Module Catalog

M.Sc. Earth Oriented Space Science and Technology

Civil, Geo and Environmental Engineering

Technische Universität München

www.tum.de
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Module Catalog: General Information and Notes to the Reader

What is the module catalog?

One of the central components of the Bologna Process consists in the modularization of university curricula, that is, the transition of universities away from earlier seminar/lecture systems to a modular system in which thematically-related courses are bundled together into blocks, or modules.
This module catalog contains descriptions of all modules offered in the course of study.
Serving the goal of transparency in higher education, it provides students, potential students and other internal and external parties with information on the content of individual modules, the goals of academic qualification targeted in each module, as well as their qualitative and quantitative requirements.

Notes to the reader:

Updated Information

An updated module catalog reflecting the current status of module contents and requirements is published every semester. The date on which the module catalog was generated in TUMonline is printed in the footer.

Non-binding Information

Module descriptions serve to increase transparency and improve student orientation with respect to course offerings. They are not legally-binding. Individual modifications of described contents may occur in praxis. Legally-binding information on all questions concerning the study program and examinations can be found in the subject-specific academic and examination regulations (FPSO) of individual programs, as well as in the general academic and examination regulations of TUM (APSO).

Elective modules

Please note that generally not all elective modules offered within the study program are listed in the module catalog.

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Required Modules

Module Description

BV450001: Introduction to Earth System Science [ES]

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
In the written exam, the students should verify, by answering theoretical and numerical questions, that they are able to understand the basic components of system Earth and its main geodynamic processes in the Earth interior, at the surface, and the global energy budget. By means of numerical tasks and problems, it is verified that students are able to apply the mathematical and physical concepts for the solution of practical problems. By means of selected tasks, students should verify that students are able to interpret geophysical, geodetic and geodynamical results and to put them into the scope of geoscientific concepts.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Mathematical physics, linear algebra, time series analysis

Content:
Part A: components of the Earth System (atmosphere, ocean, cryosphere, solid Earth), electromagnetic radiation and matter, solar radiation, solar radiation and the Earth system, radiation balance, greenhouse effect, astronomical rhythms (day/night, seasons, Milankovitch cycle), atmospheric circulation, climate and land, oceans, mountains, deserts; what can be measured by satellites (active and passive sensors)
Part B: dynamics of the solid Earth
dynamics of the earth interior, heat exchange, mantle convection, lithosphere, analysis of seismic wave propagation, magnetic field, gravity field; what can be measured by/ with satellites (GPS, gravimetry, magnetometry, topography)
Interaction of inner and outer part of the earth system

Intended Learning Outcomes:
Upon successful completion of the module, students are able
- to understand the fundamental principles of the complex Earth system, its main geodynamic processes in the interior and on the surface, as well as their coupling mechanisms, - to understand the global energy budget,
- to understand the role of satellite observations for the monitoring of geodynamic processes in the Earth system,
- to work with observations, data and models of selected components fo the Earth system,
- to apply the mathematical and physical concepts concerning selected components of the Earth system,
- to analyze the results of these data and models,

- to understand these scientific contributions as integral component of geodetic Earth system research,
- to communicate on a scientific level with experts of different geoscientific disciplines.

Teaching and Learning Methods:
Classical teaching, ad hoc discussions with students, small assignments, short presentatiions

Media:
- Blackboard
- Powerpoint presentations in electronic form
- Exercise handouts

Reading List:
Part A: Kandel (1980): Earth and Cosmos. Pergamon
Part B: Grotzinger (2007): Understanding Earth and Lowrie (1997): Fundamentals of Geophysics

Responsible for Module:
Roland Pail (pail@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Module Description

BV570004: Numerical Modeling

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
In the written exam, the student should demonstrate that they are able to apply the mathematical methods listed in the learning outcomes and do the required calculations under time pressure. Also they should prove that they are able to analyse the accuracy of solutions and error budgets in a limited time. In addition course work in the form of 3-5 exercise reports for selected topics has to be provided as pass/fail credit requirements, i.e. they are not part of the grade, but have to be submitted. The work is usually started during supervised labs and finalized in groups as homework. Hereby the student should demonstrate that he/she is able to apply the mathematical methods and solve specific mathematical problems in a programming environment such as Matlab. In addition to the application and implementation, the student should show that he/she can interpret the results and be able to tell whether the results are reasonable or not.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Required:
- Knowledge in linear algebra, calculus, physics
- Programming in MATLAB

Recommended:
Basic knowledge in
- Statistics
- Signal Processing

Content:
Deepen the knowledge on:
- Mathematical foundations
- Series expansions
- Taylor expansion
- Finite difference methods
- Solutions of 1-D differential equations
- Time integration procedures

- Partial differential equations
- Methods of finite elements

Intended Learning Outcomes:
Upon successful completion of the module, students are able:
- to understand mathematical problems such as the solution of partial differential equations (PDEs),
- to apply the methods to given problems and to measurements;
- to understand, how physical/mathematical problems can be solved by numerical methods;
- to apply MATLAB routines for solving physical/mathematical problems;
- to analyse the accuracy of solutions and error budgets

Teaching and Learning Methods:
The module consists of a lecture and labs.

The lecture will be given by presentations. It provides the theoretical foundations.

In the labs, numerical exercises on the topics covered by the lecture are performed using MATLAB; for the most part, the lab is organised as homework with the requirement of preparing a written report on methodology and results.

Media:
- Presentation slides

- Lecture notes

- Selected text books and scientific publications

Reading List:
Selected text books and publications; will be recommended or distributed in the course

Responsible for Module:
Roland Pail (pail@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Labs in Numerical Modeling (exercise, 1 SWS)
Schmidt M

Numerical Modeling (lecture, 3 SWS)
Schmidt M

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV480026: Introduction to Photogrammetry, Remote Sensing and Image Processing

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The written exam takes 120 minutes with content of Photogrammetry and Remote Sensing on one hand and Image Processing on the other hand count both 50% of the achievable points. Questions contain drawing and explaining figures, answering questions on methods and solutions, calculations or comparisons of methods and their applicability. Additionally, multiple-choice-questions are including with statements that have to be evaluated as true or false. This part does not contain more than 20% of the total points. No aids or materials are allowed.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
None

Content:
Introduction: Definition Photogrammetry and Remote Sensing
"" Characteristics of Photogrammetry, applications und development
"" Characteristics of Remote Sensing, applications and development
"" Introduction the Photogrammetry: stereoscopic vision and measurement, photogrammetric image analysis, digital stereo processing
"" Introduction to Remote Sensing: Radiometric basics, multispectral classification
"" Optical basics: models and geometric quality of optical projections, description of image quality
"" Introduction to Image Processing
"" Features of digital images
"" Image transformation, convolution, edge detection
"" Segmentation
"" Binary image processing
"" Vectorization and geometric primitives
"" Feature extraction

"" Analyse applications from different points of view
"" Planning aerial image campaigns
"" Understand the principles of stereoscopic records
"" Evaluate stereo records and produce anaglyohe images
"" Understand concepts of photogrammetric image analysis
"" Know the physical basics of the electromagnetic spectrum and radiometric basics
"" Understand the principles of supervised and unsupervised classification
"" Use different classifiers and evaluate the classification results
"" Evaluate the influence of different factors on the image quality

"" evaluate characteristic features of images,
"" create and to apply different image transformations,
"" analyze images by semenetation and feature extraction
"" analyse binary images and to assess results
"" compare image processing operations

Intended Learning Outcomes:
After the successful conclusion oft the module, the students are able
- to understand basic concepts of photogrammetriy, remote sensing and image processing
- to apply fundamental methods to practical problems,
- to interpret the results
- to analyze applications from different points of view
- to plan aerial image campaigns
- to evaluate characteristic features of images,
- create and to apply different image transformations,
- to analyze images by semenetation and feature extraction
- to compare and assess image processing operations

Teaching and Learning Methods:
Lecture: Slides and lecture notes with small examples and discussion
Programming exercises with tutors for better understanding of the methods of image processing, home exercise for self problem solving

Media:
Lecture: Slides, lecture notes, whiteboard
Exercise: Working sheets, matlab exercises

Programming exercises with tutors for better understanding of the methods of image processing

Reading List:
"" Haralick, Shapiro (1992): Computer and Robot Vision (Vol. 1). Addison-Wesley, New York.
"" Castleman (1995): Digital Image Processing. Prentice Hall, Englewood Cliff, New Jersey.

Responsible for Module:
Uwe Stilla (stilla@tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Image Processing (lecture, 2 SWS)
Hoegner L

Photogrammetry and Remote Sensing (Espace) (lecture, 2 SWS)
Hoegner L [L], Stilla U

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV290016: Signal Processing and Microwave Remote Sensing

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
5	150	90	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
In the written exam, the student should demonstrate that they are able to apply the main mathematical methods and algorithms listed in the learning outcomes and do the required calculations under time pressure. By doing the calculations they should also in addition verify that they have understood the concepts of system theory and signal processing and the relation between space/time and frequency domain. The exam also contains theoretical questions related to the methods and applications of synthetic apperture radar (SAR) and by answering those the student should verify that they are able to explain the main concepts behind SAR.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Complex calculus, linear algebra, integrals, MATLAB programming skills are helpful

Content:
Teaching of advanced skills in the field of
- application of complex numbers in signal processing
- signals in time, space, and frequency domain (continuous and discrete)
- convolution of signals
- linear time-invariant systems
- random signals, signal reconstruction, and interpolation
- microwave remote sensing and synthetic aperture radar

Intended Learning Outcomes:
After the successful conclusion oft the module, the students are able to
- evaluate the applied mathematical models and algorithms
- explain advanced theoretical basics of system theory and signal processing
- analyze the potential of system theory and signal processing by different practice examples
- to evaluate the relation between space/time domain and frequency domain
- apply methods of signal processing to basic datasets
- explain basic methods and applications of synthetic aperture radar

Teaching and Learning Methods:
The module consists of two lectures whose contents are taught by talks, presentations, and panel painting. Practical examples and discussions encourage the students to devote themselves to topical contents. The understanding of lecture theory is supported by theoretical tutorials and programming exercises.

Media:
presentations in electronic form
handout
exercise sheets
panel

Reading List:
Bracewell, RN, The Fourier Transform and its Applications, McGraw Hill, New York,1965

Marko H, Methoden der Systemtheorie, Springer, 1982

Hänsler E, Statistische Signale, Springer, 1997

Gaskill JD, Linear Systems, Fourier Transforms, and Optics, John Wiley & Sons, 1976

Responsible for Module:
Richard Bamler (Richard.Bamler@dlr.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Systems Theory and Signal Processing (lecture, 2 SWS)
Bamler R (Körner M)

Introduction into Microwave and SAR Remote Sensing (lecture, 1 SWS)
Eineder M

Tutorial Systems Theory and Signal Processing (exercise, 1 SWS)
Zhu X

For further information in this module, please click
campus.tum.de or here.

Module Description

BV450002: Applied Computer Science

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The expected learning outcomes are verified by a written exam. In this written exam, it is verified that the students are able to know the theoretical and practical basics in computer science, and that they are able to use the respective terminology. Based on dedicated practical questions, it shall be verified that the students are able to analyze practical problems and that they are able to find appropriate solutions.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Basic knowledge in programming or computer science

Content:
Transfer knowledge about interdisciplinary topics in applied computer science on the basis of different computer science theories. The students should acquire theoretical and practical basics in computer science to find solutions for given tasks in their daily work and to use the terminology of computer science correctly within interdisciplinary teams. The dedicated contents are: computer architecture, binary logic, programming languages and language theory, software design, numeric, data organization, management and communication in combination with a practical programming task using Matlab, data and software engineering standards. The goal of this module is to bring the students coming from a range of different Bachelor studies to the same level of knowledge concerning software engineering skills.

Intended Learning Outcomes:
After the successful conclusion oft the module, the students are able to
- to understand the theoretical backgrounds of different computer science disciplines in combination with use cases,
- to apply language theory and state machines for lexical processing tasks (e.g. reading of coded files),
- to evaluate, rank and classify programming languages,
- to design software basics and to organize in software project phases,
- to process binary data with a Matlab-program,

Teaching and Learning Methods:
Classic university course with practical exeamples, feedbacks and a practical training section

Media:
The theory part consists of Powerpoint presentations, which are also provided to the students. The slides are extended with white board notes and exercise sheets with solutions for the private studies. The practical part offers code snippets and examples.

Reading List:
Lecture Notes, ECSS Standards Documents

Responsible for Module:
Roland Pail (pail@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Applied Computer Science (lecture, 2 SWS)
Neidhardt A, Gruber T

For further information in this module, please click
campus.tum.de or here.

Module Description

BV610001: Orbit Mechanics [OrbMech1]

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
4	120	75	45

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The expected learning outcomes are verified by a written exam. In this written exam, it is verified that the students are able to reproduce and to understand the theoretical and methodological basics of orbit dynamics. By means of dedicated numerical questions and tasks, it is verified that students are able to apply the mathematical and physical concepts of orbit dynamics for the solution of practical problems, and that they are able to interprete and assess the results. In addition, the competence to solve daily-work practical and numerical problems is supported by course work in the form of three exercise reports for selected topics of orbit dynamics, which have to be provided as pass/fail credit requirement. These numerical problems should be implemented in a programming environment such as Matlab. Hence it is ensured that the students have gained the programming skills, that they are able to apply them for the implementation of the main applications of orbit mechanics, and that they are able to assess and interpret the results. Time to work on the exercises is foreseen during the contact hours.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Basics in mathematics and physics are recommended

Content:
Lecture:
- Reference systems in space and time
- Two-body problem and Keplerian motion
- Orbit representations, Keplerian elements, groundtracks, repeat orbits
- Orbit perturbations, osculating elements, Gaussian perturbation equations, types of perturbations
- Gravitational perturbations by third bodies and Earth's gravity field
- Special orbit types: geostationary, sun-synchronous, critical inclination, frozen orbits
- Non-gravitational perturbations, solar radiation pressure, Earth albedo, air drag

Labs with Matlab:
- Representation of orbits in different frames
- Ephemeris calculation
- Transformation between inertial, earth-fixed and topocentric reference frames
- Methods of numerical integration
- Impact of different forces on orbits

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- to understand the basics of satellite motion and Celestial Mechanics,
- to apply the basic concepts and methods for orbit computation and for the conversion between reference frames,
- to understand the concept of gravitational and non-gravitational orbit perturbations,
- to assess the magnitude of different perturbations on satellite orbits at different heights,
- to analyze and to assess the properties of special orbits and to understand their use for specific applications,
- to understand the concept of ground track repeatability and its relevance in practise,
- to apply methods of numerical orbit integration.

Teaching and Learning Methods:
In the lecture the basics of representation of orbital motion in the two-body case and under the influence of perturbations are presented. Calculations and derivations are written to the blackboard. To demonstrate daily and annual motion of Sun and stars a mechanical model and an electronic simulator are used.
In the labs, based on Matlab, the students lern to apply the concepts of orbit representation in different frames with orbits of different types.

Media:
Lecture with power-point presentations with electronic handouts and blackboard, interleaved lab exercises with electronic handouts

Reading List:
- Montenbruck, Gill (2000):Satellite Orbits. Springer.
- Beutler (2005):Methods of Celestial Mechanics. Springer
- Lecture notes

Responsible for Module:
Urs Hugentobler (urs.hugentobler@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Orbit Mechanics (Lecture w/ Exercise, 3 SWS)
Hugentobler U [L], Hugentobler U

For further information in this module, please click
campus.tum.de or here.

Module Description

BV450021: Projects in Earth Oriented Space Science and Technology

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
8	240	150	90

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The expected learning outcome is verified with a scientific project report covering three areas: electrodynamics, satellite altimetry and a self-chosen topic. In the area of electrodynamics the students carry out the subproject "Optical properties of clouds and aerosols" and submit a written report on their own work. In doing so, they should show that they are able to implement the theory behind optical characteristics of clouds and aerosols in appropriate software. In the area of satellite altimetry for sea level determination the students carry out the subproject "Earth Observation Satellite Mission Data Analysis according to Software Engineering Standards" and submit a written documentation for the subproject (project proposal, definition of software, architecture, etc.). Hereby, the students should verify that they are able to develop software package for Earth observation data and know how to document it. In addition, the learning outcome of this area is also tested by an oral presentation. In the third area students choose, work out and present an up-to-date scientific topic on Earth oriented space science and technology. The presentations are spread over the lecture period. During the preparation of their presentation, students are guided by a supervisor who gives feedback and provides information material (in the form of scientific articles, books, slides, etc.). Hereby, with this module, the teamwork skills during the preparation as well as the presentation skills of the students are tested. The final grade arise out of work performed in all three areas: 37.5% in electrodynamics, 37.5% in satellite altimetry and 25% the self-chosen topic.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Recommended: Successful participation in the module Applied Computer Science

Content:
The module consists of three lectures; Electrodynamics, Software Engineering for an Earth Observation Satellite Mission and a Seminar

The theoretical part of the lecture Electrodynamics is organized as follows:
1. Mathematical background: scalar and vector fields; line and surface integrals; nabla operator; differential relationships for vector fields; irrotational and solenoidal fields; Gauss and Stokes theorems.
2. Electrostatic: Coulomb's law; the elastostatic field; divergence and curl of the elastostatic field.
3. Magnetostatic: Ampere's law; the magnetostatic field; divergence and curl of the magnetostatic field.
4. Electrodynamics: equation of continuity for the electric charge; Maxwell's displacement current; electromotive force; Faraday's law of induction; Maxwell's microscopic and macroscopic equations.
5. Electromagnetic waves: wave equation in time and frequency domains; plane and spherical waves; observables and averages.
6. Electromagnetic scattering theory: Stratton-Chu representation theorem; far-field pattern and amplitude matrix;

phase and extinction matrices; extinction, scattering and absorption cross-sections; optical theorem; reciprocity principle.
7. Mie theory: vector wave equation; vector spherical wave functions, solution of the transmission boundary-value problem; computation of the far-field pattern, optical cross-sections and phase function in the framework of the Mie theory.
8. Derivation of the adiative transfer equation starting from Maxwell's equations.

The last four lectures of Electrodynamics are devoted to practical aspects and consist in the elaboration of a project with the title: Optical properties of clouds and aerosols. The project will contain a theoretical part, which should be a synthesis of the electromagnetic scattering theory and should include the following topics: field characterization, extinction, scattering and absorption processes, polarization, and Mie theory. The computational part will involve the calculation of the phase matrix and of the wavelength-dependent extinction cross-section, scattering cross-sections and asymmetry parameter for clouds (stratus continental and maritime, cumulus continental and maritime, fog) and aerosols (small and large rural, small and large urban, maritime). The computations will be performed by using a dedicated Mie code for radiative transfer calculation. Great importance is attached to the synthesis abilities of the theoretical part and the interpretation of the numerical results.

Project: Earth Observation Satellite Mission Data Analysis according to Software Engineering Standards.
- Preparation of a project proposal
- Definition of Software & system requirements
- Development of a Software architecture
- Software development and implementation
- Data analysis (real data)
- Documentation of project
- Presentation of project
The topic of the project might vary. Currently a sea level analysis using satellite altimeter data is performed.

Seminar: Each student gives an oral presentation of 25 minutes length on an up-to-date scientific topic. Students can choose between various topics proposed by ESPACE teachers from different fields. Presentations are spread over the lecture period. During the preparation of their presentation the students are guided by a supervisor who gives feedback and provides information material (in the form of scientific articles, books, slides, etc..

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able:
- to know the process of developing software and know how to develop specific software packages for Earth Observation Data
- to deal with a large amount of satellite data
- to work in teams and to prepare scientific results,
- to present scientific results to an audience, i.e. how to design slides, structure the presentation, and how to defend the content in a discussion
- to know how to document a satellite application project in a written report
- to be familiar of how the way space agencies are running projects

Moreover students have gained an understanding for the theory behind the projects, i.e:
- understand the electromagnetic scattering aspect of radiative transfer
- be able to prepare with the appropriate software lookup tables for the optical characteristics of clouds and aerosols

Teaching and Learning Methods:

Media:
Blackboard teaching, power point presentations

Reading List:
lecture notes and scientific publications (distributed during the course)

Responsible for Module:
Roland Pail (pail@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV450020: Applied Earth Observation and Mission Engineering

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	105	75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
A written exam takes place in the end of the semester. By answering a number of questions under time pressure, the students should demonstrate that they are able to understand, analyze and develop concepts of ground segment design and have gained knowledge about the most important Earth observation satellite missions and an understanding for its most important applications. In addition course work in the form of an oral group presentation and a written group report is required as pass/fail credit requirements. Here the student should not only verify that they have gained the learning outcome defined for the project, but also that they are able to work in teams for preparing scientific results and that they are able to present orally their ideas and concepts for a satellite mission and to defend it in a discussion with the lecturers and the working teams.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Recommended: Successful participation in the module "Introduction to Photogrammetry, Remote Sensing and Image Processing"

Content:
The module Applied Earth Observation and Mission Engineering consists of two lectures, 1) Mission Engineering and Ground Infrastructure and 2) Applied Remote Sensing, as well as a project, Satellite Mission Design Project.

Mission Engineering and Ground Infrastructure:
Part 1: Mission Engineering: mission concepts, requirements and performance analysis, engineering standards and legal aspects
Part 2: Transfer of remote sensing data to ground and its technical and operational impact on mission and ground infrastructure
Part 3: Payload data handling, processing, data management, archiving and user interfaces. Thematic processing from raw data towards geo-information products
Part 4: Upcoming technologies and new mission concepts

Applied Remote Sensing:
- Earth observation systems and sensors
- Data processing and information extraction methods
- Remote sensing applications for environmental monitoring
- Integration into Geo Information Systems (GIS)
- Applications of remote sensing in natural disasters management and humanitarian aid
- Emergency response and early warning systems
- European Earth Observation Program - Copernicus

- Infrastructure for Spatial Information in Europe

Satellite Mission Design Project:
In groups of about 5-7 students a proposal for a satellite mission (the topic is provided by the teacher) has to be worked out. The proposal should contain scientific objectives and mission design such as orbit, payload, spacecraft, and launcher. Existing software is applied for orbit computations. In a final presentation, the proposals of each group have to be defended.

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to understand the elements of an Earth observation ground segment and its interaction with the satellite and its sensors. They are able to analyze existing ground segments and to develop concepts for new and user specific ground segments based on engineering methods and standards.
The students know about the most relevant Earth observation missions and are able to analyze their appropriate fields of applications according to the sensor specifications. They are able to understand the application of remote sensing and GIS techniques for environmental mapping and monitoring. They can evaluate the possibilities and limitations of using earth observation for disaster management and emergency mapping, and they know the relevant international mechanisms, which are put in place by space agencies world-wide. They are able to provide an overview on the main objectives of the European programs COPERNICUS and INSPIRE.
The students have acquired knowledge about the design and the various components of a satellite mission. Also they should be able to define their own ideas regarding the design and describe certain components of the mission design in detail. They are able to apply existing planning software and evaluate the results of the simulations. In addition they should be able to present the ideas in an oral presentation.
The students have acquired social and self-compentencies regarding teamwork and presentation of scientific material to a larger audience.

Teaching and Learning Methods:
Lectures on Mission Engineering and Ground Infrastructure and Applied Remote Sensing: Teaching using power point slides and black board. The lectures also contain practical examples and discussions.
Satellite Mission Design Project: Group work, which should be presented in an oral presentation.

Media:
- Lecture slides
- Lecture notes
- Exercise sheets
- Black / white board

Reading List:
Presentations and lecture notes
Handbook of Space Technology, Wiley & Sons, 2009
Space Mission Analysis and Design, Wiley J. Larson and James R. Wertz

Responsible for Module:
Roland Pail (pail@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Module Description

BV610023: Satellite Navigation and Advanced Orbit Mechanics

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The expected learning outcomes are verified by a written exam at the end of the semester. In this written exam, the students should demonstrate that they are able to understand the concepts and algorithms used for satellite navigation and precise absolute and relative positioning, that they are familiar with the concept of linear combinations of observations, have an understanding of the impact of signal propagation errors, and can discuss advanced aspects of satellite orbits. The competence to solve daily-work practical and numerical problems is supported by course work in the form of 3-5 exercise reports for selected topics of carrier phase data analysis and analytical orbit theory, which have to be provided as pass/fail credit requirement and are evaluated by applying a pre-defined evaluation scheme. These numerical problems should be implemented in a programming environment such as Matlab ensuring that the students have gained the programming skills required to solve specific problems in satellite navigation and orbit theory. Time to work on the exercises is foreseen during the contact hours.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Recommended: Mathematics, fundamentals of probability calculations and statistics as well as successful participation in the module Orbit Mechanics

Content:
The module consists of three lectures; Introduction to Satellite Navigation, Carrier Phase Positioning, and Advanced Celestial Mechanics. The first two lectures are blocked, Introduction to Satellite Navigation takes place in the first part of the semester, Carrier Phase Positioning takes place in the second part of the semester. Carrier Phase Positioning and Advanced Celestial Mechanics are accompanied by exercise labs.

Introduction to Satellite Navigation:
- Principles of satellite navigation
- Space segment and ground segment
- Code and phase observations
- Observation equations
- Propagation error sources
- Differences and linear combinations

Carrier Phase Positioning:
- Differential GPS and GNSS

- Carrier smoothing
- Augmentation systems for aeronautical and other critical navigation tasks
- Carrier phase ambiguity resolution

Advanced Orbit Mechanics:
- Orbit determination
- Selected problems: Lagrange points, swing-by
- Analytical orbit theory: Hill-theory

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to:
- to understand the concept and algorithms of satellite navigation and precise positioning,
- to apply them to practical problems of satellite navigation and precise positioning,
- to assess the impact of error sources on signal propagation,
- to compute linear combinations and evaluate tracking data quality,
- to apply processing strategies to analyze GNSS data for precise positioning applications,
- to understand the principles and concepts of differential navigation and augmentation systems,
- to apply phase ambiguity resolution strategies,
- to understand the concepts of orbit determination, analytical orbit theories and the origin of Lagrange points,
- to apply these concepts to practical problems and to analyze and assess the results.

