ST5 – 51 – PILOTING AND FLIGHT CONTROL IN AERONAUTICS AND SPACE TRANSPORTATION

Dominante : GSI (Large Interacting Systems) and CVT (Construction, City and Transport)
Langue d'enseignement : French
Campus où le cours est proposé : Paris-Saclay

Engineering problem

This sequence addresses the problem of designing flight control laws and dynamic control of vehicle flight (aircraft, satellite and launcher). It aims to give students the basic concepts associated with the design of control systems of a flying object around its 6 degrees of freedom in order to ensure stability of operation and the required performance. The technologies in the fields of aeronautics and space being in constant evolution (propulsion, structure, materials, etc.), the laws of piloting must adapt to guarantee the best performances while taking into account the new constraints, in particular regulatory, environmental and economic.

The integration course allows students to apply the skills and knowledge acquired in the case of an aircraft, a nanosatellite and/or a launcher. These vehicles have become very popular in recent years due to the reduced cost associated with their construction and operation. However, it raises new problems, in particular for the control of attitude and performance due to the miniaturization of the components and thus the reduction of their capacities of action and their effectiveness.

The intervention of industrialists from the aeronautics and space sector in this sequence allows a better understanding of the issues associated with the design and operation of increasingly constrained systems.

Adviced prerequisites

Two main topics are covered in this sequence: modeling of undeformable objects and modeling of linear systems (transfer functions, state representation, differential equations) for control. These recommended prerequisites are part of the common course of Modeling (ST2) and the SPI course of Mechanics and Continuous Media. The rest of the necessary skills are based on the capitalization of CPGE knowledge and self-training.

Context and issue modules: The introduction of the sequence is organized around four half-days of training aiming at presenting the sequence, the integration teaching and introducing the stakes of the various sectors of space and aeronautics, according to the actions:

1. Presentation of the thematic sequence and introduction to the integration lessons

2. Conference on the civil and military aeronautics sector: from the design of airliners to operations and traffic management (speaker: Air France, Dassault Aviation)

3. Conference on applications and uses in space (speakers: CNES, Thalès Alinea Space)

4. Introductory conference on the law of space activities (speaker: Institut du Droit de l'Espace et des Télécommunications, IDEST). Introduction to the concepts of liability and insurance (speaker: ArianeGroup). Conference on the economy in space (speaker: CNES).

5. Conference on sustainable development in aeronautics and space (speaker: Parrot, ESA).

Specific course (60 HEE) : *Performance and flight trajectories*

Brief description : The objectives of this specific course are to:

- model the behavior of a vehicle in flight in the framework of rigid body mechanics,

- describe the dynamics of vehicles in the case of flights in and out of the atmosphere (trajectory, eigenmodes, instabilities)

- choose and deploy control and piloting strategies.

It is organized in two steps. First, based on the mechanics course offered in the first year, the mechanics of rigid bodies is introduced to give the necessary tools for the construction of models of aircraft, launchers, satellites, UAVs... For this, two courses will give the basic concepts of flight mechanics and space mechanics. In a second phase, the course will describe the dynamics and control strategies of an aircraft, a satellite and a launcher. These three phases of the course will involve several actors from the aeronautics and space sectors. The sessions will provide an understanding of the models used and the control strategies to be used. The students will take control tools on a specific system and will be able to set up a control strategy in a pre-project phase during the integration teaching.

Challenge Week :

Preamble: The three integration courses are built in the same way and cover the same learning objectives. The aim is to start from a performance specification for an aircraft, a nanosatellite or a launcher and to make architecture and piloting choices to ensure the expected performance. The common objectives are therefore:

- Understand the constraints of flying systems, and the different levels of modeling of dynamic behavior

- Choose the relevant technical solutions for the control of trajectory, stability and orientation (sensors/actuators...)

- Design a complete system by modeling, including actuators and sensors, actuator sizing, power generation and CPU capacity

- Implementation of an optimal control law, taking into account economic aspects

- Validation of the control law on a realistic model

Challenge week n°1 : *Control strategy for a nanosatellite*

- Associated partner: Thalès Alenia Space via the CentraleSupélec Space Center

- Location: Paris-Saclay campus

- Brief description: This integration course will be conducted in collaboration with Thalès Alenia Space. The objective is to design a nanosatellite (Cubesat). For a specific mission defined by a specification, participants will propose an orbit, choose the satellite components, design the operating modes and develop a control law.

Challenge week n°2: *Definition and design of a launcher mission*

- Associated partner: CNES Direction des Lanceurs

- Location: Paris-Saclay campus

- Brief description : The objective of this integration course is to bring the students, through a space launcher design project, to experience a multi-disciplinary dimensioning loop. To this end, the project is articulated in modules reflecting the unfolding of a design loop, with CNES DLA (Direction des Lanceurs) engineers accompanying the students during each of these modules.

Challenge Week n°3: *Aircraft design*

- Associated partner: Dassault Aviation

- Location: Paris-Saclay campus

- Brief description: The objective of this challenge week is to discover the different stages of the design process of a business aircraft, both from a theoretical and a practical point of view. The study will focus on the design of the aircraft and improvement of its performance, the development of a control law, and the risk analysis and certification associated with the developed solution.