# Degree Program Documentation Master's Program Earth Oriented Space Science and Technology (ESPACE)

Part A

TUM School of Engineering and Design
Technical University of Munich

## General Information:

- Administrative responsibility: TUM School of Engineering and Design
- Name of degree program: Earth Oriented Space Science and Technology (ESPACE)
- Degree: Master of Science (M.Sc.)
- Standard duration of study and credits: 4 semesters of enrollment and 120 credit points (CP)
- Form of study: full time
- Admission: Aptitude assessment (EV – Master's),
- Start: Winter semester (WiSe) 2024/2025
- Language(s) of Instruction: English
- Main Location: Munich
- Additional information: Double-Degree with Wuhan University (China)
  1:1 Program with Technical University of Denmark
- Academic administrator: Univ.-Prof. Dr. techn. Mag. rer. nat. Roland Pail (Program Director)
- Academic Program Director: Prof. Dr. Christoph Holst
- Contact for further questions (regarding this document):
  Dr. Thomas Gruber
  Thomas.Gruber@tum.de
  Phone number: +49 (0)89 289 23192
- Status as of: 09.01.2024

# Table of Contents

**1 Degree Program Objectives ..... 4**

1.1 Purpose ..... 4

1.2 Strategic Significance ..... 5

**2 Qualification Profile ..... 7**

**3 Target Groups ..... 10**

3.1 Target Audience ..... 10

3.2 Prerequisites ..... 10

3.3 Target Numbers ..... 11

**4 Demand Analysis ..... 14**

**5 Competition Analysis ..... 15**

5.1 External Competition Analysis ..... 15

5.2 Internal Competition Analysis ..... 15

**6 Program Structure ..... 17**

**7 Organization and Coordination ..... 27**

**8 Enhancement Measures ..... 29**

# 1 Degree Program Objectives

## 1.1 Purpose

Earth observation satellites help us to better understand and monitor our environment. Today, all Earth science disciplines as well as national agencies, public entities and private enterprises have an urgent need in up-to-date satellite data providing essential information for their research, administrative or economic activities. Satellites provide a unique tool to monitor the Earth and its changes globally within reasonable time and with pre-defined sampling rates compared to other existing methods like airborne, shipborne, or terrestrial measurement systems. In the context of a highly significant public interest for Earth observation data, the number of Earth orbiting satellites has increased tremendously. For example, the European Union established and operates on one hand the Copernicus Earth observation space programme, which consists of a fleet of satellites providing continuous and sustainable Earth observation data from space to operational Copernicus services and to the public, and on the other hand the Galileo global satellite-based navigation system, which provides continuous positioning services to European services and users. The design, development and data analysis of respective satellite missions require experts with knowledge not only in spacecraft design and orbital mechanics, but also in satellite data analysis techniques and applications for satellite-based positioning and for monitoring the Earth and its environment.

With this development it turned out that there exists a knowledge gap between satellite technology and interpretation of acquired data for Earth observation applications and satellite positioning. From an educational point of view, this diversity is a challenge. Classical university programs only cover parts of this spectrum in different disciplines. These are aerospace engineering, electrical engineering, or geodesy - just to mention a few - yet there is hardly any connection between these programs. With the **interdisciplinary master's degree program Earth Oriented Space Science and Technology (ESPACE)** of the School of Engineering and Design (ED) of Technical University of Munich (TUM), established in 2005, several institutions in and around Munich have combined their expertise and set up a graduate program which also addresses the interfaces between these disciplines, and with the aim of educating **Satellite Application Engineers**.

Graduates of the ESPACE degree program are capable to bridge the above-mentioned gap between satellite engineering, high performance data processing and Earth science applications and have the necessary knowledge portfolio to define the science and mission requirements, and to design and operate Earth observation and navigation satellite constellations. As satellite application engineers they analyse interactions between satellite sensors, processing algorithms and applications to obtain the optimal results. They contribute to the definition, development and data exploitation of satellite missions, that are providing key information for a sustainable development of the Earth and that are enabling advanced techniques for navigation and remote sensing. Typically, tasks of space science and technology in Earth observation are handled in an international framework and at the interface of science and industry with major contributions by national and international space agencies (e.g., ESA, NASA, DLR, JAXA), which requires evidently globally interlinked expert knowledge. Therefore, the ESPACE master's program addresses international students with the goal to educate talented professionals for both the German and the international market.

## 1.2 Strategic Significance

TUM is committed to the progress of **sustainable innovation for people, nature, and society**. This fundamental understanding shapes the teaching and objectives of over 40 programs offered by TUM ED. In the education of its students, TUM ED embraces a "**human-centered engineering**" approach as a central guideline across the various engineering disciplines it encompasses. TUM ED considers it essential for graduates to not only possess technical competencies but also to be able to critically reflect on their own discipline within a societal context. The engineering solutions produced by future graduates must be socially acceptable and serve humanity and its environment sustainably to maintain society's trust in sometimes highly complex technologies. The master's degree program ESPACE adopts in manifold ways this central guideline. Being positioned **at the interface of technology and science**, ESPACE fosters interdisciplinary engineering solutions for monitoring and quantification of global change processes in all relevant sub-components of the Earth system, for the determination and visualization of natural hazards as well as for early warning systems. In **interdisciplinary** and **intercultural** working groups and projects, not only tailored solutions for specific applications are developed, but also their societal impact is reflected, and the benefit for society is evaluated.

Correspondingly, TUM ED offers the ESPACE master's degree program to educate future interdisciplinary engineers in the field of Earth system science, navigation, remote sensing and satellite technology. It supplements the portfolio of rather more specialized TUM ED degree programs in these disciplines. Beyond these topical competencies, the ESPACE study program trains students to take responsibility not only for their developed problem solutions, but the latter contributing to policy advice and decision-making processes. As such, the study program serves to provide recommended actions in the sense of **TUM's Sustainable Future Strategy 2030**. Student project and seminars are promoting interdisciplinary research aspects towards sustainable technologies, products, and services. Specifically, the ESPACE program offers opportunities to students in collaboration with teachers and researchers to develop new Earth observation products based on satellite data to support sustainable developments in climate protection, optimal navigation, sustainable tourism, organic farming, just to mention a few. Additionally, the content of the subject matter covered by the ESPACE program is highly relevant to the TUM's interdisciplinary core theme **"Shaping a sustainable living environment"** and provides important stimuli for the focal research areas **"Climate and the environment"** and **"Mobility"**. Through research-oriented teaching, the ESPACE program ensures that innovations and knowledge from research directly influence education. At the same time, this program systematically incorporates interdisciplinary learning opportunities and cross-cutting contextual knowledge into the curricular to impart key competencies for transformative capability, open thinking, and dealing with ambiguous questions.

The degree programs at TUM are assigned to Professional Profiles (PPs). These profiles no longer categorize the programs and their competence or qualification profiles solely based on "traditional" disciplines. Building on the exploration of current, new, and future challenges, the profiles assigned to a Professional Profile are developed across disciplinary and school boundaries. This is done along scientific frameworks and methods, as well as along professional fields or industries. The PPs are designed as flexible structures within TUM, allowing for a quick response to new challenges and the creation of new PPs. Currently, the degree programs in the School of Engineering Design are assigned to the following nine PPs:

1. Aerospace
2. **Geodesy**
3. Geo Engineering
4. Civil Engineering
5. Environmental Engineering
6. Mechanical Engineering
7. Architecture and Design
8. Mobility
9. Interdisciplinary Engineering

The master's program ESPACE is allocated to the **PP Geodesy**. The PP Geodesy bundles TUM ED's extensive research and teaching expertise in 6 study programs that are all tightly related to geodetic research and engineering with different topical foci. Due to its interdisciplinary character, ESPACE is also linked to the PPs Aerospace and Geo-Engineering.

