Universität Bremen

Faculty 04:
Production Engineering

Wintersemester 25/26

Module Guide

for the study of

Space Engineering

Masterstudiengang

valid in connection with the examination regulations MPO 2025

Generated: July 3, 2025

Studienverlaufsplan M.Sc. Space Engineering

Regelstudienverlauf zur Masterprüfungsordnung ab Wintersemester 2025/26

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CP = Credit Points

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1) Information and extra-curricular offers

2) Foundations (30 CP)

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6) Master Thesis (30 CP)

Module 04-PT-MA-M30-0: Informatoin and extra-curricular offers
Information and extra-curricular offers

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Information and extra-curricular offers	none

Learning content:
This section contains information events and extracurricular courses that are helpful in preparing for or supplementing your studies.

Learning outcomes / competencies / targeted competencies:

Calculation of student workload:

Are there optional courses in the modules?
yes

Language(s) of instruction: English / German	**Responsible for the module:** Prof. Dr. Marc Avila
Frequency: each semester	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 0 / 0 hours

This module is ungraded!

Module examinations

Module examination: *** Prf neu ***	
Type of examination: module exam	
Form of examination: See description	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: - / - / -	
Language(s) of instruction: German	
Description: no examination	

Module courses

Course: Information and extra-curricular offer	
Frequency: each semester	**Language(s) of instruction:** English / German

Contact hours: 0,00	University teacher:
Teaching method(s):	**Associated module examination:**

Module 04-PT-MA-M30-FM-01: Thermofluid Dynamics

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Foundations	Fluid Mechanics

Learning content:

- Dimensional analysis and nondimensionalization
- Buoyancy and natural convection
- Entropy functions and thermodynamic cycles
- Burn-off mechanisms and rates
- Evaporation and vaporization
- Isentropic supersonic flows
- Vertical and oblique schock waves
- Molecular motion of ideal and real gases
- Molecular collision and diffusion
- Velocity slip in microchannels
- Boltzmann velocity distribution
- Euler equations in phase space

Learning outcomes / competencies / targeted competencies:

- The students know about forced and natural convection in heat exchangers.
- The students can leverage phase transitions for the design of cooling mechanisms.
- The students can compute energy conversion rates in gas turbines and heat pumps.
- The students understand supersonic flow properties and can use them for the development of thruster engines and re-entry systems.
- The students can describe molecular gas flows in microchannels.
- The students understand the generalized modeling of rarefied gas dynamics.

Calculation of student workload:
68 h Exam preparation
56 h Preparation / follow-up work
56 h SWS / presence time / working hours

Are there optional courses in the modules?
no

Language(s) of instruction:	**Responsible for the module:**
English	Prof. Dr. Ing. Rodion Groll
Frequency: winter semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Thermofluid Dynamics

Type of examination: module exam

Form of examination:	The examination is ungraded?
Oral	no
Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -	
Language(s) of instruction: English	

Module courses

Course: Thermofluid Dynamics - Lecture	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Literature: • Zeytounian, Radyadour Kh.: Convection in Fluids, ISBN 978-90-481-2432-9, Springer Verlag 2009 • Chung Fang: An Introduction to Fluid Mechanics, ISBN 978-3-319-91829-4, Springer Verlag 2019 • George Karniadakis, Ali Beskok, Narayan Aluru: Microflows and Nanoflows, ISBN 0-387-22197-2, Springer Verlag 2005 • Hans Dieter Baehr, Karl Stephan: Heat and Mas Transfer, ISBN 978-3-642-20020-5, Springer Verlag 2011 • Jose J.C. Teixeira-Dias, Molecular Physical Chemistry, ISBN 978-3-319-41092, Springer Verlag 2017 • Alexander Piel: Plasma Physics, ISBN 978-3-319-63425-8, Springer Verlag 2017	
Teaching method(s): Lecture	**Associated module examination:** Thermofluid Dynamics

Course: Thermofluid Dynamics - Exercise	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Additional comments: Lernziele de	
Teaching method(s): Tutorial	**Associated module examination:** Thermofluid Dynamics

Module 04-PT-MA-M30-FM-02: Space Flight Mechanics

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Foundations	Mechanics/Dynamics, Physics

Learning content:

- Introduction to reference frames
- Introduction to basic orbital mechanics
- Orbital velocities and Kepler equation
- Characteristic trajectories
- The rocket equation
- Maneouvers and Transferorbits
- Subsatellite tracks
- Environmental perturbations
- Relative Orbital mechanics
- Attitude dynamics and Transformations
- Methods of attitude stabilisation

Learning outcomes / competencies / targeted competencies:

- The students know the basic physical laws of orbital motion and orbital mechanics.
- The students can design simplified maneuvers for insertion into other orbits and escape trajectories
- The students understand the setups of typical orbital scenarios and the characteristic dimensions of the implied velocities, altitudes and orbital elements.
- The students can compute the necessary delta vs for chosen mission setups by means of analytical relations as well as the implied temporal evolution
- The students can compute the dynamic evolution of environmental perturbations with respect to orbital setup and spacecraft features
- The students are able to obtain a subsatellite track from given orbital elements and vice-versa
- The students can apply the rocket equation for simple manoeuvres and are able to compute fuel requirements for given technical setups
- The students understand the basics of rotational motion and different applications for attitude orientations in spaceflight
- The students understand the connection between different reference frames and can determine the transformation matrices between different frames in a dynamical orbital setup (e.g. using the quaternion method)
- The students understand the relation between relative and absolute frames and can compute relative velocities and manoeuvres in the relative frame
- The students can apply different methods of attitude stabilisation for chosen AOCS setups

Calculation of student workload:

56 h SWS / presence time / working hours
68 h Exam preparation
56 h Preparation / follow-up work

Are there optional courses in the modules?

no

Language(s) of instruction: English	**Responsible for the module:** Dr.-Ing. Benny Rievers
Frequency: winter semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Space Flight Mechanics	
Type of examination: module exam	
Form of examination: Written examination	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -	
Language(s) of instruction: English	
Description: The exercises are part of the examination.	

Module courses

Course: Space Flight Mechanics - Lecture	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Literature: James R. Wertz, Wiley J. Larson, “Space Mission Analysis and Design”, Springer, ISBN 978-1881883104 James R. Wertz, “Spacecraft Attitude Determination and Control”, Springer, ISBN 978-9027712042	
Teaching method(s): Lecture	**Associated module examination:** Space Flight Mechanics

Course: Space Flight Mechanics - Exercise	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Teaching method(s): Tutorial	**Associated module examination:** Space Flight Mechanics

Module 04-PT-MA-M30-FM-03: Structural Mechanics

Assignment to areas of study:	Content-related prior knowledge or skills:
• Foundations	Technical mechanics

Learning content:

- Load Analysis
- Design Criteria
- Metallic and Composite Materials
- Stress Analysis and Failure Criteria
- Truss Structures, Beams and their Computational Analysis
- Stress Analysis in Tanks (Beam on Elastic Foundations)
- Orthotopic Stiffened Shells (Membrane Theory, Ring Stiffeners)
- Stability of Beams
- Stability of Plates
- Stability of Cylindrical Shells
- Single-DoF and Two-DoF-Vibration System
- Modal Analysis
- Frequency Response
- Transient Response

Learning outcomes / competencies / targeted competencies:

- The students know about the process chain of a structural design and verification
- The students know how to idealize aerospace structures
- The students know about Computational Analysis of Structures (to build a System Stiffness Matrix based on Element Stiffness Matrices)
- The students have a basic understanding about stress, stability and vibrational analysis of space structures
- The students are able to perform analyses with simple self programed tools
- The students are able to dimension space structures to minimum weight

Calculation of student workload:

56 h Preparation / follow-up work
68 h Exam preparation
56 h SWS / presence time / working hours

Are there optional courses in the modules?

no

Language(s) of instruction:	Responsible for the module:
English	Prof. Dr.-Ing. Andreas Rittweger
Frequency: winter semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Structural Mechanics	
Type of examination: module exam	
Form of examination: Written examination	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -	
Language(s) of instruction: English	

Module courses

Course: Structural Mechanics - Lecture	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Literature: • H.Öry, Structural Design of Aerospace Vehicles I and III, Space Course Aachen, 1991, RWTH Aachen • ESA Buckling Handbook • Roy R. Craig, Structural Dynamics, John Wiley &Sons	
Teaching method(s): Lecture	**Associated module examination:** Structural Mechanics

Course: Structural Mechanics - Exercise	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Teaching method(s): Tutorial	**Associated module examination:** Structural Mechanics

Module 04-PT-MA-M30-FM-04: Computational Methods

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Foundations	none

Learning content:

- Introduction to Data Analysis: Exploring data sets, visualization techniques, and data fitting methods.
- Numerical Methods for Solving Systems of Equations: Gaussian elimination, LU decomposition (matrix factorization), and iterative methods such as Jacobi and Gauss-Seidel.
- Non-linear Systems of Equations: Newton-Raphson method and its variants for solving nonlinear systems.
- Numerical Integration and Differentiation: Techniques like Simpson's rule, trapezoidal rule, and finite difference methods.
- Numerical solution of Ordinary Differential Equations (ODEs): Initial value problems (IVPs) and boundary value problems (BVPs).
- Finite Difference Methods for PDEs: Discretization of partial differential equations for numerical solution.
- Introduction to Numerical Methods for Surface Representations: Basics of mesh generation, finite element methods, and surface fitting.
- Python Programming for Computational Engineering: Basics of Python programming with emphasis on libraries such as NumPy, SciPy,
- Introduction to Machine Learning: Overview of selected machine learning methods applicable to engineering problems.
- Application-oriented Labs: Practical implementation of algorithms using Python for solving engineering problems, including data analysis, equation solving, and basic machine learning tasks.

