## Semester 1

<table>
<thead>
<tr>
<th>Course</th>
<th>Lecture (UE)</th>
<th>Exercise (UE)</th>
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<tbody>
<tr>
<td>Space Resources Fundamentals</td>
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<td>Space Resources Fundamentals</td>
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<tr>
<td>Space Mission Design &amp; Engineering</td>
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<td>Space Robotics I</td>
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<td>Space informatics</td>
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<td>Space Project Management</td>
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<td>Space Policy, Law, &amp; Ethics</td>
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<tr>
<td>CubeSat Laboratory</td>
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<td>Semester 2</td>
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## Semester 2

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<tbody>
<tr>
<td>Spacecraft design and Subsystems engineering</td>
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<tr>
<td>Spacecraft design and Subsystems engineering</td>
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### Interdisciplinary Space Master

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<tr>
<th>Course</th>
<th>Lecture (UE)</th>
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<tbody>
<tr>
<td>Space Economics : This course will cover the following topics: General economy principle Space Economy in Figures Mapping of the Space sector and Global value chain Main drivers and Market challenges Socio-Economic impacts of Space Investments New Space and on-going transformation of the global space sector</td>
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<td>Entrepreneurial Space Finance : This course will help students look from an investor's perspective and understand how investors make their investment decisions. The content covers all phases of the company’s life cycle from startup to exit and covers deal structures, incentives, business models and valuations. The course will then look at a variety of financing models throughout the startup cycle. For better practical understanding, the course will use cases of startup investments in the space sector. The students are asked to prepare the cases prior to each class and participate actively in class.</td>
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<td>Space Resource Utilization Technologies : This course will cover the following topics: 1) spacecraft systems and space instruments, 2) remote sensing and surface prospecting technologies, 3) excavation, beneficiation, drilling, and transportation equipment, 4) extraction, refining, and processing systems, 5) manufacturing and construction technologies, 6) economic, legal, societal, environmental, and sustainability issues, and 7) systems integration into space resource utilization plan</td>
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<tr>
<td>Space Business</td>
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<tr>
<td>GNCSS (Guidance, Navigation and Control for Space Systems ) : Guidance, Navigation and Control will cover the following topics: 1) kinematics and dynamics of spacecraft 2) orbital manoeuvres and trajectories; 3) sensors and actuators for satellites and spacecraft GNC; 4) mathematical description of GNC tasks; 5) introduction to control systems engineering; 6) algorithms for spacecraft GNC; and 7) design, simulation and implementation of GNC solutions.</td>
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<tr>
<td>Autonomous Space Systems Lab</td>
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<td>Law, Science and Technology</td>
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Semester 1

**Space Resources Fundamentals**

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<tr>
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<td>ECTS:</td>
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<tr>
<td>Language:</td>
<td>Anglais</td>
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<tr>
<td>Mandatory:</td>
<td>Oui</td>
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**Space Mission Design & Engineering**

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<tr>
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<td>Language:</td>
<td>Anglais</td>
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<tr>
<td>Mandatory:</td>
<td>Oui</td>
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<tr>
<td>Evaluation:</td>
<td>The attendance to 80 % of the courses is mandatory to be accepted to the exam.</td>
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<tr>
<td></td>
<td>50 % homework/project work</td>
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<td>50 % written exam</td>
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<tr>
<td>Professor:</td>
<td>FABER Nicolas Thomas</td>
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**Space Robotics I**

<table>
<thead>
<tr>
<th>Module:</th>
<th>Space Robotics I (Semester 1)</th>
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<tbody>
<tr>
<td>ECTS:</td>
<td>5</td>
</tr>
<tr>
<td>Objective:</td>
<td>To introduce students to</td>
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<tr>
<td></td>
<td>· History of robotics technology and challenge to space missions. (Yoshida)</td>
</tr>
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<td></td>
<td>· Orbital robotics: motion dynamics and control. (Yoshida)</td>
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<td></td>
<td>· Lunar/planetary robotics: mobility design, traction control, sensing and navigation. (Yoshida)</td>
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<td></td>
<td>· Teleoperation and autonomy. (Yoshida)</td>
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</tbody>
</table>
Course learning outcomes:

Having taken this course students will be able to

- Answer to "what", "why" and "how" questions about robots and their application to space missions.
- Outline the basics of robot control and the challenges of space robotics.
- Describe the principle core technologies for both Earth orbital robotics and lunar/planetary robotics.

