COURSE DESCRIPTION AND OBJECTIVES

1.1. COURSE DESCRIPTION

This course "**Satellite project phases 0/A/B**" is designed for engineers or engineering students with little or no experience in a space-related field. It provides an introduction to the space environment to explain the factors to be taken into account for designing a space product, and it explains more specifically satellite subsystems with the design process (phases 0/A/B) and its methods.

1.2. TOPICS OF THE COURSE

The topics cover the following phases of a space project:

- **Phase 0: Mission analysis and need identification**
  - supports the identification of customer's needs;
  - proposes possible system concepts;
  - supports the Mission Definition Review (MDR) and ensures the implementation of the MDR actions;
  - performs an analysis of the Mission Statement document, and integrates this analysis and any relevant contribution from lower level suppliers into a Mission Description document;
  - proposes the requirements according to the user's needs for the agreement with the customer.

- **Phase A: Feasibility study**
  - finalizes the expression of the needs identified in Phase 0;
  - proposes system solutions (including the identification of critical items and risks) to meet the customer's needs;
  - supports the Preliminary Requirement Review (PRR) and ensures the implementation of PRR actions;
  - finalizes the validation of the requirements according to the expressed needs together with the customer.

- **Phase B: Preliminary Definition**
  - establishes the system preliminary definition for the system solution selected at the end of Phase A;
  - demonstrates that the solution meets technical requirements according to the schedule, the target cost and the customer's requirements;
  - supports the System Requirements Review (SRR) and Preliminary Design Review (PDR), and ensures the implementation of the SRR and PDR actions;
  - defines developmental approach and the plan of engineering activities.

SCHEDULE

The timeline schedule is presented in the table below.

Lp.		Data:	Dzień tygodnia:	Temat:	Liczba godzin:	Prowadzący
1	Week 1	21.05.2021	piątek	A.3.1 Space environment	4	Błęcki
2	Week 1	22.05.2021	sobota	A.1 Introduction to space technology	2	Mężyk
				A.2 Orbital mechanics	6	Sochacki
3	Week 1	23.05.2021	niedziela	A.3.2 Space environment interaction on materials and mechanics of spacecraft	8	Boczkowska/Ossowski
4	Week 2	28.05.2021	piątek	B.2 Platform – Thermal Control System	4	Furmański
5	Week 2	29.05.2021	sobota	B.2 Platform – Thermal Control System	4	Furmański
6	Week 2	30.05.2021	niedziela	B.2 Platform – Structure	6	Michałowski
7	Week 3	11.06.2021	piątek	B.2 Platform – Data Handling	4	Kurek
8	Week 3	12.06.2021	sobota	B.2 Platform – Attitude and Orbit Control System	8	Narkiewicz
9	Week 3	13.06.2021	niedziela	B.2 Platform – Propulsion	6	Kindracki
	Week 3	13.06.2021	niedziela	B.2 Platform – De-orbitating systems	2	Mężyk
10	Week 4	18.06.2021	piątek	B.2 Platform – Data Handling	4	Kurek
11	Week 4	19.06.2021	sobota	B.2 Platform – Data Handling	2	Kurek
				B.2 Platform – Power supply	6	Wawrzaszek
12	Week 4	20.06.2021	niedziela	A.4 Launchers and ground segment	2	Kurek
				B.1 Payload	2	Kurek
13	Week5	25.06.2021	piątek	C.1 Spacecraft design process	4	Mężyk
14	Week5	26.06.2021	sobota	C.1 Spacecraft design process	6	Mężyk
15	Week5	27.06.2021	niedziela	D.1 Case study	8	Mężyk

Piątek: 1 2 3 4 — Sobota: 1 2 3 4 L 5 6 7 8 — Niedziela: 1 2 3 4 L 5 6 7 8

On Friday, classes start at 4 p.m., on Saturday and Sunday, classes start from 9.30 a.m. to 6.30 p.m. with an hour-long lunch / lunch break between 1.30 p.m. and 2.30 p.m.
On Saturdays and Sundays, there will be 1 lunch break - 60 minutes (1.30 pm - 2.30 pm), coffee breaks set

COURSE UNITS DESCRIPTION

Whole course content will be divided into four main parts. First, three parts focus on the maximum information about space environment and its interaction with satellite; space system architecture and design process. Fourth part is some kind of exercise where lecturer interacts with course participants.

