Introduction

This is the Student Handbook for the UCL MSc/Graduate Diploma/Graduate Certificate Programme in *Space Science and Engineering*, which has two Pathways:

- Spacecraft Technology and Satellite Communications
- Space Science

The programme normally runs over one year. This Handbook is intended to give students joining the programme the basic information they will need about it, information about the facilities and the host departments, the main procedures to be followed, and references to further sources of information.

The MSc/Graduate Diploma/Graduate Certificate Programme in *Space Science and Engineering* is run jointly by the Department of Space and Climate Physics and the Department of Electronic and Electrical Engineering.

The Department of Space and Climate Physics is the Admitting Department for the Programme.

The following abbreviations are used in this Handbook:

SSE	(MSc/Graduate Diploma/Graduate Certificate) **Space Science and Engineering**
ST&SC	(Pathway) **Spacecraft Technology and Satellite Communications**
SS	(Pathway) **Space Science**
S&CP	Department of **Space and Climate Physics**
E&EE	Department of **Electronic and Electrical Engineering**

UCL's *Academic Regulations for Students* apply to this MSc /Graduate Diploma/Graduate Certificate Programme.

The information in this Handbook is believed to be correct at the time of printing, but may be subject to change during the year.

Programme Information

Aims and Objectives

The Programme aims to enable successful students to put the skills and knowledge gained to good use, in either employment or in further study such as PhD research.

The ST&SC Pathway is focussed on the application of space technology in industrial settings, and therefore has this main objective:

- To provide students with a sound knowledge of the underlying principles which form a thorough basis for careers in space technology, satellite communications and related fields.

The SS Pathway is focussed on scientific research applications of space technology, and has the objective:

- To provide students with a sound knowledge of the underlying principles which form a thorough basis for careers in space science and related fields.

The two Pathways share a number of common aims and objectives:

- To enable students to develop insights into the techniques used in current space missions.
- To allow students to have an in-depth experience of a particular specialised area, through project work, as a member of a research team.
- To develop students' professional skills which are necessary to play a meaningful role in industrial or academic life and satisfy the need, both nationally and internationally, for well-qualified postgraduates who will be able to respond to the challenges that arise from future developments.
- To give students the experience of teamwork, to develop students' report-writing and presentation skills, and to train students to work to deadlines.

The two Pathways share a great deal, but there are important differences, especially in the course options structure.

Programme Details

Both ST&SC and SS Pathways of the MSc/Diploma/Certificate Programme in 'Space Science and Engineering' comprise taught Core and Advanced modules, the Individual Project and the Group Project.

The two Pathways differ in one of their Core modules and in the options available for the Advanced modules, so these notes should be studied carefully.

Course Codes

We use internal Departmental codes (beginning with the letters SS or ST) for some of the modules that make up the MSc/Diploma/Certificate Programme. Lecture modules and the projects also have longer UCL codes – you will need these for accessing information on them via PORTICO (see later).

Structure of the MSc/Diploma/Certificate Programme

Students gain 'credits' when they complete each one of the components of the MSc/Diploma/Certificate Programme (taught Core and Advanced modules, the Individual Project and the Group Project); the total number of credits required to obtain the MSc degree is 180, while a Graduate Diploma and a Certificate require 120 and 60 credits, respectively. The structure of the MSc/Diploma/Certificate Programme is summarised in the table on the next page.

The overall average MSc/Diploma/Certificate mark is the average of the marks obtained in all components (taught Core and Advanced modules, the Individual Project and the Group Project), weighted according to the number of credits attributed to each. To obtain an award, students must obtain an overall average mark of at least 50%, and a mark of at least 50% in all individual components, i.e. each Core and Advanced module, the Individual Project and the Group Project. Provided that these criteria are met, the Examination Board will normally condone a failure to achieve the MSc/Diploma/Certificate pass mark of 50% in one of the taught modules, provided that the mark for that module is at least 40%.

Otherwise, failure of any taught module examination requires a re-sit of that component to be completed successfully in a subsequent year in order to obtain the MSc/Diploma/Certificate. Failure in the Individual or Group Project component requires a re-submission in a subsequent year.

In order to be awarded a Distinction, a student must obtain an overall average mark of at least 70%, and obtain a mark of at least 70% for the Individual Project and a mark of at least 50% for each other component.

At the discretion of the Examination Board, considering all students together on both SS and ST&SC Pathways of the Programme, prizes are sometimes awarded for Best Individual Project and Best Overall Achievement.

The main formal meeting of the Examination Board takes place on the last day of the Programme and it is at this meeting that the MSc results are decided - not before! You will be invited to a Progress Meeting with the Programme Team early in the second term to review your performance in the first term and to discuss your Initial Project Report. ***It is important that you heed the advice offered during this meeting***, otherwise you may not be successful later in the year.

Diploma/Certificate-registered students

Graduate Diploma and Certificate

MSc/Diploma/Certificate programme elements are operated concurrently, and the entry qualifications are the same for all three. The lectures and exams are the same, but the Diploma does ***not*** include participation in the Group Project, and includes work on the Individual Project only to the point of producing an Interim Report (worth 15 credits – thus corresponding to 120 credits total). The Certificate is obtained by passing the three Core modules and one Advanced module (60 credits total).

MSc/Graduate Diploma/Graduate Certificate Programme in 'Space Science and Engineering'

