectrum Situation Awareness application (workshop). 5G network Military Application and use cases: (own work/seminar/workshop with teacher support).
38.	Advanced Cryptanalysis Tools	Elliptical curves, hyperelliptical curves and the concept of a division. Attacks on elliptic curves using transfer methods. Attacks using inappropriate and degenerate curves: an example of a practical attack on TLS-ECDH. The index method on elliptic curves over extended and simple bodies. Quantum attacks: Shor and Grover's algorithm. Algebraic attacks. Transformation of the factorization problem, discrete logarithm, and algebraic attacks into the QUBO problem. Application of quantum annealing in cryptanalysis. Isogeny-based cryptography. Practical attacks on the post-quantum schema of SIDH. Cryptanalysis of selected cryptologic problems.
39.	GNSS – Systems and signals" (GNSS)	The state of the art of GNSS - the introduction to GNSS, the classification of systems, and areas of implementation of GNSS. The architecture of systems and elements – structures, description & characterization of physical processes, technical parameters, and areas of application. Signals in GNSS – classification, mathematical models of signals, propagation of signals, interferences of signals, methods of protection of signals. Modeling and simulation of systems and signals. Modeling and simulation of jamming and spoofing.
40.	Multidimensional Data Processing (WDP)	Basics of pattern recognition theory in data. Definition of a pattern, a class of patterns, and a process for recognizing patterns in data. Pattern recognition techniques used. Division of methods of classification and grouping of data. Grouping criteria and methods. Threshold criteria (nearest and farthest neighbour). Distance of Euclid, Sebestyen, Mahalanobis, Hamming, Cannber, and selected similarity functions. Grouping methods based on hierarchical grouping algorithms. Construction of dendrograms. Extraction of distinctive features using polynomial interpolation (Lagrange analysis).
41.	Automated Battlefield Database Systems (SBD-ZPW)	Basic terminology and characteristics of databases. Requirements for databases. Database technology, data models, data structures, data model operators, integrity constraints. Development tools. Database management system (software, functionality). Database System Architecture (ANSI/SPARC). Database system users. Implementation technologies. Communication architecture. Division of database systems. Entity relationship model, relationship modeling, entity hierarchy. Transformation, entity transformation rules, relationship transformation rules. Standardization and its process and basic concepts. The first (1NF), second (2NF), third (3NF) and fourth (4NF) normal form. Concurrent data access, data loss after a failure is performed. ACID transaction properties, transaction state diagram, logical vs. physical transaction, transaction model and classification, transaction execution. Operational data structures in the MIP model JC3IEDM database. DEM replication, transformation, and data exchange. Databases in battlefield analytics
42.	Hiding data in telecommunications	Data formation in the process of mapping and shaping signals, modern methods of tagging and steganography, detection of hidden information channels, paradigms of data hiding, study of selected mishaps, perception and steganoanalysis of hidden communication channels. Development of marking methods for the needs of telecommunication systems and their qualitative analysis.
43.	AI in Spectral Processing and Analysis	Analysis of signals in the radio spectrum. Basic characteristics and imagery for the spatial domain and the field of transforms. Detect and isolate events on the radio stage. Formation, detection and classification of radio signals using Deep Learning methods. Short- and long-term prediction using LSTM networks. Identification of one's own and a stranger in the radio spectrum.
44.	Special numbers in cryptology	The aim of the lecture is to familiarize the students with numbers (mainly natural) of particular importance in cryptology. Examples of numbers used in cryptography are RSA numbers and their extensions. On the other hand, in cryptanalysis, smooth and partially smooth numbers play a special role, but also generic and balanced natural numbers. Their significance is manifested, for example, when examining the arrangement of divisors of the first typical natural numbers, as well as their numbers - described by classical "omega" functions. Applications will concern, among others, the complexity of algorithms used in cryptanalysis of asymmetric ciphers.
45.	Elliptic curves in cryptanalysis of asymmetric ciphers	The aim of the lecture will be to study asymmetric ciphers, selected attacks on such cryptosystems and computational problems related to their security. The main emphasis will be on the importance of special numbers in the cryptanalysis of

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		ciphers using the difficulty of the natural number factorization problem and the discrete logarithm problem, with particular emphasis on the problems of DLPC, ECDLP, CDH, DDH and their applications in cryptosystems with bilinear operation. Reductions between special computational problems will be shown, including the reduction of the factorization problem of natural numbers for the calculation of Fourier coefficients of the L-Hecke function.
46.	Selected elements of lattice theory	The aim of the lecture is to familiarize the student with advanced concepts in the field of number geometry and lattice theory, which are used in modern asymmetric cryptography. We will analyze in detail the computational problems on the gratings, their difficulty, complexity and appropriate reductions. We will discuss the meaning of dual gratings, their properties and grating-dual grating compounds. We will explain in detail the concept of smoothing factor and its impact on the quality of mesh solutions in the context of cryptographic security.
47.	Application of modular gratings in postquan cryptography	As part of the lecture, we will discuss the origin and construction of selected cryptographic schemes based on MLWE, MLWR modular problems. We will analyze in detail the special importance of modular gratings for post-quantum cryptography and discuss the reasons for the advantage of modular gratings and MLWE/MLWR over RLWE. We will analyze the schemes (KEM, DSS) from the CRYSTALS family and the Smaug, Haetae schemes, we will perform a comparative analysis in order to indicate the global tendencies of their construction from the perspective of achieving safety. We will discuss ROM and QROM along with the differences, and conduct formal safety proofs of IND-CCA2 and UF-CPA, respectively for KEM and DSS.
48.	Basis for measuring revealing emissions	Revealing emission – myths and reality (not every issue is a revealing issue). Sources of revealing emissions and methods of reception. Electromagnetic compatibility issues, substitute schemes of emission sources. Issues of measuring conducted emissions, construction of emission measurement stations for 230V power supply and low voltage power supply (of the maximum 5V order). Measuring stations for emission measurement at communication and management interfaces.
49.	Digital Data Processing Techniques	Functions and functional spaces; Banach and Hilbert spaces. Interpolation and approximation of the mean square with polynomials. Interpolation, Medium Square Approximation, and Plywood Smoothing. Smooth discrete data. Numerical integration, simple and complex interpolation quadrature. Numerical differentiation.
50.	Advanced technologies for next generation mobile networks	The aim of the course is to deepen knowledge of mechanisms and algorithms implemented in the latest generation of cellular networks (5G and 6G) used for network management and traffic management based on the division of traffic (slicing). Since the fifth generation of mobile networks, traffic management has been based on Slices and Network Function Virtualization. Lectures provide knowledge about operating mechanisms and knowledge about research on new management mechanisms. The projects convey the ability to propose other mechanisms and algorithms along with their implementation in mobile networks.
51.	Machine learning for telecommunications	<p>The first part of the course will reveal statistical data learning theories, which are a toolkit for understanding data. These tools essentially cover two classes: supervised learning and unsupervised learning. Basically, supervised learning refers to the prediction of outcomes based on one or more inputs. One or more estimators make such a forecast. The estimator(s) choice is closely related to the nature of the data. On the other hand, unsupervised learning provides a relationship or pattern in data with no supervised outcome.</p> <p>The second part of the theory described in the course presents the AI decision-making theory. This theory discusses how to represent knowledge, including incomplete and uncertain knowledge about the data (measurements, estimations, etc.); how to use these models and inference methods to decide what to do, especially by making plans (Constraint Satisfaction Problems, CSP); and how to reason and make decisions (Multi-criteria decision making) in the face of uncertainty about the world.</p> <p>The final part deals with Machine Learning, which describes both symbolic and statistical learning methods and reinforcement learning, deep learning, and multi-agent learning (game theory) to generate the knowledge required by the reasoning and/or decision components of intelligent agents or systems. Here, the methods and algorithms for providing machine learning will be analysed, and the theory of artificial intelligence will be revealed and analysed.</p>
52.	Quantum Communications	The main objective of the course is to explore the fundamentals of quantum communications technology. The first part of the course introduces basic concepts of quantum electrodynamics like field quantisation, coherent states, entanglement,

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		<p>annihilation and creation operators. Based on this knowledge, main quantum key exchange algorithms are consistently introduced, i.e. BB84 and E91. In the second part, the basics of bit error analysis, quantum information theory and vulnerabilities of quantum key distribution algorithms are discussed. In the last part, selected implementation aspects of quantum key distribution in modern telecom networks are explored.</p>

Curriculum content for elective subjects

Scientific discipline: civil engineering, geodesy and transport

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1.	Safety and reliability of building structures	Knowledge in the field of safety and reliability of building structures. Classifications and rules for shaping the load-bearing structures of buildings and the conditions for assessing their safety. Methods of description and distribution of random variables. Functions of reliability and damage intensity. Methodology for conducting reliability tests, risk assessment, the safety of building maintenance and their effectiveness.
2.	Dynamic interaction of building structures with a ground center	Methods of formulating computational models of the dynamics of structural elements and systems and the ground center of the foundation of the building. Determination of physical properties of the soil medium under static and dynamic loads. The influence of phase content on substrate parameters.
3.	Environmental Physics	The rights of the body of a perfectly black one. The atmosphere as a perfect gas. Thermodynamic processes in the Earth's atmosphere. The greenhouse effect and ozone holes. Greenhouse gases – a reminder. Natural disasters (earthquakes, volcanic eruptions, tsunamis). Atmospheric, hydrosphere and lithosphere pollution, Noise and civilization diseases. Renewable energy sources – Polish's attitude to the protocols of the Climate Summits. Types of light sources for lighting. Indoor and outdoor illumination, luminous flux, illuminance intensity, luminous efficacy, light source spectrum, standard observer, objective determination of source color.
4.	Space weather	Space weather – can it be defined as Earth weather? Solar System: essential information related to the structure of the Sun, its magnetic field, the Sun-Earth relationship, and the Earth's magnetosphere and ionosphere. Solar activity, solar cycle. Characteristics of solar phenomena occurring on the surface of the Sun in the context of shaping the interplanetary environment and the Earth. Discussion of the types of electromagnetic radiation of the Sun, mass ejections and high-energy particles. Major space weather forecasting models, geomagnetic storm and coronal mass ejection (CME) prediction models, solar flares and other solar phenomena forecasting models.
5.	Modeling of heat and humidity processes	Energy balances of heat demand and air conditioning of the building. Conduction of heat and moisture through the layered partitions of the building – walls, ceilings and floors on the ground, in the conditions of various centers adjacent to the partitions. Conduction equations and methods of solving them. Solutions to the Laplace equation using field theory concepts. (gradient, divergence, rotation). Description of solutions to the Laplace and Poisson equations by the method of variable separation. Main potentials in the theory of moisture diffusion and heat conduction in a porous medium. Equations of moisture diffusion and heat conduction in a porous medium.
6.	Identification of loads and structural systems	Identification of load intensity, weight and stiffness. Gravitational and dynamic loading of structural systems along with the analysis of their reasonable static schematization or determination of a dynamic model. The basis for identification are the results of initiating reactions of the supporting systems of objects, manifested by static or dynamic displacements or vibration frequencies.
7.	Investment process in construction	Organization of construction investments, in particular methods of analysis, testing and design of construction, assembly, reconstruction, renovation and operation of buildings in a specific place, time, system environment and natural environment. Principles of testing the efficiency, technology and organization of construction works, preparation and implementation of construction projects, structure and process of operation of construction facilities.
8.	Mechanics of road and airport runway soil foundations	Modeling of the soil as a single-phase or three-phase continuum depending on the type of soil (cohesive or no-cohesive). Stiffness and load carrying capacity of the ground as the problem of an elastic half-space. Dynamic effects generated by moving loads.
9.	Methods of testing the stiffness and bearing capacity of the pavement road and airport	Testing the stiffness and bearing capacity of road surfaces and airports makes it possible to verify the workmanship and allow for safe use, The research techniques are based on the use of the wave theory of elastic half-space, which is equipped with layers of the substructure and the surface itself. Forcing the reaction of the half-space is used by means of shocks with a dynamic plate and recording of deflections of the surface under moving loads. Factors influencing the results of the tests - soil, material and climatic parameters.