In fact, within the School's Department of Aerospace and Geodesy, the ESPACE program has a particularly important strategic role as a front-runner at the interface of space science and geodesy. Historically, it was the first study program in Europe with this specific interdisciplinary focus. As such, it has been operated already very successfully for many years. Therefore, within the ED it is the study program with the strongest institutionalized link between aerospace (satellite technologies) and geodesy (Earth observation and satellite applications), utilizing the expertise of the involved lecturers on both sides. With its specific focus, it fully complies with the Department's leading principle "Mission Earth" in many respects, by developing observational tools such as satellite missions to monitor, analyze, model and interpret the state as well as change processes on Earth.

As an **interdisciplinary program**, ESPACE involves interdisciplinary experts from various universities, research institutes and industry. With the unique concentration of expertise in the fields of satellite technology, natural science, remote sensing and navigation in the Munich region, there are ideal conditions to include external lecturers in the program. Thus, the students become involved in current projects, state-of-the-art technology and science, and daily practice and get prepared to possible entrepreneurial activities.

TUM's and ED's strategic goal of **internationality** is fostered, further extended and has been solidly established within the ESPACE program by the integration of a double master's program with Wuhan University in China - the first of its kind at the TUM - and of a 1:1 program with Technical University of Denmark.

# 2 Qualification Profile

The following qualification profile corresponds to the specifications of the Qualifications Framework for German Higher Education Qualifications (Hochschulqualifikationsrahmen - HQR) and the requirements contained therein (i) Knowledge and Understanding, (ii) Use, Application and Generation of Knowledge, (iii) Communication and Cooperation and (iv) Scientific Self-Image/Professionalism. The formal aspects according to the HQR (entry requirements, duration, degree options) are detailed in chapters 3 and 6 as well as in the corresponding subject examination and study regulations.

**Knowledge and Understanding**

The ESPACE master's program is application- and research-oriented. Its graduates possess advanced knowledge of the principles of Earth observation with satellites, ranging from the observations via data analyses techniques to their applications. They can apply this knowledge to both engineering science and application-oriented problems. Graduates of the ESPACE master's program have solid thematic and methodological competencies in the disciplines of **Earth System Science from Space, Remote Sensing, and Navigation**. They can perform quality conscious, responsible and creative approaches and have a solid and comprehensive fundament of expert knowledge in the core themes of **satellite data analysis, space engineering and satellite applications**, always with focus to the Earth. They not only acquire fundamental knowledge and competencies in these three themes as a general basis, but they understand the interfaces among them and are able to link technological know-how with practical application. This enables them to work in a wide range of space sciences and its application.

The focus of the core theme **satellite data analysis** lies on the development and application of processing methods to satellite-derived data and models. With this core subject, graduates acquire the methodological competence to apply mathematical processing methods and approaches to practical problems of satellite and space engineering and they can select the optimal method for certain practical problems in the field of analysis of big data in Earth observation. The graduates are able work with data and process models, to assess the results quantitatively and to interpret the results in the context of space science and technology.

In the core theme **space engineering**, students acquire thematic and methodological competencies in the field of spacecraft technology (spacecraft design, spacecraft subsystems, launcher systems, rocket design), orbit mechanics and dynamics, ground segment design, and robotics. Graduates have the basic know-how and competencies required to review state-of-the-art knowledge of space engineering and to systematically expand existing specialized know-how by developing, upgrading and implementing new methods and technologies in the field of space engineering. They can realize and analyze the interplay among the fields of space engineering. They can understand and apply the control principles for orbital, spacecraft attitude and robotic operations, and can reproduce the behavior of these systems on ground for verification purposes.

The focus of the core theme **satellite applications** lies on the analysis, modelling and interpretation of Earth Observation data related to key satellite applications. Graduates have a thorough understanding of the basic components of system Earth and its main geodynamic processes in the Earth's interior, at the surface, and the global energy budget, and they are able to develop, upgrade and implement mathematical and physical concepts and to apply them for the solution of practical

problems in the field of satellite applications, to interpret geophysical, geodetic and geodynamical results, and to put them into the scope of geoscientific concepts. They can understand the basic principles and concepts of photogrammetry, remote sensing, geoinformation systems and satellite navigation and they can apply related methods, assess, and interpret the results. Graduates have the competence to view processes in their entirety, to connect the expertise acquired in a particular discipline with a more general scope and to derive consequences and guidelines for action on this basis.

Beyond their competencies in the three core themes as described above, there are three selective areas of specialization: (1) **Earth System Science from Space**, (2) **Remote Sensing**, and (3) **Navigation**. Here, students acquire specialized expert knowledge in one thematic field and are trained to acquire in-depth knowledge, to apply related methods, to assess and to evaluate results and to create new methods and technologies in this field.

Graduates selecting the specialization in **Earth System Science from Space** acquire a profound scientific knowledge of the Earth's system and its sub-components (oceans, atmosphere, hydrosphere/cryosphere, solid Earth). They can link data from Earth observing satellites and geophysical models describing Earth system dynamics, to apply them to record, present and evaluate processes and mass transport in the system Earth, and to evaluate their impact for global change.

Graduates specializing in **Remote Sensing** can apply in-depth methods to record, analyze and visualize sensor data of various wavelengths and scales. They can evaluate the suitability of ground-based, airborne and space-assisted optical, infrared and microwave sensors for task-specific problems in the field of remote sensing. They have the competence to combine data analysis methods for creating digital city and terrain models, change analysis, and monitoring/forecasting natural hazards.

Graduates specializing in **Navigation** can apply and evaluate methods for precise navigation and global surveying using geodetic space procedures and calculate precise orbits using data from GNSS and terrestrial navigation systems. They can analyze and solve problems of sensor fusion and integrated navigation systems and related practical applications such as car navigation, aeronautical and space applications.

**Application, Use, and Generation of Knowledge**

The core competencies in the three themes enable ESPACE graduates to have knowledge of the most important fundamentals in the field of Earth-oriented space science and technology, to build interfaces and to develop overarching concepts and technologies among them. This interdisciplinary expertise in Earth sciences, satellite technology and navigation qualifies ESPACE graduates for a wide range of professional profiles both in science and industry. Graduates can determine the appropriate theories, develop methodological approaches and apply them either in an industrial or in a scientific environment. Going deeper, they can design actual research questions, select and justify concrete ways of implementing their research, select adequate research methods, justify this selection and explain research results and interpret them critically.

With their interdisciplinary knowledge in data analysis methods, signal processing, sensor technology, orbital mechanics, spacecraft technology and Earth system science, ESPACE graduates are able to support planning and development of future satellite missions for Earth observation and navigation. They are involved in designing all phases of the development cycle of a

satellite mission, be it the satellite design in terms of payload, instruments, orbit, rocket launch, signal processing or the data analysis and application products generation at the ground segment. These fundamental competencies enable ESPACE graduates to discuss and interact with experts of all relevant fields in an interdisciplinary environment and therefore, they can be regarded as experts for satellite missions and their use in Earth observation. Even if the focus of the program is on Earth observation, the acquired knowledge also can be transferred to outer planets monitoring applying similar techniques.

