2. SPECIALIZATION IN AERONAUTICS/AEROSPACE

The aim of this series of courses is to provide the student with an overall appreciation of the role of aerodynamics in aeronautics/aerospace, as well as providing the required background to study a particular topic in greater depth. The common part of the program is designed to achieve the first objective. It comprises courses devoted to some areas of flight dynamics as well as courses dealing with the theory of inviscid and viscous flows for the different speed regimes. At the end of these courses, the attendee should be aware of the problems and methods encountered in aeronautical aerodynamics and re-entry aerothermodynamics. He should also understand the compromises and trade-offs that are necessary for any aircraft, missile or spacecraft design. After completion of this general program, the attendee can select more specialized courses in either high speed or low speed aerodynamics within the experimental or numerical approach.

Students with a good background in aeronautics may replace one or more of the general course by some optional courses.

2.1. General Courses in Aeronautics/Aerospace

Aircraft Performance, Stability and Control (APSC - 2.0 ECTS)

After successful completion of this introductory course the student should have a good knowledge of the basic concepts of aeronautics as there are: lift and drag characteristics of vehicles and their relation to power and general performance for horizontal, climbing or accelerated flight. The student should be able to predict ceiling, range and endurance, explain maneuvering performance and understand the aspects of aircraft stability and control.

The exam is based on an individual open book exercise consisting in predicting some performance of a given aircraft, plus an oral interview or a closed book written exam based on a list of 28 questions covering all the course subjects.

Inviscid Aerodynamics in Aeronautics (IAAI – 4.0 ECTS)

A. Incompressible Inviscid Flows (IAAI - 2.5 ECTS)

This tutorial course gives insight into the characteristics of lifting aerofoils in two-dimensional flows. In addition to the relation between circulation and lift the student should understand the limitations and possibilities of linearized theory for thin airfoils and panel methods for wing sections (2D and 3D). He/she should be able to use the latter correctly.

The examination is based on a prior written preparation of a complete individual problem (open book) by the student and an oral interview about the proposed solution. A mid-course homework is also part of the overall evaluation.

B. Compressible Inviscid Flows (IAAC - 1.5 ECTS)

This course explains the characteristics of compressible flow including shock relations, Prandtl-Meyer expansion theory, numerical method of characteristics (MOC), shock/expansion method, and small disturbance theory applied to supersonic wing and slender bodies.

The exam consists of a small exercise/project (e.g. using the MOC to design a 2D nozzle), and oral questions about the project and other theory.

At the end of these courses the student should understand the physics of compressible and incompressible flows and be capable of using these theories in the interpretation of wind tunnel experiments or CFD simulations.

Two-dimensional Boundary Layers (2DBL – 4.0 ECTS)
The detailed description is given in the section **Optional Courses for all departments**.

The attendees to the Aeronautics/Aerospace program will specialize in one of the following two subgroups :

- **Experimental option**
- **Numerical option**

Following courses are mandatory for the respective options.

Experimental option

Low Speed Wind Tunnels: Analysis and Design (WTAD – 1.0 ECTS)
The detailed description is given in the section **Optional Courses for all departments**.

Computational Fluid Dynamics Laboratory (CFD Lab - 1.5 ECTS)
The purpose of this activity is to acquaint experimentalists with the use of CFD tools for investigating fluid flow problems. Students should be able to compute a simple flow (e.g. one of the flows investigated experimentally in the measurement technique labs) using either an in-house or a commercial CFD package. Issues to become familiar with include: the influence of the discretization scheme on the computational results, the iterative convergence and grid convergence.
Evaluation are based on a written report, presenting/discussing the simulation results Ercoftac DNS database test cases.

Introduction to Computational Fluid Dynamics LS (ICFD - 1.25 ECTS)
The detailed description is given in the section **Optional Courses for all departments**.

Advanced Measurement Techniques Laboratories (MT Labs 1.5 – 6.0 ECTS)
Detailed description is given in the section **Optional Courses for all departments.** Students following the experimental option have to choose all four sections of this course.

Numerical option

Numerical Methods for Fluid Dynamics, part 2 (NMFD2 – 3.0 ECTS)
The detailed description is given in the section **Optional Courses for all departments**.

Computational Methods for Compressible Flows (CMCF – 4.0 ECTS)

Both parts of this course, theory and Lab sessions, are mandatory for the numerical option in Aeronautics and aerospace, and fully described in the **Optional Courses for all departments**.

Advanced Measurement Techniques Laboratories (MT Labs 1.5 – 6.0 ECTS)
Detailed description is given in the section **Optional Courses for all departments.** Students following the numerical option have to choose minimum one of the four sections of this course.

2.1 Optional Courses in Aeronautics/Aerospace

Students should take an equivalent of minimum 2 ECTS of following optional courses, depending on the project.

For all options

Boundary Layers and flow Separation in 3 dimensions (3DBL - 1.25 ECTS)
The detailed description is given in the section **Optional Courses for all departments**.

Introduction to Aeroacoustics (ACOUS – 1.0 ECTS)
The detailed description is given in the section **Optional Courses for all departments**.

Transonic Aerodynamics (TRANS – 1.0 ECTS)
After successful completion of this course the students should be aware of the specific problems of transonic flows over airfoils and bodies and master the transonic small disturbance technique and similarity rules, as well as the solution techniques for the transonic full potential and small disturbance equations. They should also understand the conditions for shock-free supercritical flows, law of stabilization around M = 1 and specificities of the drag at transonic speeds.
Evaluation consists of two parts: a common exercise in the class guided by the professor and a written exam, closed book, at the end of the course period, estimating the understanding of transonic flow problems

Hypersonic Aerodynamics (HYP – 2.0 ECTS)
The objective of this course is to assure that the student has a good understanding of the specificities of inviscid and viscous hypersonic flows such as: Newtonian flow, shock expansion, tangent wedge and cone, similarity rules, small disturbance theory, strong and weak viscous interactions. The student must have a good insight into the physics of the hypersonic boundary layers and the consequences of the high temperature (i.e. dissociation, non-equilibrium, etc.). He/she should also be able to select the appropriate experimental techniques and interpretation of high enthalpy experiments.
The evaluation is based on a synthesis report including comments about a reference publication in hypersonic aerothermodynamics selected from a list provide at the end of the course period.

For the Experimental option

Design and operation of plasma Wind Tunnels (PWT – 1.0 ECTS)
The detailed description is given in the section **Optional Courses for all departments**.

Low Speed Wind Tunnel Test Techniques (WTTT – 1.0 ECTS)
The detailed description is given in the section **Optional Courses for all departments**.

Data Acquisition and Processing (DAP – 2.0 ECTS)
The detailed description is given in the section **Optional Courses for all departments**.

For the Numerical option

Computational Methods for Incompressible Flows (CMIF - 1.5 to 4.0 ECTS)
A full description of this course is given in the **Optional Courses for all departments.**