Ip.	Item Name	Program content
10.	Calculation methods of folding bridge structures	Construction of folding bridges with specification of their technical and operational parameters. Theory of calculation of folding bridges taking into account mounting clearances for objects in static and dynamic layout.
11.	Design methods of the experiment	The essence of experimental research. Resistance extensometers. Measurements and analysis of measurement errors. Organization of the measurement line. Experimental methods of testing materials in simple stress conditions - tensile, compression, shear, bend, torsion tests. Materials testing in complex stress states. Assessment of rheological properties of materials - creep and relaxation. Optical research methods in mechanics – elastooptics, optical, mesh and holographic interferometry.
12.	Modeling the behavior of elements and structures reinforced concrete	Reinforced concrete structures as material compositions of concrete and reinforcing materials. Modeling of static and dynamic behavior of structural materials: concrete and reinforcing steel. Modeling of cooperation of structural material components in reinforced concrete elements. Method of homogenization of reinforced concrete: models of a substitute, homogeneous structural material taking into account the properties of the components of structural materials. Modelling of the mechanisms of destruction of reinforced concrete elements and structures: scratching and crushing of concrete. The use of FEM in modeling the behavior of reinforced concrete structures
13.	Geometric and physical nonlinearities in mechanics construction	Deformation of flaccid materials, elements and structures with low rigidity, use of geometric relationships with linear and nonlinear components. Consequences of deformation in equilibrium equations written in a deformed configuration. The full spectrum of nonlinearity of the physical compounds of the material is considered, along with the associated and unassociated laws of plastic deformation.
14.	Explosive effects on defensive structures	Physics of phenomena generated by the explosion of charges and fuel-air mixtures. Methods of determining the parameters of explosive loads. Types of mechanisms destroying elements and load-bearing structures of buildings.
15.	Construction Work Scheduling and Estimation Systems	Principles of scheduling and cost estimation using currently available specialist IT techniques and software. The idea of BIM technology and its possibilities at all stages of the construction project and the operation of the facility. Optimization formulas and methods of solving multi-criteria decision-making problems in construction.
16.	Engineering of building materials	Contemporary trends in the modification of building, construction and finishing materials. Technologies of preparation, implementation and optimal procedures for incorporating materials and products under building conditions. Structure and material considerations of composites used in construction. The role of additives and admixtures in buildings technologies.
17.	Cartographic research methods	The use of maps to describe, analyze and learn about phenomena scientifically, including cartometric research, mathematical and statistical analysis and methods of mathematical information theory. The scope of the course covers issues related to, among others, distribution analyses (potential method, entropy, cartographic concentration method) and correlation and their application in scientific research.
18.	Spatial data mining	An overview of methods of exploratory data analysis with particular emphasis on geospatial data, including the issues of classification and grouping, reduction of the number of variables, finding spatial patterns. Classification using decision trees and Bayesian classifier, hierarchical grouping, and quality assessment of classifiers and model verification.
19.	Methods and technologies in Geospatial Data Science	Advanced processing, analysis and modeling of geospatial data. Searching for trends and relationships using exploratory data analysis, machine learning and artificial intelligence techniques m.in.: real estate market, land cover changes, population distribution. Data quality and their impact on the effect of forecasting and modelling, as well as effective reporting and visualization of results.
20.	Advanced methods of development photogrammetric	Problems of radar image filtration. The use of wavelet analysis in image filtration. Morphological operations on digital images. Determination of the MTF. Fundamental problems of contemporary digital photogrammetry. Digital image acquisition systems – photogrammetric digital cameras and VHRS and Nano satellite systems. Remote sensing and photogrammetric methods of data acquisition. Contemporary photogrammetric technologies – their applications in the development of situational and elevation maps, numerical terrain models and orthophotomaps, as well as 3D spatial maps. Application of Computational Intelligence Algorithms in Contemporary Photogrammetric Studies. Characteristics of new multi-image matching methods. Methodology for developing dense point clouds based on images.

Ip.	Item Name	Program content
21.	Programming in spatial information systems	Using the programming environment, the concept of a procedure, functions and instructions for data processing. A method of accessing and processing spatial data directly using programming code. Libraries that enable spatial data processing in the .NET environment, the ability to automate the ArcGIS environment using Python.
22.	Reference systems in geosciences	We live on a dynamic planet in constant motion that requires long-term continuous quantification of its changes in a truly stable frame of reference. To be understood in context, when the motion of the Earth's crust is observed, it must be referenced. The global geodetic frame of reference is the fundamental basis for measuring worldwide processes and is crucial for its proper interpretation, especially for climatic studies. A terrestrial reference frame provides a set of coordinates of some points located on the Earth's surface. It can be used to measure plate tectonics, regional subsidence or loading and/or used to represent the Earth when measuring its rotation in space. This rotation is assessed with respect to a frame tied to stellar objects, called a celestial reference frame. The Earth Orientation Parameters (EOPs) connect these two frames together. Nowadays, four main geodetic techniques are used to compute accurate coordinates: the GPS (Global Positioning System), VLBI (Very Long Baseline Interferometry), SLR (Satellite Laser Ranging), and DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite). They all use networks of stations located on sites covering the whole Earth. Modern realizations are of kinematic type, which means that they include station positions and velocities. They model secular Earth's crust changes that is why they can be used to compare observations from different epochs. The Ph.D. students will learn about advancements of the International Terrestrial Reference System (ITRS) which is a World spatial reference system co-rotating with the Earth in its diurnal motion in space for the geodetic, but also astronomical, and geophysical communities.
23.	Global Geodetic Observing System	Global Geodetic Observing System (GGOS) is the Observing System of the International Association of Geodesy (IAG). GGOS and its related research and services address the relevant science issues related to geodesy, geodynamics and geophysics in the 21st century, but also issues relevant to society, like global risk management, geo-hazards, natural resources, climate change, severe storm forecasting, sea level estimations and ocean forecasting, or the space weather. The Global Geodetic Observing System works with the IAG components to provide the geodetic infrastructure necessary for monitoring the Earth system and global change research. GGOS mission is to: (i) provide the observations needed to monitor, map, and understand changes in the Earth's shape, rotation, and mass distribution, (ii) provide the global geodetic frame of reference that is the fundamental backbone for measuring and consistently interpreting key global change processes and for many other scientific and societal applications, and (iii) benefit science and society by providing the foundation upon which advances in Earth and planetary system science and applications are built. Within this subject, Ph.D. students will advance their understanding of the dynamic Earth system by quantifying our planet's changes in space and time and learn about the integration within the geodetic, geodynamic and geophysical communities at the highest level, in service to the technical community and society as a whole.
24.	Modern photogrammetric techniques	A modern approach to photogrammetric studies based on the use of the latest techniques for processing imagery obtained from various ceilings and the use of their geometric relationships in the field of situational and elevation measurement in areas including: developing and updating maps, powering topographic databases, supporting the construction of 3D cadastre, as well as cooperation with mobile systems in the field of building virtual reality at various levels of detail.
25.	Selected numerical methods in geodesy	Practical use of numerical methods to solve scientific and technical problems (geodesy), ideas and concepts of numerical methods, numerical algorithms, programming elements - computational scripts. Use of selected utility libraries of scripting languages such as Matlab, Octave and Scilab.
26.	Parallel data processing methods	Methods of parallel data processing for solving scientific and technical problems in geodesy. Ideas and concepts of parallel data processing methods. Selected parallel processing algorithms. Examples of programs that parallelize numerical calculations. Methods of parallel processing of scripting languages: Octave, Scilab. Methods and functions of the Parallel Computing and MATLAB Distributed Computing Server Toolbox.

Ip.	Item Name	Program content
27.	Mathematical foundations of digital image processing	Creating gradient and edge filter masks based on differential diagrams constructed using the finite difference method (FDM) and the finite element method (FEM) (convergence, conformity, order of accuracy, π - as the first form of differential approximation). Spectral properties of masks (third and fifth degree arrays), including the spectral transfer function and its graphical presentation. The goodness of the mask is defined as the quotient of the spectral transfer function of the test filter and the spectral differential transfer function of the Laplace operator. Actions on masks (addition, subtraction, 45° rotation), determining the form of the differential operator related to the results of these transformations (Laplasyan, bi-Laplasyan, etc.). Filters that identify corners (vertices) only. Mask bi-Laplacean vs. Harris corner detector.
28.	Numerical methods with linear algebra	Vector norm, matrix norm, induced norm. Norms 1, 2 and maximum. Matrix conditioning indicator. The use of linear algebra methods in numerical (differential) solving of mathematical physics problems (advection equation, diffusion, diffusion with advection problem). Convergence and stability of the differential method. Spectral transfer operator. π - the form of the first differential approximation. Numerical diffusion, creation. Analysis of selected differential schemes in terms of spectral properties – explicit, implicit, semi-implicit, Crank-Nicholson, Crank-Nicholson-Galerkin scheme. Dissipation and dispersion in Lax-Wendroff and Beam-Warming schemes used in civil engineering and transport.
29.	Finite element methods in Hermite spaces (polynomials of degree 2 and 3). Nonlinear issues.	The scope of the course in the winter semester includes the presentation of differential schemes for the problem of nonlinear advection, nonlinear diffusion and the equation BKdV – soliton on shallow and deep water. Fortran program + presentation and discussion of results.
30.	Finite element methods in Hermite spaces (polynomials of degree 2, 3 and 5). Linear issues.	The finite element method has been known for many years (at the Military University of Technology it was created and developed by Prof. Szmelter, Dacko, Dobrociński, Wieczorek, Niezgodna, and now Winnicki). It is an engineering method (light, heavy, aircraft, medical structures - stents) and a method of solving equations and systems of partial differential equations (linear and non-linear). These issues have been dealt with by the team of the Department of Military Hydrometeorology for years. The scope of the course in the summer semester includes the presentation of polynomial forms of degree 2-5 forming the basis of functions approximating the solution of the differential problem with the initial condition, as well as examples of differential schemes for linear advection and linear diffusion. Fortran program + presentation of results.
31.	Methods of natural environmental research using GNSS	Issues related to the use of satellite navigation systems in geodynamic and tectonic research and atmospheric monitoring. The basics of GNSS systems such as GPS, GLONASS, Galileo or BeiDou, as well as various types of GNSS receivers and their applications in the scientific and technical environment. Processing GNSS data and interpreting results in environmental studies. Application of GNSS data in modelling of atmospheric processes. Analysis of ionospheric parameters based on GNSS signals. Determination of tropospheric water vapour content (PWV) from GNSS data. Monitoring tectonic plate movements. Analysis of crust deformation: landslides, subsidence, vertical and horizontal movements.
32.	Hydrographic studies	Basics of hydroacoustics, influence of sound velocity distribution on acoustic wave propagation. Structure and principle of operation of single and multibeam fish finders. Planning bathymetric measurements. Calibration of data from a multi-beam sonar. Development of a numerical DNA model. Bathymetric board. Structure and principle of operation of sonar systems. Detection and measurement of objects in sonar images. Development of sonar mosaic, Integration of hydrographic data with Lidar data.
33.	LiDAR systems in photogrammetry and remote sensing	The course focuses on theoretical and practical aspects of the use of laser scanning technology in modern photogrammetric processes, with particular emphasis on the architecture and technical parameters of LSL, NSL and MSL systems. Both the physical and technical foundations of LiDAR systems are discussed, as well as advanced methods of processing, analyzing, and interpreting 3D point clouds obtained from various platforms (aeronautical, mobile, and ground). Particular emphasis is placed on: integration of LiDAR data with other remote sensing sources, research and operational applications (terrain modeling, vegetation analysis, infrastructure, object recognition), current development trends, including full-waveform LiDAR analysis, single-photon LiDAR, satellite LiDAR and methods based on machine learning and deep learning. The course prepares

Ip.	Item Name	Program content
		doctoral students to independently use LiDAR data in scientific work, including critical assessment of data quality, selection of analysis methods and design of their own research experiments.
34.	Advanced Fiber-Reinforced Concrete Composite Materials – Design, Mechanisms, and Experimental Research	The course covers advanced issues related to the design, manufacture and evaluation of the properties of fiber-reinforced concrete composite materials (HPFRC/UHPC). Particular emphasis is placed on hybrid fibrous systems (steel, polymer, mineral, natural), their role in the mechanisms of load transfer, scratching and destruction of material under static and dynamic loads. The course discusses the mechanisms of fibre work in a cement matrix (crack bridging, pull-out, debonding), the influence of composition and microstructure on mechanical properties and durability, methods of experimental research (compression, intermediate tensile, bending, impact and high deformation velocity tests), the basics of interpretation of results in terms of fracture mechanics and deformation compatibility.
35.	Rules for the creation, verification, control and suitability of databases for means of transport	Methods of processing operational data. Development of a raw (raw) database. Substantive and formal control of databases. Database Treatment Methods. Phase trajectory of the process. Analysis and assessment of the suitability of databases for modeling transport processes.