**Communication and Cooperation**

Due to the international composition of the student cohort, graduates are used to work in international teams and to act effectively in accordance with the needs of all parties involved in communication and interaction. Besides, graduates of the ESPACE master's program have the capacity for teamwork and cooperation as well as constructive, scientific, and conceptual decision-making competences. They can present results and methods in accordance with good scientific practice. A goal-oriented and situation-specific interaction of these experts conducts to a successful project completion. The interdisciplinary nature of the ESPACE program, with the variety of qualifications and expertise from the students' bachelor studies (e.g., mechanical engineering, aerospace engineering, electrical engineering, general engineering, physics, mathematics, geosciences, geodesy), supports interdisciplinary interaction and an understanding for different scientific backgrounds, as well as intercultural competence. Graduates can enter dialog with both academics and non-academics from various disciplines and fields about viable alternatives to solving discipline-specific, subject-related problems. In the framework of ESPACE

**Scientific self-conception/professionalism**

ESPACE graduates can work independently and autonomously, they are able to define research questions in the field of Earth observation from space precisely, they can develop solution strategies to these questions, and they learn to critically discuss their work and to analyze the impact of their work to science and society. Furthermore, the graduates have acquired the ability to act problem-oriented on a respective task and beyond to integrate this task into a wider context. This is complemented by the ability for professional and self-reflective action in the core themes and in the selected specialization area. Summarized this can be understood as the development of a professional self-image.

# 3 Target Groups

## 3.1 Target Audience

Admission requirements for national and international applicants are a bachelor's degree or diploma in a natural or engineering science subject. Generally, the target group is composed of highly motivated candidates with affinity and interest in technical and geoscientific subjects and engineering talents from all over the world, who intend to work in the field of satellite technologies in conjunction with Earth observation.

Within the school, ESPACE represents a program which is open to graduates of many bachelor programs of the school and specifically is regarded as a possible master's program following the newly established aerospace bachelor program. The same is true for students holding a bachelor's degree in engineering, geosciences or computer sciences from TUM.

## 3.2 Prerequisites

The qualification of candidates for the ESPACE program is ensured by means of an aptitude assessment process which examines the specific competence and the ability to work in a methodological, principle-based, interdisciplinary, and scientific manner, details are provided in the Degree Program and Examination Regulations (FPSO). The aptitude assessment process is based on the submitted documents. In addition to the content of the degree held (natural or engineering science subject), one point of focus is to check whether the competencies gained in the fields of mathematics, physics and informatics are equivalent to those skills gained in a natural or engineering science bachelor's degree taken at TUM. Students must submit proof of competence in English (e.g., IELTS, TOEFL) with a minimum score of 6.5 (IELTS) or 88 (TOEFL) before they can be admitted to the program. A letter of motivation, and an essay on a scientific subject relevant to the general scope of the degree program need to be submitted together with the application documents. The aptitude assessment process is governed by the FPSO of the degree program and is carried out by an aptitude assessment commission. If there are questions related to the candidate's fulfilment of the above-mentioned qualification requirements, the applicant is invited to a video interview. The aptitude assessment process ensures that only qualified and motivated candidates are admitted, as is reflected in the very low drop-out numbers. Over 90% of those who have taken part in the ESPACE program since it was launched have completed it successfully.

Fast processing of the applications is essential especially in the case of international degree programs, which all compete globally for the most talented students. Most of these students apply for several degree programs at different universities. Experience has shown that many of these applicants decide in favor of the degree program that admits them first, giving more time to take care of their funding, visas, and accommodation. This is why ESPACE endeavors to carry out aptitude testing promptly and to inform the applicants of their results as soon as possible. ESPACE aptitude assessment commission recommends applicants from non-EU countries to apply before15th of March for the following winter semester intake. The goal is an international group of students composed by applicants from all over the world plus a significant group of TUM internal graduates from the Aerospace bachelor program who are planning to continue with ESPACE.

## 3.3 Target Numbers

The target number of newly enrolled students per year is in the order of 40. It is driven by available infrastructure and personnel resources.

The program was launched in the winter semester 2005/2006 with a target number of 30 students per year. With the newly established Aerospace bachelor program at TUM, where first graduates are expected in autumn 2024, a significantly higher number of TUM internal applicants to the ESPACE program is expected, as the master course is regarded as one option to continue the studies of this student group. Therefore, the target number has been increased with respect to previous years.

Since the start of the program, over 2000 applications have been received (incl. applications for the winter semester 2022/2023). After the aptitude assessment process, 618 students were admitted, 415 students were enrolled, and more than 300 students had successfully completed the ESPACE master's program (until winter semester 2021/2022). The most common reasons why 32% of the admitted students do not actually enroll in the program are difficulties related to funding, difficulties with visa application and decisions to start with a different master's degree program. See **Figure 3-1** for the numbers per year.

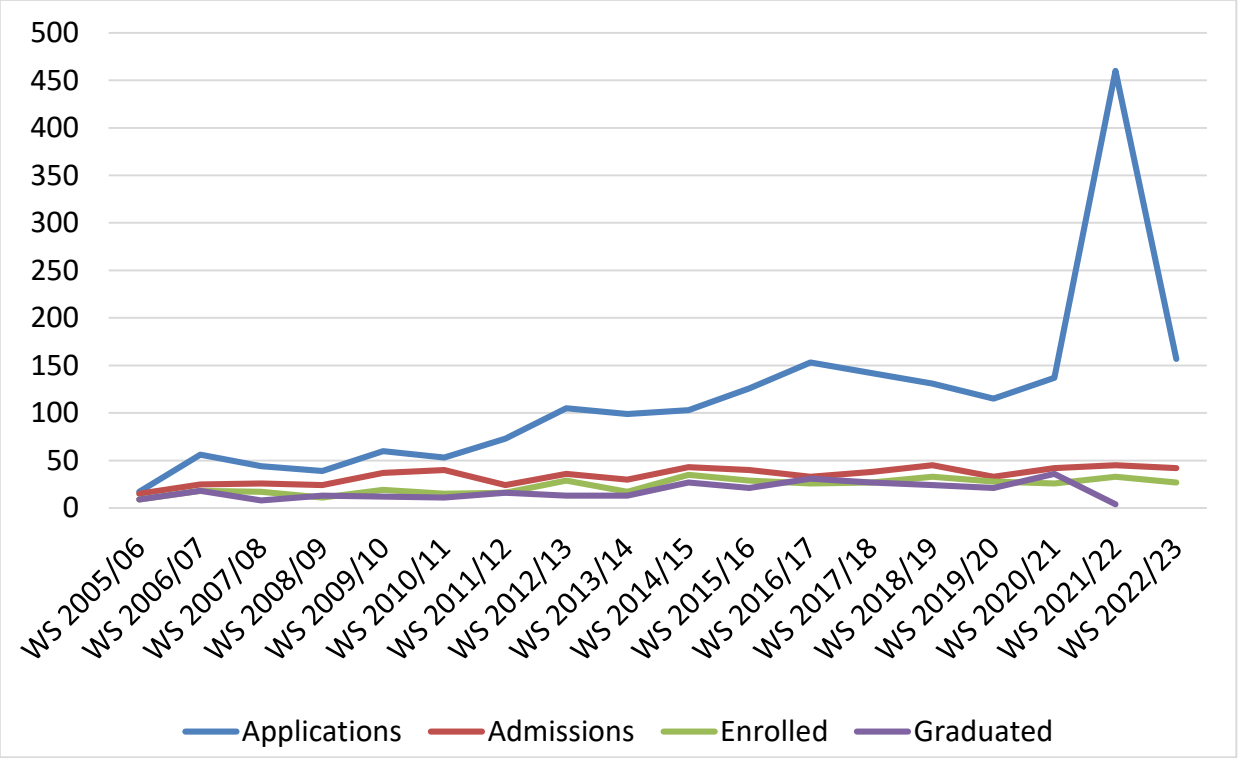


**Figure 3-1: Number of applications, admissions, enrolment figures and graduates of the respective program year since the Master's degree program started in WS 2005/06.**