Learning outcomes / competencies / targeted competencies:

- Students have the ability to analyze and visualize engineering data effectively.
- Students have the proficiency in solving linear and non-linear systems of equations using numerical methods.
- Students have the competence in solving ordinary and partial differential equations numerically.
- Students understand the principles of numerical integration and differentiation techniques and their applications.
- Students have the capability to implement finite difference methods for solving partial differential equations.
- Students have the proficient programming skills in Python, specifically for computational engineering tasks.
- Students are familiar with basic machine learning concepts and their potential applications in engineering.
- Students have the ability to apply computational methods to solve real-world engineering problems efficiently and accurately.

Calculation of student workload:

56 h SWS / presence time / working hours
56 h Self-study
68 h Exam preparation

Are there optional courses in the modules?

no

Language(s) of instruction: English	**Responsible for the module:** Prof. Dr.-Ing. habil. Lutz Mädler
Frequency: winter semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Computational Methods	
Type of examination: module exam	
Form of examination: Oral	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -	
Language(s) of instruction: English	

Module courses

Course: Computational Methods - Lecture	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**

Literature:

Python Programming and Numerical Methods

A Guide for Engineers and Scientists

1st Edition - November 27, 2020

Authors: Qingkai Kong, Timmy Siauw, Alexandre Bayen

Language: English

Paperback ISBN: 9780128195499

9 7 8 - 0 - 1 2 - 8 1 9 5 4 9 - 9

eBook ISBN: 9780128195505

Finite Difference Computing with PDEs

A Modern Software Approach

Hans Petter Langtangen, Svein Linge

978-3-319-55455-6

Published: 07 July 2017	
Teaching method(s): Lecture	**Associated module examination:** Computational Methods

Course: Computational Methods - Computer Lab	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Teaching method(s): Laboratory class	**Associated module examination:** Computational Methods

Module 04-PT-MA-M30-FM-05: Advanced Fluid Mechanics

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Foundations	Fluid Mechanics

Learning content:

- Microscopic and macroscopic properties of liquids and gases: the continuum hypothesis
- Stresses and constitutive equations
- The Navier—Stokes equations for incompressible and compressible fluid flows
- Conservation of energy in fluid flows
- Vorticity and circulation
- Potential flow
- Conformal mappings
- Thin-airfoil theory
- Viscous creeping flow
- Boundary layer flows
- Introduction to stability and turbulence
- Modelling of multiphase flows

Learning outcomes / competencies / targeted competencies:

- The students understand the equations governing, energy, mass and momentum conservation in fluid flows and can compute simple laminar flows
- The students can estimate the lift on thin airfoils
- The students can compute potential flows around airfoils
- The students understand the basic differences between laminar and turbulent flows
- The students can estimate surface drag on in compressible and incompressible boundary layer flows
- The students understand boundary conditions in single and multiphase fluid flows
- Students know and can select models for multiphase flows.

Calculation of student workload:

56 h Preparation / follow-up work
68 h Exam preparation
56 h SWS / presence time / working hours

Are there optional courses in the modules?

no

Language(s) of instruction:	**Responsible for the module:**
English	Prof. Dr. Marc Avila
Frequency: summer semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Advanced Fluid Mechanics

Type of examination: module exam	
Form of examination: Oral	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -	
Language(s) of instruction: English	

Module courses

Course: Advances Fluid Mechanics - Lecture	
Frequency: summer semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Literature: • D.J. Acheson, Elementary Fluid Dynamics, Oxford Applied Mathematics and Computing Science Series, Clarendon Press; 1st edition, 1990 • J.W. Garwin, A Student's Guide to the Navier–Stokes Equations, Cambridge University Press; 1st edition, 2023 • H. Schlichting, K. Gersten: Boundary-Layer Theory, Springer; 9th edition, 2000	
Teaching method(s): Lecture	**Associated module examination:** Advanced Fluid Mechanics

Course: Advanced Fluid Mechanics - Exercise	
Frequency: summer semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Additional comments: Lernziele de	
Teaching method(s): Tutorial	**Associated module examination:** Advanced Fluid Mechanics

Module 04-PT-MA-M30-CM-11: Space Environment and Human Space Flight

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Compulsory Modules	Thermo-fluid dynamics Design of space systems

Learning content:

Space environment physics:

• Properties of the near-Earth space environment, the lunar and Martian surface as well as the interplanetary medium (including the geomagnetic field, magnetosphere, ionosphere, thermosphere and microgravity).
• The Sun and its interaction with planets such as the Earth and Mars, but also its impact on the Moon (different radiation types, solar winds, aurora, radiation belts etc.); basic solar-terrestrial physics relevant to spacecraft charging and drag.
• Space weather.

History of human space flight

Challenges and design features for spacecrafts, space habitats and space suits.
• Material choices and engineering of hardware systems ensuring a reliable performance in harsh space environments.
• Brief introduction to surface analysis techniques of materials for spaceflight (XPS, XRD, SEM, etc., examples from ESA analyses).
• Terrestrial material tests prior to launch (e.g., radiation tests at DLR).
• Sustainable material production in space via in-situ resource utilisation (ISRU): challenges and opportunites.

Life support technologies for air revitalisation, food production and materials manufacturing (“closed-loop” and “100% atom economy” requirements of (chemical) processes).

Introduction to space psychology and physiology.

Learning outcomes / competencies / targeted competencies:

• At the end of this module, the student should understand the key physical parameters and processes of the near-earth space environment and how these affect spacecraft design and operation as well as the design of space habitats and space suits.
• They should be able to critically evaluate the choice of materials used in these applications and be able to discuss analytical methods to evaluate the degree of material degradation and corrosion in space environments.
• The students should be able to suggest terrestrial methods to test material stability e.g., against space radiation.
• In a student-led podium discussion, they should be able to critically discuss in-situ resource utilisation strategies and sustainable approaches for material fabrication e.g., on Moon and Mars and potential consequences for the material properties and safety (“Sustainability vs. stability and safety: which compromises can we make - if any?).
• The students should be able to understand the requirements for life support technologies and processes. They should be able to name and explain existing processes and associated difficulties.
• In a brief introduction to space psychology and physiology, the students should be familiarized with the challenges of space travel from a medicial and psychiological point of view.

Calculation of student workload: 56 h SWS / presence time / working hours 68 h Exam preparation 56 h Preparation / follow-up work

Are there optional courses in the modules? no

Language(s) of instruction: English	**Responsible for the module:** Prof. Dr. Katharina Brinkert
Frequency: each semester	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Space Environment and Human Space Flight	
Type of examination: module exam	
Form of examination: Written examination	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -	
Language(s) of instruction: English	

Module courses

Course: Space Environment and Human Space Flight - Lecture	
Frequency: each semester	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**

Literature:

- Physics of the Earth’s Space Environment: An Introduction, ISBN # 978-3540214267, Springer Verlag 2004
- Space Habitats and Habitability: Designing for Isolated and Confined Environments on Earth and in Space (Space and Society), ISBN 978-3030697396, Springer Verlag 2021
- Use of Extraterrestrial Resources for Human Space Missions to Moon or Mars, ISBN 978-3319726939, Springer Verlag 2018
- Mars: Prospective Energy and Material Resources, ISBN 978-3642036286, Springer Verlag 2010
- Life Support Systems for Humans in Space, ISBN 978-3030528584, Springer Verlag 2010
- Research articles distributed during the seminars/ lectures

Teaching method(s): Lecture	**Associated module examination:** Space Environment and Human Space Flight

Course: Space Environment and Human Space Flight	
Frequency: each semester	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Additional comments: Lernziele de	
Teaching method(s): Laboratory class	**Associated module examination:** Space Environment and Human Space Flight

