Flight Performance & Propulsion (FPP)

Master Weeks 2020

Dr. ir. Gianfranco La Rocca (Track Coordinator)
Welcome! ..on behalf of the PP group!

**Prof. dr.ir. Piero Colonna**  
Chairholder  
P.Colonna@tudelft.nl

**Dr. A. (Arvind) Gangoli Rao**  
Associate Professor  
A.GangoliRao@tudelft.nl

**Dr. ir. M. (Matteo) Pini**  
Assistant Professor  
M.Pini@tudelft.nl

**Dr. ir. G.A. (Alexis) Bohlin**  
Assistant Professor  
G.A.Bohlin@tudelft.nl

**Dr. ir. W.P.J. (Wilfried) Visser**  
Part-time Lecturer  
W.P.J.Visser@tudelft.nl

Ms. Kimberley Graauw  
Secretary  
K.Graauw@tudelft.nl  
+31 (0) 52785176  
Office: LR7.02
...and on behalf of the FP group!
Contents

• **Who we are and what we do**
  • Educational program
  • How you can contribute to our research
  • Lab facilities
  • The ideal FPP student
Who we are and what we do

A unique group of **aircraft designers** and **propulsion specialists** working together to address the future challenges faced by aviation

- 3 Full professors
- 1 Associate professor
- 6 Assistant professors
- 3 Lecturers
- 6 Researchers
- 23 PhD students

- Established in 2013
- Responsible/involved in 18 courses (BSc+MSc)
- About 60 MSc Theses/year
Expertise Flight Performance – a few examples

- Unconventional aircraft design
- Propeller wing interaction
- Flight mechanics of advanced systems
- Hybrid electric propulsion
- Advanced design methodologies
- Scaled flight testing
Expertise Power and Propulsion – a few examples

Hybrid aircraft engines

Unconventional turbomachinery

NICFD experiments

ORC and scCO2 turbogenerators

Mini turboprop for UAV

Clean Combustion for GT
Contents

• Who we are and what we do
• **Educational program**
• How you can contribute to our research
• Lab facilities
• The ideal FPP student
Educational program

• Overall structure
• Courses (core, profile, elective)
• Internship
• Graduation project
Overall structure

Ideal planning

Periods 1-3: Courses
Period 4: Internship
Period 5: Literature study + research methods
Periods 6-8: Thesis

2 years

Note that one academic year consists of 4 periods, starts in September and finishes early July
Overall structure

Alternative option to cope with late internship

- Courses
- Literature study + research methods
- Internship
- Thesis

2 years
Overall structure

1 Track (FPP, Track 5)

2 Profiles: FP & PP

Profile I
Flight Performance (FP)

Profile II
Power and Propulsion (PP)
Courses – Flight Performance Profile (FP)
Profile I

### Common Courses

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>AE4010</td>
<td>Research Methodologies</td>
<td>2</td>
</tr>
<tr>
<td>WM0324LR</td>
<td>Ethics and Engineering for Aerospace Engineering</td>
<td>3</td>
</tr>
</tbody>
</table>

All Aerospace students

### Track Core Courses

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>AE4020</td>
<td>Literature Study</td>
<td>12</td>
</tr>
<tr>
<td>AE4130</td>
<td>Aircraft Aerodynamics</td>
<td>3</td>
</tr>
<tr>
<td>AE4202</td>
<td>CFD for Aerospace Engineers</td>
<td>3</td>
</tr>
<tr>
<td>AE4205</td>
<td>MDO for Aerospace Applications</td>
<td>4</td>
</tr>
<tr>
<td>AE4238</td>
<td>Aero Engine Technology</td>
<td>4</td>
</tr>
<tr>
<td>AE5050</td>
<td>Internship</td>
<td>18</td>
</tr>
<tr>
<td>AE5211</td>
<td>Thesis Flight Performance and Propulsion</td>
<td>42</td>
</tr>
</tbody>
</table>

All Track 5 FPP students (thus: both FP and PP)