The ESPACE degree program was approved in May 2005 so that there was little time to advertise it for the upcoming winter semester 2005/06; nevertheless, 9 students enrolled. Since then, advertising both at home and abroad has intensified. In particular, a new website was created, and the information material revised. The application figures have also increased thanks to the attendance

of ESPACE staff at numerous TUM internal and external student information events and the inclusion of the ESPACE program in the German Academic Exchange Service (DAAD) information web site about international study programs in Germany. The successful definition and establishment of a job profile (Satellite Applications Engineer) also led to a continuous increase in the number of applications for the program (Figure 3-1). The number of applications increased over the years up to around 150 Typically, tasks of space science and technology in Earth observation are handled in an international framework and at the interface of science and industry with major contributions by national and international space agencies (e.g., ESA, NASA, DLR, JAXA), which requires evidently globally interlinked expert knowledge. Therefore, the ESPACE master's program addresses international students with the goal to educate talented professionals for both the German and the international market per year and has been stable for a few years (the outlier in the year 2021/2022 resulted from a large number of incomplete applications; nonetheless, there were around 150 complete ones). The number of admissions of about 40 students per year shows the intention of ESPACE to select only top qualified students. Since the winter semester 2012/2013 the number of admitted students also includes 5 to 10 candidates studying in the Double Degree program with Wuhan university in China.

The academic backgrounds held by enrolled ESPACE students vary greatly. Exemplary, Figure 3-2 shows the variety of programs, which have been studied by students before enrolling to the ESPACE program. Most common backgrounds are Electronic Engineering, Geodesy, Geosciences and Aerospace Engineering as their previous degree (all about 13%). Most enrolled students hold a bachelor's degree (83%), while the remaining students already have a master or diploma degree and continue with ESPACE to further improve their educational profiles.

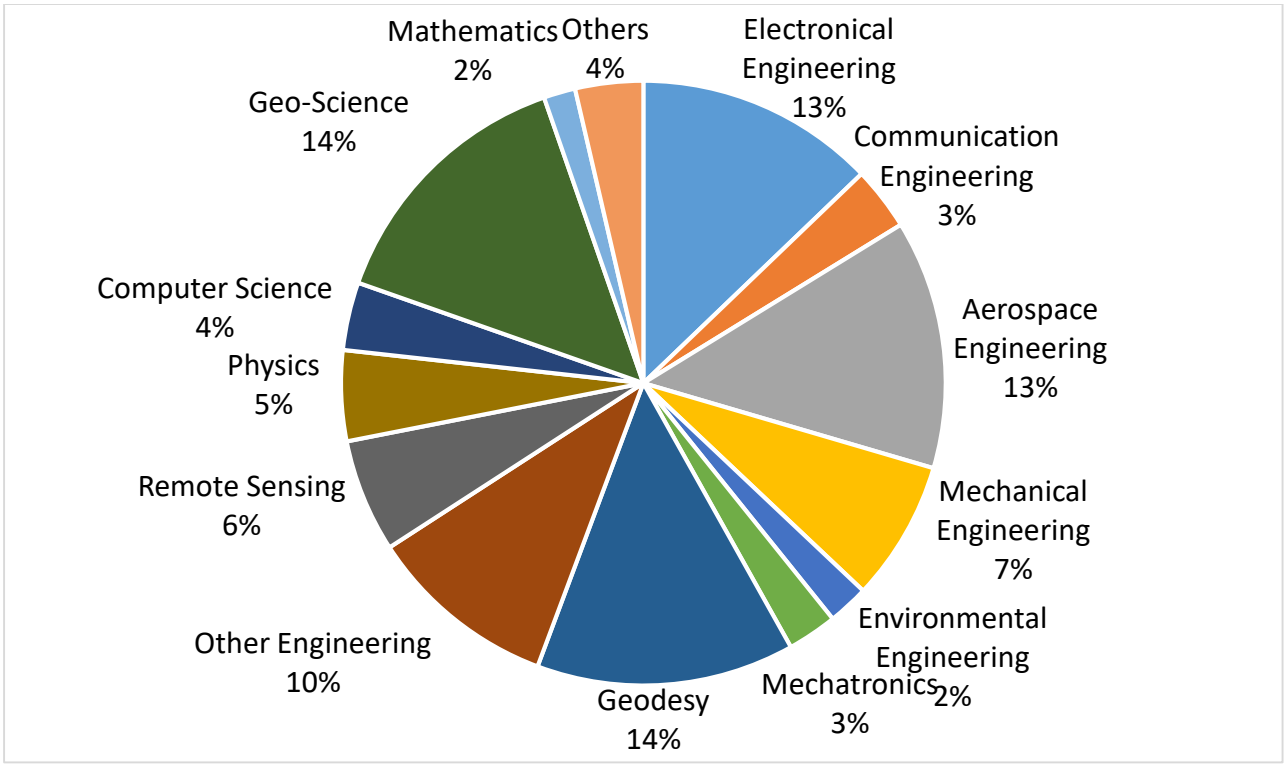


**Figure 3-2: Distribution of engineering and scientific subjects studied by enrolled students before attending the ESPACE master's program (WS 2005/06 – WS 2022/23).**

The students who enroll in the program come from many countries worldwide. The student distribution regarding continents is as follows: Asia (61%), Europe (25%), North America (8%), Africa (3%), South America (3%), Australia (<1%). The largest number of students comes from China (34%) followed by Germany (9%), Greece (8%) and India (8%). Consequently, with 91% the rate of international students is very high.

# 4 Demand Analysis

ESPACE alumni are satellite application engineers, who are working in space agencies, space industry, geo-information service provider companies, research institutions, or universities. In space agencies there is a demand of interdisciplinary experts to manage the complete lifecycle of an Earth observation satellite mission from mission planning, via development and implementation, satellite operations and data analysis to applications. Space industry is seeking for qualified personnel with good engineering background, but also knowledge in Earth observation applications, to design Earth observation missions, specifically matching overall mission requirements and industrial Hardware and Software development. The quickly growing market of geo-information service providers has a high demand for specialists developing value-added products based on Earth observation satellite data. Research institutions and universities need qualified graduates to perform cutting-edge research to further develop satellites and sensors, data analysis techniques and applications of Earth observation data.

As satellite application engineers ESPACE graduates analyze interactions between satellite sensors, processing algorithms and science applications to obtain the optimal results. The space technology industry and the fields of Earth system sciences, remote sensing and navigation are employment sectors that steadily grow and increase in importance. Also, many new start-up companies develop small satellite Earth observation constellations and innovative applications of Earth observation data demanding experts in this field. For example, natural catastrophes such as earthquake, floods, forest fires, hurricanes, tsunamis, landslides, and many others are impressive reminders that there is a great need for Earth system sciences research; the primary information sources here are the observations made from space. There is also a great need for globally available data in connection with security-related applications (e.g., for civil defense and humanitarian aid). Likewise, there is a growing international market in the field of satellite-supported positioning, navigation, and logistics, all of which indicates that ESPACE graduates have excellent professional prospects. Graduates' excellent competencies and skills makes the young scientists enrolled in the ESPACE program very sought-after employees specifically regarding the very dynamic "New Space" market developing small satellites for a wide range of applications.

