ADVANCED GUIDANCE, NAVIGATION AND CONTROL - 2024/5

Module code: EEEM009

Module Overview

Expected prior learning: EEE3039 SPACE DYNAMICS AND MISSIONS and EEE3040 SPACE SYSTEM DESIGN, or equivalent learning. General prior knowledge of basic control theory is recommended.

Module purpose: This module provides advanced understanding of the dynamics of satellites and of methods for controlling satellite motion.

Module provider

Computer Science and Electronic Eng

Module Leader

LUCCA FABRIS Andrea (Maths & Phys)

Number of Credits: 15

ECTS Credits: 7.5

Framework: FHEQ Level 7

Module cap (Maximum number of students): N/A

Overall student workload

Independent Learning Hours: 97

Lecture Hours: 13

Tutorial Hours: 10

Guided Learning: 10

Captured Content: 20

Module Availability

Semester 2

Prerequisites / Co-requisites

None.

Module content

Indicative content includes the following.

- Essential elements of control theory.
- Review of Attitude dynamics and coordinates (e.g., quaternions). Euler and kinematic equations. Rotational motion of a spinning body. Gravity Gradient Stabilisation.
- Attitude determination and estimation: attitude sensors. Estimation methods: triad method, q-method Quest algorithm, the Extended Kalman Filter.
- Attitude control. Attitude actuators: momentum/reaction wheels, thrusters, magnetotorques. Design of control loops Application examples.
- Overview of Satellite orbits. Review of Keplerian orbits and the most useful orbits for Earth orbiting satellites. Brief introduction to time and coordinate frames and the complexities of their definition.
- Perturbation effects in real orbits. Long and short periodic variations and secular evolution.
- Atmospheric drag modelling. Effects of Solar radiation pressure. Earth's non-spherical mass distribution. Perturbations effects on key Earth orbits.
- Orbit determination and Estimation. Data for orbit estimation and determination, GPS, Radar tracking, Least Squares method, Weighted Least Squares Methods, Batch Least Squares method, The Conventional and Extended Kalman filters.
- Orbit control: Gauss Variational Equations; Impulsive vs Low-thrust manoeuvres; Principle of Lyapunov control theory and nonlinear control design;
- Rendezvous in space: Hill-Clohessy-Wiltshire equations and relative motion control via pole placement and linear quadratic regulators.

Assessment pattern

Assessment type	Unit of assessment	Weighting
Coursework	COURSEWORK (MATLAB)	20
Examination	OPEN BOOK EXAM (2HR)	80

Alternative Assessment

N/A

Assessment Strategy

The assessment strategy for this module is designed to provide students with the opportunity to demonstrate the following. The written examination will assess the knowledge and assimilation of real satellite orbits and how to model them, evaluation of real-world algorithms used for attitude and orbit control, and the limitations of sensors and actuators used on modern satellites. The practical software-tool-based theoretical assignment will assess how the student can apply these models to representative cases.

Thus, the summative assessment for this module consists of the following.

- Software-tool-based theoretical assignment.
- Open-book written examination

Any deadline given here is indicative. For confirmation of exact date and time, please check the assessment calendar issued to you.

Formative assessment and feedback

For the module, students will receive formative assessment/feedback in the following ways.

- During lectures, by question-and-answer sessions.
- Via the marking of written reports.

Module aims

- To develop an understanding of the complexities of real satellite missions, and of practical methods to determine and control the orbit and attitude of spacecraft.

Learning outcomes

Ref		Attributes Developed	
002	Understand and evaluate algorithms for attitude and orbit determination	KCT	M1, M2, M3

Ref		Attributes Developed	
003	Apply spacecraft attitude and orbit models to representative cases	KCT	M3, M4, M6
004	Design algorithms for spacecraft attitude and orbit control and report them in written format	CPT	M3, M4, M17
005	Gain knowledge about the working principles and limitations of sensors and actuators used on modern satellites	KC	M13
001	Understand orbital and attitude dynamics	KC	M1, M2, M3

Attributes Developed

C - Cognitive/analytical

K - Subject knowledge

T - Transferable skills

P - Professional/Practical skills

Methods of Teaching / Learning

The learning and teaching strategy is designed to achieve the aims that students should

- Develop an understanding of real satellite orbits and the factors that influence (perturb) these orbits.
- Develop an understanding of real satellite attitude dynamics.
- Apply and evaluate practical methods in order to control satellite orbits.
- Apply and evaluate practical methods in order to control satellite attitude dynamics.

Learning and teaching methods include the following.

- Captured lectures
- Summary lectures
- Tutorials (guided study of example problems/past examinations)
- Practice lecture
- Guided learning

- Independent study (including practical problem-based assignment and preparation for final exam)

Indicated Lecture Hours (which may also include seminars, tutorials, workshops and other contact time) are approximate and may include in-class tests where one or more of these are an assessment on the module. In-class tests are scheduled/organised separately to taught content and will be published on to student personal timetables, where they apply to taken modules, as soon as they are finalised by central administration. This will usually be after the initial publication of the teaching timetable for the relevant semester.

Reading list

https://readinglists.surrey.ac.uk
Upon accessing the reading list, please search for the module using the module code: EEEM009

Other information

- Sustainability. The module introduces students to the orbit determination problem, a core topic that is essential for the understanding and the identification of mitigation strategies for the contemporary space debris problem, as well as end-of-life deorbiting strategies needed for a sustainable space exploitation.
- Digital Capabilities are expanded via a MATLAB assignment that constitutes an exercise of evaluation, analysis and synthesis of the theoretical background learnt during lectures and represents an opportunity to improve student's coding skills.
- Employability. The contents of the module include methods and algorithms that are used in real-life missions, preparing students for space engineering jobs such as AOCS engineer and spacecraft operator. Examples of implementations in flying spacecraft will be discussed throughout of the module to provide students examples of applications they might encounter in their future career.

Programmes this module appears in

Programme	Semester	Classification	Qualifying conditions
Electronic Engineering with Space Systems MEng	2	Optional	A weighted aggregate mark of 50% is required to pass the module
Space Engineering MSc	2	Optional	A weighted aggregate mark of 50% is required to pass the module

Please note that the information detailed within this record is accurate at the time of publishing and may be subject to change. This record contains information for the most up to date version of the programme / module for the 2024/5 academic year.