Part A – Space environment, spacecraft-environment interaction

Course title	A.1 Introduction to space technology
Objectives of the course:	• To achieve basic knowledge on satellite technology applications; • To build the awareness of the universality of use and multiplicity of space applications; • To provide basic knowledge on space missions and national programs; • To build the awareness on space policies; • To give an overview on space industry.
Course contents:	The course is dedicated to give a brief introduction to space industry in general. The course comprises: • Definition of upstream, midstream and downstream technologies; • Types of space services, with examples; • Objectives of space services; • Types of space missions; • Introduction to space industry, customers, supply chain; • The most popular space missions: scientific, commercial, public services; • Brief history of space programs, main trends and factors; • European and global space policy; • Future missions and strategies;
Recommended reading:	• Peter Fortescue, Grahan Swinerd, John Stark, *Spacecraft Systems Engineering*, Wiley, 2011; • A.F. Inglis, A.C. Luther, *Satellite Technology: An Introduction*, Focal Press, 1997;

	• Malcolm Macdonald, Viorel Badescu, *The International Handbook of Space Technology*, Springer Praxis Books, 2014; • Guy Collins, *Europe in Space*, Palgrave Macmillan, 1990; • Greg Matloff, C Bangs, Les Johnson, *Harvesting Space for a Greener Earth*, Springer Praxis Books, 2014; • Joseph N. Pelton, Scott Madry, Sergio Camacho-Lara, *Handbook of Satellite Applications*, Springer New York, 2016 • W. Ley, K. Wittmann, W. Hallmann, *Handbook of Space Technology*, John Wiley & Sons, Ltd, 2009.

Course title	A.2 Orbital mechanics
Objectives of the course:	The objective of the course is to present the main aspects of spacecraft motion. The acquired knowledge will allow to understand how the “position” of spacecraft in space is described by means of orbit, how the orbit is changed due to manoeuvres and disturbances acting on a spacecraft, how the orbit is related to spacecraft’s ground track and visibility. The course should provide the background forthe mission analysis.
Course contents:	• The two-body problem: equation of motion in non perturbated, spherically symmetric gravity field, Kepler’s Laws, types of orbits (circular, elliptical, parabolic, hyperbolic), orbital position as function of time, orbits in three dimensions, orbital parameters; • Orbital manoeuvres: impulsive manoeuvres, Hohmann transfer, bi-elliptic Hohmann transfer, phasing manoeuvres, apse line rotation, plane change manoeuvres; • Relative motion and rendezvous; • Interplanetary trajectories: sphere of influence, method of patched conics, planetary departure, planetary flyby; • Orbital perturbations: atmospheric drag, gravitational perturbations, solar radiation pressure, third bodies gravity; orbital systems: lunch window considerations, ground track, orbital coverage, satellite constellations.
Recommended reading:	• Curtis, Howard D. *Orbital mechanics for engineering students*. Butterworth-Heinemann, 2013; • Chobotov, Vladimir A. (ed.). *Orbital mechanics*. Aiaa, 2002; • Gurfil, Pini. *Modern astrodynamics*. Butterworth-Heinemann, 2006;

	• Montenbruck, Oliver; Gill, Eberhard. *Satellite orbits: models, methods and applications*. Springer Science & Business Media, 2012; • Schaub, Hanspeter; Junkins, John L. *Analytical mechanics of space systems*. Aiaa, 2003; • Wie, Bong. *Space vehicle dynamics and control*. Aiaa, 1998.

Course title	A.3.1 Space environment
Objectives of the course:	Basic knowledge about space environments, plasma and space physical processes. Basic knowledge about Sun activity and interactions with the Earth environment. Disturbances in the near Earth's space. Significance of space environments processes, influence on technical devices in space and for radio communication and satellite navigation as well on the security of the space crew
Course contents:	The Earth in the Solar System, definition and basic information about space plasma, Earth magnetic fields, ionosphere – structure and variation, overall information about the Sun, solar radiation, magnetosphere, space radiation, influence on technical devices and the human being
Recommended reading:	• Tadanori Ondoh and Katsushida Marubashi, *Science of the Space Environment,* Tokyo, 2001, ISBN 1586030973; • Y.Kamide, A.Chian, *Hanbook of the Solar-Terrestrial Environment*, Springer, 2007.

