Universität Bremen

Module description

Master study program

Space Sciences and Technologies - Sensing, Processing, Communication (Space - ST)

University of Bremen
Faculty 1 Physics/ Electrical Engineering

February 6, 2019

The module description serves as a guideline for students. The master program Space Sciences and Technologies is regulated by the respective “Masterprüfungsordnung” (examination regulations).

Änderungshistorie

Datum	Version	Art der Änderung
26.09.2017	170926_Modulhandbuch_Space-ST.pdf (SK)	Modulplan, VAKs, Seitenzahlen
26.01.2018	180126_Modulhandbuch_Space-ST.pdf (SK)	Module title updated “Atmospheric Chemistry Modeling”; Module “Engineering Ethics” added
13.02.2018	180213	Elective module “Fascination Space” added
23.05.2018 01.06.2018	180523 (SK) 180601 (SK)	Elective module “Practical Data Analysis with Python” added, examination forms for several modules adjusted
03.09.2018	180903 (SK)	Update of module description “Communication Technologies”
06.02.2019	190602 (SK)	Update of module description Master’s Thesis

Contents

Module Plan “Space-ST”

Semester	Pflichtbereich (Compulsory Modules) + Modul Masterarbeit (inkl. Kolloquium) insgesamt 96 CP			Project (12 CP)	Wahlpflichtbereich (Compulsory Elective Modules, 12 CP)		Wahlbereich (Elective Modules, 12 CP)		∑ 120 Ver-teilung CP/Semester
					„Physics for Space Observation” (PSO) (Specialization)	„Information Technologies for Space“ (ITS) (Specialization)	PSO	ITS	
1	**Foundations (30 CP)**								30
	Inverse Methods and Data Analysis, 6 CP	Control Theory I, 3 CP	Space Electronics, 6 CP						
	Science and Exploration Missions, 3 CP	Atmospheric Physics, 6 CP	Communication Technologies, 6 CP						
2	**Remote Sensing and Communication (24 CP)**				Remote Sensing of Ocean and Cryosphere, 6 CP	RF Frontend Devices and Circuits, 4 CP	Elective Course, 9 CP	Elective Course, 3CP	30
	Channel Coding I, 3 CP	Sensors and Measurement Systems, 3 CP	Digital Image Processing, 3 CP			Architectures and Design Methodologies of Integrated Digital Systems, 4 CP			
		Space Lab, 3 CP	Atmospheric Spectroscopy, 3 CP			Microfluidic Devices, 4 CP			
3	Communication Networks for Space, 3 CP	Space Lab, 3 CP(Part II)		Project, 12 CP	Atmospheric Chemistry Modeling, 3 CP		Elective Course, 3CP	Elective Course, 9 CP	30
	Geodesy and Gravity, 3 CP				Atmospheric Aerosols, 3 CP				
4	Master Thesis, 30 CP								30

CP = Credit Points

1. Compulsory Modules

Abbreviations

L: Lecture

EC: Exercises

SL: Study achievement (Studienleistung)

PL: Examination achievements (Prüfungsleistung)

Oral/Written examinations are examination achievements (PL)

Exercises are study achievements (SL)

1.1 Foundations (30 CP)

Code no.	01-01-03-AtPhy-V
Module title /	Atmospheric Physics
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies Compulsory for MSc Environmental Physics Optional compulsory for MSc Physik Optional compulsory for MSc Marine Geosciences Optional compulsory for MSc Technomathematik Optional compulsory for MSc Physical Geography: Environmental History
Requirements for participation	None
Content	History of the earth's atmosphere, atmospheric composition, radiation in atmosphere, physical laws, description of radiation and atmospheric radiation transport; Climate change; Atmospheric thermodynamics and hydrological cycle; Aerosols and cloud physics; Introduction into atmospheric dynamics
Learning outcome	Students have background knowledge in Basics physics of the atmosphere
Workload / **credit points**	6 CP, 180 h • presence (L + EC): 56 h (4 SWH x 14 weeks) • preparation, learning + exercises: 56 h (4 SWH x 14 weeks) • preparation for exam: 68 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr. John P. Burrows Module section / Foundations
Compulsory / optional	Compulsory
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (1st academic year)
ECTS	6 CP
Semester Weekly Hours	4 SWS (4 semester weekly hours (SWH) / 2x lecture (L) + 2x exercise classes (EC))
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of exercise classes
Literature	• Houghton, J.T., The physics of atmospheres, Cambridge University Press, 1977, ISBN 0 521 29656 0. • Wallace, John M. and Peter V. Hobbs, Atmospheric Science, An Introductory Survey, Academic Press, 2nd Edition 2005, ISBN 0-12-732951-x

Code no.	01-29-03-ComT-V
Module title /	Communication Technologies for Space
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies
Requirements for participation	Basics in linear algebra, calculus, differential equations, Fourier transformation, and basics in electromagnetic waves
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
Learning outcome	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.
Workload / **credit points**	6 CP, 180 h • presence (L + EC): 56 h (4 SWH x 14 weeks) • preparation, learning + exercises: 56 h (4 SWH x 14 weeks) • preparation for exam: 68 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Dr.-Ing. Carsten Bockelmann Module section / Space Communication Technology
Compulsory / optional	Compulsory
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (1st academic year)
ECTS	6 CP
Semester Weekly Hours	(4 semester weekly hours (SWH) / 2x lecture (L) + 2x exercise classes (EC))
Course and examination performance, type of exam	Module exam Examination performance: Written exam
Literature	• J. Proakis: Digital Transmission