Annex VI.4

to the Curriculum at the Doctoral School of the Military University of Technology

Curriculum content for elective subjects
Scientific discipline: materials engineering

Ip.	Item Name	Program content
1.	Structural studies using X-ray diffraction methods	Basic concepts and laws of crystallography. Translation, spatial lattice and crystal lattice. Crystal lattice theory, Interplane distances. Reverse network. Stereographic projection. Wulf mesh. Classification of crystalline bodies. Types of structures. X-ray radial diffraction on a crystal lattice. Structure, principle of operation and analytical capabilities of X-ray diffractometer. X-ray qualitative and quantitative analysis. Stress and texture measurements.
2.	Structural studies using scanning microscopy methods	Concepts used in electron microscopy. Principles of operation of electron microscopes (scanning and transmission). Basic research methods used in electron microscopy. Preparation used in reflection and transmission electron microscopy. Selected by advanced microscopic methods (microanalysis of chemical composition, diffraction orientation of crystallites, quantitative analysis of images and breakthroughs).
3.	Testing of mechanical properties of engineering plastics	General characteristics of technological and strength tests. Stress-strain relationship in a construction material. Hook's law, material constants. Classification of strength test methods depending on the nature of the load. Characteristics of endurance indicators determined in laboratory tests. Static methods for measuring hardness and microhardness. Static endurance tests. Tests carried out at elevated temperatures. Fatigue and stroke tests. Basics of fracture mechanics.
4.	Physical Basis of Electro-Optical Effects in Liquid Crystals	Physical basis of electro-optical effects in Liquid Crystals (CK). Selected optical, dielectric, flexoelectric, elastic and viscosity properties of CK, interaction of the ordered layer of CK with an external electric field. Basic electro-optical effects in CK such as: dynamic scattering effect, Freedericks effect, TN (Twisted Nematic) effect, STN (Super Twisted Nematic) effect. Bistable switches in Ferroelectric Liquid Crystals and tristable switches in AntiFerroelectric Liquid Crystals.
5.	Calorimetric, thermogravimetric and volumetric methods of testing the properties of materials	Testing of materials, in particular materials for hydrogen storage in the solid phase, using: differential calorimetry, thermogravimetry and analyses using volumetric methods. Types of equipment, principles of operation, calibration methods, good practices of use, disadvantages, advantages, possibilities and limitations. Basics of test result analysis, correction of results and selection of test parameters in order to obtain the best results.
6.	Semiconductor Materials for Optoelectronic Applications	Basic properties of semiconductor materials used in the construction of optoelectronic devices: band structures, absorption coefficient, mechanisms of carrier generation and recombination, carrier mobility. Semiconductor compounds of group III-V materials used in semiconductor lasers. Group III-V nitrides used in blue optoelectronics. Solid solutions II-VI in the detection of infrared radiation. Low-dimensional quantum structures (supergrids, quantum wells, quantum dots) in the detection and generation of electromagnetic radiation. Materials for I, II and III generation photovoltaics (silicon, CdTe, CIS, CIGS, organic semiconductors).
7.	Nano and ultracrystalline engineering materials	Nano and ultracrystalline engineering materials – definitions and basic concepts. Structural determinants of the properties of nano and ultracrystalline materials. Methods of obtaining materials with extremely fragmented structure. Methods of studying the structure of nano and ultracrystalline materials. Characterization of selected groups of materials with nano and ultracrystalline structure.
8.	Nanoporous Anode Aluminum Oxide: Synthesis, Design and Applications	Mechanism of growth of anode aluminum oxide (ionic conductivity, basic chemical reactions, ion transport induced by network tension, etc.). Geometric parameters of an anode aluminum oxide matrix (pore diameter, distances between pores, etc.) and their relationship with the applied parameters of electrochemical synthesis (temperature, voltage, time). The process of self-assembly of the matrix pores into a hexagonal system. Soft anodizing. Hard anodizing. Pulsed anodizing. Synthesis of nanostructures using methods supported by an anodic aluminum oxide matrix (electrochemical deposition, sol-gel, CVD, ALD methods). Applications of anode aluminum oxide matrix (biosensors, filters, optoelectronic components, tissue engineering, etc.). New perspectives and development trends related to the production and application of anode aluminum oxide.

Ip.	Item Name	Program content
9.	Non-telecom applications of optical fibers	Technique of interference (phase) fiber optic sensors. Terminology used in the description of sensors, the ideology of mathematical formalism of the description of the sensor along with the determination of the role of the transducer as well as the processing of optical and electronic signals. Methods of building sensors with a point and an extended detection field. Multiplication of point sensors.
10.	Measurements of machine and equipment components, parts using coordinate measuring techniques	Use of coordinate measurement techniques and contact profilometry at different stages of the production process. Metrological properties of coordinate measuring machines and contact profilometers Programming a multi-sensor measuring machine to carry out measurements as part of the final acceptance of machine parts and equipment manufactured in mass production conditions.
11.	Experiment planning and data analysis with Origin and Statistica	The use of computer programs to plan an experiment. Statistical methods. Origin and Statistica capabilities for experiment planning and data analysis.
12.	Basic properties of liquid crystals	Liquid crystals as a separate state of matter matter. Classification of liquid crystals. Chemical structure of mesogenes. Description of the liquid crystal phase, the concept of the director and the ordering parameter. Liquid crystals as a viscoelastic medium. Free energy of deformation of liquid crystal. Organizing liquid crystals. Anisotropy of physicochemical properties of liquid crystals. Electrooptics and magnetooptics of liquid crystals. Nonlinear optics and liquid crystal acoustooptics. Applications.
13.	Keysight Vee and Lab View programs in control and data processing	Basics of programming in LabView, including the logic of the so-called graphical language. Basic programming structures - sequential blocks, loops (for loop, while), selection structures, feedback, etc. The way of using objects of various types (numeric, string, bool), including matrices and clusters. Methods of data processing and transmission. Creating a program algorithm to control a given device according to specific assumptions. Execution of a program to control the device in the form of a "virtual device". Extension of the executed program with given elements such as menu buttons. Basics of programming in the Keysight Vee language, including the logic of the so-called graphical language. Basic programming structures - sequential blocks, loops, selection structures, conditional statements, etc. How to use objects of various types, including matrices and complex variables. Basic methods of data processing and transmission. Keysight Vee – MS Excel cooperation. Development of our own program algorithm for controlling a given device according to specific assumptions. Expansion of the executed program with given elements, such as a panel.
14.	Process design for Direct Deposition incremental methods	Design of machine and equipment parts, parts using solid and surface modeling. Rules for creating and editing and repairing data exchange files dedicated to incremental techniques. Initial assessment of the functionality of products in a concurrent production process - defining the material, process window and generating source files for Rapid Prototyping techniques. Direct Deposition technological process design - production of the target production series
15.	Dielectric spectroscopy	Dielectric spectroscopy (impedance spectroscopy/radio frequency spectroscopy) as an experimental method in materials engineering and chemistry, as well as in electronics in the analysis of the properties of materials used in electronics. Electrical phenomena at the atomic, molecular and macroscopic (medium) level. Theoretical foundations (mathematical apparatus) of relaxation phenomena in condensed matter. Parasitic effects in impedance measurements. Research equipment (impedance analyzers), experiment and analysis of experimental data in the context of the properties of various materials.
16.	Structural determinants of material properties	Terminology, methodology, critical reception of external data, critical evaluation of the results of solving scientific problems in the field of materials and technology. Improvement in formulating research assumptions, scientific goals, analysis of results and inference.
17.	Contemporary methods of material characterization	Basics of material characterization methods. Cleaning materials. Densitometry. Methods of testing thermal, electrical, magnetic and optical properties. UV, IR, Raman and Mossbauer spectroscopy. Selected specialized spectroscopic methods. TEM and SEM electron microscopy. Atomic force microscopy and scanning tunneling microscopy. Radiography, electronography and neutronography. Methods for the study of photonic, nanomaterials and metamaterials. Material characterization path.
18.	High-energy ball grinding and mechanical synthesis	Issues related to high-energy grinding of materials in ball mills as well as mechanical melting. Types of ball grinders, the principle of their operation, capabilities and grinding results.

Ip.	Item Name	Program content
		As part of the classes, mechanical synthesis of alloys of selected metals and high-energy grinding of pure metals and their alloys, as well as selected ceramic materials, will be carried out.
19.	Advanced Hydrogen Storage Materials	The assumptions of the idea of the hydrogen economy with its limitations. Characterization of hydrogen storage methods including solid storage materials. Hydrogen storage materials based on adsorption. Low-capacity materials for storing hydrogen at room temperature. Magnesium-based hydrogen storage materials. Complex hydrides as high-capacity hydrogen storage materials. Methods to improve the hydrogenation capacity of materials. Methods of testing hydrogen storage materials.
20.	Basics of plasmonics and metamaterials	Basic definitions of plasmonics and metamaterials. Physical basis, interaction of electromagnetic waves of different frequencies with metamaterials in different wavelength ranges, surface plasmons, metasurfaces. Technological conditions for the realization of one-, two- and three-dimensional metamaterial structures. Physical and technological requirements and constraints for different types of metamaterials, as well as the use of classical technologies for the production of nano- and metamaterials. Methods of simulating the properties of selected metamaterial and plasmonic structures and methods of characterization of nanometer-sized metamaterials and structures using AFM, STM microscopy, etc. to assess the properties and shaping of the SRR. Application of metamaterial structures in photonic devices and prospects for the development of nano- and metamaterials with particular emphasis on military applications.
21.	Selected materials and functional structures for photonic applications	Properties and applications of such materials and structures as: optical glass and polymer substrates for the construction of electro-optical transducers, oxide and organic functional layers used as anti-reflective layers, bandpass and edge filters, transparent conductive organic and inorganic layers, nanomaterials for organic applications, photonic polymers and liquid crystals, including composite structures. The construction, construction and operation of selected photonic elements, made on the basis of min. the above-mentioned functional materials; spatial light modulator, dynamic wave plates, dynamic elements of diffraction optics (diffraction gratings), optical vortices, microlasers based on self-assembling structures, Kerr and Pockels cells, materials and optical elements for spatial imaging and others.
22.	Computer Image Analysis in Materials Engineering	Basics of stereology, including basic assumptions and stereological implementations. Detection methods and binarization procedures necessary for quantitative image analysis. Basics of image acquisition and processing (m.in. morphological transformations, logical and arithmetic operations). Procedures performed during computer image analysis in the study of real engineering materials.
23.	Additive manufacturing of functional materials	Practical aspects of additive manufacturing of functional metallic materials using LMD/LENS laser technology. The influence of manufacturing parameters on the ability to shape the microstructure, structure and properties of functional materials.
24.	Methods for amplifying light emission from broadband semiconductor nanostructures	Basic types of broadband semiconductors. Luminescent properties of broadband semiconductors on specific examples (e.g. GaN, ZnO, SnO ₂). Methods of synthesis of nanostructures. Modulating the optical properties of nanostructures at the synthesis stage. Post-synthetic methods of luminescence amplification. Intentional doping of broadband semiconductors. The phenomenon of charge and energy transfer. The phenomenon of surface plasmon resonance (SPR) and localized surface plasmon resonance (LSPR). Plasmon light amplification from semiconductor nanostructures – basic criteria for coupling SPR or LSPR with optical transition frequency in semiconductors at the metal/semiconductor interface.
25.	Electrochemical synthesis of anti-reflective, super-hydrophobic coatings and photonic crystals	Basic information about the production of porous anode aluminum oxide (AAO). Parameters of electrochemical synthesis. The phenomenon of constructive and destructive interference. Single-layer and multi-layer interference. Features of perfect anti-reflection coating. Anti-reflective coatings with gradient refractive index. The microstructure of the moth eye. Surface wettability. High-energy and low-energy surfaces. Hysteresis of the wetting angle. Wetting textured surfaces: Wenzel's model and Cassie-Baxter's model. General characteristics of 1D, 2D and 3D photonic crystals. Structural coloration. Inspirations drawn from nature, or what biomimetics is. Multi-step electrochemical synthesis of AAO with conical pore shapes. Electrochemical production of 1D crystals using the pulsed method. Design of sequences of voltage or current pulses, taking into account processes limited by diffusion and the rate of ion transport through the barrier layer. Control

