205070 - High Performance Computing Projects for Aerospace Engineering

**Coordination unit:** 205 - ESEIAAT - Terrassa School of Industrial, Aerospace and Audiovisual Engineering

**Teaching unit:** 758 - EPC - Department of Project and Construction Engineering

**Academic year:** 2019

**Degree:**
- MASTER'S DEGREE IN SPACE AND AERONAUTICAL ENGINEERING (Syllabus 2016). (Teaching unit Optional)
- MASTER'S DEGREE IN AERONAUTICAL ENGINEERING (Syllabus 2014). (Teaching unit Optional)

**ECTS credits:** 3

**Teaching languages:** English

### Teaching Staff

**Coordinator:** Manel Soria

**Others:**
- Ivette Rodríguez
- Josep Maria Bergadà
- Daniel García-Almiñana
- Silvia Rodríguez-Donaire

### Prior Skills

The student must have a basic understanding of programming (in C or Fortran), fluid dynamics, Computational Fluid Dynamics (CFD), and project management.

### Teaching Methodology

After a short theoretical introduction, most of the lessons are developed in a workshop-like format, with students distributed in groups to work in a group project.

### Learning Objectives of the Subject

- Understand what is a high performance computing project for aerospace applications
- Understand the basic aspects of high performance computing aerodynamics, such as turbulence models, mesh generation, post-processing
- Be able to planify a high performance computing project, from its initial proposal to its conclusion, managing correctly the computer time available, as well as the project schedule

### Study Load

<table>
<thead>
<tr>
<th>Total learning time: 75h</th>
<th>Hours large group: 27h</th>
<th>36.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hours medium group: 0h</td>
<td>0.00%</td>
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<tr>
<td>Hours small group: 0h</td>
<td>0.00%</td>
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<tr>
<td>Guided activities: 0h</td>
<td>0.00%</td>
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<tr>
<td>Self study: 48h</td>
<td>64.00%</td>
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</tbody>
</table>
## 205070 - High Performance Computing Projects for Aerospace Engineering

### Content

| **Introduction to turbulence modelling for aerodynamic applications** | **Learning time:** 18h 45m  
Theory classes: 6h 45m  
Self study: 12h |
|---|---|
| **Description:**  
The equations governing turbulent flows (the Navier-Stokes equations) are well known since 1820. However, the computational effort needed to solve them is huge and grows with $Re^3$ (Reynolds number to the power of three). Thus, to understand and predict turbulent flows typically found in aerospace applications, with very large $Re$ numbers, turbulence modelling is needed. In this part of the course, the basic turbulence concepts will be reviewed and the main ideas behind LES and RANS models will be outlined.  
**Related activities:**  
Theory lessons  
**Specific objectives:**  
- Understand the main turbulence concepts and the main ideas behind LES and RANS turbulent models |

| **Fundamentals of Parallel Computing for CFD** | **Learning time:** 18h 45m  
Theory classes: 6h 45m  
Self study: 12h |
|---|---|
| **Description:**  
The key concepts of parallel computing for CFD will be outlined.  
**Related activities:**  
- Theory lessons.  
- Workshops.  
**Specific objectives:**  
- Understand the different types of parallel computers  
- Understand the main parallel programming models  
- Understand the distributed memory programming model  
- Understand the standard MPI  
- Be able to program, compile and debug a small MPI program (in C or Fortran) |
Use of CFD software

<table>
<thead>
<tr>
<th>Description:</th>
<th>Learning time: 18h 45m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using an open-source CFD code, the fundamentals of CFD will be described. The topics to be covered are: mesh generation, selection of a turbulence model, selection of an algorithm, parallel running of the code, post-processing of the results, obtention of mesh-independent results.</td>
<td>Theory classes: 6h 45m</td>
</tr>
<tr>
<td>Related activities:</td>
<td>Self study : 12h</td>
</tr>
<tr>
<td>-Workshops</td>
<td></td>
</tr>
<tr>
<td>Specific objectives:</td>
<td></td>
</tr>
<tr>
<td>-Understand how to generate a mesh</td>
<td></td>
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<tr>
<td>-Be able to select a turbulence model, understanding the implications of the decision in terms of simulation cost and accuracy</td>
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</tr>
<tr>
<td>-Be able to select the main parameters for a CFD solver: accuracy, algorithm, number of iterations etc</td>
<td></td>
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<tr>
<td>-Understand the concept of mesh independency</td>
<td></td>
</tr>
</tbody>
</table>

Supercomputing project management

<table>
<thead>
<tr>
<th>Description:</th>
<th>Learning time: 18h 45m</th>
</tr>
</thead>
<tbody>
<tr>
<td>The steps involved in the management of a supercomputing project will be outlined. The main aspects to be discussed will be: estimation of resources needed, proposal submission, project milestones, dealing with uncertainty in computing cost.</td>
<td>Theory classes: 6h 45m</td>
</tr>
<tr>
<td>Related activities:</td>
<td>Self study : 12h</td>
</tr>
<tr>
<td>-Workshops</td>
<td></td>
</tr>
<tr>
<td>Specific objectives:</td>
<td></td>
</tr>
<tr>
<td>-Understand the main aspects associated with the management of a supercomputing project</td>
<td></td>
</tr>
</tbody>
</table>

Qualification system

- Individual exercises: 30%
- Final group project: 70%

Bibliography

**Basic:**