Course title	A.3.2 Space environment interaction on materials and mechanics of a spacecraft
Objectives of the course:	To teach basic definitions and classes of materials used in spacecraft's structures; To provide overall knowledge on the requirements and properties which material must fulfill in space environment; To show the possibilities of modifying material's properties to obtain materials with desired properties; To provide knowledge on a selection of materials for particular applications; To provide basic knowledge on spacecraft mechanics.

Course contents:	The course is oriented on teaching advanced engineering materials used for spacecraft applications. The course comprises: • Requirements for materials used in space environment, materials for mechanical elements, influence of the environment on properties of materials, special requirements for material processing for space applications, fundamentals of material strength. Materials to be covered: metallic alloys, intermetallics, ceramics, polymers, composites, intelligent structures, nanomaterials. Examples of materials deterioration under space conditions; • Directions of materials development for space applications; • Tribology and mechanical wear of mechanisms under space condition. Selection of lubricants (solid or liquid) and lubrication methods; • Selection of materials and possibility of their modification to improve their durability in space conditions; • Possibility of improvement and protection of mechanisms of spacecraft against wear in space conditions.
Recommended reading:	• Klaus Wittmann, Willi Hallmann, Wilfried Ley, *Handbook of Space Technology*, Wiley, 2009; • E. Wyn Roberts, *Space Tribology Handbook*, ESR Technology Ltd., 2013; • George E. Totten, *Handbook of Lubrication and Tribology Vol. 1*, CRC Press Taylor & Francis Group, 2006; • G.W. Stachowiak, A.W. Batchelor, *Engineering Tribology*, Butterworth-Heinemann, 2005; • R. Talreja, J.A.E. Manson, *Comprehensive Composite Materials*, vol. 1-3, Pergamon, 2000.

Course title	**A.4 Launchers and ground segment**
Objectives of the course:	To provide basic information on tasks and the architecture of a ground segment, ground station and launchers.
Course contents:	The course comprises: • Tasks of the ground station in communication with a satellite (TC, TM, payload data channels); • Architecture of the ground segment in a satellite system; • Architecture of the ground station: ○ structure of the ground station;

	◦ parabolic antenna; ◦ tracking a satellite; • Communication session with a satellite; • Examples of existing ground stations; • Networks of ground stations; • Launchers, especially payload systems.
Recommended reading:	• B. Elber, *The Satellite Communication Ground Segment and Earth Station Handbook*, Artech House, 2014; • Klaus Wittmann, Willi Hallmann, Wilfried Ley, *Handbook of Space Technology*, Wiley, 2009; • Rajat Acharya, *Satellite Signal Propagation, Impairments and Mitigation*, Elsevier, 2017; • E-ST-50 (Communications) standards sieries of ECSS (European Cooperation for Space Standardization) http://ecss.nl/

PART B – SPACE SYSTEM ARCHITECTURE

Course title	B.1 Payload
Objectives of the course:	• To familiarize with the spacecraft payload design process; • To build the awareness of the strong relation between mission goals and payload instrumentation; • To introduce the path of decision making process; • To provide basic knowledge on the system requirements for the payload; • To present the payload instrumentation on the example of the • EO mission.
Course contents:	The course is dedicated to give a brief introduction to space industry in general. The course comprises: • Mission goals definition with the customer; • Payload requirements definition, design and sizing; • Payload constrains, limitation and trade-offs in relation with mission objectives; • Spacecraft subsystems selection according to the payload requirements; • Service module design and sizing: requirements, constrains and design process, configuration, design budgets; • Payload TRL; • Payload and BUS interfaces;

	• Example of the payload instrumentation for the Earth Observation mission.
Recommended reading:	• Wiley J. Larson, James R. Wertz, *Space Mission Analysis and Design*, Microcosm Press, 1999; • Charles D. Brown, *Elements of Spacecraft Design*, AIAA, 2002; • Peter Fortescue, Grahan Swinerd, John Stark, *Spacecraft Systems Engineering*, Wiley, 2011; • Klaus Wittmann, Willi Hallmann, Wilfried Ley, *Handbook of Space Technology*, Wiley, 2009; • Michael D. Griffin, James R. French, *Space Vehicle Design*, AIAA, 2004.