Description:

This course will cover the following topics:

- What is robot: history and applications
- Basics of feedback control
- Design consideration in space robots
- Orbital robotics
  - History of robotic manipulators for orbital missions
  - Kinematics, dynamics and control of free-flying robots
  - Vibration dynamics and suppression control
  - Target capture and impact dynamics
  - Hardware test bed principles for the motion in micro-gravity
    - Lunar/planetary robotics
  - History of lunar/planetary robots
  - Mobility system design for surface locomotion
  - Wheel-soil traction mechanics
  - Sensing and navigation
  - Localization and mapping
    - Teleoperation and autonomy
  - Communication bandwidth and latency in teleoperation
  - Shared autonomy

Teaching modality:

- In class
- Individual work
Interdisciplinary Space Master

- Individual and team Laboratory Work

**Language:** Anglais

**Mandatory:** Oui

**Evaluation:**
- Individual work
- Peer Assessment
- Final Exam

All written work MUST be submitted digitally in PDF-format. All assignments will be checked for plagiarism.

**Professor:** OLIVARES MENDEZ Miguel Angel, YOSHIDA Kazuya

### Space informatics

**Module:** Space informatics (Semester 1)

**ECTS:** 5

**Course learning outcomes:** Having completed this course the student will be able to:

- explain the broad role of informatics in the design and operations of space systems.
- program in Python, an emerging language for data science.
- harness machine learning techniques and architectures (deep learning, generative adversarial networks, etc.) in order to process satellite imagery data.
- explain game theoretic and optimization models which can be applied to space mission planning problems
- use tools facilitating spacecraft engineering with an emphasis on the importance of reliability and requirements
- confidently write in a technical style

**Description:** This is the introductory course to data science and software engineering aspects of the Interdisciplinary Space Master program. Due to the low barriers for launching CubeSATs into low earth orbit (LEO), many NewSpace companies have a business model involving satellite constellation management and data processing. Satellites produce petabytes of data where the value is often in the analytics, e.g., maritime asset tracking or land usage change, rather than the raw data itself. These companies require data scientists with an understanding of the mathematics and programming skills necessary for automating the process of extracting analytics. Data science also plays a role in space mission planning and operations. This course will also provide the students with experience working with tools for specifying and verifying the requirements of space systems. In particular, they will become aware of challenges designing space systems that are typically expected to operate reliably, without servicing, for the duration
of their lifetime in space. Due to the low barriers for launching CubeSATS into low earth orbit (LEO), many NewSpace companies have a business model involving satellite constellation management and data processing. Satellites produce petabytes of data where the value is often in the analytics, e.g., maritime asset tracking or land usage change, rather than the raw data itself. These companies require data scientists with an understanding of the mathematics and programming skills necessary for automating the process of extracting analytics. Data science also plays a role in space mission planning and operations. This course will also provide the students with experience working with tools for specifying and verifying the requirements of space systems. In particular, they will become aware of challenges designing space systems that are typically expected to operate reliably, without servicing, for the duration of their lifetime in space.

The course Space Informatics is driven by lectures presenting case studies. Each case study will focus on a critical challenge faced when processing data or designing space systems. A case study can be, for example, a space mission where inadequate system design lead to disruption, increased cost, or failure of a mission. Such case studies will serve as motivation for employing a technique also introduced in the lectures. The main data science example, will demonstrate applications of deep learning to satellite image processing. As an engineering example, lectures may cover the need for operating systems with strong separation guarantees, e.g., while sharing hardware, meteorology software should not conflict with data distribution tasks (a problem in Mars Pathfinder). As another engineering example, a cracked diode in a shuttle in 2008 caused system disagreement that could have been avoided with Byzantine fault-tolerance. Sufficient knowledge will be provided to perform some preliminary analysis, assuming no previous computer science background.

**Teaching modality:**

**Expectations**

The following guidelines will create a comfortable and productive learning environment for all students throughout the semester.

You can expect the tutors:

- To start and end class on time.
- To inform you of any changes in the course schedule on Moodle at least the night before the course (e.g. illness).
- To reply to e-mails within 48 hours on weekdays.
- To assign homework/projects that adequately covers the material and meets the learning objectives of the course while adhering to the time expectations for a 5 unit course.
- To give projects that accurately reflect the material covered in class and assigned in homework.

We can expect you:

- To come to class on time.
- To be respectful to your tutors and to your fellow classmates (refrain from talking)
- To be attentive and engaged in class.
· To refrain from using cell phones and other electronic devices during class except for note taking if approved.

· To spend an adequate amount of time on the homework each week, making an effort to solve and understand each problem.

· To engage with both the abstract and computational sides of the material.

· To seek help when appropriate.

As research on learning shows, unexpected noises and movement automatically divert and capture people's attention, which means you are affecting everyone's learning experience if your cell phone, pager, laptop, etc. makes noise or is visually distracting during class.

For this reason, we

· ask you to turn off your mobile devices and close your laptops during class.

· allow you to take notes on your laptop, but you must turn the sound off so that you do not disrupt other students' learning. If you are doing anything other than taking notes on your laptop, please sit in the back row so that other students are not distracted by your screen.

