Join us in the exploration of future aircraft and propulsion systems!

At TU Delft we offer you a leading academic programme in aerospace engineering and technology in Europe. Our internationally oriented programme prepares you to respond effectively and rapidly to the needs in the aerospace sector with solutions that are innovative, technically feasible and commercially viable. At our state-of-the-art test and laboratory facilities you acquire the engineering skills needed in advanced industrial applications. During your specialisation phase – the MSc track – you will develop into an independently-thinking, professionally-oriented, innovative engineer and researcher.

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**MSc Track structure**

<table>
<thead>
<tr>
<th>Course</th>
<th>Description</th>
<th>EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Core courses</td>
<td>Gain a broad view on a field of expertise</td>
<td>≥18</td>
</tr>
<tr>
<td>Profile courses</td>
<td>Focus on either flight performance or power and propulsion</td>
<td>≥13</td>
</tr>
<tr>
<td>Elective courses</td>
<td>Specialise in a particular area of expertise or add multidisciplinary elements, repair educational deficiencies or address a personal interest *</td>
<td>+/-16</td>
</tr>
<tr>
<td>Literature study</td>
<td>Prepare for the thesis subject</td>
<td>12</td>
</tr>
<tr>
<td>Research methodologies</td>
<td>Prepare for the thesis subject</td>
<td>2</td>
</tr>
<tr>
<td>Internship</td>
<td>Acquire professional skills during a three-month internship at a Dutch or international company or institute *</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>An in-depth research project or design assignment in your subject of choice</td>
<td>42</td>
</tr>
</tbody>
</table>

*Optionally abroad

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The master track Flight Performance and Propulsion teaches students about design aspects of innovative solutions for the modern and next-generation aircraft, and about cutting-edge engines, their components and power systems. Therefore, aircraft-engine integration is also an important topic in the lectures we provide, and of research performed by our group. These research areas are highly relevant if we want to contribute to the ambitious targets to reduce the environmental impact of aviation, as proposed by the Advisory Committee for Aeronautics Research in Europe (ACARE).
Research programmes in Flight Performance

We focus our research on advanced and innovative aircraft configurations, novel propulsion concepts, and aircraft engine integration. Our mission is to advance the design of innovative aircraft configurations and propulsion concepts, by exploration of new technologies to obtain novel or improved solutions, advances in flight physics to improve the prediction and simulation of air-vehicle performance, and new methods and tools to improve the quality and effectiveness of the design process. The knowledge and competences are therefore clustered in three key areas: aircraft design & design methodologies, flight mechanics, and propulsion integration.

Aircraft design & design methodologies

Major technological advances in flight performance can be realized by new unconventional airplane designs. To support the development of such novel configurations, new design methodologies are required that go beyond statistical and analytical methods. To that extent, design support tools are developed that are able to sustain the evolutionary improvement of current aircraft design, as well as to support the investigation of novel aircraft configurations and the assessment of the impact of new technologies such as morphing structures or hybrid laminar flow control.

NOVAIR

This project, funded by the European Commission, deals with the development of radically novel aircraft configurations and scaled flight testing that is used to demonstrate new technologies. The further development of future green and sustainable air transport requires novel and radical aircraft configurations. In particular, Hybrid Electric Propulsion (HEP) is expected to have the potential to create major breakthroughs towards more electric aircraft and thus to more sustainable air transport. In NOVAIR the focus will be on the design of radical aircraft configurations specifically exploiting the potential benefits of HEP. The optimized concepts are aimed to be selected for demonstration by Airbus. Scaled Flight Testing (SFT) will be prepared as it promises to generate important complementary information about novel aircraft configurations. The advantage of the SFT compared to wind tunnel testing is the assessment of the dynamics of free flying aircraft. Advantages over full-scale flight testing include reduced risk and cost. The project will be performed in collaboration with the Dutch National Aerospace Laboratory (NLR).

AGILE

This European Commission sponsored project targets advanced multidisciplinary optimisation of aircraft using distributed analysis frameworks. Advanced optimisation techniques and strategies will be developed in order to exploit available computing systems and to gain faster convergence to optimal solutions. Knowledge-enabled information technologies will be developed in order to support complex collaborative design process. The methods and tools that will be developed in AGILE will be tested and verified using realistic overall aircraft design tasks for conventional, strut braced, box-wing and BWB configurations, including UAVs. The project is set up to proof a speed up of 40% for solving realistic MDO problems compared to today’s state-of-the-art. This will enable also a more agile way of collaboration between OEMs and suppliers, open opportunities for joint aircraft development and experimenting on innovative products. Airbus, Alenia, Bombardier, Fokker, Saab, NLR, DLR, ONERA, Noesis and KE-works are just some of the 20 partners which collaborate with the TU Delft.