### Profile Courses

<table>
<thead>
<tr>
<th>Code</th>
<th>Title</th>
<th>EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>AE4204</td>
<td>Knowledge Based Engineering</td>
<td>4</td>
</tr>
<tr>
<td>AE4240</td>
<td>Geometric Aircraft Design I</td>
<td>4</td>
</tr>
<tr>
<td>AE4115</td>
<td>Experimental Simulations</td>
<td>3</td>
</tr>
<tr>
<td>AE4ASM506</td>
<td>Aeroelasticity</td>
<td>3</td>
</tr>
</tbody>
</table>

All Flight Performance profile students
Courses - Power and Propulsion profile (PP) Profile II

<table>
<thead>
<tr>
<th>Power &amp; Propulsion profile (Profile II)</th>
<th>Code</th>
<th>Title</th>
<th>EC</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Common Courses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AE4010</td>
<td></td>
<td>Research Methodologies</td>
<td>2</td>
</tr>
<tr>
<td>WM0324LR</td>
<td></td>
<td>Ethics and Engineering for Aerospace Engineering</td>
<td>3</td>
</tr>
<tr>
<td><strong>Track Core Courses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Code</td>
<td>Title</td>
<td>EC</td>
<td></td>
</tr>
<tr>
<td>AE4020</td>
<td>Literature Study</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>AE4130</td>
<td>Aircraft Aerodynamics</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>AE4202</td>
<td>CFD for Aerospace Engineers</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>AE4205</td>
<td>MDO for Aerospace Application</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>AE4238</td>
<td>Aero Engine Technology</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>AE5050</td>
<td>Internship</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>AE5211</td>
<td>Thesis Flight Performance Propulsion</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td><strong>Profile Courses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Code</td>
<td>Title</td>
<td>EC</td>
<td></td>
</tr>
<tr>
<td>AE4206</td>
<td>Propulsion Theory</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>AE4261</td>
<td>Internal Flows</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>AE4262</td>
<td>Combustion for propulsion and power technologies</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>AE4263</td>
<td>Modeling, Simulation and Application of Propulsion and Power Systems</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>ME45000</td>
<td>Advanced Heat Transfer</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

Same as Flight Performance profile

All Power and Propulsion profile students
Courses – Electives

- FP and PP have each a list of preferred electives.
- The list of FP preferred electives includes all PP profile courses and vice versa.