	Core Modules - Term 1					
Selection	**Current code**	**UCL code**	**credits 45 total**	**Title**		**Teaching Department**
	Space Science (SS) pathway				**Notes**	
Take all three CORE courses						
CORE		SPCEGC01	15	Space Science, Environment and Satellite Missions		S&CP
CORE		SPCEGC02	15	Space Systems Engineering		S&CP
CORE		SPCEGC03	15	Space Data Systems and Processing	Short, intensive (Type II)	S&CP
	Space Technology and Satellite Communications (ST&SC) pathway					
Take all three CORE courses						
CORE		SPCEGC01	15	Space Science, Environment and Satellite Missions		S&CP
CORE		SPCEGC02	15	Space Systems Engineering		S&CP
CORE	ST103	ELECGT02	15	Communications Systems Modelling	Type II	EEE
	Advanced Modules - Term 2					
Selection	**Code**	**UCL code**	**credits 60 total**	**Title**		**Teaching Department**
	Space Science (SS) pathway					
Take COMPulsory module, and three OPTIONs						
COMP	ST10	SPCEG001	15	Space Instrumentation and Applications		S&CP
OPTION	SS4	SPCEG011 PHAS4312	15	Planetary Atmospheres		S&CP
OPTION	SS6	SPCEG012 PHAS4314	15	Solar Physics		S&CP
OPTION	SS7	SPCEG013 PHAS4315	15	High Energy Astrophysics	In Term 1	S&CP
OPTION	SS109	SPCEG002 PHAS4465	15	Space Plasma and Magnetospheric Physics		S&CP
OPTION*		CEGEG046	7.5	Principles and Practice of Remote Sensing	In Term 1	CE&GE
OPTION*		CEGEG044	7.5	Global Monitoring of Environment and Security	In Term 1	CE&GE
* These two options have to be taken together						
	Space Technology and Satellite Communications (ST&SC) pathway					
Take COMPulsory module, and three OPTIONs, at least one each from group A and group B.						
COMP	ST105	ELECGC13	15	Satellite Communications	Type II	EEE
A: OPTION	ST7	SPCEG008	15	Spacecraft Design - Electronic Sub-sytems		S&CP
A: OPTION	ST8	SPCEG009	15	Spacecraft Mechanical and Structural Design		S&CP
A: OPTION	ST106	ELECGC01	15	Antennas and Propagation	Type II	EEE
A: OPTION	ST112	ELECGC11	15	RF Circuits and Sub-systems	Type II	EEE
B: OPTION	ST10	SPCEG001	15	Space Instrumentation and Applications		S&CP
B: OPTION	SS109	SPCEG002	15	Space Plasma and Magnetospheric Physics		S&CP
B: OPTION*		CEGEG046	7.5	Principles and Practice of Remote Sensing	In Term 1	CE&GE
B: OPTION*		CEGEG044	7.5	Global Monitoring of Environment and Security	In Term 1	CE&GE
* These two options have to be taken together						
Exit Point : Graduate Certificate, if passed Core modules and one Advanced module (i.e. 60 credits total)						
	Problem-based learning and career training: Group Project					
			credits 15 total			
		SPCEG089	15	Group Project (6 weeks in summer)		
	Research Programme: Individual Project					
			credits 60 total			
No difference between SS and ST&SC pathways, except choice of Individual Project subject.						
		SPCEG099	15	Interim Report (during Terms 1 and 2)		
			45	Final Report (Term 3)		
	MSc award if successful in all four components (described in the four boxes)					
Exit Point: Graduate Diploma, if worked on an Individual Project up to producing an Interim Report worth 15 credits (i.e. 120 credits total)						
S&CP	Space and Climate Physics Department					
EEE	Electronic & Electrical Engineering Department					
CE&GE	Civil, Environmental & Geomatic Engineering Department					

Assessment of Diploma/Certificate

In order to be eligible for a Graduate Diploma/Certificate award, a student must complete all required components of the programme satisfactorily. The overall mark for the Diploma/Certificate is the average of the marks for all these components, weighted according to the number of credits attributed to each.

The results for the Diploma/Certificate students are decided at a special meeting of the Examination Board in June. If a student fails to achieve the marks required for a Graduate Diploma/Certificate (i.e. at least 50% for each component) he/she can re-sit the relevant exams for the Diploma/Certificate in a subsequent year.

Transfer from Diploma to MSc

At the discretion of the Examination Board, a Diploma-registered student can be transferred to MSc registration, provided that he/she achieves satisfactory marks in the taught modules examinations. If transferred to MSc registration, the student will then continue with the project work so as to try and obtain an MSc. An extra fee is also then due. Students wishing to have the option of transferring to MSc registration at the June Exam Board meeting ***must therefore have already continued to work on their Individual Project past the Interim Report stage***, the same as the MSc-registered students. Their enrolment can be initially re-considered at the progress meeting taking place early in second term (see later, under ‘Course Assessment and Examinations’), by when they should demonstrate good progress in their approach to the Individual Project work.

NOTE: Under the current UCL regulations, if a Diploma-registered student fails to achieve the marks required for transfer to MSc registration, he/she ends the programme in June, and ***is not allowed to complete a project or re-sit any exams for the MSc degree***. The student can, however, re-sit for the Diploma if he/she has failed to obtain the marks required for a Diploma.

Learning Agreements

Some overseas students are required to submit ‘Learning Agreements’ forms for College approval. Please note that the forms should be handed in to the Programme Team by 10th November at the latest.

Programme Timetable/Calendar

The Programme Timetable/Calendar is distributed at the introductory meeting (a draft version), and is published on the Programme Moodle Website; the Moodle version will always be kept up-to-date, so students should use it in preference to other versions.

Format of courses

There are two different formats for the lecture modules and their exams.

- *‘SHORT FAT’ MODULES (SPCEGC03, ST103, ST105, ST106, ST112)*

  These modules are ‘short and fat’, i.e. running with many lectures condensed into a short period. All are run with 6 lectures per day over 4 consecutive days (over 5 days for SPCEGC03), followed by tutorial(s) and an exam in the following few weeks. The Core modules that are ‘short and fat’ are SPCEGC03 and ST103; the Advanced modules are ST105, ST106 and ST112.

- *‘LONG THIN’ MODULES (all others)*

  These modules are ‘long and thin’, i.e. running with a few lectures per week over a whole term, with an exam in the summer.

Core modules

During the first term (September - December) students attend the following Core Modules. Lecture dates and times are given in the Programme Timetable/Calendar. Examinations for modules SPCEGC03 and ST103 take place during the first term, as shown in the Programme Timetable/Calendar. These modules aim to give all students, with their diverse academic backgrounds, a thorough, basic understanding of the major aspects of the field, and they form an essential background to the Advanced modules. They also provide an introduction to the UK examination style for non-UK students.

ST&SC Core Modules

SPCEGC01	Space Science, Environment and Satellite Missions – Dr S. Matthews, Mr M. Whyndham, Prof. G. Branduardi- Raymont
SPCEGC02	Space Systems Engineering – Mr M.Whyndham, Dr I. Hepburn
ST103	Communications Systems Modelling – Dr K. K. Wong, Dr Y. Andreopoulos, Dr S. Savory, Dr R. Clegg

During the weeks before starting the Programme it will be very useful for students to read up on basic electromagnetism (up to Maxwell's equations) & basic electronics (including AC circuits and transmission lines). This is particularly important for those with a physics-based degree rather than an electronic engineering degree. Students will be emailed a list of suggested textbook chapters to use for revision at the start of term.

SS Core Modules

SPCEGC01	Space Science, Environment and Satellite Missions – Dr S. Matthews, Mr M. Whyndham, Prof. G. Branduardi- Raymont
SPCEGC02	Space Systems Engineering – Mr M.Whyndham, Dr I. Hepburn
SPCEGC03	Space Data Systems and Processing – Prof. L. Harra, Dr I. Ferreras, Prof. A. Smith, Dr P. Groves, Prof. M. Ziebart

ST&SC students are also encouraged to attend the SPCEGC03 module, which covers many aspects of 'downstream' space activities of interest to them too, although they would not be able to take the exam.

Advanced Modules

The details here are different for the two Pathways, so please read carefully.

You are welcome to attend more than four of the Advanced lecture modules, but you can only be examined in four of them.

You must make a decision in early October on which Advanced module exams to take for the MSc/ Diploma/Certificate, and you will have to enter your exam choices into the Registry PORTICO database – the Programme Team will contact you about this in early October.

ST&SC Advanced Modules

During the second term (January - March) all students take the Satellite Communications course ST105. Students also take 3 other Advanced module options including at least 1 Systems course and 1 Applications course (see below). Each course lasts for approximately 27-30 hours (including tutorials, if given). Dates and times of all courses, and of the examination times for the short fat courses, are given in the Programme Timetable/Calendar. The examinations for the long thin courses take place between the end of April and the beginning of June, and students will be notified in March of the times/dates/locations for these.