Flight mechanics

It is our objective to focus on three specific aspects of flight mechanics and thereby to advance the current state of the art:

- Investigation of the inherent flying qualities of novel fixed wing aircraft configurations
- Automatic generation of flight mechanics simulation models for application in multi-disciplinary design optimization frameworks
- High fidelity modelling and simulation of advanced rotorcraft configurations for loads prediction and flight performance analysis

Propulsion integration

Apart from the optimisation of isolated aircraft engines, the efficient integration of engines to the airframe is also of crucial importance to maximise aircraft performance and minimise noise emissions. One major ongoing project within this domain focuses on the aerodynamic and acoustic performance of propellers integrated on the airframe. Apart from the analysis and optimization of the isolated propeller system, also the interactions between the airframe and the propeller need to be considered. The goal of the investigations is to reduce the performance and noise penalties associated with these airframe interaction effects. Students involved in the project perform experiments in the faculty’s various wind tunnel facilities using powered propeller test rigs and advanced measurement techniques, while also CFD tools are applied for numerical evaluations.

Crispijn Huijts (2015)

During my BSc I discovered that my interests of study courses are very broad, I like mathematics, aircraft performance, aerodynamics, aircraft design and many more subjects. In selecting a Master Track, I first had some difficulty. Due to this wide interest, many tracks seemed like a good choice to me. However, the combination of the focus areas flight mechanics and aircraft design, offered by Flight Performance profile, seemed to be the a perfect fit for my interests. A varying Master programme can be chosen in which you can focus on your personal preference, but still have a complete portfolio full of different aircraft design courses (and not only focusing on one area). With the program you learn a lot about air breathing engines, aerodynamics, aircraft design and design optimization. This makes you a student with a broad range of knowledge, ready for the aerospace industry! Currently I am writing my MSc thesis about the impact of control allocation (CA) techniques on trim drag for various (new) aircraft configurations. I have been able to do wind tunnel tests for my research, where I analyzed the performance of the control allocation algorithms. This is done by deflecting various control surfaces on a blended wing body aircraft model and logging the model’s coefficients. After the tests, the second part of the research consisted of implementing the CA algorithms in a conceptual design tool for (un)conventional aircraft. This software tool is developed by the department of FPP itself and by adding a trim module, I can help develop this tool further. By combining wind tunnel tests and the implementation in the design tool, I am not only working on one program for 8 months, but also have a practical touch with performing wind tunnel tests, which has been amazing and made me even more enthusiastic about the subject.
Research programmes in propulsion and power
Propulsion and power systems account for at least 30% of the life-cycle value of a passenger aircraft and are evidently essential to flight. As such, education in topics specifically related to propulsion and power is at the core of all aerospace Master programs in relevant institutions all over the world, and TU Delft is no exception. The courses of our profile create the knowledge needed to effectively perform thesis work within one of the running research programs. They all provide an exciting opportunity to learn about cutting-edge technologies that will dramatically improve the efficiency and sustainability of aviation.

NextGen Aircraft Propulsion Systems
We are currently pursuing the study of three disruptive concepts with the potential to leapfrog propulsion systems to a much higher efficiency level and much lower emissions. The Hybrid Engine proposed in the AHEAD project is a novel propulsion system with a different architecture as compared to the conventional turbofan engine. The hybrid engine concept is based on several unique technologies like shrouded contra-rotating fans, bleed cooling, and a dual hybrid combustion system. Such system uses cryogenic fuel (like LH2 or LNG), and biofuel under flameless conditions to reduce CO2 and NOx emission respectively.

These technologies allow for a leap forward in terms of environmental friendliness, thanks to the adoption of sustainable fuels. Furthermore, the hybrid engine is particularly suited for Blended Wing Body (BWB) aircraft configurations, which also promises to yield substantial gains. Partners in this project are, among others, Pratt & Whitney Poland, DLR, TU Berlin, Technion Israel Institute of Technology. Investigations are theoretical, numerical and also experimental, thanks to the newly established Clean Combustion Lab.

Together with MIT and NASA, our group is at the forefront of the research on Boundary Layer Ingestion, namely the study of the placement of the engines in such a way that they ingest the boundary layer formed by the fuselage. This arrangement has the potential of improving the propulsive efficiency significantly. We are at the moment cooperating with Safran and other European partners in a project involving sophisticated experiments in our open jet wind tunnel, accompanied by detailed numerical simulations to understand the fundamentals of BLI and to apply it in an aircraft.

Last but not least, we were possibly the first to conceive the Combined-Cycle Engine (CC Engine) configuration from the idea that even in modern and future gas turbine engines, approximately half of the energy of the fuel is dissipated into the atmosphere as thermal energy.

Combustion Research
We carry out fundamental investigations on low emission combustion techniques (such as flameless combustion) using conventional and alternative fuels. The clean combustion lab is equipped with an unique hyper-spectral laser based diagnostics system (one of its kind in Europe) that will provide unprecedented insights expanding our understanding of combustion physics.

Waste Heat Recovery from Engines
A more imminent application of waste recovery from mobile engines is that of recovering heat from the exhaust of long-haul truck engines. We have been running for several years a successful pioneering program supported by major global companies (Bosch, Dana, DAF, SKF, Bosal, Eastman) whose aim is to provide knowledge for the development of mini-ORC systems capable of increasing the efficiency of powertrains by as much as 7-10%. Our work covers system design, working fluid selection, and specialty turbomachinery design. Thanks to the recently commissioned ORCHID (ORC Integrated Hybrid Device) setup, we are uniquely positioned to provide much needed experimental information for the realization of this disruptive technology. The aerospace industry already showed interest and it is likely that new projects will consider heat recovery on-board of aircraft.

