# 2SC5693 – Hybrid aeronautical propulsion

**Instructors:** Antoine Renaud
**Department:** DOMINANTE - ENERGIE
**Language of instruction:** FRANCAIS
**Campus:** CAMPUS DE PARIS - SACLAY
**Workload (HEE):** 40
**On-site hours (HPE):** 27,00

**Description**

The electrification of aviation is a topical issue, given the challenges of reducing polluting emissions to which the air transport community has committed itself: by the middle of the 21st century, the aim is to halve CO2 emissions from all air traffic. At the same time, it is estimated that the volume of passengers carried will almost double.

In this context, it is legitimate to focus on electrically-powered aircraft, which raises the problem of energy storage: batteries are still very heavy and are barely sufficient to move light aircraft with two passengers over a few hundred kilometers.

During this challenge week, we will focus on a light aircraft of the high-end ultralight class. For this category of aircraft, we can already consider electrification of the propulsion with existing technologies. We will consider a hybrid architecture combining a battery with a hydrogen fuel cell.

**Quarter number**

ST5

**Prerequisites (in terms of CS courses)**

Transport phenomena or Electrical energy courses

**Syllabus**

A general Simulink template of the model will be provided, with a number of blank sub-templates that will need to be completed. Validation tests will then have to be carried out on each of the sub-systems.

1. Fuel Cell

- Battery core electrochemistry
- Thermal management
- Sequencing logic

2. Electrical distribution and motorization

- Engine and its regulation
- Battery and its management system
- Power regulation

3. Airframe

- Flight mechanics and taxiing
- Control loops and piloting

4. Preparation of the test procedure

- Definition of mission profiles
- Pre- and post-processing

In a second part, the groups will be redistributed into three teams and the models of the sub-systems will be shared. Each team will be in charge of assembling its aircraft and testing it.

**Class components (lecture, labs, etc.)**
The work will be supervised by speakers from SafranTech as well as CentraleSupélec teachers. Students will be divided into groups and sub-groups according to the different tasks to be accomplished. Reconfigurations will take place during the week according to the progress of the work.

**Grading**
The evaluation is based on attendance, motivation and efficiency throughout the week as well as on two group presentations, one in the middle of the week and the second on the last day.

**Resources**
The whole activity will take place using Matlab/Simulink software to simulate the problem.

**Learning outcomes covered on the course**
By the end of the week, students will have learned about flight mechanics, how to fly an airplane, and how electric motors and fuel cells work. Most importantly, they will have learned how to manage the constraints associated with these different elements when they are assembled in a complex system. Finally, the scope and complexity of the problem necessarily require teamwork with different core businesses, replicating real-life work situations.

**Description of the skills acquired at the end of the course**

C1.3: Apply problem-solving through approximation, simulation and experimentation.
C1.4: Design, detail and corroborate a whole or part of a complex system.
C2.3: Rapidly identify and acquire the new knowledge and skills necessary in applicable/relevant domains, be they technical, economic or others.
C7.1: Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value.
C8.1: Work collaboratively in a team

# ST5 – 57 – CONTROL OF ACOUSTIC AND ELECTROMAGNETIC POLLUTION

**Dominante :** MDS (Mathematics, Data Science) and Info&Num (Computer Science and Digital)

**Langue d'enseignement :** French

**Campus où le cours est proposé :** Paris-Saclay

**Engineering problem**

Noise pollution is nowadays considered as a major annoyance by the population, while electromagnetic pollution raises many questions and interrogations related to health problems. The practical realizations allowing to control this pollution represent a technical and industrial challenge of the first rank, but do not yet benefit from the new developments that mathematical analysis, numerical simulation and data processing can bring.

This course focuses on the design of innovative products (acoustic or electromagnetic coatings) intended to control acoustic/electromagnetic pollution. Having introduced the physical context, it aims to give students the mathematical and computer science notions associated with the design and manufacture of such products. This teaching proposes two paths of training:

1. Mathematical Methods Track: a track based on mathematical theory (PDEs, functional analysis, Fréchet derivative) associated with numerical algorithms to master the control of waves to define the shape of an acoustic or electromagnetic coating. In particular, in this track are treated the PDEs on irregular edges (fractals) and is developed the method of optimization of shapes and the notion of the derivative with respect to the edge.

2. Scientific Computing, numerical methods and algorithms: the objective of this track is to deepen the numerical methods used in the mathematical track, it is oriented towards scientific computing. By focusing on the same common goal as the mathematical track, this track allows to go further in the numerical implementation of the method of optimization of forms.

Both tracks study methods (theoretical or numerical) that are useful for controlling external acoustic waves (in the vicinity of highways, airports, construction sites) or internal acoustic waves (sound insulation in offices by perforated panels or acoustic liners in aircraft engines for example), as well as for controlling electromagnetic pollution (anechoic chambers).

The integration course allows students to apply the skills and knowledge acquired in the case of a chosen application to guarantee the best performance while taking into account regulatory, environmental and economic constraints.