### Flight Performance preferred electives

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AE4120</td>
<td>Viscous Flows</td>
<td>3</td>
</tr>
<tr>
<td>AE4135</td>
<td>Rotor / wake Aerodynamics</td>
<td>4</td>
</tr>
<tr>
<td>AE4136</td>
<td>CFD 2: Discretization Techniques</td>
<td>2</td>
</tr>
<tr>
<td>AE4139</td>
<td>CFD 3: Large Eddy Simulation</td>
<td>3</td>
</tr>
<tr>
<td>AE4138-18</td>
<td>CFD 4: Uncertainty Quantification</td>
<td>3</td>
</tr>
<tr>
<td>AE4140</td>
<td>Gas Dynamics</td>
<td>3</td>
</tr>
<tr>
<td>AE4180</td>
<td>Flow Measurement Techniques</td>
<td>3</td>
</tr>
<tr>
<td>AE4206</td>
<td>Turbomachinery</td>
<td>3</td>
</tr>
<tr>
<td>AE4245</td>
<td>Advanced Aircraft Design II</td>
<td>4</td>
</tr>
<tr>
<td>AE4260A</td>
<td>Fundamentals of Aeroacoustics</td>
<td>3</td>
</tr>
<tr>
<td>AE4260B</td>
<td>Experimental Applications of Aeroacoustics</td>
<td>4</td>
</tr>
<tr>
<td>AE4261</td>
<td>Internal Flows</td>
<td>3</td>
</tr>
<tr>
<td>AE4262</td>
<td>Combustion for propulsion and power systems</td>
<td>4</td>
</tr>
<tr>
<td>AE4263</td>
<td>Modeling, Simulation and Application of Propulsion and Power Systems</td>
<td>5</td>
</tr>
<tr>
<td>AE4301</td>
<td>Automatic Flight Control Systems</td>
<td>3</td>
</tr>
<tr>
<td>AE4301P</td>
<td>Exercise Automatic Flight Control Systems</td>
<td>1</td>
</tr>
<tr>
<td>AE4314</td>
<td>Helicopter Performance, Stability and Control</td>
<td>3</td>
</tr>
<tr>
<td>AE4314P</td>
<td>Helicopter Performance, Stability and Control Practical</td>
<td>3</td>
</tr>
<tr>
<td>AE4315</td>
<td>Advanced Dynamics</td>
<td>3</td>
</tr>
<tr>
<td>AE4431</td>
<td>Aircraft noise and emissions</td>
<td>3</td>
</tr>
<tr>
<td>AE4462-17</td>
<td>Aircraft Emissions and Climate Effects</td>
<td>4</td>
</tr>
<tr>
<td>AE4463-17</td>
<td>Advanced Aircraft Noise Modeling and Measurement</td>
<td>3</td>
</tr>
<tr>
<td>AE44SM03</td>
<td>Linear Modeling (incl. F.E.M)</td>
<td>3</td>
</tr>
<tr>
<td>AE44SM109</td>
<td>Design &amp; Analysis of Composite Structures I</td>
<td>5</td>
</tr>
<tr>
<td>AE44SM17</td>
<td>Aircraft Manufacturing Laboratory</td>
<td>6</td>
</tr>
<tr>
<td>ET4117</td>
<td>Electrical Machines and Drives</td>
<td>4</td>
</tr>
<tr>
<td>ME45000</td>
<td>Advanced Heat Transfer</td>
<td>3</td>
</tr>
<tr>
<td>AE4040TU</td>
<td>Joint Interdisciplinary Project</td>
<td>15</td>
</tr>
</tbody>
</table>

### Propulsion & Power profile preferred electives

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>AE4115</td>
<td>Experimental Simulations</td>
<td>3</td>
</tr>
<tr>
<td>AE4120</td>
<td>Viscous Flows</td>
<td>3</td>
</tr>
<tr>
<td>AE4135</td>
<td>CFD 2: Discretization Techniques</td>
<td>2</td>
</tr>
<tr>
<td>AE4136</td>
<td>CFD 3: Large Eddy Simulation</td>
<td>3</td>
</tr>
<tr>
<td>AE4138-18</td>
<td>CFD 4: Uncertainty Quantification</td>
<td>3</td>
</tr>
<tr>
<td>AE4140</td>
<td>Gas Dynamics</td>
<td>3</td>
</tr>
<tr>
<td>AE4180</td>
<td>Flow Measurement Techniques</td>
<td>3</td>
</tr>
<tr>
<td>AE4204</td>
<td>Knowledge Based Engineering</td>
<td>4</td>
</tr>
<tr>
<td>AE4206</td>
<td>Advanced Aircraft Design I</td>
<td>4</td>
</tr>
<tr>
<td>AE4245</td>
<td>Advanced Aircraft Design II</td>
<td>4</td>
</tr>
<tr>
<td>AE4260A</td>
<td>Fundamentals of Aeroacoustics</td>
<td>2</td>
</tr>
<tr>
<td>AE4260B</td>
<td>Experimental Application of Aeroacoustics</td>
<td>2</td>
</tr>
<tr>
<td>AE4261</td>
<td>Aircraft noise and emissions</td>
<td>3</td>
</tr>
<tr>
<td>AE4262</td>
<td>Aircraft Emissions and Climate Effects</td>
<td>4</td>
</tr>
<tr>
<td>AE4263</td>
<td>Advanced Aircraft Noise Modeling and Measurement</td>
<td>4</td>
</tr>
<tr>
<td>AE4301</td>
<td>Linear Modeling (incl. F.E.M)</td>
<td>3</td>
</tr>
<tr>
<td>AE4301P</td>
<td>Design &amp; Analysis of Composite Structures I</td>
<td>5</td>
</tr>
<tr>
<td>AE4ASM003</td>
<td>Fundamentals of Aeroelasticity</td>
<td>3</td>
</tr>
<tr>
<td>AE4ASM17</td>
<td>Aircraft Manufacturing Laboratory</td>
<td>6</td>
</tr>
<tr>
<td>ET4117</td>
<td>Electrical Machines and Drives</td>
<td>4</td>
</tr>
<tr>
<td>ME45025</td>
<td>Introduction to Multiphase Flow</td>
<td>5</td>
</tr>
<tr>
<td>ME45100</td>
<td>Fuel Cell Systems</td>
<td>3</td>
</tr>
<tr>
<td>ME46060</td>
<td>Engineering Optimization: Concepts and Applications</td>
<td>3</td>
</tr>
<tr>
<td>MS43310</td>
<td>Materials at High Temperature</td>
<td>4</td>
</tr>
<tr>
<td>AE4040TU</td>
<td>Joint Interdisciplinary Project</td>
<td>15</td>
</tr>
</tbody>
</table>
Courses – summary