Ip.	Item Name	Program content
		of electrochemical synthesis parameters to achieve the desired photonic properties of AAO-based photonic crystals.
26.	Modeling of semiconductor instruments.	The genesis of transport equations derived from the principles of conservation and postulates of thermodynamics of irreversible processes. Generational-recombinant mechanisms responsible for the concentration of charge carriers. Contribution of interband processes and SHR mechanisms involving point defects, dislocations and surface states. Process modeling and definition of active cross-sections. Mechanism of interband absorption of radiation. Construction of iterative schemes enabling numerical solution of a system of transport equations. Notation on a numerical grid. Problems related to numerical solving of nonlinear equations. He will be able to write a fragment of the program as a task that passes the subject. This fragment can be implemented in my program to design a specific instrument or to investigate the physical parameters of a structure.
27.	High Entropy Alloys – Synthesis, Structure, Research and Properties	The latest group of materials – the so-called high-entropy alloys. Theoretical aspects of their formation and stability, properties, structure, synthesis methods and heat treatment. Practical attempts to synthesize and investigate the properties of alloys from this group.
28.	Additive manufacturing of alloys based on intermetallic phases	Specific aspects related to the additive manufacturing of alloys based on intermetallic phases (in particular FeAl). The influence of manufacturing parameters on the ability to shape the microstructure, structure and properties of these materials.
29.	Combinatorial Fabrication and Research of Engineering Materials	Possibilities of using DED laser additive techniques for the combinatorial search for new engineering materials. As part of the course, attempts will be made to synthesize both continuous and discrete alloy libraries and the possibility of their rapid examination.
30.	Reactive mechanical grinding as a method of synthesis of modern materials for solid-phase hydrogen storage.	Synthesis of solid-phase hydrogen storage materials using reactive grinding in hydrogen atmospheres in ball mills. Attempts to synthesize selected metal hydrides and complex hydrides and studies of the influence of synthesis conditions on its result and properties of the produced material.
31.	Additive techniques with reverse engineering elements	Devices used in reverse engineering. Editing and processing of the point cloud and generation of STL files, taking into account the specifics of technology. Preparation for 3D printing (model positioning, material selection, degree of filling, division into layers, source code generation). Multi-variant production of models with complex geometries using FDM and SLA techniques. "Post-processing" and quality assessment of the obtained prints using a 3D scanner and a computer microtomograph.
32.	An overview of the additive techniques used in modern technology	The idea, technical solutions and development tendencies of 3D printing. An overview of additive methods used in strategic industries – material, technological and economic conditions. Specificity of processing high-strength thermoplastics used in aviation and medicine – devices, technological parameters of 3D printing. Evaluation of geometric and metallurgical quality of sample printed machine parts using various additive techniques. Additive technologies and Industry 4.0.
33.	Selected issues from 3D printing	Analysis of the possibility of manufacturing structural elements using Rapid Manufacturing techniques. Specificity of processing advanced structural materials using laser methods of additive forming. Material testing and assessment of geometric quality of prints. Traditional vs. laser methods of regeneration of machine and equipment components. Analysis of the possibility of reproducing performance indicators of machine and equipment parts using the semi-industrial LENS system – multi-criteria quality assessment.
34.	Researcher's Workshop 1 – Tools for Writing Scientific Texts	The course introduces the student to issues related to the basic methods of creating texts describing the results of research work, including the advanced use of the functions of the following programs: MS Word, LATEX, ENDNOTE, MENDELEY and practical ways of creating table drawings and citations. In addition, students are acquainted with the methodology of selecting the right journal and practical tips when sending manuscripts for publication in prestigious journals.
35.	Researcher's Work Workshop 2 – Writing Scientific Articles	The course introduces the student to issues related to the basic methods of designing the content of scientific articles, the vocabulary used, the methods of graphic development of results and the use of software helpful in the creation of scientific texts. In addition, the methods of literature analysis, the ethics of creating scientific texts and the selection of authors, the basis of the methodology for the

Ip.	Item Name	Program content
		development of results, as well as the possibilities of using software and services for linguistic correction of scientific texts will be presented.
36.	Researcher's Workshop 3 – Writing Scientific Articles	The course introduces the student to issues related to estimating measurement uncertainty in scientific papers. The issues discussed in the classes are aimed at learning practical methods of determining uncertainty in real measurements. The theoretical aspects, i.e. the mathematical apparatus used in estimating uncertainty, is reduced to the necessary minimum. Part of the classes is intended to solve issues reported by students.
37.	Quantum mechanics in examples	The aim of the course is to solve in detail and analyze the most important examples describing the behavior of particles in the microworld in the language of quantum mechanics. After the introduction to wave mechanics, the following examples will be analyzed: free particle; transmission (reflection) through the potential threshold; transmission (reflection) through the potential barrier (tunnel effect); an infinite pit of potential; finite potential pit; harmonic oscillator; the Krönig-Penney model; solution to the issue of the Koulomb potential.
38.	Corrosion testing in materials engineering	The phenomenon of corrosion and mechanisms of various types of electrochemical and chemical corrosion, thermodynamic determinants of corrosion phenomena: corrosion vs. passivity – Pourbaix diagrams, qualitative and quantitative methods in corrosion studies – overview, polarization and polarization curve with its characteristic points and ranges, determination of corrosion current potential and density from extrapolation by Tafel equation, chronoamperometry and determination of the time of initiation and propagation of pits in corrosion Basics of electrochemical impedance spectroscopy: surrogate circuits and real elements of materials and coatings, salt chambers, immersion tests.
39.	Anodic oxides of copper and its alloys – production, characteristics and applications	Synthesis and mechanism of growth of passive layers on copper, review of applied methods and experimental conditions in the production of copper oxides and hydroxides by electrochemical, thermodynamic conditions allowing for the growth of oxides and hydroxides, redeposition and growth of layers, modifications of copper oxides and hydroxides, applications of nanostructured copper oxides and hydroxides: corrosion protection, photocatalysis, electrochemical reduction of carbon dioxide to alcohols and hydrocarbons.
40.	Anodizing Aluminum Alloys	Structure and mechanical properties of alloys and corrosion resistance, mechanisms of corrosion destruction of common aluminum alloys, overview of industrial anodizing methods, conversion coatings vs. anode coatings, soft, hard and plasma anodizing (PEO / MAO), hexavalent chromium problem, chromium-free alternatives used in anodizing aluminum alloys, nanoporous oxide and corrosion protection, pore closure, REACH convention and anodizing and closing pores, durability of anodic aluminum oxide on technical alloys, methods of quantitative capture of corrosion of aluminum alloys after anodizing.

Curriculum content for elective subjects
Scientific discipline: mechanical engineering

Ip.	Item Name	Program content
1.	Numerical analyses in load-bearing structures	Theoretical foundations of numerical methods of analysis of load-bearing structures including multi-stage analyses, FEM computer simulation strategy of two- and three-dimensional issues in the field of mechanics and strength of materials, and methodology of simplification (reduction of static schemes) of real structures enabling the creation of a correct and effective numerical model. Methods of modeling mechanical structures with particular emphasis on load-bearing structures using graphics preprocessors. Construction of 2D and 3D models for analysis in the field of selected engineering issues, performance of calculations with attention to the selection of optimal analysis parameters and evaluation of the correctness of calculation results with the use of analytical methods and available results of experimental tests, on the example of elements and subassemblies of vehicles, special and load-bearing structures.
2.	Autonomy of mobile robots	Introduction, definitions, components of mobile robot construction. Drive systems of wheeled robots. Navigation and self-location of robots. Navigation using markers. Odometry, methods of improving self-localization results. Determine the position of the robot from the map. Methods for planning the path of a mobile robot. Local planning, probabilistic methods. Tasks, construction, architecture of control systems Vision systems in mobile robotics. Walking robots. Applications of autonomous mobile robots.
3.	Non-destructive testing of aircraft	Types of defects, defects and damages that threaten the safety of operation of technical facilities. Non-destructive testing methods – physical basics. Visual and penetrative methods. Ultrasound method. Acoustic methods. Current Viral Method. Thermographic method. X-ray method. Shearography and DSight. Non-destructive testing methods – advantages, disadvantages and limitations in use. Non-destructive testing certification.
4.	Biomechanics of human body movement during a road accident	Biomechanics of the human body. Human anthropometric analysis. Dynamic loads and the process of injury formation. Basics of building measuring dummies. Basics of modeling the human body. Computer simulation of the movement of a human body model and experimental research. Calculating the risk of injury to the head, torso and thighs. Injury risk forecasting models.
5.	Construction and operation of industrial robots	Construction and principle of operation of industrial robots. Principles of robotization of production lines. Environments and languages for programming industrial robots
6.	Digital signal processing	Mathematical models of deterministic signals. Advanced signal sampling techniques. Selected problems of discrete signal analysis in the time and frequency domain. Frequency resolution of digital spectral analysis algorithms. Quick weave algorithm. Selected specialized implementations of digital filters. The basics of digital filter design. Decimation and interpolation of digital signals. Digital signal spectrum conversion. Direct Digital Signal Generation Method (DDS). Software receiver.
7.	Dynamics of mechatronic system design	Issues of modeling mechatronic systems. Elements of motion and vibration analysis of linear systems with one and many degrees of freedom. Elements of motion analysis of nonlinear mechatronic systems. Stability testing of linear and nonlinear mechatronic systems. Self-excitation vibrations. Methods of measuring vibrations of mechatronic systems.
8.	Car dynamics	Modeling the movement of a car. Motion modeling on hard, snowy and deformable ground. Analysis of dynamics of rectilinear and curvilinear motion. Controllability and stability. Overcoming off-road obstacles. Wheeled and tracked chassis. Modeling the process of collision of a car with an obstacle. Analysis of vibrations and driving comfort of the car.
9.	Dynamics and modeling of hydrostatic systems	Principles of dynamics of hydrostatic systems. Description of the dynamics of the units and drive systems. Steady and transient, start-up processes. Dynamic analysis and its description. Modeling of assemblies, subassemblies, elements and

Ip.	Item Name	Program content
		hydrostatic drive systems. Open and closed systems. Modeling of hydrostatic systems in MATLAB-SIMULINK.
10.	Dynamics of multi-part systems	Theoretical foundations of numerical methods of analysis with the use of rigid solids and strategy of computer simulation of multibody with the use of various algorithms for formulating equations of motion and their integration. Overview of multibody analysis software environments and sample solutions in the field of mechanical engineering. Methods of modeling mechanical structures using rigid solids in planar and spatial systems. Construction of planar and spatial models using various applications for the analysis of kinematics and dynamics of multi-component systems in the field of selected issues of mechanical engineering. Multi-variant numerical analyses with attention to the selection of optimal calculation parameters and the assessment of the correctness of the obtained results using analytical and experimental methods.
11.	Impulse loads of motor vehicles – selected issues	Operating conditions of motor vehicles, dynamic loads – sources. Impulse loads – characteristics. Experimental and model studies of impulse loads acting on vehicles, methods and design solutions to reduce the effects of these interactions.
12.	Computer-aided machine operation	Operational system information needs. Information management – information system. Characteristics of computer software. Design and operation of management IT systems. Features of IT systems supporting operation management. ICT services in management.
13.	Shaping a safe car body	Body construction - shaping energy-intensive zones and survival zones; construction of the floor slab. Estimating the energy dissipated by the body during a collision. Materials used in body construction. Body equipment - passive and preventive safety elements. Paint coatings. Crash tests.
14.	Composite materials in mechanical engineering and operation	Definition and classification of composite materials. Strength and performance properties of composite materials. Technologies for the production of composite materials. Tests used in the experimental analysis of mechanical properties of composites. Joining composite materials. Metal-composite joints. Exploitation of composite materials. Repairs of composite structures.
15.	Finite Element Method	Selected examples of FEM applications. FEM in displacement terms. Bar structures. Triangular and quadrangular elements. Flat state of stress and strain. Axisymmetrical issues. Plate and coating elements in FEM terms. Three-dimensional elements. Selection parameters when creating an FEM mesh – criteria. Isoparametric formulation of finite elements. Shape features. Definition of initial boundary conditions. Material models in FEM terms. Structure of the rigidity matrix. Global matrix aggregation. Transformations of quantities between coordinate systems. Matrix equilibrium equation. Methods of solving systems of equations. Analysis of the model and results. Basics of adaptive methods with criteria. Determination and measures of error.
16.	Methods of analysis of numerical and experimental research results	Selected deterministic and stochastic examples in research methodology allowing to use the results of experimental research both in the process of validation of numerical models and verification of the obtained results using the nonlinear method of least squares, verification of statistical hypotheses, or analysis of ANOVA variance.
17.	Methods of testing the condition of machines	Basic terms and definitions. Condition of the object. Object model. Methods of analysis and recognition of the state of the object. Classification and recognition of emergency states of objects. Criteria and rules for the selection of decision variables. Procedures and methods of testing the condition of the machine. Selected aspects of the construction of measurement and diagnostic systems. Vibroacoustic systems for testing the condition of machines. Computed tomography of machines. The use of artificial intelligence in the study of the condition of machines.
18.	Experimental methods for investigating thermophysical properties of solids	Thermophysical properties of solids, thermal conductivity, specific heat, thermal diffusivity, thermal expansion. Mechanical properties of solids – dynamic mechanical analysis (DMA).
19.	Methods and techniques of testing the mechanical	Methods of testing mechanical properties under quasi-static load conditions. Impact tests. Methods for determining material constants. Methods of static strength testing of elastomeric and ceramic materials. Methods of measuring