COMPULSORY MODULE

ST105	(ELECGC13)	Satellite Communications – Dr K. Woodbridge, Dr C. Renaud & Prof. I. Darwazeh

SYSTEMS MODULES

ST7	(SPCEG008)	Spacecraft Design: Electronic Sub-systems – Dr I. Hepburn
ST8	(SPCEG009)	Mechanical Design of Spacecraft – TBD
ST106	(ELECGC01)	Antennas and Propagation – Prof. K. Tong, Dr K. Woodbridge, Dr P. Brennan

ST112 (ELECGC11) RF Circuits Sub-systems and Devices – Dr E. Romans, Prof. A. Nathan, Dr C.-P. Liu, Prof. H. Griffiths

APPLICATIONS MODULES

CEGEG046 Principles and Practice of Remote Sensing – Dr M. Disney (***note: this course is taught in the first term)***

CEGEG044 Global Monitoring of Environment and Security – Prof. P. Muller, Dr M. Disney, Dr S. Laxon (***note: this course is taught in the first term)***

ST10 (SPCEG001) Space Instrumentation and Applications – Prof. A.Coates, Prof. A. Fazakerley, Dr K. al-Janabi, Dr I. Hepburn, Dr D. Kataria, Prof. P. Muller

SS109 (SPCEG002) Space Plasma and Magnetospheric Physics – Prof. C. Owen, Prof. A. Fazakerley

Note that modules CEGEG046 and CEGEG044 have to be taken together.

Lecturers will recommend suitable textbooks during their courses. One book that gives a good general introduction to the whole field is *Spacecraft Systems Engineering (3rd Edition)* edited by P Fortescue, J.Stark & G.Swinerd, published by Wiley (2003). A copy is available in Room B7.

SS Advanced Modules

During the second term (January - March), all students take the Space Instrumentation & Applications module ST10. Students also take 3 other advanced space science modules from those listed below. Each module lasts for approximately 30 hrs and examinations are in the third term. Dates and times of these modules are given in the Programme Timetable/Calendar - ***some of them may be scheduled in the first term (see below)***, though they are examined in the summer. Students will be notified in March of the times/dates/locations for the exams, which take place between the end of April and the beginning of June.

COMPULSORY MODULE

ST10 (SPCEG001) Space Instrumentation and Applications – Prof. A. Coates, Prof. A. Fazakerley, Dr K. al-Janabi, Dr I. Hepburn, Dr D. Kataria, Prof. P. Muller

SPACE SCIENCE MODULES

SS4 (SPCEG011) Planetary Atmospheres – Prof. A. Coates, Dr G. Jones

SS6 (SPCEG012) Solar Physics – Dr K. Phillips, Dr L. van Driel-Gesztelyi

SS7 (SPCEG013) High Energy Astrophysics – Prof K. Wu (***note: this course is taught in the first term)***

SS109 (SPCEG002) Space Plasma and Magnetospheric Physics – Prof. C. Owen, Prof. A. Fazakeley

CEGEG046 Principles and Practice of Remote Sensing – Dr M. Disney (***note: this course is taught in the first term)***

CEGEG044 Global Monitoring of Environment and Security – Prof. P. Muller, Dr M. Disney, Dr S. Laxon (***note: this course is taught in the first term)***

Lecturers will recommend suitable textbooks during their courses. One book that gives a good general introduction to the whole field is *Space Science*, edited by L Harra and K Mason, published by Imperial College Press (2004). This book has 14 chapters on different aspects of Space Science, each written by a member of staff at MSSL.

Project Work

Individual Project (SPCEG099)

Students start work on an Individual Project during the first term.

This may involve attachment to any of the relevant Departmental Research Groups:

ST&SC:	S&CP or E&EE
SS:	S&CP, Physics and Astronomy, or Earth Sciences (by special arrangement).

General Notes

- Some set topics for Individual Projects have been selected by potential supervisors, and lists will be available during the first term. Alternatively students can suggest areas in which they are interested. It is, however, essential that the subject of the chosen project is relevant to the programme, and a willing supervisor is also required. Discussions with the Programme Team and potential supervisors start in October and a project title must be defined, and a supervisor appointed by mid-November (see the exact deadline on the Programme Timetable/Calendar). Work begins in the first term, usually with a literature survey or other background work. Progress, plans and difficulties are outlined in an Initial Report and a second (Interim) Report, due at the end of the first and second terms respectively (see the Programme Timetable/Calendar for the exact dates). Part of the Individual Project are also: a) A presentation, given to an audience of staff and students of the S&CP and E&EE Departments (as appropriate) about one month before the Final Report submission deadline, and b) The preparation of a poster, or a Website, or a 'New Scientist'**-**style article (to be submitted at the same time as the Final Report). Assessment of the project is based mainly on the Final Report, but the second (Interim) Report, the presentation and the poster/Website/'New Scientist' article also provide 10% of the assessment each.
- The Individual Project is a piece of research related to your MSc subject, but at a level, and within a timescale, appropriate to an MSc rather than an MRes or a PhD.
- NOTE: THE AVAILABLE TIME IS SHORTER THAN IN MOST OTHER MSc PROGRAMMES (this is because of the 7 weeks taken up afterwards by the Group Project). Therefore you will start your project work much earlier than on most other MSc programmes.
- The Individual Project counts for one third of the assessment of the whole MSc (see p. 4). As part of the pass criteria, the Individual Project must be passed with a mark of at least 50% to obtain an MSc (70% for a Distinction).
- DO NOT LEAVE NEARLY ALL THE WORK TO THE LAST FEW WEEKS. Spread your project work between the three terms as suggested below.
- MAINTAIN REGULAR CONTACT WITH YOUR SUPERVISOR to ensure that the project remains "on course", i.e. with the correct work being done, on schedule.

Summary of Deadlines and Deliverables

- Early in First Term → Identify supervisor and project title
- End of First Term → Initial Project Report submission
- End of Second Term → Interim Project Report submission
- About mid-June → Mid-Term presentation
- About mid-July → Final Project Report and poster/Website/'New Scientist' article submission

Work in the First Term

- By the "project definition" deadline (see the Programme Timetable/Calendar for the exact date), define your project, in consultation with a potential supervisor, using the information and lists that will be provided. Try to choose something that interests you – it may be useful to look at previous years' reports (some are kept in room B7). If you need more help, ask one of the Programme Tutors.
- Email the title of the project, and your supervisor's name and Department, to the Programme Tutor, Graziella Branduardi-Raymont and to the Programme Administrator, Libby Daghorn by the "project definition" deadline (see the Programme Timetable/Calendar for the exact date). Ask your Project Supervisor to confirm this by emailing both, the Programme Tutor and the Administrator.
- Try to complete the literature review and any other preliminary tasks in the first term.
- Start the main project work if possible.
- Email (in Word or pdf format) a 2 to 4 page <u>INITIAL PROJECT REPORT</u> to Libby Daghorn by the deadline, at the end of the first term (the actual date will be listed in the Programme Timetable/Calendar). This should give: your name, supervisor's name, project title, objectives, summary of work programme, work done so far, outline project schedule (including writing up time). IT IS IMPORTANT TO AGREE THE CONTENTS OF THIS REPORT WITH YOUR SUPERVISOR BEFORE SUBMITTING IT.