Code no.	01-15-03-CTh1-V
Module title /	Control Theory I
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies Optional compulsory for MSc CMM Optional compulsory for MSc CIT
Requirements for participation	Knowledge about basics of control (bode diagrams, nyquist plots, nyquist stability criterion, PID controller design)
Content	Introduction to the definition and features of state variables, State space description of linear systems, Normal forms, Coordinate transformation, General solution of a linear state space equation, Lyapunov stability, Controllability and observability, Concept of state space control, Steady-state accuracy of state space controllers, Observer, Controller design by pole placement, Riccati controller design, Falb-Wolovitch controller design.
Learning outcome	Students have background knowledge in understanding and handling of state space methodology, design of state space controllers with different methods, observer design
Workload / **credit points**	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + exercises: 42 h (3 SWH x 14 weeks) • preparation for exam: 20 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr.-Ing. Kai Michels Module section / Introduction to Space Systems
Compulsory / optional	Compulsory
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (1st academic year)
ECTS	3 CP
Semester Weekly Hours	(2 semester weekly hours (SWH) / 1x lecture (L) + 1x exercise classes (EC))
Course and examination performance, type of exam	Module exam Examination performance: Written or oral exam depending on the number of participants
Literature	• K. Michels, Control Engineering, Script, Norman S. Nise: Control Systems Engineering. • Norman S. Nise: Control Systems Engineering

Code no.	01-01-03-IMDA-V
Module title /	Inverse Methods and Data Analysis
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies Compulsory for MSc Environmental Physics Optional compulsory for MSc Physik Optional compulsory for MSc Marine Geosciences Optional compulsory for MSc Technomathematik
Requirements for participation	None
Content	Error analysis and statistics, techniques for the optimal solution of under and over determined systems of linear equations including methods for calculating variances and covariances of the solutions, concepts of resolution and methods to calculate them, practical examples and applications to test data sets from oceanography, image processing and atmospheric remote sensing
Learning outcome	Students are competent to identify linear inverse methods
Workload / **credit points**	6 CP, 180 h • presence (L + EC): 56 h (4 SWH x 14 weeks) • preparation, learning + exercises: 56 h (4 SWH x 14 weeks) • preparation for exam: 68 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr. Reiner Schlitzer, Prof. Dr. Emily King Module section / Optimization
Compulsory / optional	Compulsory
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (1st academic year)
ECTS	6 CP
Semester Weekly Hours	4 SWS (4 semester weekly hours (SWH) / 2x lecture (L) + 2x exercise classes (EC))
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of exercise classes
Literature	Will be announced in the respective course.

Code no.	01-29-03-SEM-V
Module title /	Science and Exploration Missions
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies Optional compulsory for MSc Physik
Requirements for participation	Basic courses in Physics on mechanics, electrodynamics, quantum mechanics
Content	Introduction of completed and planned space missions, Examples are (i) Gravity Probe A for testing the gravitational redshift, (ii) Gravity Probe B for testing the gravitomagnetic Schiff effect, (iii) Cassini for Saturn exploration and testing the gravitational time delay, (iv) Pioneer for planetary exploration and testing the gravitational field in the Solar system, (v) MICROSCOPE for testing the Equivalence Principle, (vi) LISA for searching for gravitational waves and the technology mission LISA pathfinder, (vii) GRACE and GRACE-FO for satellite based geodesy, (viii) ACES on the ISS for testing relativity and establishing space-based metrology, (ix) further missions testing Special and General Relativity using quantum optics, (x) asteroid and comet missions HAYABUSA and Rosetta. For each mission the requirements on the payload technology, the spacecraft technology, and on the mission scenario will be derived.
Learning outcome	Participants are able to discuss science cases for space and exploration missions, measurement schemes and payload as well as technology requirements on payload and mission.
Workload / **credit points**	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + exercises: 42 h (3 SWH x 14 weeks) • preparation for exam: 20 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr. Claus Lämmerzahl Module section / Introduction to Space Systems
Compulsory / optional	Compulsory
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (1st academic year)
ECTS	3 CP
Semester Weekly Hours	(2 semester weekly hours (SWH) / 1x lecture (L) + 1x exercise classes (EC))
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer), graded Course performance: Successful assessment of exercise classes, not graded
Literature	• H. Dittus, C. Lämmerzahl, S. Turyshev (Editors): Lasers, Clocks and Drag-Free Control - Exploration of Relativistic Gravity in Space, Astrophysics and Space Science Library, Vol. 349 (Springer Verlag, Berlin and Heidelberg 2008), ISBN 978-3-540-34376-9, ISSN 0067-0057. • C. Lämmerzahl and H. Dittus: Fundamental physics in space: A guide to present projects, Annalen der Physik 11, 95 (2002).

