AGH UNIVERSITY OF SCIENCE AND TECHNOLOGY

Code:	int.courses-221	Module name:	Nanosatellite attitude determination and control		
Academic year:	2019/2020	Semester:	Spring, Fall	ECTS credits:	6
Programme:	AGH UST International Courses				
Course homepage:	http://home.agh.edu.pl/~agallina/?NANOSATELLITE_ATTITUDE_DETERMINATION_AND_CONTROL	Lecture language:	English		
Responsible teacher:	dr hab. inż. Gallina Alberto (agallina@agh.edu.pl)				

Module summary

Theoretical understanding of fundamentals of satellite dynamics enforced by hands-on experience provided by students' projects.

Description of learning outcomes for module

MLO code	Student after module completion has the knowledge/ knows how to/is able to	Method of learning outcomes verification (form of completion)
Social competence		
M_K001	Organization of the work inside a team	Execution of a project
M_K002	Avoid conflicts inside a team	Execution of a project
Skills		
M_U001	Fundamentals of numerical tools for the analysis of space missions	Activity during classes
M_U002	Ability to design, manufacture and assemble an attitude determination and control system for small satellite	Project
M_U003	Ability of reporting and presenting work carried out	Presentation
Knowledge		
M_W001	Knowledge of general aspects of Space missions	Activity during classes
M_W002	Knowledge of fundamentals of orbital mechanics	Completion of laboratory classes
M_W003	Knowledge of dynamics of rigid body in three dimensions	Completion of laboratory classes
M_W004	Knowledge of principal solutions of systems for attitude determination control system	Examination

Number of hours for each form of classes

Suma	Form of classes										
	Lectures	Auditorium classes	Laboratory classes	Project classes	Conversation seminar	Seminar classes	Practical classes	Fieldwork classes	Workshops	Prace kontrolne i przejściowe	Lektorat
60	20	0	18	22	0	0	0	0	0	0	0

FLO matrix in relation to forms of classes

MLO code	Student after module completion has the knowledge/ knows how to/is able to	Form of classes										
		Lectures	Auditorium classes	Laboratory classes	Project classes	Conversation seminar	Seminar classes	Practical classes	Fieldwork classes	Workshops	Prace kontrolne i przejściowe	Lektorat
Social competence: is able to												
M_K001	Organization of the work inside a team	-	-	-	+	-	-	-	-	-	-	-
M_K002	Avoid conflicts inside a team	-	-	-	+	-	-	-	-	-	-	-
Skills: he can												
M_U001	Fundamentals of numerical tools for the analysis of space missions	-	-	+	-	-	-	-	-	-	-	-
M_U002	Ability to design, manufacture and assemble an attitude determination and control system for small satellite	-	-	-	+	-	-	-	-	-	-	-
M_U003	Ability of reporting and presenting work carried out	-	-	-	+	-	-	-	-	-	-	-
Knowledge: he knows and understands												
M_W001	Knowledge of general aspects of Space missions	+	-	-	-	-	-	-	-	-	-	-
M_W002	Knowledge of fundamentals of orbital mechanics	+	-	-	-	-	-	-	-	-	-	-
M_W003	Knowledge of dynamics of rigid body in three dimensions	+	-	-	-	-	-	-	-	-	-	-
M_W004	Knowledge of principal solutions of systems for attitude determination control system	+	-	-	-	-	-	-	-	-	-	-

Student workload (ECTS credits balance)

Student activity form	Student workload
Udział w zajęciach dydaktycznych/praktyka	60 h
Preparation for classes	20 h
przygotowanie projektu, prezentacji, pracy pisemnej, sprawozdania	90 h
Summary student workload	170 h
Module ECTS credits	6 ECTS

Additional information

Module content

Lectures

General picture (4h)
- Introduction to the subject
- Short history of spaceflights
- How far is the space and how to get there
- Space environment
- Satellite mission phases
- Satellite subsystems

Orbital dynamics and mission design (6h)
- Kepler’s laws
- Keplerian Orbital Elements
- Types of orbits (LEO, Geosynchronous, Geostationary, etc.)
- Orbital propagation (Keplerian, secular J2)
- Ground station communication windows
- Satellite instrument coverage
- Understanding sun visibility on different orbits

Satellite attitude dynamics (6h)
- Vector operations
- Reference frames
- Rotational Kinematics
- Euler angles
- Quaternions
- Dynamics of a particle
- Dynamics of a system of particles
- Dynamics of a rigid body

Satellite attitude determination and control (4h)
- Disturbance Torques
- Sensors (Sun sensor, star tracker, horizon sensor, magnetometer, gyro)
- Passive systems (gradient, spin stabilization)
- Active system (reaction wheels, magnetorquers, thrusters)
- Avionics testing facilities

Laboratory classes

Matlab exercises on attitude dynamics (6h)
- Vector operation
- Rotational Kinematics
- Torque free attitude motion
- SIMMECH implementation

