Your lift-off to a spaceflight career

At TU Delft we offer you a leading academic programme in Aerospace Engineering 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.

The Space Flight Master track is offered to a range of graduates that are looking for an academic program that prepares them well for an exciting career in the international space sector covering Earth observation to planetary exploration, launch vehicles, satellites and constellations of satellites.

### MSc Track structure

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<tr>
<th>Module</th>
<th>Description</th>
<th>EC</th>
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<tbody>
<tr>
<td>Core courses</td>
<td>Provide an overview of the Spaceflight field of expertise</td>
<td>≥18</td>
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<tr>
<td>Profile courses</td>
<td>Deepen the knowledge of either Space Engineering or Space Exploration</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>
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<tr>
<td>Literature study</td>
<td>Prepare for the thesis subject</td>
<td>12</td>
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<tr>
<td>Research methodologies</td>
<td>Prepare for the thesis subject</td>
<td>2</td>
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<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>
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<tr>
<td>MSc thesis</td>
<td>An in-depth research project or design assignment in your subject of choice</td>
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*Optionally abroad
Profiles

1. Space Engineering

Space Engineering is the field of engineering concerned with the development of high-performance space systems and system components. Areas of interest include the engineering of space missions, space vehicles and instruments, sensors, actuators, mechanisms, and thrusters. In Space Engineering applying state-of-the-art technologies and providing innovative solutions is daily business. The Space Engineering profile aims to educate future academic engineers in end-to-end space engineering.

You will learn how to engineer complex space vehicles: on their subsystems, instruments and components using a systematic approach. You will gain expertise on every phase of a spacecraft system development including design, development, integration, verification/testing and operations. You will also learn about management aspects of engineering including scheduling and planning, and about working in multi-disciplinary design teams to formulate spacecraft system solutions. This will enable you to apply your gained knowledge also to other complex technical systems outside of Aerospace Engineering. Students do their specialised thesis work in one of three areas:

Spacecraft Engineering

Spacecraft engineering deals with the design, development, construction, testing, and operation (end-to-end engineering) of space vehicles: launchers, satellites, etc. operating around Earth and other planetary bodies as well as in outer space. It addresses the engineering of the spacecraft and their subsystems in relation to the overall spacecraft and its life cycle. Emphasis is on miniaturisation and spin-in of commercial technology into space systems for increased performance or cost reduction. Examples of research projects:

- highly miniaturized satellites (Delfi-C3, Delfi-n3Xt, Delfi PQ (PocketQube))
- Micro-propulsion systems for small satellites
- one of the world’s smallest reaction wheel systems
- advanced algorithms for satellite attitude determination and control
- Novel miniaturized and deployable optical sensor/camera concepts

Research facilities include industrial software tools and a state-of-the-art clean room.

Space Systems

The field of space systems focuses on the development of complete space systems architectures (including launcher selection, ground control, orbits and constellations, payloads, mission operations, etc.) needed to achieve mission objectives. Of special interest is the category of distributed systems, i.e. space systems that involve multiple spacecraft which together enable high-performance mission objectives. Examples are global coverage for communication or navigation or innovative missions, for example using long and flexible baselines to allow multipoint sensing. Formation flying of Delfi cubesats is a typical example of a research project in this field. Some other research projects:

- robotic test bed for distributed systems
- swarm of satellites to observe the dark ages of the universe (OLFAR)
- Space environment & effects analysis

Space Propulsion

Space propulsion/rocket systems constitute a critical enabling technology for most space missions. Research projects in this field encompass the engineering of extremely miniaturised and highly integrated propulsion systems, as well as the engineering of advanced rocket stages and the associated rocket propulsion systems. Projects are typically embedded in (inter)national research activities. The research facilities includes a vacuum chamber and a number of small thrust benches. Some example of research projects:

- MEMS resistojet thruster system
- solar electric and solar thermal propelled orbital transfer stages
- solid/liquid/hybrid rocket motor development
- air-launched nanosatellite launch vehicle
2. Space Exploration
This profile covers spacecraft navigation and planetary missions, and aims at delivering skilled space mission engineers and scientists. Using mathematical methods and knowledge of the physical world, it is possible to design and/or estimate spacecraft trajectories, or to retrieve properties of planets and moons from measurements taken by planetary orbiters and space probes. Mastering this chain enables the student to design space missions (navigation and observation systems inclusive) that are used in the exciting area of space exploration.