Code no.	01-29-03-SpEl-V
Module title /	Space Electronics
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies
Requirements for participation	Basic knowledge of semiconductors, analog and digital circuit
Content	• Radiation environments • MOS Device and radiation • Circuit Reliability basics • Single event effects on analog and digital circuits, memories • Displacement damage (DD) effects • Radiation hard device technologies and circuit design • Noise • gm/Id Method • Mismatch • two pole opamps (OTA) • feedback
Learning outcome	After this course, students are able to: • describe and characterize noise in electronics circuits • apply the gm/Id sizing method to design amplifier circuits for advance CMOS technologies • deal with process variations and mismatch • understand the frequency behaviour of amplifier circuits • understand and size compensation networks • use feedback to modify circuit characteristics. • understand the impact of radiation on the behavior of circuits • design radiation hard circuits
Workload / credit points	6 CP, 180 h • presence (L + EC): 56 h (4 SWH x 14 weeks) • preparation, learning + exercises: 56 h (4 SWH x 14 weeks) • preparation for exam: 68 h
Course language	English
Responsible for the module, lecturers / Module assignment	Prof. Dr.-Ing. Steffen Paul Module section / Space Electronics
Compulsory / optional	Compulsory
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (1st academic year)
ECTS	6 CP
Semester Weekly Hours	(4 semester weekly hours (SWH) / 2x lecture (L) + 1 seminar + 1x exercise classes (EC))
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer), graded Course performance: Successful assessment of exercise classes, not graded
Literature	Will be announced in the respective course.

1.2 Remote Sensing and Communication (24 CP)

Code no.	01-01-03-AtSp-V
Module title /	Atmospheric Spectroscopy
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies Optional for MSc Environmental Physics Optional compulsory for MSc Marine Geosciences Optional compulsory for MSc Technomathematik
Requirements for participation	None
Content	Prisms and grating spectrometers, Fourier-Transform-Spectroscopy, transitions, rotational spectra, vibrational spectra, rotational-vibrational spectra, remote sensing methods
Learning outcome	The students have background knowledge in basics of spectroscopy, understanding and interpretation of measured spectra with regard to the structure of the molecules as well as basics of the FTIR-spectroscopy, understanding of remote sensing methods.
Workload / **credit points**	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + exercises: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr. Justus Notholt Module section / Remote Sensing and Communication
Compulsory / optional	Compulsory
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (1st academic year)
ECTS	3 CP
Semester Weekly Hours	(2 semester weekly hours (SWH) / 1,5x lecture (L) + 0,5x exercise classes (EC))
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer), graded Course performance: Successful assessment of exercise classes and/or successful writing of an essay, not graded
Literature	Will be announced in the respective course.

Code no.	01-01-03-CCod1-V
Module title /	Channel Coding I
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies Optional compulsory for MSc CIT Optional compulsory for MSc Elektrotechnik und Informationstechnik
Requirements for participation	Basics of communication technology and digital signal processing
Content	1) Basic Concepts and channel models 2) Information theory 3) Linear block codes: a. Generator and parity check matrix b. Standard array and syndrome decoding c. Examples (SPC, Hamming, Simplex), d. Cyclic Codes (description by polynomials), e. Examples (CRC, BCH, Reed-Solomon), 4) Convolutional codes: a. Encoder structure and graphical representations b. Viterbi decoding c. Code properties
Learning outcome	Channel Coding I is a one semester course. The aim is to provide a basic understanding how channel coding works and to present the most important code families. Moreover, results obtained from information theory show the ultimate limits theoretically achievable with optimal codes. After this course, the students should be able to: • Explain the principle of channel coding • Explain the ultimate limits from information theory • Perform encoding and decoding for linear block and convolutional codes • Grade the performance of different codes
Workload / **credit points**	3 CP, 90 h • presence (L + EC): 42 h (3 SWH x 14 weeks) • preparation, learning + exercises: 28 h (2 SWH x 14 weeks) • preparation for exam:20 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Dr.-Ing. Dirk Wübben Module section / Remote Sensing and Communication
Compulsory / optional	Compulsory
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (1st academic year)
ECTS	3 CP
Semester Weekly Hours	(3 semester weekly hours (SWH) / 2x lecture (L) + 1x exercise classes (EC))
Course and examination performance, type of exam	Module exam Examination performance: Written exam
Literature	• Neubauer, A., J. Freudenberger, V. Kühn: Coding Theory: Algorithms, Architectures and Applications. • Lin, S., D. J. Costello, Jr.: Error Control Coding: Fundamentals and Applications. • Moreira, J. C., P.G. Farr: Essentials of Error-Control.