Environmental Control System Based on High-Speed Compressor Technology
The group recently engaged in an ambitious project in partnership with Aeronomic: the development of a system providing heating and cooling to aircraft (cabin and electronics) utilizing a new type of efficient and light centrifugal compressor. The ECS consumes approximately 75% of the non-propulsive power and 1% of the propulsive power of an aircraft. It is thus apparent that substantial improvements in this system will positively impact the energy efficiency of next-generation more-electric aircraft.

Mini Gas Turbine for Civil UAV applications
The expertise of the group in small ultra-fast turbomachinery is also applied to the study of mini-turboprops for Unmanned Aerial Vehicles for missions like land monitoring and surveillance. We benefit from our involvement in the development of mini-gas turbines for domestic cogeneration applications, and we are applying the lessons learned to further study this promising application in aviation.
Education
The research and education activities within this Master track are pursued and coordinated by two full time professors, one part-time professor, eight assistant professors and two dedicated lecturers. Each of the staff members has a different expertise, varying from air-breathing propulsion systems, turbo-machinery and power systems to flight mechanics and aircraft design and integration.

Profiles
The Master track has one profile focused on flight performance, which covers the areas of flight mechanics and aircraft design & design methodologies, and one profile dedicated to propulsion and power. The two profiles tightly collaborate to address common challenges with the aim to devise forefront solutions for the aircraft industry. The educational program consists of a shared set of core courses that are relevant to both profiles. Each profile has a set of mandatory courses that deepens the knowledge of the students in the respective fields. Elective courses are typically selected in consultation with the master track coordinator such that the student becomes an expert in a specific area.

The competence acquired during the first year of the Master program is put to fruition in the final year during the research period dedicated to the thesis. During the Master thesis, the student is engaged in a project most often within one of the active research programs. The project is carried out under the supervision of one of the academic staff members, but often the student also benefits from the closer supervision of one of the PhD candidates involved in the same project.

Flight Performance
The profile program consists of courses that deal with aerodynamic design of high subsonic transport aircraft, aircraft performance analysis and optimisation, aircraft aerodynamics and mathematical optimisation techniques to support aircraft design. Some of the courses have a more theoretical approach and aim to provide a fundamental understanding of the governing physics whereas other courses are more applied and require good programming skills. Elective courses are grouped in three areas, Flight mechanics, Propulsion integration and Aircraft Design & Design Methodologies. A selection of elective courses is made in consultation with the profile coordinator.

Propulsion and Power
Several mandatory courses form the core of the knowledge that specializes our graduate students, covering relevant aspects in turbomachinery, combustion, system and component design, integration and verification. Elective courses are chosen together with the Profile Coordinator and these are grouped in Methods, Advanced Topics, and Aircraft Design, so that the student can choose to become an expert in one of these aspects.

Job perspective
The job perspective for graduates of the FPP track is great. Most graduates already find a job prior to their graduation. Many of our graduates decide to pursue a career in the aerospace field, either in industry or research institutes, both nationally and abroad. In the Netherlands popular employers are Fokker Aerostructures, the Dutch National Aerospace Laboratory (NLR), Atkins, Fokker Elmo, Royal Dutch Shell and Ke-Works. Many of our graduates aspire an international career. They work for example for companies dedicated to designing and building aircraft and propulsion systems, such as Airbus, Rolls Royce, MTU Aero Engines, Pilatus Aircraft and Siemens. Other students start their own companies or work in consultancy and finance. Finally, some choose to pursue a PhD degree.

Admission requirements
- A Dutch BSc degree in Aerospace Engineering, Mechanical Engineering, Maritime Engineering, Electrical Engineering, Civil Engineering, Physics, Applied Physics, or Physics & Astronomy or
- A BSc degree in Military Systems & Technology of the Netherlands Defense Academy (NLDA) or
- A Dutch degree of a University of Applied Sciences in Aeronautics, Aviation, Mechanical Engineering, Maritime Engineering, Civil Engineering, Design & Innovation. These students have to complete a special bridging programme prior to enrolment on the MSc.

Ideally you have obtained either a BSc degree in Aerospace or Mechanical Engineering at a top level University. In case of a mechanical engineering background, the program followed should have a strong emphasis on fluid mechanics, thermodynamics and power and propulsion systems. Details about the admission with a BSc degree from a non-Dutch university are available on the TU Delft website: www.tudelft.nl/admission

Permission for doing research within this track of this Master is partly dependent on a screening under the Missile and Nuclear Research Exemption scheme: https://www.government.nl/topics/secondary-vocational-education-mbo-and-higher-education/exemption-certain-engineering-or-nuclear-related-courses-of-study

For further information
More information on the MSc track “Flight Performance and Propulsion” can be obtained at: www.ir.tudelft.nl/fpp
Alternatively, you can also contact the MSc track coordinator:
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International students are recommended to visit: www.tudelft.nl/admission

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