ADCS implementations (4h)
- Example of TRIAD algorithm
- B-dot detumbler

AGI STK (4h)
- Calculating ground station visibility periods
- Calculation of sensor coverage
- Simulation of Sun energy availability

Celestlab (6h)
- Basic orbital propagators
- Understanding ground-tracks

Project classes

Introduction (2h)
- Team division
- Workflow organization
- System overview
- Mission summary
- Program schedule
- System requirement summary

SatLab description (2h)
- Lab test rig
- SatLab system physical layout
- SatLab subsystems

Project assignment (2h)
- Project’s tasks assignment
- Hardware requirements
- Software requirements

Design (10h)
- Team work
- Trainer support

Assembling (2h)
- B-dot algorithm review
- Coils design review
- Hardware printing and assembling

Testing (2h)
- Experimental tests
- Experimental-numerical comparison
- Analysis of error

Final presentation (2h)
- Project’s presentation
- Lesson learned

Teaching methods and techniques:

Lectures: Treści prezentowane na wykładzie są przekazywane w formie prezentacji multimedialnej w połączeniu z klasycznym wykładem tablicowym wzbogaconymi o pokazy odnoszące się do prezentowanych zagadnień.
Laboratory classes: W trakcie zajęć laboratoryjnych studenci samodzielnie rozwiązują zadany problem praktyczny, dobierając odpowiednie narzędzia. Prowadzący stymuluje grupę do refleksji nad problemem, tak by otrzymane wyniki miały wysoką wartość merytoryczną.
Project classes: Studenci wykonują zadany projekt samodzielnie, bez większej ingerencji prowadzącego. Ma to wykształcić poczucie odpowiedzialności za pracę w grupie oraz odpowiedzialności za podejmowane decyzje.

Warunki i sposób zaliczenia poszczególnych form zajęć, w tym zasady zaliczeń poprawkowych, a także warunki dopuszczenia do egzaminu:

All students who have taken part to the practical experimental part are allowed to write the examination.
The realization of the project is the necessary condition for writing the exam and receiving a final grade.

Zasady udziału w poszczególnych zajęciach, ze wskazaniem, czy obecność studenta na zajęciach jest obowiązkowa:

Lectures:
– Attendance is mandatory: No
– Participation rules in classes: Studenci uczestniczą w zajęciach poznając kolejne treści nauczania zgodnie z syllabusem przedmiotu. Studenci winni na bieżąco zadawać pytania i wyjaśniać wątpliwości. Rejestracja audiowizualna wykładu wymaga zgody prowadzącego.
Laboratory classes:
– Attendance is mandatory: Yes
– Participation rules in classes: Studenci wykonują ćwiczenia laboratoryjne zgodnie z materiałami udostępnionymi przez prowadzącego. Student jest zobowiązany do przygotowania się w przedmiocie wykonywanego ćwiczenia, co może zostać zweryfikowane kolokwium w formie ustnej lub pisemnej. Zaliczenie zajęć odbywa się na podstawie zaprezentowania rozwiązania postawionego problemu. Zaliczenie modułu jest możliwe po zaliczeniu wszystkich zajęć laboratoryjnych.
Project classes:
– Attendance is mandatory: Yes
– Participation rules in classes: Studenci wykonują prace praktyczne mające na celu uzyskanie kompetencji zakładanych przez syllabus. Ocenie podlega sposób wykonania projektu oraz efekt końcowy.

Method of calculating the final grade

- Attendance to the lessons : 15% of final grade
- Final examination : 25% of final grade
- Project presentation and report : 60%

Sposób i tryb wyrównywania zaległości powstałych wskutek nieobecności studenta na zajęciach:

Students are provided with notes from the lectures and laboratory classes. The material should be enough to recover the lack of knowledge resultant form the absence.
In the case of justified absence to the project classes, the student will be supported to repeat practical experiments in another date.

Prerequisites and additional requirements

- Basic knowledge of MATLAB

Recommended literature and teaching resources

- Notes of the course.
- Howard Curtis, Orbital Mechanics for Engineering Students, Elsevier Aerospace Engineering Series.
- Peter Fortescue, Graham Swinerd, John Stark, Spacecraft Systems Engineering, Wiley.

• Roger Bate, Donald Mueller, Jerry White, Fundamentals of Astrodynamics, Dover.
• Anton De Ruiter, Schristopher Damaren, James Forbes, Spacecraft Synamics and Control An Introduction, Wiley.

Scientific publications of module course instructors related to the topic of the module

Additional scientific publications not specified

Additional information

The subject is divided into two main parts. Initially, the theoretical background and numerical tools for simulating satellite attitude control system are presented. Next, acquired knowledge is applied to a mechatronic project that aims to design, manufacture and assemble the missing part of an attitude control system of a small satellite simulator (SatLab). Eventually, students will test the fully integrated SatLab on the existing ADCS testrig and compare results with numerical simulations previously carried out.

Main part of the lectures will be held by prof. Karol Seweryn from CBK – Space Research Centre, Polish Academy of Sciences.