Language: Anglais
Mandatory: Oui
Evaluation: Major Assignments:

The course will be assessed based on a technical report prepared by each student individually. The report will be submitted in two phases. The first, draft will report on the first half of the course (a detailed case study of using machine learning to process satellite imagery). By week 11 we expect that each students will have received detailed feedback on a draft report based on the first part of the course. The feedback will recommend how they can improve the content and presentation. They will be asked to resubmit an extended version of their report as for the final assessment.

The report will be marked on: (1) how they addressed the feedback they received; (2) how they reflected material in the later part of the course; (3) how far they went beyond just reproducing the material in lectures and tutorials.

Since this report replaces an examination, we expect a high quality of exposition, and maturity of analysis in the reports. Also each report should be written individually, even if the student have cooperated at some level to understand the underlying mathematics and programming skills. The idea is that students will be prepared for project-based learning early in the program and have a product they can refer back to representing their own understanding of the material in the course.

Couse Grading:

Advice: try to provide grades based on projects instead of exams if possible
Remember we are basing this master on Project Based Learning.

- Participation and reasonable effort in lab sessions: 10% of total grade.
- Project: 90% of total grade.
- Note mandatory submission mid-semester is not graded, since students will be expected to resubmit, taking into account feedback (as described in the previous section).

Attendance Policy

- Class Presence and Participation. Class presence and active participation and discussion are encouraged explaining why you can get credit for this.
- Presence: Although it is not required, most students send us a brief e-mail to explain their absence in advance. Students who repeatedly arrive late to the lecture will have their Class Attendance/Participation grade lowered.
- Participation: For some classes, you may be requested to read material and be prepared to discuss that material in class, i.e. the flipped classroom. The lecturers' role in that case will be as moderators. We will be looking for input that represents thoughtful contributions that complement the debate or move it in a new direction. If you are uncomfortable speaking up in class, we encourage you to visit us and discuss how to develop this skill.

Penalties for Late Work and Requests for Extensions

Late submission of work will be accepted for illness or injury (medical certificate), family crisis (death, illness), psychological distress (discuss with me), too many overlapping deadlines in other classes. You will use Moodle to turn in your assignments. Moodle automatically checks for plagiarism. Use google docs to avoid problems with computer or printer malfunctions.

If you submit your coursework late without justification, it will be graded and a penalty will then be applied. The original grade and the penalty will be clearly indicated.

The penalty for a late submission will be 5% per normal working day, until the mark reaches zero. For example, an original mark of 67% would be successively reduced to 62%, 57%, 52%, 47% etc.

Policies on Missed Labs or Exams, Make up Labs or Exams

You will only be allowed to take an Exam outside of the exam date for family crisis or illness supported with a medical certificate. For missed laboratory work, you will be able to make up the work. For team-based assignments, provisions for making up the work will need to be discussed with me.

Policies on Team Projects

Members of a team submitting a team project must have all contributed an equal amount to the assignment. Once an assignment is turned in, all members of the team will be queried individually and asked to assign a percentage of credit to the other team members. Large discrepancies in effort will be discussed.
Plagiarism

This is your one and only warning. We have a zero tolerance for plagiarism. All written assignments will be checked for plagiarism.

Plagiarism means using words, ideas, or arguments from another person or source without citation. Cite all sources consulted to any extent (including material from the internet), whether or not assigned and whether or not quoted directly. For quotations, four or more words used in sequence must be set off in quotation marks, with the source identified.

For further information on plagiarism, please see https://www.plagiarism.org or speak with me.

Academic Integrity

We recognize that peer learning is a valuable method to advance understanding. And we encourage students to work together.

Students who copy assignments, allow assignments to be copied, or cheat on exams will fail the assignment or exam on the first offense, and may fail the entire course on the second. All instances of copying will be referred to the Dean.

What is too much "help" on homework or projects? The line between help and cheating is this: Are you able explain the information yourself on your own? If yes, then that's okay. If no, then you shouldn't turn in the assignment as your own work. You should, at the very least, indicate those parts of the assignment where you received help.

Remark:

Book

http://www.deeplearningbook.org


Professor:

MAUW Sjouke, HORNE Ross James, MIZERANDrzej

Space Project Management

Module: Space Project Management (Semester 1)
ECTS: 3
Objective: The course will aim at giving the students a background on the management of space projects and the role of the project manager. This will be done through a course (15h) lead by Philippe Kletzkine who will cover the points described below, and by exercises classes (30h) lead my
Muriel Hooghe who will illustrate various aspects of space project management with projects from the satellite industry.

**Course learning outcomes:**

The students will acquire an understanding of the above topics, and in particular will be able to understand why different types of projects are organized in specific ways, at technical, managerial and political (mostly but not exclusively, funding) levels.

