SPACE SYSTEMS DESIGN - 2024/5

Module code: ENGM273

Module Overview

Module purpose: This is a key module for students interested in becoming space systems engineers, or in working in a related field. It introduces the student to the key principles and techniques of spacecraft systems design, through real-world examples, and is delivered by a lecturer with more than 25 years practical experience of designing and building spacecraft systems and payloads.

Module provider

Mechanical Engineering Sciences

Module Leader

LIM Sungwoo (CS & EE)

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: 88

Lecture Hours: 11

Tutorial Hours: 11

Guided Learning: 10

Captured Content: 30

Module Availability

Semester 1

Prerequisites / Co-requisites

None

Module content

Indicative content includes:

Designing for Space: Elements of a space mission; the physical environments of spacecraft manufacture, launching and space and their impact on spacecraft system design.

Mechanical Design: Launch vehicle interface; frameworks and structures – forms and requirements; stress analysis, loads and stiffness, elastic instabilities, vibration, materials selection, structural analysis, verification.

Thermal Design: Temperature limits; thermal sources and heat transport mechanisms in space – conduction, black-body radiation; Stefan-Boltzmann Law emissivity, absorptivity; greybody assumptions, Kirchhoff's law, view factors; thermal balance, thermal modelling, finite difference method; thermal control elements – passive and active, thermal design and implementation.

Mechanisms and Optics: Bearings and lubrication; flexures, flexure hinges and tape booms; electric motors and drives; pyrotechnics and one-shot devices; continuously rotating and intermittently operated mechanisms. Materials selection; optical materials, mountings, alignment, and stray-light control. Basic optics, diffraction limits; fields of view; sensor topologies, lens and mirror based telescopes; filters and optical bench layouts.

Attitude & Orbit Control Systems: Attitude Determination Control and Stabilisation (ADCS) systems: Body dynamics – forces, torques, momenta, inertia matrix, kinematics. Attitude determination sensors – Sun sensors, Earth horizon sensors, star cameras, magnetometers, inertial sensors. Attitude control system technologies – reaction control systems, magnetorquers, gravity-gradient booms, reaction and momentum wheels, control-moment gyros; ADCS requirements and capabilities; small satellite ADCS. Orbit control systems: choice of propellant; liquid engines, solid motors; hybrid engines; arc-jets, resistojets, ion-thrusters.

Power Systems: Power generation – fuel cells, RTGs, nuclear fission reactors, solar arrays; solar cell I-V characteristics – thermal and radiation effects; power storage – battery technologies, charge/discharge profiles and effects on cell lifetimes, super-capacitors; power regulation and monitoring, regulated and unregulated bus topologies; Energy budgets and efficiencies. Harnesses, shielding and grounding policy. Component protection, redundancy, and good design practices.

TT&C, RF and OBDH Systems: Telemetry, Tracking and Command (TT&C) systems, space and ground segments, tracking schemes, basic telemetry and telecommand systems, packet-switched systems, CCSDS, simple RF link equation, Eb/N0 and data robustness. On-Board Data Handling (OBDH) schemes and standards; digital interfaces, On-Board Computers (OBCs), radiation effects and mitigation – error detection and correction (EDAC) coding schemes; software design principles.

Manufacture and AIT, Operation and Disposal: PA/QA, reliability issues; manufacture process; testing: mechanical properties (MoI, CoG); vibration, shock and acoustic testing, EMC test; thermal vacuum test; solar simulation; launch campaign. Operation and disposal.

Assessment pattern

Assessment type	Unit of assessment	Weighting
Coursework	COURSEWORK: FORMAL WRITTEN REPORT	20
Examination	2 HOUR CLOSED BOOK EXAM	80

Alternative Assessment

Not applicable.

Assessment Strategy

The **assessment strategy** for this module is designed to provide students with the opportunity to demonstrate the learning outcomes. The written examination will assess the knowledge and assimilation of terminology, concepts and theory of spacecraft systems, as well as the ability to analyse and find solutions to problems of the mechanical and electrical design of spacecraft systems. The coursework exercise will examine the ability of the student to apply the knowledge gained in this module to provide a space platform design to meet a specific space mission objective and its associated design requirements.

