UNSW SYDNEY | Australia's Global University

Mechanical and Manufacturing Engineering

# Course Outline

Term 3 2019

# AERO9500

# SPACE SYSTEMS ARCHITECTURE AND ORBITS

# 1. Staff contact details

**Contact details and consultation times for course convenor**

Name: Dr. Manuj Awasthi
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Consultation will be via email, during the tutorials, and after the lectures if time permits.

**Contact details and consultation times for additional lecturers/demonstrators/lab staff**

Name: Mr. Michael Moschetti
Email: m.moschetti@unsw.edu.au

# 2. Important links

- Moodle
- Lab Access
- Computing Facilities
- Student Resources
- Course Outlines
- Engineering Student Support Services Centre
- Makerspace
- UNSW Timetable
- UNSW Handbook
- UNSW Mechanical and Manufacturing Engineering

# 3. Course details

**Credit points**

This is a 6 unit-of-credit (UoC) course and involves 4 hours per week (h/w) of face-to-face contact.

The normal workload expectations of a student are approximately 25 hours per term for each UOC, including class contact hours, other learning activities, preparation and time spent on all assessable work.

You should aim to spend about 9 h/w on this course. The additional time should be spent in making sure that you understand the lecture material, completing the set assignments, further reading, and revising for any examinations.

**Contact hours**

| | Day | Time | Location |
|---|---|---|---|
| **Lectures** | Monday<br>(Weeks 1-3, 5-11) | 12noon - 2pm | Ainsworth 202 (K-J17-202) |
| | Thursday | 3pm - 4pm | Ainsworth 102 (K-J17-102) |
| (Web stream) | Any | Any | Moodle |
| | | | |
| **Demonstrations** | Thursday | 4pm – 5pm | Ainsworth 102 (K-J17-102) |
| Weeks 1 - 10 | Thursday | 5pm – 6pm | Ainsworth 101 (K-J17-101) |

Please refer to your class timetable for the learning activities you are enrolled in and attend only those classes.

**Summary and Aims of the course**

This course gives an overview of satellite systems from the space segment to the ground segment, describing the main applications of satellite systems, as well as providing a detailed introduction into the principles of orbital mechanics.

The course is divided into two major parts: the first part will paint the overall picture of a satellite system, setting it in the wider context of space, describing its major components and central concepts, to provide students with a solid introduction to satellite systems and the associated technologies. The second part of the course focuses on the details of orbital mechanics, covering orbit description and analysis, orbital perturbations, orbital maneuvers, and satellite launch systems.

**Student learning outcomes**

At the conclusion of this course, it is expected that you will be able to:

- Explain the main applications of satellites and the way they affect our everyday lives.
- Describe the overall system design of a satellite and its supporting earth stations and be able to cite the major functional subsystems of a satellite along with the principles of operation of each, and the associated overall design aspects.
- Gain a basic understanding of space mission design and analysis.
- Understand basic spacecraft orbital principles, such as how satellites acquire orbits, maintain orbits, the key parameters used to describe an orbit, and commonly employed satellite orbits.
- Apply fundamental principles in the analysis of basic orbital mechanics problems
- Describe and plan basic orbital maneuvering techniques, such as impulse maneuvers, Hohmann transfers, orbital plane changes and rendezvous
- Explain the basic principles of satellite launch mechanics.

This course is designed to address the learning outcomes below and the corresponding Engineers Australia Stage 1 Competency Standards for Professional Engineers as shown. The full list of Stage 1 Competency Standards may be found in Appendix A.

After successfully completing this course, you should be able to:

| Learning Outcome | | EA Stage 1 Competencies |
|---|---|---|
| 1. | Explain the main applications of satellites and the way they affect our everyday lives. | 1.1, 1.3 |
| 2. | Design spacecraft orbits, analyse these orbits and their perturbations, and recognise commonly employed satellite orbits. | 1.1, 1.2, 1.3, 2.1 |
| 3. | Compute delta-V and fuel requirements for various orbital manoeuvres, interplanetary transfers, and launches. | 1.3, 2.1, 2.2 |
| 4. | Have a thorough understanding of the anatomy of a spacecraft mission and the steps involved in designing the mission. | 2.3, 2.2 |

# 4. Teaching strategies

The course material will be taught through a combination of in-class lectures, textbook content, and research articles. The lectures will focus on presentation of the core content of the course, while supplementary reading material will be used to expand upon the course topics and highlight the current trends in spacecraft systems design.