Work in the Second Term

- Aim to work at least 1 day per week on the project during the second term.
- Aim to have completed about 25% of the project work by the end of the second term.
- Submit one file (a Word document or pdf, via Moodle) containing your <u>INTERIM PROJECT REPORT</u> (a maximum of 2000 words long) by the deadline, at the end of the second term (see the Programme Timetable/Calendar). THIS IS A REAL DEADLINE - STUDENTS WILL BE PENALISED (MARKS SUBTRACTED) FOR LATE SUBMISSION OF THE REPORT. The Interim Report accounts for 10% of the overall Project mark. Note the following:
    - The report should have 3 sections (section 2 being the largest):
        1. A brief introduction to the project, including a brief outline of the envisaged work;
        2. A description of the work completed to date, with any conclusions;
        3. A summary of the work still to do, with a provisional contents list for the Final Report, and an updated project schedule.
    - You should discuss the contents and style of this report with your supervisor before writing it and at the draft stage, but it will be assessed, so it must be your own work.
    - The Interim Report should typically have about of 10 pages of text, plus any Figures, Tables and Reference list. However, it can be longer if the work done justifies the additional length – if in doubt, ask your supervisor for advice.
    - THE INTERIM REPORT ACCOUNTS FOR 10% OF THE AVAILABLE PROJECT MARKS – it can make the difference between pass & failure, or pass & distinction.

Work in the Third Term & the Summer period

- Work full time on the Individual Project, and complete it, after the summer exams. DISCUSS ANY DIFFICULTIES WITH YOUR SUPERVISOR WELL IN ADVANCE OF THE FINAL REPORT DEADLINE.
- Prepare, in consultation with your supervisor, a presentation on your project work, to be delivered at MSSL about a month before the Final Report submission deadline (the date will be posted in the

Programme Timetable/Calendar), to an audience of academics, scientists, engineers and graduate students. It is expected that following the presentation students will receive feedback on their project work that can be incorporated into their Final Report. Remember that the mark on the presentation accounts for 10% of the overall Project mark.

- Discuss the structure of your Final Report (i.e. its sections & subsections) with your supervisor at an early stage. The detailed structure may vary depending on the subject, but should always include:
  - An Abstract, which is a concise summary of your report and its results (in no more than 300 words), at the beginning of the report.
  - An introductory section which states the aims and objectives of the project, discusses the rationale for the project (including how it relates to previous work) and outlines what is covered by each main Section in the report.
  - A concluding section which discusses the extent to which the main results and discussion meet the aims and objectives of the project, and discusses any possible future research that could follow on from the project.
- Complete a draft of the report well before the deadline to allow for proof reading & alterations.
- A template will be issued for the front cover. All reports should have a cover conforming to this template.
- The Final Report should be produced in a font such as Times New Roman (font size 12) or Arial (font size 10), with 1.0 or 1.5 line spacing. Any Figures or Tables should be labelled and numbered, and each of these must be referred to in the text by number. References should be referred to in the text and reference list in a conventional way (as in scientific papers). Pages must be numbered.
- Your Final Report must be between 10,000 and 12,000 words long, excluding reference/bibliography lists and appendices. Note that 12,000 words is a MAXIMUM, and reports will not necessarily be as long as this; if in doubt ask your supervisor for advice. The Final Report accounts for 70% of the overall Project mark.
- You will have to make the choice between preparing and submitting (at the same time as the project Final Report) a poster, a Website, or a 'New Scientist'-style article (about 2000 words long). A template will be issued for the poster and Website. Also this material will contribute 10% of the overall Project mark.

Submission of the Final Report and additional material

- Provide 3 bound copies of your FINAL PROJECT REPORT and a printed copy of the poster/article (if you have chosen one of these) by the deadline date (usually around mid-July – see the Programme Timetable/Calendar), handing them in at the offices at 3 Taviton St.
- An electronic copy of the Final Report and of the poster (or Website, or 'New Scientist'-style article) should also be submitted via Moodle by the same deadline (file type and size restrictions may apply).
- THIS IS A REAL DEADLINE – STUDENTS WILL BE PENALISED (MARKS SUBTRACTED) FOR LATE SUBMISSION OF THE REPORT AND/OR THE ADDITIONAL MATERIAL.
- You should be aware that the Department now uses a sophisticated detection system (Turnitin® [xix]) to scan work for evidence of plagiarism (see the box below). This system has access to billions of sources worldwide (websites, journals, etc.) as well as work previously submitted to this Department and other departments.
- The Final Report will be assessed (independently by 2 markers) for its main content (including originality, analysis and discussion of results), for its introductory content (including introduction, problem definition and references), and for its style (including structure, literary style and presentation). The assessment of the first marker (your supervisor) will also take into account the effort and initiative that you put into your project.

- The additional material will be assessed (independently by the same two markers as the Final Report) for content, style and impact.

Group Project

Supervisor : Dr David Williams

For the final 7 weeks of the MSc Programme, students on the ST&SC Pathway combine with those on the SS Pathway to carry out a Group Project, generally an industrial-style space mission design study (similar to a "Phase A" feasibility study). Weekly meetings are held with the supervisor to monitor progress and help to solve the problems that may be encountered.

A report is written and the study is presented and assessed by a panel of experts from outside UCL during a formal Review. Each student is expected to give part of the presentation. The Presentation and Review are held just before the beginning of the new term.

By way of an introduction to the Programme, students about to join the Programme the following year are invited to attend the current year's Group Project Presentation.

More details, about the organization of the Group Project, including its key dates, will be given out later in the year.

Assessment of the Group Project is based on four components: 1) The Final Report (60%), 2) The Presentation (15% - each student is marked individually on their performance), 3) Team work (10% - each student is assessed individually by the supervisor on their performance during the weekly meetings) and 4) Peer assessment (15% - more details will be provided closer to the time).

Students are likely to make use of the **STK (Satellite Tool Kit)** software provided by AGI for their Individual and Group Projects. It is well worth checking the link

http://www.agi.com

Module Assessment and Examinations

Assessment of work will take two forms: assignments set during each module, marked and returned to the student with feedback, and "closed-book" examinations consisting of unseen questions based on the syllabus.

The in-module assignments allow tutors to give constructive feedback about each student's progress.

Feedback is also given in a specific individual tutorial, the Progress Meeting with the Programme Team early in the second term, which is held to review the student's performance in the first term and to discuss the Initial Project Report. The Advanced Modules examinations follow standard UCL practice: detailed feedback is not given.

The main opportunities to receive feedback about the Individual Project are the comments and suggestions given on the Interim Report and at the Mid-Term Presentation. This feedback should be noted carefully.

Plagiarism

The presentation of another person's thoughts or words or artifacts or software as though they were your own is a very serious offence known as ***plagiarism***.

Plagiarism is taken extremely seriously by the Departments and by UCL, as well as in the academic and publishing world at large. If a student is found to have carried out plagiarism, it can lead to the student not being awarded a degree, and being excluded from all future examinations at UCL and/or the University of London.

