Introduction to Space for Engineers

Satellite systems development with focus on project phases C/D"

Course duration – 5 weekends/ 86h

1. INTRODUCTION

Notwithstanding a growing number of university students in space domain it will take years until the supply of space engineers in CEE Countries will be sufficient to meet growing demand.

To address this shortage an alternative approach could be considered. As significant numbers of well-educated and experienced engineers are available in CEE, especially in electronics, optics, mechanics, robotics and information technology some of them could be trained to support space projects.

Special training courses for engineers need to be developed for this purpose starting with the introductory level. After completion of such courses their participants could continue their training, if needed through more advanced courses, internships and on the job training in Country or abroad.

The Military University of Technology is a leading entity in defence research and education in Poland providing military and civilian engineers of all specialties for the Polish Armed Forces and the defence and security sectors. The Military University of Technology is the leader of the 'Nanosatellite Optoelectronic Image Recognition Constellation PIAST (Polish ImAging SaTellites)' project. Its aim is to build and deploy in space a constellation of three nanosatellites, which will be used for Earth observation and image data acquisition. The implementation of the project is part of the development of a key element of the national Earth observation satellite system for the Polish government.
In this project, the Military University of Technology is responsible for the mission requirements, the construction and operation of the ground segment and the data collection centre, as well as algorithms to improve image resolution, laser rangefinders with communications and solar position sensors.

To develop the training course for engineers as contracted by ARP (Industrial Development Agency JSC), we have partnered with the most experienced Polish institution in space domain, the Space Research Center of the Polish Academy of Sciences. We also considered it of high importance to include the contributions of an industrial partner Creotech Instruments JSC., the Polish industrial leader in space sector.

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No	Date	Day		Training Unit	No of lectures
1	14.10.2022	Friday		Course Opening	1
2	14.10.2022	Friday	1.1	Introduction to Environment of Space	4
3	15.10.2022	Saturday	1.1	Introduction to Environment of Space	1
4	15.10.2022	Saturday	1.2	Introduction to Space Standards ECSS	3
5	15.10.2022	Saturday	1.3	Project Phases and Planning	4
6	16.10.2022	Sunday	2.1	Mission types, Payloads and Instruments	2
7	16.10.2022	Sunday	2.2	Launchers and Platforms	2
8	21.10.2022	Friday	2.3	Satellite Systems and Subsystems	4
9	22.10.2022	Saturday	2.3	Satellite Systems and Subsystems	6
10	22.10.2022	Saturday	3.1	Basic rules of design of space electronic systems	2
11	23.10.2022	Sunday	3.2	Basic rules of design of space optical systems	2
12	23.10.2022	Sunday	3.3	Basic rules of design of space mechanical systems	2
13	04.11.2022	Friday	4.1	AIT of Satellite Subsystems and Instruments	4
14	05.11.2022	Saturday	4.1	AIT of Satellite Subsystems and Instruments	8
15	06.11.2022	Sunday	4.1	AIT of Satellite Subsystems and Instruments	2
16	06.11.2022	Sunday	4.2	AIT at the Satellite System Level	4
17	18.11.2022	Friday	4.2	AIT at the Satellite System Level	4
18	19.11.2022	Saturday	5.2	Satellite Operations	2
19	19.11.2022	Saturday	6.1	Design of space electronic systems	3
20	19.11.2022	Saturday	6.2	Design of space mechanical systems	3
21	20.11.2022	Sunday	5.1	Ground Segment and Mission Control	4
22	20.11.2022	Sunday		Final Test	1
23	02.12.2022	Friday		VIP Day - course certification	1
24	02.12.2022	Friday	8	Closing lecture on Space Missions	2
25	02.12.2022	Friday	7	On-site Visits - Research Centers and Industry	2
26	03.12.2022	Saturday	7	On-site Visits - Research Centers and Industry	8
27	04.12.2022	Sunday	7	On-site Visits - Research Centers and Industry	5

2. COURSE PARTICIPANTS AND APPROACH

A training course **"Introduction to Space for Engineers"** is meant to be addressed to engineers as participants with comprehensive knowledge and possibly experience in electronics, optics or mechanics. As the training is at the introductory level no prior knowledge of space domain or space terminology by participants are required.

3. TRAINING OBJECTIVES

To achieve that it is proposed that the following topical areas are covered during the training course:

1) the basics of space environment, space standards as well as space project phases and planning

   Main competences to be acquired:
   - student understands main aspects of spacecraft dynamics
   - student knows reference frames and its main features
   - student acquires general knowledge of Space environment parameters and characteristics
   - student acquires knowledge of impact of Space environment properties on spacecraft design
   - student understands ECSS concepts
   - student knows ECSS content in general
   - student knows the most important ECSS regulations and their content
   - student knows the phases of flight unit development process and hardware models expected
   - student knows how development process fits into mission phases and stages
   - student is familiar with requirements regarding preparations for standard reviews

2) mission types, launchers, platforms and payloads as well as satellite systems and subsystems

   Main competences to be acquired:
   - student knows spacecraft categories with respect to mass, size and purpose
   - student knows basic properties of different types and categories of spacecraft and space systems
   - student knows categories of launchers available on the market
   - student knows main properties and requirements of respective launchers
   - student understands a process of launch procurement
   - student understands basic rules and needs regarding preparation and conduct of launch campaign
   - student knows the different concepts of satellite structures and configurations
   - student knows basic properties of satellite subsystems