Thus, the **summative assessment** for this module consists of:

Thus, the summative assessment for this module consists of:

- Coursework [Learning outcomes 2, 3] (30 hours) {20%}
- Examination [Learning outcomes 1, 2, 3] (2 hours) {80%}

Formative assessment and feedback

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

- During lectures, by question and answer sessions
- During tutorials/tutorial classes
- By means of unassessed tutorial problem sheets (with answers/model solutions)
- Via the marking of written reports
- Via assessed coursework

Module aims

- Through a series of lectures, exercises and coursework, the module aims to give the student an introduction to the design and construction of spacecraft, showing how the mission and the space environment, itself, constrain the engineering. The module forms a key part of the MEng Aerospace programme. Students who complete this module, along with the other modules in the Aerospace Engineering pathway, should have gained sufficient background knowledge to begin a career in aerospace engineering with a specialisation in space, and will find the material invaluable in their early career development, as they work on real space missions.

Learning outcomes

Ref		Attributes Developed	
001	Knowledge and understanding of the physical and mathematical principles underpinning the design and engineering of spacecraft and the ability to apply this knowledge to a variety of spacecraft subsystem design problems and space mission scenarios, including ones not previously encountered.	KC	M1, M2, M3, M6, M13
002	Knowledge and understanding of the engineering tools and approaches to problems of space system design and to have a grasp of the development and future possibilities of the topic.	KPT	M3
003	Ability to select appropriate technical solutions for spacecraft sub-systems for a variety of space mission scenarios.	KPT	M4, M13

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 give students a good understanding of the principles and techniques involved in the mechanical and electrical design of space systems, at a level which is sufficiently advanced to fit them for carrying out such activities in a real spacecraft design context.

Learning and teaching methods include the following.

- Lecture/tutorial
- Guided study of example problems/ past examinations
- Coursework – Spacecraft System Design Exercise and Report
- Independent study

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: ENGM273

Other information

Surrey's Curriculum Framework is committed to developing graduates with strengths in Employability, Digital Capabilities, Global aand Cultural Capabilities, Sustainability, Resourcefulness and Resilience.

This module addresses the "5 pillars" as follows:

- Sustainability - All spacecraft subsystems must be operated efficiently to ensure sustainable mission operations and extend the spacecraft's operational lifespan. Thus, this module discusses the design strategies employed to achieve these objectives. This includes selecting materials and structures for electrical, thermal and mechanical considerations. These design choices, such as power generation, depend on the type of orbit and mission and are influenced by the specific demands of the space environment.
- Global and Cultural Intelligence – There is a large cultural aspect to the development of space technology, both historically (e.g. Cold War rivalries) and currently – e.g. through the emergence of new space powers and the role of private enterprise in the commercial utilisation of space assets (Global and Cultural Awareness). discusses the role of political rivalries in stimulating space exploration from the USA/USSR in the context of the Cold War to today's emerging Asian superpower rivalries – e.g. China/India.
- Digital Capabilities are touched upon in terms of discussions of digital/OBDH systems and also the use of digital tools in practical engineering and design including Computer Aided Design/ Computer Aided Manufacture (CAD/CAM), Finite Element Modelling (FEM) for mechanical design and Finite difference Modelling (FDM) for thermal design. Preferred computer languages for space, and the need for special techniques to enable digital hardware and software systems to operate successfully in the harsh ionising radiation environment of space are discussed.
- Employability – Throughout, the industrial context of the module content is given through real examples and the skills/knowledge developed are aligned very closely with industrial needs. The needs of industry, what space companies are look for, and advice on applying to relevant companies is given.
- Resourcefulness and Resilience – the module discusses how to build a team to achieve a successful space mission and the approaches and skills needed including working under significant pressures. The practical experiences of working as a space engineer is passed on throughout the module based on the lecturer's almost 40 years of working in the field. Systems design and systems thinking is critical to how industries handle complex engineering projects such as space missions. It is important that students become familiar with this concept and approach (Employability) and become aware of the resources, such as the key documents, that are available to the engineer to help them achieve well engineered systems.

Programmes this module appears in

Programme	Semester	Classification	Qualifying conditions
Aerospace Engineering MEng	1	Optional	A weighted aggregate mark of 50% is required to pass the module