Teaching and Learning Methods:
Lecture using power point with calculations derived at the blackboard in interaction with the students. Labs using Matlab.

Media:
Presentations, lecture notes in electronical form, exercises

Reading List:
Recommended books:
- Montenbruck and Gill (2000): Satellite Orbits, Springer
- Beutler (2005): Methods of Celestial Mechanics, Springer
- Misra and Enge (2004): Global Positioning System: Signals, Measurements, and Performance, Ganga-Jamuna Press.
- Kaplan and Hegarty (1996): Understanding GPS: Principles and Applications, Artech House.
- Parkinson and Spilker Jr. (1996): Global Positioning System: Theory and Applications Vol. I/II, American Institute of Aeronautics and Astronautics.
- Teunissen and Kleusberg (1998): GPS for Geodesy, Springer

Responsible for Module:
Urs Hugentobler (urs.hugentobler@mytum.de)

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV310004: Estimation Theory

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	45	45

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
In a written exam, it is verified that the students are able to reproduce and to understand the basics of probability theory and the key features of different estimation methods, enabling them to select in practice the appropriate method for a certain practical problem. Based on selected case studies and practical problems, it is verified that the students are able to analyze and to solve fundamental estimation problems, that they are able to assess the feasibility of various estimation models, and that they are able to interpret the results within a limited timeframe and without additional support material.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
complex calculus, signal processing, linear algebra, integrals, probability theory, principles of photogrammetry and remote sensing

Content:
Teaching of advanced skills in the field of
- basics of probability theory
- methods for detection, classification, and parameter estimation
- estimation methods in time- and frequency domain
- selection of proper estimation models
- examples for the application of estimation methods in practice

The topic of estimation theory is a pre-requisite for a multitude of applications in the analysis, modelling and interpretation of satellite data.

Intended Learning Outcomes:
Upon successful completion of the module, the students are able to
- understand the basics of probability theory
- analyze the potentials and limitations of different estimation methods
- solve basic estimation problems and to evaluate therefore the applicability of estimation models

Teaching and Learning Methods:
The module consists of one lecture whose contents are taught by talks, presentations, and panel painting. Practical examples and discussions encourage the students to devote themselves to topical contents. The understanding of lecture theory is supported by solving practice related problems.

Media:
- presentations in electronic form
- handout
- exercise sheets
- panel

Reading List:
- Papoulis, A., Probability, Random Variables, and Stochastic Processes, McGraw Hill, New York, 1977.
- Sivia, D.S., Data Analysis: A Bayesian Tutorial, Oxford Science, Publications, 1996.
- Hänsler, E, Statistische Signale, 2. Aufl., Springer, Heidelberg, 1997.
- Rodgers, C. D., Inverse methods for atmospheric sounding: Theory and practice, World Science, London, 2000.

Responsible for Module:
Richard Bamler (Richard.Bamler@dlr.de)

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Module Description

MW1860: On Orbit Dynamics and Robotics

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
In a written exam, by means of dedicated questions it is verified that the students are able to reproduce the principles of spacecraft dynamics and of robotic systems dynamics in orbit and the basic principles of orbit control operations. With dedicated tasks and questions, it is also verified that the students are able to apply these principles for ground validation, that they are able to understand the future potential of robots in orbit, and that they are able use the competencies acquired to link present-day strategies for the design of future systems.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Recommended: Basics of astronautics, mechanics and control systems.

Content:
Kinematics and dynamics of mechanical systems, including a material point, a rigid body and a multibody system.
Orbit dynamics and control, including also orbital relative motion, orbital transfers and rendevous-and-docking.
Attitude dynamics and control, including also actuators and sensors.
Robot control, including open-loop, closed-loop and tele-presence control methods (basics), actuators and sensors, experimental facilities.

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able
- to understand the principles of spacecraft flight and of orbital robotic systems dynamics
- to apply these principles to practical problems and to evaluate and asses the results
- to understand the control principles applied for orbital, spacecraft attitude and robotic operations,
- to apply them in practical application,
- to apply the techniques for verification of the behaviour of these systems on ground,
- to gain insight into the current and possible future uses of robots in orbit and to develop potential future applications.

Teaching and Learning Methods:
class lecture
The module contains lectures and exercises within the lectures.

Media:
Lecture with power-point presentations with electronic handouts and blackboard,
interleaved lab exercises with electronic handouts.

Reading List:
Walter: Astronautics
Sidi: Spacecraft Dynamics and Control
Sciavicco/Siciliano: Modelling and Control of Robot Manipulators
Wertz: Spacecraft Attitude Determination and Control

Responsible for Module:
Wilde, Markus; Dipl.-Ing. (Univ.)

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

MW1983: Spacecraft Technology

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	two semesters	winter/summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
8	240	150	90

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The module Spacecraft Technology comprises two thematically related subject areas which are based upon each other, namely the theory and physics of rocketry and astronautics (summer term) and the engineering and desing of the spacecraft system and its mission. The evaluating and analytical command of both expertise clusters is a fundamental prerequisite for the professional qualification of a space craft engineer. This fact requires the independent and successful verification of the learning outcome of both competence bundles. An academically educated engineer in the field of rocketry, astronautics and spacecraft desing has to proof knowledge in the field of the physical and theoretical rocket science on the one side and the engineering and desing part of the spacecraft itself on the other side. Both aspects are indispensable for the professional competence of the prospective graduate. Besides the advantage to split the exam burden of a two-semester module into two seperate, timely staggered exams (at the end of the 2nd semester and at the end of the 3rd semester), this assesment approach enables effectually the learning achievement of both study clusters. Both parts have to be passed individually. Only this test scheme for the module "Spacecraft Technology" allows the documentation of the achievement of the entire course objectives. Each of the two exams comprises typically 20 tasks - short questions as well as calculation problems with a partitioning of about 50% and 50%, respectively, which have to be answered and solved pressed for time. To work on the exam, the students are provided with a formulary; besides a non-programmable calculator, no further auxiliary material is allowed.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
None

Content:
The lectures of the summer semester provide knowledge of the fundamentals of Rocketry:
Rocket Equation
Rocket Staging
Rocket Propulsion (chemical and electrical)
Launcher Systems
Space Environment
Rocket Ascent
Astrodynamics
Trajectories
Orbit Transfers

The lectures of the winter semester provide knowledge of the fundamentals of space mission and spacecraft design:

Mission Design (requirements, trade studies)
Mission Geometry & Orbit Selection
Orbit Perturbations
Space Environment
Satellite Payloads (typical)
Structure & Mechanisms
Attitude Determination and Control System
Propulsion System
Communication System
Power System
Thermal Control System

Intended Learning Outcomes:
After the successful conclusion of the first part of the module (summer term) , the students will be able to apply the basic physics of rocketry and propulsion to carry out a first order desing of a launcher system with respect to the design budgets of mass, power and volume. The students are able to analyse the complexity and the limitations of launching space craft systems and payloads into orbit. Furthermore, the students are able to apply the basic theory of astronautics, especially that of orbital trajectories and transfer maneuvers, with respect to the space craft's propulsion efficiency and the mission time. In general, the students are able to evaluate typical baseline launcher concepts and mission concepts with respect to the typical trade-offs in rocketry, namely mass and power.

After the successful conclusion of the second part of the module (winter term) the students will have learned all relevant theory and engeneering tools for analysing the major elements of a typical space mission with special emphasis on the space element, namely the spacecraft itself. The students will be able to understand the complex interactions between the spaceflight environment, spacecraft sub-systems and mission needs, can analyze relevant requirements and find first order solutions for mission planning purposes. Students will be able to evaluate spacecraft systems and perform basic optimizations with respect to the typical trade-offs comprising power, mass, data rate, lifetime, complexity and reliability. The students will be able to evaluate the basic interactions between the design drivers for spacecraft systems and to implement them in the typical design processes.

Teaching and Learning Methods:
In the lecture, the topics are taught with the help of presentations and black board sketches. The accompanying tutorials repeat and engross the crucial topics. With the help of rough calculations and rule of thumb methods, the studens lern how to do first order system evaluations.

Media:
lecture, presentation, powerpoint assistance, hand-outs, black board

Reading List:
Lecture notes; U.Walter, Astronautics, Wiley-VCH, ISBN 3-527-40685-9;

Further literature survey is given in the hand-out

Responsible for Module:
Rott, Martin; Dr.-Ing.

Courses (Type of course, Weekly hours per semester), Instructor:
Spacecraft Technology 2 (lecture, 3 SWS)
Rott M, Killian M

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

MW1979: Introduction to Spacecraft Technology

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
4	120	75	45

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The module Introduction to Satellite Technology coveres the theory and physics of rocketry and astronautics. The evaluating and analytical command of this expertise cluster is a fundamental prerequisite for the professional qualification of an academically educated rocket engineer. To proof the learning achievement of this study cluster, the students have to pass a written exam pressed for time. The exam comprises typically 20 tasks, which are short questions as well as calculation problems with a partitioning of about 50% to 50%. To work on the exam, the students are provided with a formulary; besides a non-programmable calculator, no further auxiliary material is allowed.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Student has to be registered in ESPACE Double Degree Program and spend the 5th semester at Wuhan University.

Content:
The course provides knowledge of the fundamentals of Rocketry: Rocket Equation; Rocket Staging; Rocket Propulsion (chemical and electrical); Launcher Systems; Space Environment; Rocket Ascent; Astrodynamics; Trajectories; Orbit Transfers

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to apply the basic physics of rocketry and propulsion to carry out a first order desing of a launcher system with respect to the design budgets of mass, power and volume. The students are able to analyse the complexity and the limitations of launching space craft systems and payloads into orbit. Furthermore, the students are able to apply the basic theory of astronautics, especially that of orbital trajectories and transfer maneuvers, with respect to the space craft's propulsion efficiency and the mission time. In general, the students are able to evaluate typical baseline launcher concepts and mission concepts with respect to the typical trade-offs in rocketry, namely mass and power.

Teaching and Learning Methods:
In the lecture, the topics are taught with the help of presentations and black board sketches. The accompanying tutorials repeat and engross the crucial topics. With the help of rough calculations and rule of thumb methods, the studens lern how to do first order system evaluations.

Media:
lecture, presentation, powerpoint assistance, hand-outs, black board

Reading List:
Lecture notes; U.Walter, Astronautics, Wiley-VCH, ISBN 3-527-40685-9;

Further literature survey is given in the hand-out

Responsible for Module:
Rott, Martin; Dr.-Ing.

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Specialization Subjects

Technische Universität München

Specialization Subject 1: Earth System Science from Space

Required Elective Modules

Technische Universität München

Module Description

BV450006: Atmosphere and Ocean

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
With an oral examination it shall be ensured that the students are not only able to remember and understand the individual concepts covered by the two lectures, but they should verify that they are able to build interrelations among these concepts, and that they have an insight into their contribution to the overarching concept of system Earth. By means of dedicated questions, it is verified that the students are able to interpret results of observation technologies and that they are able to build connections to physical modelling.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Atmospheric Physics and Remote Sensing: Mathematics, experimental Physics; Oceanography and Satellite Altimetry: Mathematical physics, linear algebra, time series analysis

Content:
Atmospheric Physics and Remote Sensing: Introduction to atmospheric physics with an emphasis on remote sensing of atmospheric components and processes from space:
- atmosphere, weather and climate,
- clouds, aerosols and trace gases,
- radiative transfer,
- Earth's energy budget,
- remote sensing of the atmosphere,
- climate modelling and climate change

Oceanography and Satellite Altimetry:
- Equation of motion,
- geostrophic currents,
- hydrostatic balance,
- temperature, salinity, and density,
- ocean tides, tidal analysis,
- de-aliasing,
- radar and laser altimetry,
- altimeter mission overview,
- where to get what data,
- corrections of altimeter observations,
- repeat pass and crossover analysis,

- mean sea surface, geoid, dynamic ocean topography, sea level variability, sea level rise

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to understand the basic principles of atmosphere, weather, and climate and the methods for determining atmospheric composition and dynamics from space, and they shall be able to apply these principles and methods for practical problems. Further the student shall understand and apply the most basic principles of physical oceanography and recognize satellite altimetry as an operational remote sensing technique with important applications in geodesy, oceanography and other geosciences. In addition, students shall know about satellite altimeter missions, be able to understand and to apply observation techniques and the necessary measurement correction, shall know where to get data and products and how to access data. The students shall also be able to understand important analysis methods and to apply them to practical problems. They should also remember and understand the geophysical application of satellite altimetry and they shall be able to link it to the monitoring of several components of the Earth system.

Teaching and Learning Methods:
Power point presentations; handouts in electronic form; blackboard

Media:
- presentations in electronic form
- Blackboard
- Selected text books and scientific publications

Reading List:
Atmospheric Physics and Remote Sensing: F.W. Taylor, Elementary Climate Physics, Oxford University Press, 2005.
Further reading:
J.M. Wallace and P.V. Hobbs, Atmospheric Science: An Introductory Survey, Academic Press, 2nd edition, 2006.
W. Roedel, Physik unserer Umwelt: Die Atmosphaere, Springer, 3. Auflage, 2000.
L. Bergmann und C. Schaefer, Lehrbuch der Experimentalphysik Band 7: Erde und Planeten, de Gruyter, 2. Auflage, 2001.
Oceanography and Satellite Altimetry: Stewart, R.: Introduction to Physical Oceanography (OpenSource Book, see download)
Fu, L.L. and A. Cazenave (Eds.) Satellite Altimetry. International Geophysics Series, Vol. 69, San Diego, CA, 2000

Responsible for Module:
Roland Pail (pail@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Atmospheric Physics and Remote Sensing (lecture, 2 SWS)
Kiemle C

Satellite Altimetry and Physical Oceanography (lecture, 2 SWS)
Seitz F [L], Bosch W, Passaro M

For further information in this module, please click
campus.tum.de or here.

Module Description

BV570001: Earth System Dynamics

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The learning outcome of the module is certificated after students have passed a written exam and the corresponding labs. By the written exam, it is verified that the students are able to deeply understand the main dynamical processes of the Earth system, that they are able to apply methodologies to practical geophysical problems, and that they are able to evaluate and to interpret the results. During the semester students are expected to prepare individually a written report on a project in the frame of a seminar. By this written reports, is verified that the students are able to interlink in a self-contained way various sub-topics of Earth system dynamic into a global picture.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Required:
- Basic knowledge in linear algebra, calculus, mechanics
- Programming in MATLAB

Recommended:
Successful participation in the modules
- Introduction to Earth System Science
- Numerical Modeling
- Signal Processing

Content:
1 Introduction to Earth System Science
1.1 System Earth and its Components
1.2 Geophysical Fluids and Solid Earth
1.3 Geometrical and Gravimetrical Observation Techniques

2 Geophysical Fluids: Internal Processes and Interactions
2.1 Atmosphere Dynamics
2.2 Ocean Dynamics
2.3 Atmosphere-Ocean Interaction

3 Models of Atmosphere and Hydrosphere
3.1 Atmospheric General Circulation Models and Reanalyses
3.2 Ocean Circulation Models and Data Assimilation
3.3 Coupled Models

4 Interactions Between Geophysical Fluids and Solid Earth
4.1 Earth rotation and the Balance of Angular Momentum
4.2 Gravity Field Variations and their Geophysical Interpretation
4.3 Surface Deformation by Atmospheric and Hydrospheric Loading

5 Seminar on Climate Change
5.1 Keynote Lectures by invited guests
5.2 Project work

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to understand dynamic processes in the Earth system, apply geophysical models of processes and evaluate numerical results and prognoses.
Through the preparation of a written report on a project related to climate change on the basis of three invited keynote speakers, students are able to gain competence across various subjects covered by ESPACE.

Teaching and Learning Methods:
2 SWS lecture on Earth System Dynamics: Provides theoretical foundations of dynamic processes and interactions in the Earth system as well as of numerical physical models.

1 SWS labs on Earth System Dynamics: Numerical exercises on the topics covered by the lecture using MATLAB; for the most part, the lab is organised as homework with the requirement of preparing a written report on methodology and results.

1 SWS Seminar with guest lecturers: Three invited guests from space agencies, research institutes and the space industry give keynote lectures on topics related to climate change. On the basis of these introductory lectures, students will work on a project using actual satellite or model data from the context of climate change signals. Students will prepare a written report on the methodology and outcome of the project which contributes with 1/4 to the final mark of the module.

Media:
- Presentation slides

- Lecture Notes

- Selected Scientific Publications which will be distributed in class

Reading List:
- Lecture Notes

- IPCC (2007): Climate Change 2007: Synthesis Report, Geneva.

- Kandel, R. (1980): Earth and Cosmos, Pergamon Press, Oxford

- Selected scientific publications will be distributed in the course

Responsible for Module:
Florian Seitz (seitz@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Seminar with Guest Lecturers (seminar, 1 SWS)
Pail R

Earth System Dynamics (lecture, 2 SWS)
Seitz F [L], Bloßfeld M

Labs in Earth System Dynamics (exercise, 1 SWS)
Seitz F [L], Bloßfeld M

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV570002: Earth Observation Satellites

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The written exam aims to verify that the student knows the concept behind satellite gravimetry and satellite magnetometry as well as the relationship between the measurements and the respective potential field parameters by answering a number of theoretical questions under time pressure. In addition the students should hand in 3-5 lab reports. The student should demonstrate that they are able to analyze different satellite data on specific applications and know how to document this in a report. The students should also defend the results in discussions with the lecturer and thereby the lecturer can make sure that the student has gained a deeper understanding for the outcome of the labs. The final grade is an averaged grade from the exam (50%) and from the lab reports (50%). The evaluation of the lab reports contains both the quality of the report itself, but also the performance during the defense and discussion.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Recommended:
Successful participation in the modules:
- Introduction to Earth System Science
- Introduction to Photogrammetry, Remote Sensing and GIS
- Orbit Mechanics 1
- Signal Processing
- Electrodynamics

Content:
This lecture is devoted to Earth observation satellites. Instead of giving an overview of existing Earth Observation satellites, this lecture shall concentrate on some Earth observation satellites. For these Earth Observation Satellites, the lecture will concentrate on the connection between the scientific objectives, the instrument and the satellite data.

The first part will give an introduction to potential field theory, to the principles of satellite gravimetry and magnetometry. The principles and goals of the satellite missions CHAMP, GRACE, GOCE, ØRSTED, SAC-C and SWARM are discussed, as well as applications of these satellite data in earth sciences.

The second part will give an introduction to ESA's Earth Observation programs and satellite missions, such as

ERS, ENVISAT, Sentinel. The lecture will focus on the scientific missions, the instruments carried on board and the obtained data sets. The main applications of Earth Observation data within Earth System Science will be introduced.

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to describe the principle characteristics of satellite gravimetry and satellite magnetometry, as well as to explain the relationship between the measurements and the respective potential field parameters. The students have a basic understanding of satellite missions of this type and their application in earth sciences.

In addition, the students are able identify main goals of satellite missions and explain the principles of typical Earth Observation satellite instruments. They can apply remote sensing methods for satellite data and retrieve information from Earth Observation data from selected instruments with means of available software provided by ESA. They are able to evaluate the performance and usability of the software and document it in a report and defend in a scientific discussion.

Teaching and Learning Methods:
2 SWS: Lectures and labs on Gravity and Magnetic Field from Space. Further the student shall hand in written lab reports.
2 SWS: Labs on different ENVISAT instruments. Written lab reports are required.

Media:
Presentations and Lecture notes
ENVISAT Product Handbooks and documentation of the toolboxes
software for the labs

Reading List:
Selected scientific publications
Presentations and Lecture notes
ENVISAT Product Handbooks and Documentation of the toolboxes

Responsible for Module:
Florian Seitz (seitz@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Earth Observation Toolboxes (lecture, 2 SWS)
Iwaszczuk D [L], Iwaszczuk D, Schack P

Gravity and Magnetic Field from Space (lecture, 2 SWS)
Pail R [L], Pail R, Gruber T

For further information in this module, please click
campus.tum.de or here.

Elective Modules

Module Description

BGU45026: Earth Observation Mission Design Seminar

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	45	45

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The module will be evaluated by a presentation of at least 30 min. which will be regarded as a study result of this course.
With the study result it will be evaluated if the students acquired competences to define, analyze and evaluate the scientific and technical requirements of a new Earth observation satellite mission. For this it is required to do a literature survey and to apply competences obtained during previous studies. The design of a new concept requires in addition to cross-check the technical and scientific requirements against each other, which will be done by team work and exchange of competences within the team of students. The student teams will be supported by consultancy of the lecturers.
Information about study result: At the end of the seminar the student team gives an overview about the developed mission design and the related scientific and technical requirements. During intermediate meetings with the lecturers the next development steps will be discussed. The study results will be done by students homework.

Repeat Examination:

(Recommended) Prerequisites:
It is recomemnded to have basic knowledge about matehmatics, physics and engineering sciences as it is typically acquired in an engineering course at Bachelor level.

Content:
Course: ¿Earth Observation Mission Design Seminar¿
The course will be organized as seminar, which will address the following content: Definition of scientific and technical requirements for am Earth observation satellite mission; Introduction of the various components of a satellite mission (satellite bus, instruments, ground segment, etc.); Planning of satellite orbits in order to reach the mission requirements; Development of a measurement concept in order to reach the mission requirements; Specification of the data management on board of the satellite and together with groudn stations; Definition of processing algorithms for the data products to be computed.

Intended Learning Outcomes:
After participating at the module students are capable,
- to understand the components needed to design an Earth observation satellite mission,
- to understand and to analyze the interactions between the various components,
- to define the scientific requirements for an Earth observation satellite mission,
- to develop a mission design for one or a constellation of satellites meeting the scientific requirements,

- to analyze the mission concept and the developped mission design,
- to assess the scientific and technical requirements of a new Earth observation satellite mission.

Teaching and Learning Methods:
The course will be held as seminar, i.e. the students develop a mission design for a given topic and present intermediate and final results to the lectureres. All results will be discussed with the complete team and next steps to be done will be discussed.

Media:
Presentations, Documents, Publications

Reading List:
not required

Responsible for Module:
Roland Pail

Courses (Type of course, Weekly hours per semester), Instructor:
Earth Observation Mission Design Seminar (seminar, 3 SWS)
Gruber T, Pail R

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BGU45027: Earth Observation Mission Development Seminar

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3			

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:

Repeat Examination:

(Recommended) Prerequisites:

Content:

Intended Learning Outcomes:

Teaching and Learning Methods:

Media:

Reading List:

Responsible for Module:

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Module Description

BV290015: Remote Sensing

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
A written exam takes place in the end of the semester. The exam contains theoretical questions as well as calculations. By answering the questions in a limited time, the student should demonstrate that he/she is able to apply signal processing methods on remote sensing applications. Furthermore the student should hand in a written lab report and thereby verify that he/she is able to implement self-containedly certain parts of regularization theory and to evaluate the results in a project report. In addition the student should present a research work in an oral presentation and defend their ideas. Here it is tested that the student has gained a deeper understanding for research topics within remote sensing, that he/she is able to work independently on a research topic and is able to defend his/her own ideas. The final grade is an averaged grade from the written exam (50%) and from the written project report and oral presentations (50%).

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Required: Basic knowledge in photogrammetry, mathematics and physics.
Recommended: Successful participation in the module Introduction to Photogrammetrie, Remote Sensing and GIS.

Content:
Remote Sensing - Advanced Methods:
1. Along-Track and Across-Track Interferometry
2. Differential SAR Interferometry
3. Persistent Scatterer Interferometry
4. Remote Sensing of the Atmosphere
5. Remote Sensing of the Oceans

The processing of SAR data is trained in tutorials.

Non-linear Optimization Methods:
Inverse Problems and Nonlinear Optimization Theory:
1. Ill-posed linear problems (concept of ill-posedness, regularization issues, discretization by projection, regularization by projection)
2. Tikhonov regularization for linear problems (formulation, error analysis, parameter choice methods)
3. Tikhonov regularization for nonlinear problems (formulation, error analysis, implementation issues)
4. Optimization theory: Minimization methods for smooth functions (step-length based methods, trust-region methods)

5. Optimization theory: Minimization methods for sum of squares (Gauss-Newton method, quasi-Newton method, trust-region methods)
6. Iterative regularization methods (Landweber iteration, Newton-type methods, regularizing Levenberg-Marquardt method, regularizing trus-region methods

Seminar Remote Sensing
The seminar provides deep insight into specific and selected topics of remote sensing. Topics to be elaborated and presented are given at the Kick-Off meeting and combine, for instance, methods and applications of remote sensing/image analysis.