3) basic rules of space systems technical design and design of space electronic, optical and mechanical systems

   Main competences to be acquired:
   - student knows the most general rules of design of space electronic, optical and mechanical systems and understands general relations between them
   - student knows rules, methods and good practices related to a given category of technical design

4) satellite assembly, integration and tests (AIT) at subsystem, instrument and system

levels

Main competences to be acquired:

- student knows the most important documentation related to design and development of satellite subsystems
- student knows basic processes of flight model (FM) assembly preparation and manufacturing
- student knows theory basics regarding FM units testing
- student knows general scenarios and purposes of different tests regarding FM modules
- student knows the most important documentation related to preparation of the satellite AIT process
- student knows the basics related to processes of satellite development, testing and manufacturing
- student knows different models of subsystems utilized in a frame of satellite development and assembly process
- student knows general scenarios and purposes of different tests performed during the satellite AIT process

5) ground segment, mission control and satellite operations.

Main competences to be acquired:

- student knows general functionalities and structures of Ground Station and Mission Control Centre
- student knows basics of communication bands allocation, properties and availability
- student knows basics regarding satellite communication link design and budgeting
- student knows tasks and procedures for satellite operation just after the launch and later on
- student knows typical/common problems and failures happening in the past

6) on-site visits at space research centers and space industry to address practical aspects e.g. related to C/D phases of space projects

4. COURSE CURRICULUM

Course curriculum is presented below and the detailed description of all training units is provided in chapter 5. Each training unit is intended for all participants. Total course duration is 5 weekends and it consists of 82 hours of training.

The training providers and their potential replacements are listed in each training unit/ school subject description card. They are the employees of the Space Research Centre of the Polish Academy of Sciences, the Military University of Technology, Creotech Instruments S.A. (the Polish industrial leader in space sector), VIGO system S.A. or Plasma Physics and Laser Microfusion.

1. Space Basics, Standards and Projects (11h)

1.1. Introduction to Environment of Space (4h)

- Introduction to celestial mechanics
- Celestial and Terrestrial Reference Systems
- Methods of precise orbit determination
- Transport of mass and energy in Earth's dynamics
- Electromagnetic phenomena (radiation)
- Vacuum and thermal gradient influence on design

1.2. Introduction to Space Standards ECSS (3 h)

1.3. Project Phases and Planning (4h)

- Mission phases and stages
- Design and development process
- Satellite management and use

2. Missions, Payloads and Satellite Systems (14h)

2.1. Mission types, Payloads and Instruments (2h)

- Observation satellites
- Telecommunication satellites
- Navigation satellites
- Scientific satellites
- Probes and landers

2.2. Satellite Systems and Subsystems (10h)

- Satellite structures
- Onboard computer (Command and Data Handling)
- Attitude and Orbit Control System
- Telecommunication system (uplink +downlink)
- Electrical power supply and distribution subsystems
- Navigation subsystem
- Environmental subsystem (thermal stabilization and radiation protection)
- Propulsion and maneuver subsystems
- Reliability and system issues

3. Basic Rules of Technical Design of Space Systems (6h)

3.1. Basic rules of design of space electronic systems (2 h)
3.2. Basic rules of design of space optical systems (2 h)
3.3. Basic rules of design of space mechanical systems (tribology) (2 h)

4. Satellite Assembly, Integration & Test (AIT) (22h)

4.1. AIT of Satellite Subsystems and Instruments (14h)

- Documentation, planning, logbooks
- Flight components, material, coating and process list and procurement
- Incoming test of components or subunit (Product Assurance/Quality Assurance)
- Functional performance tests
- Vibration tests,
- Thermo-balance vacuum tests
- Electromagnetic compatibility tests
- End Item Data Package Reports

4.2. AIT at the Satellite System Level (8h)

- Documentation, planning, logbooks
- Flight components, material, coating and process list and procurement
- Satellite test with Structural Thermal Models
- Satellite tests with electrical models of instruments
- Software tests
- Incoming test of instruments
- Functional tests of instruments and satellite (with launch)
- Vibration tests
- Thermo-balance vacuum tests
- Electromagnetic compatibility tests

5. Ground Segment, Mission Control and Satellite Operations (6h)

5.1. Ground Segment and Mission Control (4h)

- Ground segment
- Modulation and demodulation
- Multiplexing
- Signal power and its bands, coherence

5.2. Satellite Operations (2h)

- Launch and Early Operations
- Commissioning
- Satellite operations

6. Design of Space Electronic and Mechanical Systems (6h)

6.1. Design of space electronic systems (3 h)

6.2. Design of space mechanical systems (3 h)

7. On-site Visits – practical aspects related to C/D phases of space projects (15h)

7.1. On-site Visit at the Space Research Center of the Polish Academy of Sciences (Main purpose: infrastructure related to space projects and testing, BRITE Ground Station.)

7.2. On-site Visit at the Creotech Instruments S.A. (Main purpose: infrastructure related to space projects; practices and procedures, preparation for assembly, soldering.)

7.3. On-site Visit at the Military University of Technology (Main purpose: testing infrastructure, e.g. EMC chamber.)

7.4. On-site Visit at the Institute of Plasma Physics and Laser Microfusion (infrastructure and practical aspects related to design, application and testing of plasma propulsion systems).