Module 04-PT-MA-M30-CM-12: Satellite Subsystems

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Compulsory Modules	Thermodynamics, Fluid Mechanics, Dynamics, Spaceflight Mechanics

Learning content:
- Introduction to Thermal Control of spacecraft
- Passive and active components for thermal control systems (TCS)
- Introduction to thermal boundaries and budgeting
- Introduction to qualification measures for thermal control concepts
- Simplified methods for dimensioning TCS
- Introduction to spacecraft attitude and orbit control
- Introduction to design, concepts and elements of a navigation and control subsystem for a spacecraft and its functions

Learning outcomes / competencies / targeted competencies:
- The students can derive thermal boundaries form given mission scenarios
- The student can apply order-of-magnitude check to derive principle design drivers for the TCS
- The students can perform a budgeting for a TCS and design a TCS concept by choosing and scaling relevant components
- The students can analyse the performance of a TCS concept with respect to mission requirements by means of analytical and simplified numerical methods
- The students understand the different requirements in terms of testing and qualifying TCS components
- The students know different active and passive methods for the control of spacecraft and have an overview on the implied sensor and actuator components
- The students have an overview on design, concepts and elements of a navigation and control subsystem for a spacecraft and their functions
- The students are familiar with methods for state estimation used in spacecraft navigation systems

Calculation of student workload:
56 h SWS / presence time / working hours
68 h Exam preparation
56 h Preparation / follow-up work

Are there optional courses in the modules?
no

Language(s) of instruction: English	**Responsible for the module:** Dr.-Ing. Benny Rievers
Frequency: summer semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Satellite Subsystems	
Type of examination: module exam	
Form of examination: Portfolio (AT § 8 Abs. 8)	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: 2 / - / -	
Language(s) of instruction: English	
Description: The examination is divided into a written and an oral part.	

Module courses

Course: Space Craft Navigation and Control	
Frequency: summer semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Literature: • James R. Wertz, “Spacecraft Attitude Determination and Control”, Springer, ISBN 978-9027712042 • David G. Gilmore, Spacecraft Thermal Control Handbook, AIAA, ISBN 978-1884989117	
Teaching method(s): Lecture	**Associated module examination:** Satellite Subsystems

Course: Satellite Therman Control	
Frequency: summer semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Literature: • James R. Wertz, “Spacecraft Attitude Determination and Control”, Springer, ISBN 978-9027712042 • David G. Gilmore, Spacecraft Thermal Control Handbook, AIAA, ISBN 978-1884989117	
Teaching method(s): Lecture	**Associated module examination:** Satellite Subsystems

Module 04-PT-MA-M30-CM-13: Space System Design

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Compulsory Modules	Space flight mechanics, Thermofluid dynamics

Learning content:

Space systems engineering:

- Basics of Space Project Management: ECSS Standards, Project Management Process, Project planning, Project Phases and Reviews, Project Structure, Cost Estimation, Time Management
- Configuration and Information Management
- Risk Management: Risk Management Process, Risk Identification and Evaluation, Risk Steering, Risk Documentation
- Systems Engineering for Space Projects:V-Model, Project Phases, Requirements, Verification / Validation, Mission Objectives, Mission Architecture (from Launch to Disposal), Space System Design, Subsystem / Domain Overview
- Concurrent Engineering Process
- MBSE (i. e. Virtual Satellite)
- Collaborative Engineering
- Agile Scrum Design Method

Space vehicle design:

- Velocity of Orbits, Transfer Orbits
- Rocket Equation and Losses
- Dimensioning of stages
- Staging Principle, Optimum Staging
- Performance Calculation
- Propulsion System Dimensioning
- Prediction of Specific Impulse (Calculation of Combustion Temperature, influence of combustion pressure and Nozzle Design)
- Ascent Trajectory
- Orbital Reentry and Landing

Learning outcomes / competencies / targeted competencies:

Space systems engineering:

- The students know the basics of Space Project Management applied in Europe (acc. to ESA-Standards)
- The students are able to outline a rough project and mission process including work package structure, work package descriptions, cost estimation as well as schedules and product trees
- The students know the basics of Space Systems Engineering applied in Europe (acc. to ESA-Standards) in particular regarding to Requirements Management
- The students know the modern design process “Concurrent Engineering” applied at DLR to design a spacecraft in cost effective manner

Space vehicle design:

- The students know about the interdisciplinary relations between spaceflight mechanics, propulsion system, performance calculation, structural, thermal and aerodynamic engineering
- The students are able to design conceptionally and to perform a sizing of a space vehicle
- The students are able to assess and evaluate different space designs

Calculation of student workload: 56 h SWS / presence time / working hours 56 h Preparation / follow-up work 68 h Exam preparation

Are there optional courses in the modules? no

Language(s) of instruction: English	**Responsible for the module:** Prof. Dr.-Ing. Andreas Rittweger
Frequency: summer semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Space Systems Engineering	
Type of examination: partial exam	
Form of examination: Written examination	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -	
Language(s) of instruction: English	

Module examination: Space Vehicle Design	
Type of examination: partial exam	
Form of examination: Written examination	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -	
Language(s) of instruction: English	

Module courses

Course: Space Systems Engineering	
Frequency: summer semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Literature:	

• Wertz, James R.; Everett, David F.; Puschell, Jeffery J. Space Mission Engineering: The New SMAD. Portland: Microcosm Press • Sage, Andrew P.; Rouse, William B. Handbook of Systems Engineering and Management. New Jersey, Wiley • Kossiakoff, Alexander; Sweet, William N.; Seymour, Samuel J.; Biemer, Steven M. Systems Engineering Principles and Practice. New Jersey: Wiley • Cogan, Boris. Systems Engineering – Practice and Theory, Rijeka: InTech, • Aguirre, Miguel A. Introduction to Space Systems. New York: Springer • Larson, Wiley J.; Kirkpatrick, Doug; Sellers, Jerry Jon; Thomas, L. Dale; and Verma, Dinesh. Applied Space Systems Engineering. New York: McGraw-Hill • NASA. Systems Engineering Handbook. Washington D.C. • Fortescue, Peter; Swinerd, Graham; Stark, John. Spacecraft Systems Engineering (Fourth Edition), Chichester: Wiley
Additional comments:

Teaching method(s): Lecture	**Associated module examination:** Space Systems Engineering

Course: Space Vehicle Design	
Frequency: summer semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Literature: • W.T. Thomson, Introduction to Space Dynamics, Dover Publications, ISBN 0-486-65113-4	
Teaching method(s): Lecture	**Associated module examination:** Space Vehicle Design

Module 04-PT-MA-M30-CM-14: Space Propulsion

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Compulsory Modules	Thermo-Fluid Dynamics

Learning content:
- Introduction and classification of space propulsion systems
- Chemical propulsion systems (solid, liquid, hybrid)
- Main components (tank, turbopump, injector, combustion chamber, nozzle)
- Advantages and disadvantages of fuel combinations
- Energy cycles (e.g., gas generator cycle)
- Combustion instabilities
- Hybrid rocket engine (preparation laboratory)
- Conservation of momentum, rocket equations, delta-v, staging
- Electric propulsion
- Other propulsion systems

Learning outcomes / competencies / targeted competencies:
- The students can divide different types of space propulsion systems into categories.
- The students are familiar with the structure and function of individual components in the field of chemical rocket propulsion.
- The students can calculate and evaluate propellant combinations with regard to different aspects such as specific impulse, mass, volume, but also with regard to economic and ecological aspects.
- The students know the basic energy cycles and the causes of combustion instabilities.
- The students understand basic aspects of engine design and a hybrid engine test (laboratory).
- The students are able to apply the rocket equations and calculate the performance limits of engine combinations.
- The students are familiar with the systems and fundamentals of electric and other propulsion systems.