It should be noted that "presenting of others' work as your own work" is a very wide-ranging concept. It includes, for example, the copying of text or figures from Websites, articles or books as part of a review or methodology description in a project report. ***Such copying is completely unacceptable, even if there is no intention to deceive the reader as to its origin***. Any such material must be referenced in the report and, if text, either presented in quotation marks, or not directly quoted at all. If in doubt, consult your supervisor or the Programme Team about what is acceptable and normal practice; ***do not jeopardise your future through ignorance or uncertainty.***

For more detailed information concerning plagiarism, students are strongly advised to read the relevant section on the UCL website [i].

You should be aware that ***the Department now uses a sophisticated detection system,*** Turnitin® ***[ii], to scan work for evidence of plagiarism***. This system has access to billions of sources worldwide (Websites, journals, etc.) as well as work previously submitted to this Department and other Departments.

For this MSc/Diploma/Certificate Programme this affects essays and project reports, and means that you may have to submit electronic copies of work in addition to paper copies. You will be told during each relevant module how this will be organised and what file formats will be acceptable.

Candidate codes

For the purposes of anonymity during standard UCL examinations, students are issued with alphanumeric codes which are written on papers. In this way, the markers will not know who has written each script. The Programme tutors and administrators will however have access to the names and candidate codes.

Absence

Attendance on all components of the Programme is mandatory, and it is not possible to repeat a missed course or examination during the same academic year. If a student needs to be absent from UCL for any reason he/she must inform the Programme Team, and explain the reason. ***Absence during the Group Project is only permitted in very exceptional circumstances***.

Extenuating circumstances

Any circumstances likely to affect your examination performance should be ***notified in writing, with appropriate supporting documentation***, to the Programme Team ***no later than one week after the end of the examination in question***. These circumstances will be considered in ***strict confidence***.

Circumstances which have ***already*** been brought to the attention of the Board of Examiners and for which allowance has already been made (e.g. extra time allowed because of dyslexia, extension of deadline for coursework) should ***not*** be notified in this way. The examiners will be aware of these circumstances, but any circumstances which might affect your examination performance can be taken into account only ***once*** for each diet (annual cycle) of examinations.

Deferral of Examinations or Interruption of Study

In exceptional circumstances beyond the student's control (e.g. illness), and at the discretion of the UCL authorities, students may be permitted to defer (postpone) examinations [iii].

In various circumstances UCL may, at its discretion, grant an Interruption of Study, usually for one year [iv].

If you think it may be necessary to apply for either of these possibilities, please discuss this first with the Programme Tutor.

Calculators in Examinations

Only certain specific electronic calculators may be used during examinations at UCL, namely the **Casio FX83ES / FX83WA / FX83MS** (battery powered versions) or the **Casio FX85ES / FX85WA / FX85MS** (solar powered versions). All students on the MSc/Diploma/Certificate Programme are required to purchase one of these calculators for use in the exams. Mobile phones, personal organisers, etc., are not permitted as substitutes, nor is any programmable calculator.

The mandated models are economically priced and are available from various outlets in UCL, including the UCL shop in South Junction [v] and in the basement of the Bloomsbury Theatre.

- **Please make sure you buy one of these before your first exam**.

Lecture module syllabus details

Refer to the table on page 18 summarising the MSc/Diploma/Certificate Programme structure for details of which modules apply to the two Pathways. Some modules are present in both Pathways: in such cases, the descriptions below appear only once. This syllabus is for guidance only: lecturers may on occasion make minor changes.

Core modules syllabus summaries

SPCEGC01: SPACE SCIENCE, ENVIRONMENT AND SATELLITE MISSIONS

Lecturers: Dr S. Matthews, Mr M. Whyndham, Prof. G. Branduardi- Raymont

Credits: 15 **Teaching Term:** 1

Assessment method and timing: 10% coursework, 90% examination in Term 3

Space science and other space applications. Brief history of early spaceflight to 1961. Examples of early space science satellites: Ariel 1, Orbiting Observatories, European programme. Brief outline descriptions of the following space science fields, with major related space science missions and discoveries: solar physics, space plasmas (solar wind and Earth's magnetosphere), solar system exploration (moons, planets, asteroids and comets), astrophysics from space, Earth observation from space (remote sensing).

The spacecraft environment - Earth's atmosphere, equation of hydrostatic equilibrium, measurements of density, atmospheric drag. The ionosphere and solar radiation, the trapped particle zone (radiation belts). The magnetosphere, the Sun and the solar wind.

Spacecraft dynamics - Orbits, trajectories and launching. The nature of satellite orbits and elementary orbit theory, perturbations. Rocket propulsion - the rocket equation, propellants and specific impulse, nozzle design, staging.

Mission objectives. Design concept and assessment of requirements. Proposal document - scientific justification, technical plan, management plan, cost, PA, interface document. Funding application.

Project management - organogramme, work packages, schedule. PERT network, milestones, critical path, progress meetings, expenditure profiles and financial control.

Mission planning and operations, science planning, timelining, ground support

SPCEGC02: SPACE SYSTEMS ENGINEERING

Lecturers: Mr M.Whyndham, Dr I. Hepburn

Credits: 15 **Teaching Term:** 1

Assessment method and timing: 10% coursework, 90% examination in Term 3

Review of scientific spacecraft subsystems, with examples from modern space vehicles. Spacecraft and instrument design constraints and evolution - size, mass, geometry, power, apertures, thermal control, surface requirements, booms, e-m properties, command capability, data rate.

Power sub-system and other electronic sub-systems, including analogue signal amplification and processing.

Attitude control and station keeping, including attitude dynamics of rigid bodies in free space, the effects of non-rigidity, and the basic technology of attitude sensors.

Thrusters and actuators, examples of attitude determination and of active attitude control using feedback control theory.

Test and evaluation. Component, sub-assembly, instrument and spacecraft level tests. Vibration, temperature, vacuum, solar simulation tests. Design changes.

Product assurance - approved parts and materials lists, cleanliness, testing, protection during shipping, documentation.

Commanding and data acquisition - Data relay satellites, ground stations, control centre requirements.

Digitised signal data, On-Board Data Handling (OBDH), telemetry and telecommanding, including encoding and command decoding, error detection and correction, RF satellite communications links and link budgets.

SPCEGC03: SPACE DATA SYSTEMS AND PROCESSING

Lecturers: Prof. L. Harra, Dr I. Ferreras, Prof. A. Smith, Dr P. Groves, Prof. M. Ziebart

Credits: 15 **Teaching Term:** 1

Assessment method and timing: 20% coursework, 80% examination in Term 1

This is a short, intensive module, run over five days, with 6 hours of lectures on a specific topic, and delivered by a different lecturer, each day. The five topics are:

1) Telecommunications
Communications and broadcast services and applications; interfaces between satellites and end users; managing spare spacecraft/operations; data formatting and encryption; data security. Telecom infrastructure in developing countries. Rapid deployment for defense purposes/disaster relief/emergency management. Combination of ground and space comm.s and associated economics.

2) Positioning
Principles of positioning systems and practicalities. Applications (methods and uses): vehicles, ground transport in general, personal, navigation, metrology, asset management, security, defence services. Future developments and enhancements.

