2SC5110 – Performance and flight paths

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Department: DÉPARTEMENT MÉCANIQUE ENERGÉTIQUE PROCÉDÉS
Language of instruction: FRANCAIS
Campus: CAMPUS DE PARIS - SACLAY
Workload (HEE): 60
On-site hours (HPE): 34,50

Description

The course provides the skills and knowledge needed to model and control flying vehicles (in and out of the atmosphere) to improve system performance. It is divided into two parts.

The first part of this course is a core curriculum whose objectives are to provide a common basis of knowledge and skills. This common core is organized into three parts. First, solid mechanics is introduced to give the necessary tools for the modeling of airplanes, launchers, satellites, UAVs... In a second step, the course describes the dynamics and control strategies of an aircraft. Finally, space mechanics is introduced to give the necessary tools to describe movement, disturbances, and maneuvers of a spacecraft.

The objectives of the second part of the course are to provide new knowledge and skills to reinforce those seen in the core curriculum of this course. It will focus on the design and control of three systems: an aircraft, a launcher, and a satellite. It will provide specific knowledge and skills necessary for the topics of the challenge week.

Numerous experts in aeronautics and aerospace fields are involved in this course.

Quarter number

ST5

Prerequisites (in terms of CS courses)

There is no specific prerequisites.

Syllabus

Core curriculum:

1. General mechanics :

This course will provide the basic notions in solid mechanics. It will address the following points:

- Equation of motion of a rigid body. Fundamental Principles of Dynamics
- Tutorial 1: Measurement of the parameters of inertia of a mricosatellite.
- Mechanical linkage between rigid bodies.
- Tutorial 2: movement of a Cubli.
- Aerospace actuators (stability of rotation around the main axis of inertia, gyroscopic effect, application to gyroscopic actuators, reaction wheels).
- TD 3: attitude of a satellite

2. Flight Mechanics :

This part of the course will illustrate the dynamic stability through the stability study of an airplane in flight. The objective is to identify the movements induced by small disturbances around a state of equilibrium and to determine the damping or the amplification of these movements according to the properties of the aircraft. The lecture part gives all the mathematical modeling tools that will be used in the stabilization study. It will address the following points:

- Definition of Euler angles. Matrix formulation
- Linearized dynamic equations of motion
- Solving linearized equations
- Presentation of the representative modes: phugoid, incidence oscillation, Dutch roll, Roll subsidence mode and spiral divergence.

3. Space mechanics

This course introduces the fundamentals of space mechanics, focusing on the study of free motion in gravity field, orbital manoeuvres and space environmental perturbations. Some insights on inter-planetary missions are given.

Elective course (One course depending on the chosen topic of the challenge week)

In the second part of the course, three courses are proposed, corresponding to an introduction to the projects of the challenge week.

1. **Control of an airplane**

This course aims to detail the modeling and control of an airplane. It will address the following points:

- Presentation of the specification for the flight performance of an airplane
- Modeling forces acting on the aircraft (including thrust, lift and drag)
- Coefficients and ratio for the study of the trajectory performance.

2. **Control of a launcher**

The course aims to address the fundamentals of attitude control of a launcher, in both propelled and ballistic phases. The requirements to be met by the control system as well as the physical disturbances to be managed during the flight will be addressed. Command synthesis principles will be presented, as well as aspects relating to the actuators.

3. **Control of a satellite**

This course aims to detail the modeling and control of a satellite. It will address the following points:

- Architecture of a AOCS
- Typical missions, families of AOCS, types of orbits, disturbing couples,
- Sensors and actuators for a satellite
- control modes and algorithms, contribution of the AOCS
- Specifications for a AOCS system (stability, performance, robustness, different developped controllers).

Class components (lecture, labs, etc.)

Lectures and tutorials.
Several examples of real aircraft and aerospace systems will be presented.

Grading

The specific course will be evaluated individually by a final examination lasting 1 hour 30 minutes. This evaluation will be done by MCQ. Ten questions per section on the first part of the course (core curriculum), i.e., 30 questions in total. These questions can include small exercises of application.

Course support, bibliography

- Orbital Mechanics for Engineering Students, H. D. Curtis, Butterworth-Heinemann. 2013.

- Practical Methods for Aircraft and Rotorcraft Flight Control Design: An Optimization-Based Approach, Mark B. Tischler, Tom Berger, Christina M. Ivler, Mohammadreza H. Mansur, Kenny K. Cheung and Jonathan Y. Soong. ISBN: 978-1-62410-443-5.
- Advances In Aircraft Flight Control, M B Tischler, CRC Press, 28 jun. 1996.
- Aircraft Control and Simulation: Dynamics, Controls Design, and Autonomous Systems Brian L. Stevens, Frank L. Lewis, Eric N. Johnson, John Wiley & Sons, 2 oct. 2015 - 768 pages
- Performance, Stability, Dynamics and Control of Airplanes, Third Edition 2015, Bandu N. Pamadi, ISBN: 978-1-62410-274-5.

Resources

- Teaching team: F. Gatti, E. Bourgeois, Ch. Betrancourt, teachers from CNES, TAS and Dassault Aviation, S. Tebbani (coordinator)
- Maximum of 35 students in each tutorial group.
- Software tools: Matlab

Learning outcomes covered on the course

The objectives are to acquire skills and knowledge to:

- Model the behavior of a flight vehicle in the framework of solid mechanics, flight mechanics, and space mechanics.
- Describe the dynamics of flying vehicles into and out of the atmosphere (trajectory, modes, instabilities).
- Choose and develop control strategies.

This course will also provide a global view of control systems for flying vehicles, as well as performance requirements and associated constraints.

Description of the skills acquired at the end of the course

At the end of the course, students will acquire an operational understanding of the design tools of a flying vehicle in flight through the acquisition of:

- basic concepts in solid mechanics, flight mechanics and space mechanics
- good knowledge of the requirements and constraints of the control of a flying system
- good knowledge of different aerospace systems and vehicles (aircraft, UAV, satellite, launcher).

They will be able to:

- model vehicle dynamics in the case of flights in and out of the atmosphere (trajectory, modes, instabilities).
- Choose and develop control strategies.
- Evaluate the flight performance of the flight of a vehicle and to propose effective and economical solutions to improve it.

More specifically, the aquired skills are:

- Analyze, design and implement complex systems with scientific, technological, human and economic components (C1).
- Develop in-depth skills in a scientific or sectoral field and a family of professions (C2).
- Act, undertake and innovate in a scientific and technological environment (C3).
- Be operational, responsible, and innovative in the digital world (C6).
- Know how to convince (C7)