Calculation of student workload:
56 h SWS / presence time / working hours
56 h Preparation / follow-up work
68 h Exam preparation

Are there optional courses in the modules?
no

Language(s) of instruction: English	**Responsible for the module:** Dr. Florian Meyer
Frequency: summer semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Space Propulsion

Type of examination: module exam	
Form of examination: Announcement at the beginning of the semester	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -	
Language(s) of instruction: English	

Module courses

Course: Space Propulsion - Lecture	
Frequency: summer semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Literature: • Sutton, Biblarz: Rocket Propulsion Elements, Wiley, 9th edition (2017) • Ley, Wittmann, Hallmann: Handbuch der Raumfahrttechnik, Hanser, 5th edition (2019) • Messerschmid, Fasoulas: Raumfahrtsysteme, Springer, 2nd edition (2005)	
Teaching method(s): Lecture	**Associated module examination:** Space Propulsion

Course: Space Propulsion - Lab	
Frequency: summer semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Additional comments: Laborübung	
Teaching method(s): Laboratory class	**Associated module examination:** Space Propulsion

Module 01-ET-MA-CTh1(a): Control Theory 1 / Regelungstheorie 1
Control Theory 1

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Elective Modules	Vorlesung Grundlagen der Regelungstechnik

Learning content:
- Definition und Eigenschaften von Zustandsvariablen / Definition and features of state variables
- Zustandsdarstellung linearer Systeme / State space description of linear systems
- Normalformen / Normal forms
- Koordinatentransformation / Coordinate transformation
- Allgemeine Lösung der linearen Zustandsgleichung / General solution of a linear state space equation
- Lyapunov-Stabilität / Lyapunov stability
- Steuerbarkeit und Beobachtbarkeit / Controllability and observability
- Stationäre Genauigkeit von Zustandsreglern / Steady-state accuracy of state space controllers
- Beobachter / Observer
- Polvorgabeverfahren / Pole Placement controller design
- Riccati-Regler / LQR controllero
- Falb-Wolovitch-Regler / Falb-Wolovitch controller

References:
- K. Michels: Regelungstechnik / Control Engineering (Detailed script in German and English)

German:
- J. Lunze: Regelungstechnik 2
- O. Föllinger: Regelungstechnik
- H. Unbehauen: Regelungstechnik II

English:
- Norman S. Nise: Control Systems Engineering

Learning outcomes / competencies / targeted competencies:
- Sicherer Umgang mit der Zustandsraum-Methodik / Handling of state space methodology
- Entwurf von Zustandsreglern / Design of state space controllerso
- Entwurf von Beobachtern / Observer design

Calculation of student workload:
56 h Preparation / follow-up work
68 h Exam preparation
56 h SWS / presence time / working hours

Are there optional courses in the modules?
no

Language(s) of instruction:	**Responsible for the module:**
English / German	Prof. Dr.-Ing. Kai Michels
Frequency:	**Duration:**
winter semester, yearly	1 semester[s]

The module is valid since / The module is valid until: WiSe 24/25 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Modulprüfung	
Type of examination:	
Form of examination: Announcement at the beginning of the semester	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: - / - / -	
Language(s) of instruction: English / German	
Description: Anzahl Prüfungsleistungen: 1	

Module courses

Course: Control Theory 1	
Frequency: winter semester, yearly	**Language(s) of instruction:** English / German (Ein detailliertes Vorlesungsskript liegt auf Deutsch und Englisch vor / A detailed script in German and English is available)
Contact hours: 4,00	**University teacher:** Prof. Dr.-Ing. Kai Michels
Literature: K. Michels: Regelungstechnik / Control Engineering (Detailed script in German and English) Ein detailliertes Vorlesungsskript liegt auf Deutsch und Englisch vor / A detailed script in German and English is available.	
Teaching method(s): Lecture Tutorial	**Associated module examination:** Modulprüfung

Module 01-ET-MA-ComSp: Communication Technologies for Space
Communication Technologies for Space

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Elective Modules	Basics in linear algebra, calculus, differential equations, fourier transformation and physics (basics in electromagnetic waves) are recommended.

Learning content:

- Introduction to communications: history of wireless communication and space communication
- Basic concepts and terminology in communications
- Recap of Fourier transformation
- Introduction to system theory (signals, linear time invariant systems, convolution, statistic process, etc.)
- Passband-Baseband transformation and receiver concepts
- Wireless channel basics (linear and non-linear distortions, noise, Nyquist, etc.)
- Analog modulation
- Basics in sampling theory and discrete systems and signals
- Digital modulation
- Introduction to channel coding

Learning outcomes / competencies / targeted competencies:

As outcome, the students should be able to:

- explain basic communications concepts and theoretical foundations;
- apply mathematical tools and concepts relevant in communications;
- explain and apply analog and digital modulation.

Calculation of student workload:

56 h Self-study
68 h Exam preparation
56 h SWS / presence time / working hours

Are there optional courses in the modules?

no

Language(s) of instruction:	**Responsible for the module:**
English	Dr.-Ing. Carsten Bockelmann
Frequency: winter semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: SoSe 20 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Modulprüfung

Type of examination: module exam

Form of examination: Written examination	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: - / - / -	
Language(s) of instruction: English	
Description: Gemäß MPO-Space-ST-02-24, PL:1	

Module courses

Course: Communication Technologies for Space	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 4,00	**University teacher:** Dr.-Ing. Carsten Bockelmann
Teaching method(s):	**Associated module examination:** Modulprüfung

Module 01-ET-MA-SAMS(a): Sensors and Measurement Systems
Sensors and Measurement Systems

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Elective Modules	none

Learning content:
The class will cover fundamentals of sensor science starting at the underlying physical mechanisms, different sensor devices, and integrated sensor systems. Process technology used to fabricate sensors will be discussed.

The following sensors will be addressed:

• Thermal Sensors

• Force and Pressure Sensors

• Inertial Sensors

• Magnetic Sensors

• Flow Sensors

Reference:

Walter Lang: Sensors and Measurement systems, ISBN-10: 877022028X

Learning outcomes / competencies / targeted competencies:
Students will gain an overview on different sensor technologies that will enable them to select a particular sensor for a defined application. They will be able to understand the working mechanism of various sensors and to make suggestions on how to improve their performance. Furthermore, they will be able to understand and optimize the different processing steps of a complex sensor module.

Calculation of student workload:
56 h SWS / presence time / working hours
56 h Preparation / follow-up work
68 h Exam preparation

Are there optional courses in the modules?
no

Language(s) of instruction: English	**Responsible for the module:** Prof. Dr.-Ing. Björn Lüssem
Frequency: summer semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: SoSe 24 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Modulprüfung

Type of examination:	
Form of examination: Written examination	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: - / - / -	
Language(s) of instruction: English	
Description: Anzahl der Prüfungsleistungen: 1	

Module courses

Course: Sensors and Measurement Systems	
Frequency: summer semester, yearly	**Language(s) of instruction:** English
Contact hours: 4,00	**University teacher:** Prof. Dr.-Ing. Björn Lüssem
Literature: Walter Lang: Sensors and Measurement systems, ISBN-10: 877022028X	
Teaching method(s): Lecture Tutorial	**Associated module examination:** Modulprüfung

Module 01-PHY-MA-RSOC: Remote Sensing of Ocean and Cryosphere
Remote Sensing of Ocean and Cryosphere

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Elective Modules	-

Learning content:

- Concepts for satellite remote sensing of the ocean and cryosphere
- Microwave radar and radiometer observations of sea and land ice and of sea surface temperature and salinity
- Altimetry for sea surface height, circulation, sea level and ice thickness change
- Optical satellite data for ocean color and sea ice
- Error analysis and statistics
- Practical examples and applications to use satellite data sets from oceanography and cryosphere
- Satellite data processing

A list of references will be provided at the start of the semester.

Learning outcomes / competencies / targeted competencies:
Students gain knowledge in basics and application of remote sensing of sea ice extent, type, drift and thickness, ice shelves and glaciers, sea surface height, winds over the ocean, waves, ocean color, surface temperature and salinity, sea level rise, ocean color and other remote sensing applications for ocean and cryosphere.

Calculation of student workload:
56 h Preparation / follow-up work
56 h SWS / presence time / working hours
68 h Exam preparation

Are there optional courses in the modules?
no

Language(s) of instruction: English	**Responsible for the module:** Dr. Gunnar Spreen
Frequency: summer semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: SoSe 24 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Prüfungsleistung	
Type of examination:	
Form of examination: Announcement at the beginning of the semester	**The examination is ungraded?** no

Number of graded components / ungraded components / prerequisites of the examination: - / - / -
Language(s) of instruction: English
Description: ACHTUNG: Gemäß MPO-Space-ST-02-24, Prüfungstyp = Teilprüfung; Anzahl Studienleistung: 1, Anzahl Prüfungsleistung: 1 Prüfungsleistung: 3 CP Studienleistung: 3 CP

Module examination: Studienleistung	
Type of examination:	
Form of examination: Announcement at the beginning of the semester	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: - / - / -	
Language(s) of instruction: English	
Description: ACHTUNG: Gemäß MPO-Space-ST-02-24, Prüfungstyp = Teilprüfung; Anzahl Studienleistung: 1, Anzahl Prüfungsleistung: 1 Prüfungsleistung: 3 CP Studienleistung: 3 CP	

Module courses

Course: Remote Sensing of Ocean and Cryosphere	
Frequency: summer semester, yearly	**Language(s) of instruction:** English
Contact hours: 4,00	**University teacher:** Dr. Gunnar Spreen
Literature: A list of references will be provided at the start of the semester.	
Teaching method(s):	**Associated module examination:** Prüfungsleistung Studienleistung