Course title	B.2 Platform: structure
Objectives of the course:	To teach the basics of spaceship construction, environmental and technical aspects of design, mechanisms used in satellites and ensuring their proper functioning.
Course contents:	Knowledge how to ensure correct functioning of mechanisms in: vacuum, microgravity, ionizing radiation, temperature shifts, vibration. Mounting of components still and movable; Type of structure, advantages and disadvantages of each solution; Construction materials; Influence of subsystems on the structure configuration; Launcher – satellite interface; Brief introduction to structural strength; Methods of structural analysis (examples); Tribo-component selection, design and performance: rolling bearings, plain bearings, linear bearings, gears; Solvent cleaning.
Recommended reading:	• Emyr W. Roberts, *Space Tribology Handbook*, ESR Technology Ltd., 2013; • Brown, C. D., *Elements of Spacecraft Design,* Reston: AIAA, 2002; • P. Fortescue, J. Stark, G. Swinerd, *Spacecraft Systems Engineering*, Wiley, 2007; • Website: http://www.esmats.eu/esmatspapers/ • Website: http://ntrs.nasa.gov/search.jsp?R=20160004038

Course title	B.2 Platform: Thermal Control System
Objectives of the course:	The objective of the course is to present methods of a thermal control of satellites and spacecraft. Heat transfer modes will be discussed together with their role in heat transfer in space. Subsequently, the active and passive methods of thermal protection will be presented. Finally, a thermal testing will be briefly described.
Course contents:	• Thermal environment of the space; • Heat dissipation in satellites and spacecraft and its distribution; Thermal problems in space and temperature range requirements; Determination of temperature and heat fluxes; • Basic and complex heat transfer modes (heat conduction, convection and radiation); • Thermal properties of spacecraft components; • Role of the thermal contact resistance; • Passive methods of temperature control (thermal insulations including MLI, selective coatings and changing thermo-optical properties, thermal fillers, thermal washers and spreaders, radiators and mirrors, heat storage materials (PCM), heat pipes (including heat switches), radio-isotope heaters, ablative materials); • Active methods of temperature control (electric heaters, thermoelectric heaters and coolers, louvers, fluid loops, Stirling coolers, spray cooling); • Thermal control testing of spacecraft components (thermal cycling, thermal balance and thermal vacuum test and facilities).
Recommended reading:	Selected chapters from: • INCROPERA, F.P., *Fundamentals of Heat and Mass Transfer* (6 ed.), John Wiley & Sons, 2006; • HOWELL J.R., SIEGEL R, MENGÜÇ M.P., *Thermal Radiation Heat Transfer* (5th edition) Taylor & Francis, 2010; • GILMORE D.G., *Spacecraft Thermal Control Handbook*, The Aerospace Corporation Press, 2002; • DONABEDIAN, M., *Spacecraft Thermal Control Handbook Volume 2: Cryogenics*, The Aerospace Corporation, 2002; • MESEGUER J., PÉREZ-GRANDE I., SANZ-ANDRÉS A., *Spacecraft Thermal Control*. Woodhead Publishing Limited, 2012;

	• KARAM, R.D., *Satellite Thermal Control for Systems Engineers*, Progress in Astronautics and Aeronautics, AIAA, 1998; • FORTESCURE P. STARK J., SWINERD G., *Spacecraft Systems Engineering*, John Willey&Sons, 2004; • V. BATURKIN, *Micro satellites thermal control concepts and components*,. Acta Astronautica 56 (2005), pp. 161-170.