Intended Learning Outcomes:
After participating in the module, the students are able to

- understand and apply methods of signal processing in remote sensing
- evaluate the usability of specific remote sensing methods for practical problems
- understand the fundamental basics of regularization theory
- evaluate results of the application of regularization techniques in a project report
- analyze autonomously tasks in the research field of remote sensing
- prepare methodical basics for a selected research topic
- evaluate alternative approaches in practice and to develop own solutions
- present the elaborated results in a talk

Teaching and Learning Methods:
Lecture notes, slides, applications and examples, discussion, presentation, literature work, programming

Media:
Slides, lecture notes, exercise sheets, white-/blackboard

Reading List:
Remote Sensing - Advanced Methods: Sabins FF, Remote Sensing Principles and Interpretation, W.H. Freeman and Company, 1997 Cumming IG, Digital Processing of Synthetic Aperture Radar, Artech House, 2005
Non-linear optimization: lecture notes
Remote Sensing Seminar: selected litterature (such as scientific papers) will be provided for each topic individually

Responsible for Module:
Richard Bamler (Richard.Bamler@dlr.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Non-linear Optimization (lecture, 1 SWS)
Doicu A

Lab for Remote Sensing - Advanced Methods (exercise, 1 SWS)
Schmitt M

Remote Sensing - Advanced Methods (lecture, 1 SWS)
Zhu X

Remote Sensing Seminar (seminar, 1 SWS)
Zhu X

For further information in this module, please click
campus.tum.de or here.

Module Description

BV300003: Geo-Information

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
A written exam takes place in the end of the semester. By answering the questions the student should verify that they have gained the required knowledge about spatial data management, the analysis of geodata, spatial data mining and cartographic techniques for visualising spatial data. The exam contains questions in which they have to give valid definitions, explain concepts, theoretically implement and evaluate case studies, as well as mastering design challenges. All learning outcomes are covered by this written exam.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Knowledge of higher mathematics and experiences of handling spatial data

Content:
This module includes the following topics:
¿ Introduction to GIS;
¿ Spatio-temporal representations and databases;
¿ Spatial data analysis;
¿ Spatial data mining;
¿ Data retrieval and cartographic techniques;
¿ Case studies of Geoinformation;
¿ Introduction to ArcGIS components;
¿ Working with multiple data tables;
¿ Learning spatial analysis methods;
¿ Building 3D models;
¿ Creating animations;
¿ Designing a quality Map in a GIS;
¿ Collecting spatial data during field work;
¿ Integrating GPS data to a GIS;
¿ Publishing geographic information online.

Intended Learning Outcomes:
Upon completion of the module, students are able to¿
¿ illustrate the dimensions of geoinformation;
¿ explain the structure of a GIS;
¿ understand data mining concepts;
¿ implement concepts of geodata harmonization to integrate geodata into a GIS;
¿ implement geostatistical methods;

¿ apply properties of different map projections and to select appropriate projections for specific purpose;
¿ implement map generalization concepts and algorithms;
¿ integrate the functional and the organizational workflow of geodata-management and implement them into system-architectures using established concepts of geodata modelling;
¿ evaluate spatial databases and the spatial data quality within geodata-management;
¿ create queries for geodata analysis;
¿ create well designed maps;
¿ generate three dimensional data models.

Teaching and Learning Methods:
The module is structured in lectures and exercises. The lectures provide the theoretical foundations of geoinformation. They impart knowledge about spatial data management, the analysis of geodata, spatial data mining and cartographic techniques for visualising spatial data. The exercise part of this module allows the students to employ their GIS knowledge to applied studies. An introduction to ArcGIS will be given and the students can analyse and visualise geodata using a variety of analysis tools and visualisation techniques. A set of exercises put the theoretical knowledge into practice. The exercises are carried out in a computer lab individually, partly under supervision and partly in self-study. Feedback on the exercises is given to each student within a personal one-on-one discussion.

Media:
Moodle E-learning, presentations, script, GIS laboratory, hand-outs, recommended literature

Reading List:
Longley, P. A., Goodchild, M. F., Maguire D. J., Rhind, D. W. (Eds.) (2005): Geographical Information Systems ¿ Principles, Techniques, Management and Applications. John Wiley & Sons.
Law, M., Collins, A. (2013): Getting to Know ArcGIS for Desktop. Esri Press.

Responsible for Module:
Liqiu Meng, liqiu.meng@tum.de

Courses (Type of course, Weekly hours per semester), Instructor:
Geoinformation (lecture, 4 SWS)
Meng L, Murphy C

For further information in this module, please click
campus.tum.de or here.

Module Description

BV400016: Scientific Paper Writing [SPW]

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	70	20

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Students have to submit a scientific paper which is written in groups. The students demonstrate with their papers that they have gained deeper knowledge of the specific requirements of a scientific paper, including structure, appropriate presentation of information and discussion as well as the related formalities. The students are able to develop a topic for their papers and formulate the problem statement, objectives and research questions. Furthermore, the students are able to develop a conceptual frame and present as well as analyze information and formulate conclusions. Finally, the students are able to meet the formalities of a scientific paper including proper quotations, layout and language.

Repeat Examination:

(Recommended) Prerequisites:
none

Content:
1. The research process: main steps to undertake in a research project leading to the preparation of a scientific paper.
2. Scientific paper writing: main components of a scientific paper and their respective contents with focus on topic development and logical construction of line of argument.
3. Sources of Information: main sources of information for writing scientific paper, with focus on scientifically valid sources and how to identify these.
4. Referencing: aspects to consider when providing references and how to provide quotations in a proper way.
5. Technical tips: a few technical tips to use time efficiently when writing a scientific paper.

Intended Learning Outcomes:
At the end of the module the students understand the main steps to undertake in order to write a scientific paper. In addition, students are able to develop the topic for a scientific paper and establish the main components of its structure. Furthermore, the students are able to write a scientific paper by presenting and following a clear line of argument, discussion and conclusions. The students are also able to identify scientifically valid sources of information and provide quotations in an appropriate way. Finally, the students are able to conduct collaborative work in an academic environment.

Teaching and Learning Methods:
Lectures, exercise and excursion are held as types of instruction. Teaching method includes presentation and group discussion which help students to understand how to do a scientific research.

Media:
Presentations followed by discussion.

Reading List:
Anglia Ruskin University Library (2013): Harvard System of Referencing Guide.
Clanchy, J. and B. Ballard (1998): How to Write Essays. A practical Guide for Students. Longman.
Cottrell, S. (1999): The Study Skills Handbook. Palgrave Study Guides.
Cottrell, S. (2001): Teaching Study Skills and Supporting Learning. Palgrave Study Guides.
Cresswell, J. (2009): Research design. Qualitative, quantitative, and mixed methods approaches. Third Edition. Sage, London.
Fairbairn, J. and C. Winch (1996): Reading, Writing and Reasoning. A Guide for Students. Open University Press.
Gillham, B. (2000): Developing a Questionnaire. Continuum, London.
Redman, P. (2001): Good Essay Writing. A Social Sciences Guide. The Open University.
Malmfors, B. and P. Garnsworthy (2004): Writing and Presenting Scientific Papers

Responsible for Module:
Florian Siegert (florian.siegert@tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Scientific Paper Writing (lecture, 1 SWS)
de Vries W [L], Chigbu U, de Vries W

For further information in this module, please click
campus.tum.de or here.

Module Description

BV480025: Photogrammetry [PSC]

Selected Chapters

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:

The exams consist of a presentation of 45 minutes of a prepared scientific topic and an oral examination on the topics the whole lecture. The student has to show the ability to prepare and present a scientific topic and evaluate different methods in a presentation. In the oral exam, the broad knowledge on the different topics of lecture is checked.

Repeat Examination:

Next semester

(Recommended) Prerequisites:

" Introduction to Photogrammetry, Remote Sensing and GIS or Photogrammetrie & Fernerkundung 1
" Digital Image Processing or Digitale Bildverarbeitung

Content:

Lectures on Photogrammetry and remote sensing:
" Extraction of buildings from aerial images, satellite images, LiDAR, SAR
" Extraction of roads from aerial images, satellite images, LiDAR, SAR
" Extraction of vehicles from aerial images, satellite images, LiDAR, IR
" Classification of vegetaion from aerial images, satellite images, LiDAR, SAR
" Glaciers DEM from aerial images, satellite images, LiDAR, SAR
Topics from the fields of photogrammetry, remote sensing and image analysis are selected by the students.

Intended Learning Outcomes:

Upon successful completion of the module, the students are able to
- understand and apply methods of Photogrammatry and Remote Sensing
- evaluate the usability of specific methods for specific tasks
- evaluate results in a project report
- to present scientific results to an audience, i.e. how to design slides, structure the presentation, and how to defend the content in a discussion
- analyse problems and solution of a specific task in Photogrammetry and Remote Sensing
- evaluate actual problems and methods in photogrammetry and remote sensing
- prepare methodical basics and present elaborated results in a talk and report

Teaching and Learning Methods:
Lecture (interactive) and seminar

Media:
" Lecture (interactive) and seminar

Reading List:
Scientific papers

Responsible for Module:
Uwe Stilla (Uwe.Stilla@bv.tu-muenchen.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Photogrammetry - Selected Chapters (PSC) (lecture, 4 SWS)
Stilla U, Hoegner L

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV610003: Precise GNSS [PreciseGNSS]

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	105	75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
A written exam takes place in the end of the semester. The aim of the written exam is to ensure that the student has gained the required knowledge and understanding for precise positioning with GNSS data as listed in the intended learning outcomes. The students have to participate in a written midterm exam. The grade of the exam is an averaged grade from the midterm exam (25%) and the final exam (75%). With the midterm exam it is validated that the target competences of the first part have been achieved, because they are a pre-requisite for the second part of the module.
The labs consist of data analysis tasks, which the students should work on by means of appropriate software during supervised labs. The labs should be documented in 3-5 lab reports, which are evaluated according to a pre-defined evaluation scheme. Based on these labs and written reports, the student should demonstrate that he/she can independently validate the quality of the GNSS data and to apply processing strategies for the GNSS data analysis in terms of precise positioning. The final grade is an averaged grade from the exam (75%) and the lab reports (25%).

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Recommended: Fundamentals of linear algebra and statistics as well as successful participation in the module Satellite Navigation and Advanced Orbit Mechanics

Content:
Theory courses (3h) and labs (2h). The aim of the course is to
- get familiar with GNSS, with models involved, and with processing strategies used for precise GNSS positioning applications,
- get experience with GNSS data in practical work.

The theoretical part covers:
- Introduction to GPS and Galileo: position estimation with iterative least-squares method
- Precise Point Positioning with carrier phase measurements (centimeter accuracy)
- Estimation of satellite phase and code biases with geodetic networks
- Estimation of multipath
- Cascaded Kalman filters, method of Bryson
- Real Time Kinematic (RTK) positioning
- Satellite orbit determination: numerical integration, calculation of perturbations, estimation of Keplerian parameters
- Integer ambiguity resolution with statistical a priori knowledge

- Inequality constrained ambiguity resolution
- Statistical evaluation of success rates of carrier phase ambiguity resolution

The practical work includes:
- development of a simple point positioning tool using matlab,
- experiments using a scientific software package to study the impact of different effects and analysis strategies on positioning results.

The practical work is accompanied by short presentations by the participants of their results.

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- understand the theory, the basic methodologies and algorithms, and the current trends for Precise Point Positioning and Real-Time Kinematic (RTK) positioning with GPS and Galileo signals
- to evaluate tracking data quality and multipath
- to assess the impact of different model options on the positioning results
- to understand and apply algorithms and statistical tests for reliable phase ambiguity resolution
- to apply optimized processing strategies to analyze GNSS data for precise positioning applications

Teaching and Learning Methods:
In the lecture the content is presented with powerpoint presentations with examples and demonstrations using Matlab. Calculations and derivations are written to the blackboard.

Labs are based on Matlab and on the Bernese GPS Software, a professional GNSS data analysis software. The students work in groups on specific questions and present the results in short oral presentations.

Media:
Lecture with power-point presentations with electronic handouts and blackboard, demonstration of Matlab code.
Lab exercises with electronic handouts, electronic tutorials with solutions.

Reading List:
Hofmann-Wellenhof, Lichtenegger, Collins (2001): GPS-Theory and Practice, Springer
Mistra (2006): GPS-Signals, Measurements and Performance. Ganga-Jamuna Press
Theunissen, Kleusberg (Eds.) (1998): GPS for Geodesy. Springer
Parkinson, B.W. & Spilker Jr., J.J. (1996), Global Positioning System: Theory and Applications Vol. I/II, American Institute of Aeronautics and Astronautics
Kaplan, E., Hegarty C. (2006), Understanding GPS: Principles and Applications, Second Edition, Artech House (available in the library: www.ub.tum.de)
GPS Interface Control Document, ICD-GPS-200C
Bernese GPS Software Version 5.0 User Manual

Responsible for Module:
Urs Hugentobler (urs.hugentobler@mytum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Precise Point Positioning with GPS and Galileo (lecture with integrated exercises, 4 SWS)
Henkel P

Labs in Precise GNSS (practical training, 2 SWS)
Hugentobler U [L], Selmke I

For further information in this module, please click
campus.tum.de or here.

Module Description

BV610004: Navigation Labs

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
During the semester, the students shall hand in written 4-6 lab reports, which documents the labs and the lab results as well as answering on questions relevant to the lab. These written reports are prepared in small groups and are later on discussed with the lecturer. They are evaluated according to a pre-defined evaluation scheme. The grade of the module is based on the written reports and on individual questions of the lecturer during the discussion. The aim of the written reports is to ensure that the students have gained the required competences to work with GNSS equipment, to characterise GNSS receivers and tracking data, to perform specific analysis tasks in a small team, and to document the used methods and obtained results.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Introductory lectures on GNSS

Content:
Exercises and labs on
- GPS mapping
- Receiver characterization
- Multipath and ionopshere analysis
- Software correlation
- Spaceborne GPS tracking

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- work with and handle GNSS equipment
- understand and apply GNSS data analysis
- understand GNSS processing concepts
- apply dedicated problems of GNSS including receiver technology and data collection
- apply methods for the analysis of GNSS data
- analyze, assess and interprete the results.

Teaching and Learning Methods:
Each lab exercise is introduced with short presentation; students work in small groups using hardware and software and prepare a written report; the results of the report are discussed in the group

Media:
Handouts for each lab exercise, work with hardware and software, presentation of results with written report and discussions.

Reading List:
Misra P., Enge P.; Global Positioning System (GPS): Signals, Measurements and Performance; Ganga-Jamuna Press (2001).

Responsible for Module:
Urs Hugentobler (urs.hugentobler@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
GNSS Lab Exercises (practical training, 4 SWS)
Montenbruck O, Selmke I

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV610005: Advanced Aspects of Navigation Technology

Civil, Geo and Environmental Engineering

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 6	**Total Hours:** 180	**Self-study Hours:** 120	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
A written exam takes place in the end of the semester. The aim of the written exam is to ensure that the student has gained the required knowledge and understanding of methods and strategies used in GNSS applications for time synchronization, indoor navigation, geodynamic applications and aeronautical and space applications. The lab exercises focus on specific aspects of receiver technology and GNSS signal processing. Based on the written lab reports the student should verify that he/she gained the expertise to develop simple software GNSS receiver modules, simple signal generators and to model a radio frequency chain. The final grade is an averaged grade from the exam (33%) and the lab reports (67%).

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Introduction to Satellite Navigation, Signal Processing

Content:
Receiver Technology: Receiver concepts 1: History, fundamentals, review of GNSS signal structures, basic receiver functions, structural elements of a GNSS receiver, fundamentals of signal processing
Receiver concepts 2: Signal acquisition, detectors, tracking loops, pseudorange generation and position estimator, noise performance of DLL and PLL, narrow versus wide correlation, multipath mitigation
Advanced Aspects: Front-end techniques, pre-correlation sampling, crystal oscillators, GALILEO receivers, L2 civil signal implementation, codeless and semi-codeless techniques, receiver integration levels and component figures

GNSS Applications: Different lecturers from DLR and from industry highlight various GNSS and navigation applications:
- Galileo, Precise Time Facility, time synchronization
- Indoor navigation, sensor fusion
- Aeronautical applications, integrity
- Applications in geodynamics
- Space applications

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- to understand the fundamentals of GNSS signals;
- to understand the structure and working principles of a GNSS receiver;
- to develop a software GNSS receiver including acquisition, tracking, navigation modules;
- to develop simple signal generators;
- to model radio frequency chain such as satellite transmission power, link budget, receiver power budget.
- to analyze and to assess typical GNSS applications for navigation and time synchronization;
- to apply combination methods of different sensors and applications;
- to assess and to interpret the results.

They acquired insight into current projects performed and applications developed by industry in and around Munich.

Teaching and Learning Methods:
Receiver Technology: Powerpoint presentations and exercises;
GNSS Applications: Powerpoint presentations by different lecturers from DLR and from Industry on specific topics.

Media:
Powerpoint presentations, blackboard
Receiver technology: Interleaved with exercises done as home work and discussed in the lectures.
GNSS Applications: demonstations in some of the lectures

Reading List:
Receiver Technology: Lecture notes;
GNSS Applications: Lecture handouts

Responsible for Module:
Urs Hugentobler (urs.hugentobler@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Seminar GNSS Applications (seminar, 2 SWS)
Hugentobler U

Receiver Technology (lecture, 2 SWS)
Hugentobler U [L], Frankl K

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV610013: Receiver Technology

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
4	120	90	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination is accomplished through written project reports based on the exercises performed. Based on the written lab reports it is verified that the student gained the expertise relevant for receiver technology such as to develop simple software GNSS receiver modules, simple signal generators and to model a radio frequency chain. With the implementation of such software modules in Matlab and their documentation in the project reports it is ensured that the student gained the respective programming skills. The students work on the projects in the self-studyhours while support is provided during contact hours.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Prerequisite is the module "Satellite Navigation and Advanced Orbit Mechanics"

Content:
- Receiver concepts 1: History, fundamentals, review of GNSS signal structures, basic receiver functions, structural elements of a GNSS receiver, fundamentals of signal processing
- Receiver concepts 2: Signal acquisition, detectors, tracking loops, pseudorange generation and position estimator, noise performance of DLL and PLL, narrow versus wide correlation, multipath mitigation
- Advanced Aspects: Front-end techniques, pre-correlation sampling, crystal oscillators, GALILEO receivers, L2 civil signal implementation, codeless and semi-codeless techniques, receiver integration levels and component figures

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- to understand the fundamentals of GNSS signals,
- to understand the structure and working principles of a GNSS receiver,
- to develop a software GNSS receiver including acquisition, tracking, navigation modules,
- to develop simple signal generators,
- to model radio frequency chain such as satellite transmission power, link budget, receiver power budget

Teaching and Learning Methods:
The module consists of a lecture and preparations and discussions of the home works. During the lectures and contact hours the theoretical concepts of receiver technology are presented and the exercises are introduced and discussed. The labs allow the students to implement these concepts in software and thus to gain a deep understanding on receiver working principles and GNSS signal processing.

Media:
Power point, handouts for homeworks

Reading List:
Lecture notes

Responsible for Module:
Urs Hugentobler (urs.hugentobler@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Receiver Technology (lecture, 2 SWS)
Hugentobler U [L], Frankl K

For further information in this module, please click
campus.tum.de or here.

Module Description

EI5028: Satellite Navigation Laboratory

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
In an oral exam students prove that the are able to program a satelite receiver in a step by step approach by discussing their approcah during the lab coure with the examiner.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Basics on satellite navigation and communications engineering

The following modules should be passed before taking the course:
-

It is recommended to take the following modules additionally:
-

Content:
During six experiments the student will program a complete satellite navigation receiver in Matlab. The experiments cover the following topics:
- Satellite Orbits
- Positioning algorithms
- Signal acquisition
- Signal tracking
- Corrected pseudoranges
- Differential positioning

Intended Learning Outcomes:
After completion of the module students understand the process of developing a satellite navigation receiver by programming its components function after function. They re able to apply methods for the sensitivity to parameter changes, the convergence behavior and computational complexity of algorithms, as well as the size of individual terms and corrections.

Teaching and Learning Methods:
The laboratory is centered around a supervised development of the software code for a receiver by the student himself. The task is subdivided into a number of subtasks, which represent one particular function in the receiver, like initial acquisition of the signal or orbit determination.

Media:
The following kinds of media are used:
- Lecture notes and exercises available for download
- Whiteboard notes
- Matlab programs and simulations

Reading List:
The following literature is recommended:
- K. Borre, D. Akos, N. Bertelsen, P. Rinder, S. Jensen (2007), A Software-Defined GPS and Galileo Receiver: A Single-Frequency Approach, Birkhäuser Boston.
- P. Misra, P. Enge (2006) Global Positioning System - Signals, Measurements and Performance, 2nd Edition, Ganga-Jamuna Press.
- E. Kaplan, C. Hegarty (2006) Understanding GPS: Principles and Applications, 2nd Edition, Artech House.

Responsible for Module:
Günther, Christoph; Prof. Dr.

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Module Description

MW0229: Satellite Design Workshop

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Bachelor/Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
In Form von kleinen Projektgruppen sind die vermittelten Inhalte auf die konkrete Aufgabenstellung des Workshops anzuwenden. Betreut durch Experten aus Industrie und Universitäten, erarbeitet jede Gruppe einen Lösungsvorschlag und präsentiert diesen in einer Schlussveranstaltung den jeweils anderen Gruppen. Weiterhin findet eine mündliche Prüfung statt, bei der jeder einzelne Studierende unter Beweis stellen muss, dass er in der Lage ist, die beim Satellitenentwurf grundlegenden Einflussfaktoren und deren komplexe Zusammenhänge zu verstehen und daraus die für die konkrete Workshopaufgabe resultierenden Anforderungen zu erfassen und zu beschreiben.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
RFT I und RFT II

Content:
Die Veranstaltung ist als einwöchiger Workshop außerhalb der regulären Voprlesungszeit konzipiert. Da die Teilnahme auf 20 Personen begrenzt ist, findet eine Auswahl nach Semesteranzahl und Vorbildung statt. Verteilt auf mehrere Gruppen wird jedes Jahr ein neues Problem aus dem Bereich des Satellitenentwurfs bearbeitet. Hierfür geben zunächst erfahrene Dozenten aus Universitäten, Industrie und Forschungseinrichtungen Vorlesungen zu den relevanten Themen der Aufgabenstellung. Beim Workshop im Jahre 2008 wurde zum Beispiel ein erster Entwurf für einen Kleinsatelliten erarbeitet. Die vertiefenden Vorlesungen hierzu behandelten Aspekte des Projektmanagements, des Kleinsatellitenentwurfs, des mechanisch-thermischen Subsystems, des Antriebssystems und des elektrischen Systementwurfs. Im Jahre 2010 lag der Schwerpunkt auf dem Subsystem Kommunikation. Die vertiefenden Vorlesungen behandelten Aspekte der Nachrichtenübertragung, der HF Meßtechnik, der Bahnmechanik und Lageregelung von Satelliten und des Tests und Integration von Satelliten. Ergänzt werden die vertiefenden Vorlesungen durch allgemeine Vorlesungen zu Sonderthemen der Raumfahrttechnik, wie z.B. Raumfahrtrecht und Raumfahrtversicherungen.

Intended Learning Outcomes:
Nach der Teilnahme an der Modulveranstaltung sind die Studierenden in der Lage, die relevanten Grundlagen der speziellen Workshopaufgabe, aber auch Aspekte der allgemeninen Satellitentechnik zu verstehen und deren Auswirkungen auf das Satellitengesamtsystem zu identifizieren. Sie sind in der Lage auf Basis dieser Kenntnisse bestehende Satelliten oder deren Subsysteme zu analysieren und gewählte Lösungen zu hinterfragen. Sie besitzen nach Abschluss der Veranstaltung notwendige Kenntnisse um beim Satellitenentwurf mitreden und einen relevanten Beitrag leisten zu können.

Teaching and Learning Methods:
In dem ein-wöchigen Workshop werden die Lehrinhalte anhand von Vorträgen, Präsentationen und Tafelanschrieb vermittelt. Die hauptsächliche Lehr- und Lernmethode ist allerdings die Arbeit in Gruppen unter Anleitung und Aufsicht der Dozenten aus Industrie und Universitäten. Je nach Workshopthema können dies rechnergestützte Entwurfsaufgaben sein oder auch die Durchführung und Auswertung von Messungen, z.B. an einer Satellitenkommunikationsstrecke.

Media:
Vortrag, Präsentation, Handzettel, Tafelanschrieb

Reading List:
U. Walter, Astronautics, Wiley-VCH, ISBN 3-527-40685-9

J. Wertz, W. Larson, Space Mission Analysis and Design, Space Technology Library, ISBN 1-881883-10-8

Responsible for Module:
Walter, Ulrich; Prof. Dr.

Courses (Type of course, Weekly hours per semester), Instructor:
Satellite Design Workshop (lecture, ,1 SWS)
Walter U [L], Rückerl S, Dziura M

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

MW0460: Space Environment and its Simulation [Umwelt und Simulation in der Raumfahrt]

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Bachelor/Master	German	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
With a written examination it shall be ensured that the students are able to remember and to understand basic principles of space environment and its impact on spacecraft and satellites, as well as the main technologies for simulation of the extreme space environmental conditions on Earth. They should verify that they are able to build interrelations between space environment and its effect on satellites.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
none

Content:
Space activities are affected by extreme environmental conditions, such as verberation, vibrations and shock load during start, the residual atmosphere and vacuum during launch, and neutral particles, plasma, radiation, fields, particles and µg conditions in orbit during operation. In the frame of this lecture die individual conditions of the space environment are described in detail, and their effect on technology and operation of spacecraft and satellites are described. Additionally, the simulation of these extreme conditions on Earth is addressed.

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- understand the conditions of space environment in space flight;
- analyze the effects which are relevant for space flight;
- understand and to recognize the necessity for pre-launch simulation of the space environment;
- analyze the challenges and restrictions of these simulation in laboratories on Earth.

Teaching and Learning Methods:
In the classroom the competencies and contents are communicated by blackboard and slides. The slides are provided to the students in the form of written handouts. Additionally, further self-studies are recommended based on the provided list of literature.