Module 03-INF-MA-M30-EM-SR: Space Robotics
Space Robotics

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Elective Modules	none

Learning content:

- Introduction to robotics as an integrating field of electrical engineering, mechatronics, and computer science
- Principal challenges of the environment of space and the similarities/differences to terrestrial robotics
- Fundamentals of modern robot control approaches that enable robotic agents to operate in the environment autonomously
- Types of sensors and actuators employed in autonomous robotic platforms
- Robot geometry, its kinematic and dynamic models
- Control the robotic system from a deliberative and reactive point of view
- Python implementation and robot simulations
- Role of Artificial Intelligence to meet the challenges mentioned above

Learning outcomes / competencies / targeted competencies:

- The students have knowledge in the functioning and safe technical handling of robotic components
- They can evaluate sensors in different robotic application areas and can classify motors, gears and mechanisms for robots
- They understand the main methods and procedures for autonomous robot navigation
- They use and program ROS software packages and are confident using robotics terminology
- They define robot autonomy and list its key aspects
- They describe the sensor and actuator modalities used in robotics and can explain their relevance for robot control
- They can implement low-level actuator control methods
- They can compute the 3D world coordinate transformations for rigid bodies and apply the robot forward and inverse geometric models
- They can describe a robotic system based on its kinematic and dynamic properties and use probabilistic methods for robot localization.
- They can generate an optimal path for a mobile robot or manipulator using graph search methods.
- They can plan a path considering the robot kinematic and dynamic properties.
- They can use reinforcement learning methods to control simple robotic systems and apply dynamical and optimal control that they are robust against disturbances
- They assess the strengths and limitations of different control methods presented in the course
- They identify open challenges in robotics research and current trends in state-of-the-art

Calculation of student workload:

68 h Exam preparation
56 h SWS / presence time / working hours
56 h Preparation / follow-up work

Are there optional courses in the modules?

no

Language(s) of instruction: English	**Responsible for the module:** Prof. Dr. Dr. h.c. Frank Kirchner
Frequency: winter semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Module Examination Space Robotics	
Type of examination: module exam	
Form of examination: Announcement at the beginning of the semester	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -	
Language(s) of instruction: English	

Module courses

Course: Lectures, Exercises and Programming Lab	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 4,00	**University teacher:**
Literature: Mechanics of Robotic Manipulation, Mathew T. Masen, MIT press, 2001. Algebra and Geometry, Alan F. Beardon, Cambridge University Press, 2005. Modelling and Control of Robot Manipulators, Lorenzo Sciavicco, Bruno Siciliano, Springer, 2000. Probabilistic Robotics (Intelligent Robotics and Autonomous Agents), Sebastian Thrun, Wolfram Burgard, and Dieter Fox, MIT Press, 2005. Introduction to Autonomous Mobile Robots, Siegwart R., Nourbakhsh I., Scaramuzza D., MIT press, 2011. Automated Planning: Theory and Practice, Malik Ghallab, Dana Nau, Paolo Traverso, Elsevier, 2004. Behaviour-based robotics, R. C. Arkin, MIT press, 1998. Modern Robotics: Mechanics, Planning, and Control, Kevin M. Lynch and Frank C. Park, Cambridge University Press,	
Teaching method(s):	**Associated module examination:** Module Examination Space Robotics

Module 03-MAT-MA-M30-EM-TO: Trajectory Optimization
Trajectory Optimization

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Elective Modules	Spaceflight mechanics, Computational Methods

Learning content:

- Introduction to optimization (linear programming, nonlinear programming), theoretical background and numerical methods
- Solution methods for Kepler’s equation
- Coordinate systems and orbit determination
- Introduction to optimal control (parameter identification, direct/indirect methods for optimal control), theoretical background and numerical methods
- Multi-body problems (two-body problem and restricted three-body problem), Jacobi’s integral, stability of stationary points
- Real-time methods for optimization (parametric sensitivity analysis, MPC)
- Maneuvers (orbit change, swing-by)
- Global optimization
- Applications (coverage of earth by satellites, moon landing, rendezvous maneuver, …)
- Convex optimization

Learning outcomes / competencies / targeted competencies:

- The students are familiar with definitions and terms of optimization and optimal control.
- The students are confident in using GUI based numerical software (WORHP Lab) to solve optimization and optimal control problems.
- The students can generate space-related optimization and optimal control problems, and formulate them in mathematical notation.
- The students have a basic understanding of numerical problems in optimization and optimal control and know ways to resolve them.
- The students have a basic understanding of how to improve or automate the solution process.

Calculation of student workload:

56 h Preparation / follow-up work

68 h Exam preparation

56 h SWS / presence time / working hours

Are there optional courses in the modules?

no

Language(s) of instruction: English	**Responsible for the module:** Prof. Dr. Christof Büskens
Frequency: winter semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Module Examination Trajectory Optimization	
Type of examination: module exam	
Form of examination: Announcement at the beginning of the semester	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: - / - / -	
Language(s) of instruction: German	

Module courses

Course: Lecture with Exercise and Exam	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 4,00	**University teacher:**
Literature: • D. Vallado. Fundamentals of Astrodynamics and Applications. Springer, 2007. • J. Betts. Practical Methods for Optimal Control and Estimation Using Nonlinear Programming, 2010. • J. Nocedal , S. Wright. Numerical Optimization, 2006.	
Teaching method(s):	**Associated module examination:** Module Examination Trajectory Optimization

Module 04-PT-MA-M30-EM-01: Computational Fluid Dynamics

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Elective Modules	Fluid Mechanics, Computational Methods

Learning content:

- Introduction to Computational Fluid Dynamics (CFD): domains of application
- Conservation equations: mass, momentum and energy
- Numerical discretization of conservation equations with the finite-volume method
- Numerical solution of the Navier-Stokes equations with projection schemes (including SIMPLE and PISO)
- Numerical simulation of turbulent flows with the Reynolds-averaged Navier-Stokes equations (RANS)
- Generation of numerical grids
- Numerical simulation of compressible flows
- Computer application of CFD to the numerical simulation of simple flows with the open-source Software OpenFOAM

Learning outcomes / competencies / targeted competencies:

- The students know the domains of application of CFD in engineering, especially mechanical, aerospace and process (chemical) engineering.
- The students can numerically discretize conservation equations with the finite-volume method and with explicit and implicit temporal integration.
- The students understand the difficulties in numerically solving to the Navier—Stokes equations (for incompressible and compressible flows) and know the main models and types of grids applied for the numerical solution of laminar and turbulent flows in industrial settings.
- The students can numerically solve conservations equations with the finite-volume method with the open-source Software OpenFOAM.
- The students can compute simple laminar and turbulent fluid flows.
- The students can visualize, numerically analyze and quantitatively characterize simple flows and interpret them.

Calculation of student workload:
56 h Preparation / follow-up work
68 h Exam preparation
56 h SWS / presence time / working hours

Are there optional courses in the modules?
no

Language(s) of instruction:	**Responsible for the module:**
English	Prof. Dr. Marc Avila
Frequency: winter semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Computational Fluid Dynamis	
Type of examination: module exam	
Form of examination: Oral	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -	
Language(s) of instruction: English	

Module courses

Course: Computational Fluid Dynmics	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Literature: • Ferziger, Peric & Street: Computational Methods for Fluid Dynamics, Springer; 4th ed. 2020 • Cebeci, Shao, Kafyeke & Laurendeau: Computational Fluid Dynamics for Engineers, Cambridge University Press; Illustrated edition (22 Dec. 2011)	
Teaching method(s): Lecture	**Associated module examination:** Computational Fluid Dynamis

Course: Computational Fluid Dynamics - Computer Lab	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Teaching method(s): Laboratory class	**Associated module examination:** Computational Fluid Dynamis

Module 04-PT-MA-M30-EM-02: Sustaining Humans on Mars

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Elective Modules	Space environment and human space flight

Learning content:

The students will gain an overview of the following topics, with a strong focus on research conducted in Bremen:

- Past missions to Mars and roadmaps for the future
- Challenges and potentials of the Mars environment
- In-situ resource utilization (resource extraction, materials and energy, production)
- Life support: habitats and closed loops
- Human Factors and safety systems, psychology of humans under Mars conditions
- Automation, robotics and communication in the context of a sustained human presence on Mars
- Sustainability and protection of the Mars environment

Learning outcomes / competencies / targeted competencies:

- Understand the engineering requirements and “soft” requirements for sustaining human life on celestial bodies, particularly Mars.
- Understand the conflicting goals of a human presence and preserving the Martian environment.
- Have an overview of ongoing research in Bremen, including potential options for Master’s theses.
- Have deeper knowledge in a specific area of human Mars exploration selected by the student.