The intervention of industrialists (ONERA, SIEPEL) and specialists in the design of anti-noise walls allows a better understanding of the economic constraints and issues associated with the design and operation of innovative products.

**Adviced prerequisites**

For the "Mathematical Methods" track, mastery of the first year PDE course is required. From a general point of view, having followed the SPI course "Physics of Waves" would be a plus.

**Context and issue modules:** This part is organized around half-days of training aimed at presenting the sequence, the integration teaching and introducing the issues and associated locks. Thus, the following topics will be addressed: fractals for innovation in acoustic and electromagnetic applications, control by acoustic liners in aeronautical engines, current challenges in the control of electromagnetic waves, research and innovation in the control of waves.

**Specific course (60 HEE) :** *Wave control: theory and algorithmic*

Brief description: The two proposed tracks have the same objectives. The concepts of the common course of Automatic are deepened in the context of the control of the dissipation of the energy of a wave. The observability in this case depends on the geometry of the absorbing edge. To illustrate the reasons why geometric irregularity is needed, the notions of fractal geometry are introduced with results known in physics and, for the theoretical way, in mathematics. In particular, we present the phenomena of localization and absorption of waves (acoustic or electromagnetic) which are linked by the spectral analysis of the model (theoretical and numerical). In order to better understand the environmental and sociological stakes of the development of acoustic barriers, some psycho-acoustic aspects are presented, which show the importance of the dissipation of certain frequencies. The course studies in particular, for a fixed frequency, the obtaining of an optimal form for a frequency model via the Helmholtz equations with the aim of allowing its use in AR on two types of control: geometric and topological. For the numerical path, the algorithmic part of this method will be presented in detail. In the mathematical path, these numerical methods will also be presented but much more briefly.

We then consider the main difficulty of having a "near optimal" shape over a large frequency band, important from a psycho-acoustic point of view and from industrial interests. The final goal in AR is to be able to quickly and robustly determine the optimal or "near optimal" shape of the geometry over a frequency band by numerical simulation.

The two proposed tracks include a joint numerical project on eigenmode localization and two different examination topics.

**Challenge week n°1:** *Design of a cladding to control wave pollution Control of external acoustic pollution*

**- Associated partner:** ONERA

**- Location:** Paris-Saclay campus

**Brief description :** We position ourselves on the industrial issues that impose economic constraints and technological constraints necessary for the improvement of existing products on the market, to design innovative coatings to absorb noise from aircraft, trains, cars. The aim is to develop these innovative products in an optimal way by controlling the energy of the waves through the geometry of the wall while taking into account the economic constraints. For example, COLAS and École Polytechnique have developed a noise barrier called "Fractal Wall" TM, which was empirically designed with a complex geometry to dissipate the different wavelengths. However, this wall, even if it is four times more efficient than conventional walls for low frequencies, is hardly sold... The explanation lies in the fact that its construction, being done by demolding, risks breaking the wall, which results in a high manufacturing cost. This AR proposes to find, by wave control methods, optimal shapes as absorbent as possible (in decibel) which satisfy the constraints imposed by the industrialist, for example, the lowest manufacturing cost with the highest decibel reduction. First numerical results in this context show the existence of optimal shapes "not too complex" able to improve by a factor of 6 the performances of the "Fractal wall" TM.

**Challenge week n°2** : *Design of a cladding to control wave pollution. Control of indoor acoustic pollution*

**- Associated partner:** ONERA

**- Location:** Paris-Saclay campus

- Brief description : We are positioned on the industrial issues that impose economic constraints and technological constraints necessary to improve existing products on the market, in order to design interior coatings to absorb noise inside buildings and also acoustic liners in aircraft engines. In this context we are interested in three main applications: (i) the design of liners in anechoic chambers (so far acoustic anechoic chambers have been designed empirically based on geometries using different scales), (ii) the design of perforated absorbing panels (absorbing materials are made of fibers that have very good absorbing acoustic properties, and are usually covered with wooden panels for aesthetic reasons, which unfortunately impairs their effectiveness) and finally (iii) perforated absorbing insulators in aircraft engines. In the last application it is important to optimize the diameter and positioning of the holes in the material. The objectives are to control the waves as well as possible by an analysis of the optimal shape of the surface of these coatings in order to improve the acoustic absorption in decibel by taking into account the industrial stakes and constraints.

**Challenge week n°3**: *Design of a coating to control wave pollution. Control of electromagnetic pollution*

- **Associated partner:** ONERA

- **Location:** Paris-Saclay campus

- **Brief description :** We position ourselves on the industrial stakes, presented by SIEPEL, which impose the economic and technological constraints necessary to improve the existing products on the market, in order to absorb the electromagnetic waves. As fields of application, we aim at the design and the optimization of an anechoic chamber. We notice that the absorbing materials for electromagnetic waves are different from the dissipative materials for acoustic waves. The different nature of these waves implies an adaptation of the model seen in class.