**Description:**

The course will cover (not necessarily strictly in that order):

- various types of space projects
- description of several past and current scientific space projects, including science objectives and technical and organisational challenges
- comparison of the various challenges and drivers of the respective types of space projects
- specifics of the ESA context compared to other space agencies and other organisations
- public procurement (institutional funding of large projects, and space specifics), various private and hybrid funding schemes (as seen by the space agency player)
- space project complexity management and risk management
- space standardisation
- space project team building and management
- introduction to "New Space".

The course will emphasise the role of the project manager but will also deal with the roles of the other team members.

The course will emphasise the European context, in particular that of European Space Agency projects, and specifically scientific projects, but other organisational settings and applications will also be discussed.

The course will emphasise "Classic Space" management but significant discussion of "New Space" developments will also take place.

**Teaching modality:**

15 lectures + 30 exercise classes

**Language:**

Anglais

**Mandatory:**

Oui

**Evaluation:**

Class attendance, active and constructive participation, feedback and course evaluation including specific improvement suggestions: 20% of total grade.

Project 1: 20% of total grade.

Project 2: 20% of total grade.
**Project 3: 20% of total grade ·
Project 4: 20% of total grade.**

**Remark:** Space Project Management ECSS documents (references to be announced) and small number of general purpose ESA publications as background information (references to be announced)

**Professor:** HOOGHE Muriel Brigitte, KLETZKINE Philippe

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### Satellite communications & Security

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<tr>
<th>Module:</th>
<th>Satellite communications &amp; Security (Semester 1)</th>
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<tr>
<td>ECTS:</td>
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<tr>
<td>Course learning outcomes:</td>
<td>The students will be able to study and understand:</td>
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<td></td>
<td>· the SatCom system architecture and constellations</td>
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<td>· the satellite spectrum and its implications in SatCom services</td>
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<td>· the satellite channel characteristics and link budgets</td>
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<td>· latest digital communication techniques for SatComs</td>
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<td>· the various architectures and capabilities of SatCom payloads</td>
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<td>· relevant standards and security aspects</td>
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<td>· integration of satellite systems within the 5G ecosystem</td>
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<td>· Internet of Things services over satellite</td>
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<td>· Comm aspects of deep space scientific missions</td>
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**Description:**

- Course project : The students will be offered a range of project topics relevant to the delivered lectures. They will have to work in pairs throughout the semester to investigate their topic of preference and deliver the results in the form of presentation.

- Course lab : The students will attend a series of lab sessions where they have to follow the instructions and complete the lab projects under the guidance of the lab assistants.

**Language:** Anglais

**Mandatory:** Oui

**Evaluation:** Attendance is mandatory to both lectures and labs ·

**Course Project:** 60% of total grade or maximum points
The grade will depend on the quality of the presentation material and delivery, as well as the performance during the Q&A session.

**Course Lab: 40% of total grade or maximum points**

The grade will depend on the successful completion of the lab experiments.

**Penalties for Late Work and Requests for Extensions**

Extensions will be granted only in exceptional cases and with proper justification.

**Policies on Missed Labs or Exams, Make up Labs or Exams**

There will be a single Lab session to compensate for missed labs.

There will be two Exam sessions on different weeks.

The course material will be available on Moodle.

**Remark:**


2/ Advanced topics: https://www2.theiet.org/resources/books/telecom/sat-com-5g.cfm

3/ Advanced topics: https://www.elsevier.com/books/cooperative-and-cognitive-satellite-systems/chatzinotas/978-0-12-799948-7

**Professor:**

CHATZINOTAS Symeon

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**Space Policy, Law, & Ethics**

**Module:** Space Policy, Law, & Ethics (Semester 1)

**ECTS:** 3

**Objective:** This class will be divided into groups and each group will function as a law firm. Throughout the semester, the law firms will be requested to advise clients on various issues arising from their space activities. Firms will be required to turn in three legal memos advising clients and complete a final presentation.

- Group memo 1: Authorization (20%)
- Group memo 2: Licensing (20%)
- Group memo 3: Horizon 2020 (20%)
- Final Project: Presentation (35%)

**Expectations**
You can expect the instructors:

- To start and end class on time.
- To inform you of any changes in the course schedule on Moodle at least the night before the course (e.g. illness).
- To reply to e-mails within 24 hours on weekdays and 48 hours on weekends.
- To assign homework/projects that adequately covers the material and meets the learning objectives of the course while adhering to the time expectations for a N unit course.
- To give exams that accurately reflect the material covered in class and assigned in homework.

The instructors can expect you:

- To come to class on time.
- To be respectful to us and to your fellow classmates (refrain from talking).
- To be attentive and engaged in class.
- To refrain from using cell phones and other electronic devices during class except for note taking if approved.
- To spend an adequate amount of time on the homework each week, making an effort to solve and understand each problem.
- To engage with both the abstract and computational sides of the material.
- To seek help when appropriate.