Code no.	01-01-03-CNS-V
Module title /	Communication Networks for Space
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies Compulsory for MSc CIT (under the title Communication Networks Systems) Optional compulsory for MSc CMM (under the title Communication Networks Systems)
Requirements for participation	None
Content	Distributed Systems, ISO/OSI 7 Layer Reference Model for Open Communication, Formal Specification Methods for Protocols (SDL), Data Link Layer, Network Layer, Transport Layer, Application Oriented Layers, Local Area Networks, Wide Area Networks, Network Control: (virtual) connections, Routing, Addressing, Flow Control, System Examples: TCP/IP, ISDN / B-ISDN / ATM, Wireless Networks, Performance Analysis
Learning outcome	The participants are able to describe exemplary systems of communication networks, name and explain the layers of a communication network, know the basic technologies used for communication protocols, know basic error handling mechanisms for communication protocols.
Workload / **credit points**	3 CP, 90 h • presence (L + EC): 42 h (3 SWH x 14 weeks) • preparation, learning + exercises: 28 h (2 SWH x 14 weeks) • preparation for exam:20 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr. Anna Förster Module section / Remote Sensing and Communication
Compulsory / optional	Compulsory
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (2nd academic year)
ECTS	3 CP
Semester Weekly Hours	(3 semester weekly hours (SWH) / 2x lecture (L) + 1x exercise classes (EC))
Course and examination performance, type of exam	Partial exam Examination performance: Project presentation graded Course performance: Successful assessment of homework assignments and a successful work on a project, not graded presentation.
Literature	• Walrand, J.: Communication Networks, A first course, WCB/McGraw-Hill 1998, ISBN 0-256-17404-0. • Tanenbaum, A.S.: Computer Networks, Prentice Hall 1996, ISBN 0-13 349945-6 (and newer editions). • Ross/Kurose, Computer Networking: A Top Down Approach, 4th ed., Addison-Wesley, July 2007.

Code no.	01-01-03-DIP-V
Module title /	Digital Image Processing
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies Optional for MSc Environmental Physics Optional compulsory for MSc Marine Geosciences Optional compulsory for MSc Technomathematik
Requirements for participation	None
Content	• Digital image, sampling • Image enhancement using filters • Image analysis methods using segmentation, feature extraction and classification • Fourier transformation of digital image, linear filters in spatial and frequency domains • Data compression
Learning outcome	Students know the fundamentals of digital image processing.
Workload / **credit points**	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + exercises: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Dr. Christian Melsheimer, Dr. Gunnar Spreen Module section / Remote Sensing and Communication
Compulsory / optional	Compulsory
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (1st academic year)
ECTS	3 CP
Semester Weekly Hours	(2 semester weekly hours (SWH) / 1,5x lecture (L) + 0,5x exercise classes (EC))
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer), graded. Course performance: Successful assessment of exercise classes and/or successful writing of an essay, not graded
Literature	Will be announced in the respective course.

Code no.	01-29-03-GG-V
Module title /	Geodesy and Gravity
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies
Requirements for participation	None
Content	Classical geodesy • Repetition of Newtonian gravitational theory • Multipole moments of the Earth and the gravitational field of the Earth • Definition of the geoid on the rotating Earth • Equation of motion for satellites • Calculation of satellite orbits • Description of orbits for satellite formation flight and extraction of the gravitational field Relativistic geodesy • Elements of relativistic gravity theory • Post-Newtonian solution for the gravitational field of the Earth • Definition of the geoid • Clocks in the gravitational field: clock geodesy • Relativistic satellite orbits, basic effects
Learning outcome	The students will have knowledge of notions of nonrelativistic gravity theory, knowledge of basic notions of geodesy, an understanding of methods to measure the gravitational fields, knowledge of basic principles of relativistic gravity and an understanding of clock geodesy
Workload / **credit points**	3 CP, 90 h • presence (L + EC): 42 h (3 SWH x 14 weeks) • preparation, learning + exercises: 28 h (2 SWH x 14 weeks) • preparation for exam: 20 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr. Claus Lämmerzahl Module section / Remote Sensing and Communication
Compulsory / optional	Compulsory
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (2nd academic year)
ECTS	3 CP
Semester Weekly Hours	(3 semester weekly hours (SWH) / 2x lecture (L) + 1x exercise classes (EC))
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer), graded. Course performance: Successful assessment of exercise classes and/or successful writing of an essay, not graded
Literature	Will be announced in the respective course.

Code no.	01-15-03-SAMS-V
Module title /	Sensors and Measurement Systems
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies Optional compulsory for MSc CIT Optional compulsory for MSc CMM Optional compulsory for MSc Elektrotechnik und Informationstechnik
Requirements for participation	Basics of electrical engineering and electrical measurement
Content	• Basics of Sensors • Thermal Sensors • Sensor Technology • Force and Pressure Sensors • Inertial Sensors • Magnetic Sensors • Flow Sensors
Learning outcome	The students know how to name and explain important sensors, apply characterization parameters for sensors, choose sensors for a given application and apply them, analyze sensor systems, understand micromachining technologies for sensors
Workload / **credit points**	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + exercises: 42 h (3 SWH x 14 weeks) • preparation for exam: 20 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr. Walter Lang Module section / Remote Sensing and Communication
Compulsory / optional	Compulsory
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (1st academic year)
ECTS	3 CP
Semester Weekly Hours	Sensors and Measurement Systems (2 semester weekly hours (SWH) / 1,5x lecture (L) + 0,5x exercise classes (EC) in the clean room)
Course and examination performance, type of exam	Module exam Examination performance: Written exam
Literature	• Sinclair: Sensors and Transducers. • J. Bentley: Principles of measurement systems.