Course title	B.2 Platform: Attitude Determination and Control System
Objectives of the course:	The objective of the course is to present the process of controlling spacecraft's attitude. The relation between mission goals and the design of ADCS will be discussed with regard to requirements formulation. The sensors and algorithms for attitude determination and control will be described.
Course contents:	• Description of ADCS and its role in the spacecraft and mission design and requirement formulation, relationship with other spacecraft subsystems; reference systems: heliocentric, Earth inertial, Earth-fixed, orbit, body-fixed; • Basics of attitude representation methods and attitude dynamics, disturbance torques; attitude sensors: star sensor, sun sensor, earth sensor, magnetometers, gyroscopes, GNSS; attitude actuators: thrusters, magnetorquers, momentum exchange devices; • Attitude determination and control methods.
Recommended reading:	Selected chapters from: • LEY Wilfried; WITTMANN, Klaus; HALLMANN, Willi (ed.), *Handbook of space technology*. John Wiley & Sons, 2009; • BROWN Charles D., *Elements of spacecraft design*. Aiaa, 2002; • EICKHOFF J., ROESER,H.-P., *Simulating spacecraft systems*. Springer, 2009; • FALANGAS E.T., *Performance Evaluation and Design of Flight Vehicle Control Systems*. John Wiley & Sons, 2015; • GRIFFIN M.D., *Space vehicle design*. AIAA, 2004; • NEBYLOV A., *Aerospace Sensors*. Momentum Press, 2012; • PISACANE V.L., (ed.). *Fundamentals of space systems*. Johns Hopkins University, 2005;

	• TEWARI A., *Advanced control of aircraft, spacecraft and rockets*. John Wiley & Sons, 2011; • WERTZ J.R. (ed.), *Spacecraft attitude determination and control*. Springer Science & Business Media, 2012; • WIE, B., *Space vehicle dynamics and control*. AIAA, 1998; • ZIPFEL, P.H., *Modelling and simulation of aerospace vehicle dynamics*. AIAA, 2000.

Course title	B.2 Platform: Data Handling – On Board Computer
Objectives of the course:	• To provide basic information on tasks and architecture of an on-board computer; • To present types and structures of collected data (TC/TM, Payload data)
Course contents:	The course comprises: • Tasks of the on-board computer; • Architecture of the on-board computer: hardware, software, reliability and robustness – protection against space environmental exposure, telecommand types (TC), telemetry data (TM), payload data; • External interfaces: CAN, RS485, RS422, MIL-STD1553, Spacewire, Ethernet/IP; • Data formats and transmission protocols (according to ECSS standards): TC packets, TM packets, payload data packets; • Elements of the on-board computer (structure, solutions, basic parameters): core processor (FPGA- LEON3-FT, ARM, PowerPC), memory (ROM, RAM, Flash), interface drivers, software; • Software development process.
Recommended reading:	• Jens Eichkhoff, *Onboard Computers, Onboard Software and Satellite Operations*, Springer, 2012; • Klaus Wittmann, Willi Hallmann, Wilfried Ley, *Handbook of Space Technology*, Wiley, 2009; • Vincent L. Pisacane, *Fundamentals of Space Systems*, Oxford University Press, 2005; • Herbert Hecht, *Systems Reliability and Failure Prevention*, ArtechHouse, 2003; • E-ST-50 (Communications) and E_ST-40 (software) standards series of ECSS (European Cooperation for Space Standardization) - http://ecss.nl/

Course title	B.2 Platform: Data Handling – Communication System
Objectives of the course:	To provide basic information on tasks and architecture of a communication system; To present basics analysis of link budget and examples of calculations.
Course contents:	The course comprises: • Tasks of the communication system; • Organization of communications between a satellite and a ground station GS (TC, TM, payload data channels); • Architecture of the communication system: general structure of radio-communication system (transmitter and receiver), structure of satellite communication system (satellite -GS link, satellite-satellite link); • Organization of data transmission: layer model, protocols, data packets, modulations, speed of data transmission and signal bandwidth, channel coding, frequency bands; • Elements of the communication system (structure, solutions, basic parameters): antennas, TC/TM transponder, payload data transmitter, ground station (structure, parabolic antenna, satellite tracking); • Basics of radio link budget: antenna gain and radiation pattern, attenuation of radio channel (free space loss, losses in atmosphere), power flux and received signal power, received signal quality – influence of noise and interferences (signal to noise ratio, energy per bit to noise spectral density, signal to interference ratio), bit error rate (noise characteristics for different modulations, influence of channel coding); • Examples of radio link budget calculations: satellite – GS link, satellite-satellite link.
Recommended reading:	• Klaus Wittmann, Willi Hallmann, Wilfried Ley, *Handbook of Space Technology*, Wiley, 2009; • Anil K. Maini, Varsha Agrawal, *Satellite Technology: Principles and Applications*, Wiley, 2011; • Joseph N. Pelton, Scott Madry, Sergio Camacho-Lara, *Handbook of Satellite Applications*, Springer, 2017; • Rajat Acharya, *Satellite Signal Propagation, Impairments and Mitigation*, Elsevier, 2017; • E-ST-50 (Communications) standards series ECSS (European Cooperation for Space Standardization) http://ecss.nl/