Calculation of student workload:

56 h SWS / presence time / working hours
56 h Preparation / follow-up work
68 h Exam preparation

Are there optional courses in the modules?

no

Language(s) of instruction: English	**Responsible for the module:** Dr.-Ing. Christiane Heinicke
Frequency:	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Sustaining Humans on Mars	
Type of examination: module exam	
Form of examination: Presentation and written assignment	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -	

Language(s) of instruction:
English

Module courses

Course: Sustaining Humans on Mars	
Frequency:	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Teaching method(s):	**Associated module examination:** Sustaining Humans on Mars

Module 04-PT-MA-M30-EM-03: Sustainable Space Exploration through in-situ Resource Utilisation (ISRU)

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Elective Modules	Modules "Space environment and human space flight" and "Design of space systems"

Learning content:

• Concept and motivation for In-Situ Resource Utilization (ISRU) for a sustainable exploration of space: practice of collecting and utilizing local resources found on extraterrestrial bodies such as Moon, Mars or astroids to support human space exploration and space operations (key words: minimizing Earth dependence, sustainability, resource extraction and processing).

• Applications and focus areas:

- Water (extraction from ice deposits in lunar polar regions, the Martian subsurface and used for drinking water, radiation shielding and as a rocket propellant)
- Oxygen (extraction from water ice, lunar and Martian regolith and biological organisms and used for life support and as a rocket propellant).
- Regolith (lunar and Martian surface soil, used for constructing habitas and radiation shielding, mineral support for the growth of biological systems, 3D printing of tools and structures as well as the extraction of metals).
- Metals (e.g., iron, aluminium and titanium extracted from regolith or astroids and used for constructions and infrastructure, manufacturing of tools and equipment).
- Gases (e.g., CO2, nitrogen, methane and argon that are present in the Martian atmosphere and that are trapped within regolith and which can be used for the production of oxygen, carbon- and nitrogen containing chemicals, as propellants and/ or industrial processes).
- Key processes: resource prospecting (identifying and mapping resource locations and concentrations), extraction (removing resources from their natural environment via mining, drilling and heating), processing (transforming raw materials into usable products # Excellence Cluster “Martian Mindset”), manufacturing (creating tools, equipment, and structures from processed materials).

• Benefits of ISRU (reduced mission costs, increased mission duration, enhanced exploration capabilities, potential for space-based economy).

• Challenges (technological development, harsh environments, resource uncertainty, planetary protection) and research questions.

• Towards sustainable space exploration: ISRU and waste reduction/ recycling.

Learning outcomes / competencies / targeted competencies:
This module aims at equipping students with a comprehensive understanding of the principles, technologies and applications of utilizing extraterrestrial resources. Learning outcomes are:
- Understanding of the fundamentals of ISRU (defining ISRU and its importance for space exploration, identifying key resources available on extraterrestrial bodies such as water ice, regolith and minerals, understanding the environmental conditions on extraterrestrial bodies and their impact on ISRU operations).
- Knowledge of ISRU processes (describing various resource prospecting techniques, explaining different extraction methods such as mining, thermal extraction, chemical processing, understanding of resource processing and refinement techniques, learning processes for manufacturing useful products from extracted materials).
- Understanding the applications of ISRU (recognizing the role of ISRU in supporting human space exploration technologies, understanding how ISRU can produce propellants, life support materials and construction materials, analysing the potential fo ISRU to contribute to a space-based economy).

Achievable Skills

- Analytical Skills
  - Evaluating the feasibility of ISRU missions.
  - Analyzing resource availability and distribution on different extraterrestrial bodies.
  - Assessing the technological challenges and risks associated with ISRU.
- Problem-Solving Skills
  - Developing solutions for resource extraction and processing in challenging environments.
  - Designing ISRU systems and processes.
  - Troubleshooting potential problems in ISRU operations.
- Technical Skills
  - Understanding the principles of relevant engineering processes (e.g., in chemical engineering, mechanical engineering, materials science).
  - Familiarity with relevant technologies (e.g., in robotics, automation, remote sensing).
- Critical Thinking
  - Evaluating the ethical implications of ISRU.
  - Considering the potential for planetary contamination.
  - Analyzing the long-term sustainability of ISRU practices.

Practical Applications

- Mission Planning
  - Selecting appropriate ISRU technologies for specific mission objectives.
  - Considering the logistical and economic factors involved in ISRU missions.
- Technology Assessment
  - Being able to analyze the technology readiness level of various ISRU technologies.
  - Understanding the strengths and weaknesses of different ISRU approaches.

By achieving these learning outcomes, students are well-prepared to contribute to the development and implementation of future ISRU missions and technologies.

Calculation of student workload: 56 h SWS / presence time / working hours 68 h Exam preparation 56 h Preparation / follow-up work

Are there optional courses in the modules? no

Language(s) of instruction: English	**Responsible for the module:** Prof. Dr. Katharina Brinkert
Frequency: summer semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Sustainable Space Exploration through in-situ Resource Utilisation (ISRU)	
Type of examination: module exam	
Form of examination: Written examination	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -	
Language(s) of instruction: English	

Module courses

Course: Sustainable Space Exploration through in-situ Resource Utilisation (ISRU)	
Frequency: summer semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Literature: Use of Extraterrestrial Resources for Human Space Missions to Moon and Mars, ISBN # 978-3319726939, Springer Verlag 2018 Mars: Prospective Energy and Material Resources, ISBN 978-36442441547, Springer Verlag 2014 Advances in Manufacturing and Processing of Materials and Structures, ISBN 978-1315232409, Springer Verlag 2018 Research articles distributed during the seminars/ lectures (e.g., Starr S. O., Muscatello A. C. Mars (2020). Mars in-situ resource utilisation, Planetary and Space Science 182, 104824). Forschungsartikel, die während der Seminare/ Vorlesungen verteilt werden (z.B. Starr S. O., Muscatello A. C. Mars (2020). Mars in-situ resource utilisation, Planetary and Space Science 182, 104824).	

Teaching method(s):	**Associated module examination:**
Lecture	Sustainable Space Exploration through in-situ Resource Utilisation (ISRU)

Course: Sustainable Space Exploration through in-situ Resource Utilisation (ISRU)	
Frequency: summer semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Teaching method(s): Tutorial	**Associated module examination:** Sustainable Space Exploration through in-situ Resource Utilisation (ISRU)

Module 04-PT-MA-M30-EM-04: Materials and Processes for Spacecrafts and Extreme Environments

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Elective Modules	Introduction to Materials Science and Engineering

Learning content:
- Extreme environments on Earth and in Space
- Requirements and consideration for materials and their processing technologies for spacecrafts and extreme environments
- Metallic materials for spacecrafts and extreme environments including titanium aluminides, shape memory alloys, superalloys, me-tallic glasses, etc.
- Non-metallic materials for spacecrafts and extreme environments
- Selection of materials and processes for spacecrafts and extreme environments
- Coatings for materials for spacecrafts and extreme environments
- Additive manufacturing of materials for spacecrafts and extreme environments
- Joining of materials for spacecrafts and extreme environments
- Failure of materials for spacecrafts and extreme environments

Learning outcomes / competencies / targeted competencies:
- The students have theoretical knowledge about design, synthesis, and recycling of structural and functional materials used for spacecrafts and extreme environments
- Students understand the principles of materials selection for spacecrafts and extreme environments
- Students understand the processing technologies of materials for spacecrafts and extreme environments
- Students can analyse failure of the materials for spacecrafts and extreme environment

Calculation of student workload:
56 h SWS / presence time / working hours
68 h Exam preparation
56 h Preparation / follow-up work

Are there optional courses in the modules?
no

Language(s) of instruction:	**Responsible for the module:**
English	Prof. Dr. Ilya Okulov
Frequency: winter semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Materials and Processes for Spacecraft and Extreme Environments

Type of examination: module exam

Form of examination:	The examination is ungraded?
Oral	no

Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -
Language(s) of instruction: English

Module courses

Course: Materials and Processes for Spacecraft and Extreme Environments	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Literature: • Barrie D. Dunn, Materials and Processes for Spacecraft and High Reliability Applications, Springer; 2016 • Michael F. Ashby, Materials Selection in Mechanical Design, Elsevier Butterworth-Heinemann; Third edition, 2005	
Teaching method(s): Lecture	**Associated module examination:** Materials and Processes for Spacecraft and Extreme Environments

Course: Materials and Processes for Spacecraft and Extreme Environments - Exercise	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Teaching method(s): Tutorial	**Associated module examination:** Materials and Processes for Spacecraft and Extreme Environments