Ip.	Item Name	Program content
	properties of materials	hardness and microhardness. Methods of measuring deformation during strength tests. Methods of testing the mechanical properties of materials under shock load conditions. (Hopkinson test, Taylor test, ring test).
20.	Numerical Methods in Engineering Applications	Basic concepts related to numerical calculations, sources of errors. Interpolation and approximation. Differentiation and quadrature. Systems of linear equations. Algebraic eigenproblem. Methods of solving ordinary differential equations. Linear problem of least squares. Fourier analysis. Optimization elements. Information on other areas of numerical analysis (partial differential equations, stochastic methods, etc.).
21.	Numerical Methods in Mechanical Engineering	Basics of numerical methods. Interpolation polynomials. Approximation methods. Integration methods. Methods of solving systems of equations. Methods for solving nonlinear equations. Methods of solving differential equations. Application of numerical methods in mechanical engineering, including CAD/CAE systems.
22.	Methods of design and optimization of aeronautical structures	Parameterization of aerodynamic structure geometry, dimensionless form factors. Optimization methods in application applications. Numerical optimization methods: structural modeling, shape-dimensional optimization. Stages of the optimization process. Aircraft quality indicators, task and mission modeling in aircraft optimal design tasks. Converging and divergent design spiral. Systems and systems that are subject to the optimization process: geometry, aerodynamics, powertrain, mission, performance, structure and mass properties. GRIP programming language for Siemens NX. Application of the GRIP language to the processes of searching for the optimal geometry of the designed optimization object using integrated design systems.
23.	Constitutive Models of Materials in FEM Analysis	Mathematical description of constitutive models of materials such as steels, alloys, rubbers, elastomers, foams, ceramics, etc. Experimental studies to determine the parameters of models. Numerical analyses using learned material models.
24.	Modelling of heat transfer processes	The subject prepares to formulate mathematical models of heat and mass transfer processes, which require solution of the boundary-value problems for systems of partial differential equations. Within the framework of lectures mechanisms of complex and coupled (conductive-radiative) heat and mass transfer, constitutive equations of Cattaneo-Vernotte and Tzou dual-phase lag models, selected analytical as well as numerical methods of solution both the direct (including phase transitions) and the inverse heat conduction problems are discussed. During tutorials and laboratory practices, PhD students use practically knowledge gained in lectures to find analytical solution of simple radiative heat transfer problems and they are searching for numerical solutions of coupled heat and mass transfer problems by using their own numerical codes as well as commercial software
25.	Modeling and simulation of mechatronics issues	Principles of physical, mathematical modeling and parametric identification of the model. Application of the Matlab/Simulink environment in the simulation of mechatronics problems
26.	Modeling and simulation of nonlinear mechanics	Description of the implementation of deformations of solids characterized by physical nonlinearity in the range of small and large deformations. Introduction to numerical methods for solving nonlinear problems and methods to refine the solution.
27.	Parametric modeling and structural optimization using FEM	Theoretical foundations of the optimization procedure. Optimization algorithms. Methods of structural optimization using FEM structural analyses. Methods for creating MES parametric models using preprocessor scripts. Analysis of optimization results. Topologic optimization.
28.	Flow modeling	Methods of computer modeling of flow processes in basic and applied issues of fluid motion dynamics. Simulation methods of research on streamlined issues. Basics of flow-through process modeling. Conservative formulations of basic equations of fluid mechanics, boundary conditions in computational problems, basic numerical schemes and the basic computational solver CFD - Fluent. Flow turbulence modeling, including averaged Navier-Stokes equations, turbulent stress tensor, turbulence modeling capabilities and problems. Direct methods of solving turbulent movements (the so-called DNS method), the large vortex method (LES). Mapping of complex simulation test objects, construction and performance of basic operations on computational grids, analysis of reliability and accuracy of numerical modeling results.
29.	Machine Motion Modeling	General principles of modeling mechanical systems. hydrostatic, electromechanical. Deterministic and random processes. Construction of simulation models. Identification of model parameters and their validation. Characteristics of basic dynamic terms. Fundamentals of dynamics of systems with variable mass.

Ip.	Item Name	Program content
30.	Modeling composite structures	The use of laminates. Laminate configuration. Micromechanics and macromechanics of laminates. Modeling at the level of lamina and laminate. Determination of material parameters. Stiffness and strength of laminates. Strength hypotheses. Design elements and modeling of composite (laminate) structures. Analysis of the strength of the composite structure for selected load conditions.
31.	Contact Modeling in Structural Mechanics	General classification of contact phenomena. Mathematical foundations of description and solution of the problem of contact. Algorithms for defining and solving the contact problem in the environment of computer-aided engineering calculations. Use of a large-scale approach.
32.	Modelling and research of wheel-road cooperation processes	Issues of modelling and research of wheel-to-road cooperation processes to the extent necessary to model the dynamics of vehicle movement (selected mathematical models, methods and techniques of testing tire wheels on a drum stand and with the use of a test trailer).
33.	Modeling of car movement and control	An overview of vehicle dynamics models and models describing the driver-vehicle-road system (models of car lateral dynamics in various control configurations).
34.	Modern technologies for joining construction materials	Friction Stir Welding (FSW), Laser Beam Welding (LBW), Areas of Application and Strength Properties of Obtained Cohesion Joints. The influence of bonding processes on the microstructure of selected construction materials. Heat and mechanical treatment of FSW and LBW cohesion joints.
35.	Modern design and manufacturing systems CAD\CAM\Additive Manufacturing	Computer aided CAx design, construction and manufacturing systems. CAM process support systems. Additive manufacturing technology – Rapid-prototyping, Rapid-manufacturing and reverse engineering techniques.
36.	Renewable energy sources	The importance of energy in the development of modern civilization. Modern energy sources based on fossil raw materials and ecological factors. Renewable energy sources. Solar energy. Wind energy. Hydropower. Geothermal energy. Bioenergy. Energy from the use of hydrogen as the fuel of the future. Energy storage systems.
37.	CAE Engineering Software	An overview of CAE engineering support systems with an indication of their purpose and the possibility of using them in structural analyses. Preparation of numerical models for calculations in the static and dynamic range. Running calculations and presenting and processing the results obtained.
38.	Experiment planning and mechanical object optimization	Introduction to experiment planning. Measurement errors and uncertainties. Characteristics of random variables. Statistical hypotheses and their verification. Correlation and regression analysis. Planning your experiment. Two-tier plans. Three-level plans. Multi-tier plans. Simplex plans for composition-property analysis. Criteria for the optimality of plans. Optimization in machine technology. Extremes of statistical functions and their limitations. Methods for determining the extrema of statistical functions. Examples of experiment optimization in mechanical engineering.
39.	Road safety basics	Basics of road safety analysis. Modeling the course of a road accident. Models of driver action. Methods of road accident analysis. Safety in the traffic of autonomous vehicles. Road accident statistics and their interpretation.
40.	Basics of Intake Air Filtration for Internal Combustion Engines in Partition Filters	Classification of intake air filters of internal combustion engines. Performance requirements for air filters. Porous filter materials. Aerosol filtration mechanisms in a fibrous bed. Models of filtration efficiency and aerosol flow resistance in a fibrous bed. Properties of papers and filter composite materials with the addition of nanofibers. Types and methods of shaping filter partitions. Panel, cylindrical and core inserts. Criteria for selecting air filters for the vehicle engine. Rules for the use and operation of air filters.
41.	Basics of Intake Air Filtration for Internal Combustion Engines in Inertial Filters	Classification and characteristic values of inertial filters. Types of cyclones. Characteristic dimensions of the cyclone. Geometric parameters of cyclones. Factors determining the effectiveness of cyclones and multicyclones. Aerosol filtration process in cyclones. Forces acting on a particle in a cyclone. Condition for the separation of a particle from a gas. Formulas for determining the diameter of the boundary grain. Models of filtration efficiency and gas flow resistance in a cyclone. The impact of dust extraction from the clarifier on the efficiency of multicyclone operation. Criteria for the selection of inertial filters for motor vehicle engines. The essence of intake air filtration for engines in two-stage filters.

Ip.	Item Name	Program content
42.	Fundamentals of Continuous Media Mechanics	Fluid mechanics in the field of statics and hydrodynamics, mechanics of deformable solids in the field of elasticity and plasticity theory, modeling of materials.
43.	LabVIEW in experimental studies	The process of creating programs in the LABVIEW environment with the use of control and measurement equipment (myRIO, sbRIO, DAQmx). Data types in LABVIEW. Complex data types in LABVIEW, Communication with measuring devices in LABVIEW. Analysis of measurement results.
44.	Starting processes for internal combustion engines	Engine starting characteristics. Crankshaft drive characteristics of engines. Ignition processes and fuel combustion under start-up conditions. Characteristics and models of start-up processes. Methods and devices of starting aid. Diagnostic aspects of the boot process.
45.	Programming control systems for unmanned working machines and robots	Introduction to the UML standard. Construction of relational diagrams and use case diagrams. Creating control algorithms. Introduction to programming, programming devices for hydrotronic applications. Feedback loop design. Implementation of feedback loops in control systems.
46.	Mechatronic sensors	Mathematical models of mechatronic sensors. General principles of operation of mechatronic sensors. Methods of measurement, defects and methods of calibration of sensors.
47.	Condition monitoring systems	Sensors used in condition monitoring. Resistance strain gauge. Fiber optic sensors. Crack sensors. Data transmission. Recording and analysis of measurement data. Inference. Coupling of condition monitoring systems with the maintenance and operation system.
48.	Aircraft Operation Systems	Rules for the operation and overhaul of military aircraft in the Republic of Poland. Harmonized European Military Airworthiness Regulations (EMAR). European Airworthiness Regulations (PART). The role of EASA and the Civil Aviation Authority in supervising the operation of aircraft. Bulletins and other documents regulating operation.
49.	Control systems in mechanical engineering	Advanced control systems for mobile machines. Machine control system functions. Types of control systems. Development trends of sensors used in mobile machines. Vision and lidar localization and navigation systems. Satellite systems in machine control Centralized and distributed control. Smart communication networks. PLC control. Fuzzy logic in machine control
50.	Technologies for the production and processing of composite materials	Composites, ways of defining them, types of components that make up them, more important methods of their production and processing, the importance of this class of materials in mechanical engineering. The structure of modern composite materials depending on the method of production and the treatment used, e.g. heat, heat and plastic. Manufacturing of ceramic matrix composites and multilayer metallic composites and achievements in the use of composites.
51.	Selected solutions in the field of automotive technology and vehicle movement	Problems of development of automotive technology and road traffic. Intelligent transport systems concepts. Selected issues of modern automotive technology (progress in engine construction, development of drive systems - solutions used in modern gearboxes, all-wheel drive, adjustable and active suspensions, wheel hubs, new tire designs, lighting systems). Driver assistance systems. Autonomous cars.
52.	Theory and organization of machine operation	Processes of machine operation. Measurement and analysis of diagnostic signals. Machine diagnostic procedures. Features and measures of machine reliability. Reliability of repairable objects and systems. Planning the use and renewal of machines. Process and system design. Principles of rational operation of machines.
53.	Thermomechanics of materials and thermophysical properties research	Phenomenological description of processes related to the accumulation and transport of energy in the form of heat in substances and presentation of selected issues of statistical description of these phenomena to explain the nature of thermophysical properties. Heat transfer phenomena in materials and material structures. Properties of materials and resultant and apparent properties of material structures. Methodology of testing thermophysical properties. Thermal analysis methods. Methods for determining specific heat, thermal conductivity, thermal diffusivity, thermal expansion of materials and material structures.
54.	Tribology	Tribology – interdisciplinary and multidisciplinary science. Tribological systems of machines and technical devices. Solids and liquids as structural elements of tribological systems. Friction processes in tribological systems of machines. Tribological wear processes of machine components. Lubrication in tribological systems of machine components. Selected methods of friction and wear tests of