Trajectories
Knowing the trajectory of the vehicle is essential to any space mission. Clearly, this is relevant both when designing and flying a mission and in retrospect, when processing actual measurements. A clear first category of “trajectory design” is that of launch vehicles, with questions on the optimal steering program, the number and layout of the various stages, the propellant, etc. Then there is the transfer orbit, from e.g. a parking orbit around Earth to the nominal operational orbit, or an interplanetary transfer. For instance: what is the best trajectory to reach a particular asteroid? Is this to be done with high-thrust propulsion (i.e. using traditional chemical engines) or with low-thrust propulsion? Finding the best combination of altitude, eccentricity, inclination and such is also crucial for the design of operational orbits. Finally, when a spacecraft enters a planetary atmosphere to land at a prescribed position, a control strategy is needed and thermal and mechanical loadings have to be accounted for. In orbit determination, measurements are used to determine the vehicle’s trajectory in retrospect. For spacecraft orbiting Earth, measurements taken by the Global Positioning System (GPS) are typically used. Here, the challenge is to derive the most accurate orbit from the measurements.

Science
Precise knowledge on the actual orbit of a space vehicle serves several scientific purposes. For example, satellite orbits around Earth are sensitive to the amount of ice stored on the polar caps, and may provide the reference to observe ocean levels, tides and tsunamis. Dedicated gravity measurements as obtained by the satellite GOCE allow to distinguish between mass and surface forces. It thus provides the unique capability not only to estimate Earth’s gravity field, but also to accurately characterise atmospheric drag and lift, and solar radiation pressure, all with unprecedented spatial and temporal resolution. A similar story goes for Swarm, a 3-satellite constellation to investigate the magnetic field of Earth but also equipped with accelerometers. Another application is the use of GPS data for the precise positioning of receivers on Earth’s surface. Such information is important for studies on earthquakes, for example. A relatively novel development within the Space Exploration profile is the scientific exploration of Solar System bodies. With precise orbit determination of planetary spacecraft, information about the internal structure of such bodies can be obtained.

Also, laser ranging is being studied as a tool to accurately measure distances to Solar System bodies, such as Jupiter’s moon Europa, and Very Long Baseline Interferometry (VLBI) is being used to track radio signals of distant spacecraft and hence determine their location. An application of the latter was the measurement of wind speeds in the atmosphere of Saturn’s moon Titan, by tracking ESA’s descending Huygens probe.

Measurements from scientific instruments on planetary spacecraft or landers are also being used to study the composition and structure of atmospheres and surfaces of planets and moons (dust on Mars, whirling clouds on Jupiter), as well as other phenomena (weather patterns, or dynamical processes in planetary ring systems). This profile also includes instrument studies, where the best measurement techniques for answering a given scientific question are investigated, including observational strategies given the constraints of the spacecraft’s orbit or the lander’s location on a distant surface, and, for example, the available power and downlink data rates.
Because of the nature of planetary exploration and missions, student projects are typically embedded in international research activities.

**Key academic staff**
- Professor Dr. E.K.A. Gill
  Expertise: Space Engineering
- Professor Dr. Ir. P.N.A.M. Visser
  Expertise: Space exploration
- Ir. R. Noomen master track coordinator Expertise: Astrodynamics and Space missions
- Professor Dr. L.L.A. Vermeersen
  Expertise: Planetary Exploration
- Ir. B.T.C. Zandbergen
  Expertise: Space Engineering

**Research programmes**
In the first three quarters of the first year you will mainly work on courses (core, profile and electives). In the last quarter of the first and the entire second year, you will be engaged in research that is typically embedded in ongoing research programmes in one of these themes:
- small satellite integration and testing
- spacecraft design and analysis
- distributed space systems
- miniaturisation
- systems engineering
- propulsion
- navigation and control
- rockets, trajectories and re-entry systems
- altimetry
- orbits and missions
- atmosphere at satellite altitude
- GPS tracking
- solar system exploration
- deformation analysis using GPS

Since these themes show a large variety, your preference has consequences for your choice of electives, and should be made at the very beginning of your MSc programme.

**Job perspective**
The prospects of finding a job with a MSc degree in Aerospace Engineering and a specialization Spaceflight are typically very good. Many of our graduates find work in leading Aerospace and Space industries and institutes (Dutch and international). This includes companies and institutions such as Airbus Defence and Space Netherlands, NLR, TNO, SRON, ISIS, ESA, EADS, NASA and many others. Other graduates remain in the academic world, begin their own firm, or find employment in other sectors (technical advisory firms, energy companies, banking, etcetera). The increasing dependence of business on systems engineering technologies continues to increase the demand for highly qualified aerospace engineers.

**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 enrollment in the MSc.

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 can be dependent on a screening under the Missile and Nuclear Research Exemption scheme:
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 “Space Flight” can be obtained at:
www.ir.tudelft.nl/sf

Alternatively, you can also contact the MSc track coordinator:
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Room number: 9.20

International students are recommended to visit:
www.tudelft.nl/admission

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