3) Earth Observations (EO) and Global Change
Different purposes of EO, of which climate is one; weather monitoring and forecasting, defense, agriculture, natural resource exploitation, geographical science, disaster monitoring and predicting, urban and territory planning, climate and global change, importance of remote sensing.

4) Solar-Terrestrial Relationships
Terrestrial applications, Earth magnetosphere and space weather, solar cycle and activity in general (e.g. CMEs), NOAA reports, end users (e.g. aircraft and spacecraft operators, power lines on the ground). Science of space weather and solar-terrestrial relationships, possible connection between solar activity and Earth's climate.

5) Astronomy
Downstream processes; GAIA: astrometry and large databases; distance scale and how measurements link together; the cases for next generation observatories (e.g. NGST), turning to different wavebands and to different techniques.

ST103 (ELECGT02): COMMUNICATION SYSTEMS MODELLING

Lecturers: Dr K. K. Wong, Dr Y. Andreopoulos, Dr S. Savory, Dr R. Clegg

Credits: 15 **Teaching Term:** 1

Assessment method and timing: 50% coursework, 50% examination in Term 1

This module introduces students to the techniques and tools used to model and simulate today's communications systems and networks. Consideration is given to both the Physical Layer and the Network Layer and the module looks at the theory of modelling and practical applications using standard simulation packages. This module provides in-depth exposure to analytic and simulation techniques appropriate for the representation, analysis and performance evaluation of communications systems and networks.

Topics covered by the module:
Methods of Performance Evaluation, Simulation Approach: Waveform-Level Simulation of Communication Systems, The Application of Simulation to the Design of Communication Systems, Methodology of Problem Solving for Simulation, Basic Concepts of Modelling, Error Sources in Simulation, Simulation Environment and Software Issues, Deterministic Signals and Systems,

Continuous and Discrete Time Signals, Signals in the Time and Frequency Domains, Fourier Series and Transforms, Convolution, Probability and Stochastic Processes, Discrete and Fast Fourier Transform (DFT/FFT), Hilbert Transform and the Complex Envelope, Sampling, Signal Design and Analysis, Modelling and Simulation of LTI Systems, Simulation of Filtering with FIR Filters, Simulation of Filtering with IIR Filters, Effects of Finite Word Length in Simulation of Digital Filters, Time-Varying Linear Systems in the Time and Frequency Domains, Modelling Considerations for Nonlinear Systems, Memoryless Nonlinearities, Nonlinearities with Memory, Nonlinear Differential Equations, Measurement Technique for Nonlinear Components, Modelling with Matlab, Simulating the internet.

Advanced module syllabus summaries

ST&SC Compulsory Module

ST105 (ELECGC13): SATELLITE COMMUNICATIONS

Lecturers: Dr K. Woodbridge, Dr C. Renaud, Prof. I. Darwazeh

Credits: 15 **Teaching Term:** 2

Assessment method and timing: 100% examination in Term 2

Fundamentals of satellite communication systems: Orbit types, ground stations, support sub-systems. Satellite channels: link budgets; modulation schemes; multiple access types and beam switching. Direct Broadcast Systems (DBS). Mobile systems. Geostationary and low earth orbit systems and services. Space and ground segment technology, voice and data services. The Intelsat and Inmarsat systems; terrestrial, maritime and aeronautical communications services. Next generation broadband satellite systems for high bandwidth data and multi-media services. Fast packet switching on the satcom link including Asynchronous Transfer Mode (ATM) protocols and IP applications. Intersatellite and satellite-to-ground optical data links. Satellite position finding systems, NAVSTAR GPS and GLONASS.

SS Compulsory Module

ST10 (SPCEG001): SPACE INSTRUMENTATION AND APPLICATIONS

Lecturers: Prof. A.Coates, Prof. A. Fazakerley, Dr K. al-Janabi, Dr I. Hepburn, Dr D. Kataria, Prof. P. Muller

Credits: 15 **Teaching Term:** 2

Assessment method and timing: 100% examination in Term 3

Spacecraft as observation platforms: Why go into space, space environment, space effects from Earth's surface, in situ measurements, remote sensing, space as a laboratory, impact of space studies.

Systems approach to measurements: analysis, detection, signal processing, data encoding, control. Spacecraft interface: accommodation, attitude control, power conditioning.

Examples of solar system missions

Review of sensors on spacecraft: Photomultipliers, channeltrons, microchannel plates, solid state detectors, charge coupled devices, current collectors, antennas and probes, magnetometers

On board and ground data processing: Instrument on-board data analysis and autonomous control. Adaptive and non-adaptive data compression techniques. Spacecraft on-board data handling and telemetry system. The ground segment.

In situ plasma measurements: Energy and mass analysis for charged species from 1eV to 1MeV. Neutral mass spectrometers. Electric and magnetic field measurements from DC to 1MHz.

Spacecraft-environment interactions: Spacecraft charging in low Earth orbit and geostationary orbit. Radiation damage effects. Background effects and their minimisation. Plasma influx, penetrating radiation, sunlight.

Atmospheric measurements: Basic physics and chemistry, spectroscopy, practical instrument examples, applications of fundamental principles to measurements.

Astronomical observations: Spectroscopic techniques and telescopes from infra-red to gamma rays.

Planetary analysis: Dust detectors and analysers, sample return techniques, surface analysis by remote measurements, surface sampling in-situ techniques, surface imaging.

Case studies I: Case studies of missions

Case studies II: Student presentations of case study missions

ST&SC Systems Modules (OPTIONS A)

ST7 (SPCEG008): SPACECRAFT DESIGN - ELECTRONIC SUB-SYSTEMS

Lecturers: Dr I. Hepburn

Credits: 15 **Teaching Term:** 2

Assessment method and timing: 100% examination in Term 3

Introduction - Comparison of spacecraft electronic systems to an equivalent ground based unit.

Power Systems - Solar cells, solar arrays; storage cells; regulation dissipative and non-dissipative, regulators linear and switched mode, noise reduction, filters, supply monitoring, decentralised regulation.

Attitude sensing and control - Earth and Sun sensors, charge coupled devices, wedge and strip, crossed anode, magnetic sensors, search coil and fluxgate, magnetic torquers.

Mechanisms & Housekeeping - Control monitoring; optical and magnetic, pyrotechnic actuators, bridge techniques.

Harnesses - EMC magnetic and electric coupling, shielding efficiencies for near and far field, EMC outgassing ports, connector types, low and high voltage, printed circuit board types.

Reliability - Design techniques, heat dissipation, latch-up, interface and single point failures, housekeeping requirements, components specification, failure rates, fabrication, radiation testing, effect of radiation, displacement and ionisation damage, transients effects, designing for radiation protection.

Analogue design - Charge sensitive amplifiers, noise considerations, practical circuits, pulse shaping circuits, unipolar and bipolar pulses, base line depression, pulse pile-up, low frequency measurements.

Data Handling - Queueing, compression, on-board data handling system, data management system, fixed frame format and packet telemetry, command transmission, reception and distribution, high power on-off commands, memory load commands, block error detection and correction systems, linear code blocks.