Media:
- presentations in electronic form
- blackboard
- movies and animations

Reading List:
- Alan C. Tribble, The Space Environment, Princeton University Press, 2003, ISBN: 0-691-10299-6
- Gerd W. Prölls, Physics of the Earth's Space Environment, Springer Verlag, 2004, ISBN: 3-540-21426-7
- Frank Fahy, John Walker, Fundamentals of Noise and Vibration, E&FN Spon, 1998, ISBN: 0-419-27700-8
- NASA Technical Handbook, Dynamic Environmental Criteria, NASA-HDBK-7005, 2001

Responsible for Module:
Rott, Martin; Dr.-Ing.

Courses (Type of course, Weekly hours per semester), Instructor:
Space Environment and its Simulation (lecture, 2 SWS)
Rott M

For further information in this module, please click
campus.tum.de or here.

Specialization Subject 2: Remote Sensing

Technische Universität München

Required Elective Modules

Module Description

BV480025: Photogrammetry [PSC]

Selected Chapters
Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The exams consist of a presentation of 45 minutes of a prepared scientific topic and an oral examination on the topics the whole lecture. The student has to show the ability to prepare and present a scientific topic and evaluate different methods in a presentation. In the oral exam, the broad knowledge on the different topics of lecture is checked.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
" Introduction to Photogrammetry, Remote Sensing and GIS or Photogrammetrie & Fernerkundung 1
" Digital Image Processing or Digitale Bildverarbeitung

Content:
Lectures on Photogrammetry and remote sensing:
" Extraction of buildings from aerial images, satellite images, LiDAR, SAR
" Extraction of roads from aerial images, satellite images, LiDAR, SAR
" Extraction of vehicles from aerial images, satellite images, LiDAR, IR
" Classification of vegetaion from aerial images, satellite images, LiDAR, SAR
" Glaciers DEM from aerial images, satellite images, LiDAR, SAR
Topics from the fields of photogrammetry, remote sensing and image analysis are selected by the students.

Intended Learning Outcomes:
Upon successful completion of the module, the students are able to
- understand and apply methods of Photogrammatry and Remote Sensing
- evaluate the usability of specific methods for specific tasks
- evaluate results in a project report
- to present scientific results to an audience, i.e. how to design slides, structure the presentation, and how to defend the content in a discussion
- analyse problems and solution of a specific task in Photogrammetry and Remote Sensing
- evaluate actual problems and methods in photogrammetry and remote sensing
- prepare methodical basics and present elaborated results in a talk and report

Teaching and Learning Methods:
Lecture (interactive) and seminar

Media:
" Lecture (interactive) and seminar

Reading List:
Scientific papers

Responsible for Module:
Uwe Stilla (Uwe.Stilla@bv.tu-muenchen.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Photogrammetry - Selected Chapters (PSC) (lecture, 4 SWS)
Stilla U, Hoegner L

For further information in this module, please click
campus.tum.de or here.

Module Description

BV290015: Remote Sensing

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
A written exam takes place in the end of the semester. The exam contains theoretical questions as well as calculations. By answering the questions in a limited time, the student should demonstrate that he/she is able to apply signal processing methods on remote sensing applications. Furthermore the student should hand in a written lab report and thereby verify that he/she is able to implement self-containedly certain parts of regularization theory and to evaluate the results in a project report. In addition the student should present a research work in an oral presentation and defend their ideas. Here it is tested that the student has gained a deeper understanding for research topics within remote sensing, that he/she is able to work independently on a research topic and is able to defend his/her own ideas. The final grade is an averaged grade from the written exam (50%) and from the written project report and oral presentations (50%).

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Required: Basic knowledge in photogrammetry, mathematics and physics.
Recommended: Successful participation in the module Introduction to Photogrammetrie, Remote Sensing and GIS.

Content:
Remote Sensing - Advanced Methods:
1. Along-Track and Across-Track Interferometry
2. Differential SAR Interferometry
3. Persistent Scatterer Interferometry
4. Remote Sensing of the Atmosphere
5. Remote Sensing of the Oceans

The processing of SAR data is trained in tutorials.

Non-linear Optimization Methods:
Inverse Problems and Nonlinear Optimization Theory:
1. Ill-posed linear problems (concept of ill-posedness, regularization issues, discretization by projection, regularization by projection)
2. Tikhonov regularization for linear problems (formulation, error analysis, parameter choice methods)
3. Tikhonov regularization for nonlinear problems (formulation, error analysis, implementation issues)
4. Optimization theory: Minimization methods for smooth functions (step-length based methods, trust-region methods)

5. Optimization theory: Minimization methods for sum of squares (Gauss-Newton method, quasi-Newton method, trust-region methods)
6. Iterative regularization methods (Landweber iteration, Newton-type methods, regularizing Levenberg-Marquardt method, regularizing trus-region methods

Seminar Remote Sensing
The seminar provides deep insight into specific and selected topics of remote sensing. Topics to be elaborated and presented are given at the Kick-Off meeting and combine, for instance, methods and applications of remote sensing/image analysis.

Intended Learning Outcomes:
After participating in the module, the students are able to

- understand and apply methods of signal processing in remote sensing
- evaluate the usability of specific remote sensing methods for practical problems
- understand the fundamental basics of regularization theory
- evaluate results of the application of regularization techniques in a project report
- analyze autonomously tasks in the research field of remote sensing
- prepare methodical basics for a selected research topic
- evaluate alternative approaches in practice and to develop own solutions
- present the elaborated results in a talk

Teaching and Learning Methods:
Lecture notes, slides, applications and examples, discussion, presentation, literature work, programming

Media:
Slides, lecture notes, exercise sheets, white-/blackboard

Reading List:
Remote Sensing - Advanced Methods: Sabins FF, Remote Sensing Principles and Interpretation, W.H. Freeman and Company, 1997 Cumming IG, Digital Processing of Synthetic Aperture Radar, Artech House, 2005
Non-linear optimization: lecture notes
Remote Sensing Seminar: selected litterature (such as scientific papers) will be provided for each topic individually

Responsible for Module:
Richard Bamler (Richard.Bamler@dlr.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Non-linear Optimization (lecture, 1 SWS)
Doicu A

Lab for Remote Sensing - Advanced Methods (exercise, 1 SWS)
Schmitt M

Remote Sensing - Advanced Methods (lecture, 1 SWS)
Zhu X

Remote Sensing Seminar (seminar, 1 SWS)
Zhu X

Technische Universität München

For further information in this module, please click
campus.tum.de or here.

Module Description

BV300003: Geo-Information

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
A written exam takes place in the end of the semester. By answering the questions the student should verify that they have gained the required knowledge about spatial data management, the analysis of geodata, spatial data mining and cartographic techniques for visualising spatial data. The exam contains questions in which they have to give valid definitions, explain concepts, theoretically implement and evaluate case studies, as well as mastering design challenges. All learning outcomes are covered by this written exam.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Knowledge of higher mathematics and experiences of handling spatial data

Content:
This module includes the following topics:
¿ Introduction to GIS;
¿ Spatio-temporal representations and databases;
¿ Spatial data analysis;
¿ Spatial data mining;
¿ Data retrieval and cartographic techniques;
¿ Case studies of Geoinformation;
¿ Introduction to ArcGIS components;
¿ Working with multiple data tables;
¿ Learning spatial analysis methods;
¿ Building 3D models;
¿ Creating animations;
¿ Designing a quality Map in a GIS;
¿ Collecting spatial data during field work;
¿ Integrating GPS data to a GIS;
¿ Publishing geographic information online.

Intended Learning Outcomes:
Upon completion of the module, students are able to¿
¿ illustrate the dimensions of geoinformation;
¿ explain the structure of a GIS;
¿ understand data mining concepts;
¿ implement concepts of geodata harmonization to integrate geodata into a GIS;
¿ implement geostatistical methods;

¿ apply properties of different map projections and to select appropriate projections for specific purpose;
¿ implement map generalization concepts and algorithms;
¿ integrate the functional and the organizational workflow of geodata-management and implement them into system-architectures using established concepts of geodata modelling;
¿ evaluate spatial databases and the spatial data quality within geodata-management;
¿ create queries for geodata analysis;
¿ create well designed maps;
¿ generate three dimensional data models.

Teaching and Learning Methods:
The module is structured in lectures and exercises. The lectures provide the theoretical foundations of geoinformation. They impart knowledge about spatial data management, the analysis of geodata, spatial data mining and cartographic techniques for visualising spatial data. The exercise part of this module allows the students to employ their GIS knowledge to applied studies. An introduction to ArcGIS will be given and the students can analyse and visualise geodata using a variety of analysis tools and visualisation techniques. A set of exercises put the theoretical knowledge into practice. The exercises are carried out in a computer lab individually, partly under supervision and partly in self-study. Feedback on the exercises is given to each student within a personal one-on-one discussion.

Media:
Moodle E-learning, presentations, script, GIS laboratory, hand-outs, recommended literature

Reading List:
Longley, P. A., Goodchild, M. F., Maguire D. J., Rhind, D. W. (Eds.) (2005): Geographical Information Systems ¿ Principles, Techniques, Management and Applications. John Wiley & Sons.
Law, M., Collins, A. (2013): Getting to Know ArcGIS for Desktop. Esri Press.

Responsible for Module:
Liqiu Meng, liqiu.meng@tum.de

Courses (Type of course, Weekly hours per semester), Instructor:
Geoinformation (lecture, 4 SWS)
Meng L, Murphy C

For further information in this module, please click
campus.tum.de or here.

Elective Modules

Technische Universität München

Module Description

BGU45024: Gravity and Magnetic Field from Space

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
With an oral examination it shall be ensured that the students are able to remember and to understand the main concepts of potential field theory and the observation techniques of the Earth s gravity and magnetic field from space. The students should verify that they are able to build interrelations among these concepts, that they are able to apply methods for processing of satellite gravity and magnetic field data and to link them to global potential field modelling. By means of dedicated questions, it is verified that the students are able to interpret results of gravity and magnetic field observation technologies and that they are able to build connections to system Earth processes. The format of an oral exam allows interactive queries, and the ability to give precise and well-structured answers in real time is verified.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Recommended:
- Introduction to Earth System Science
- Orbit Mechanics 1
- Signal Processing
- Electrodynamics

Content:
Introduction to potential field theory
- principles of satellite gravimetry and magnetometry
- mission concept and goals of the satellite gravity missions CHAMP, GRACE, GOCE
- mission concept and goals of the magnetic field missions ØRSTED, SAC-C, SWARM
- applications of satellite gravity and magnetic field data in earth sciences

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- to understand the basics of potential field theory and the mathematical description of the Earth s gravity and magnetic field;
- to understand the basic mission concepts and objectives of satellite gravity and magnetic field missions

- to recognize the relationship between the measurements and the respective potential field parameters
- to apply these concepts for the solution of practical problems
- to analyze and to interpret the results
- to link the observation of the global gravity and magnetic field and its changes to the global monitoring of the Earth system.

Teaching and Learning Methods:
Power point presentations; handouts in electronic form; blackboard

Media:
- presentations in electronic form
- blackboard
- Selected text books and scientific publications

Reading List:
Handouts

Responsible for Module:
Roland Pail (pail@bv.tu-muenchen.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Gravity and Magnetic Field from Space (lecture, 2 SWS)
Pail R [L], Pail R, Gruber T

For further information in this module, please click
campus.tum.de or here.

Module Description

BGU45026: Earth Observation Mission Design Seminar

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	45	45

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The module will be evaluated by a presentation of at least 30 min. which will be regarded as a study result of this course.
With the study result it will be evaluated if the students acquired competences to define, analyze and evaluate the scientific and technical requirements of a new Earth observation satellite mission. For this it is required to do a literature survey and to apply competences obtained during previous studies. The design of a new concept requires in addition to cross-check the technical and scientific requirements against each other, which will be done by team work and exchange of competences within the team of students. The student teams will be supported by consultancy of the lecturers.
Information about study result: At the end of the seminar the student team gives an overview about the developed mission design and the related scientific and technical requirements. During intermediate meetings with the lecturers the next development steps will be discussed. The study results will be done by students homework.

Repeat Examination:

(Recommended) Prerequisites:
It is recomemnded to have basic knowledge about matehmatics, physics and engineering sciences as it is typically acquired in an engineering course at Bachelor level.

Content:
Course: ¿Earth Observation Mission Design Seminar¿
The course will be organized as seminar, which will address the following content: Definition of scientific and technical requirements for am Earth observation satellite mission; Introduction of the various components of a satellite mission (satellite bus, instruments, ground segment, etc.); Planning of satellite orbits in order to reach the mission requirements; Development of a measurement concept in order to reach the mission requirements; Specification of the data management on board of the satellite and together with groudn stations; Definition of processing algorithms for the data products to be computed.

Intended Learning Outcomes:
After participating at the module students are capable,
- to understand the components needed to design an Earth observation satellite mission,
- to understand and to analyze the interactions between the various components,
- to define the scientific requirements for an Earth observation satellite mission,
- to develop a mission design for one or a constellation of satellites meeting the scientific requirements,

- to analyze the mission concept and the developped mission design,
- to assess the scientific and technical requirements of a new Earth observation satellite mission.

Teaching and Learning Methods:
The course will be held as seminar, i.e. the students develop a mission design for a given topic and present intermediate and final results to the lectureres. All results will be discussed with the complete team and next steps to be done will be discussed.

Media:
Presentations, Documents, Publications

Reading List:
not required

Responsible for Module:
Roland Pail

Courses (Type of course, Weekly hours per semester), Instructor:
Earth Observation Mission Design Seminar (seminar, 3 SWS)
Gruber T, Pail R

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BGU45027: Earth Observation Mission Development Seminar

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:

Credits:*	Total Hours:	Self-study Hours:	Contact Hours:
3			

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:

Repeat Examination:

(Recommended) Prerequisites:

Content:

Intended Learning Outcomes:

Teaching and Learning Methods:

Media:

Reading List:

Responsible for Module:

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Module Description

BV230050: Atmospheric Physics and Remote Sensing

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
With an oral examination it shall be ensured that the students are able to remember and to understand the individual concepts and processes of atmosphere and its composition, weather and climate, the Earth s energy budget and radiation balance, and climate predictions. The students should verify that they are able to build interrelations among these concepts, and that they have an insight into their contribution to the overarching concept of system Earth. By means of dedicated questions, it is verified that the students are able to interpret results of observation technologies and that they are able to build connections to physical modelling. The format of an oral exam allows interactive queries, and the students are required to give precise and well-structured answers in real time.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Mathematics, experimental Physics

Content:
Atmospheric Physics and Remote Sensing: Introduction to atmospheric physics with an emphasis on remote sensing of atmospheric components and processes from space:
- atmosphere, weather and climate,
- clouds, aerosols and trace gases,
- radiative transfer,
- Earth's energy budget,
- remote sensing of the atmosphere,
- climate modelling and climate change

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- to understand the basic principles of atmosphere, weather, and climate;
- to understand the methods for determining atmospheric composition and dynamics from space;
- to apply analysis methods for practical problems related to atmosphere and climate;
- to apply atmospheric remote sensing methods, and to analyze the results;
- to link these topics to the monitoring of the Earth system.

Teaching and Learning Methods:
Power point presentations; handouts in electronic form; blackboard

Media:
- presentations in electronic form
- Blackboard
- Selected text books and scientific publications

Reading List:
F.W. Taylor, Elementary Climate Physics, Oxford University Press, 2005.
J.M. Wallace and P.V. Hobbs, Atmospheric Science: An Introductory Survey, Academic Press, 2nd edition, 2006.
W. Roedel, Physik unserer Umwelt: Die Atmosphaere, Springer, 3. Auflage, 2000.
L. Bergmann und C. Schaefer, Lehrbuch der Experimentalphysik Band 7: Erde und Planeten, de Gruyter, 2. Auflage, 2001.

Responsible for Module:
Roland Pail (pail@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Atmospheric Physics and Remote Sensing (lecture, 2 SWS)
Kiemle C

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV400016: Scientific Paper Writing [SPW]

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	70	20

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Students have to submit a scientific paper which is written in groups. The students demonstrate with their papers that they have gained deeper knowledge of the specific requirements of a scientific paper, including structure, appropriate presentation of information and discussion as well as the related formalities. The students are able to develop a topic for their papers and formulate the problem statement, objectives and research questions. Furthermore, the students are able to develop a conceptual frame and present as well as analyze information and formulate conclusions. Finally, the students are able to meet the formalities of a scientific paper including proper quotations, layout and language.

Repeat Examination:

(Recommended) Prerequisites:
none

Content:
1. The research process: main steps to undertake in a research project leading to the preparation of a scientific paper.
2. Scientific paper writing: main components of a scientific paper and their respective contents with focus on topic development and logical construction of line of argument.
3. Sources of Information: main sources of information for writing scientific paper, with focus on scientifically valid sources and how to identify these.
4. Referencing: aspects to consider when providing references and how to provide quotations in a proper way.
5. Technical tips: a few technical tips to use time efficiently when writing a scientific paper.

Intended Learning Outcomes:
At the end of the module the students understand the main steps to undertake in order to write a scientific paper. In addition, students are able to develop the topic for a scientific paper and establish the main components of its structure. Furthermore, the students are able to write a scientific paper by presenting and following a clear line of argument, discussion and conclusions. The students are also able to identify scientifically valid sources of information and provide quotations in an appropriate way. Finally, the students are able to conduct collaborative work in an academic environment.

Teaching and Learning Methods:
Lectures, exercise and excursion are held as types of instruction. Teaching method includes presentation and group discussion which help students to understand how to do a scientific research.

Media:
Presentations followed by discussion.

Reading List:
Anglia Ruskin University Library (2013): Harvard System of Referencing Guide.
Clanchy, J. and B. Ballard (1998): How to Write Essays. A practical Guide for Students. Longman.
Cottrell, S. (1999): The Study Skills Handbook. Palgrave Study Guides.
Cottrell, S. (2001): Teaching Study Skills and Supporting Learning. Palgrave Study Guides.
Cresswell, J. (2009): Research design. Qualitative, quantitative, and mixed methods approaches. Third Edition. Sage, London.
Fairbairn, J. and C. Winch (1996): Reading, Writing and Reasoning. A Guide for Students. Open University Press.
Gillham, B. (2000): Developing a Questionnaire. Continuum, London.
Redman, P. (2001): Good Essay Writing. A Social Sciences Guide. The Open University.
Malmfors, B. and P. Garnsworthy (2004): Writing and Presenting Scientific Papers

Responsible for Module:
Florian Siegert (florian.siegert@tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Scientific Paper Writing (lecture, 1 SWS)
de Vries W [L], Chigbu U, de Vries W

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV450005: Satellite Altimetry and Physical Oceanography [AltiOcean]

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
With an oral examination it shall be ensured that the students are able to remember and to understand the individual concepts of physical oceanography, the observation technique of satellite altimetry, and the products derived from it. They should verify that they are able to build interrelations between the observational component of satellite altimetry and the physical processes of oceanography, and that they are able to understand their contribution to the overarching concept of system Earth. By means of dedicated questions, it is verified that the students are able to interpret results of observation technologies and that they are able to build connections to physical modelling. The format of an oral exam allows interactive queries, and the ability to give precise and well-structured answers in real time is verified.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Mathematical physics, linear algebra, time series analysis

Content:
Oceanography and Satellite Altimetry:
- Equation of motion,
- geostrophic currents,
- hydrostatic balance,
- temperature, salinity, and density,
- ocean tides, tidal analysis,
- de-aliasing,
- radar and laser altimetry,
- altimeter mission overview,
- where to get what data,
- corrections of altimeter observations,
- repeat pass and crossover analysis,
- mean sea surface, geoid, dynamic ocean topography, sea level variability, sea level rise.

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- to understand the basic principles of physical oceanography;

- to understand the basic principles of satellite altimeter missions
- to recognize satellite altimetry as an operational remote sensing technique with important applications in geodesy, oceanography and other geosciences;
- to apply observation techniques and the necessary measurement correction;
- to apply key analysis methods to practical problems of satellite altimetry and physical oceanography;
- to analyze and to interpret the results;
- to link these topics to the monitoring of the Earth system.

Teaching and Learning Methods:
Power point presentations; handouts in electronic form; blackboard

Media:
- presentations in electronic form
- blackboard
- Selected text books and scientific publications

Reading List:
Stewart, R.: Introduction to Physical Oceanography (OpenSource Book, see download)
Fu, L.L. and A. Cazenave (Eds.) Satellite Altimetry. International Geophysics Series, Vol. 69, San Diego, CA, 2000

Responsible for Module:
Roland Pail (pail@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Satellite Altimetry and Physical Oceanography (lecture, 2 SWS)
Seitz F [L], Bosch W, Passaro M

For further information in this module, please click
campus.tum.de or here.

Module Description
BV450006: Atmosphere and Ocean

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
With an oral examination it shall be ensured that the students are not only able to remember and understand the individual concepts covered by the two lectures, but they should verify that they are able to build interrelations among these concepts, and that they have an insight into their contribution to the overarching concept of system Earth. By means of dedicated questions, it is verified that the students are able to interpret results of observation technologies and that they are able to build connections to physical modelling.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Atmospheric Physics and Remote Sensing: Mathematics, experimental Physics; Oceanography and Satellite Altimetry: Mathematical physics, linear algebra, time series analysis

Content:
Atmospheric Physics and Remote Sensing: Introduction to atmospheric physics with an emphasis on remote sensing of atmospheric components and processes from space:
- atmosphere, weather and climate,
- clouds, aerosols and trace gases,
- radiative transfer,
- Earth's energy budget,
- remote sensing of the atmosphere,
- climate modelling and climate change

Oceanography and Satellite Altimetry:
- Equation of motion,
- geostrophic currents,
- hydrostatic balance,
- temperature, salinity, and density,
- ocean tides, tidal analysis,
- de-aliasing,
- radar and laser altimetry,
- altimeter mission overview,
- where to get what data,
- corrections of altimeter observations,
- repeat pass and crossover analysis,

- mean sea surface, geoid, dynamic ocean topography, sea level variability, sea level rise

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to understand the basic principles of atmosphere, weather, and climate and the methods for determining atmospheric composition and dynamics from space, and they shall be able to apply these principles and methods for practical problems. Further the student shall understand and apply the most basic principles of physical oceanography and recognize satellite altimetry as an operational remote sensing technique with important applications in geodesy, oceanography and other geosciences. In addition, students shall know about satellite altimeter missions, be able to understand and to apply observation techniques and the necessary measurement correction, shall know where to get data and products and how to access data. The students shall also be able to understand important analysis methods and to apply them to practical problems. They should also remember and understand the geophysical application of satellite altimetry and they shall be able to link it to the monitoring of several components of the Earth system.

Teaching and Learning Methods:
Power point presentations; handouts in electronic form; blackboard

Media:
- presentations in electronic form
- Blackboard
- Selected text books and scientific publications

Reading List:
Atmospheric Physics and Remote Sensing: F.W. Taylor, Elementary Climate Physics, Oxford University Press, 2005.
Further reading:
J.M. Wallace and P.V. Hobbs, Atmospheric Science: An Introductory Survey, Academic Press, 2nd edition, 2006.
W. Roedel, Physik unserer Umwelt: Die Atmosphaere, Springer, 3. Auflage, 2000.
L. Bergmann und C. Schaefer, Lehrbuch der Experimentalphysik Band 7: Erde und Planeten, de Gruyter, 2. Auflage, 2001.
Oceanography and Satellite Altimetry: Stewart, R.: Introduction to Physical Oceanography (OpenSource Book, see download)
Fu, L.L. and A. Cazenave (Eds.) Satellite Altimetry. International Geophysics Series, Vol. 69, San Diego, CA, 2000

Responsible for Module:
Roland Pail (pail@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Atmospheric Physics and Remote Sensing (lecture, 2 SWS)
Kiemle C

Satellite Altimetry and Physical Oceanography (lecture, 2 SWS)
Seitz F [L], Bosch W, Passaro M

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV570001: Earth System Dynamics

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The learning outcome of the module is certificated after students have passed a written exam and the corresponding labs. By the written exam, it is verified that the students are able to deeply understand the main dynamical processes of the Earth system, that they are able to apply methodologies to practical geophysical problems, and that they are able to evaluate and to interpret the results. During the semester students are expected to prepare individually a written report on a project in the frame of a seminar. By this written reports, is verified that the students are able to interlink in a self-contained way various sub-topics of Earth system dynamic into a global picture.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Required:
- Basic knowledge in linear algebra, calculus, mechanics
- Programming in MATLAB

Recommended:
Successful participation in the modules
- Introduction to Earth System Science
- Numerical Modeling
- Signal Processing

Content:
1 Introduction to Earth System Science
1.1 System Earth and its Components
1.2 Geophysical Fluids and Solid Earth
1.3 Geometrical and Gravimetrical Observation Techniques

2 Geophysical Fluids: Internal Processes and Interactions
2.1 Atmosphere Dynamics
2.2 Ocean Dynamics
2.3 Atmosphere-Ocean Interaction

3 Models of Atmosphere and Hydrosphere
3.1 Atmospheric General Circulation Models and Reanalyses
3.2 Ocean Circulation Models and Data Assimilation
3.3 Coupled Models

4 Interactions Between Geophysical Fluids and Solid Earth
4.1 Earth rotation and the Balance of Angular Momentum
4.2 Gravity Field Variations and their Geophysical Interpretation
4.3 Surface Deformation by Atmospheric and Hydrospheric Loading

5 Seminar on Climate Change
5.1 Keynote Lectures by invited guests
5.2 Project work

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to understand dynamic processes in the Earth system, apply geophysical models of processes and evaluate numerical results and prognoses.
Through the preparation of a written report on a project related to climate change on the basis of three invited keynote speakers, students are able to gain competence across various subjects covered by ESPACE.