7.5. On-site Visit at the VIGO System S.A. (practical aspects related to design, application and testing of space infrared systems.)

8. Closing Lecture on Space Missions (2h)

5. COURSE UNITS DESCRIPTION

The detailed description of all training units of the course is provided below. Each subpoint in the training curriculum is described by an individual training unit/ school subject description card containing information about: the title, training providers and their potential replacements, subject description, topics of lectures/ laboratories and references.

Notice: <u>Please kindly note that all the training providers and their potential replacements are to be confirmed or changed for each individual contract.</u>

TRAINING UNIT 1.1 / SCHOOL SUBJECT DESCRIPTION CARD

TRAINING UNIT/ SCHOOL SUBJECT: Introduction to Environment of Space
4 hours of lectures

Training Providers:
Janusz BOGUSZ, Marcin SZOŁUCHA

Subject description:
The basics of celestial mechanics are covered including: the motions of celestial bodies by application of the physical principles (Newtonian mechanics) to astronomical objects such as stars, planets as well as artificial satellites, the Kepler's law, basic (Keplerian) elements of the orbits, types of orbits with the origins of their perturbations. The theory of celestial and terrestrial reference systems is discussed: the modern systems recommended by the International Earth Rotation and Reference System Service, their transformation using general relativity and Lorentz transformation between the two coordinate frames (inertial and non-inertial) that move at constant velocity relative to each other, the newest realizations of International Celestial Reference System (namely ICRF-2) as well as International Terrestrial Reference System (namely ITRF2014) indispensable to describe the position of artificial satellites, the movement of the Earth's rotation axis in the inertial frame, the Very Long Baseline Interferometry technique in determination of the Earth's rotation time (UT1-UTC factor). The transport of mass and energy in Earth's dynamics is considered: dynamic processes within the Earth's system disturbing the motion of Low Earth Orbit satellites, tides of the Earth, modern methods of investigation of Earth's gravity field, basics of magnetic field and the chosen methods of its research. The methods of Precise Orbit Determination are presented: technics of orbit determination (SLR, DORIS), broadcast and precise GNSS satellite ephemeris. Moreover the electromagnetic phenomena (radiation) as well as vacuum and thermal gradient influence on design are discussed.

Topics of lectures:
1. Introduction to celestial mechanics.
2. Celestial and Terrestrial Reference Systems.
3. Transport of mass and energy in Earth's dynamics.
4. Methods of Precise Orbit Determination.
5. Electromagnetic phenomena (radiation).
6. Vacuum and thermal gradient influence on design.

Topics of laboratories:
1. Creating a satellite in System Tool Kit software.

References:
1. Altamimi, Z., Rebischung, P., Métivier, L., & Collilieux X. (2016). "ITRF2014: A new release of the International Terrestrial Reference Frame modeling nonlinear station motions". J. Geophys. Res. Solid Earth, 121, doi:10.1002/2016JB013098.
2. Fey A.L., et al. (2011): "The Second Realization of the International Celestial Reference Frame By Very Long Baseline Interferometry". The Astronomical Journal.
3. Hofmann-Wellenhof B., Lichtenegger H., Collins J. (2001): "Global Positioning System: Theory and Practice". Springer-Verlag, Wien, 2001.
4. Lowrie W. (2007): "Fundamentals of Geophysics". Cambridge University Press.
5. Morbidelli A. (2011): „Modern Celestial Mechanics. Aspects of Solar System Dynamics".
6. Petit G., Luzum B. (eds.) (2010) : „IERS Conventions (2010)". IERS Technical Note No. 36.
7. Turcotte D.L., Schubert G. (2002): "Geodynamics". Cambridge University Press.
8. Tadanori Ondoh, Katsuhide Marubashi: „Wave Summit Course: Science of Space Environment".

TRAINING UNIT 1.2 / SCHOOL SUBJECT DESCRIPTION CARD

TRAINING UNIT/ SCHOOL SUBJECT: Introduction to Space Standards ECSS

3 hours of lectures

Training Provider: Marcin MAZUR

Subject description:

This course focuses on selected issues of European Cooperation for Space Standardization (ECSS).

ECSS establishes the requirements for the verification of space products in order to increase the effectiveness of all space programmes in Europe through the application of a single, integrated set of Standards and Requirements from which all generic requirements of future space projects can be derived. It defines the fundamental concepts of the verification process, the criteria for defining the verification strategy and specifies the requirements for the implementation of the verification programme. It includes also the list of the expected documentation.

The main topics of the lecture are:

- history of ECSS
- present ECSS membership
- ECSS types of documents: standards, handbooks, technical memorandum
- characteristics of ECSS standards
- tailoring of the ECSS standards to the technical, cost, schedule, programmatic and economic requirements of the space programmes and projects

Topics of lectures:

1. Introduction to ECSS organization.
2. Structure of ECSS standards tree.
3. Introducing changes and new standards.
4. Standards vs Handbooks.
5. Different ECSS branches.
6. How to access ECSS documents.
7. Structure of a single ECSS standard document/understanding different chapters and key phrases.