Students are expected to prepare for the lecture in advance, as the sections of the textbook to be read will be available prior to each lecture. The lecture slides will build upon the framework provided by the text, but they will also contain additional material. Both the textbook and lecture slides together constitute examinable material. Additionally, students will be encouraged to read research articles (and discuss them) in order to learn about the present state of spacecraft systems design. This material will ***not*** be included in the exams and is purely intended to help students learn about the present and the future of spacecraft systems design.

The schedule below provides a breakdown of the course along with some suggested reading during each week. Note that lectures notes will be provided for each lecture and the suggested reading is in addition to these notes. In addition to these, the students are encouraged to explore further reading material suggested in the "*Expected resources for students*" section below.

# 5. Course schedule

| Week | Topic | Suggested Readings |
|---|---|---|
| 1 | Course introduction, a historical overview of space flight; satellite applications and examples; Anatomy of spacecraft missions and their objectives. | Notes provided<br>*Elements of Spacecraft Design*, Ch. 1, 2<br>*Optional Reading:*<br>"Countdown: *A History of Space Flight*" by T.A. Heppenheimer |
| 2 | Systems view of spacecraft design and principles of spacecraft system engineering.<br>Space systems architecture overview.<br>Design and operation of the space segment. | *Notes provided. Elements of spacecraft design Ch. 2.* |
| 3 | The space segment wrap-up.<br>Design and operation of the ground segment.<br>Introduction to orbital mechanics and historical overview of astrodynamics. | *Notes provided.* |
| 4 | Kepler's laws and Newton's law of gravitation.<br>Spatial and temporal coordinate systems in orbital mechanics.<br>Point-mass dynamics review. | *Notes provided. Elements of spacecraft design Ch. 3.* |
| 5 | Point mass dynamics review (contd.).<br>Introduction to the two-body problem in orbital mechanics.<br>Conic sections and orbit shapes. | *Notes provided. Elements of spacecraft design Ch. 3.* |
| 6 | **Mid-Semester Exam** | |
| 7 | The two-body problem in orbital mechanics (contd.).<br>The restricted three-body problem and Lagrange points.<br>Orbits in three-dimensions.<br>Description of orbits: the orbital elements. | *Notes provided. Elements of spacecraft design Ch. 3.* |
| 8 | Orbital manoeuvres and transfers.<br>Interplanetary trajectories.<br>Patched conic approximation.<br>Planetary rendezvous. | *Notes provided. Elements of spacecraft design Ch. 3.* |
| 9 | Orbital mechanics wrap-up: Orbit determination; orbit perturbations and ground tracks.<br>Spacecraft launch systems: rocket propulsion, vehicle staging, and launch sites. | *Notes provided. Elements of spacecraft design Ch. 3, 4.* |
| 10 & 11 | Revision and overflow | |

# 6. Assessment

## Assessment overview

| Assessment | Group Project? | If Group, # Students per group | Length | Weight | Learning outcomes assessed | Assessment criteria | Due date and submission requirements | Deadline for absolute fail | Marks returned |
|---|---|---|---|---|---|---|---|---|---|
| Mid-Semester Exam | No | N/A | 2 Hours | 30% | 1, 2, and 3 | Course content from Weeks 1 through 5 | 21st October (Week 6), in class | N/A | Week 8 |
| Assignment#1 | No | N/A | Less than 10 pages of content | 15% | 1, 2, and 3 | Lecture material from weeks 1-3 | Midnight, Friday October 4th via Moodle | N/A | Week 4 |
| Assignment#2 | No | N/A | Less than 10 pages of content | 15% | 1,2, and 3 | Lecture material from weeks 4-8. | Midnight, Monday November 11th via Moodle | N/A | Week 10 |
| Final exam | No | N/A | 2 hours | 40% | 1, 2 and 3 | All course content from weeks 1-10 inclusive. | Exam period, date TBC | N/A | Upon release of final results |

## Assignments

The assignments can be accessed from the course's moodle page: https://moodle.telt.unsw.edu.au/mod/page/view.php?id=2452560.
The assignments must be submitted electronically via Moodle before the due date.