Teaching and Learning Methods:
2 SWS lecture on Earth System Dynamics: Provides theoretical foundations of dynamic processes and interactions in the Earth system as well as of numerical physical models.

1 SWS labs on Earth System Dynamics: Numerical exercises on the topics covered by the lecture using MATLAB; for the most part, the lab is organised as homework with the requirement of preparing a written report on methodology and results.

1 SWS Seminar with guest lecturers: Three invited guests from space agencies, research institutes and the space industry give keynote lectures on topics related to climate change. On the basis of these introductory lectures, students will work on a project using actual satellite or model data from the context of climate change signals. Students will prepare a written report on the methodology and outcome of the project which contributes with 1/4 to the final mark of the module.

Media:
- Presentation slides

- Lecture Notes

- Selected Scientific Publications which will be distributed in class

Reading List:
- Lecture Notes

- IPCC (2007): Climate Change 2007: Synthesis Report, Geneva.

- Kandel, R. (1980): Earth and Cosmos, Pergamon Press, Oxford

- Selected scientific publications will be distributed in the course

Responsible for Module:
Florian Seitz (seitz@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Seminar with Guest Lecturers (seminar, 1 SWS)
Pail R

Earth System Dynamics (lecture, 2 SWS)
Seitz F [L], Bloßfeld M

Labs in Earth System Dynamics (exercise, 1 SWS)
Seitz F [L], Bloßfeld M

For further information in this module, please click
campus.tum.de or here.

Module Description

BV570002: Earth Observation Satellites

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The written exam aims to verify that the student knows the concept behind satellite gravimetry and satellite magnetometry as well as the relationship between the measurements and the respective potential field parameters by answering a number of theoretical questions under time pressure. In addition the students should hand in 3-5 lab reports. The student should demonstrate that they are able to analyze different satellite data on specific applications and know how to document this in a report. The students should also defend the results in discussions with the lecturer and thereby the lecturer can make sure that the student has gained a deeper understanding for the outcome of the labs. The final grade is an averaged grade from the exam (50%) and from the lab reports (50%). The evaluation of the lab reports contains both the quality of the report itself, but also the performance during the defense and discussion.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Recommended:
Successful participation in the modules:
- Introduction to Earth System Science
- Introduction to Photogrammetry, Remote Sensing and GIS
- Orbit Mechanics 1
- Signal Processing
- Electrodynamics

Content:
This lecture is devoted to Earth observation satellites. Instead of giving an overview of existing Earth Observation satellites, this lecture shall concentrate on some Earth observation satellites. For these Earth Observation Satellites, the lecture will concentrate on the connection between the scientific objectives, the instrument and the satellite data.

The first part will give an introduction to potential field theory, to the principles of satellite gravimetry and magnetometry. The principles and goals of the satellite missions CHAMP, GRACE, GOCE, ØRSTED, SAC-C and SWARM are discussed, as well as applications of these satellite data in earth sciences.

The second part will give an introduction to ESA's Earth Observation programs and satellite missions, such as

ERS, ENVISAT, Sentinel. The lecture will focus on the scientific missions, the instruments carried on board and the obtained data sets. The main applications of Earth Observation data within Earth System Science will be introduced.

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to describe the principle characteristics of satellite gravimetry and satellite magnetometry, as well as to explain the relationship between the measurements and the respective potential field parameters. The students have a basic understanding of satellite missions of this type and their application in earth sciences.

In addition, the students are able identify main goals of satellite missions and explain the principles of typical Earth Observation satellite instruments. They can apply remote sensing methods for satellite data and retrieve information from Earth Observation data from selected instruments with means of available software provided by ESA. They are able to evaluate the performance and usability of the software and document it in a report and defend in a scientific discussion.

Teaching and Learning Methods:
2 SWS: Lectures and labs on Gravity and Magnetic Field from Space. Further the student shall hand in written lab reports.
2 SWS: Labs on different ENVISAT instruments. Written lab reports are required.

Media:
Presentations and Lecture notes
ENVISAT Product Handbooks and documentation of the toolboxes
software for the labs

Reading List:
Selected scientific publications
Presentations and Lecture notes
ENVISAT Product Handbooks and Documentation of the toolboxes

Responsible for Module:
Florian Seitz (seitz@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Earth Observation Toolboxes (lecture, 2 SWS)
Iwaszczuk D [L], Iwaszczuk D, Schack P

Gravity and Magnetic Field from Space (lecture, 2 SWS)
Pail R [L], Pail R, Gruber T

For further information in this module, please click
campus.tum.de or here.

Module Description

BV610003: Precise GNSS [PreciseGNSS]

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	105	75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
A written exam takes place in the end of the semester. The aim of the written exam is to ensure that the student has gained the required knowledge and understanding for precise positioning with GNSS data as listed in the intended learning outcomes. The students have to participate in a written midterm exam. The grade of the exam is an averaged grade from the midterm exam (25%) and the final exam (75%). With the midterm exam it is validated that the target competences of the first part have been achieved, because they are a pre-requisite for the second part of the module.
The labs consist of data analysis tasks, which the students should work on by means of appropriate software during supervised labs. The labs should be documented in 3-5 lab reports, which are evaluated according to a pre-defined evaluation scheme. Based on these labs and written reports, the student should demonstrate that he/she can independently validate the quality of the GNSS data and to apply processing strategies for the GNSS data analysis in terms of precise positioning. The final grade is an averaged grade from the exam (75%) and the lab reports (25%).

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Recommended: Fundamentals of linear algebra and statistics as well as successful participation in the module Satellite Navigation and Advanced Orbit Mechanics

Content:
Theory courses (3h) and labs (2h). The aim of the course is to
- get familiar with GNSS, with models involved, and with processing strategies used for precise GNSS positioning applications,
- get experience with GNSS data in practical work.
The theoretical part covers:
- Introduction to GPS and Galileo: position estimation with iterative least-squares method
- Precise Point Positioning with carrier phase measurements (centimeter accuracy)
- Estimation of satellite phase and code biases with geodetic networks
- Estimation of multipath
- Cascaded Kalman filters, method of Bryson
- Real Time Kinematic (RTK) positioning
- Satellite orbit determination: numerical integration, calculation of perturbations, estimation of Keplerian parameters
- Integer ambiguity resolution with statistical a priori knowledge

- Inequality constrained ambiguity resolution
- Statistical evaluation of success rates of carrier phase ambiguity resolution

The practical work includes:
- development of a simple point positioning tool using matlab,
- experiments using a scientific software package to study the impact of different effects and analysis strategies on positioning results.

The practical work is accompanied by short presentations by the participants of their results.

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- understand the theory, the basic methodologies and algorithms, and the current trends for Precise Point Positioning and Real-Time Kinematic (RTK) positioning with GPS and Galileo signals
- to evaluate tracking data quality and multipath
- to assess the impact of different model options on the positioning results
- to understand and apply algorithms and statistical tests for reliable phase ambiguity resolution
- to apply optimized processing strategies to analyze GNSS data for precise positioning applications

Teaching and Learning Methods:
In the lecture the content is presented with powerpoint presentations with examples and demonstrations using Matlab. Calculations and derivations are written to the blackboard.

Labs are based on Matlab and on the Bernese GPS Software, a professional GNSS data analysis software. The students work in groups on specific questions and present the results in short oral presentations.

Media:
Lecture with power-point presentations with electronic handouts and blackboard, demonstration of Matlab code. Lab exercises with electronic handouts, electronic tutorials with solutions.

Reading List:
Hofmann-Wellenhof, Lichtenegger, Collins (2001): GPS-Theory and Practice, Springer
Mistra (2006): GPS-Signals, Measurements and Performance. Ganga-Jamuna Press
Theunissen, Kleusberg (Eds.) (1998): GPS for Geodesy. Springer
Parkinson, B.W. & Spilker Jr., J.J. (1996), Global Positioning System: Theory and Applications Vol. I/II, American Institute of Aeronautics and Astronautics
Kaplan, E., Hegarty C. (2006), Understanding GPS: Principles and Applications, Second Edition, Artech House (available in the library: www.ub.tum.de)
GPS Interface Control Document, ICD-GPS-200C
Bernese GPS Software Version 5.0 User Manual

Responsible for Module:
Urs Hugentobler (urs.hugentobler@mytum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Precise Point Positioning with GPS and Galileo (lecture with integrated exercises, 4 SWS)
Henkel P

Labs in Precise GNSS (practical training, 2 SWS)
Hugentobler U [L], Selmke I

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV610004: Navigation Labs

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
During the semester, the students shall hand in written 4-6 lab reports, which documents the labs and the lab results as well as answering on questions relevant to the lab. These written reports are prepared in small groups and are later on discussed with the lecturer. They are evaluated according to a pre-defined evaluation scheme. The grade of the module is based on the written reports and on individual questions of the lecturer during the discussion. The aim of the written reports is to ensure that the students have gained the required competences to work with GNSS equipment, to characterise GNSS receivers and tracking data, to perform specific analysis tasks in a small team, and to document the used methods and obtained results.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Introductory lectures on GNSS

Content:
Exercises and labs on
- GPS mapping
- Receiver characterization
- Multipath and ionopshere analysis
- Software correlation
- Spaceborne GPS tracking

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- work with and handle GNSS equipment
- understand and apply GNSS data analysis
- understand GNSS processing concepts
- apply dedicated problems of GNSS including receiver technology and data collection
- apply methods for the analysis of GNSS data
- analyze, assess and interprete the results.

Teaching and Learning Methods:
Each lab exercise is introduced with short presentation; students work in small groups using hardware and software and prepare a written report; the results of the report are discussed in the group

Media:
Handouts for each lab exercise, work with hardware and software, presentation of results with written report and discussions.

Reading List:
Misra P., Enge P.; Global Positioning System (GPS): Signals, Measurements and Performance; Ganga-Jamuna Press (2001).

Responsible for Module:
Urs Hugentobler (urs.hugentobler@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
GNSS Lab Exercises (practical training, 4 SWS)
Montenbruck O, Selmke I

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV610005: Advanced Aspects of Navigation Technology

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
A written exam takes place in the end of the semester. The aim of the written exam is to ensure that the student has gained the required knowledge and understanding of methods and strategies used in GNSS applications for time synchronization, indoor navigation, geodynamic applications and aeronautical and space applications. The lab exercises focus on specific aspects of receiver technology and GNSS signal processing. Based on the written lab reports the student should verify that he/she gained the expertise to develop simple software GNSS receiver modules, simple signal generators and to model a radio frequency chain. The final grade is an averaged grade from the exam (33%) and the lab reports (67%).

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Introduction to Satellite Navigation, Signal Processing

Content:
Receiver Technology: Receiver concepts 1: History, fundamentals, review of GNSS signal structures, basic receiver functions, structural elements of a GNSS receiver, fundamentals of signal processing
Receiver concepts 2: Signal acquisition, detectors, tracking loops, pseudorange generation and position estimator, noise performance of DLL and PLL, narrow versus wide correlation, multipath mitigation
Advanced Aspects: Front-end techniques, pre-correlation sampling, crystal oscillators, GALILEO receivers, L2 civil signal implementation, codeless and semi-codeless techniques, receiver integration levels and component figures

GNSS Applications: Different lecturers from DLR and from industry highlight various GNSS and navigation applications:
- Galileo, Precise Time Facility, time synchronization
- Indoor navigation, sensor fusion
- Aeronautical applications, integrity
- Applications in geodynamics
- Space applications

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- to understand the fundamentals of GNSS signals;
- to understand the structure and working principles of a GNSS receiver;
- to develop a software GNSS receiver including acquisition, tracking, navigation modules;
- to develop simple signal generators;
- to model radio frequency chain such as satellite transmission power, link budget, receiver power budget.
- to analyze and to assess typical GNSS applications for navigation and time synchronization;
- to apply combination methods of different sensors and applications;
- to assess and to interpret the results.

They acquired insight into current projects performed and applications developed by industry in and around Munich.

Teaching and Learning Methods:
Receiver Technology: Powerpoint presentations and exercises;
GNSS Applications: Powerpoint presentations by different lecturers from DLR and from Industry on specific topics.

Media:
Powerpoint presentations, blackboard
Receiver technology: Interleaved with exercises done as home work and discussed in the lectures.
GNSS Applications: demonstations in some of the lectures

Reading List:
Receiver Technology: Lecture notes;
GNSS Applications: Lecture handouts

Responsible for Module:
Urs Hugentobler (urs.hugentobler@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Seminar GNSS Applications (seminar, 2 SWS)
Hugentobler U

Receiver Technology (lecture, 2 SWS)
Hugentobler U [L], Frankl K

For further information in this module, please click
campus.tum.de or here.

Module Description

BV610013: Receiver Technology

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
4	120	90	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination is accomplished through written project reports based on the exercises performed. Based on the written lab reports it is verified that the student gained the expertise relevant for receiver technology such as to develop simple software GNSS receiver modules, simple signal generators and to model a radio frequency chain. With the implementation of such software modules in Matlab and their documentation in the project reports it is ensured that the student gained the respective programming skills. The students work on the projects in the self-studyhours while support is provided during contact hours.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Prerequisite is the module "Satellite Navigation and Advanced Orbit Mechanics"

Content:
- Receiver concepts 1: History, fundamentals, review of GNSS signal structures, basic receiver functions, structural elements of a GNSS receiver, fundamentals of signal processing
- Receiver concepts 2: Signal acquisition, detectors, tracking loops, pseudorange generation and position estimator, noise performance of DLL and PLL, narrow versus wide correlation, multipath mitigation
- Advanced Aspects: Front-end techniques, pre-correlation sampling, crystal oscillators, GALILEO receivers, L2 civil signal implementation, codeless and semi-codeless techniques, receiver integration levels and component figures

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- to understand the fundamentals of GNSS signals,
- to understand the structure and working principles of a GNSS receiver,
- to develop a software GNSS receiver including acquisition, tracking, navigation modules,
- to develop simple signal generators,
- to model radio frequency chain such as satellite transmission power, link budget, receiver power budget

Teaching and Learning Methods:
The module consists of a lecture and preparations and discussions of the home works. During the lectures and contact hours the theoretical concepts of receiver technology are presented and the exercises are introduced and discussed. The labs allow the students to implement these concepts in software and thus to gain a deep understanding on receiver working principles and GNSS signal processing.

Media:
Power point, handouts for homeworks

Reading List:
Lecture notes

Responsible for Module:
Urs Hugentobler (urs.hugentobler@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Receiver Technology (lecture, 2 SWS)
Hugentobler U [L], Frankl K

For further information in this module, please click
campus.tum.de or here.

Module Description

EI5028: Satellite Navigation Laboratory

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
In an oral exam students prove that the are able to program a satelite receiver in a step by step approach by discussing their approcah during the lab coure with the examiner.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Basics on satellite navigation and communications engineering

The following modules should be passed before taking the course:
-

It is recommended to take the following modules additionally:
-

Content:
During six experiments the student will program a complete satellite navigation receiver in Matlab. The experiments cover the following topics:
- Satellite Orbits
- Positioning algorithms
- Signal acquisition
- Signal tracking
- Corrected pseudoranges
- Differential positioning

Intended Learning Outcomes:
After completion of the module students understand the process of developing a satellite navigation receiver by programming its components function after function. They re able to apply methods for the sensitivity to parameter changes, the convergence behavior and computational complexity of algorithms, as well as the size of individual terms and corrections.

Teaching and Learning Methods:
The laboratory is centered around a supervised development of the software code for a receiver by the student himself. The task is subdivided into a number of subtasks, which represent one particular function in the receiver, like initial acquisition of the signal or orbit determination.

Media:
The following kinds of media are used:
- Lecture notes and exercises available for download
- Whiteboard notes
- Matlab programs and simulations

Reading List:
The following literature is recommended:
- K. Borre, D. Akos, N. Bertelsen, P. Rinder, S. Jensen (2007), A Software-Defined GPS and Galileo Receiver: A Single-Frequency Approach, Birkhäuser Boston.
- P. Misra, P. Enge (2006) Global Positioning System - Signals, Measurements and Performance, 2nd Edition, Ganga-Jamuna Press.
- E. Kaplan, C. Hegarty (2006) Understanding GPS: Principles and Applications, 2nd Edition, Artech House.

Responsible for Module:
Günther, Christoph; Prof. Dr.

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

MW0229: Satellite Design Workshop

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Bachelor/Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
In Form von kleinen Projektgruppen sind die vermittelten Inhalte auf die konkrete Aufgabenstellung des Workshops anzuwenden. Betreut durch Experten aus Industrie und Universitäten, erarbeitet jede Gruppe einen Lösungsvorschlag und präsentiert diesen in einer Schlussveranstaltung den jeweils anderen Gruppen. Weiterhin findet eine mündliche Prüfung statt, bei der jeder einzelne Studierende unter Beweis stellen muss, dass er in der Lage ist, die beim Satellitenentwurf grundlegenden Einflussfaktoren und deren komplexe Zusammenhänge zu verstehen und daraus die für die konkrete Workshopaufgabe resultierenden Anforderungen zu erfassen und zu beschreiben.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
RFT I und RFT II

Content:
Die Veranstaltung ist als einwöchiger Workshop außerhalb der regulären Voprlesungszeit konzipiert. Da die Teilnahme auf 20 Personen begrenzt ist, findet eine Auswahl nach Semesteranzahl und Vorbildung statt. Verteilt auf mehrere Gruppen wird jedes Jahr ein neues Problem aus dem Bereich des Satellitenentwurfs bearbeitet. Hierfür geben zunächst erfahrene Dozenten aus Universitäten, Industrie und Forschungseinrichtungen Vorlesungen zu den relevanten Themen der Aufgabenstellung. Beim Workshop im Jahre 2008 wurde zum Beispiel ein erster Entwurf für einen Kleinsatelliten erarbeitet. Die vertiefenden Vorlesungen hierzu behandelten Aspekte des Projektmanagements, des Kleinsatellitenentwurfs, des mechanisch-thermischen Subsystems, des Antriebssystems und des elektrischen Systementwurfs. Im Jahre 2010 lag der Schwerpunkt auf dem Subsystem Kommunikation. Die vertiefenden Vorlesungen behandelten Aspekte der Nachrichtenübertragung, der HF Meßtechnik, der Bahnmechanik und Lageregelung von Satelliten und des Tests und Integration von Satelliten. Ergänzt werden die vertiefenden Vorlesungen durch allgemeine Vorlesungen zu Sonderthemen der Raumfahrttechnik, wie z.B. Raumfahrtrecht und Raumfahrtversicherungen.

Intended Learning Outcomes:
Nach der Teilnahme an der Modulveranstaltung sind die Studierenden in der Lage, die relevanten Grundlagen der speziellen Workshopaufgabe, aber auch Aspekte der allgemeninen Satellitentechnik zu verstehen und deren Auswirkungen auf das Satellitengesamtsystem zu identifizieren. Sie sind in der Lage auf Basis dieser Kenntnisse bestehende Satelliten oder deren Subsysteme zu analysieren und gewählte Lösungen zu hinterfragen. Sie besitzen nach Abschluss der Veranstaltung notwendige Kenntnisse um beim Satellitenentwurf mitreden und einen relevanten Beitrag leisten zu können.

Teaching and Learning Methods:
In dem ein-wöchigen Workshop werden die Lehrinhalte anhand von Vorträgen, Präsentationen und Tafelanschrieb vermittelt. Die hauptsächliche Lehr- und Lernmethode ist allerdings die Arbeit in Gruppen unter Anleitung und Aufsicht der Dozenten aus Industrie und Universitäten. Je nach Workshopthema können dies rechnergestützte Entwurfsaufgaben sein oder auch die Durchführung und Auswertung von Messungen, z.B. an einer Satellitenkommunikationsstrecke.

Media:
Vortrag, Präsentation, Handzettel, Tafelanschrieb

Reading List:
U. Walter, Astronautics, Wiley-VCH, ISBN 3-527-40685-9

J. Wertz, W. Larson, Space Mission Analysis and Design, Space Technology Library, ISBN 1-881883-10-8

Responsible for Module:
Walter, Ulrich; Prof. Dr.

Courses (Type of course, Weekly hours per semester), Instructor:
Satellite Design Workshop (lecture, ,1 SWS)
Walter U [L], Rückerl S, Dziura M

For further information in this module, please click
campus.tum.de or here.

Module Description

MW0460: Space Environment and its Simulation [Umwelt und Simulation in der Raumfahrt]

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Bachelor/Master	German	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
With a written examination it shall be ensured that the students are able to remember and to understand basic principles of space environment and its impact on spacecraft and satellites, as well as the main technologies for simulation of the extreme space environmental conditions on Earth. They should verify that they are able to build interrelations between space environment and its effect on satellites.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
none

Content:
Space activities are affected by extreme environmental conditions, such as verberation, vibrations and shock load during start, the residual atmosphere and vacuum during launch, and neutral particles, plasma, radiation, fields, particles and µg conditions in orbit during operation. In the frame of this lecture die individual conditions of the space environment are described in detail, and their effect on technology and operation of spacecraft and satellites are described. Additionally, the simulation of these extreme conditions on Earth is addressed.

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- understand the conditions of space environment in space flight;
- analyze the effects which are relevant for space flight;
- understand and to recognize the necessity for pre-launch simulation of the space environment;
- analyze the challenges and restrictions of these simulation in laboratories on Earth.

Teaching and Learning Methods:
In the classroom the competencies and contents are communicated by blackboard and slides. The slides are provided to the students in the form of written handouts. Additionally, further self-studies are recommended based on the provided list of literature.

Media:
- presentations in electronic form
- blackboard
- movies and animations

Reading List:
- Alan C. Tribble, The Space Environment, Princeton University Press, 2003, ISBN: 0-691-10299-6
- Gerd W. Prölls, Physics of the Earth's Space Environment, Springer Verlag, 2004, ISBN: 3-540-21426-7
- Frank Fahy, John Walker, Fundamentals of Noise and Vibration, E&FN Spon, 1998, ISBN: 0-419-27700-8
- NASA Technical Handbook, Dynamic Environmental Criteria, NASA-HDBK-7005, 2001

Responsible for Module:
Rott, Martin; Dr.-Ing.

Courses (Type of course, Weekly hours per semester), Instructor:
Space Environment and its Simulation (lecture, 2 SWS)
Rott M

For further information in this module, please click
campus.tum.de or here.

Specialization Subject 3: Navigation

Required Elective Modules

Module Description

BV610003: Precise GNSS [PreciseGNSS]

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	105	75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
A written exam takes place in the end of the semester. The aim of the written exam is to ensure that the student has gained the required knowledge and understanding for precise positioning with GNSS data as listed in the intended learning outcomes. The students have to participate in a written midterm exam. The grade of the exam is an averaged grade from the midterm exam (25%) and the final exam (75%). With the midterm exam it is validated that the target competences of the first part have been achieved, because they are a pre-requisite for the second part of the module.
The labs consist of data analysis tasks, which the students should work on by means of appropriate software during supervised labs. The labs should be documented in 3-5 lab reports, which are evaluated according to a pre-defined evaluation scheme. Based on these labs and written reports, the student should demonstrate that he/she can independently validate the quality of the GNSS data and to apply processing strategies for the GNSS data analysis in terms of precise positioning. The final grade is an averaged grade from the exam (75%) and the lab reports (25%).

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Recommended: Fundamentals of linear algebra and statistics as well as successful participation in the module Satellite Navigation and Advanced Orbit Mechanics

Content:
Theory courses (3h) and labs (2h). The aim of the course is to
- get familiar with GNSS, with models involved, and with processing strategies used for precise GNSS positioning applications,
- get experience with GNSS data in practical work.

The theoretical part covers:
- Introduction to GPS and Galileo: position estimation with iterative least-squares method
- Precise Point Positioning with carrier phase measurements (centimeter accuracy)
- Estimation of satellite phase and code biases with geodetic networks
- Estimation of multipath
- Cascaded Kalman filters, method of Bryson
- Real Time Kinematic (RTK) positioning
- Satellite orbit determination: numerical integration, calculation of perturbations, estimation of Keplerian parameters
- Integer ambiguity resolution with statistical a priori knowledge

- Inequality constrained ambiguity resolution
- Statistical evaluation of success rates of carrier phase ambiguity resolution
The practical work includes:
- development of a simple point positioning tool using matlab,
- experiments using a scientific software package to study the impact of different effects and analysis strategies on positioning results.
The practical work is accompanied by short presentations by the participants of their results.

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- understand the theory, the basic methodologies and algorithms, and the current trends for Precise Point Positioning and Real-Time Kinematic (RTK) positioning with GPS and Galileo signals
- to evaluate tracking data quality and multipath
- to assess the impact of different model options on the positioning results
- to understand and apply algorithms and statistical tests for reliable phase ambiguity resolution
- to apply optimized processing strategies to analyze GNSS data for precise positioning applications

Teaching and Learning Methods:
In the lecture the content is presented with powerpoint presentations with examples and demonstrations using Matlab. Calculations and derivations are written to the blackboard.

Labs are based on Matlab and on the Bernese GPS Software, a professional GNSS data analysis software. The students work in groups on specific questions and present the results in short oral presentations.

Media:
Lecture with power-point presentations with electronic handouts and blackboard, demonstration of Matlab code.
Lab exercises with electronic handouts, electronic tutorials with solutions.