Course learning outcomes:

Having taken this course students will be able to

- Understand the policy making in the area of the exploration and use of outer space, especially in the UN and in Europe
- Understand the interface between international law and policy and national law and policy
- Understand the system of authorization of space activities, and its consequences
- Understand the system of allocation of frequency bands to space services, and assignment of radio frequencies to radio stations
- Be aware of ethical aspects of space activities, especially the Ethics Appraisal Procedure applicable to the EU financed projects.

Description:

This course will cover following topics:

I. Introduction, significance of space activities for the society, their impact on the society; criteria for an exam, literature and documents (5 TU)
II. Space Policy: Definition, significance, examples (UN, EU and ESA, national space policies) (5 TU)

III. Authorization of space activities: National and international framework (5 TU)

IV. Licensing radio stations: National and international framework (5 TU)

V. Ethical aspects of space activities: example - the Ethics Appraisal Procedure applicable to the EU financed projects (5 TU)

VI. Conclusion, presentation of class work (moot application for a space activity, moot application for a radio station license, moot application for Horizon 2020 – ethics criteria) (5 TU).

Teaching modality: This class will be divided into groups and each group will function as a law firm. Throughout the semester, the law firms will be requested to advise clients on various issues arising from their space activities. Firms will be required to turn in three legal memos advising clients and complete a final presentation.

- Group memo 1: Authorization (20%)
- Group memo 2: Licensing (20%)
- Group memo 3: Horizon 2020 (20%)
- Final Project: Presentation (35%)

Language: Anglais

Mandatory: Oui

Evaluation: TVD: Advice: try to provide grades based on projects instead of exams if possible

Remember we are basing this master on Project Based Learning.

- Class attendance/participation 5% of total grade
- Group Memos: 60% of total grade
- Presentation of a Project: 35% of total grade

Remark: Tanja Masson Zwaan & Mahulena Hofmann, Introduction to Space Law, Kluwer 2019

Mahulena Hofmann (ed.), Ownership of Satellites, Nomos/ Hart 2017


**Interdisciplinary Space Master**


**Professor:** HOFMANN Mahulena, BLOUNT Percy

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**CubeSat Laboratory**

**Module:** CubeSat Laboratory (Semester 1)

**ECTS:** 1

**Objective:**

Goal of the course:

- project based learning of satellite system engineering

**Means:**

- design of a cubesat mission

**Course learning outcomes:**

1. translate scientific space objectives into system requirements
2. space mission analysis, spacecraft design and data processing
3. space project management
4. software programming tools and hardware

**Description:**

* ISM class 2019 is a design team divided into engineering groups:

1. system
2. power
3. communication
4. attitude determination and control
5. data handling
6. payload

* each group works independently and syncs with team weekly

* topical lectures

**Language:** Anglais

**Mandatory:** Oui
Professor: THOEMEL Jan
Semester 2

Spacecraft design and Subsystems engineering

Module: Spacecraft design and Subsystems engineering (Semester 2)
ECTS: 5
Objective: To teach students how to design a space mission. Focus is on maximizing the intrinsic value of the mission, systems engineering and the space systems technology needed to implement the mission.

Course learning outcomes:

After taking this course students will be able to:

1. Explain the concepts of "space mission", "space system" and "systems thinking";
2. Perform basic space mission analysis and design;
3. Assess the value of a space mission within its scientific/engineering/business/historical context;
4. Explain the notion of space systems lifecycle and state the main goals and outcomes of each phase of the lifecycle;
5. Understand the scope of activities of a space-systems engineer: Requirements Engineering, Design and Configuration, Verification and Validation, Analysis, Integration and Control;
6. Describe the main disciplines interfacing with the space system engineer: Production, Operations & Logistics, Product Assurance and Project Management.
7. Perform basic systems engineering analyses such as technical budgets, trade-offs, safety/reliability analysis, risk registers; Failure mode analysis;
8. Describe the function of key spacecraft sub-systems;
9. Describe the functioning of key spacecraft technology and components;
10. Understand the importance of interface engineering;
11. Use a toolbox of simple mathematical models for use as 'hand calculations' in the design of a space mission, space system, or sub-system.
12. Use state of the art tools and processes to accelerate and improve the design of a space mission (in particular, Model-Based Systems Engineering and Concurrent Engineering)

Description: This course is about space mission design. It reaches back to the beginning of the space age and the first space missions, and spans over more than half a century of space mission design.
The course ends with a range of best practices for mission design in the current "new space economy".

The learning material is supported by hands-on exercises providing the entry point for a deeper understanding of the topics. The exercises make use of industry relevant software and, occasionally, of hardware developed through rapid prototyping.