ST8 (SPCEG009): MECHANICAL DESIGN OF SPACECRAFT

Lecturers: TBD

Credits: 15 **Teaching Term:** 2

Assessment method and timing: 100% examination in Term 3

Spacecraft configurations - Interplay of mission, solar power requirements, attitude system and launch vehicle. Mechanical interfaces. Subsystems.

Launch accelerations, acoustic fields, vibrations - cases, loads and factors.

Foundations of stress analysis and mechanics of materials - Examples of application to spacecraft.

Frame structure and analysis - Strut buckling and optima. Shell structure and analysis - Finite elements. Sandwich panels theory and practice.

Materials for lightness, space vacuum and the radiation environment - Metals, polymers, ceramics and composites. Cryogenics and low temperatures.

Nuts, bolts and joints generally.

The deployment of booms, arrays and antennas.

Mechanisms - Elements, kinematics, kinematic design.

Bearings - Sliding, rolling and flexing. Space lubrication.

Actuators - Stepping motors. Pyrotechnics.

Gear transmissions. Space Tribology. Mechanism life.

Vibration theory for space technology - Single degree of freedom frequency, damping, transmissibility. Response of systems with 2 or more systems. Random excitation and response.

Vibration testing - Typical test specifications. Derivation from measurements. Notching. Modes of failure.

Thermal design - Physics of temperature and heat exchange. Thermal control materials and devices. Models and computing. Thermal simulation and testing.

ST106 (ELECGC01): ANTENNAS AND PROPAGATION

Lecturers: Prof. K. Tong, Dr K. Woodbridge, Dr P. Brennan

Credits: 15 **Teaching Term:** 2

Assessment method and timing: 100% examination in Term 2

Definitions: Gain, directivity, efficiency, effective area & length; directional patterns; polarisation; Hertzian dipole reactive and far field patterns; types of radiating element; Fourier transforms in antennas, displacement theorem, amplitude tapers & sidelobe levels; orthogonality, pattern synthesis; near and far field patterns, focussed apertures. Arrays and Electronic Beam Control: Interferometers, linear arrays, product theorem; frequency-scanned array, phase & time delay compensation, null steering; switched-line phase shifter & sidelobe levels, vector modulator; multiple beamforming arrays. Digital beamforming: smart antenna systems in mobile applications. Reflector and Lens Antennas: Reflector antennas, feed systems; lens antennas. Antenna Measurements: Anechoic chambers, far-field definition; gain, three-antenna measurement; impedance & polarisation. Other Antenna Topics: Pyramidal & corrugated horns; printed and helical antennas; slot antennas. Propagation Principles: Friis transmission formula; atmospheric effects; fading types and statistics; line-of sight microwave transmission; edge effects; application of propagation models in mobile communications to model urban, suburban and rural environments.

ST112 (ELECGC11): RF CIRCUITS AND SUB-SYSTEMS

Lecturers: Dr E. Romans, Prof. A. Nathan, Dr C.-P. Liu, Prof. H. Griffiths

Credits: 15 **Teaching Term:** 2

Assessment method and timing: 100% examination in Term 2

Review of carrier dynamics: effective mass, scattering, mobility; drift and diffusion currents; negative differential resistance, Two-terminal devices (Schottky and tunnel barriers, detector and mixer diodes, varactors, PIN switches, transferred electron devices and avalanche sources), Radio frequency CMOS technology, Three-terminal devices (bipolar devices including SiGe and III-V HBTs, GaAs MESFETs, III-V HEMTs, and SiGe heterostructure MOSFETs), Microwave transmission line theory and scattering parameters, RF circuit design techniques in MIC and MMIC form, Amplifier gain, noise and stability analysis using scattering parameters.Applications: RF transmitters and receivers, amplifier linearisation, mixers, modulators, Integration technology and the design of monolithic RF circuits.

ST&SC Applications Modules (OPTIONS B)

ST10 (SPCEG001): SPACE INSTRUMENTATION AND APPLICATIONS

See above for details.

SS109 (SPCEG002): SPACE PLASMA AND MAGNETOSPHERIC PHYSICS

This Space Science module is very relevant to spacecraft technology, with regard to the spacecraft environment and potential detrimental effects on spacecraft (e.g. spacecraft charging, space weather). The main physics background required is electromagnetism, including Maxwell's Equations.

See below for details.

CEGEG046: PRINCIPLES AND PRACTICE OF REMOTE SENSING

Lecturers: Dr M. Disney

Credits: 7.5 **Teaching Term:** 1

Assessment method and timing: 100% examination in early January

The course is broadly divided into three sections.

The first section introduces fundamental concepts of electromagnetic radiation (EMR), EMR properties and the interactions of EMR with the Earth system which constitute the measured RS signal: Radiation laws and units; solar radiation and the blackbody concept; radiation geometry and interactions; scattering within the atmosphere and at the surface; atmospheric windows; how and why we use radiation at different parts of the EM spectrum.

The second section introduces concepts of remote sensing instrument design, data collection and information content. Particular emphasis is given to the various design considerations determining how electromagnetic radiation is captured and exploited by remote sensing instruments, in particular: spatial, spectral, temporal, radiometric, polarisation considerations; sensor designs and scanning mechanisms; choices of orbit; detector resolution; information collection and handling. An introduction is given of newer active methods such as LIDAR.

The third section introduces the concepts of microwave (RADAR) remote sensing, specific to wavelengths much longer than optical, covering the fundamental principles of microwave image formation, geometry and radiometry, interaction of microwaves with the atmosphere and surface; instrument design - side-looking airborne RADAR (SLAR), synthetic aperture RADAR (SAR) and interferometry, as well as applications of RADAR remote sensing.

CEGEG044: GLOBAL MONITORING OF ENVIRONMENT AND SECURITY

Lecturers: Prof. P. Muller, Dr M. Disney, Dr S. Laxon

Credits: 7.5 **Teaching Term:** 1

Assessment method and timing: 100% examination in early January

Earth system science and first order climate models, Climate change and the role of anthropogenic cf. natural sources, global warming and current unknowns in the system. International scientific programmes, GEOSS and GMES.

Climate prediction: methods and models. Current limits in understanding. Role of remote sensing in climate modelling. Current and future EO systems, especially ESA and NASA. Physical parameters from EO sensors : Earth radiation budget and solar-terrestrial connections,cloud properties.

Global warming mini-debate. Physical parameters from EO sensors : Socio-economics from night-time lights; land cover, especially urbanisation and urban heat islands.

Principles of Radar Altimetry.

Physical parameters from EO sensors : Global topography for disaster management and planning including volcanic ash and solid earth surface.

Physical parameters from EO sensors: Human security and the role of automated mapping. SST and LST from Thermal Infra-Red.

Radar altimetry of ocean, land and marine ice. Velocity structure of ice-sheets.

Biophysical properties of the land surface.

Role of calibration/validation and GIS in GMES.

SS Advanced Modules

SS4 (SPCEG011): PLANETARY ATMOSPHERES

Lecturers: Prof. A. Coates, Dr G. Jones

Credits: 15 **Teaching Term:** 2

Assessment method and timing: 10% coursework, 90% examination in Term 3

Comparison of planetary atmospheres - competition between gravitational attraction and thermal escape processes; factors which differentiate between planetary atmospheres; energy and momentum sources; accretion and generation of gases; loss processes; dynamics; composition.