Code no.	01-29-03-LSPA-V
Module title /	Space Lab
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies
Requirements for participation	None
Content	Measurements of meteorological quantities, atmospheric trace gases, ocean currents, environmental radioactivity, absorption cross-sections, measurements of Embedded Systems and Communications.
Learning outcome	Participants know the basics of measurement techniques in Space Sciences and Technologies.
Workload / **credit points**	6 CP, 180 h • presence (L): 18 h (6 SWH x 3 weeks) • presence (Lab): 24 h (6 SWH x 4 weeks) • preparation, report: 84 h (12 SWH x 7 weeks) • preparation for exam: 54 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	PD Dr. Annette Ladstätter-Weißenmayer, Dr. A. Richter, Prof. Dr.-Ing. A. Garcia-Ortiz, Prof. Dr.-Ing. St. Paul, Prof. Dr.-Ing. A. Dekorsy, Prof. Dr.-Ing. A. Förster, Prof. Dr. J. Burrows, Prof. Dr. J. Notholt, Prof. Dr. M. Rhein, Prof. Dr.-Ing. K Michels Module section / Remote Sensing and Communication
Compulsory / optional	Compulsory
Offered frequency	Semesterly
Duration / semester	2 semesters / summer semester (1st academic year), winter semester (2nd academic year)
ECTS	6 CP
Semester Weekly Hours	(8 laboratory (Lab) + 1 lecture (L))
Course and examination performance, type of exam	Partial exam Examination performance: Oral exam Course performance: Successful experiments with accepted reports
Literature	Will be announced in the respective course.

1.3 Project (12 CP)

Code no.	01-29-03-PrSpa
Module title /	Project
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies
Requirements for participation	None
Content	The content is related to the respective area of research of the project. Working in the laboratories of the Institute of Environmental Physics / Electrical Engineering / AWI Individual instruction (practical training) Preparation of a thesis paper on a possible research project which - as a rule - should be closely related to the subsequent Master's Thesis.
Learning outcome	The students should be able to transfer a scientific problem/question into an experimental and/or theoretical study, should develop successful strategies for the planning and conducting of scientific studies and should be able to summarize and present preliminary scientific results in a thesis paper.
Workload / **credit points**	12 CP, 360 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr. John P. Burrows, Prof. Dr. Justus Notholt, Prof. Dr. Monika Rhein, PD Dr. Annette Ladstätter-Weißenmayer, Prof. Dr.-Ing.Dr.-Ing. Steffen Paul, Prof. Dr. Alberto Garcia-Ortiz, Prof. Dr. Kai Michels, Prof. Dr. Walter Lang, Prof. Dr.-Ing.Dr.-Ing. Martin Schneider, Prof. Dr. Anna Förster as well as further university lecturers of the IUP (Institute of Environmental Physics) / AWI (Alfred Wegener Institute for Polar and Marine Research) depending on the area of research Module section / Project
Compulsory / optional	Compulsory
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (2nd academic year)
ECTS	12 CP
Semester Weekly Hours	(12 CP, 360 h)
Course and examination performance, type of exam	Module examination • Successful assessment of the project Thesis paper on research project which can be conducted within the context of the Master's Thesis.
Literature	Will be announced in the respective course.

1.4 Master Thesis (30 CP)

Code no.	01-29-03-ThsSpa
Module title /	Master Thesis (incl. colloquium)
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies
Requirements for participation	Required for the application for the Master's Thesis is the passing of all the mandatory exams of the module sections "Compulsory", "Compulsory Elective" and the module "project".
Content	The content is related to the respective area of research of the thesis project. Working in the laboratories of the Institute of Environmental Physics / Electrical Engineering / Alfred Wegener Institute. Individual instruction (practical training). Preparation of a thesis and defense thereof in a colloquium.
Learning outcome	The students should be able to transfer a scientific problem/question into an experimental and/or theoretical study, should develop successful strategies for the planning and conducting of scientific studies, be able to conduct a critical evaluation, assessment and discussion of own scientific results and summarize and present scientific results in a thesis and in a colloquium.
Workload / **credit points**	30 CP, 900 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr. John P. Burrows, Prof. Dr. Justus Notholt, Prof. Dr. Monika Rhein, PD Dr. Annette Ladstätter-Weißenmayer, Prof. Dr.-Ing. Steffen Paul, Prof. Dr. Alberto Garcia-Ortiz, Prof. Dr. Kai Michels, Prof. Dr. Walter Lang, Prof. Dr.-Ing. Martin Schneider, Prof. Dr. Anna Förster as well as further university lecturers of the IUP (Institute of Environmental Physics) / AWI (Alfred-Wegener-Institute for Polar and Marine Research) depending on the area of research Module section / Master Thesis and Colloquium
Compulsory / optional	Compulsory
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (2nd academic year)
ECTS	30 CP
Semester Weekly Hours	(30 CP, 900 h)
Course and examination performance, type of exam	Module examination • Successful assessment of the Master's Thesis • Successful colloquium to the Master's Thesis Credit points for the finale module are granted on the basis of the marks for the Master's Thesis (75%) and the colloquium (25%).
Literature	Will be announced in the respective course.