The course covers the 3 segments of a space system

- Launch segment: rockets, launch vehicles
- Ground segment
- Space segment
  - Bus
  - § EPS, AOCS, Communications, OBDH, Structure, Thermal, Propulsion, etc
  - Payload
  - § Earth Observation, Navigation, Communication, Science, etc

**Teaching modality:** Lectures

**Language:** Anglais

**Mandatory:** Oui

**Evaluation:** All work must be submitted digitally in PDF-format. All assignments will be checked for plagiarism.

**Professor:** FABER Nicolas Thomas, RANA Loveneesh

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**Space Economics**

**Module:** Space Economics (Semester 2)

**ECTS:** 3

**Objective:** This course has as main objectives to provide an answer to the question how space contributes to the global economy and for that the subsequent objectives are to introduce some fundamental knowledge and to give an overview (360 degree tour) on the space economy.

**Course learning outcomes:** Having taken this course students will be able to

- acquire the fundamental principle of the economy: production, distribution, or trade, and consumption of goods and services …
- acquire an overview on the space economy including drivers, eco-system, global value chain, market challenge …
- better understand the new space including change of paradigm
- better perform in the Space Business module
Description: This course will cover the following topics:

- General economy principle
- Space Economy in Figures
- Mapping of the Space sector and Global value chain
- Main drivers and Market challenges
- Socio-Economic impacts of Space Investments
- New Space and on-going transformation of the global space sector

Teaching modality:
- In class and online instruction
- Individual work

Language: Anglais

Mandatory: Oui

Evaluation: Individual and Group work: all written work MUST be submitted digitally in PDF-format and/or Power-point

Professor: ROUESNEL Frédéric

Entrepreneurial Space Finance

Module: Entrepreneurial Space Finance (Semester 2)

ECTS: 1

Objective: This course is aimed for students who at a certain point in their career are involved in a startup in the space industry as a founder, early employee, advisor or investor. This course gives an overview of the financing value chain, such as venture capital, angel and debt financing.

Course learning outcomes: Having taken this course students will be able to

- acquire an overview on the space finance eco-system and the different types of investors
- acquire the fundamental principle of entrepreneurial finance
- understand the different roles of investors throughout the venture’s life cycle and how they select, fund, and develop emerging growth companies
- evaluate startup investment opportunities, reviewing business plans, conducting due diligence, determining valuations, negotiating with management teams, constructing term sheets, and implementing exit strategies.

Description: This course will help students look from an investor’s perspective and understand how investors make their investment decisions. The content covers all phases of the company’s life cycle from startup to exit and covers deal structures, incentives, business models and valuations. The course will then look at a variety of financing models throughout the startup cycle.

For better practical understanding, the course will use cases of startup investments in the space sector. The students are asked to prepare the cases prior to each class and participate actively in class.

Language: Anglais
Mandatory: Oui

Evaluation:
• Class participation and case preparation
• Final paper: provides the opportunity for students to apply theories and insights gathered in this course to explore the investment opportunity of a space company they know/have interest in

All written work MUST be submitted digitally in PDF-format and/or Power-point

Professor: FLEISCHER Sarah

Space Resource Utilization Technologies

Module: Space Resource Utilization Technologies (Semester 2)
ECTS: 3

Objective: This course provides an overview of space resource utilization technologies, including prospecting, excavation, drilling, extraction, processing, refining, manufacturing, and construction systems and their integration into a detailed space resource utilization plan. Students will build an in-depth knowledge of the technical aspects of the field of space resources, while developing confidence in solving a variety of engineering problems, as well as the accompanying economic, societal, environmental, and sustainability implications.

Course learning outcomes:
At the completion of this course, the student will be able to:

1. Identify aerospace engineering practices and technologies relevant to the development of space resources and list and contrast the various spacecraft systems and instrumentsto be used for the prospecting, extraction, and utilization of in situ resources
2. Identify space mining technologies being developed for lunar, asteroidal, and planetary applications, and evaluate the feasibility and readiness of current excavation, beneficiation, drilling, and transportation systems
3. Identify resource extraction and processing technologies being developed for lunar, asteroidal, and planetary applications, and evaluate the feasibility and readiness of current extraction systems for volatiles, minerals, metals, non-metals, and atmospheric gases
4. Describe the objective and status of space manufacturing and construction systems, categorize the technologies being developed to create products and build parts from in situ raw materials and evaluate the business case of the various companies currently participating in this field
5. Analyze space resource utilization systems from the economic, legal, societal, environmental, and sustainability points of view

Create a complete space resource utilization plan that incorporates prospecting instruments, excavation and drilling equipment, extraction and processing systems, and manufacturing/construction technologies, including a quantitative analysis of material flows, power, mass, and volume requirements, and legal, environmental, and socio-economic considerations

Description: This course will cover the following topics:

1) spacecraft systems and space instruments,
2) remote sensing and surface prospecting technologies,
3) excavation, beneficiation, drilling, and transportation equipment,
4) extraction, refining, and processing systems,
5) manufacturing and construction technologies,
6) economic, legal, societal, environmental, and sustainability issues, and
7) systems integration into space resource utilization plan.