Flight Performance (FP)

- 5 ECTS common
- 86 ECTS Track 5
- FP: 14 ECTS
- PP: 18 ECTS Profile FP

Propulsion & Power (PP)

- 5 ECTS common
- 86 ECTS Track 5
- FP: 14 ECTS
- PP: 18 ECTS Profile PP

Elective

- Preferred electives
  - Specific FP
  - Profile PP
- Free electives

Profile FP

- FP: ≥ 15 ECTS
- PP: ≥ 11 ECTS

Profile PP

- FP: ≥ 15 ECTS
- PP: ≥ 11 ECTS

Your choice*

Prescribed

Overall Track structure

Courses

Internship

Graduation project

5 ECTS

Total ≥ 120 ECTS
Courses – free electives

How “free” are the free electives?
• As far as they are a meaningful contribution to a Master in Engineering
• …and they are approved by the Master track coordinator and Profile coordinator

• You can pick courses from other tracks and even from other faculties!
• Not engineering courses (e.g. language) can be taken as extras, outside the official study plan
Special courses: AE4ASM517 Aircraft

- Build a real, to be certified Van’s RV12 aircraft
- Everything, from planning to certification, done by students
- Team of ~15 students,
Special courses:
AE4040TU Joint Interdisciplinary Project

- Pilot started in Sept 2018 for AE, 3mE, AS, etc..
- Interdisciplinary project teams of 4-5 students each
- It can replace internship or yield 15 ECTS extracurricular
- Selection process applies. Application before May 12th

Entry criteria:
- You are a 2nd-year masters student
- You have almost completed the first year of the master’s degree programme and will enroll in your second year of master’s degree programme at TU Delft in September 2020
- You are full time available (40 hours per week) in Q1

Link for more info:
Courses - Where to find detailed information?

Course descriptions:
• www.studyguide.tudelft.nl

Tip:
• Check on our website the suggested preparation for period 1 courses
Internship

“Learn and explore” to acquire different skills than those taught at university

80% abroad: 45% EU + 35% non-EU

18 ECTS – 12 weeks full time

Cultural shock of the real work environment
Graduation project

- (Research methodologies)
- Literature study (12 ECTS)
- Thesis (42 ECTS) = 54 ECTS
Graduation project

FPP graduation projects are **diverse** in nature to satisfy the **ambitions** and **fit the skills** of different students.

- All provide a good balance of **basic science** and **applied technology**
- Some are more **conceptual design** oriented
- Some are more **computational and simulation** based
- Some focus on the **system** to be designed
- Some focus on the enabling **design methods**
- Some require an **experimental** approach
- Most of them are a **combination** of the above
Contents

• Who we are and what we do
• Educational program
• **How you can contribute to our research**
• Lab facilities
• The ideal FPP student
Thesis research topics examples

Airframe - Propulsion integration

Objective
Development of design and analysis capability for novel propulsion system integration