2. Specialization Subjects

One specialization subject has to be selected out of “Physics for Space Observation” or “Information Technologies for Space”.

2.1 Physics for Space Observation (12 CP)

Code no.	01-01-03-AtA-V
Module title /	Atmospheric Aerosols
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies Optional compulsory for MSc Marine Geosciences Optional compulsory for MSc Technomathematik
Requirements for participation	None
Content	Description of atmospheric aerosols, their composition and measuring methods. Introduction to radiative transfer in the troposphere with emphasis on aerosols and clouds.
Learning outcome	Students have an advanced knowledge of the atmosphere and light scattering.
Workload / credit points	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + exercises: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Course language	English
Responsible for the module, lecturers / Module assignment	Dr. Marco Vountas, Dr. Luca Lelli Module section / Specialization Subject – Physics for Space Observation
Compulsory / optional	Compulsory
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (2nd academic year)
ECTS	3 CP
Semester Weekly Hours	(2 semester weekly hours (SWH) / 1,5x lecture (L) + 0,5x exercise classes (EC))
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of exercise classes and/or successful writing of an essay
Literature	Will be announced in the respective course.

Code no.	01-01-03-AtCM1-V
Module title /	Atmospheric Chemistry Modeling
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies Optional compulsory for MSc Marine Geosciences Optional compulsory for MSc Technomathematik
Requirements for participation	None

Content	• Concept of chemistry transport models
	• Atmospheric Chemical Composition/Processes
	• Model equations and numerical approaches focusing on the:
	  ○ formulation of atmospheric rates
	  ○ numerical methods for chemical systems
	• Surface fluxes/emissions
	• Observations and model evaluations
	• Inverse modeling for atmospheric chemistry

Learning outcome	Participants will have the chance to: Get a theoretical overview of the concepts of numerical atmospheric chemistry modelling, to review fundamentals of atmospheric chemistry and physics, to formulate model equations and numerical (differential) approaches for various systems focusing on atmospheric chemistry mechanisms and to assess the role of chemistry transport models as components of the atmospheric observing system. Concepts of inverse modelling will be also presented.
Workload / **credit points**	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + exercises: 42 h (3 SWH x 14 weeks) • preparation for exam: 20 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr. Mihalis Vrekoussis Module section / Specialization Subject – Physics for Space Observation
Compulsory / optional	Compulsory
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (2nd academic year)
ECTS	3 CP
Semester Weekly Hours	(2 semester weekly hours (SWH) / 1,5x lecture (L) + 0,5x exercise classes (EC))
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of exercise classes and/or successful writing of an essay
Literature	• Modeling Methods for Marine Science: David M. Glover, William J. Jenkins, Scott C. Doney. • Numerical Recipes: William H. Press, Saul Teukolsky, William T. Vetterling und Brian P. Flannery. • Further references will be provided at the start of the course.

Code no.	01-29-03-RSOC-V
Module title /	Remote Sensing of the Ocean and Cryosphere
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies
Requirements for participation	None
Content	Error analysis and statistics, techniques for the optimal solution of under and over determined systems of linear equations including methods for calculating variances and covariances of the solutions, concepts of resolution and methods to calculate them, practical examples and applications to test data sets from oceanography, image processing and atmospheric remote sensing
Learning outcome	Students have background knowledge in basics and application of remote sensing of sea ice extent and thickness, sea surface height, winds over the ocean, waves, ocean bottom, surface temperature and salinity, ocean color and other remote sensing applications for ocean and cryosphere.
Workload / credit points	6 CP, 180 h • presence (L + EC): 56 h (4 SWH x 14 weeks) • preparation, learning + exercises: 56 h (4 SWH x 14 weeks) • preparation for exam: 68 h
Course language	English
Responsible for the module, lecturers / Module assignment	Prof. Dr. Monika Rhein, Prof. Dr. Astrid Bracher, Dr. Georg Heygster, Dr. Gunnar Spreen, Prof. Dr. Christian Haas, Prof. Dr. Ben Marzeion Module section / Specialization Subject – Physics for Space Observation
Compulsory / optional	Compulsory
Offered frequency	Annually /summer semester
Duration / semester	1 semester / summer semester (1st academic year)
ECTS	6 CP
Semester Weekly Hours	(4 semester weekly hours (SWH) / 2x lecture (L) + 2x exercise classes (EC))
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer), graded Course performance: Successful assessment of exercise classes, not graded
Literature	Will be announced in the respective course.