Teaching modality:
• Asynchronous online instruction
• Weekly one-hour synchronous sessions
• Individual work and presentations
• Discussion boards
• Team project

Language: Anglais
Mandatory: Oui
Evaluation:
• Individual work
• Quizzes
• Presentations
• Peer Assessment
• Final Team project
All written work MUST be submitted digitally in PDF-format. All assignments will be checked for plagiarism.

Professor: OLIVARES MENDEZ Miguel Angel

Space Business

Module: Space Business (Semester 2)
ECTS: 3

Objective: This course will use real-life examples of protagonists of space companies wrestling with business problems to introduce the students to the major elements of a space business. This will enable the successful student to be an effective and value added member of a space business.

Description:
1. The course will be taught with 14 case-study discussions plus 2 exams. Class participation and attendance is mandatory and 50% of the grade.
2. Each case study involves a real-life business problem of a space company
3. The 14 case studies will cover
   • Intro Lecture - There is no Business like Space Business: dreams, challenges, aspirations and some definitions
   • What is Space Business: market/s overview, value chain, competitive environment, classic vs emerging Space business sectors
   • What is Strategy
   • Strategic Marketing: Segmentation, Position, Positioning and Go to Market strategies
Interdisciplinary Space Master

- Tactical marketing: Branding, Advertising and talking to Customers
- Managing resources for Success (1): Managing Social and Human Capital
- Managing resources for Success (2): operational model, trading-off capital investments, trading-off internal operations vs outsourcing
- Managing resources for Success (3): Technology, IPR and regulatory environment
- Introduction to Corporate Finance: models and sources of financing
- When things go wrong: dealing with uncertainty and risk
- When things go right: strategic developments and diversification
- Concluding lecture

Teaching modality: Case-method – pre-class reading and mandatory in-class participation

Language: Anglais

Mandatory: Oui

Evaluation:  
- 50% in class participation
- 20% Mid-term case study (4h)
- 30% Final case study (4h)

All written work MUST be submitted digitally in PDF-format. All assignments will be checked for plagiarism.

Professor: PLATZER Peter, MILIC Edgar

GNSSS (Guidance, Navigation and Control for Space Systems )

Module: GNSSS (Guidance, Navigation and Control for Space Systems ) (Semester 2)
ECTS: 5

Objective: Guidance, navigation and control are basic capabilities for all spacecraft. Therefore, the main objective of this course is to provide the students with the capability to understand and develop GNC systems for all kind of spacecraft missions. In addition, they will acquire general knowledge about spacecraft modelling and also control engineering that will be necessary in further courses in the program.

Course learning outcomes: Having taken this course students will be able to

- model the kinematics and dynamics of spacecraft
- to understand the tasks of guidance, navigation and control (GNC) of spacecraft and their related challenges
- understand and apply the basic sensing and actuating devices for GNC
- design, analyse, simulate and implement the basic control algorithms for GNC tasks

Description: Guidance, Navigation and Control will cover the following topics: 1) kinematics and dynamics of spacecraft 2) orbital manoeuvres and trajectories; 3) sensors and actuators for satellites and spacecraft GNC; 4) mathematical description of GNC tasks; 5) introduction to control systems engineering; 6) algorithms for spacecraft GNC; and 7) design, simulation and implementation of GNC solutions.
Teaching modality:  
- In class and online instruction  
- Project-based learning  
- Individual and work in groups  
- Peer Assessment  

Language:  Anglais  
Mandatory:  Oui  
Evaluation:  
- Individual work  
- Project-based work and reports  
- Peer Assessment  
- Final Exam  

All written work MUST be submitted digitally in PDF-format. All assignments will be checked for plagiarism.  

Remark:  

Professor:  VOOS Holger, OLIVARES MENDEZ Miguel Angel  

Autonomous Space Systems Lab  

Module:  Autonomous Space Systems Lab (Semester 2)  
ECTS:  5  
Objective:  Professional competency:  
- A thorough understanding of an autonomous system architecture  
- A thorough understanding of the sensors solutions available  
- A basic understanding of tools and frameworks to extract and process the data from the sensors  
- A basic understanding of data filtering  
- A basic understanding of the planning and generation of collision free path and trajectories  
Methodological competency:  
- Ability to decompose all the parts of full autonomous system  
Individual competency:  

Course learning outcomes:
After completing the course students will be able to:

- Identify and select the right sensor(s) for the different applications
- Extract data from the sensors using ROS
- Basic uses for image and cloud points processing algorithms
- Control of a lunar rover vehicle
- Use basic path planning algorithms on ROS
- Self-localization on an unknown environment
- Improve odometry using filtering algorithms

Description:
Engineering autonomous and intelligent space systems such as rovers or satellites that are capable of robust, long-term operations with little to no human-intervention is a challenging exercise. Advanced perception, planning and decision-making abilities need to be composed both on a technical and conceptual level into an overall architecture without sacrificing functional and non-functional requirements such as reliability, availability and robustness. The main objective of this course is not only to raise awareness of the impact of functional and architectural design decisions, but also to endow students with the knowledge to describe, analyze and develop dependable space systems with a high-degree of autonomy as required by space scenarios operating over a long-period of time in challenging and remote environments.