Topics of laboratories:

References:

ECSS set from 2016.04.15 including:

- ECSS-S-ST-00-01 ECSS system — Glossary of terms.
- ECSS-E-ST-10 Space engineering – System engineering general requirements
- ECSS-E-ST-10-03 Space engineering — Testing
- ECSS-M-ST-10 Space project management — Project planning and implementation
- ECSS-Q-ST-10-09 Space product assurance — Non-conformance control system
- ECSS-Q-ST-20 Space product assurance — Quality assurance

TRAINING UNIT 1.3 / SCHOOL SUBJECT DESCRIPTION CARD

TRAINING UNIT/ SCHOOL SUBJECT: Project Phases and Planning

4 hours of lectures

Training Provider: Piotr ORLEAŃSKI, Roman WAWRZASZEK, Mirosław RATAJ

Subject description:

In a frame of the lecture information regarding the phases of flight unit development process is provided. Each phase of the project is described taking into account the documents, data, hardware and software at the entry into the phase and those at the phase exit. The goals of every phase are briefly presented
The reviews system is described and the content of each review is provided and discussed.
Hardware models expected in the development process are presented. Each model is described taking into account its role, purpose and properties.
The relation between development process and mission phases and stages is elaborated.

Topics of lectures:

1. Mission phases and stages (scope of work in every phase; Phase O - conceptual study, Phase A - preliminary analysis, Phase B - definition, Phase C/D - design and development, Phase E/F - operation phase and disposal).
2. Design and development process (flight unit design and development process, requirements, reports, verifications, reviews and documentation).
3. Satellite management and use (operation strategy of a satellite, tracking system, AOCS, data upload and download, lifetime).

Topics of laboratories:

References:

1. ECSS-E-10A, Space Engineering - System Engineering
2. ECSS-M-30, Project Phasing and Planning
3. ECSS-M-20, Project Organisation
4. ECSS-E-ST-10 Space engineering – System engineering general requirements

TRAINING UNIT 2.1 / SCHOOL SUBJECT DESCRIPTION CARD

TRAINING UNIT/ SCHOOL SUBJECT: Mission types, Payloads and Instruments

2 hours of lectures

Training Provider: Marcin SZOŁUCHA, Roman WAWRZASZEK , Piotr ORLEAŃSKI, Mirosław RATAJ

Subject description:

The goal of the lecture is to provide general information about variety of space mission purposes, tasks and configurations. Different hardware solutions, mission philosophy and satellite system properties are presented to underline purpose-oriented methodology in mission definition and satellite configuration concepts.

Basic categorisation of space missions and satellite types are presented taking into account different criteria like: size, mass, rank of the mission, payload, etc. Short characteristics of the most common satellite types are provided.

Main blocks and subsystems of a satellite are discussed and brief descriptions of satellite navigation and telematics are provided.

Topics of lectures:

1. Mission categories.
2. Satellite types and categories.
3. Mission goals.
4. The relation and impact of payload and mission purpose on satellite components and configuration.
5. Space mission system structure: ground segment, space segment and orbit types.
6. Typical mission examples.

Topics of laboratories:

References:

1. Wertz, James R. and Larson, Wiley J. “Space Mission Analysis and Design 3rd Edition”, Space Technology Library, Springer NY, 1999,
2. Ley, Wilfried andWittmann, Klaus and Hallmann Willi, “Handbook of Space Technology”, Wiley, 2009
3. Fortescue P., Swinerd G., Stark J., “Spacecraft Systems Engineering”, Wiley, ed. 2011.https://directory.eoportal.org/
4. http://database.eohandbook.com/database/missiontable.aspx
5. D'Errico, Marco “Distributed Space Missions for Earth System Monitoring” Springer 2013

TRAINING UNIT 2.2 / SCHOOL SUBJECT DESCRIPTION CARD

TRAINING UNIT/ SCHOOL SUBJECT: Launchers and platforms

2 hours of lectures

Training Provider: Tomasz ZAWISTOWSKI, Andrzej KOTARSKI, Roman WAWRZASZEK

Subject description:

In a frame of the lecture general information regarding launcher categories and availability, launcher selection, launch procurement and launch campaign organization is provided.

Different categories of launchers are described. Launch vehicles available on the market are presented and short specifications provided.

Basic rules and needs regarding launch preparation and launch campaign are discussed.

Exemplary launch campaign is presented and discussed as a case study.

Topics of lectures:

1. Selection of launcher: launcher size, availability, costs.
2. Matching of the satellite to the launcher.
3. Launch procurement.
4. Launch campaign preparation: definition of satellite accommodation, interfaces to launch vehicle (Interface Control Document – ICD) definition, logistics, launch site activities.

Topics of laboratories:

References:

1. Fortescue P., Swinerd G., Stark J., “Spacecraft Systems Engineering”, Wiley, ed. 2011;
2. Wertz, James R. and Larson, Wiley J. “Space Mission Analysis and Design 3rd Edition”, Space Technology Library, Springer NY, 1999;
3. Long March 4B/C (LM-4B/C) launch vehicle manual;
4. Space Launch System DNEPR User’s Guide (link: https://snebulos.mit.edu/projects/crm/DNEPR/Dnepr_User_Guide.pdf)

TRAINING UNIT 2.3 / SCHOOL SUBJECT DESCRIPTION CARD

TRAINING UNIT/ SCHOOL SUBJECT: Satellite systems and subsystems

10 hours of lectures

Training Provider: Roman WAWRZASZEK, Piotr ORLEAŃSKI

Subject description:

The main goal of the lecture is to provide information regarding typical structures of satellites and to elaborate main properties and topologies of their subsystems.