Module 04-PT-MA-M30-EM-05: Handling of Storable and Cryogenic Fluids in Spacecraft

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Elective Modules	Thermo-fluid dynamics, advanced fluid mechanics, spaceflight mechanics, computational methods, space propulsion

Learning content:

Focal point A: introduction and theoretical background

- Introduction
- Propulsion system
- Mission design
- Governing equations

Focal point B: basics of liquid movements in a tank

- Two-dimensional analysis of a liquid-gas interface
- Dynamic behavior of liquids
- Liquid sloshing in closed containers

Focal point C: fundamentals of propellant management systems

- Tasks of propellant management systems
- Basics of capillary rise
- Capillary rise in porous media
- Screen resistance and bubble point pressure
- Design of propellant management components

Focal point D: introduction, properties and thermodynamic states of hydrogen

- Introduction of hydrogen
- Fluid properties
- Thermodynamic states

Focal point E: fundamentals of the low temperature technology

- Basics of cryogenics
- Typical cooling systems
- Cryostat technology

Focal point F: cryogenic fluid handling in spacecraft

- Cryogenic fluid handling in spacecraft
- Evaporation and condensation
- Prediction of thermodynamic states with the aid of node models
- Depressurization und pressurization
- Liquid filling and withdrawal

Learning outcomes / competencies / targeted competencies:

- The students have basic knowledge about fuels, boundary conditions and tanks for different space vehicles and missions as well as the theoretical background to model the fluid behavior based on mass, linear momentum and energy conservation equations.
- The students can select a combination of fuel, tank and propulsion system which fits to specific mission requirements and boundary conditions of a spaceflight.
- The students understand the connection of liquid-gas configurations and fluid movements with acting accelerations, rotation rates, surface curvatures and certain excitations.
- The students predict the shape and pressure difference across static free surface configurations.
- The students calculate the natural frequency and the transient free surface position of typical sloshing modes, influencing the attitude and motion of a spacecraft.
- The students design and position baffles in a tank in order to influence the liquid motion.
- The students have fundamental knowledge about the function of a special component in most spacecraft tanks: the propellant management devise (PMD). The understanding requires the introduction of the basics of capillary rise, screen resistance and bubble point pressure of certain porous materials (screens).
- The students can select certain propellant management devices (PMDs) with respect to the boundary conditions of a corresponding space flight mission. The students will be able to compute and influence the bounds of functionality of PMDs and subcomponents.
- The students understand the fluid properties, thermodynamic states, peculiarities and useful features of the liquid and the gaseous phase of hydrogen.
- The students understand the fundamentals of the low temperature technology with a special focus on the thermal environment, needed to store and provide cryogenic liquids like liquid hydrogen.
- The students can classify different cryostat and cooling machine types.
- The students can select suitable components in order to develop a cryostat design.
- The students develop and apply so called node models in python or matlab in order to predict the most important processes in a cryogenic tank.

Calculation of student workload:
56 h Preparation / follow-up work
56 h SWS / presence time / working hours
68 h Exam preparation

Are there optional courses in the modules?
no

Language(s) of instruction: English	**Responsible for the module:** Andre Pingel
Frequency: winter semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Handling of Storable and Cyrogenic Fluids in Spacecraft

Type of examination: module exam

Form of examination: Oral	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -	
Language(s) of instruction: English	

Module courses

Course: Handling of Storable and Cyrogenic Fluids in Spacecraft	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Literature: Baehr, H. D., Stephan, S.: Wärme- und Stoffübertragung. 5th edition, Springer Berlin Heidelberg New York, ISBN-13: 978-3-540-32334-1 (2006). Baehr, H. D., Kabelac, S.: Thermodynamik. Grundlagen und technische Anwendungen. 13th edition, Springer Berlin Heidelberg New York, ISBN-13: 978-3-540-32513-0 (2006). Bird, R. B., Stewart, W. E., Lightfoot, E. N.: Transport phenomena. Second edition, John Wiley and Sons, Inc., ISBN: 0-471-41077-2, New York, New York, USA (2002) Brown, C. D.: Elements of Spacecraft Design. AIAA Education Series, ISBN: 978-1-56-347524-5 (2002). Carey, V. P.: Liquid-vapor phase-change phenomena. An introduction to the thermophysics of vaporization and condensation processes in heat transfer equations, ISBN: 978-1-560-32074-6, Taylor & Francis, Bristol (1992). Dodge, F. T.: The new dynamic behavior of liquids in moving containers. Southwest Research Institute, San Antonio, Texas, USA (2000). Hartwig, J. W.: Liquid acquisition devices for advanced in-space cryogenic propulsion systems. Academic Press, ISBN 978-0-12-803989-2 (2016). Lehmann, J., Luschtinetz, T.: Technik im Fokus. Daten Fakten Hintergründe. Wasserstoff und Brennstoffzellen. Unterwegs mit dem saubersten Kraftstoff. Springer Vieweg, ISBN: 978-3-642-34667-5. Doi: 10.1007/978-3-642-34668-2 (2014). McCarty, R. D.: Selected properties of hydrogen (engineering design data). U.S. Department of Commerce, National Bureau of Standards, University of Michigan Library (1981). Toepler, J., Lehmann, J.: Wasserstoff und Brennstoffzelle. 2. Aufl. Springer Vieweg, ISBN: 978-3-662-53359-8. doi: 10.1007/978-3-662-53360-4 (2017). White, F. M.: Fluid Mechanics. Seventh edition, ISBN 978-0-07-352934-9, McGraw-Hill series in mechanical engineering, the McGraw-Hill companies, Inc., NY, USA (2011). Wutz, W., Adam, H., Walcher, W., Jousten, K.: Handbuch Vakuumtechnik - Theorie und Praxis. 7th edition, Vieweg+Teubner Verlag, ISBN: 978-3-322-99948-1 (2000).	
Teaching method(s): Lecture	**Associated module examination:** Handling of Storable and Cyrogenic Fluids in Spacecraft

Course: Handling of Storable and Cyrogenic Fluids in Spacecraft - Exercise

Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Teaching method(s): Tutorial	**Associated module examination:** Handling of Storable and Cyrogenic Fluids in Spacecraft

Module 04-PT-MA-M30-EM-06: FEM Simulations for the Design of Space Systems

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Elective Modules	Mechanics, kinematics, heat transfer, fluid mechanics, numerical methods

Learning content:
- Basics / Principles of FEM
- Quality Assurance of FEM/CFD Simulations (Error Sources in FEM, Error Estimation, Proper documentation)
- Modelling & Meshing (Best Practices, Import and Simplifications of CAD Models, Mesh Analysis)
- Mechanical Analysis (Theoretical Background and exercises for simulation of static & dynamic loads, bolted connection. Including space relevant cases as parameter studies, modal and PSD analysis)
- Conduct four exercises of static and dynamic mechanical simulation in ANSYS, including documentation in form of mandatory graded reports
- Prepare and Run a Shakertest, Record Data and compare these with simulation results from Modal and PSD analysis
- Thermal Analysis (Theoretical Background, Implementation of Conduction, Convection, Radiation, Implementation of water cooling)
- Transient and static thermal simulation in ANSYS workbench incl. fluid cooling with Fluid 116 elements
- Prepare and Run a Thermal Test under forced conv., natural conv. & under vacuum, Record Data, Compare with simulation results
- Summary of the different simulation types and relation to applications in space systems design

Learning outcomes / competencies / targeted competencies:
- The students will learn the theory behind the FEM Simulations and gain awareness of potential error sources in the simulation.
- The students will learn best-practices for meshing, geometry simplification and for different simulation types
- The students apply these best-practices to cunduct 6 exercises using ANSYS workbench
- The students will learn to document the simulation setup and the results.
- The students will learn how the simulations can aid space system design and testing

Calculation of student workload:
80 h Preparation / follow-up work
44 h Exam preparation
56 h SWS / presence time / working hours

Are there optional courses in the modules?
no

Language(s) of instruction:	**Responsible for the module:**
English	Dr.-Ing. Jens Große
Frequency: winter semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: FEM Simulations for the Design of Space Systems	
Type of examination: module exam	
Form of examination: Written examination	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -	
Language(s) of instruction: English	
Description: The submission of three reports is a prerequisite for the exam.	