Course title	B.2 Platform: Propulsion
Objectives of the course:	To provide basic information about rocket propulsion for launch vehicles, satellites and space probes; To present basic analysis of different space maneuvers using different types of devices.
Course contents:	The course comprises: • Definitions and basic parameters of rocket engines; • Type of rocket engines; • Division on rocket engines based on the function and energy source: solid, liquid, hybrid and non-chemical rocket engines; • Basics of combustion process and combustion disorders in rocket engines; • Rocket propellants; • Basics of thermodynamic calculations; • Combustion chambers and cooling of the engines; • Nozzles – types, characteristic features, examples; • Engine feeding systems – type, features, pros and cons, examples; • Analysis of maneuvers using different types of the engines Present and future rocket engines – examples.
Recommended reading:	• Klaus Wittmann, Willi Hallmann, Wilfried Ley, *Handbook of Space Technology*, Wiley, 2009; • Sutton, George P., and Oscar Biblarz, *Rocket propulsion elements,* John Wiley & Sons, 2017; • Jahn, Robert G., *Physics of electric propulsion,* Courier Corporation, 2006; • Mattingly, Jack D., and Hans Von Ohain, *Elements of propulsion: gas turbines and rockets,* Reston, Virginia: American Institute of Aeronautics and Astronautics, 2006; • Sforza, Pasquale M., *Theory of aerospace propulsion. Butterworth-Heinemann*, 2016; • Curtis, Howard D., *Orbital mechanics for engineering students,* Butterworth-Heinemann, 2013; • Fortescue, Peter, Graham Swinerd, and John Stark, eds., *Spacecraft systems engineering,* John Wiley & Sons, 2011; • Chobotov, Vladimir A., ed., *Orbital mechanics,* Aiaa, 2002; • Barrere, Marcel, et al., *Rocket propulsion. No. OA-2,* LTAS, • Dieter, K. H., and H. D. Huang, Scientific and Technical Information Office, NASA (1971).

Course title	B.2 Platform: Power Supply
Objectives of the course:	The main objective of the course is to describe the major role, characteristics, properties and technical solutions related to satellite power systems. In the frame of the course, a brief description of power sources, acquisition, storage and distribution will be provided.
Course contents:	Role of satellite power system: methods of operation and its main properties depending on the mission type and mission target; • Description of Satellite Power system elements: ▪ energy sources used in space – properties and description, ▪ energy storage – properties, description, components, ▪ power conversion and distribution units – properties, description, components; • Structure and components of typical solutions of the satellite power system; • Power budget calculation; • Safety factors, derating rules, risks related to satellite's power system.
Recommended reading:	• Wertz James R. and Larson, Wiley J., *Space Mission Analysis and Design 3rd Edition*, Space Technology Library, Springer NY, 1999; • Ley Wilfried and Wittmann, Klaus and Hallmann Willi, *Handbook of Space Technology*, Wiley, 2009; • Hyder A.K., Wiley R.L., Halpert G., Flood D.J., Sabripour S., *Spacecraft Power Technologies*, Imperial College Press 2003; • Fortescue P., Swinerd G., Stark J., *SPACECRAFT SYSTEMS ENGINEERING*, Wiley, ed. 2011.

Course title	B.2 Platform: De-orbiting Systems
Objectives of the course:	• To inform participants about problems connected with inactive satellites, space debris (space junk) and its removal. • To clarify the threat and consequences of littering the space around the Earth.
Course contents:	The course comprises: • Definition and possible parameters of space debris;