An impact of mission goal on satellite structure is presented. The different concepts of satellite structures and configurations are discussed with emphasis on the criteria for selection and justification to be considered for the mission and during the satellite design process.

Satellite subsystems are presented and described one by one. For each subsystem a set of main parameters and properties are discussed.

Topics of lectures:

1. Satellite structures.
2. Onboard computer (Command and Data Handling).
3. Attitude and Orbit Control System.
4. Telecommunication system (uplink +downlink).
5. Electrical power supply and distribution subsystems.
6. Navigation subsystem.
7. Environmental subsystem (thermal stabilization and radiation protection) .
8. Propulsion and maneuver subsystems.
9. Reliability and system issues.

Topics of laboratories:

References:

1. Wertz, James R. and Larson, Wiley J. “Space Mission Analysis and Design 3rd Edition”, Space Technology Library, Springer NY, 1999,
2. Ley, Wilfried and Wittmann, Klaus and Hallmann Willi, “Handbook of Space Technology”, Wiley, 2009
3. Hyder A.K., Wiley R.L., Halpert G., Flood D.J., Sabripour S., “Spacecraft Power Technologies”, Imperial College Press 2003,
4. Fortescue P., Swinerd G., Stark J., “Spacecraft Systems Engineering”, Wiley, ed. 2011.

TRAINING UNIT 3.1 / SCHOOL SUBJECT DESCRIPTION CARD

TRAINING UNIT/ SCHOOL SUBJECT: Basic rules of design of space electronic systems

2 hours of lectures

Training Provider: Andrzej CICHOCKI, Piotr ORLEAŃSKI, Roman WAWRZASZEK

Subject description:

In a frame of the lecture it is briefly described how electronic engineers design electronics to be used in space.

General information about problems like radiation, heat dissipation and reliability of systems with emphasizing on the main issues to be considered by space electronic engineer is provided.

An important goal for the lecture is to make the participants aware of the relations between electronics design and other satellite elements like the structure, satellite configuration, optics, etc.

Topics of lectures:

1. Problems and mitigation of radiation effects.
2. Reliability and worst case scenarios.
3. General rules of space electronic circuits design.

Topics of laboratories:

References:

1. ECSS-Q-TM-30-12 - End-of-life parameter drifts - EEE components.
2. ECSS-Q-30-11A Space product assurance: Derating - EEE components.
3. Roland J. Duphily, Space Vehicle Failure Modes, Effects, and Criticality Analysis (FMECA) Guide.
4. Space and Missile Systems Center Air Force Space Command, Contract No. FA8802-09-C-0001, June 2009.
5. L.H. Mutuel, Single Event Effects Mitigation Techniques Report, U.S. Department of Transportation Federal Aviation Administration.
6. R.Velazco, P.Fouillat, R.Reis, Radiation Effects on Embedded Systems, Springer 2007.

TRAINING UNIT 3.2 / SCHOOL SUBJECT DESCRIPTION CARD

TRAINING UNIT/ SCHOOL SUBJECT: Basic rules of design of space optical systems

2 hours of lectures

Training Provider: Zbigniew ZAWADZKI, Mirosław RATAJ

Subject description:

Basic parameters of optical systems are discussed and their typical structure and characteristics are presented.

Specific requirements for space-based optical systems are discussed and a few methods and technologies used in design of such systems are presented.

Typical space systems are presented. Brief description of the method of space optical systems design is presented.

Topics of lectures:

1. Basic parameters of optical systems (focal length and focal plane, field of view and instantaneous field of view, pupil and its size, numerical aperture and F-number, lens speed and amount of collected light, resolution and its diffraction limit, depth of field, field of view versus lens speed).

2. Typical optical systems used in imaging observation (dioptric, catoptric and catadioptric).

3. Basic requirements for space-based optics (large apertures - often deployable that needs accurate alignment, structures lightweight enough to be transported to the orbit, compensation of thermal aberrations and deformations caused by thermal gradients, resistance to acceleration forces during the launch).

4. Methods and solutions used in design of space optical systems to meet the requirements (specific materials, segmentation, space frames,).

Topics of laboratories:

References:

1. P.Yoder, D.Vukobratovich - Opto-Mechanical Systems Design, Fourth Edition, CRC Press, 2015.
2. R.E.Fischer, B.Tadic-Galeb – Optical System Design, McGraw-Hill, 2000.
3. P.R. Yoder “Mounting Optics in Optical Instruments” SPIE, 2001.

TRAINING UNIT 3.3 / SCHOOL SUBJECT DESCRIPTION CARD

TRAINING UNIT/ SCHOOL SUBJECT: Basic rules of design of space mechanical systems

2 hours of lectures

Training Provider: Karol SEWERYN

Subject description:

The basic information regarding a design of space mechanisms is provided.

Methods and requirements for finite element method (FEM) structural and thermal analysis are presented.

Tribology aspects of space mechanical systems are described.

Methods of tests and condition are provided

Topics of lectures:

1. Fundamental rules of space mechanical systems.
2. Goals and methods of structural and thermal analysis.
3. Basic information about tribology issues.
4. Lubrication in space – solid lubricants, liquid lubricants.
5. Testing methods of mechanical systems.