Based on all graduates whose employment situation is known to the ESPACE program office (more than 100, e.g., from answers to graduate surveys), about 50% of the graduates are working as researchers, either in ESPACE cooperating institutions (about two thirds) or in other research institutions worldwide (about one third). From this group about 80% are going to complete a PhD. The other 50% of the graduates continue their professional carrier in industry primarily in the aerospace, energy, or automotive sectors, in geo-information service provider companies or in start-up companies in the aerospace and geo-information sector developing new technologies and applications. About two thirds of the ESPACE graduates start their professional career in Germany indicating the great demands for satellite application engineers in Germany. These numbers support the high demand of interdisciplinary satellite application engineers and shows the high diversity of employment options of ESPACE graduates. By virtue of the high concentration of scientific institutions in the fields of satellite technology, Earth sciences, remote sensing and navigation, and the various companies working in the space industry, there is a high level of interest in the Munich region for the junior scientists trained in the ESPACE program. Therefore, the degree program is ideally positioned at the TUM.

# 5 Competition Analysis

## 5.1 External Competition Analysis

ESPACE is an international interdisciplinary consecutive master's degree program. **There is no degree program with a comparable portfolio in Germany, neither in Europe.** In Germany and Europe, there exist various programs which either focus on aerospace engineering or on Earth system data sciences, remote sensing and geo-information, but none of them covers the complete range of topics addressed by the ESPACE master program.

In Germany, **University of Bremen** offers the international master's degree program "Space Science and Technologies – Sensing, Processing, Communication". This program provides knowledge in the fields of remote sensing, earth observation, retrieval theory, space electronics and communications, but does not cover aspects of spacecraft technology, navigation, and Earth system science. At **Julius-Maximilians University of Würzburg** the master's program "Applied Earth Observation and Geoanalysis of the Living Environment" is offered with a strong focus on application of remote sensing data, but not covering engineering science and navigation.

In Europe, there exist a few related international master's degree programs on other space-related topics with different focal points. For example, at **TU Delft** master programs in Aerospace Engineering or Applied Earth Sciences are offered, which address either technology or satellite data applications. At **DTU Copenhagen** there is offered a master program in Earth and Space Physics and Engineering, with special focus on technologies for monitoring and mapping the Earth and exploring the universe, but less on spacecraft technologies. In contrast, ESPACE intends to cover the complete spectrum from satellites to applications, which makes the program also unique in Europe. But, in case ESPACE students want to get a deeper knowledge in one of these areas, these universities could be a possibility for studying abroad.

## 5.2 Internal Competition Analysis

The ESPACE degree program is primarily run by the TUM Chair of Astronomical and Physical Geodesy (APG), supported by further Chairs of the Department of Aerospace and Geodesy in the TUM School of Engineering and Design. These are Satellite Geodesy, Photogrammetry and Remote Sensing, Remote Sensing Technology, Data Science in Earth Observation, Cartography, Big Geospatial Data Management, Earth System Modeling, Remote Sensing Applications, Astronautics, Space Systems, and the German Geodetic Research Institute. The profile of ESPACE is different from all other master's degree programs run at the TUM.

In terms of content, there is no competition. The related master's programs Geodesy and Geoinformation and Aerospace Engineering are much more specialized and consequently have a different focus and pursue other objectives and qualification profiles. Geodesy and Geoinformation, for example, is a consecutive master program building on bachelor programs in Geodesy, Geomatics or similar, while Aerospace Engineering focuses on technology. As the qualification profile for ESPACE is much broader, there is hardly any competition in terms of applicants.

In some subjects there are correlations between ESPACE and other degree programs from different departments at the TUM School of Engineering and Design and LMU. ESPACE lecturers also teach

in the English-language master's degree programs Geodesy and Geoinformation, Environmental Engineering, Transportation Systems, Cartography, Communications Engineering, Geophysics and Aerospace. Numerous teaching events from the ESPACE program can also be selected as elective subjects for Geodesy and Geoinformation and several other degree programs.

# 6 Program Structure

The standard period of study for the ESPACE master's degree program is four semesters. The program can be started only in the winter semester and is taught in English only. The number of credits to be earned is 120. Credits are earned in modules and are divided as follows:

- Required master modules 25 credits
- Required elective master modules 35 credits
- Required modules in specialization 15 credits
- Elective interdisciplinary master modules 10 credits
- Elective key competence modules 5 credits
- Master thesis with seminar 30 credits

Figure 6-1 shows the general structure of the program and how the modules of the curriculum are distributed among the four semesters, related to the competences to be achieved by students. In each semester there is offered some flexibility in choosing several required electives from a given list of modules. They should earn on average 30 credits per semester. All modules of the degree program are organized in a way that they do not overlap within the respective semester and that they logically build on each other from the first semester to the third.

| Semester | Modules | | | | | | CP/ Exams |
|---|---|---|---|---|---|---|---|
| 1 | Master Module 5CP | Master Module 5CP | Master Module 5CP | Master Module 5CP | Master Module 5CP | Master Module 5CP | 30/6 |
| 2 | Master Module 5CP | Master Module 5CP | Master Module 5CP | Master Module 5CP | Master Module 5CP | Elective Module 5CP | 30/6 |
| 3 | Master Module 5CP | Master Module 5CP | Master Module 5CP | Master Module 5CP | Elective Module 5CP | Elective Module 5CP | 30/6 |
| 4 | Master Thesis 30 CP | | | | | | 30/1 |
| | Specialist Competences: Spacecraft Engineering, Navigation, Earth System Science, Remote Sensing | | | | General competences: Mathematics, Statistics, Information Technology | | |
| | Interdisciplinary Competences: Projects, Seminars, Interdisciplinary Electives, Research | | | | Key Competences | | |

**Figure 6-1: General ESPACE study plan with competences to be addressed by required, required elective and elective modules.**

ESPACE is a method- and application-oriented degree program. Important elements are technical key components (as required e.g., to plan, design or execute a satellite mission) and special engineering and scientific methods required to evaluate, analyze, and interpret satellite data. The detailed structure of the degree program modules is shown in Figure 6-2 and described in the following paragraphs in more detail.

***Basics and Fundamentals - Core Themes (Semester 1)***

In the first semester most modules are mandatory, because students must acquire basic skills in mathematical and physics-based subjects as well as attend introductory modules in the fields of satellite navigation, spacecraft technology, Earth system science and remote sensing. The goal is to bring students from a wide range of different background knowledge from their various bachelor programs on the same level. Depending on their background (engineering, geosciences, or remote sensing) students have the possibility to select two out of three introductory modules and to drop the one which has already been covered in their bachelor program (either satellite technology, Earth system science or remote sensing). The course coordinator will make individual recommendations at the start of the students' studies. Throughout the first semester students gain overall basic skills in each of the later areas of specialization (see semester 3).

***Intensifying Fundamentals – Selected Core Themes (Semester 2)***

In the second semester eight modules are offered from which students shall select five according to their interests. The titles of these modules are listed in Figure 6-2 (second semester column). The content of these modules is designed such that they achieve the general competences of the ESPACE master in the fields Earth system science from space, remote sensing and navigation after the second semester and simultaneously prepare themselves for the specialization offered in the third semester. This is a pre-requisite to fulfil one of the program's main goals, i.e., that ESPACE graduates can work in an interdisciplinary environment and with experts from all relevant fields of Earth-oriented space science and technology.