Atmospheric structure - hydrostatic equilibrium; adiabatic lapse rate; stability; radiative transfer; the greenhouse effect and the terrestrial planets.

Oxygen chemistry - ozone production by Chapman theory; comparison with observations; ozone depletion and the Antarctic ozone hole.

Atmospheric temperature profiles - troposphere, stratosphere, mesosphere and thermosphere described; techniques of measurement for remote planets; use of temperature profiles to deduce physical processes.

Origin of planetary atmospheres and their subsequent evolution - formation of the planets; primeval atmospheres; generation of volatile material; evolutionary processes; consideration of terrestrial and outer planets.

Atmospheric dynamics - equations of motion; atmospheric circulation and storms; dynamics of the atmospheres of the outer planets; comparison of the behaviour of wet and dry air; formation of clouds and rain.

Ionospheres and magnetospheres - ionisation and recombination processes; formation of a Chapman layer; interaction of the solar wind with planets and atmsopheres.

Atmospheric loss mechanisms - exosphere and Jeans escape; non-thermal processes.

Observational techniques - occultation methods from UV to radiofrequencies; limb observation techniques in the UV, visible, IR and microwave spectrum.

Global warming - recent trends and the influence of human activity; carbon budget of the Earth; role of the oceans in climate moderation; positive and negative feedback effects; climate history; the Gaia hypothesis; terraforming Mars.

SS6 (SPCEG012): SOLAR PHYSICS

Lecturers: Dr K. Phillips, Dr L. van Driel-Gesztelyi

Credits: 15 **Teaching Term:** 2

Assessment method and timing: 10% coursework, 90% examination in Term 3

Introduction to solar physics: basics and properties of the Sun.

The solar interior. Structure of the interior and the Standard Solar Model - assumptions, processes, relevant equations, energy generation and transport. Sun's evolution from birth to white dwarf. Nuclear reactions and the solar neutrino problem.

Reflection of acoustic waves in the interior, oscillations, helioseismology. The structure of the solar interior as deduced from helioseismology. Problems with the Standard Solar Model - long term behaviour, surface abundances, activity, rotation.

The solar atmosphere. Total solar irradiance (solar "constant"). The photosphere - processes and basic structure. Sunspots and solar rotation. Local thermodynamic equilibrium. The chromosphere - heating, network, spicules. The corona - its high temperature and ionization properties. Coronal structure: streamers, active regions, coronal holes, X-ray bright points. Plasma properties, ionization and excitation conditions. Using spectroscopy to find temperatures and densities in the corona. The coronal heating problem: waves versus nanoflares.

The formation and characteristics of the solar wind. Parker's solar wind equations. Fast wind and slow wind. Heliosphere.

Solar magnetic fields. Magneto-hydrodynamics - basic effects and equations, frozen-in fields. Equilibrium in sunspots, filaments and prominences. Force-free fields, current sheets. Instabilities - kink, Rayleigh-Taylor, Kelvin-Helmholtz, tearing mode. Generation of magnetic fields, dynamo theories, emergence of new magnetic flux. Convective rolls.

Solar activity and solar magnetic cycle. Sunspots and active regions. Observations of the high and low temperature aspects of flares - thermal and non-thermal phenomena, particle emission, mass motions, magnetic field changes. Pre-flare energy storage, role of the magnetic field. Energy release mechanisms, role of current sheets and magnetic field dissipation. Hard X-rays from flares, energetic Particles and their acceleration. Chromospheric evaporation.

Coronal mass ejections. Association with flares. Energetics. Travel into the heliosphere and interaction with the Earth. Space weather.

Relationship of the Sun to other stars. The Sun as a star. Stellar magnitudes and spectral types. Solar-type stars and stellar activity. Stellar flares, spots and other phenomena. The Sun's early history.

SS7 (SPCEG013): HIGH ENERGY ASTROPHYSICS

Lecturers: Prof K. Wu

Credits: 15 **Teaching Term:** 1

Assessment method and timing: 10% coursework, 90% examination in Term 3

The scope of high energy astrophysics. Prerequisites, units.

General relativity and black holes: Space-time and metric, Schwarzschild and Kerr black holes,. Properties of the event horizon, Ergospheres.

Radiation processes: Cyclotron and Synchrotron radiation. Thomson and Compton scattering, Thermal Bremsstrahlung radiation, Free-bound, bound-free and bound-bound processes.

Interaction of radiation with matter: Absorption, scattering, pair production.

Cosmic rays: Origin, spectrum, angular distribution.

Supernovae: Stellar collapse, Supernova remnants, evolution and observational properties.

Neutron stars: Model, Pulsars, Magnetars.

Accretion onto compact objects: Eddington limit, Galactic X-ray binaries, Active Galactic Nuclei.

Jets: Radio emission, energy partition, Galactic and extragalactic sources.

New generation astrophysics: Gravitational wave astronomy, Neutrino astrophysics.

SS109 (SPCEG002): SPACE PLASMA AND MAGNETOSPHERIC PHYSICS

Lecturers: Prof. C. Owen, Prof. A. Fazakeley

Credits: 15 **Teaching Term:** 2

Assessment method and timing: 10% coursework, 90% examination in Term 3

Available as an Applications module option in the ST&SC Pathway.

Introduction - Plasmas in the solar system, solar effects on Earth, historical context of the development of this rapidly developing field

Plasmas - What is a plasma, and what is special about space plasmas; Debye shielding, introduction to different theoretical methods of describing plasmas

Single Particle Theory - Particle motion in various electric and magnetic field configurations; magnetic mirrors; adiabatic invariants; particle energisation

Earth's Radiation Belts - Observed particle populations; bounce motion, drift motion; South Atlantic Anomaly; drift shell splitting; source and acceleration of radiation belt particles; transport and loss of radiation belt particles

Introduction to Magnetohydrodynamics - Limits of applicability; convective derivative; pressure tensor; continuity equation; charge conservation and field aligned currents; equation of motion; generalised Ohm's law; frozen-in flow; magnetic diffusion; equation of state; fluid drifts; magnetic pressure and tension

The Solar Wind - Introduction, including concept of heliosphere; fluid model of the solar wind (Parker); interplanetary magnetic field and sector structure; fast and slow solar wind; solar wind at Earth; coronal mass ejections

The Solar Wind Interaction with Unmagnetised Bodies - The Moon; Venus, Comets

The Solar Wind and Magnetised Bodies (I) - Closed Magnetosphere Model. The ring current, boundary currents; shape of the magnetopause; corotation; convection driven by viscous flow

The Solar Wind and Magnetised Bodies (II) - Open Magnetosphere Model, Steady State

Magnetic reconnection; steady state convection; currents and potentials in an open magnetosphere; the magnetotail; the plasmasphere; the aurorae

The Solar Wind and Magnetised Bodies (II) - Open Magnetosphere Model, Non-Steady State

Phases of a substorm; Substorm current systems and unanswered questions about substorms; magnetic storms; dayside reconnection.