	• Threats and consequences connected with space junk (Kessler syndrome); • Methods of protection against the space junk; • Legal regulations connected with space debris; • De-orbiting methods – graveyard orbit, bringing the objects into the atmosphere; • Space cleaning – de-orbiting methods for not cooperating objects.
Recommended reading:	• J. Morio, J.C. Dolado Pérez, C. Vergé, R. Pastel and M. Balesdent, Estimation of collision probability between space debris and satellites, *In Estimation of Rare Event Probabilities in Complex Aerospace and Other Systems*, Woodhead Publishing, 2016, pp. 169-175; • Martha Mejía-Kaiser, Chapter 27, Removal of hazardous space debris, *In Space Safety Regulations and Standards*, edited by Joseph N. Pelton and Ram S. Jakhu, Butterworth-Heinemann, Oxford, 2010, pp. 371-382; • Appendix 7 – 'UN COPUOS Space Debris Mitigation Guidelines, *In Space Safety Regulations and Standards*, edited by Joseph N. Pelton and Ram S. Jakhu, Butterworth-Heinemann, Oxford, 2010, pp. 475-479; • D. Rex, P. Eichler, U. Soppa, J. Zuschlag and A. Bade, Space Debris – Origin, evolution and collision mechanics, In *Space and Humanity*, edited by L.G. NAPOLITANO, Pergamon, Oxford, 1989, pp. 209-216; • Heiner Klinkrad, Chapter 10 – Meteoroid and Debris Protection, In *Safety Design for Space Systems*, Butterworth-Heinemann, Burlington, 2009, pp. 319-340; • Vladimir S. Aslanov, Chapter 5 – Removal of Large Space Debris by a Tether Tow, In *Rigid Body Dynamics for Space Applications*, Butterworth-Heinemann, 2017, pp. 255-356; • Orbital Debris Quarterly News – NASA; • NASA, ESA Webpage.

PART C – SPACECRAFT DESIGN PROCESS

Course title	C. Spacecraft Design Process
Objectives of the course:	• To achieve basic knowledge on the spacecraft design process; • To familiarize with the European Cooperation for Space Standardization; • To provide basic knowledge on the procedures during the design, manufacturing, test and launch processes; • To give an overview on the project phases and activities related to each step of the design process.
Course contents:	The course is dedicated to give a brief introduction to space industry in general. The course comprises: • Basic description of the mission elements and segments; • Mission definition; • Design philosophy – design to objectives, design to budget; • Phases of space project; • Test campaign; • Launch campaign; • ESA standards – what are these, where to find them, how touse them? • Risk managements – risk assessment methods connected with a space mission and project execution; • Co-engineering (team coordination); • Technology Readiness Level; • Space debris mitigation.
Recommended reading:	• Peter Fortescue, Grahan Swinerd, John Stark, *Spacecraft Systems Engineering*, Wiley, 2011; • Wiley J. Larson, James R. Wertz, *Space Mission Analysis and Design*, Microcosm Press, 1999; • Klaus Wittmann, Willi Hallmann, Wilfried Ley, *Handbook of Space Technology*, Wiley, 2009; • Michael D. Griffin, James R. French, Space Vehicle Design, AIAA, 2004; • ECSS standards, ESA.

PART D – CASE STUDY

Course title	D. Case study
Objectives of the course:	This part of the course will be conducted as an exercise with interaction between course participants and lecturer taking into account a real case of space mission: • To familiarize with the spacecraft design process; • To build the awareness of the differences in the theoretical and practical approaches; • To introduce the path of decision making process; • To provide basic knowledge on the mission analysis process; • To present the project phases on a practical example.
Course contents:	The course is dedicated to give a brief introduction to space industry in general. The course comprises: • Mission goals definition with the customer; • Mission evaluation: definition of the critical requirements, mission analysis, mission utility, mission concept selection, trade off discussion with the customer: lifetime, data availability, time etc.; • Requirements definition; • Space payload design and sizing; • Spacecraft BUS design and sizing: requirements, constrains and design process, configuration, design budgets; • Spacecraft subsystems: detailed selection; • Subsystems manufacturing and test campaign; • Communication architecture; • Mission operations; • Ground system design and sizing; • Project management: planning, logistics, documentation, analysis of influence of realisation time, costs and quality of a mission, quality assurance, risk assessment.
Recommended reading:	• Wiley J. Larson, James R. Wertz, *Space Mission Analysis and Design*, Microcosm Press, 1999; • John Hrastar, *NASA EOSDIS case study*, NASA, 2003; • Charles D. Brown, *Elements of Spacecraft Design*, AIAA, 2002; • Emery I. Reeves, *Case Study in Spacecraft Design*, AIAA, 1979; • Edward W. Rogers, Office of the Chief Knowledge Officer, *A Catalog of NASA-Related Case Studies*, NASA, 2011; • J. Homer Saleh, J.-F. Castet, *Spacecraft Reliability and Multi-State* • *Failures: A Statistical Approach*, John Wiley & Sons, Ltd, 2011.