Ip.	Item Name	Program content
		machine components. Contemporary tribological problems - from nano to tera tribology. Microsystems and tribological nanosystems. Selected research techniques of tribological microsystems. Micro/nanomechanical research. Micro/nanotribological studies. Application of micro/nanotribological test results. Selected problems of biotribology and ecotribology.
55.	Durability of aircraft structures	Methods for determining and testing the durability of aircraft. Aircraft operation concepts, factors limiting the durability of aircraft, the impact of operation on durability, load measurement and monitoring, methods of estimating aircraft durability, full-scale fatigue tests, techniques of non-destructive testing in aircraft operation. Corrosion of aircraft.
56.	Introduction to Mathematical Physics Equations	Formulation of mathematical models of physical processes that require the solution of boundary problems for systems of partial differential equations. General principles of formulating boundary problems for partial differential equations. The method of deriving equations describing convection, diffusion and wave transport is discussed. A general approach to building mathematical models based on mathematical physics equations. The method of reducing boundary issues to a dimensionless form is discussed. Formulating mathematical models based on mathematical physics equations.
57.	Modern machine and vehicle drive systems	Engines used to drive machines and vehicles. Piston internal combustion engines. Turbine internal combustion engines. Electric motors. Hybrid powertrains. Energy storage systems. Other energy sources for powering machinery and vehicles. Ecological aspects of the use of different powertrains. Directions of development of propulsion systems of machines and vehicles.
58.	Modern methods of testing internal combustion engines and vehicles	Identifying the purpose of the research. Selection of the test method. Validation of research methods and procedures. Homologation test procedure. Selected methods of homologation tests, measuring equipment. Processing of measurement results. Analysis of outliers, estimation of measurement uncertainty. Analysis and presentation of test results. Calibration of measuring systems. Practical implementation of selected research methods.
59.	Selected methods and techniques of temperature measurement	Theoretical foundations of temperature measurement, contact and non-contact temperature sensors (structure, principle of operation), their dynamic properties and related measurement errors, and calibration procedures. Types of thermometers: liquid, thermoelectric, resistive, thermistor, quartz, bimetallic, radiation, fiber optic and thermal imaging cameras. Statistical processing of measurement results
60.	Selected problems of rocket technology	Mathematical models of physical processes related to the dynamics of rocket movement. General principles of rocket construction. Construction of rocket compartments with mathematical models. Computer simulation and visualization of the flight path of rockets. Rocket overloads on the flight path.
61.	Selected issues of waste gas treatment from motor vehicles	The impact of the automotive industry is on the environment. Characterization of harmful substances. Systems and methods of waste gas purification of motor vehicles. Development trends in flue gas treatment methods. Test methods and equipment for the testing of exhaust gases from internal combustion engines and vehicles. Studies of the influence of the operating condition of the internal combustion engine on the emissions of individual exhaust components and the granulometric composition of particulate matter.
62.	Selected issues of simulation of combustion processes and working processes of internal combustion engines.	Simulation tasks. Selection of the simulation method. Selected models of the internal combustion engine duty cycle. Workflow simulation software. Procedure for simulating selected workflows. Analysis and presentation of simulation results. Evaluation of simulation results. Simulation of selected working processes of internal combustion engines.
63.	Selected issues of contemporary programming - an introduction to	Introduction to programming using high-level languages. The issue of structured and object-oriented programming. Introduction to Python with basic libraries and the PyCharm environment. Creating console programs using Python. Introduction to creating programs with a graphical user interface.

Ip.	Item Name	Program content
	modern programming languages.	
64.	Fatigue strength and fracture mechanics of materials and structures	Material fatigue phenomena and quantities describing the fatigue process. Basics of design and strength calculations of structures in the field of unlimited and limited fatigue life. Application of the principles of fatigue strength of materials and fracture mechanics. Fatigue test methodologies and fatigue testing devices. Crack development due to cyclic loads. Characteristics of fatigue crack growth. Methods for assessing the strength of components containing cracks
65.	Advanced methods for manufacturing products from sintered powders	Processes of manufacturing machine parts using modern methods of manufacturing engineering, including powder metallurgy.
66.	Advanced ballistics, modeling and simulation departments	Development trends in the field of solid projectile materials and projectile systems (theoretical foundations for modeling the operation of atypical projectile systems from the point of view of internal ballistics). Outflow of powder gases from the barrel during firing and their flow through the muzzle brake (description of phenomena occurring during the outflow of gunpowder gases from the barrel during firing - transient ballistics). Geometric, mass-inertial and aerodynamic characteristics of missiles and rockets (theoretical foundations for modeling the movement of flying objects from the point of view of external ballistics). Modelling of impact effects of objects (theoretical basis for analytical and numerical modelling of phenomena that are the domain of final ballistics).
67.	Advanced Math Departments	Basics of tensor calculus. Vector and Euclidean space. Activities in Euclidean space. Base and determination of the matrix of the change of base. The concept of tensor. Tensor space. Base and polybase. Basic tensor operations and operations. Euclidean valence tensors 2. Types and properties of tensors, tensor distribution. Tensor invariants. Values and main directions. Scalar, vector and tensor fields. Derivative of tensor function, tensor field gradient, divergence, and rotation of vector field. Stress and strain tensors. Strain energy density. Constitutive equations. Basics of variation calculus. Functional. A variation of the functional. Conditions of the minimum functional – Euler's equations. Formulation of local and global balance issues
68.	Advanced modeling in structural dynamics	Methods of solving dynamic problems in computer terms. Constitutive modeling for impulse-loaded structural cases. Implementation of impulse extortion – analytical and coupling approach. Testing the response of the structure. Description of the dynamic interaction of two bodies for the contact problem.
69.	Advanced Measurement Systems	Structure and organization of computer-controlled measurement systems and with procedures and selected "tools" for programming system controller controllers. concepts and basic methods of numerical calculations. Basics of programming and ways to use virtual instruments to collect, collect and develop measurement data.
70.	Advanced Materials Testing Methods	Methods of testing materials, possibilities and limitations of various test methods based on the use of specialized equipment. Contemporary electron microscopy, confocal microscopy and X-ray microanalysis (qualitative and quantitative) and their practical use in mechanical engineering. Methods of testing the macro- and microstructure of metals, their alloys and ceramic materials and interpretation of test results obtained by various methods of material testing. Topographic contrast and its use for fractographic studies, evaluation of changes in the microstructure of materials as a result of treatments, testing of powders and thin surface layers. Microanalysis of phases and inclusions in materials studies. Studies of material heterogeneity. Trace analysis of elements. Light microscopy in materials research. Metallography. Image analysis. Electron beam and its properties. Electron diffraction. Construction of scanning and transmission electron microscope.
71.	Application of experimental mechanics in scientific research 1	Mechanical properties of engineering materials. Testing the mechanical properties of materials in static tests. Elaboration of experimental research results.
72.	Application of experimental mechanics in scientific research 2	Rheological research. Determination of material characteristics in cyclic load tests. Determination of material characteristics in shock load tests. Testing of materials at high and very high strain speeds. Non-destructive testing.

Ip.	Item Name	Program content
73.	Application of the Finite Element Method in Mechanical Wave Propagation Analysis	Issues related to wave propagation (elastic, plastic). Mathematical description of the phenomenon of propagation of mechanical waves. Boundary conditions. Methods to solve the presented issue. Numerical analysis of wave propagation.
74.	Selected issues of vibration theory	Equations of motion of systems with only two degrees of freedom. Free vibrations of conservative systems. Free vibrations of non-conservative systems. The Force Method. Forced vibrations, resonance analysis. Vibrations forced by any force. Free vibrations of discrete systems with any finite number of degrees of freedom. Frequencies and forms of vibrations. Vibrations of continuous systems.
75.	Selected issues in acoustic electronics	Physical Basics of Acoustic Electronics. Properties of volumetric and surface waves. Excitation and propagation of surface waves in piezoelectric materials. Analytical models of acoustic surface wave transducers. Classification of Acoustic Electronic Components. A technique for generating and processing complex signals. Selected signal processing methods, compression receiver, generator. Physical quantity sensors. Nonlinear Acoustic Surface Wave Components and Their Applications. Elements of acoustic surface wave component technology.
76.	Numerical methods	Selected elements of linear algebra. Systems of linear equations, vector and matrix norms. Determining the solution of a system of linear equations - conditioning indicator. Gaussian method of numerical solution of a system of linear equations. Direct methods of numerical solution of a system of linear equations (LU distribution method, inverse matrix method). Iterative methods for numerical solution of a system of linear equations (Jacobi and Gauss-Seidler methods). A linear problem of least squares. Methods for approximate solving of nonlinear algebraic equations. Interpolation with polynomials. Glued functions. Approximation of functions. Integration and numerical differentiation of functions. Methods of numerical solution of ordinary differential equations.
77.	Electromagnetic field theory	Maxwell's equations; Differential form of Maxwell's equations in material media; Maxwell's equations for harmonically variable fields; Integral form of Maxwell's equations. Electromagnetic waves in an ideal dielectric; TEM type flat wave; Wave impedance and specific impedance. Electromagnetic waves in a losing medium. Boundary conditions and energy relationships in an electromagnetic field. Power balance in electromagnetic field in real and complex description. Real, complex, and time-mean Poynting vector. A wave falling diagonally on the dielectric-dielectric boundary; Fresnel formulas for a plane wave falling diagonally on the boundary of two dielectric media. Reflective and power transmission coefficients. A wave falling perpendicular to the dielectric-dielectric boundary. Determination of reflectance and power transmission coefficients for a plane wave incident perpendicular to the boundary of two dielectric media. Electromagnetic waves in waveguides. Wave fashions. Potentials in electrodynamics and radiation from current sources; Vector and scalar potential. Electromagnetic potentials are delayed. Potentials generated by localized sources. Hertz's dipole.
78.	Quantum mechanics	Wave function and Schrödinger's equation. Probabilistic interpretation of a wave function. Probability current density. Expected value. Separation of the wave equation. Formalism of quantum mechanics; Vector space n-dimensional; Space Base; Scalar product; Hilbert space; Orthogonality of vectors and systems. Orthonormal bases; Linear operators; Operator equations; Operator matrix representation; Hermitian and unitary operators; Dirac notation. Selected solutions of the Schrödinger equation in 1D; A quantum particle in an infinite well of potential. A free quantum particle. Uncertainty of observables - Heisenberg's uncertainty principles. Values and eigenfunctions of a quantum harmonic oscillator. Creative and annihilation operators. Separation of the Schrödinger equation in 3D. A quantum particle in a spherical potential well in 3D. Values and eigenfunctions of the angular momentum operator. The spin theory of the electron. - Pauli matrices. Mutual indeterminacy of the components of the spin. Entangled states and non-locality. - The concept of entangled states and qubit. Their role in new quantum technologies.