Reading List:
Hofmann-Wellenhof, Lichtenegger, Collins (2001): GPS-Theory and Practice, Springer
Mistra (2006): GPS-Signals, Measurements and Performance. Ganga-Jamuna Press
Theunissen, Kleusberg (Eds.) (1998): GPS for Geodesy. Springer
Parkinson, B.W. & Spilker Jr., J.J. (1996), Global Positioning System: Theory and Applications Vol. I/II, American Institute of Aeronautics and Astronautics
Kaplan, E., Hegarty C. (2006), Understanding GPS: Principles and Applications, Second Edition, Artech House (available in the library: www.ub.tum.de)
GPS Interface Control Document, ICD-GPS-200C
Bernese GPS Software Version 5.0 User Manual

Responsible for Module:
Urs Hugentobler (urs.hugentobler@mytum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Precise Point Positioning with GPS and Galileo (lecture with integrated exercises, 4 SWS)
Henkel P

Labs in Precise GNSS (practical training, 2 SWS)
Hugentobler U [L], Selmke I

For further information in this module, please click
campus.tum.de or here.

Module Description

BV610005: Advanced Aspects of Navigation Technology

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
A written exam takes place in the end of the semester. The aim of the written exam is to ensure that the student has gained the required knowledge and understanding of methods and strategies used in GNSS applications for time synchronization, indoor navigation, geodynamic applications and aeronautical and space applications. The lab exercises focus on specific aspects of receiver technology and GNSS signal processing. Based on the written lab reports the student should verify that he/she gained the expertise to develop simple software GNSS receiver modules, simple signal generators and to model a radio frequency chain. The final grade is an averaged grade from the exam (33%) and the lab reports (67%).

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Introduction to Satellite Navigation, Signal Processing

Content:
Receiver Technology: Receiver concepts 1: History, fundamentals, review of GNSS signal structures, basic receiver functions, structural elements of a GNSS receiver, fundamentals of signal processing
Receiver concepts 2: Signal acquisition, detectors, tracking loops, pseudorange generation and position estimator, noise performance of DLL and PLL, narrow versus wide correlation, multipath mitigation
Advanced Aspects: Front-end techniques, pre-correlation sampling, crystal oscillators, GALILEO receivers, L2 civil signal implementation, codeless and semi-codeless techniques, receiver integration levels and component figures

GNSS Applications: Different lecturers from DLR and from industry highlight various GNSS and navigation applications:
- Galileo, Precise Time Facility, time synchronization
- Indoor navigation, sensor fusion
- Aeronautical applications, integrity
- Applications in geodynamics
- Space applications

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- to understand the fundamentals of GNSS signals;
- to understand the structure and working principles of a GNSS receiver;
- to develop a software GNSS receiver including acquisition, tracking, navigation modules;
- to develop simple signal generators;
- to model radio frequency chain such as satellite transmission power, link budget, receiver power budget.
- to analyze and to assess typical GNSS applications for navigation and time synchronization;
- to apply combination methods of different sensors and applications;
- to assess and to interpret the results.
They acquired insight into current projects performed and applications developed by industry in and around Munich.

Teaching and Learning Methods:
Receiver Technology: Powerpoint presentations and exercises;
GNSS Applications: Powerpoint presentations by different lecturers from DLR and from Industry on specific topics.

Media:
Powerpoint presentations, blackboard
Receiver technology: Interleaved with exercises done as home work and discussed in the lectures.
GNSS Applications: demonstations in some of the lectures

Reading List:
Receiver Technology: Lecture notes;
GNSS Applications: Lecture handouts

Responsible for Module:
Urs Hugentobler (urs.hugentobler@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Seminar GNSS Applications (seminar, 2 SWS)
Hugentobler U

Receiver Technology (lecture, 2 SWS)
Hugentobler U [L], Frankl K

For further information in this module, please click
campus.tum.de or here.

Module Description

BV610004: Navigation Labs

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
During the semester, the students shall hand in written 4-6 lab reports, which documents the labs and the lab results as well as answering on questions relevant to the lab. These written reports are prepared in small groups and are later on discussed with the lecturer. They are evaluated according to a pre-defined evaluation scheme. The grade of the module is based on the written reports and on individual questions of the lecturer during the discussion. The aim of the written reports is to ensure that the students have gained the required competences to work with GNSS equipment, to characterise GNSS receivers and tracking data, to perform specific analysis tasks in a small team, and to document the used methods and obtained results.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Introductory lectures on GNSS

Content:
Exercises and labs on
- GPS mapping
- Receiver characterization
- Multipath and ionopshere analysis
- Software correlation
- Spaceborne GPS tracking

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- work with and handle GNSS equipment
- understand and apply GNSS data analysis
- understand GNSS processing concepts
- apply dedicated problems of GNSS including receiver technology and data collection
- apply methods for the analysis of GNSS data
- analyze, assess and interprete the results.

Teaching and Learning Methods:
Each lab exercise is introduced with short presentation; students work in small groups using hardware and software and prepare a written report; the results of the report are discussed in the group

Media:
Handouts for each lab exercise, work with hardware and software, presentation of results with written report and discussions.

Reading List:
Misra P., Enge P.; Global Positioning System (GPS): Signals, Measurements and Performance; Ganga-Jamuna Press (2001).

Responsible for Module:
Urs Hugentobler (urs.hugentobler@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
GNSS Lab Exercises (practical training, 4 SWS)
Montenbruck O, Selmke I

For further information in this module, please click
campus.tum.de or here.

Elective Modules

Technische Universität München

Module Description

BGU45024: Gravity and Magnetic Field from Space

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
With an oral examination it shall be ensured that the students are able to remember and to understand the main concepts of potential field theory and the observation techniques of the Earth s gravity and magnetic field from space. The students should verify that they are able to build interrelations among these concepts, that they are able to apply methods for processing of satellite gravity and magnetic field data and to link them to global potential field modelling. By means of dedicated questions, it is verified that the students are able to interpret results of gravity and magnetic field observation technologies and that they are able to build connections to system Earth processes. The format of an oral exam allows interactive queries, and the ability to give precise and well-structured answers in real time is verified.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Recommended:
- Introduction to Earth System Science
- Orbit Mechanics 1
- Signal Processing
- Electrodynamics

Content:
Introduction to potential field theory
- principles of satellite gravimetry and magnetometry
- mission concept and goals of the satellite gravity missions CHAMP, GRACE, GOCE
- mission concept and goals of the magnetic field missions ØRSTED, SAC-C, SWARM
- applications of satellite gravity and magnetic field data in earth sciences

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- to understand the basics of potential field theory and the mathematical description of the Earth s gravity and magnetic field;
- to understand the basic mission concepts and objectives of satellite gravity and magnetic field missions

- to recognize the relationship between the measurements and the respective potential field parameters
- to apply these concepts for the solution of practical problems
- to analyze and to interpret the results
- to link the observation of the global gravity and magnetic field and its changes to the global monitoring of the Earth system.

Teaching and Learning Methods:
Power point presentations; handouts in electronic form; blackboard

Media:
- presentations in electronic form
- blackboard
- Selected text books and scientific publications

Reading List:
Handouts

Responsible for Module:
Roland Pail (pail@bv.tu-muenchen.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Gravity and Magnetic Field from Space (lecture, 2 SWS)
Pail R [L], Pail R, Gruber T

For further information in this module, please click
campus.tum.de or here.

Module Description

BGU45026: Earth Observation Mission Design Seminar

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	45	45

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The module will be evaluated by a presentation of at least 30 min. which will be regarded as a study result of this course.
With the study result it will be evaluated if the students acquired competences to define, analyze and evaluate the scientific and technical requirements of a new Earth observation satellite mission. For this it is required to do a literature survey and to apply competences obtained during previous studies. The design of a new concept requires in addition to cross-check the technical and scientific requirements against each other, which will be done by team work and exchange of competences within the team of students. The student teams will be supported by consultancy of the lecturers.
Information about study result: At the end of the seminar the student team gives an overview about the developed mission design and the related scientific and technical requirements. During intermediate meetings with the lecturers the next development steps will be discussed. The study results will be done by students homework.

Repeat Examination:

(Recommended) Prerequisites:
It is recomemnded to have basic knowledge about matehmatics, physics and engineering sciences as it is typically acquired in an engineering course at Bachelor level.

Content:
Course: ¿Earth Observation Mission Design Seminar¿
The course will be organized as seminar, which will address the following content: Definition of scientific and technical requirements for am Earth observation satellite mission; Introduction of the various components of a satellite mission (satellite bus, instruments, ground segment, etc.); Planning of satellite orbits in order to reach the mission requirements; Development of a measurement concept in order to reach the mission requirements; Specification of the data management on board of the satellite and together with groudn stations; Definition of processing algorithms for the data products to be computed.

Intended Learning Outcomes:
After participating at the module students are capable,
- to understand the components needed to design an Earth observation satellite mission,
- to understand and to analyze the interactions between the various components,
- to define the scientific requirements for an Earth observation satellite mission,
- to develop a mission design for one or a constellation of satellites meeting the scientific requirements,

- to analyze the mission concept and the developped mission design,
- to assess the scientific and technical requirements of a new Earth observation satellite mission.

Teaching and Learning Methods:
The course will be held as seminar, i.e. the students develop a mission design for a given topic and present intermediate and final results to the lectureres. All results will be discussed with the complete team and next steps to be done will be discussed.

Media:
Presentations, Documents, Publications

Reading List:
not required

Responsible for Module:
Roland Pail

Courses (Type of course, Weekly hours per semester), Instructor:
Earth Observation Mission Design Seminar (seminar, 3 SWS)
Gruber T, Pail R

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BGU45027: Earth Observation Mission Development Seminar

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3			

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:

Repeat Examination:

(Recommended) Prerequisites:

Content:

Intended Learning Outcomes:

Teaching and Learning Methods:

Media:

Reading List:

Responsible for Module:

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV230050: Atmospheric Physics and Remote Sensing

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
With an oral examination it shall be ensured that the students are able to remember and to understand the individual concepts and processes of atmosphere and its composition, weather and climate, the Earth s energy budget and radiation balance, and climate predictions. The students should verify that they are able to build interrelations among these concepts, and that they have an insight into their contribution to the overarching concept of system Earth. By means of dedicated questions, it is verified that the students are able to interpret results of observation technologies and that they are able to build connections to physical modelling. The format of an oral exam allows interactive queries, and the students are required to give precise and well-structured answers in real time.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Mathematics, experimental Physics

Content:
Atmospheric Physics and Remote Sensing: Introduction to atmospheric physics with an emphasis on remote sensing of atmospheric components and processes from space:
- atmosphere, weather and climate,
- clouds, aerosols and trace gases,
- radiative transfer,
- Earth's energy budget,
- remote sensing of the atmosphere,
- climate modelling and climate change

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- to understand the basic principles of atmosphere, weather, and climate;
- to understand the methods for determining atmospheric composition and dynamics from space;
- to apply analysis methods for practical problems related to atmosphere and climate;
- to apply atmospheric remote sensing methods, and to analyze the results;
- to link these topics to the monitoring of the Earth system.

Teaching and Learning Methods:
Power point presentations; handouts in electronic form; blackboard

Media:
- presentations in electronic form
- Blackboard
- Selected text books and scientific publications

Reading List:
F.W. Taylor, Elementary Climate Physics, Oxford University Press, 2005.
J.M. Wallace and P.V. Hobbs, Atmospheric Science: An Introductory Survey, Academic Press, 2nd edition, 2006.
W. Roedel, Physik unserer Umwelt: Die Atmosphaere, Springer, 3. Auflage, 2000.
L. Bergmann und C. Schaefer, Lehrbuch der Experimentalphysik Band 7: Erde und Planeten, de Gruyter, 2. Auflage, 2001.

Responsible for Module:
Roland Pail (pail@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Atmospheric Physics and Remote Sensing (lecture, 2 SWS)
Kiemle C

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV290015: Remote Sensing

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
A written exam takes place in the end of the semester. The exam contains theoretical questions as well as calculations. By answering the questions in a limited time, the student should demonstrate that he/she is able to apply signal processing methods on remote sensing applications. Furthermore the student should hand in a written lab report and thereby verify that he/she is able to implement self-containedly certain parts of regularization theory and to evaluate the results in a project report. In addition the student should present a research work in an oral presentation and defend their ideas. Here it is tested that the student has gained a deeper understanding for research topics within remote sensing, that he/she is able to work independently on a research topic and is able to defend his/her own ideas. The final grade is an averaged grade from the written exam (50%) and from the written project report and oral presentations (50%).

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Required: Basic knowledge in photogrammetry, mathematics and physics.
Recommended: Successful participation in the module Introduction to Photogrammetrie, Remote Sensing and GIS.

Content:
Remote Sensing - Advanced Methods:
1. Along-Track and Across-Track Interferometry
2. Differential SAR Interferometry
3. Persistent Scatterer Interferometry
4. Remote Sensing of the Atmosphere
5. Remote Sensing of the Oceans

The processing of SAR data is trained in tutorials.

Non-linear Optimization Methods:
Inverse Problems and Nonlinear Optimization Theory:
1. Ill-posed linear problems (concept of ill-posedness, regularization issues, discretization by projection, regularization by projection)
2. Tikhonov regularization for linear problems (formulation, error analysis, parameter choice methods)
3. Tikhonov regularization for nonlinear problems (formulation, error analysis, implementation issues)
4. Optimization theory: Minimization methods for smooth functions (step-length based methods, trust-region methods)

5. Optimization theory: Minimization methods for sum of squares (Gauss-Newton method, quasi-Newton method, trust-region methods)
6. Iterative regularization methods (Landweber iteration, Newton-type methods, regularizing Levenberg-Marquardt method, regularizing trus-region methods

Seminar Remote Sensing
The seminar provides deep insight into specific and selected topics of remote sensing. Topics to be elaborated and presented are given at the Kick-Off meeting and combine, for instance, methods and applications of remote sensing/image analysis.

Intended Learning Outcomes:
After participating in the module, the students are able to

- understand and apply methods of signal processing in remote sensing
- evaluate the usability of specific remote sensing methods for practical problems
- understand the fundamental basics of regularization theory
- evaluate results of the application of regularization techniques in a project report
- analyze autonomously tasks in the research field of remote sensing
- prepare methodical basics for a selected research topic
- evaluate alternative approaches in practice and to develop own solutions
- present the elaborated results in a talk

Teaching and Learning Methods:
Lecture notes, slides, applications and examples, discussion, presentation, literature work, programming

Media:
Slides, lecture notes, exercise sheets, white-/blackboard

Reading List:
Remote Sensing - Advanced Methods: Sabins FF, Remote Sensing Principles and Interpretation, W.H. Freeman and Company, 1997 Cumming IG, Digital Processing of Synthetic Aperture Radar, Artech House, 2005
Non-linear optimization: lecture notes
Remote Sensing Seminar: selected litterature (such as scientific papers) will be provided for each topic individually

Responsible for Module:
Richard Bamler (Richard.Bamler@dlr.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Non-linear Optimization (lecture, 1 SWS)
Doicu A

Lab for Remote Sensing - Advanced Methods (exercise, 1 SWS)
Schmitt M

Remote Sensing - Advanced Methods (lecture, 1 SWS)
Zhu X

Remote Sensing Seminar (seminar, 1 SWS)
Zhu X

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV300003: Geo-Information

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
A written exam takes place in the end of the semester. By answering the questions the student should verify that they have gained the required knowledge about spatial data management, the analysis of geodata, spatial data mining and cartographic techniques for visualising spatial data. The exam contains questions in which they have to give valid definitions, explain concepts, theoretically implement and evaluate case studies, as well as mastering design challenges. All learning outcomes are covered by this written exam.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Knowledge of higher mathematics and experiences of handling spatial data

Content:
This module includes the following topics:
¿ Introduction to GIS;
¿ Spatio-temporal representations and databases;
¿ Spatial data analysis;
¿ Spatial data mining;
¿ Data retrieval and cartographic techniques;
¿ Case studies of Geoinformation;
¿ Introduction to ArcGIS components;
¿ Working with multiple data tables;
¿ Learning spatial analysis methods;
¿ Building 3D models;
¿ Creating animations;
¿ Designing a quality Map in a GIS;
¿ Collecting spatial data during field work;
¿ Integrating GPS data to a GIS;
¿ Publishing geographic information online.

Intended Learning Outcomes:
Upon completion of the module, students are able to¿
¿ illustrate the dimensions of geoinformation;
¿ explain the structure of a GIS;
¿ understand data mining concepts;
¿ implement concepts of geodata harmonization to integrate geodata into a GIS;
¿ implement geostatistical methods;

¿ apply properties of different map projections and to select appropriate projections for specific purpose;
¿ implement map generalization concepts and algorithms;
¿ integrate the functional and the organizational workflow of geodata-management and implement them into system-architectures using established concepts of geodata modelling;
¿ evaluate spatial databases and the spatial data quality within geodata-management;
¿ create queries for geodata analysis;
¿ create well designed maps;
¿ generate three dimensional data models.

Teaching and Learning Methods:
The module is structured in lectures and exercises. The lectures provide the theoretical foundations of geoinformation. They impart knowledge about spatial data management, the analysis of geodata, spatial data mining and cartographic techniques for visualising spatial data. The exercise part of this module allows the students to employ their GIS knowledge to applied studies. An introduction to ArcGIS will be given and the students can analyse and visualise geodata using a variety of analysis tools and visualisation techniques. A set of exercises put the theoretical knowledge into practice. The exercises are carried out in a computer lab individually, partly under supervision and partly in self-study. Feedback on the exercises is given to each student within a personal one-on-one discussion.

Media:
Moodle E-learning, presentations, script, GIS laboratory, hand-outs, recommended literature

Reading List:
Longley, P. A., Goodchild, M. F., Maguire D. J., Rhind, D. W. (Eds.) (2005): Geographical Information Systems ¿ Principles, Techniques, Management and Applications. John Wiley & Sons.
Law, M., Collins, A. (2013): Getting to Know ArcGIS for Desktop. Esri Press.

Responsible for Module:
Liqiu Meng, liqiu.meng@tum.de

Courses (Type of course, Weekly hours per semester), Instructor:
Geoinformation (lecture, 4 SWS)
Meng L, Murphy C

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV400016: Scientific Paper Writing [SPW]

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	70	20

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Students have to submit a scientific paper which is written in groups. The students demonstrate with their papers that they have gained deeper knowledge of the specific requirements of a scientific paper, including structure, appropriate presentation of information and discussion as well as the related formalities. The students are able to develop a topic for their papers and formulate the problem statement, objectives and research questions. Furthermore, the students are able to develop a conceptual frame and present as well as analyze information and formulate conclusions. Finally, the students are able to meet the formalities of a scientific paper including proper quotations, layout and language.

Repeat Examination:

(Recommended) Prerequisites:
none

Content:
1. The research process: main steps to undertake in a research project leading to the preparation of a scientific paper.
2. Scientific paper writing: main components of a scientific paper and their respective contents with focus on topic development and logical construction of line of argument.
3. Sources of Information: main sources of information for writing scientific paper, with focus on scientifically valid sources and how to identify these.
4. Referencing: aspects to consider when providing references and how to provide quotations in a proper way.
5. Technical tips: a few technical tips to use time efficiently when writing a scientific paper.

Intended Learning Outcomes:
At the end of the module the students understand the main steps to undertake in order to write a scientific paper. In addition, students are able to develop the topic for a scientific paper and establish the main components of its structure. Furthermore, the students are able to write a scientific paper by presenting and following a clear line of argument, discussion and conclusions. The students are also able to identify scientifically valid sources of information and provide quotations in an appropriate way. Finally, the students are able to conduct collaborative work in an academic environment.

Teaching and Learning Methods:
Lectures, exercise and excursion are held as types of instruction. Teaching method includes presentation and group discussion which help students to understand how to do a scientific research.

Media:
Presentations followed by discussion.

Reading List:
Anglia Ruskin University Library (2013): Harvard System of Referencing Guide.
Clanchy, J. and B. Ballard (1998): How to Write Essays. A practical Guide for Students. Longman.
Cottrell, S. (1999): The Study Skills Handbook. Palgrave Study Guides.
Cottrell, S. (2001): Teaching Study Skills and Supporting Learning. Palgrave Study Guides.
Cresswell, J. (2009): Research design. Qualitative, quantitative, and mixed methods approaches. Third Edition. Sage, London.
Fairbairn, J. and C. Winch (1996): Reading, Writing and Reasoning. A Guide for Students. Open University Press.
Gillham, B. (2000): Developing a Questionnaire. Continuum, London.
Redman, P. (2001): Good Essay Writing. A Social Sciences Guide. The Open University.
Malmfors, B. and P. Garnsworthy (2004): Writing and Presenting Scientific Papers

Responsible for Module:
Florian Siegert (florian.siegert@tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Scientific Paper Writing (lecture, 1 SWS)
de Vries W [L], Chigbu U, de Vries W

For further information in this module, please click
campus.tum.de or here.

Module Description

BV450005: Satellite Altimetry and Physical Oceanography [AltiOcean]

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
With an oral examination it shall be ensured that the students are able to remember and to understand the individual concepts of physical oceanography, the observation technique of satellite altimetry, and the products derived from it. They should verify that they are able to build interrelations between the observational component of satellite altimetry and the physical processes of oceanography, and that they are able to understand their contribution to the overarching concept of system Earth. By means of dedicated questions, it is verified that the students are able to interpret results of observation technologies and that they are able to build connections to physical modelling. The format of an oral exam allows interactive queries, and the ability to give precise and well-structured answers in real time is verified.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Mathematical physics, linear algebra, time series analysis

Content:
Oceanography and Satellite Altimetry:
- Equation of motion,
- geostrophic currents,
- hydrostatic balance,
- temperature, salinity, and density,
- ocean tides, tidal analysis,
- de-aliasing,
- radar and laser altimetry,
- altimeter mission overview,
- where to get what data,
- corrections of altimeter observations,
- repeat pass and crossover analysis,
- mean sea surface, geoid, dynamic ocean topography, sea level variability, sea level rise.

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- to understand the basic principles of physical oceanography;

- to understand the basic principles of satellite altimeter missions
- to recognize satellite altimetry as an operational remote sensing technique with important applications in geodesy, oceanography and other geosciences;
- to apply observation techniques and the necessary measurement correction;
- to apply key analysis methods to practical problems of satellite altimetry and physical oceanography;
- to analyze and to interpret the results;
- to link these topics to the monitoring of the Earth system.

Teaching and Learning Methods:
Power point presentations; handouts in electronic form; blackboard

Media:
- presentations in electronic form
- blackboard
- Selected text books and scientific publications

Reading List:
Stewart, R.: Introduction to Physical Oceanography (OpenSource Book, see download)
Fu, L.L. and A. Cazenave (Eds.) Satellite Altimetry. International Geophysics Series, Vol. 69, San Diego, CA, 2000

Responsible for Module:
Roland Pail (pail@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Satellite Altimetry and Physical Oceanography (lecture, 2 SWS)
Seitz F [L], Bosch W, Passaro M

For further information in this module, please click
campus.tum.de or here.

Module Description

BV450006: Atmosphere and Ocean

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
With an oral examination it shall be ensured that the students are not only able to remember and understand the individual concepts covered by the two lectures, but they should verify that they are able to build interrelations among these concepts, and that they have an insight into their contribution to the overarching concept of system Earth. By means of dedicated questions, it is verified that the students are able to interpret results of observation technologies and that they are able to build connections to physical modelling.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Atmospheric Physics and Remote Sensing: Mathematics, experimental Physics; Oceanography and Satellite Altimetry: Mathematical physics, linear algebra, time series analysis

Content:
Atmospheric Physics and Remote Sensing: Introduction to atmospheric physics with an emphasis on remote sensing of atmospheric components and processes from space:
- atmosphere, weather and climate,
- clouds, aerosols and trace gases,
- radiative transfer,
- Earth's energy budget,
- remote sensing of the atmosphere,
- climate modelling and climate change

Oceanography and Satellite Altimetry:
- Equation of motion,
- geostrophic currents,
- hydrostatic balance,
- temperature, salinity, and density,
- ocean tides, tidal analysis,
- de-aliasing,
- radar and laser altimetry,
- altimeter mission overview,
- where to get what data,
- corrections of altimeter observations,
- repeat pass and crossover analysis,

- mean sea surface, geoid, dynamic ocean topography, sea level variability, sea level rise

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to understand the basic principles of atmosphere, weather, and climate and the methods for determining atmospheric composition and dynamics from space, and they shall be able to apply these principles and methods for practical problems. Further the student shall understand and apply the most basic principles of physical oceanography and recognize satellite altimetry as an operational remote sensing technique with important applications in geodesy, oceanography and other geosciences. In addition, students shall know about satellite altimeter missions, be able to understand and to apply observation techniques and the necessary measurement correction, shall know where to get data and products and how to access data. The students shall also be able to understand important analysis methods and to apply them to practical problems. They should also remember and understand the geophysical application of satellite altimetry and they shall be able to link it to the monitoring of several components of the Earth system.

Teaching and Learning Methods:
Power point presentations; handouts in electronic form; blackboard

Media:
- presentations in electronic form
- Blackboard
- Selected text books and scientific publications

Reading List:
Atmospheric Physics and Remote Sensing: F.W. Taylor, Elementary Climate Physics, Oxford University Press, 2005.
Further reading:
J.M. Wallace and P.V. Hobbs, Atmospheric Science: An Introductory Survey, Academic Press, 2nd edition, 2006.
W. Roedel, Physik unserer Umwelt: Die Atmosphaere, Springer, 3. Auflage, 2000.
L. Bergmann und C. Schaefer, Lehrbuch der Experimentalphysik Band 7: Erde und Planeten, de Gruyter, 2. Auflage, 2001.
Oceanography and Satellite Altimetry: Stewart, R.: Introduction to Physical Oceanography (OpenSource Book, see download)
Fu, L.L. and A. Cazenave (Eds.) Satellite Altimetry. International Geophysics Series, Vol. 69, San Diego, CA, 2000

Responsible for Module:
Roland Pail (pail@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Atmospheric Physics and Remote Sensing (lecture, 2 SWS)
Kiemle C

Satellite Altimetry and Physical Oceanography (lecture, 2 SWS)
Seitz F [L], Bosch W, Passaro M

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV480025: Photogrammetry [PSC]

Selected Chapters

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The exams consist of a presentation of 45 minutes of a prepared scientific topic and an oral examination on the topics the whole lecture. The student has to show the ability to prepare and present a scientific topic and evaluate different methods in a presentation. In the oral exam, the broad knowledge on the different topics of lecture is checked.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
" Introduction to Photogrammetry, Remote Sensing and GIS or Photogrammetrie & Fernerkundung 1
" Digital Image Processing or Digitale Bildverarbeitung

Content:
Lectures on Photogrammetry and remote sensing:
" Extraction of buildings from aerial images, satellite images, LiDAR, SAR
" Extraction of roads from aerial images, satellite images, LiDAR, SAR
" Extraction of vehicles from aerial images, satellite images, LiDAR, IR
" Classification of vegetaion from aerial images, satellite images, LiDAR, SAR
" Glaciers DEM from aerial images, satellite images, LiDAR, SAR
Topics from the fields of photogrammetry, remote sensing and image analysis are selected by the students.