2.2 Information Technologies for Space (12 CP)

Code no.	01-15-03-DIDS-V
Module title /	Architectures and Design Methodologies of Integrated Digital Systems
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies Compulsory for MSc CMM Elective for MSc CIT Optional compulsory for MSc Elektrotechnik und Informationstechnik
Requirements for participation	None
Content	• Design tools and abstractions levels • Physical design, Floorplanning and placement, Routing and wire estimation, DRC and LVS • Design-for-Test, Scan-based design, Boundary scan, BIST Test-architectures for SoCs • Test-generation and error diagnosis, ATPG, Fault simulation
Learning outcome	The students will learn the design methodologies, theoretical algorithms, and tools used for the development of microelectronic integrated systems, as well as the strategies regarding their practical implementation with industrial CAD tools. The students will be able to implement a complex microelectronic integrated digital guarantying its correctness and testability.
Workload / credit points	4 CP, 120 h • presence (L + EC): 42 h (3 SWH x 14 weeks) • preparation, learning + exercises: 42 h (3 SWH x 14 weeks) • preparation for exam: 36 h
Course language	English
Responsible for the module, lecturers / Module assignment	Prof. Dr.-Ing. Alberto García-Ortiz Module section / Specialization Subject – Information Technologies for Space
Compulsory / optional	Compulsory
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (1st academic year)
ECTS	4 CP
Semester Weekly Hours	(3 semester weekly hours (SWH) / 2x lecture (L) + 1x exercise classes (EC))
Course and examination performance, type of exam	Module exam Examination performance: Written or oral exam
Literature	• J.M. Rabaey, A. Chandrakasan, B. Nikolic, Digital Integrated Circuits – A Design Perspective, ISBN-10_9788120322578 • Michael John Sebastian Smith, Application-Specific Integrated Circuits, Addison-Wesley Publishing Company ISBN 0-201-50022-1

Code no.	01-15-03-MiD-V
Module title /	Microfluidic Devices
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies Optional compulsory for MSc CIT Optional compulsory for MSc CMM Optional compulsory for MSc Elektrotechnik und Informationstechnik
Requirements for participation	Knowledge of microtechnology. This can be acquired by: the course on “Introduction to Micro Technology” by M. Vellekoop, or the course “Sensors and Measurement Systems” by W. Lang, or studying a textbook such as “Introduction to Microfabrication” (S. Franssila)
Content	• Contents, Organisation, Introduction Basics of microfluidics • Flow control: valves and pumps • Sensors and analysis in µfluidic devices • Examples of µfluidic devices • Technology for µfluidic devices
Learning outcome	In this class, an overview is given of the developments in the area of microfluidic devices from the early start (where especially silicon integrated valves and pumps where investigated) to the lab-on-a-chip devices of today. The functionality of the sensors and actuators, the technologies applied, and the design of fluidic chips will be discussed. Some basic fluidics aspects will be presented and a practical (Laborübung) in which COMSOL is used for the simulation of microfluidic elements is included. Practical: “Introduction to COMSOL based fluidic simulations” (Dr. S. van den Driesche).After this course, you should be able to: • understand the basics of microfluidics • understand and explain the functioning of microfluidic devices • apply characterization parameters for (elements of) microfluidic devices • understand fabrication technologies for microfluidic devices
Workload / **credit points**	4 CP, 120 h • presence (L + EC): 42 h (3 SWH x 14 weeks) • preparation, learning + exercises: 42 h (3 SWH x 14 weeks) • preparation for exam: 36 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr.-Ing. Michael Vellekoop Module section / Specialization Subject – Information Technologies for Space Engineering
Compulsory / optional	Compulsory
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (1st academic year)
ECTS	4 CP
Semester Weekly Hours	(3 semester weekly hours (SWH) / 2x lecture (L) + 1x exercise classes (EC))
Course and examination performance, type of exam	Module exam Examination performance: Written exam
Literature	• M. Koch, A. Evans, A. Brunnschweiler, Microfluidic Technology and Applications, RSP. • H. Bruus, Theoretical Microfluidics, Oxford University Press

Code no.	01-15-03-RFC-V
Module title /	RF Frontend Devices and Circuits
Assignment to study programmes	Compulsory for MSc Space Sciences and Technologies Optional compulsory for MSc CIT Optional compulsory for MSc Elektrotechnik und Informationstechnik
Requirements for participation	Basic system and communication theory
Content	• Two-port circuits • Noise in electronic circuits • Fundamentals of non-linear devices • RF devices • RF circuits and frontends
Learning outcome	The students have to know the fundamental working principles of analogue RF frontend devices and circuits that are the main building blocks of fixed and mobile devices for wireless communications (GSM, WLAN, UMTS, RFID, etc.) as well as for sensors like radar sensors. They should understand the basic principles of RF devices like amplifiers, mixers, oscillators, PLL's, and frequency synthesizers. The fundamentals of two-port circuits, electronic noise, and effects of non-linearities are addressed at first. Based on these theoretical parts students should be able to discuss the pros and cons of different RF frontend architectures and to design first basic analogue RF frontend circuits.
Workload / **credit points**	4 CP, 120 h • presence (L + EC): 42 h (3 SWH x 14 weeks) • preparation, learning + exercises: 42 h (3 SWH x 14 weeks) • preparation for exam: 36 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr.-Ing. Martin Schneider Module section / Specialization Subject – Information Technologies for Space Engineering
Compulsory / optional	Compulsory
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (1st academic year)
ECTS	4 CP
Semester Weekly Hours	(3 semester weekly hours (SWH) / 2x lecture (L) + 1x exercise classes (EC))
Course and examination performance, type of exam	Module exam Examination performance: Written exam
Literature	• Ulrich L. Rohde, David P. Newkirk, "RF/Microwave Circuit Design for Wireless Applications" John Wiley & Sons, 2000. • David M. Pozar, "Microwave Engineering," John Wiley & Sons, third edition, 2005. • David M. Pozar, "Microwave and RF Design of Wireless Systems," New York, NY: Wiley, 2001. • J. Laskar, B. Matinpour, S. Chakraborty, "Modern Receiver Front-Ends: Systems, Circuits, and Integration," Hoboken, NJ: Wiley-Interscience, 2004. • B. Razavi, "RF Microelectronics," Upper Saddle River, NJ, Prentice Hall, 1st edition, 1998.