Annex VI.6

to the Curriculum at the Doctoral School of the Military University of Technology

Curriculum content for elective subjects
Scientific discipline: chemical sciences

Ip.	Item Name	Program content
1.	Analysis of warfare poisonous agents	General characteristics and classification of combat poisonous agents. General physicochemical properties of BST. Toxicological, tactical, chemical classification. Basic concepts of toxicology. Possible hazards and required health and safety rules when working with poisonous warfare agents. Organophosphorus poisonous agents. Poisonous agents with a necrotic effect. Methods for the preparation of samples containing BST and their decomposition products for analysis. Analytical methods used in the analysis of BST, their precursors and their degradation products. Analytical methods used in the analysis of BST, their precursors and their degradation products. Modern instruments for contamination analysis in field conditions. Use of chromatography for BST analysis. Determination of sulphur mustard gas and its degradation products by gas chromatography (GC-MS/MS). Identification of BOST from the FOST group and their degradation products by liquid chromatography (LC-MS/MS).
2.	Chemistry and technology of liquid crystal materials	Molecular structure, structure and texture of CK. Elements of the structure of the molecule and the synthesis of CK compounds with thermotropic properties. Optical and dielectric properties, viscosity and elastic constants of CK. Electro-optical effects and principles of LCD operation. Chiral CK compounds, their properties and applications.
3.	Chemistry and technology of high-energy materials	Current state of knowledge in the field of chemistry and technology of modern explosives, powders and rocket fuels: structural determinants of the stability and sensitivity of explosive compounds; design, manufacture and characterization of nanostructured explosive mixtures; principles and methods of changing the shape, dimensions and morphology of the surface of explosive particles; new ways of producing explosive compositions and forming them into charges; design, manufacture and characterization of thermobaric explosives; design, synthesis and explosive properties of complex compounds; design, synthesis and properties of high-energy and high-nitrogen ionic salts and liquids, as well as new components of complex powders and rocket fuels (polymers and oxidizers).
4.	Polymer chemistry	Polymers obtained by the process of chain polyreaction. Condensation polymers, polyadducts. Inorganic-organic polymers. Polymers of natural origin. Special-purpose polymers.
5.	Chemistry of heterocyclic compounds	A course in organic chemistry covering saturated and aromatic heterocyclic compounds, methods of their obtaination, reactivity, use and importance. The course emphasizes the acquisition of the ability to plan and predict the synthesis of organic compounds that have a ring structure, whereby one or more carbon atoms forming a ring are replaced by an atom or atoms of another element (the so-called heteroatoms). Heteroatoms are most often nitrogen, oxygen, and sulfur atoms.
6.	Chemical Basis of Environmental Pollution	Basics of ecology. Man and the environment. Natural resources and ecological factors: temperature, radiation, air, water and soil. Humanity in the face of global challenges. The paradigm of sustainable development. Principles of green chemistry. Air pollution (acid flux, ozone depletion, greenhouse effect, London and Los Angeles smog). Sources of water pollution (municipal, industrial and agricultural pollution). The most important pollutants found in wastewater. Seawater pollution. Water treatment. Soil contamination. Types of harmful effects of human activity on soil: geomechanical, hydrological and chemical transformations, physical and biological degradation. Heavy metals, their characteristics, sources and impact on the environment and human health. Characteristics of cleaning and washing agents (soaps, detergents). Negative effects of cleaning and washing products. Chloroorganic compounds in the environment (chlorophenols, polychlorinated biphenyls, dioxins). Pesticides. Classification of pesticides and their properties. Chemical structure of pesticides. Pesticide Utility Forms. Benefits and problems of pesticide use. Building materials (paints, adhesives, asbestos, formaldehyde-containing products, oils) and their impact on the environment and human health. Volatile organic compounds (VOCs). VOC sources. Harmful effects of VOCs in the stratosphere. Pharmaceuticals and personal protective equipment in water. Classification, sources of origin, occurrence and impact of drug residues on the environment. Food chemistry.

Ip.	Item Name	Program content
		Classification and characteristics of food additives (preservatives, enhancers, antioxidants, flavor enhancers, sweeteners, colorants). Dietary supplements.
7.	Chemoinformatics	The course covers methods of computer representation of chemical structures and techniques for organizing and exploring chemical databases. The methodology for determining molecular descriptors and the principles of creating, optimizing and validating statistical models of the QSAR and QSPR types are discussed. The program also covers the issues of virtual screening, molecular docking and the use of machine learning algorithms in the analysis of chemical data.
8.	Chiral and polar liquid crystal functional materials	Basic concepts of functional and intelligent materials based on liquid crystal materials, both medium and large-molecule, with particular emphasis on those with chiral and polar phases. Methods for the development of chiral liquid crystal materials (ChMCC) and polar liquid crystal materials (PMCK). Description of basic methods confirming the structure/composition and physicochemical properties of ChMCK and PMCK (m.in. spontaneous polarization, director's tilt angle, helical and helical structure parameters, SHG, thermo-, chemo- and electro-optical response). Methods of measuring the described properties. Methods of modification and optimization of ChMCK and PMCK properties. Applications of the above as functional and/or intelligent materials.
9.	Physicochemical properties of carbon materials	Carbon - a chemical element and a macromolecule - a material with unique physical, physicochemical and chemical properties. Structure and properties of carbon materials (MWeG): monocrystalline graphite, graphene, natural and industrial graphite, glass-like carbon, carbon black and activated carbons, carbon and graphite fibers, fullerenes, carbon nanotubes, diamonds and diamond layers. Carbon composites. Carbon quantum dots, their production and application. Obtaining MWeG, modifying their properties and test methods. Reactivity and bioactivity of carbon materials. Prospects for the development of new coal structures and their applications.
10.	Physicochemical aspects of the explosion	Explosion and detonation processes. Classical theory. The Zeldovic-von Neuman-Doring Detonation Theory. Perfect and imperfect detonation. Detonation parameters in gases and solid explosives. Thermochemistry of explosives – codes for calculating detonation and explosion parameters. Initial parameters of shock waves at the detonation-external medium boundary. Flaring factors of the explosion. Gust waves in the air. Impact of blast waves on people and objects – criteria, danger zones. The crushing and projectile effect of the explosion. Assessment of the crushing ability of explosives. Driving bodies with detonation products. The phenomenon of accumulation, designation of debris hazard zones. Explosive hazard of gas mixtures.
11.	History of chemistry	The synthesis of elements in the universe, the first observations and chemical achievements of antiquity (alchemy). History of chemical discoveries in the world: physical chemistry, analytical chemistry, chemical analysis, organic synthesis, food chemistry. Achievements of chemistry after 1661 (R. Boyle). Development of techniques for separating substances and analysis and their impact on the development of views on chemistry and the structure of chemical compounds. Evolution of nomenclature and symbols of elements and chemical compounds. History of Mendeleev's periodic table, kinetic and thermodynamic research. The development of organic chemistry and synthesis in the twentieth century and its influence on the emergence of molecular biology.
12.	Ionization methods in analytics	Classification of ionization methods of chemical substances. Sources of ionization and methods of production of primary ions. Direct ionization of the analyte. Chemical ionization in positive and negative modes. Electron capture. Simple ionization detectors. Movement of ions in gases. Ion balance. Ion motility spectrometry. Analyte ionization in mass spectrometry. Coupling of mass spectrometers with chemical ionization systems – PTR-MS systems. Studies of kinetics and thermodynamics of ionization processes. An overview of the applications of ionization methods in analytics.
13.	Methods for preparing samples for analysis	Methods of preparing samples for their determination using gas chromatography techniques – general classification and initial discussion. Traditional methods of sample preparation for analysis compared to modern separation techniques. Solid samples: Soxhlet extraction, ultrasonic, supercritical SFE, accelerated by ASE solvents. Liquid samples: liquid-liquid extraction, solid phase extraction (SPE), SPME micro-extraction, displacement and capture method, supersurface phase analysis method. Gas samples: enrichment methods using sorption, freezing and desorption techniques. New aspects of environmental sample analysis. Calibration. Certified reference materials. Discussion of the sources of systematic and

Ip.	Item Name	Program content
		accidental errors, most often made during sampling and preparation. Ways to avoid their occurrence.
14.	Spectroscopic methods	A subject for PhD students in disciplines other than chemical sciences. Electron spectroscopy (UV-Vis), oscillating spectroscopy (IR), nuclear magnetic resonance spectroscopy (NMR), mass spectrometry (MS). The PhD student can additionally choose spectroscopic methods from the following group of methods: near-infrared spectroscopy (NIR), Raman spectroscopy, oscillation-rotational and rotational spectroscopy, two-dimensional nuclear magnetic resonance spectroscopy (2D NMR), circular dichroism spectroscopy (ECD and VCD), fluorescence spectroscopy.
15.	Modeling and simulation computer programs in chemistry	Basics of computational chemistry: assumptions and computational methods. Organization of the CHEMCAD program and basics of use. Application of CHEMCAD in chemical technology and materials engineering. Implementation of a project in the field of chemical technology using the CHEMCAD system. Organization of the SCIGRESS program and basics of use. Optimization of geometry and calculation of physicochemical properties of molecules. Modeling of chemical reactions in gas phase and solution. Modeling spectroscopic properties of molecules.
16.	Modern nanoporous materials	The latest developments in the field of nanostructures. An overview of techniques for studying the structure, morphology, chemical composition, surface and thermal properties of nanomaterials. Nitrogen and argon adsorption as a complete method for determining the specific surface area, porosity and surface properties of nanoporous materials. The latest developments in the field of nanoporous silica materials. The latest developments in the field of nanoporous carbon materials. Properties and application of activated carbons obtained from polymers. Organometallic networks (MOFs). Obtaining and investigating the adsorption properties of graphene composite materials. Study of physicochemical properties of porous materials obtained by mechanochemical method.
17.	Modern methods of synthesis of functional organic compounds	Introduction to functional materials – division, applications. Liquid Crystals, Properties, Applications, Liquid Crystals – Typical Classes – Correlation Structure – Properties. LC synthesis – synthesis of yesterday and today and synthesis of key intermediates. Synthesis of superfluorinated materials. Synthesis of positive nematics and s negative nematics. Synthesis of chiral liquid crystal compounds. OLED, OSC, OFET materials – structure, properties, applications. Organic emission materials – types and properties. Synthesis of organic p-type materials and n-type materials. Synthesis of semiconductor polymer materials and other organic functional materials
18.	Biomedical polymers and biomaterials	Definition of biomaterials, classification, role of chemical composition, working environment, properties and applications of biomaterials. Metal biomaterials. Ceramic biomaterials. Polymer biomaterials. Carbon and composite biomaterials. Modern polymer and hybrid systems used in biomedicine for diagnostic purposes (e.g. contrasts for magnetic resonance imaging) and therapeutic purposes (e.g. drug carriers).
19.	Field detection and analysis of hazardous materials	An overview of analytical techniques with the potential for miniaturization. Currently used analytical techniques in portable devices: classical infrared spectroscopy (FTIR), Raman spectroscopy (RS), ion mobility spectrometry (IMS), mass spectrometry (MS), laser-induced fluorescence (LIF), X-ray backscattering (BSX), selective electrodes, flame spectrometry (FS), laser detection and imaging (LIDAR). Examples of devices using the mentioned analytical techniques will be presented. The limitations of the methods and the prospects for their development will be discussed.
20.	Practical tools and concepts of modern organic synthesis	An advanced course in organic chemistry with an emphasis on acquiring the ability to plan syntheses of complex organic compounds. The use of modern organic synthesis techniques. Chemistry of organofluoric compounds. Flow chemistry in organic synthesis. High-pressure organic reactions.
21.	Liquid crystal synthesis	Introduction to liquid crystals, structure and anisotropic properties. Applications of liquid crystal, display and photonic materials. Methods for determining liquid crystal phases. Two-component and multi-component liquid crystal mixtures, non-additive behaviors. Superfluorinated liquid crystal materials, synthesis of fluorinated materials - an overview of synthesis methods. Design of liquid crystal synthesis, retrosynthetic analysis in the synthesis of LCs, review of transition metal-catalyzed coupling methods, typical pathways of LC synthesis. Purification and planning processes for multi-stage syntheses. Synthesis of chiral liquid crystal materials.