***Specialization (Semester 3)***

In the third semester students must specialize in one of the three topics out of **Earth System Science from Space, Remote Sensing** and **Navigation**. The chosen area of specialization serves as the thematic context for practicing and sharpening methodical competencies in a particular field. Each specialization contains 3 modules with 5 CP each, where state-of-the-art competences in these topics are provided (see Figure 6-3 for modules titles). As ESPACE intends to educate satellite application engineers, during the last semester of their regular study program, a required module named Satellite Mission Design Project (5 CP) is included. In this module all competences acquired during the first and second semester shall be applied in order to design a satellite mission for an Earth observation application.

***Interdisciplinary Electives (Semester 2 or 3)***

Students may choose electives with 10 CP in topics which are related to ESPACE but are not necessarily part of the standard program. This includes a wide range of modules with technical content, which can be chosen from TUM's module catalogue. This shall support students to deepen their technical knowledge in specific topics they are most interested in. Interdisciplinary electives can be chosen either during the second or third semester, depending on availability either in the summer or winter semester.

***Free Electives - Key Competences (Semester 2 or 3)***

In addition, free electives with 5 CP out of the complete module catalogue from TUM may be chosen to give students the opportunity to acquire societal competences and/or develop their personal skills. These modules can be in the areas of ethics, philosophy, language, and transversal key competencies to enhance their ability for reflection, societal, economic, and political contextual competence, language proficiency, and personal development. Free electives can be chosen either during the second or third semester, depending on availability either in the summer or winter semester.

Key competences are also encouraged by means of several projects and seminars that are part of the required and required elective program. This also helps to develop soft skills (presentation techniques, rhetoric, structured style of preparation and work) and thus to strengthen their individual competencies. Team-building activities in these seminars serve to promote cohesion within the group, thereby allowing interdisciplinary skills and social competencies to be acquired (e.g., intercultural communication, working at teams). This is particularly addressed in an interdisciplinary project seminar, where ESPACE students, together with aerospace students, develop a proposal for an Earth observation satellite mission for a selected application. Further-on, students are encouraged in these seminars to critically assess the technological developments versus ethical aspects and impact on the Earth.

***Master's Thesis (Semester 4)***

The fourth and last semester is used to write the master's thesis (30 CP). With the master's thesis, the competences to perform scientific work independently and to properly document and present the results are verified. The master's thesis must be completed within 6 months and has to be submitted in form of a research paper as a written and bounded document. Typically, the number of pages of the thesis is between 50 and 150, strongly depending on the thesis' topic.

<table>
<tr><th>1st Semester</th><th>2nd Semester</th><th>3rd Semester</th><th>4th Semester</th></tr>
<tr><td>Introduction to Satellite Navigation and Orbit Mechanics<br>5 CP</td><td>Project Seminar in Earth Oriented Space Science and Technology<br>5 CP</td><td rowspan="3">Specialization<br>(see separate figure)<br>15 CP</td><td rowspan="6">Master’s Thesis<br>Master’s Colloquium<br><br>30 CP</td></tr>
<tr><td>Numerical Modeling and Signal Processing<br>5 CP</td><td>Advanced Numerical Modeling and Signal Processing<br>5 CP</td></tr>
<tr><td>Estimation Theory: Mathematical and Statistical Basics<br>5 CP</td><td>Satellite Navigation and Advanced Orbit Mechanics<br>5 CP</td></tr>
<tr><td>Applied Computer Science<br>5 CP</td><td>Machine Learning for Earth Observation<br>5 CP</td><td>Satellite Mission Design Project<br>5 CP</td></tr>
<tr><td>Introduction to Spacecraft Technology<br>5 CP</td><td>Advanced Spacecraft Technology<br>5 CP</td><td rowspan="2">Interdisciplinary Electives<br>10 CP</td></tr>
<tr><td>Introduction to Earth System Science<br>5 CP</td><td>Ground and Space Mission Elements<br>5 CP</td></tr>
<tr><td>Introduction to Photogrammetry, Remote Sensing and Digital Image Processing<br>5 CP</td><td>Advanced Remote Sensing<br>5 CP</td><td rowspan="3"></td><td rowspan="3"></td></tr>
<tr><td></td><td>Earth System Modelling<br>5 CP</td></tr>
<tr><td></td><td>Free Electives<br>5 CP</td></tr>
<tr><td>Required<br>20 CP</td><td>Required<br>-</td><td>Required<br>5 CP</td><td>Required<br>30 CP</td></tr>
<tr><td>Required Electives<br>10 CP (2 of 3)</td><td>Required Electives<br>25 CP (5 of 8)</td><td>Required Electives<br>15 CP</td><td>Required Electives<br>-</td></tr>
<tr><td>Electives<br>-</td><td>Electives<br>5 CP</td><td>Electives<br>10 CP</td><td>Electives<br>-</td></tr>
<tr><td>30 CP</td><td>30 CP</td><td>30 CP</td><td>30 CP</td></tr>
<tr><td>6 Exams</td><td>6 Exams</td><td>6 Exams</td><td>1 Exam</td></tr>
</table>

**Figure 6-2: Overview of the ESPACE degree chart: The table shows the individual modules including the module type and the credits (yellow = required modules, blue = required elective modules, red = elective modules). Depending on availability, interdisciplinary and free electives may be chosen either in the 2nd or 3rd semester (summer or winter semester).**

| 3rd Semester - Themes of Specialization | | |
|---|---|---|
| **Earth System Science from Space** | **Remote Sensing** | **Navigation** |
| **Atmosphere and Ocean**<br>5 CP | **Geoinformation**<br>5 CP | **Precise GNSS and Inertial Navigation**<br>5 CP |
| **Geokinematics and Continental Hydrology**<br>5 CP or<br>**Advanced Earth System Modeling and Continental Hydrology**<br>5 CP | **Photogrammetry – Selected Chapters**<br>5 CP | **Advanced Aspects of Navigation Technology**<br>5 CP |
| **Space-based Gravity and Magnetic Field Monitoring**<br>5 CP | **Remote Sensing**<br>5 CP | **Navigation Labs**<br>5 CP |
| 15 CP | 15 CP | 15 CP |
| 3 Exams | 3 Exams | 3 Exams |

**Figure 6-3: Specialization options in the third semester: An overview of the three themes of specialization with their respective modules. The modules are required modules within the respective area of specialization (except in specialization 1, where one of the two options has to be chosen.**

### *Exemplary Study Plans*

Depending on student's interest, example study plans for the three focus areas **Earth System Science from Space, Remote Sensing** and **Navigation** are shown in Figure 6-4, Figure 6-5 and Figure 6-6. These study plans represent a possible selection of modules to meet student's interests. These plans can be adapted to individual interests and combination of required elective modules and specialization is accepted.

### *Schedule*

The students can easily attend all required and required elective modules as the schedule is organized such that there are no overlaps and that students do not have to commute during one day between different TUM campuses. There is also enough time between the courses for preparation and follow-up discussions. Depending on the selected specialization theme, some days are completely free of courses from the 3rd semester onwards. These days are available for independent study or also for other activities e.g. work as a student assistant.