Intended Learning Outcomes:
Upon successful completion of the module, the students are able to
- understand and apply methods of Photogrammatry and Remote Sensing
- evaluate the usability of specific methods for specific tasks
- evaluate results in a project report
- to present scientific results to an audience, i.e. how to design slides, structure the presentation, and how to defend the content in a discussion
- analyse problems and solution of a specific task in Photogrammetry and Remote Sensing
- evaluate actual problems and methods in photogrammetry and remote sensing
- prepare methodical basics and present elaborated results in a talk and report

Teaching and Learning Methods:
Lecture (interactive) and seminar

Media:
" Lecture (interactive) and seminar

Reading List:
Scientific papers

Responsible for Module:
Uwe Stilla (Uwe.Stilla@bv.tu-muenchen.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Photogrammetry - Selected Chapters (PSC) (lecture, 4 SWS)
Stilla U, Hoegner L

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description
BV570001: Earth System Dynamics

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The learning outcome of the module is certificated after students have passed a written exam and the corresponding labs. By the written exam, it is verified that the students are able to deeply understand the main dynamical processes of the Earth system, that they are able to apply methodologies to practical geophysical problems, and that they are able to evaluate and to interpret the results. During the semester students are expected to prepare individually a written report on a project in the frame of a seminar. By this written reports, is verified that the students are able to interlink in a self-contained way various sub-topics of Earth system dynamic into a global picture.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Required:
- Basic knowledge in linear algebra, calculus, mechanics
- Programming in MATLAB

Recommended:
Successful participation in the modules
- Introduction to Earth System Science
- Numerical Modeling
- Signal Processing

Content:
1 Introduction to Earth System Science
1.1 System Earth and its Components
1.2 Geophysical Fluids and Solid Earth
1.3 Geometrical and Gravimetrical Observation Techniques

2 Geophysical Fluids: Internal Processes and Interactions
2.1 Atmosphere Dynamics
2.2 Ocean Dynamics
2.3 Atmosphere-Ocean Interaction

3 Models of Atmosphere and Hydrosphere
3.1 Atmospheric General Circulation Models and Reanalyses
3.2 Ocean Circulation Models and Data Assimilation
3.3 Coupled Models

4 Interactions Between Geophysical Fluids and Solid Earth
4.1 Earth rotation and the Balance of Angular Momentum
4.2 Gravity Field Variations and their Geophysical Interpretation
4.3 Surface Deformation by Atmospheric and Hydrospheric Loading

5 Seminar on Climate Change
5.1 Keynote Lectures by invited guests
5.2 Project work

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to understand dynamic processes in the Earth system, apply geophysical models of processes and evaluate numerical results and prognoses.
Through the preparation of a written report on a project related to climate change on the basis of three invited keynote speakers, students are able to gain competence across various subjects covered by ESPACE.

Teaching and Learning Methods:
2 SWS lecture on Earth System Dynamics: Provides theoretical foundations of dynamic processes and interactions in the Earth system as well as of numerical physical models.

1 SWS labs on Earth System Dynamics: Numerical exercises on the topics covered by the lecture using MATLAB; for the most part, the lab is organised as homework with the requirement of preparing a written report on methodology and results.

1 SWS Seminar with guest lecturers: Three invited guests from space agencies, research institutes and the space industry give keynote lectures on topics related to climate change. On the basis of these introductory lectures, students will work on a project using actual satellite or model data from the context of climate change signals. Students will prepare a written report on the methodology and outcome of the project which contributes with 1/4 to the final mark of the module.

Media:
- Presentation slides

- Lecture Notes

- Selected Scientific Publications which will be distributed in class

Reading List:
- Lecture Notes

- IPCC (2007): Climate Change 2007: Synthesis Report, Geneva.

- Kandel, R. (1980): Earth and Cosmos, Pergamon Press, Oxford

- Selected scientific publications will be distributed in the course

Responsible for Module:
Florian Seitz (seitz@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Seminar with Guest Lecturers (seminar, 1 SWS)
Pail R

Earth System Dynamics (lecture, 2 SWS)
Seitz F [L], Bloßfeld M

Labs in Earth System Dynamics (exercise, 1 SWS)
Seitz F [L], Bloßfeld M

For further information in this module, please click
campus.tum.de or here.

Module Description

BV570002: Earth Observation Satellites

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The written exam aims to verify that the student knows the concept behind satellite gravimetry and satellite magnetometry as well as the relationship between the measurements and the respective potential field parameters by answering a number of theoretical questions under time pressure. In addition the students should hand in 3-5 lab reports. The student should demonstrate that they are able to analyze different satellite data on specific applications and know how to document this in a report. The students should also defend the results in discussions with the lecturer and thereby the lecturer can make sure that the student has gained a deeper understanding for the outcome of the labs. The final grade is an averaged grade from the exam (50%) and from the lab reports (50%). The evaluation of the lab reports contains both the quality of the report itself, but also the performance during the defense and discussion.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Recommended:
Successful participation in the modules:
- Introduction to Earth System Science
- Introduction to Photogrammetry, Remote Sensing and GIS
- Orbit Mechanics 1
- Signal Processing
- Electrodynamics

Content:
This lecture is devoted to Earth observation satellites. Instead of giving an overview of existing Earth Observation satellites, this lecture shall concentrate on some Earth observation satellites. For these Earth Observation Satellites, the lecture will concentrate on the connection between the scientific objectives, the instrument and the satellite data.

The first part will give an introduction to potential field theory, to the principles of satellite gravimetry and magnetometry. The principles and goals of the satellite missions CHAMP, GRACE, GOCE, ØRSTED, SAC-C and SWARM are discussed, as well as applications of these satellite data in earth sciences.

The second part will give an introduction to ESA's Earth Observation programs and satellite missions, such as

ERS, ENVISAT, Sentinel. The lecture will focus on the scientific missions, the instruments carried on board and the obtained data sets. The main applications of Earth Observation data within Earth System Science will be introduced.

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to describe the principle characteristics of satellite gravimetry and satellite magnetometry, as well as to explain the relationship between the measurements and the respective potential field parameters. The students have a basic understanding of satellite missions of this type and their application in earth sciences.

In addition, the students are able identify main goals of satellite missions and explain the principles of typical Earth Observation satellite instruments. They can apply remote sensing methods for satellite data and retrieve information from Earth Observation data from selected instruments with means of available software provided by ESA. They are able to evaluate the performance and usability of the software and document it in a report and defend in a scientific discussion.

Teaching and Learning Methods:
2 SWS: Lectures and labs on Gravity and Magnetic Field from Space. Further the student shall hand in written lab reports.
2 SWS: Labs on different ENVISAT instruments. Written lab reports are required.

Media:
Presentations and Lecture notes
ENVISAT Product Handbooks and documentation of the toolboxes
software for the labs

Reading List:
Selected scientific publications
Presentations and Lecture notes
ENVISAT Product Handbooks and Documentation of the toolboxes

Responsible for Module:
Florian Seitz (seitz@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Earth Observation Toolboxes (lecture, 2 SWS)
Iwaszczuk D [L], Iwaszczuk D, Schack P

Gravity and Magnetic Field from Space (lecture, 2 SWS)
Pail R [L], Pail R, Gruber T

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

EI5028: Satellite Navigation Laboratory

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
In an oral exam students prove that the are able to program a satelite receiver in a step by step approach by discussing their approcah during the lab coure with the examiner.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Basics on satellite navigation and communications engineering

The following modules should be passed before taking the course:
-

It is recommended to take the following modules additionally:
-

Content:
During six experiments the student will program a complete satellite navigation receiver in Matlab. The experiments cover the following topics:
- Satellite Orbits
- Positioning algorithms
- Signal acquisition
- Signal tracking
- Corrected pseudoranges
- Differential positioning

Intended Learning Outcomes:
After completion of the module students understand the process of developing a satellite navigation receiver by programming its components function after function. They re able to apply methods for the sensitivity to parameter changes, the convergence behavior and computational complexity of algorithms, as well as the size of individual terms and corrections.

Teaching and Learning Methods:
The laboratory is centered around a supervised development of the software code for a receiver by the student himself. The task is subdivided into a number of subtasks, which represent one particular function in the receiver, like initial acquisition of the signal or orbit determination.

Media:
The following kinds of media are used:
- Lecture notes and exercises available for download
- Whiteboard notes
- Matlab programs and simulations

Reading List:
The following literature is recommended:
- K. Borre, D. Akos, N. Bertelsen, P. Rinder, S. Jensen (2007), A Software-Defined GPS and Galileo Receiver: A Single-Frequency Approach, Birkhäuser Boston.
- P. Misra, P. Enge (2006) Global Positioning System - Signals, Measurements and Performance, 2nd Edition, Ganga-Jamuna Press.
- E. Kaplan, C. Hegarty (2006) Understanding GPS: Principles and Applications, 2nd Edition, Artech House.

Responsible for Module:
Günther, Christoph; Prof. Dr.

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

MW0229: Satellite Design Workshop

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Bachelor/Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
In Form von kleinen Projektgruppen sind die vermittelten Inhalte auf die konkrete Aufgabenstellung des Workshops anzuwenden. Betreut durch Experten aus Industrie und Universitäten, erarbeitet jede Gruppe einen Lösungsvorschlag und präsentiert diesen in einer Schlussveranstaltung den jeweils anderen Gruppen. Weiterhin findet eine mündliche Prüfung statt, bei der jeder einzelne Studierende unter Beweis stellen muss, dass er in der Lage ist, die beim Satellitenentwurf grundlegenden Einflussfaktoren und deren komplexe Zusammenhänge zu verstehen und daraus die für die konkrete Workshopaufgabe resultierenden Anforderungen zu erfassen und zu beschreiben.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
RFT I und RFT II

Content:
Die Veranstaltung ist als einwöchiger Workshop außerhalb der regulären Voprlesungszeit konzipiert. Da die Teilnahme auf 20 Personen begrenzt ist, findet eine Auswahl nach Semesteranzahl und Vorbildung statt. Verteilt auf mehrere Gruppen wird jedes Jahr ein neues Problem aus dem Bereich des Satellitenentwurfs bearbeitet. Hierfür geben zunächst erfahrene Dozenten aus Universitäten, Industrie und Forschungseinrichtungen Vorlesungen zu den relevanten Themen der Aufgabenstellung. Beim Workshop im Jahre 2008 wurde zum Beispiel ein erster Entwurf für einen Kleinsatelliten erarbeitet. Die vertiefenden Vorlesungen hierzu behandelten Aspekte des Projektmanagements, des Kleinsatellitenentwurfs, des mechanisch-thermischen Subsystems, des Antriebssystems und des elektrischen Systementwurfs. Im Jahre 2010 lag der Schwerpunkt auf dem Subsystem Kommunikation. Die vertiefenden Vorlesungen behandelten Aspekte der Nachrichtenübertragung, der HF Meßtechnik, der Bahnmechanik und Lageregelung von Satelliten und des Tests und Integration von Satelliten. Ergänzt werden die vertiefenden Vorlesungen durch allgemeine Vorlesungen zu Sonderthemen der Raumfahrttechnik, wie z.B. Raumfahrtrecht und Raumfahrtversicherungen.

Intended Learning Outcomes:
Nach der Teilnahme an der Modulveranstaltung sind die Studierenden in der Lage, die relevanten Grundlagen der speziellen Workshopaufgabe, aber auch Aspekte der allgemeninen Satellitentechnik zu verstehen und deren Auswirkungen auf das Satellitengesamtsystem zu identifizieren. Sie sind in der Lage auf Basis dieser Kenntnisse bestehende Satelliten oder deren Subsysteme zu analysieren und gewählte Lösungen zu hinterfragen. Sie besitzen nach Abschluss der Veranstaltung notwendige Kenntnisse um beim Satellitenentwurf mitreden und einen relevanten Beitrag leisten zu können.

Teaching and Learning Methods:
In dem ein-wöchigen Workshop werden die Lehrinhalte anhand von Vorträgen, Präsentationen und Tafelanschrieb vermittelt. Die hauptsächliche Lehr- und Lernmethode ist allerdings die Arbeit in Gruppen unter Anleitung und Aufsicht der Dozenten aus Industrie und Universitäten. Je nach Workshopthema können dies rechnergestützte Entwurfsaufgaben sein oder auch die Durchführung und Auswertung von Messungen, z.B. an einer Satellitenkommunikationsstrecke.

Media:
Vortrag, Präsentation, Handzettel, Tafelanschrieb

Reading List:
U. Walter, Astronautics, Wiley-VCH, ISBN 3-527-40685-9

J. Wertz, W. Larson, Space Mission Analysis and Design, Space Technology Library, ISBN 1-881883-10-8

Responsible for Module:
Walter, Ulrich; Prof. Dr.

Courses (Type of course, Weekly hours per semester), Instructor:
Satellite Design Workshop (lecture, ,1 SWS)
Walter U [L], Rückerl S, Dziura M

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

MW0460: Space Environment and its Simulation [Umwelt und Simulation in der Raumfahrt]

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Bachelor/Master	German	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
With a written examination it shall be ensured that the students are able to remember and to understand basic principles of space environment and its impact on spacecraft and satellites, as well as the main technologies for simulation of the extreme space environmental conditions on Earth. They should verify that they are able to build interrelations between space environment and its effect on satellites.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
none

Content:
Space activities are affected by extreme environmental conditions, such as verberation, vibrations and shock load during start, the residual atmosphere and vacuum during launch, and neutral particles, plasma, radiation, fields, particles and µg conditions in orbit during operation. In the frame of this lecture die individual conditions of the space environment are described in detail, and their effect on technology and operation of spacecraft and satellites are described. Additionally, the simulation of these extreme conditions on Earth is addressed.

Intended Learning Outcomes:
After the successful conclusion of the module, the students are able to
- understand the conditions of space environment in space flight;
- analyze the effects which are relevant for space flight;
- understand and to recognize the necessity for pre-launch simulation of the space environment;
- analyze the challenges and restrictions of these simulation in laboratories on Earth.

Teaching and Learning Methods:
In the classroom the competencies and contents are communicated by blackboard and slides. The slides are provided to the students in the form of written handouts. Additionally, further self-studies are recommended based on the provided list of literature.

Media:
- presentations in electronic form
- blackboard
- movies and animations

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Reading List:
- Alan C. Tribble, The Space Environment, Princeton University Press, 2003, ISBN: 0-691-10299-6
- Gerd W. Prölls, Physics of the Earth's Space Environment, Springer Verlag, 2004, ISBN: 3-540-21426-7
- Frank Fahy, John Walker, Fundamentals of Noise and Vibration, E&FN Spon, 1998, ISBN: 0-419-27700-8
- NASA Technical Handbook, Dynamic Environmental Criteria, NASA-HDBK-7005, 2001

Responsible for Module:
Rott, Martin; Dr.-Ing.

Courses (Type of course, Weekly hours per semester), Instructor:
Space Environment and its Simulation (lecture, 2 SWS)
Rott M

For further information in this module, please click
campus.tum.de or here.

Specialization Subject of Wuhan University

Technische Universität München

Approved Personalized Elective Modules of TUM / LMU

Module Description

BGUWAHL1: TUM Elective Module

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:

Repeat Examination:

(Recommended) Prerequisites:

Content:

Intended Learning Outcomes:

Teaching and Learning Methods:

Media:

Reading List:

Responsible for Module:

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BGU900010: Partner University - Elective Module

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:

Repeat Examination:

(Recommended) Prerequisites:

Content:

Intended Learning Outcomes:

Teaching and Learning Methods:

Media:

Reading List:

Responsible for Module:

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

IN3200: Selected Topics in Computer Graphics and Vision

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	German/English	one semester	irregularly
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The academic assessment will be done by a written exam. Assignments checking knowledge verify the familiarity with the main concepts of selected topics in Computer Graphics and Vision. Transfer assignments and small scenarios check the ability to apply and evaluate these concepts systematically and in a qualified manner.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
Bachelor in Informatics

Content:
Different lecturers offer courses about selected topics in Computer Graphics and Image Understanding with a varying amount of credits. Master students in Informatics may choose this module only once as an elective module in the field of Computer Graphics and Image Understanding (CGV).

Intended Learning Outcomes:
Participants know the state of the art in selected topics in Computer Graphics and Vision and are able to deal with current research projects.

Teaching and Learning Methods:
By means of a presentation, either by slides or whiteboard, the lecture presents selected concepts and techniques from the area of Computer Graphics and Image Understanding and illustrates these by examples.
Possbly accompanying assignments for individual study may deepen the understanding of the concepts explained in the
module, train students to apply the learnt concepts and techniques to solve reasonably sized tasks on their own.

Media:
Slides, whiteboard, exercise sheets, excercises, presentation

Reading List:
Primary source scientific literature (e.g. journals, conference proceedings), depending on the topic

Responsible for Module:
Westermann, Rüdiger; Prof. Dr.

Courses (Type of course, Weekly hours per semester), Instructor:
Selected Topics in Computer Graphics and Vision - Machine Learning for Computer Vision (IN3200) (exercise, 2 SWS)
Cremers D [L], Vestner M (Chiotellis I)

Selected Topics in Computer Graphics and Vision - Machine Learning for Computer Vision (IN3200) (lecture, 2 SWS)
Cremers D [L], Vestner M (Triebel R)

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

BV300002: Geostatistics and Geomarketing

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination consists of a written exam of 60 min in total (100%) at the end of the semester. The students have to answer to the questions with own formulations partially they have to sketch issues or circumstances. No auxiliary materials are permitted within the written exam.
The written exam gives the proof that the students have understood, can reflect and can apply statistical methods to spatial data and that they can adapt their skills under time pressure to create visualizations for geomarketing aspects using a combination of spatial and non-spatial data.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Knowledge of higher mathematics and experiences of spatial data handling, as well as a basic understanding of thematic cartography and graphic design are desirable. `R¿ programming experience is not required, but would be an advantage.

Content:
The content of this module covers geostatistics and geomarketing aspects which are combined to gain insights into spatial data analysis using statistical methods and to visualize these insights using advanced visualization techniques.

During the lectures in particular topics like...
¿ geovisualization vs. information visualization;
¿ geospace vs. information space;
¿ point clustering and analysis;
¿ basic statistic methods and applications;
¿ statistical interpolation methods like IDW, kriging, spline etc. and density surfaces;
¿ components, methods and applications of geomarketing;
¿ market data and micro-geographic data;
¿ business areas in geomarketing.
are covered.

Intended Learning Outcomes:
Upon completion of the module, students are able to¿
¿ create visualizations using and combining spatial and non-spatial data;
¿ evaluate visualization approaches of spatial data and build new ones upon the theoretical framework;
¿ analyse spatial data using statistical methods;
¿ apply methods of explorative spatial data analysis and evaluate results;

¿ understand the crucial components of geomarketing;
¿ apply geomarketing methods.

Teaching and Learning Methods:
The module is structured in lectures and exercises. The lectures provide the theoretical foundation of statistics focusing on spatiotemporal datasets and geomarketing. Throughout performing the exercises students will analyse spatial data using the geostatistical methods presented in the lectures. The integration of geographical intelligence into all marketing aspects including sales and distribution are introduced. During the exercises fundamental geomarketing methods will be implemented to exemplary case studies.
The exercises are carried out individually under supervision. Feedback to the exercises is given to the students by one to one discussions during the contact hours. At the end of the semester, the students have to pass the written exam.

Media:
Moodle e learning platform, presentations, script, pc-lab, hand-out, exercise sheets

Reading List:
Slocum, T., McMaster, R. B., Kessler, F. C., Howard, H. H. (2005): Thematic Cartography and Geographic Visualization. 2nd Edition. Pearson.
Tufte, E. R. (1983): The Visual Display of Quantitative Information. Graphics Press.
O´Sullivan, D., Unwin, D. J. (2003): Geographic Information Analysis. John Wiley & Sons, Inc.
Cliquet, G. (2013): Geomarketing: Methods and Strategies in Spatial Marketing. John Wiley & Sons, Inc.

Responsible for Module:
Liqiu Meng, liqiu.meng@tum.de

Courses (Type of course, Weekly hours per semester), Instructor:
Geostatistics and Geomarketing (exercise, 2 SWS)
Cron J [L], Murphy C, Strobl C, Zoßeder K

For further information in this module, please click
campus.tum.de or here.

Module Description

BV610016: Geodetic Astronomy

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	German	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The expected learning outcomes are verified with a 15 minutes oral exam at the end of the semester. In the exam it is assessed to what extent the students are able to recognize and categorize astronomical objects, to perform astronomical reductions and understand the most important astro-geodetic instruments and measurement techniques.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Requirements are the basics of astronomical reference systems as presented in the module "Physical geodesy" of the Bachelor Geodesy and Geoinformation.

Content:
- Introduction to general astronomical questions (stars, galaxies, cosmology)
- Introduction to astronomical observation techniques
- Astronomical instruments
- Sextant
- Digital astro-photography
- Astronomical objects
- Distance measurements in the universe
- Cosmology
- Astronomical reference frames
- Astrometrical reductions
- Zenith camera for determining the deviation of the vertical
- Astrometry missions Hipparcos and Gaia
- Astronomical observations at the telescope of IAPG

Intended Learning Outcomes:
At the end of the module the students are able
- to identify celestial objects and to grasp the structure of the cosmos,
- to understand the different methods for distance measurements in the universe
- to understand the functioning of basic astro-geodetic instruments,
- to perform the basic astrometric reductions,
- to understand the relevance of astrometric satellite missions.

Teaching and Learning Methods:
The module consists of a lecture with discussions and illustrative examples and Matlab demonstrations to convey competent knowledge of astronomical objects, measurement instruments and methods. The telescope on the roof of TUM is used for astronomical observations.

Media:
Powerpoint slides and handouts. Beamer and pdf-documents (also available online).

Reading List:

Responsible for Module:
Urs Hugentobler (urs.hugentobler@bv.tum.de)

Courses (Type of course, Weekly hours per semester), Instructor:
Project : Geodetic Astronomy (practical training, 2 SWS)
Hugentobler U [L], Schlicht A

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

EI0432: Satellite Navigation

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
6	180	120	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Students must participate in a written final exam where they explain the functionality of sattelite navigation systems.

Furthermore, they might participate in a mid-term exam. The grade of the mid-term counts for 25% of the final score it this improves that score.

Students might bring up to 8 handwritten one-sided A4 pages to the exam and the midterm.

The exercises are provided one week. The students are expected to solve them at home. The solutions are provided in the following week (presentation by the assistant). The assistants do not correct the student's exercises, and they do also not check whether they solved them.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Mathematics, Signal description in time and frequency domain, Fundamentals of probability calculations and statistics

The following modules should have been successfully passed:
- Höhere Mathematik 1-3
- Signale und Systeme
- Nachrichtentechnik 2

It is recommended to participate in the further modules:
-

Content:
Radio based determination of position, time and velocity
Satellite Orbits and Constellations
Navigation Services and Signals (Modulation and Codes)
Receivers: Signal Acquisition and Tracking
Propagation: Multipath, Ionosphere and Troposphere
Measures of Accuracy
GNSS Systems: Time - Relativistic Corrections; and Terrestrial Reference System

Intended Learning Outcomes:
At the end of the lecture, the student
* will understand the functioning of a satellite navigation system
* will be able to evaluate important performance parameters
* will know the algorithms needed for designing a basic receiver.

Teaching and Learning Methods:
Lerning method:
In addition to the lecture, students familiarize themselves with the material by studying their notes or a book, and by attending the mandatory exercises.

Teaching method:
Lectures are delivered in a front style manner. Questions are highly appreciated - they introduce a level of interaction, and mutual adaptation. The exercises are held in a student-centered way.

Media:
The following media are used:
- Presentations (powerpoint slides, and blackboard for derivations).
- Lecture notes (book).
- Exercises with solutions as download.

Reading List:
The following literature is recommended:
- Misra, P., Enge, P., Global Positioning System: Signals, Measurements, and Performance, Ganga-Jamuna Press, 2nd ed. (2006)
- Kaplan, E., Hegarty, C., Understanding GPS: Principles and Applications, Artech House, 2nd ed. (2006).

Responsible for Module:
Günther, Christoph; Prof. Dr.

Courses (Type of course, Weekly hours per semester), Instructor:
Satellite Navigation (lecture with integrated exercises, 4 SWS)
Günther C, Lülf M

For further information in this module, please click
campus.tum.de or here.