Ip.	Item Name	Program content
22.	Advanced pyrotechnics	The latest solutions used in military and civilian pyrotechnics. Currently used reducers, oxidizers, binders and modifiers. Pyrotechnic applications of high-nitrogen compounds. Modern compositions of curtain smokes active in the infrared range. Contemporary with multi-base solid rocket fuels. Solutions used in airbag inflators. Prospective applications of pyrotechnic mixtures in medicine. Basic algorithms used in modeling combustion processes and analytical optimization of the composition of pyrotechnic compositions.
23.	Advanced spectroscopic methods	A subject for doctoral students of the discipline of chemical sciences. Extension of knowledge on basic spectroscopic methods: electron spectroscopy (UV-Vis), oscillatory spectroscopy (NIR, IR, Raman), nuclear magnetic resonance spectroscopy (NMR), mass spectrometry (MS). Advanced spectroscopic methods, including time-resolution, two-dimensional, combined techniques.
24.	Applications of Organic Chemistry in Health and Functional Products	Introduction to chemistry of bioactive compounds in health and functional products. Classification and regulatory requirements for medicines, dietary supplements and nutraceuticals. Structure-activity relationship (SAR) analysis for vitamins, polyphenols, and terpenoids. Design of organic syntheses of active substances: review of key transformations (alkylations, esterifications, condensations) and selection of methods for selectivity. The use of protective groups and the role of stereochemistry in the synthesis of chiral compounds. Comparison of synthesis pathways and quality standards for pharmaceutical and supplementation substances. Synthesis of compounds of natural origin, insulation techniques and challenges of process optimization on an industrial scale. Problems of adulteration, contamination analysis and methods of detecting composition inconsistencies in market products.

to the Curriculum at the Doctoral School of the Military University of Technology

Curriculum content for elective subjects

Scientific discipline: security sciences

L.p.	Item Name	Program content
1.	Social Research in Security Sciences	Scientific approach in social research. Implications of the Location of the Discipline of Security Science in the Field of Social Sciences. The logical-empirical character of the social sciences. Basic research approaches in the field of theory construction, data collection and analysis. Basic concepts and elements of the research process. Theory and practice of operationalization of a research problem. Methods and techniques of quantitative and qualitative research. Non-reactive methods. Desk <i>research</i>
2.	Statistical methods in social research	Population and sample. Statistical features. Measurement scales. Random variables. Normal distribution. Characteristics of qualitative and quantitative features. Non-parametric estimation. Parametric estimation (point and interval). Verification of statistical hypotheses. Structure diagram of the significance test. Testing the normality of the distribution. Problems of analysis of the interdependence of phenomena. The research process in the social sciences and the typical structure of scientific work. The process of data collection, analysis and evaluation.
3.	Risk and Business Continuity Management in Security	Risk and uncertainty in action. Risk as a decision criterion in ensuring safety. Operational risk and the effects of making it realistic. Causes and analysis of the consequences of business disruptions. Risk management strategies. Risk assessment methods.
4.	Security systems project management	Identification of security systems. Identification of the essence, structures and attributes of the project. Complexity of projects and processes. Criteria for process analysis and evaluation. Creating process structures. Evaluation and validation of processes. Efficiency and quality of processes. Reliability of process structures. Risk in the evaluation of projects and processes. Holistic models of evaluation and validation of processes and designs of security systems. Contemporary IT tools and techniques to support project management processes.
5.	Safety Systems Engineering	The place of systems security theory in the family of sciences. Basic concepts of system security (system state, description of system security statuses, system security indicators). Principles of mathematical modeling of system security. Component and subsystem safety. Systems security models. Systems security research. Analysis of the security of systems. Control of safety, systems.
6.	Safety propaedeutics	Characteristics of three dimensions of modern security. Development of security studies. Realism and neorealism. Comparative analysis of realistic trends. The theory of liberalism in explaining security challenges and threats. The theory of constructivism. The main schools of security studies "Old" and "new" wars in interpretations of realism and constructivism.
7.	Strategies and concepts of state security management	The process of creating concepts and expressing the essence of security. Ambiguity in the understanding of international security. Safety relativity in functional terms (consciousness, relativity, environment). Verbal-functional factors and ways of defining security in doctrines and strategies (comparative analysis).
8.	Crisis management in public administration	Contemporary concepts of crisis management (the concept of vulnerability, the concept of resilience, the concept of adaptation). The subject of crisis management. Legal Basis of Crisis Management in Poland. Crisis management process. Basic types of threats – sources of crisis situations. Crisis situation. Crisis management system in Poland. Effectiveness in crisis management.
9.	Civil Protection and Civil Protection	The evolution of civil protection in Poland. Legal Bases of Civil Protection and Civil Defence. Entities and bodies performing civil protection tasks. Civil protection and civil defence tasks. Planning in civil protection and civil defense. Recognize threats, notify, warn and alert about threats. Education in the field of civil protection and civil defense. Civil protection and civil defence in selected countries of the world.
10.	Homeland Security	Perception of safety. Political determinants of internal security. Institutional system of internal security. Administrative police in the internal security system. Private entities in the internal security organization. Organization of security in the region. Organization of security in the county. Organization of security in the county.
11.	Threat Intelligence	The importance of threat analysis for security research and practice. Basic concepts and definitions in the field of threats. Identification, typology, taxonomy

L.p.	Item Name	Program content
		of threats. Quantification and measurement of threats. Assessment of hazard probabilities, hazard impacts, and hazard risks. Threat management.
12.	Designing an energy security strategy as a safety measure subjective	The essence and components of energy security and related subjective security. The energy security environment in the context of its threats and related challenges for energy security (macro) and subjective security (micro) in the national and international dimension. Development goals, innovative solutions and directions for shaping the energy security strategy as a measure of subjective security, taking into account the national interest and the implementation of the requirements of the EU Parliament.
13.	Survey Data Analysis	Creating measurement tools. Sample selection. Preliminary analysis. Analysis of timetables. Contingency tables, boundary and conditional distributions. Analysis of single-choice and multiple-choice questions. The significance and strength of the relationship between nominal and ordinal variables. Hypothesis testing.
14.	Forecasting and simulations in safety	Forecasting and social practice. Social premises for predicting behavior. Forecast and decision-making. Model methods. Extrapolation of trends. Accuracy, admissibility and error of forecast. Forecasting based on time series. Forecasting based on econometric models. Heuristic forecasting models. Social simulations.
15.	Multivariate analyses	Methods of graphical presentation of multidimensional data. Multiple regression analysis. Analysis of canonical correlations. Principal component analysis. Exploratory factor analysis (EFA). Multidimensional scaling. Linear ordering. Cluster analysis.
16.	Evaluation Study Procedures	The concept of evaluation studies. History and institutionalization of evaluation research. Types of evaluation studies – the concepts of "impact assessment", "action research". Differentiation of evaluation studies in terms of their social functions. Experimental schemes in evaluation studies. The Concept of Experimental Society by A. Etioni. Monitoring and evaluation. Elements of cost-benefit analysis in evaluation studies. Problems of measurement in evaluation studies.
17.	Logic and Theory of Argumentation	Logical argumentation. Deductive, reductive and inductive inferences. Diagrams and schemes of argumentation. Recognizing arguments. Creating a diagram. Implicit premises and conclusions. Elements of argumentation evaluation. Acceptability of premises. Reliability of sources. Relevance.
18.	Modern technologies in security	Know-how, modern technologies and their importance in ensuring safety. Modern technologies in the defense and protection system. Modern technologies in the system of economic security of the state. Modern technologies in the social security system. The use of modern safety technologies in electricity generation, in the transport system, in the protection of critical infrastructure, in the protection of the natural environment.
19.	Philosophy of Security Sciences	Origin, subject and branches of philosophy and philosophy of safety as the most general knowledge of safety. The Genesis and Types of Human Knowledge in Philosophical Discourse (Mystical, Intuitive, Philosophical, and Scientific Sources; Types: Scientific, Theoretical, Practical, and Intuitive). The logic of scientific discovery, revolution in science and the progress of knowledge in the perspective of contemporary epistemology. Semantic analytics of the name security and types of its understanding – the essence of security in a philosophical approach. A natural and conventional concept of security. Materialistic, idealistic and realistic concepts in the hermeneutic basis of security. The praxeological concept of the four simple acts and universal methods of shaping security. Trends in broadening, deepening and thickening security research The method of war, peace, non-peace and non-war in the praxeological perspective. Philosophical problems of security in contemporary societies of control and surveillance from the perspective of dataism and technohumanism.
20.	Modern terrorism	Basic concepts and their meaning. The Origins of Terrorism. Causes of modern terrorism. The main factors generating and escalating terrorism. Systematization of the causes of terrorism. The triad of terrorist motivation. Key elements and types of terrorist threat. The scope and nature of terrorism at the beginning of the 21st century. Effects of terrorism. Preventing and combating terrorism.
21.	Morale and Security Culture in National and International Relations	The essence and importance of the safety culture (KB) and morale (M) of physical and legal entities in internal and international relations. Psychosocial and praxeological models and "mechanisms" of the functioning of KB and M – relations between them. Security culture (KB) and morale as types of key resources and factors of competitive advantage in "normal" and crisis situations. Security culture as an interface integrating the security areas in question and the national security system (SBN). Intuitive and scientific ways of diagnosing and improving KB and M. Security culture and morale in times of information wars and asymmetric conflicts

L.p.	Item Name	Program content
22.	Security history	Military, political and economic security of medieval Polish and the Polish-Lithuanian Commonwealth until its collapse. The main problems of European security in the nineteenth century. Polish National Uprisings of the Nineteenth Century. World War I. Determinants of international security in the interwar period. Military, political, economic and social security of the Republic of Poland (1918–1939). World War II. International security in the second half of the twentieth century. U.S.-Soviet relations and their impact on international security. Military, political and economic security of Polish after World War II.
23.	Strategic communication	Characteristics of strategic communication (terminology, essence, responsibility in NATO). Public diplomacy (terminology, essence, structures). Informing the public (terminology, essence, structures). Information operations (NATO methods, views, US views and structures, Polish views). Psychological operations (methods and techniques of action, structures of the USA, German structures, Polish structures, structures of Great Britain).
24.	Political security sector	Political security. Concepts. Political Security in Security Sciences. Forms and types of political threats and determinants and research of political security. A model of institutionalization of political security. The need for citizen security and the tasks of a democratic state. A crisis of civic identity. Power as a security factor. Security Strategy as an Instrument of Political Security. The influence of interest groups on political decisions. Media – shaping public opinion. The basic dilemma of political security.
25.	Shaping military security in the 21st century	Characteristics of military security of selected states and associations of states in relation to the methodology of identifying and describing challenges, and thus potential opportunities and threats to the existence and development of individual societies. The terminology of military security, the components of this security, the impact of these elements on the state and process of military security in the face of the identified and described challenges (opportunities and threats) in the perspective of the current century.
26.	Information security	Definitions and interpretation of basic terms: threat, vulnerability, security, incident, information security. Basic processes of information asset protection: authentication, authorization, settlement. Formal models: Bella-LaPauduli, Biby, Ciarka-Wilson, Brewer-Nash. Basic security claims. Security policy, main objectives and challenges. Risk management and assessment of the state of protection of information resources.
27.	The economic dimension of safety	Defining economic security and its dimensions. Economization of state security. Typology of economic security threats. The state and the national economy in the face of contemporary cultural and civilizational changes. Economic aggression in international relations. Financial crises. Activities of transnational corporations. Technological espionage as a threat to economic security. State activity to ensure economic security.
28.	Energy security in the face of socio-economic transformation	The impact of socio-economic transformation on the functioning of the energy industry of developing and developed countries, and thus also on the energy security of these countries. A parallel process of influencing the way the energy industry operates, as well as the functioning of the energy security sector to protect this industry from threats (both old and new, generated by current socio-economic changes).
29.	Social determinants of the security of modern states	The essence of social security. Social security and the model of the state system. Mechanisms shaping social security. Concepts of social security. Models of social security in the EU. Problems of social security in Poland and ways of overcoming them. EU action for social security.
30.	Environmental security on a global, regional and national scale	Types of challenges (opportunities and threats) generated by climate change in the area of ecological security. Identification of the impacts of climate change on the national security of selected societies both on a national, regional and global scale.
31.	Geopolitical determinants of the security of countries and regions	The essence of the impact of geopolitics on the security of countries and regions. Types of security determinants of the main subjects of international relations in the context of different approaches to geopolitics. The strength of the influence of geographical and political factors compared to other determinants of the security of states and regions. The nature of the future impact of geopolitical factors on the security of key countries and regions of the world.

L.p.	Item Name	Program content
32.	Security policy of the Republic of Poland of the 21st century	Security typologies. National interest. Historical conditions of security. Security periodization. Doctrinal Foundations of Polish Security. National Security Strategies. The national security system. Treaty Foundations for Security. Bilateral cooperation. Regional cooperation. Allied conditions of national security. Strategic partnership in the area of security policy.