Topics of laboratories:

References:

1. T. Kałdoński: Fundamental Issues of Analysis of Tribological Processes. MUT, Warsaw, 2014.
2. J. P. Davim: Tribology for Engineers. A Practical Guide. Woodhead Publishing Limited, Cambridge, 2011 (online).
3. G.W. Stachowiak, A.W. Batchelor: Engineering Tribology. Elsevier Inc, 2014 (online).
4. J.Wijker „ Mechanical Vibrations in Spacecraft Design” SPRINGER 2008
5. ECSS-E-ST-33-01C, Mechanism,

TRAINING UNIT 4.1 / SCHOOL SUBJECT DESCRIPTION CARD

TRAINING UNIT/ SCHOOL SUBJECT: AIT of satellite subsystems and instruments

14 hours of lectures

Training Provider: Piotr ORLEAŃSKI, Mirosław RATAJ, Roman WAWRZASZEK, Marcin STOLARSKI

Subject description:
The lecture main goal is to provide theoretical and practical knowledge on instrument assembly, integration and testing.
Key documentation related to design and development of instruments and subsystems is described and examples of such documents are presented.
Based on typical sets of requirements the processes of assembly preparation and manufacturing of flight model units are discussed.
The theory and good practices regarding the performance of tests of flight model units are provided. Scenarios for different kind of tests are shown and elaborated. Clear definition of the purpose and the success criteria for each test are discussed.

Topics of lectures:

1. Documentation, planning, logbooks and End Item Data Package Reports (documentation required for the delivery of every unit and subunit).
2. Flight components, materials, coating and process list and procurement.
3. Basic processes of FM assembly preparation and manufacturing.
4. Incoming test of components or subunit (Product Assurance/Quality Assurance).
5. Functional performance tests.
6. Vibration tests (tests' purposes, types and levels of vibrations, methodology, interfaces, accessories, result analysis, reports).
7. Thermo-balance vacuum tests (tests' purposes, types and levels of thermal tests, methodology, interfaces, accessories, result analysis, reports).
8. Electromagnetic compatibility tests (tests' purposes, types and levels of thermal tests, methodology, interfaces, accessories, result analysis, reports).

Topics of laboratories:

References:

1. J.Wijker „Spacecraft Structures" SPRINGER 2008.
2. Clayton R. Paul. "Introduction to electromagnetic compatibility". A John Wiley& sons, INC. Publication, 2006.
3. ECSS-E-20-01A Space Engineering "Multipaction design and tests".
4. ECSS-E-ST-10-02C Space Engineering "Verification".
5. ECSS-E-ST-10-03C Space Engineering 'Testing".
6. Others ECSS documents.
7. Own documents and materials.

TRAINING UNIT 4.2 / SCHOOL SUBJECT DESCRIPTION CARD

TRAINING UNIT/ SCHOOL SUBJECT: AIT at the satellite system level

8 hours of lectures

Training Provider: Mirosław RATAJ, Roman WAWRZASZEK, Andrzej CICHOCKI

Subject description:

The main goal of the lecture is to provide theoretical and practical knowledge on satellite assembly, integration and testing.

In a frame of the unit the documentation related to preparation of the satellite Assembly, Integration and Test (AIT) process is presented and discussed. The main processes related to satellite development, testing and manufacturing are provided and explained.

It is described how different models of subsystems are utilized in satellite development and assembly process. The relations between subsystem and system levels are shown.
The purposes and scenarios of different tests performed during the satellite AIT process are described.

Topics of lectures:

1. Documentation, planning, logbooks
2. Flight components, material, coating, process list and procurement
3. Satellite test with Structural Thermal Models (tests' purposes, type and levels of vibrations, methodology, interfaces, accessories, result analysis, reports)
4. Satellite tests with electrical models of instruments
5. Software tests (tests' purposes, methodology, interfaces , accessories, result analysis, reports)
6. Incoming test of instruments
7. Functional tests of instruments and satellite (with launch)
8. Vibration tests (tests' purposes, type and levels of vibrations, methodology, interfaces, accessories, result analysis, reports)
9. Thermo-balance vacuum tests (tests' purposes, type and levels of thermal tests, methodology, interfaces, accessories, result analysis, reports)
10. Electromagnetic compatibility tests (tests' purposes, type and levels of thermal tests, methodology, interfaces, accessories, result analysis, reports)

Topics of laboratories:

References:

1. J. Wijker „Spacecraft Structures" SPRINGER 2008.
2. Clayton R. Paul. "Introduction to electromagnetic compatibility". A John Wiley& sons, INC. Publication, 2006.
3. ECSS-E-20-01A Space Engineering "Multipaction design and tests".
4. ECSS-E-ST-10-02C Space Engineering "Verification".
5. ECSS-E-ST-10-03C Space Engineering Testing.
6. Others ECSS documents.
7. Own documents and materials.

TRAINING UNIT 5.1 / SCHOOL SUBJECT DESCRIPTION CARD

TRAINING UNIT/ SCHOOL SUBJECT: Ground Segment and Mission Control

4 hours of lectures

Training Provider: Grzegorz WOŹNIAK

Subject description:

In a frame of the lecture information about general functionalities and typical structures of Ground Station and Mission Control Centre is provided. Characteristics of the ground components of satellite link are also covered.

Besides infrastructure and functional aspects of the ground segment the basics of communication bands allocation, their properties and availability are discussed.