• Hybrid electric propulsion
• New generation propellers
• Interaction with wing and/or fuselage
• Effects of non-uniform inflow (incl. BLI)
• Distributed propulsion
• Integration in AC design framework
• Integration in experimental settings

Methods
CFD, KBE, Experimental (wind tunnel, propulsion lab, scaled flight lab)
Thesis research topics examples

Aircraft design support frameworks

Objectives:
Development of computational systems to
- Support the synthesis of conventional and novel aircraft configurations
- Accelerate the use of (high fidelity) simulations in design
- Enable multidisciplinary design analysis and optimization (MDAO)
- Reduce cost of engineering
- Support collaborative design

Methods:
KBE, MDO, general purpose programming
Thesis research topics examples

*Flight mechanics of complex systems*

**Objectives**
Flying qualities investigation of novel fixed wing aircraft configurations
- Automatic generation of flight mechanics simulation models to support multidisciplinary design optimization
- Development of control allocation strategies for redundant movable surfaces
- Dynamic scaled flight testing

**Methods**
Multibody dynamics, multi physics simulation, MDO, experimental
Thesis research topics examples

*Hybrid aircraft engines for multi-fuel aircraft*

- LNG/LH2 Main Combustor
- Kerosene/Biofuel Secondary Flameless Combustor
- Bleed cooling by LH2
- Counter rotating shrouded fans
- Higher Specific Thrust
- Low Installation Penalty
Aircraft environmental control systems (ECS)

- **Today**: air cycle system → light, but low efficiency
- **Tomorrow**: inverse Rankine cycle system (vapor compression)
- High-speed centrifugal compressor (>200 krpm!)
- Need for several special HX’s
- Applications: small jets, helicopters, future long-haul aircraft

Diagram: Air cycle machine on a Boeing 737
Thesis research topics examples

**ORC and scCO2 turbogenerators**

- Waste-heat recovery for mobile applications
- Unconventional turbomachinery
- CFD analysis of supersonic flows of dense vapors
- Automated shape optimization
Contents

• Who we are and what we do
• Educational program
• How you can contribute to our research
• **Lab facilities**
• The ideal FPP student
FPP lab facilities

The Clean Combustion Lab
&
the Laser Diagnostic and Remote Sensing Lab
FPP lab facilities

Propulsion lab

Wind tunnels
(in cooperation with Aero)

Aircraft Manufacturing Lab
(in cooperation with Aerospace Structures and Material)

Scaled Flight Testing Lab

The ORCHID test rig
FPP lab facilities

Propulsion lab

Wind tunnels (in cooperation with Aero)

Aircraft Manufacturing Lab (in cooperation with Aerospace Structures and Material)

Scaled Flight Testing Lab
FPP lab facilities

- Propulsion lab
- Wind tunnels (in cooperation with Aero)
- Aircraft Manufacturing Lab (in cooperation with Aerospace Structures and Material)
- Scaled Flight Testing Lab
FPP lab facilities

Propulsion lab
Wind tunnels
(in cooperation with Aero)
Aircraft Manufacturing Lab
(in cooperation with Aerospace Structures and Material)
Scaled Flight Testing Lab
Contents

• Who we are and what we do
• Educational program
• How you can contribute to our research
• Lab facilities
• The ideal FPP student
The ideal FPP student

Suitable profile

- Passion for aircraft design and/or propulsion and/or their integration
- Will to make an impact on future sustainable aviation
- Multidisciplinary mind
- Able to go deep without losing the big picture
- Solid understanding of flight physics and thermodynamics
- Solid background in mathematics
- Good programming skills
- Proactive and able to work independently
- Interest in experimental work (optional)
Points of contact

FPP Master Track Coordinator
Dr. ir. Gianfranco La Rocca
G.LaRocca@tudelft.nl
+31 (0) 15 278 5384
Office: LR7.21

Profile Coordinator Power and Propulsion
Dr. ir. Arvind Gangoli Rao
A.GangoliRao@tudelft.nl
+31 (0) 15 278 3833
Office: LR7.13

FPP website: fpp.lr.tudelft.nl  Brightspace: Track 5 FPP