<table>
<tr><th>1st Semester</th><th>2nd Semester</th><th>3rd Semester</th><th>4th Semester</th></tr>
<tr><td>Introduction to Satellite Navigation and Orbit Mechanics<br>5 CP</td><td>Project Seminar in Earth Oriented Space Science and Technology<br>5 CP</td><td rowspan="3">Specialization<br>Earth System Science from Space<br>15 CP</td><td rowspan="6">Master’s Thesis<br>Master’s Colloquium<br><br>30 CP</td></tr>
<tr><td>Numerical Modeling and Signal Processing<br>5 CP</td><td>Advanced Numerical Modeling and Signal Processing<br>5 CP</td></tr>
<tr><td>Estimation Theory: Mathematical and Statistical Basics<br>5 CP</td><td>Machine Learning for Earth Observation<br>5 CP</td></tr>
<tr><td>Applied Computer Science<br>5 CP</td><td>Advanced Remote Sensing<br>5 CP</td><td>Satellite Mission Design Project<br>5 CP</td></tr>
<tr><td>Introduction to Spacecraft Technology<br>5 CP</td><td>Earth System Modelling<br>5 CP</td><td rowspan="2">Interdisciplinary Electives<br>10 CP</td></tr>
<tr><td>Introduction to Photogrammetry, Remote Sensing and Digital Image Processing<br>5 CP</td><td>Free Electives<br>5 CP</td></tr>
<tr><td>30 CP</td><td>30 CP</td><td>30 CP</td><td>30 CP</td></tr>
<tr><td>6 Exams</td><td>6 Exams</td><td>6 Exams</td><td>1 Exam</td></tr>
</table>

**Figure 6-4: Exemplary study plan for students focusing in Earth System Science from Space with background knowledge in geosciences (yellow = required modules, blue = required elective modules, red = elective modules). Depending on availability, interdisciplinary and free electives may be chosen either in the 2nd or 3rd semester (summer or winter semester).**

<table>
<tr><th>1st Semester</th><th>2nd Semester</th><th>3rd Semester</th><th>4th Semester</th></tr>
<tr><td>Introduction to Satellite Navigation and Orbit Mechanics<br>5 CP</td><td>Ground and Space Mission Elements<br>5 CP</td><td rowspan="3">Specialization Remote Sensing<br>15 CP</td><td rowspan="6">Master’s Thesis<br>Master’s Colloquium<br><br>30 CP</td></tr>
<tr><td>Numerical Modeling and Signal Processing<br>5 CP</td><td>Advanced Numerical Modeling and Signal Processing<br>5 CP</td></tr>
<tr><td>Estimation Theory: Mathematical and Statistical Basics<br>5 CP</td><td>Machine Learning for Earth Observation<br>5 CP</td></tr>
<tr><td>Applied Computer Science<br>5 CP</td><td>Advanced Remote Sensing<br>5 CP</td><td>Satellite Mission Design Project<br>5 CP</td></tr>
<tr><td>Introduction to Spacecraft Technology<br>5 CP</td><td>Satellite Navigation and Advanced Orbit Mechanics<br>5 CP</td><td rowspan="2">Interdisciplinary Electives<br>10 CP</td></tr>
<tr><td>Introduction to Earth System Science<br>5 CP</td><td>Free Electives<br>5 CP</td></tr>
<tr><td>30 CP</td><td>30 CP</td><td>30 CP</td><td>30 CP</td></tr>
<tr><td>6 Exams</td><td>6 Exams</td><td>6 Exams</td><td>1 Exam</td></tr>
</table>

**Figure 6-5: Exemplary study plan for students focusing in Remote Sensing with background knowledge in remote sensing (yellow = required modules, blue = required elective modules, red = elective modules). Depending on availability, interdisciplinary and free electives may be chosen either in the 2nd or 3rd semester (summer or winter semester).**

<table>
<tr><th>1st Semester</th><th>2nd Semester</th><th>3rd Semester</th><th>4th Semester</th></tr>
<tr><td>Introduction to Satellite Navigation and Orbit Mechanics<br>5 CP</td><td>Ground and Space Mission Elements<br>5 CP</td><td rowspan="3">Specialization Navigation<br>15 CP</td><td rowspan="6">Master’s Thesis<br>Master’s Colloquium<br><br>30 CP</td></tr>
<tr><td>Numerical Modeling and Signal Processing<br>5 CP</td><td>Advanced Numerical Modeling and Signal Processing<br>5 CP</td></tr>
<tr><td>Estimation Theory: Mathematical and Statistical Basics<br>5 CP</td><td>Advanced Spacecraft Technology<br>5 CP</td></tr>
<tr><td>Applied Computer Science<br>5 CP</td><td>Project Seminar in Earth Oriented Space Science and Technology<br>5 CP</td><td>Satellite Mission Design Project<br>5 CP</td></tr>
<tr><td>Introduction to Spacecraft Technology<br>5 CP</td><td>Satellite Navigation and Advanced Orbit Mechanics<br>5 CP</td><td rowspan="2">Interdisciplinary Electives<br>10 CP</td></tr>
<tr><td>Introduction to Earth System Science<br>5 CP</td><td>Free Electives<br>5 CP</td></tr>
<tr><td>30 CP</td><td>30 CP</td><td>30 CP</td><td>30 CP</td></tr>
<tr><td>6 Exams</td><td>6 Exams</td><td>6 Exams</td><td>1 Exam</td></tr>
</table>

**Figure 6-6: Exemplary study plan for students focusing in Navigation with background knowledge in an engineering discipline (yellow = required modules, blue = required elective modules, red = elective modules). Depending on availability, interdisciplinary and free electives may be chosen either in the 2nd or 3rd semester (summer or winter semester).**

### *Extracurricular Activities*

Beyond the curriculum, there are also seminars on the topics of intercultural awareness and culture in a university context (orientation week at the begin of the semester) and writing techniques for the master’s thesis (prior to the 4th semester). Besides this, students can also become part of one of the many outstanding, extracurricular activities organized by student teams. For example, within the Scientific Workgroup for Rocketry and Spaceflight (WARR) ESPACE students may participate at the Munich Orbital Verification Experiment (MOVE), where they can take over important roles in a large interdisciplinary and international team developing a cubesat satellite mission. These activities are also supported by the ESPACE program board.

### *Mobility*

ESPACE is an international degree program. Most of the participants therefore come from abroad. Since the program is taught in English, ESPACE courses are also highly interesting for many students that come to the TUM as part of the ERASMUS program.

To encourage mobility among the ESPACE students, the program offers students the opportunity to write their master’s thesis abroad under the joint supervision of foreign as well as TUM academic

teaching staff. Additionally, the third semester might also be used as a mobility “window”, because it contains only one single required module “Satellite Mission Design Project”, which can be acquired in equivalent form at many foreign universities. In addition, the contents of the three required modules of the three specializations in the third semester are offered in a similar way at several target universities. Therefore, it is possible to study one or even two semesters of the master’s program at another university without impairing the study progress. Regarding national and international exchange programs, the School of Engineering and Design offers consulting services.

For the ESPACE master’s program two options to study abroad have been established with bi-lateral agreements and are offered to the ESPACE students enrolled at TUM. For both, the earned intercultural experiences and competencies, besides the acquired technical expertise from a different teaching style, can be highly beneficial for their future career either in space industry or leading research institutes.