Module courses

Course: FEM Simulations for the Design of Space Systems - Lecture	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Literature: • Finite Element Modeling and Simulation with ANSYS Workbench, Second Edition, Taylor & Francis Ltd, English, ISBN-10:9781138486294 • Engineering Mechanics 2 - Mechanics of Materials, Springer, English, https://doi.org/10.1007/978-3-642-12886-8 • Engineering Mechanics 3 - Dynamics, Springer, English, https://doi.org/10.1007/978-3-642-53712-7 • Heat Transfer - Basics and Practice, Springer, https://doi.org/10.1007/978-3-642-19183-1	
Teaching method(s): Lecture	**Associated module examination:** FEM Simulations for the Design of Space Systems

Course: FEM Simulations for the Design of Space Systems - Exercise	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Teaching method(s): Laboratory class	**Associated module examination:** FEM Simulations for the Design of Space Systems

Module 04-PT-MA-M30-EM-07: Reusable Space Systems

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Elective Modules	Space Propulsion, Design of Space Systems, Satellite Subsystems, Spaceflight Mechanics

Learning content:
- Introduction to Current Space Systems
- Overview of reusability aspects in space missions
- Key requirements for reusable systems
- Reusability aspects for different space systems and their subsystems
- Impact of reusability on operations
- Discussion of practical reusability examples
- Preparatory workshop for the reusability exercise

Learning outcomes / competencies / targeted competencies:
- The students know the different main types of space systems and how reusability affects them.
- The students can estimate the effects of reusability on different system domains (mainly: propulsion, structures, power, aerodynamics, thermal, on-board data handling & sensors).
- The students are able to make informed trade-off studies with respect to reusability in different mission scenarios.
- The students are able to asses and quantify the effectiveness of different reusability technologies for different applications.
- The students understand the effect of reusability not only from a technological standpoint of the system in question but also on the mission operations of said system.

Calculation of student workload:
56 h Preparation / follow-up work
56 h SWS / presence time / working hours
68 h Exam preparation

Are there optional courses in the modules?
no

Language(s) of instruction:	**Responsible for the module:**
English	Dr.-Ing. Peter Rickmers
Frequency: summer semester, yearly	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Reusable Space Systems

Type of examination: module exam

Form of examination: Written examination	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -	
Language(s) of instruction: English	

Module courses

Course: Reusable Space Systems	
Frequency: summer semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Teaching method(s): Lecture	**Associated module examination:** Reusable Space Systems

Course: Reusable Space Systems - Computer Lab	
Frequency: summer semester, yearly	**Language(s) of instruction:** English
Contact hours: 2,00	**University teacher:**
Additional comments: Computer Lab	
Teaching method(s): Laboratory class	**Associated module examination:** Reusable Space Systems

Module 04-PT-MA-M30-EM-08: Concurrent Engineering

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Elective Modules	Students of M.Sc. Space Engineering in advanced semesters

Learning content:
• Practical block event “Space Concurrent Engineering”, which takes place in the simultaneous design laboratory "Concurrent Engineering Facility" (CEF) at DLR, where a spacecraft is conceptually developed in a guided special process exactly like in practice and done several times a year at DLR.
• Each student overtakes for one week the role as a sub-system “expert” for one of the relevant domains in a development process like e.g. Structure, Power System, OBDH, COMMS, TCS, AOCS, Cost, Risk
• Application of the DLR Concurrent Engineering Process incl. MBSE (i. e. Virtual Satellite), Collaborative Engineering, Agile Scrum Design Method

Learning outcomes / competencies / targeted competencies:
The students know (learning by doing) the modern design process “Concurrent Engineering” applied at DLR to design a spacecraft in a cost effective manner.

Calculation of student workload:

Are there optional courses in the modules?
no

Language(s) of instruction: English	**Responsible for the module:** Dr. Oliver Romberg
Frequency:	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 6 / 180 hours

Module examinations

Module examination: Concurrent Engineering	
Type of examination: module exam	
Form of examination: Portfolio (AT § 8 Abs. 8)	**The examination is ungraded?** no
Number of graded components / ungraded components / prerequisites of the examination: 1 / - / -	
Language(s) of instruction: English	
Description: Laboratory work, presentation and written exam	

Module courses

Course: Conurrent Engineering	
Frequency: winter semester, yearly	**Language(s) of instruction:** English
Contact hours: 0,00	**University teacher:**
Literature: • Tsakyridis, G., Quantius, D., Romberg, O. et al.: A Comparative Study of Scrum and Classical Concurrent Engineering Processes for Space System Design. In: Proceedings of the International Astronautical Congress, IAC. 75th International Astronautical Congress (IAC), Milan, Italy, 2024, ISSN 0074-1795 • Tsakyridis, G., Romberg, O. et al: Assessing SCRUM Agile Principles in Concurrent Engineering. 11th INTERNATIONAL SYSTEMS & CONCURRENT ENGINEERING FOR SPACE APPLICATIONS CONFERENCE (SECESA 2024, Strasburg, France • Fischer, P., Quantius, D., Romberg, O. Explicit Product Structures for Concurrent Engineering. In: 21st International Conference on Cooperative Design, Visualization, and Engineering, CDVE 2024, doi: 10.1007/978-3-031-71315-6. ISBN 978-3-031-71314-9. ISSN 0302-9743 • Martelo A.; Romberg, O., et al: Studies and Educational Activities in a Simultaneous Collaborative Engineering Setting - Recommendations and Lessons Learn. 10th International Conference on Systems & Concurrent Engineering for Space Applications, 2022 • Romberg, O, Martelo A.: Teaching Space Master Concurrent Engineering. In: Proceedings of the 9th Conference on Systems & Concurrent Engineering for Space Applications 2020 • Martelo, A.; Romberg, O., et al: Considerations and first steps towards the implementation of Concurrent Engineering in later project phases. 8th International workshop on Systems & Concurrent Engineering for Space Applications, 2018 • Wertz, James R.; Everett, David F.; Puschell, Jeffery J. Space Mission Engineering: The New SMAD. Portland: Microcosm Press • Sage, Andrew P.; Rouse, William B. Handbook of Systems Engineering and Management. New Jersey, Wiley • Kossiakoff, Alexander; Sweet, William N.; Seymour, Samuel J.; Biemer, Steven M. Systems Engineering Principles and Practice. New Jersey: Wiley • Cogan, Boris. Systems Engineering – Practice and Theory, Rijeka: InTech, • Aguirre, Miguel A. Introduction to Space Systems. New York: Springer • Larson, Wiley J.; Kirkpatrick, Doug; Sellers, Jerry Jon; Thomas, L. Dale; and Verma, Dinesh. Applied Space Systems Engineering. New York: McGraw-Hill • NASA. Systems Engineering Handbook. Washington D.C. • Fortescue, Peter; Swinerd, Graham; Stark, John. Spacecraft Systems Engineering (Fourth Edition), Chichester: Wiley	
Teaching method(s): Laboratory class	**Associated module examination:**

Module 04-PT-MA-M30-PM: Master Project

Assignment to areas of study:	**Content-related prior knowledge or skills:**
• Master Project	none

Learning content:

Learning outcomes / competencies / targeted competencies:
Students have knowledge/responsibilities in
•working on a scientific topic
•concluding scientific results in a colaborating team
•project management
•concluding scientific results in textform
•discussing and presenting own results
•communication and presentation techniques

Calculation of student workload:

Are there optional courses in the modules?
yes

Language(s) of instruction: English	**Responsible for the module:** Prof. Dr. Marc Avila
Frequency: each semester	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 12 / 360 hours

Module examinations

Module examination: Master Project

Type of examination: module exam

Form of examination:	**The examination is ungraded?**
Project report	no

Number of graded components / ungraded components / prerequisites of the examination:
1 / - / -

Language(s) of instruction:
English

Description:
written report and presentation

Module courses

Course: Master Project

Frequency: each semester	**Language(s) of instruction:** English
Contact hours: 0,00	**University teacher:**
Teaching method(s): Project	**Associated module examination:** Master Project

Module 04-PT-MA-M30-MA: Master Thesis (incl. Colloquium)
Master Thesis

Assignment to areas of study:	Content-related prior knowledge or skills:
• Master Thesis	Proof of at least 66 CP including Foundations (30 CP), Compulsory Modules (24 CP) and the Master Project (12 CP)

Learning content:

Learning outcomes / competencies / targeted competencies:
Students have knowledge/responsibilities in
•long-time working on a scientific topic
•making recherches of previous research results
•developing own theories
•discussing and comparing other work with own results
•concluding results in a written thesis

Calculation of student workload:

Are there optional courses in the modules?
yes

Language(s) of instruction: English	**Responsible for the module:** Prof. Dr. Marc Avila
Frequency: each semester	**Duration:** 1 semester[s]
The module is valid since / The module is valid until: WiSe 25/26 / -	**Credit points / Workload:** 30 / 900 hours

Module examinations

Module examination: Master Thesis

Type of examination: module exam

Form of examination: Master Thesis	**The examination is ungraded?** no

Number of graded components / ungraded components / prerequisites of the examination:
2 / - / -

Language(s) of instruction:
English

Description:
Master Thesis: 80% (24 CP)

Colloquium: 20 % (6 CP)