The link power budget for different mission configurations (GEO, LEO, interplanetary) is presented. The factors affecting transmission characteristics of satellite links are discussed to provide the basics of satellite communication link design and budgeting.

Topics of lectures:

7. Ground segment.
8. Mission control.
9. Satellite link and communication bands.

Topics of laboratories:

2. Satellite link power budget

References:

9. Louis J. Ippolito, Jr., Satellite Communications Systems Engineering, A John Wiley and Sons, Ltd, Publication, 2008
10. Bruce R. Elbert, Satelite Communication Applications Handbook, Artech House, Inc., 2004
11. Dennis Roddy, Satellite Communications, McGraw-Hill, 2001
12. D. Minoli, Innovations in Satellite Communication and Satellite Technology, A John Willey and Sons, Ltd., Publication, 2015

TRAINING UNIT 5.2 / SCHOOL SUBJECT DESCRIPTION CARD

TRAINING UNIT/ SCHOOL SUBJECT: Satellite Operations

2 hours of lectures

Training Provider: Grzegorz WOŹNIAK, Roman WAWRZASZEK, Tomasz ZAWISTOWSKI

Subject description:

The main goal of this lecture is to provide information about tasks and procedures for satellite operation just after the launch and later on.

In a frame of the lecture it is explained what might be a limitation and problems related to Early Operations, how the satellite is tracked, what might be the satellite status and typical behaviour (consequences of misalignment in orbit parameters, satellites tumbling, etc.).

The tasks related to commissioning and operational phases are being explained.

Topics of lectures:

1. Procedures and problems related to launch and early operations phase (LEOP).
2. The purpose and procedures of commissioning phase.
3. Satellite operations.

Topics of laboratories:

References:

1. Wertz, James R. and Larson, Wiley J. “Space Mission Analysis and Design 3rd Edition”, Space Technology
   Library, Springer NY, 1999,
2. Artur Scholz, CubeSat Standards Handbook. A Survey of International Space Standards with Application for CubeSat Missions; PUBLISHED BY The LibreCube Initiative http://librecube.net, January 2017;
3. Fortescue P., Swinerd G., Stark J., “Spacecraft Systems Engineering”, Wiley, ed. 2011;
4. Long March 4B/C (LM-4B/C) launch vehicle manual;
5. Space Launch System DNEPR User’s Guide (link: https://snebulos.mit.edu/projects/crm/DNEPR/Dnepr_User_Guide.pdf)

TRAINING UNIT 6.1 / SCHOOL SUBJECT DESCRIPTION CARD

TRAINING UNIT/ SCHOOL SUBJECT: Design of space electronic and mechanical systems

PANEL 1 - Design of space electronic systems

3 hours of lectures

Training Provider: Andrzej CICHOCKI, Piotr ORLEAŃSKI, Roman WAWRZASZEK

Subject description:

In a frame of the lecture it is described how electronic engineers design electronics to be used in space. It is described how radiation effects may harm the electronics and which components are the most sensitive to radiation. It is explained how electronics should be designed to avoid the failures. An exemplary radiation analysis is presented.

Derating rules regarding space electronics are presented and discussed.

An approach to deal with components ageing and worst case analysis are presented.

Finally, a set of good practices regarding preparation of electronic systems for use in space is presented.

Topics of lectures:

1. Problems and mitigation of radiation effects.
2. Derating rules.
3. Worst case scenario and worst case analysis.
4. Space electronic circuits design rules.
5. Space electronic printed circuit board (PCB) design and cabling.

Topics of laboratories:

References:

1. ECSS-Q-TM-30-12 - End-of-life parameter drifts - EEE components.
2. ECSS-Q-30-11A Space product assurance: Derating - EEE components.
3. Roland J. Duphily, Space Vehicle Failure Modes, Effects, and Criticality Analysis (FMECA) Guide.
4. Space and Missile Systems Center Air Force Space Command, Contract No. FA8802-09-C- 0001, June 2009.
5. L.H. Mutuel, Single Event Effects Mitigation Techniques Report, U.S. Department of Transportation Federal Aviation Administration.
6. R.Velazco, P.Fouillat, R.Reis, Radiation Effects on Embedded Systems, Springer 2007.

TRAINING UNIT 6.2 / SCHOOL SUBJECT DESCRIPTION CARD

TRAINING UNIT/ SCHOOL SUBJECT: Design of space electronic and mechanical systems

PANEL 3 - Design of space mechanical systems

3 hours of lectures

Training Provider: Karol SEWERYN

Subject description:

In a frame of the lecture basic rules concerning design of space mechanical systems are being addressed. Materials, tribology, coatings, lubricants for space applications are described.

Influence of space environment on mechanical systems design is elaborated.

Basic information about release and deployment mechanisms as well as moveable parts is presented.

Topics of lectures:

1. Basic rules of design of space mechanical systems.
2. Materials, tribology, coatings, lubricants for space application.
3. Influence of space environment on mechanical systems design.
4. Moveable parts, release and deployment mechanisms.
5. Structural and thermal design and analysis of space mechanical systems.