Module Description

EI7342: Inertial Navigation

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
5	150	90	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Es gibt eine Zwischen- (midterm) und Abschlussprüfung (final exam). Die Midterm-Prüfung zählt zu 25 % und das Final Exam zu 75 % zur Gesamtnote falls das Midterm-Ergebnis besser ist als das Final Exam. Andernfalls wird lediglich das Final Exam mit 100% gewertet.
Damit bietet die Midterm eine einmalige Möglichkeit zur Verbesserung der eigenen Note und zur Überprüfung des eigenen Wissenstands. Für die Prüfung sind 8 handbeschriebene DIN A4 Seiten und ein Taschenrechner erlaubt.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Grundlagen der Statistik

Content:
Introduction to fundamentals of inertial navigation: angular momentum, torque and inertia tensor; coordinate transformations: direction cosines, Euler angles and Quaternions; Euler equation; Inertial sensors: gyroscopes and accelerometers, Integration of inertial measurements, Calibration of inertial sensors with satellite navigation, Integration of inertial navigation and satellite navigation: deep coupling of tracking loops, loose coupling of navigation solution, Estimation of drift and scaling factor of inertial sensors, Attitude determination with and without carrier phase integer ambiguity resolution, MAP Estimation of attitude, Learning of error behavior of inertial sensors with GPS: Artificial Neuronal Networks, Fusion of measurements from inertial sensors, GNSS receivers and magnetometers, Applications of low-cost inertial sensors.

Intended Learning Outcomes:
Nach der Teilnahme an den Modulveranstaltungen sind die Studierende in der Lage, Algorithmen und Verfahren zur Inertialnavigation zu analysieren und zu bewerten, und eigene Algorithmen zur Kopplung von Inertial- und Satellitennavigation zu entwickeln. Die letztere der beiden Fähigkeiten wird in Matlab-Übungsaufgaben trainiert.

Teaching and Learning Methods:
Lernmethoden:
Der Vorlesungsstoff wird in Übungen regelmässig aufgearbeitet. Darüber hinaus wird ein Selbststudium des Vorlesungsskriptes und der -folien erwartet.
Lehrmethoden:
Die Vorlesungen werden abwechslungsreich gestaltet und enthalten Herleitungen an der Tafel, Zusammenfassungen in Powerpoint Folien, und kurze Demonstrationen in Matlab. Die Studenten werden in

Vorlesung und Übung durch Fragestellungen zum Mitmachen angeregt.

Media:
Folgende Medienformen finden Verwendung:
- Tafelanschrift, insbesondere für Herleitungen und Skizzen
- Powerpoint-Folien, insbesondere zur Zusammenfassung der Tafelanschriften und zum Nacharbeiten, verfügbar auf moodle
- Buch-Kapitel, insbesondere zum Nacharbeiten des Vorlesungsskriptes, verfügbar auf moodle
- Matlab-Codebeispiele, zur Veranschaulichung der Algorithmen

Reading List:
Folgende Literatur wird empfohlen:
[1] Inertial Navigation Systems with Geodic Applications, C. Jekeli, Verlag de Gruyter, 2001.
[2] Global Positioning Systems, Inertial Navigation and Integration, M. Grewal, L. Weill and A. Andrews, Wiley, 2007.

Responsible for Module:
Günther, Christoph; Prof. Dr.

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Module Description

EI7376: Radar Signals and Systems

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
5	150	90	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Modulprüfung mit folgenden Bestandteilen: - Written examination (100%)

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Knowledge of high-frequency technology

Content:
Radio location: Principles, pulse radar, cw radar, radar sensors (Doppler, level gauge, true ground speed, ACC, ground penetrating) radar signal processing, radar signal theory, synthetic aperture radar (SAR). Radio navigation: Principles, direction finding , VHF omnidirectional range (VOR), instrument landing system, microwave landing system (MLS), hyperbolic navigation systems (LORAN), satellite navigation (GPS, Galileo).

Intended Learning Outcomes:
At the end of the module students are able to understand approaches and methods playing a decisive role in high-frequency systems for location and navigation tasks.

Teaching and Learning Methods:
Lerning method:
In addition to the individual methods of the students consolidated knowledge is aspired by repeated lessons in exercises and tutorials.

Teaching method:
During the lectures students are instructed in a teacher-centered style. The exercises are held in a student-centered way.

Media:
The following kinds of media are used:
- Presentations
- Lecture notes
- Exercises with solutions as download

Reading List:
The following literature is recommended:
- Skolnik: Introduction to Radar Systems
- Detlefsen Jürgen: Radartechnik
- Ludloff Albrecht: Praxiswissen Radar und Radarsignalverarbeitung, Vieweg, 2002

Responsible for Module:
Siart, Uwe; Dr.-Ing.

Courses (Type of course, Weekly hours per semester), Instructor:
Radar Signals and Systems (lecture with integrated exercises, 4 SWS)
Siart U, Taygur M

For further information in this module, please click
campus.tum.de or here.

Module Description

EI7428: Visual Navigation

Civil, Geo and Environmental Engineering

Module Level: Master	**Language:** English	**Duration:** one semester	**Frequency:** winter semester
Credits:* 5	**Total Hours:** 150	**Self-study Hours:** 90	**Contact Hours:** 60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
The examination includes a midterm and a final exam. The midterm exam contributes 25 % and the final exam 75 % to the final grade if the midterm grade is better than the final grade; otherwise the final exam counts for 100 % and the midterm is simply disregarded.
Consequently, the midterm is a unique opportunity to improve your own grade and to check your own knowledge. You are allowed to bring 8 handwritten DIN A4 pages and a pocket calculator to the exam.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Linear Algebra

Content:
Introduction on two- and three-dimensional image formation and projective geometry. Elements of image processing: feature extraction, feature matching and outlier removal.
Position and Motion representations: parameterization of spatial displacements and rotations in the three-dimensional space, Lie algebra, dual quaternions, linear and rotational kinematics.
Optimization techniques, batch computation, filtering (Kalman, UKF, EKF)
(Relative) Positioning and Attitude determination from two- and three-dimensional images: optimization problems for motion/scene reconstrution in static scenes; optimization problems for motion/scene reconstrution in dynamic scenes; visual odometry.
Review of (non-visual) positioning sensors and attitude sensors; coupling of visual navigation with INS, GNSS and other sensors for a single navigation solution; methods and algorithms for sensor fusion
Cooperative visual navigation: handling of multiple cameras with overlapping field of view.

Intended Learning Outcomes:
After attending the course, the students will be able to apply the basic principles of visual navigation and sensor fusion, and to develop their own algorithms for the navigation and guidance of autonomous vehicles.

Teaching and Learning Methods:
Learning method:
In parallel to the individual studying of the student, the lecture material is repeated regularly with examples and exercises.
Teaching Methods:
The lectures are given in a teacher-centered style, using derivations on the board, summaries in PowerPoint

slides, and short demonstrations in Matlab. The exercises will be performed by the students, with constant guidance by the teacher.
The students are encouraged during lectures and exercises to ask questions and be actively involved.

Media:
The following media will be used:
- Blackboard, mainly used for mathematical derivations and graphical sketches
- Powerpoint slides, mainly for summarizing the blackboard notations and for self-learning, also available at moodle
- Book chapter, especially for learning the subject, available at moodle
- Matlab-code examples, for visualizing the algorithms

Reading List:
The following literature is recommended:
[1] Multiple view geometry in computer vision, R. Hartley and A. Zisserman, Cambridge University Press, March 2004.
[2] Inertial Navigation Systems with Geodic Applications, C. Jekeli, Verlag de Gruyter, 2001.
[3] Global Positioning Systems, Inertial Navigation and Integration, M. Grewal, L. Weill and A. Andrews, Wiley, 2007.

Responsible for Module:
Günther, Christoph; Prof. Dr.

Courses (Type of course, Weekly hours per semester), Instructor:
Visual Navigation (lecture with integrated exercises, 4 SWS)
Giorgi G

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

EI7640: Signals and Array Signal Processing for Global Navigation Satellite Systems [SAGNSS]

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	45	45

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
mündliche Abschlussprüfung

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Basic knowledge of linear algebra, basic knowledge of satellite navigation, basic knowledge of digital modulation, basic knowledge of MATLAB; lecture Satellite Navigation; lectures Nachrichtentechnik 1/2; lecture Adaptive and Array Signal Processing; lecture Introduction to Signal Processing; lecture Statistical Signal Processing

Content:
GNSS receivers are used in many applications, for example navigation of automobiles, aircraft or ships. In this lecture GNSS signals and signal processing are addressed. An overview on signals and digital modulations of different GNSS is provided and the general problem of signal design for ranging applications is discussed. On the other hand array signal processing methods and concepts for synchronization parameter estimation (time-delay, carrier phase, and Doppler frequency) as well as multipath and interference mitigation for GNSS are introduced. Basic GNSS signal processing using delay locked loops (DLL) and phase locked loops (PLL) are recapitulated and extended to multi-antenna systems using beamforming and multi-dimensional parameter estimation. Also the problem of attitude determination of a multi-antenna platforms based on GNSS signals is studied.

The lecture includes the following topics:
" Digital modulation
" Signal interplexing/mapping schemes
" Signal design for ranging
" Satellite payload characteristics
" Multipath propagation and interference
" Signal processing concepts for GNSS
" Signal acquisition and detection
" DLL discriminator types and their performance
" Multi-antenna receiver architectures and systems
" Robust beamforming algorithms
" Direction-of-arrival (DOA) estimation
" Attitude determination of multi-antenna platforms
" Per-whitening and orthogonal projections
" High resolution synchronization parameter estimation

" Space-time adaptive processing for GNSS

Intended Learning Outcomes:
At the end of the module students are able to understand requirements for design of ranging signals, to understand GNSS payload characteristics, and to analyse characteristics of digital modulations used for GNSS. At the end of the module students are able to understand methods and concepts for GNSS attitude determination, to analyse different GNSS signal processing concepts, and to apply different array processing methods for multipath and interference mitigation.

Teaching and Learning Methods:
Learning method:
In addition to the individual methods of the students consolidated knowledge is aspired by repeated lessons in exercises and tutorials.

Teaching method:
During the lectures students are instructed in a teacher-centered style. The exercises are held in a student-centered way.

Media:
Beamer presentation, use of blackboard for mathematical derivations and graphical sketches, tutorials with solutions, MATLAB-code examples

Reading List:
[1] Misra, P. & Enge, P. (2006), Global Positioning System: Signals, Measurements, and Performance, Second Edition, Ganga-Jamuna Press. [2] Kaplan, E., Hegarty C. (2006), Understanding GPS: Principles and Applications, Second Edition, Artech House. [3] S. M. Kay, Fundamentals of Statistical Signal Processing: Estimation Theory, vol. 1, Prentice Hall PTR, 1993. [4] Harry L. Van Trees, Optimum Array Processing. Detection, Estimation and Modulation Theory, Part IV, Wiley Interscience, 2002.

Responsible for Module:
Utschick, Wolfgang; Prof. Dr.

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Module Description

EI7777: Seminar Navigation

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	English	one semester	winter/summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
5	150	120	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
- Understanding of research topic of Satellite Navigation,
  Inertial Navigation, Visual Navigation or Sensor Fusion
  by reading of Journal paper
- Development and implementation of a method for complementing
  the research topic
- Summary of research topic in a 3-pages paper in own words
- Presentation of paper

The evaluation is based on the following criteria:

- understanding of research topic
- complexity of the research topic
- self-dependence of working
- precision of phrasing

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Satellite Navigation

Content:
- Understanding of research topic of Satellite Navigation,
  Inertial Navigation, Visual Navigation or Sensor Fusion
  by reading of Journal paper
  * Phase bias estimation with a network of reference stations
  * Partial integer ambiguity resolution
  * Visual Simultaneous Localization and Mapping (VSLAM)
  * Sensor fusion with tight coupling of GNSS, INS and barometer
    measurements
  * Precise point positioning with single-frequency GNSS receivers
- Development and implementation of method to extend/ improve
  method of research topic
- Summary of research topic in 3-pages paper in own words

Intended Learning Outcomes:
At the end of this module, students are able to understand a komplex research topic in navigation and to develop algorithms and methods to extend/ improve the navigation solution.

Teaching and Learning Methods:
In the seminar, a journal paper shall be carefully read and understood in self-study. Additional explanations from the supervisor includes derivations on the whiteboard, summaries in Powerpoint and code demonstrations in Matlab. The students are encouraged to ask questions.

Media:
The following media will be used:
- Blackboard, mainly used for mathematical derivations and graphical sketches
- Powerpoint slides, mainly for summarizing the blackboard notations and for self-learning, also available at moodle
- Matlab-code examples, for visualizing the algorithms

Reading List:
The following literature is recommended:
[1] Understanding GPS, P. Misra and P. Enge, 2006.
[2] Inertial Navigation Systems with Geodic Applications, C. Jekeli, Verlag de Gruyter, 2001.

Responsible for Module:
Christoph Günther
christoph.guenther@tum.de

Courses (Type of course, Weekly hours per semester), Instructor:
Advanced Seminar Navigation (advanced seminar, 5 SWS)
Henkel P [L], Henkel P

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

MW0141: Advanced Systems Engineering [ASE]

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Bachelor/Master	German	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
In der mündlichen Prüfung werden die vermittelten theoretischen Inhalte aus der Vorlesung geprüft. Ein weiterer Teil der mündlichen Prüfung besteht aus einem Vortrag zu einem ausgewählten Teil der Vorlesung.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Modul Systems Engineering

Content:
Die Vorlesung Advanced Systems Engineering unterteilt sich thematisch in zwei unterschiedliche Themenbereiche. Im ersten Block der Vorlesung wird anhand eines raumfahrtbezogenen Beispielsystems das allgemeine System Engineering Vorgehen   also von der Problemerfassung bis hin zur Lo sung des Problems   exemplarisch vorgestellt und im Details zusammen mit den Studenten ausgearbeitet.

Der Schwerpunkt des zweiten Blocks der Vorlesung ist aus dem Schwerpunkt der Hauptvorlesung Systems Engineering abgeleitet und soll den Studenten weitere vertiefende Kenntnisse auf dem Gebiet der Modellierung von komplexen technischen Systemen mit Hilfe der Systemmodellierungssprache SysML erla utern und anhand eines raumfahrtbezogenen Beispielsystems demonstriert werden.

Intended Learning Outcomes:
Nach der Teilnahme an der Modulveranstaltung Advanced Systems Engineering sind die Studierenden in der Lage, komplexe technische Systeme selbstständig in einer objektorientierten Modellierungssprache (z.B. SysML) zu modellieren, zu verstehen und die erarbeiteten Modelle zu bewerten.

Teaching and Learning Methods:
In der Vorlesung werden die Lehrinhalte anhand von Vortrag, Präsentation und Tafelanschrieb vermittelt.

Media:
Vortrag, Präsentation, Handzettel, Tafelanschrieb

Reading List:
Systems Engineering - Methodik und Praxis W.F. Daenzer, F. Haberfellner, ISBN 3-85743-998-X

Objektorientierte Softwaretechnik - mit UML, Entwurfsmustern, Java Bernd Brügge, Allen H. Dutoit, ISBN 3-8273-

7082-5

Responsible for Module:
Brandstätter, Markus; Dipl.-Inf. (Univ.)

Courses (Type of course, Weekly hours per semester), Instructor:
Advanced Systems Engineering (lecture, 2 SWS)
Brandstätter M, Bühler C, Pütz D

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

MW0259: Practical Course Systems Engineering

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Bachelor/Master	German	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
4	120	60	60

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Die erarbeiteten Ergebnisse des Praktikums Angewandte Systemtechnik müssen innerhalb des Praktikums präsentiert werden. Außerdem muss eine knappe Ausarbeitung verfasst werden. Die Präsentation zusammen mit Ausarbeitung ergeben die Praktikumsnote.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
Modul Systems Engineering

Content:
Im Praktikum Angewandte Systemtechnik werden die theoretischen Grundlagen des modellbasierten Systems Engineerings aus der Vorlesung Systems Engineering aufgegriffen und anhand eines konkreten Satellitenprojekts deren praktische Anwendung demonstriert.
Im Rahmen des Praktikums sollen die Studenten sowohl die Satellitenmission, als auch sämtliche relevanten Subsysteme des Satelliten modellieren und auslegen, so dass dieser gebaut werden könnte. Dabei kommt insbesondere die objektorientierte Modellierung und das "Concurrent Engineering Vorgehensmodell", also das zeitgleiche Arbeiten an einem Modell des Satelliten, zum Einsatz.
Für die Modellierung und Auslegung des Satelliten wird das am Lehrstuhl entwickelte Programm (v)Sys-ed verwendet. Mit Hilfe dieses Werkzeugs kann eine Satellitenmission, angefangen bei der Vorstudie, bis hin zur Auslegung der Subsysteme modelliert werden.

Intended Learning Outcomes:
Nach der Teilnahme an der Modulveranstaltung Angewandte Systemtechnik sind die Studierenden in der Lage, komplexe technische Systeme zu verstehen, zu bewerten, selbstständig ein einfaches Modell eines Satelliten zu erstellen sowie eine einfache Satellitenmission zu planen und erstellen. Des Weiteren sind die studierenden in der Lage technische Problemstellungen im Umfeld der Satellitenentwicklung mittels des "Concurrent Engineering Vorgehensmodells" zu lösen.

Teaching and Learning Methods:
Im Praktikum werden die Lehrinhalte anhand von Vorträgen, Präsentation, Tafelanschrieb sowie durch praktische Unterstützung vermittelt.

Media:
Vortrag, Präsentation, Handzettel, Tafelanschrieb

Reading List:
Systems Engineering - Methodik und Praxis W.F. Daenzer, F. Haberfellner, ISBN 3-85743-998-X

Responsible for Module:
Brandstätter, Markus; Dipl.-Inf. (Univ.)

Courses (Type of course, Weekly hours per semester), Instructor:
Practical Course Systems Engineering (practical training, 4 SWS)
Brandstätter M, Schummer F

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

MW1790: Near Earth Objects (NEOs)

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
3	90	60	30

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
Oral exam at the end of the semester

Repeat Examination:

(Recommended) Prerequisites:
Basics of spacecraft technology and astrodynamics.

Content:
Basic theories, methods and tools: Detection, tracking, cataloging and characterization of near earth objects.
Methods and technologies: Mitigation of danger, findings, contact, diversion, destruction.
Tools for the simulation and analysis of time, cost and risk in NO project.
Engineering Data and Information sources: National and International Agencies like DLR, NASA, ESA; Institutions like Universities, Observatories ,Amateur Groups like NEAT.
The lecture will be held in English.

1 GENERAL INTRODUCTION (2 HOURS)
2 FROM OBSERVATIONS TO MEASUREMENTS (2 HOURS)
3 ORBIT DETERMINATION AND FIRST IMPACT WARNING (4 HOURS)
4 ASTEROID PHYSICAL PROPERTIES DETERMINATION (4 HOURS)
5 IMPACT EFFECTS AND CONSEQUENCES (2 HOURS)
6 MITIGATION AVOIDING AN IMPACT (4 HOURS)
7 WAR GAME: WHAT TO DO IN CASE OF AN IMMINENT IMPACT THREAT? (2 HOURS)
8 THE NEO DECISION PROCESS AS A SYSTEM (OF SYSTEMS) (2 HOURS)
9 SUMMARY (2 HOURS)

Intended Learning Outcomes:
At the end of the module, the students will understand the physical properties of Near-Earth Objects and their threat potential for Earth. They will further have gained an understanding of the design processes behing NEO-deflection missions, as well as for the political and organizational boundary conditions for such an operation. They will also have gained insight into the technical means of NEO observation and deflection.

Teaching and Learning Methods:
The module contains lectures

Media:
Script of presentation slides

Reading List:
None beyond the lecture slides.

Responsible for Module:
Igenbergs, Eduard; Prof.

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Technische Universität München

Module Description

MW2079: Thermal Space Simulation

Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**

Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
4			

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:

Repeat Examination:

(Recommended) Prerequisites:

Content:

Intended Learning Outcomes:

Teaching and Learning Methods:

Media:

Reading List:

Responsible for Module:

Courses (Type of course, Weekly hours per semester), Instructor:

For further information in this module, please click
campus.tum.de or here.

Module Description

MW2155: Human Spaceflight [HSF]

Civil, Geo and Environmental Engineering

Module Level:	Language:	Duration:	Frequency:
Master	German	one semester	winter semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
5	150	105	45

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
After the lecture period there will be a written exam. In mostly open questions, some multiple choice questions and a few math problems the students have to demonstrate their knowledge of the basic processes, relationships, engineering issues, figures of merit and their general scale in the area of human spaceflight. This knowledge has to be transferred quantitatively to problems that were not specificly covered in the lecture or the tutorial.

Repeat Examination:
Next semester

(Recommended) Prerequisites:
Basic knowledge in the area of spaceflight and system design, as it is for instance conveyed in the Bachelor module "Fundamentals of Spaceflight", is required. It is not a compulsory prerequisite, but it immensely aids understanding the contents of this module.

Content:
Contents of the lecture:
Astronaut selection, training and education of astronauts, introduction to manned space transportation systems, living and working in space, space environment and its biomedical effects on the human body and psyche during spaceflight, space science, fundamentals of life support systems, physico-chemical vs. bio-regenerative life support systems, design of orbital and planetary habitats, space stations, preparation and execution of extra-vehicular activities, utilization of local resources (e.g. on the Moon) versus full resupply, mission analysis and planning of manned missions

In the tutorials the contents of the lecture are consolidated using a single example mission throughout and providing a weekly overview of current events in spaceflight in general and human spaceflight in particular.

Intended Learning Outcomes:
After participating in the module human spaceflight students have insight into all aspects of human spaceflight. They therefore can differentiate the areas of manned and unmanned spaceflight exactly. They are able to understand the special challenges created by the hostile environment in space and on other celestial bodies and know about their effects on engineering problems during the design of manned spacecraft and missions. The students can use their understanding of the technical and political boundary conditions to analyze the necessary requirements for the technical systems involved (e.g. life support systems). After completing the module, the students are able to independently evaluate system and mission concepts with regard to their basic mission objectives.

Teaching and Learning Methods:
During the lecture the content is conveyed through presentations. The students have online access to a collection of slides.
During the tutorial, the lecture content is consolidated and expanded through a short presentation. Afterwards, the students have to independently solve a problem using the conveyed knowledge. The problems can be either mathematical calculations or conceptual systems designs.

Media:
Lecture, slides, worksheets

Reading List:
Human Spaceflight Mission Analysis and Design, W. Larson and L. Pranke, McGraw-Hill, 2000 ISBN 0-07-236811-X

Responsible for Module:
Olthoff, Claas; Dipl.-Ing. (Univ.)

Courses (Type of course, Weekly hours per semester), Instructor:
Tutorial Human Spaceflight (exercise, 1 SWS)
Walter U [L], Walter U, Pütz D, Grill L

Human Spaceflight (lecture, 2 SWS)
Walter U, Pütz D

For further information in this module, please click
campus.tum.de or here.

Module Description

PH2090: Computational Physics 2

Simulation of Classical and Quantum Mechanical Systems
Civil, Geo and Environmental Engineering

Module Level:	**Language:**	**Duration:**	**Frequency:**
Master	English	one semester	summer semester
Credits:*	**Total Hours:**	**Self-study Hours:**	**Contact Hours:**
5	150	75	75

Number of credits may vary according to degree program. Please see Transcript of Records.

Description of Examination Method:
There will be a written exam of 90 minutes duration. Therein the achievement of the competencies given in section learning outcome is tested exemplarily at least to the given cognition level using calculation problems and comprehension questions.
For example an assignment in the exam might be:
- Derive the formula for the discrete Fourier transform by evaluating the integral in the continuous Fourier transform with the trapezoidal rule.
- Give the DE that describes a pendulum with friction and a periodic driving force. How would you solve this DE numerically? Sketch several orbits in phase space.

Repeat Examination:
End of Semester

(Recommended) Prerequisites:
No preconditions in addition to the requirements for the Master's program in Physics, but knowledge of the subjects covered in PH2057 is strongly recommended.

Content:
This is the second part of the Computational Physics course of which PH2057 is the first part.
Multiple subjects from Computational Physics are discussed:
10. Random Numbers
11. Fourier Transform
12. Nonlinear Systems and Chaos
13. Fractals
14. Time evolution of Quantum Wave Packets
15. Integral Equations
16. Finite Elements
17. Wavelets
18. Quantum Paths via Functional Integration
19. Introduction to Lattice Gauge Theory

Intended Learning Outcomes:
At the end of the module CPII students are able to construct and solve numerical descriptions of classical and quantum mechanical problems. The techniques that they apply include ordinary and partial differential equations, Monte Carlo methods and chaos theory. The students have an insight into some advanced numerical methods

used in current research.

Teaching and Learning Methods:
lecture, video projector presentation, board work, exercises in individual and group work

Media:
practise sheets, accompanying web page: http://users.ph.tum.de/srecksie/lehre

Reading List:
Much of the material in this course is covered in
ìComputational Physics: Problem Solving with Computersî by Landau, P´aez and Bordeianu, Wiley-Vch, ISBN 3527406263.
For the last chapter, we follow Lepageí's ìLattice QCD for novicesî, http://arxiv.org/abs/hep-lat/0506036.

Responsible for Module:
Recksiegel, Stefan; Dr.

Courses (Type of course, Weekly hours per semester), Instructor:
Exercise to Computational Physics 2: Simulation of Classical and Quantum Mechanical Systems (exercise, 2 SWS)
Recksiegel S

Computational Physics 2: Simulation of Classical and Quantum Mechanical Systems (lecture, 2 SWS)
Recksiegel S

For further information in this module, please click
campus.tum.de or here.

Master's Thesis

Required Additional Fundamental Subjects

Technische Universität München

Nachweis Deutschkenntnisse / Requirement Proof of Proficiency in German

Prüfungsauflagen

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