*Presentation*

All submissions are expected to be neat and clearly set out. Your results are the pinnacle of all your hard work and should be treated with due respect. Presenting results clearly gives the marker the best chance of understanding your method; even if the numerical results are incorrect.

*Submission*

Work submitted late without an approved extension by the course coordinator or delegated authority is subject to a late penalty of 20 percent (20%) of the maximum mark possible for that assessment item, per calendar day.

The late penalty is applied per calendar day (including weekends and public holidays) that the assessment is overdue. There is no pro-rata of the late penalty for submissions made part way through a day.

Work submitted after the 'deadline for absolute fail' is not accepted and a mark of zero will be awarded for that assessment item.

For some assessment items, a late penalty may not be appropriate. These are clearly indicated in the course outline, and such assessments receive a mark of zero if not completed by the specified date. Examples include:

a. Weekly online tests or laboratory work worth a small proportion of the subject mark, or
b. Online quizzes where answers are released to students on completion, or
c. Professional assessment tasks, where the intention is to create an authentic assessment that has an absolute submission date, or
d. Pass/Fail assessment tasks.

*Marking*

Marking guidelines for assignment submissions will be provided at the same time as assignment details to assist with meeting assessable requirements. Submissions will be marked according to the marking guidelines provided.

## Examinations

This course consists of two examination—a mid-semester exam during week 6 and a final exam.

You must be available for all tests and examinations. Final examinations for each course are held during the University examination periods: February for Summer Term, May for T1, August for T2, and November/December for T3.

Please visit myUNSW for Provisional Examination timetable publish dates.

For further information on exams, please see the Exams webpage.

*Calculators*

You will need to provide your own calculator of a make and model approved by UNSW for the examinations. The list of approved calculators is available at student.unsw.edu.au/exam-approved-calculators-and-computers

It is your responsibility to ensure that your calculator is of an approved make and model, and to obtain an "Approved" sticker for it from the Engineering Student Supper Services Centre prior to the examination. Calculators not bearing an "Approved" sticker will not be allowed into the examination room.

**Special consideration and supplementary assessment**

If you have experienced an illness or misadventure beyond your control that will interfere with your assessment performance, you are eligible to apply for Special Consideration prior to submitting an assessment or sitting an exam.

**Please note** that UNSW now has a Fit to Sit / Submit rule, which means that if you sit an exam or submit a piece of assessment, you are declaring yourself fit enough to do so and cannot later apply for Special Consideration.

For details of applying for Special Consideration and conditions for the award of supplementary assessment, please see the information on UNSW's Special Consideration page.

# 7. Expected resources for students

**Textbook**
There is a **required** textbook for this course which is available as an e-book via the UNSW library website:

- *Elements of Spacecraft Design*, C. Brown

The relevant chapters are shown in the course schedule and will also be posted on Moodle. A few printed copies are also available in the library. It is expected that students read the relevant chapters prior to the lecture and refer to them when studying

There are also several recommended books that are closely related to course content. Many of these books are available through the library:

- *Astronautics*, second edition, U. Walter.
- *Spacecraft Systems Engineering*, fourth edition, P. Fortescue, G. Swinerd and J. Stark
- *Introduction to Flight,* seventh edition, J. D. Anderson Jr (chapters 8 and 9).
- *Orbital Mechanics for Engineering Students*, second edition, H. Curtis.
- *Fundamentals of Astrodynamics,* R. R. Bate, D. D. Mueller and J. E. White

This course has a website on Moodle which includes lecture notes, lecture recordings and a discussion forum.