Double-Degree Program

Since 2010, there is a Double-Master’s Agreement with Wuhan University (WHU), China, one of the TUM’s partner universities. The agreement, which has been extended in 2021 for another five years, governs the TUM’s first Double-Master’s program with a Chinese university. WHU is the most recognized university in China in the fields of geodesy and geoinformation. Students who want to take part in the Double-Master’s program need to extend their study for an extra year (three instead of two years). ESPACE students spend their first and third year at the home university TUM and in the second year they can study one year at WHU. The specialization option in the third year of the program is available at both the TUM (areas of specialization: see above) and the WHU (areas of specialization: Navigation, Remote Sensing, Geodesy or Geoinformation) allowing the students free choice of where to study their specialized subjects. The master’s thesis (six months) is supervised jointly by professors of both universities. This also strengthens the research cooperation between both universities. Graduates of the Double-Master’s program receive two master’s certificates, one from the TUM and one from the WHU. The Double-Master’s agreement between both universities governs the process and the curriculum of the Double-Master’s program. The first ten students from WHU started their studies at TUM in the winter semester 2012/13. Since then, every year continuously 5 to 10 new double Degree students were enrolled at TUM. In addition, a number of students at TUM decided to pursue the Double Degree and went to Wuhan University for one year.

1:1 Exchange Program

Since 2020, a two year 1:1 exchange master’s program between TUM and Technical University of Denmark (DTU) has been established, where a track in space science and technology is offered for ESPACE students. DTU is located north of Copenhagen and is an elite technical university, recognized for its high level of international research and its sought-after graduates. The research focus areas include several societally relevant engineering disciplines, including digitalization, sustainable energy technologies, and life science. Within the exchange program ESPACE students spend their first year at TUM and continue their studies at DTU during the second year. TUM students need to acquire 30 CP during the third semester at DTU (15 CP required modules, at least 10 CP from a list of required elective modules and up to 5 CP from free elective modules). The Master's Thesis is intended in the fourth semester of the program and co-supervised by professors from both institutions. The thesis supervisor at the institution where the master's thesis work is conducted will act as the main supervisor and thus be primarily responsible for the student and local thesis rules

will apply. The master's thesis must be presented at an oral defense according to the rules and regulations of both universities. For TUM students, the grade will be determined by the TUM thesis supervisor after consultation with the DTU supervisor. The master's thesis must be written in English and handed-in accordance with the rules of the respective home university. After successful completion of the program, ESPACE students will be awarded with a TUM Master of Science with a diploma insert stating the successful completion of the 1:1 program and the transcript from DTU. The 1:1 program offers the unique possibility to study one year abroad and to get to know another top research university, all together in a regular master's program period of two years.

# 7 Organization and Coordination

The ESPACE master's program is administratively located at School of Engineering and Design. The degree program is managed by a Directing Board composed by the professors taking responsibility for teaching. Prof. Dr. Roland Pail from the chair of Astronomical and Physical Geodesy is the program director. Strategic questions of the ESPACE degree program are regularly discussed in an extended Directing Board, which is comprised of representatives of all contributing institutions. There is also an ESPACE program office in which the program coordinator and academic counsellor take care of all student affairs and the administration.

For administrative aspects of study organization, some responsibilities lie with the central units of the TUM Center for Study and Teaching (TUM CST), while others are handled by the facilities of TUM ED (see the following overview):

- Student Advising: Student Advising and Information Services (TUM CST)
  Email: studium@tum.de
  Phone: +49 (0)89 289 22245
  Provides information and advising for prospective and current students (via hotline/service desk)
- Departmental Student Advising: Chair of Astronomical and Physical Geodesy
  Dr. Thomas Gruber
  email: info@espace-tum.de
  Phone: +49 (0)89 289 23192
- Academic Programs Office: School of Engineering and Design
  Study and Teaching
  email: studyandteaching@ed.tum.de
- Study Abroad Advising/Internationalization:
  TUM-wide: TUM Global & Alumni Office
  internationalcenter@tum.de
  Departmental: Daniel Hartenstein, M.A.
  email: exchange.asg@ed.tum.de
  Phone: +49 (0)89 289 55504
- Gender Equality Officer: TUM-wide: Dr. Eva Sandmann
  sandmann@tum.de, Tel. +49 (0)89 289 22335
  Departmental: Michaela Wenzel
  Email: diversity@ed.tum.de
- Advising – Barrier-Free Education: TUM-wide: Service Office for Disabled and Chronically Ill Students (TUM CST),
  Email: Handicap@zv.tum.de
  Phone: +49 (0)89 289 22737
- Admissions and Enrollment: Admissions and Enrollment (TUM CST)
  Email: studium@tum.de

| | |
|---|---|
| | Phone: +49 (0)89 289 22245<br>Admissions, enrollment, Student Card,<br>leaves of absence, student fees payment,<br>withdrawal |
| • Aptitude Assessment (EFV): | TUM-wide: Admissions and Enrollment (TUM CST)<br>Email: studium@tum.de<br>Phone: +49 (0)89 289 22245<br>Departmental:<br>Chair of Astronomical and Physical Geodesy<br>Prof. Dr. Roland Pail<br>email: Roland.Pail@tum.de<br>Phone: +49 (0)89 289 23190 |
| • Semester Fees and Scholarships: | Fees and Scholarships (TUM CST),<br>Email: beitragsmanagement@zv.tum.de |
| • Examination Office: | Graduation Office and Academic Records (TUM CST), Campus Munich<br>Graduation documents, notifications of examination results, preliminary degree certificates |
| • Departmental Examination Office: | School of Engineering and Design, Department Aerospace and Geodesy,<br>Daniel Hartenstein. M.A.<br>Isabella Canchila Acuña, M.A.<br>examination.asg@ed.tum.de |
| • Quality Management: | TUM CST – Quality Management<br>https://www.tum.de/studium/tumcst/teams-cst/ |

**TUM ED:**

| | |
|---|---|
| • Vice Dean Academic and Student Affairs: | Prof. Dipl. Arch. ETH Mark Michaeli<br>Email: vicedean_study_teaching@ed.tum.de |
| • Academic Program Director: | Prof. Dr. Christoph Holst<br>Email: christoph.holst@tum.de |
| • Quality management: | Brit Krieger<br>Email: qualitymanagement@ed.tum.de |
| • QM circles: | Dimitri Franz<br>Email: dimitri.franz@tum.de |
| • Evaluations | Atiye Korkmaz<br>Email: evaluationen@ed.tum.de |
| • Module management | Arno Buchner<br>Email: modulverwaltung@ed.tum.de |

# 8 Enhancement Measures

In 2018 the master's program ESPACE has been shifted to the new host faculty Aerospace and Geodesy. The new faculty bundled academic research activity in the aerospace and aeronautics sectors addressing research themes new transport systems, communications, satellite technology and observation and measuring planet Earth with unprecedented precision. With its specific unique profile at the interface of satellite technology and applications in Earth Observation, the ESPACE program fitted excellently in the research and education strategy of the new department. Within the department a closer link between aerospace and geodesy programs was established. ESPACE is regarded as an optional master course for graduates of the aerospace bachelor program. Therefore, the ESPACE curriculum was slightly modified in 2019 to address more cross-cutting themes within the new faculty. The module structure became more logical and more freedom for elective modules was offered.

In 2021 the new TUM School of Engineering and Design was founded, and the ESPACE master's degree program was allocated to the school. In 2024, the ESPACE program has been slightly redesigned in order to implement more flexibility in the first two semesters, which was identified as a point to be improved from feedback of current and former ESPACE students to the program office and the program board. Background is that until 2023, the list of modules in the first and second semester consisted of 12 required modules without any flexibility. The redesigned program gives students with different backgrounds the opportunity to choose modules of interest from the first semester onwards and to partially prepare their specialization in the second semester by selecting a set of modules of interest. The specialization in the third semester is kept unchanged but is revamped with research themes more prominent in the program. With respect to the previous program structure more interdisciplinary or cross-cutting seminars are now included, which shall ensure that students finally acquire a profound knowledge in all ESPACE themes and are able to work as satellite application engineers in academia or industry.