Lecturers' biographies:

1. **Prof. dr hab. Jan Błęcki** - professor at the Space Research Center of the Polish Academy of Sciences, Head of the Department of Plasma Physics, Member of the Space and Satellite Research Committee of the Polish Academy of Sciences, Co-Leading Investigator of the Taranis mission.
   Course title: Space environment

2. **Dr inż. Łukasz Mężyk –** Research and didactic worker at the Institute of Thermal Technology at the Faculty of Power and Aeronautical Engineering of the Warsaw University of Technology (Aviation Engines Department) Member of the Polish Institute of Combustion Expert of the Team for Educational Projects of Space Technologies, Committee for Space and Satellite Research of the Polish Academy of Sciences
   Course title: Introduction to space technology
   Course title: Platform – De-orbitating systems
   Course title: Spacecraft design process
   Course title: Case study

3. **prof. dr hab. Eng. Anna Boczkowska** - Vice-Dean for General Affairs and Science at the Faculty of Materials Science and Engineering of the Warsaw University of Technology, employee of the Division of Ceramic and Polymer Materials. Areas of scientific activity: composites, polymers, nanomaterials, intelligent materials. Member of scientific councils, national and international scientific societies: incl. International Society of Optical Engineering (SPIE), American Association for the Advancement of Science (AAAS), American Chemical Society (ACS).
   Course title: Space environment interaction on materials and mechanics of a spacecraft

4. **dr inż. Maciej Ossowski** - researcher and lecturer at the Department of Surface Engineering at the Faculty of Materials Science and Engineering of the Warsaw University of Technology. As part of the cooperation between the Department of Surface Engineering of the Military Institute of Medicine, Warsaw University of Technology and the Space Research Center of the Polish Academy of Sciences, he conducts work aimed at developing and implementing surface engineering technologies for applications in mechanisms designed for the needs of international space missions.
   Course title: Space environment interaction on materials and mechanics of a spacecraft

5. **Prof. dr hab. inż. Piotr Furmański** – professor at the Faculty of Power and Aeronautical Engineering, Head of the Department of Thermodynamics, Plenipotentiary of the Rector of the Warsaw University of Technology for Nuclear Power, Member of the Thermodynamics and Combustion Committee of the Polish Academy of Sciences, former director of the Institute of Thermal Technology, former Deputy Dean of WMEIL.
   Course title: Platform: Thermal Control System

6. **Dr inż Marcin Michałowski** - researcher and lecturer at the Institute of Micromechanics at the Faculty of Mechatronics. His scientific interests focus around mechatronics, nanotechnology

and tribology. His research involve atomic force microscopy and mechanics in micro and nanoscale. He is also the main organizer of scientific conference "International Colloquium on Micro-Tribology".
Course title: Platform – Structure

7. **prof. dr hab. inż. Jerzy Kurek** – professor at the Institute of Automatic Control and Robotics, Faculty of Mechatronics, Warsaw University of Technology.
   Course title: Platform – Data Handling
   Course title: Launchers and ground segment
   Course title: Payload

8. **prof. dr hab. inż. Janusz Narkiewicz** - Head of the Department of Aviation Automation and Accessories at the Institute of Aviation Technology and Applied Mechanics at the Faculty of Power and Aeronautical Engineering. Director of the University Research Center of Aviation and Cosmonautics of the Warsaw University of Technology
   Course title: Platform: Attitude Determination and Control System

9. **dr hab. inż. Jan Kindracki** – Professor at the Warsaw University of Technology, Deputy Director of the Institute of Thermal Technology, Tutor of the COSMONAUTICS specialty; Member of the Space and Satellite Research Committee of the Polish Academy of Sciences, Chairman of the Team for Educational Projects of Space Technologies, Member of the Program Council of the National Center for Space and Satellite Engineering on behalf of the Warsaw University of Technology, Editor of the section: Aviation Engine, scientific journal: Journal of Power Technologies, academic supervisor of the Student Astronautical Circle.
   Course title: Platform: Propulsion