UNSW Library website: https://www.library.unsw.edu.au/
Moodle: https://moodle.telt.unsw.edu.au/login/index.php

## 8. Course evaluation and development

Feedback on the course is gathered periodically using various means, including the UNSW myExperience process, informal discussion in the final class for the course, and the School's Student/Staff meetings. Your feedback is taken seriously, and continual improvements are made to the course based, in part, on such feedback.

In this course, recent improvements resulting from student feedback include changes to the assessment structure, inclusion of more diverse assessment criteria to provide more feedback to students, inclusion of more worked out tutorial problems.

## 9. Academic honesty and plagiarism

UNSW has an ongoing commitment to fostering a culture of learning informed by academic integrity. All UNSW students have a responsibility to adhere to this principle of academic integrity. Plagiarism undermines academic integrity and is not tolerated at UNSW. *Plagiarism at UNSW is defined as using the words or ideas of others and passing them off as your own.*

Plagiarism is a type of intellectual theft. It can take many forms, from deliberate cheating to accidentally copying from a source without acknowledgement. UNSW has produced a website with a wealth of resources to support students to understand and avoid plagiarism, visit: student.unsw.edu.au/plagiarism. The Learning Centre assists students with understanding academic integrity and how not to plagiarise. They also hold workshops and can help students one-on-one.

You are also reminded that careful time management is an important part of study and one of the identified causes of plagiarism is poor time management. Students should allow sufficient time for research, drafting and the proper referencing of sources in preparing all assessment tasks.

If plagiarism is found in your work when you are in first year, your lecturer will offer you assistance to improve your academic skills. They may ask you to look at some online

resources, attend the Learning Centre, or sometimes resubmit your work with the problem fixed. However more serious instances in first year, such as stealing another student's work or paying someone to do your work, may be investigated under the Student Misconduct Procedures.

Repeated plagiarism (even in first year), plagiarism after first year, or serious instances, may also be investigated under the Student Misconduct Procedures. The penalties under the procedures can include a reduction in marks, failing a course or for the most serious matters (like plagiarism in an honours thesis) even suspension from the university. The Student Misconduct Procedures are available here: www.gs.unsw.edu.au/policy/documents/studentmisconductprocedures.pdf

## 10. Administrative matters and links

All students are expected to read and be familiar with UNSW guidelines and polices. In particular, students should be familiar with the following:

- Attendance
- UNSW Email Address
- Computing Facilities
- Special Consideration
- Exams
- Approved Calculators
- Academic Honesty and Plagiarism
- Disability Support Services
- Health and Safety
- Lab Access

# Appendix A: Engineers Australia (EA) Competencies

*Stage 1 Competencies for Professional Engineers*

| | **Program Intended Learning Outcomes** |
|---|---|
| **PE1: Knowledge and Skill Base** | PE1.1 Comprehensive, theory-based understanding of underpinning fundamentals |
| | PE1.2 Conceptual understanding of underpinning maths, analysis, statistics, computing |
| | PE1.3 In-depth understanding of specialist bodies of knowledge |
| | PE1.4 Discernment of knowledge development and research directions |
| | PE1.5 Knowledge of engineering design practice |
| | PE1.6 Understanding of scope, principles, norms, accountabilities of sustainable engineering practice |
| **PE2: Engineering Application Ability** | PE2.1 Application of established engineering methods to complex problem solving |
| | PE2.2 Fluent application of engineering techniques, tools and resources |
| | PE2.3 Application of systematic engineering synthesis and design processes |
| | PE2.4 Application of systematic approaches to the conduct and management of engineering projects |
| **PE3: Professional and Personal Attributes** | PE3.1 Ethical conduct and professional accountability |
| | PE3.2 Effective oral and written communication (professional and lay domains) |
| | PE3.3 Creative, innovative and pro-active demeanour |
| | PE3.4 Professional use and management of information |
| | PE3.5 Orderly management of self, and professional conduct |
| | PE3.6 Effective team membership and team leadership |