This course will combine experiments on virtual and real environments using ROS. The real experiments are planned to be done at the LunaLab facility.

Teaching modality:
- Group discussions
- Lab work

Language:
Anglais

Mandatory:
Oui

Evaluation:
Final report and presentation; Lab projects

Remark:
- Additional scientific articles from the robotics, AI, perception, control, path planning domain.

Professor:
OLIVARES MENDEZ Miguel Angel

Law, Science and Technology

Module: Law, Science and Technology (Semester 2)
ECTS: 3
Objective:

To acquaint students with the legal viewpoint and factors that might affect their work in space research on both sides of science and technology. Raising their awareness will enable them to conduct applied research on, develop and use different technologies related to space research in a judicious and responsible way, also to decide about and realize tech-transfer.

They'll also gain a general understanding of the issues in law and technology raised by the development of artificial intelligence.

The introduction to the specific questions is going to happen through selected scientific and technology case studies exemplifying the relevance of given legal factors and issues listed above.

Course learning outcomes:

Having taken this course students will be aware of foundations of the interaction of law, science and technology in relation with space research and applications.

This, on one hand, covers the practical knowledge concerning the legal conditions and implications

- of their scientific work and using specific tools and applying methodologies (software, databases, big data, machine learning, etc.)
- of implementing their research results/product to technology and of bringing technology to market
- of using specific space-related technologies.

On the other hand, this interaction covers the area of AI & Law where the emphasis is on the introduction of the theoretical questions of this interaction and their potential practical consequences (with a focus on space related technologies’ interaction with AI and law).

Description:

Law, Science and Technology will cover the following topics: Practical legal issues of working in science and technology: 1) rights and duties relating to conduct research and applying specific tools and approaches during space research and technology use (software, databases, big data, machine learning, etc.) 2) rights and duties concerning intellectual property (know-how, trade secret, copyright, patent, industrial design, trademark, etc.) 3) legal issues of bringing technology to market in space industry (basics of business law, competition law, law of business communication) 4) legal conditions and implications of developing and using space related technologies (data protection and privacy affected by satellites, info-communication rights etc.) 5) the legal construction of harm and damage, risk, security standards, legal liability and the structure of insurance 6) Theoretical and practical questions of AI & Law: 6) how law evolves with new science; scientific and technological revelations' effect on law, its scope and definitions (meaning of 'ownership', 'life', 'liability', etc.) 7) introduction to AI & Law, reasoning models in technology vs. reasoning in law 8) responsibility from a legal and a technological point of view in the light of space robotics 9) interpretations of data in technology and in law, scientific vs. legal proof, digital forensics 10) autonomous vehicles and law

Teaching modality:

- In class and online instruction
- Individual work

Language: Anglais

Mandatory: Oui
Interdisciplinary Space Master

Evaluation:

- Individual work
- Project
- Final Exam

All written work MUST be submitted digitally in PDF-format. All assignments will be checked for plagiarism.

Professor: MARKOVICH Réka, VAN DER TORRE Leon

CubeSat Project

Module: CubeSat Project (Semester 2)
ECTS: 3

Objective: Goal of the course:

- project based learning of satellite system engineering

Means:

- design of a cubesat mission

Students will contribute to the development of a cubesat that will be, over several semesters, brought to launch readiness. Then it will be launched and operated by the students.

Course learning outcomes:

1. translate scientific space objectives into system requirements
2. space mission analysis, spacecraft design and data processing
3. space project management
4. software programming tools and hardware

After having completed this course, the students will have learned to develop a hi-tec system to a quasi-market readiness. It will require planning and execution of technical tasks within a team. Optionally, legal and public communication aspects may also be addressed.

Description:

* ISM class 2019 is a design team divided into engineering groups:

1. system
2. power
3. communication
4. attitude determination and control
5. data handling
6. payload

* each group works independently and syncs with team weekly
* topical lectures

**Teaching modality:**
- Introductory lectures
- Guided self-learning
- Hands-on group lab work

**Language:** Anglais

**Mandatory:** Oui

**Evaluation:**
- Project report (chapters by group member)
- Final presentation (by group) and deliberation

All written work MUST be submitted digitally in PDF-format. All assignments will be checked for plagiarism.

**Remark:**


**Professor:** THOEMEL Jan