Topics of laboratories:

References:

1. J.Wijker „ Mechanical Vibrations in Spacecraft Design" SPRINGER 2008
2. ECSS-Q-70-71A, Data for Selection of Space Materials and Processes,
3. ECSS-E-ST-33-01C, Mechanism,
4. J. P. Davim: Tribology for Engineers. A Practical Guide. Woodhead Publishing Limited, Cambridge, 2011 (online).
5. G.W. Stachowiak, A.W. Batchelor: Engineering Tribology. Elsevier Inc, 2014 (online).
6. Own documents and materials

TRAINING UNIT 7.1 / SCHOOL SUBJECT DESCRIPTION CARD

TRAINING UNIT/ SCHOOL SUBJECT: On-site Visit at the Space Research Centre of the Polish Academy of Sciences

4 hour on-site visit

Training Provider: Mirosław RATAJ, Piotr ORLEAŃSKI, Roman WAWRZASZEK

Subject description:

Centrum Badań Kosmicznych PAN (eng.: Space Research Centre of the Polish Academy of Sciences) is the most experienced Polish space entity in designing, manufacturing and testing of space instruments and subsystems.

Since 1977 more than 70 space units have been developed, manufactured and tested in the Space Research Centre, to be successfully delivered to the primes. Space Research Centre's facilities have been used for integration and testing of two nanosatellites.

The main goal of the visit in the Centre is to familiarize visitors with facilities necessary in space projects e.g. ESD (Electrostatic Discharge) safe laboratories for electronics development, assembly and test, clean rooms for cleanliness demanded projects.

In a frame of the visit test facilities like vibration stand, thermo-vacuum chamber and climate chambers will be demonstrated. A visit to BRITE satellite ground station currently in use for regular communication and management of BRITE-PL satellites called LEM and Heweliusz is also planned.

Topics of lectures:

Topics of laboratories:

References:

TRAINING UNIT 7.2 / SCHOOL SUBJECT DESCRIPTION CARD

TRAINING UNIT/ SCHOOL SUBJECT On-site Visit at the Creotech Instruments S.A.

4 hour on-site visit

Training Provider: Marcin Mazur

Subject description:

The main goal is to visit Creotech Instruments company and its facilities. Creotech Instruments is a Polish company developing highly advanced electronics. It is the only company in Poland with laboratories, clean rooms and ESA certified assembly lines dedicated to soldering of electronics according to the flight model standard.

The visitors will have an opportunity to familiarize themselves with automatic Surface Mount Technology assembly lines, through-hole assembly machines, climatic chamber and hand/ automatic quality inspection stations. During the visit practical aspects of the assembling and testing processes will be discussed and demonstrated.

Topics of lectures:

Topics of laboratories:

1. Assembly facility properties and parameters.
2. Presentation of Surface Mount Technology and Through-hole assembly line processes according to ECSS standards.
3. Practical aspects of assembly, integration and testing procedures.

References:

1. ECSS standards on AIT procedures

TRAINING UNIT 7.3 / SCHOOL SUBJECT DESCRIPTION CARD

Institution/Company: Military University of Technology

TRAINING UNIT/ SCHOOL SUBJECT: On-site Visit at the Military University of Technology

2 hour on-site visit in EMC chamber

Training Provider: Leszek NOWOSIELSKI

Subject description:

Electromagnetic compatibility (EMC) measurements must be conducted under special conditions for both emission and immunity testing. Whether the purpose of the test is for certification to a regulatory standard, customer requirement, or troubleshooting, testing must be performed in an environment that allows for measurement to occur without disruption from external ambients.

The visit provides insight into the typical anechoic chamber (the most common shielded facility in use). Anechoic chamber contains carbon-filled absorber cones, ferrite tiles, or a combination of both. A full anechoic chamber has shielding material on the floor while a semianechoic facility has a solid metal ground plane, simulating the effects of an Open Area Test Site.

The Military University of Technology has already gathered some experience in small spacecraft testing.

Topics of lectures:

Topics of laboratories:

3. Introduction to types of EMC test facilities.
4. The construction and calibration tests of EMC chamber.
5. The equipment needed for EMC tests in EMC chamber.

References:

13. Mark I. Montrose, Edward M. Nakauchi. “Testing for EMC Compliance . Approaches and techniques”. IEEE PRESS 2004.
14. Clayton R. Paul. “Introduction to electromagnetic compatibility”. A John Wiley& sons, INC. Publication, 2006.

About IDA JSC

Industrial Development Agency JSC (ARP – Agencja Rozwoju Przemysłu S.A.) is a Polish strategic state-owned company. IDA was established in 1992 as a company to implement the Polish economy restructuring program. We are currently a large financial institution (with a capital of EUR 1,400 billion) that manages a capital group of approximately 70 companies, incl. shipyards, a company producing trains, the largest Polish rail carrier. We grant loans and implement capital investments. We are active in the field of space technologies. ARP is a shareholder of 2 space companies: Creotech Instruments and PIAP Space. We have established our own Comprehensive Support Program for the space technology sector, including internship program (Polish Space Fellowship Program), training and specialized courses (ARP Space Academy), supporting the transfer of space technologies, as well as special financial instruments. From January 2022, we are the operator of ESA BIC Poland.

ARP Space Academy

ARP Space Academy is a training dedicated to engineers who want to start working in the space sector, as well as technical staff with experience in other industries and who want to retrain for the space industry.

The trainings provide theoretical and practical basis in various fields of engineering science, with emphasis on the specificity of space engineering. As part of the Space Academy, IDA JSC organises a two-part training course Introduction to Space for Engineers.

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