2.3 Elective Modules (12 CP)

Code no.	01-15-03-Ant-V
Module title /	Antennas
Assignment to study programmes	MSc Space-ST - Wahlfach MSc Elektrotechnik und Informationstechnik – Pflicht/ Wahlpflichtlfach MSc CIT – Pflichtfach MSc Wirtschaftsingenieurswesen – Pflichtfach
Requirements for participation	Electrodynamics
Content	• Fields and wave in free space based on Maxwell's equations • Fundamentals of antennas • Hertz Dipole amd magnetic dipole • linear antennas, half wave length dipole • antenna arrays • aperture antennas • Calculation of microstrip patch antennas • presentation and discussion of realization examples
Learning outcome	After this course, the students know how • to explain the working principle of antennas • to decide which kind of antennas suits a certain application at a certain frequency • to apply the method of electrodynamic potentials for solving antenna problems • to explain and to apply the method of equivalent sources for calculating aperture antennas
Workload / credit points	3 CP, 90 h • Presence (L + EC): 42 h (3 SWH x 14 weeks) • Preparation, learning and exercises: 28 h (2 h/week x 14 weeks) • Preparation for exam: 20 h
Course language	English
Responsible for the module, lecturers / Module assignment	Prof. Dr.- Ing. Martin Schneider
Compulsory / optional	Optional
Offered frequency	Annually / winter semester
Duration / semester	1 semester / 2nd academic year
ECTS	3 CP
Semester Weekly Hours	3 semester weekly hours (SWH) 2x lecture (L) + 1x exercise classes (EC))
Course and examination performance, type of exam	Module exam (MP) / written examination (120 minutes)
Literature	• C. A. Balanis, ”Antenna Theory ”, John Wiley & Sons, 3rd Edition, 2005 • J. D. Kraus, ”Antennas For All Applications”, McGraw-Hill, 3rd Edition, 2002

Code no.	01-01-03-BGC-V
Module title /	Biogeochemistry
Assignment to study programmes	Optional for MSc Space Sciences and Technologies Optional compulsory for MSc Physik Optional compulsory for MSc Marine Geosciences Optional compulsory for MSc Technomathematik
Requirements for participation	None
Content	Global biochemical cycles of elements, important biophysical processes in atmosphere and ocean, carbon-, methane-, nitrogen and water cycle, greenhouse gases
Learning outcome	The participants will have an advanced understanding of the chemical physical, geological and biological processes and reactions that govern the composition of the natural environment (including the biosphere, the cryosphere, the hydrosphere, the pedosphere, the atmosphere and the lithosphere).
Workload / **credit points**	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + exercises: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	PD. Dr. Annette Ladstätter-Weißenmayer Module section / Elective Courses
Compulsory / optional	Optional
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (1st academic year)
ECTS	3 CP
Semester Weekly Hours	(2 semester weekly hours (SWH) / 1x lecture (L) + 1x exercise classes (EC))
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes and/or successful writing of an essay
Literature	Will be announced in the respective course.

Code no.	01-01-03-Dyn1-V
Module title /	Dynamics I
Assignment to study programmes	Optional for MSc Space Sciences and Technologies Compulsory for MSc Environmental Physics Optional compulsory for MSc Physik Optional compulsory for MSc Marine Geosciences Optional compulsory for MSc Technomathematik
Requirements for participation	None
Content	Governing equations, basic conservation laws, balances, elementary applications of the basic equations, circulation and vorticity, planetary boundary layer, Rossby waves
Learning outcome	The students will have an understanding of the basic dynamical processes in atmosphere and ocean; earning how to interpret physical equations physically
Workload / **credit points**	6 CP, 180 h • presence (L + EC): 56 h (4 SWH x 14 weeks) • preparation, learning + exercises: 56 h (2 h x 14 weeks) • preparation for exam: 68 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr. Thomas Jung Module section / Elective Courses
Compulsory / optional	Optional
Offered frequency	Annually / winter semester
Duration / semester	1 semester / winter semester (2nd academic year)
ECTS	6 CP
Semester Weekly Hours	(4 semester weekly hours (SWH) / 2x lecture (L) + 2x exercise classes (EC))
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of exercise classes
Literature	Will be announced in the respective course.

Code no.	01-29-03-EngE-V
Module title /	Engineering Ethics
Assignment to study programmes	Optional for MSc Space Sciences and Technologies Optional for MSc ET/IT
Requirements for participation	None
Content	• Basic moral concepts • Basic moral theories and values and their rationale • Codes of Ethics (examples from Associations and Agencies) • Case Studies from engineering • Professional ideals, social and environmental responsibility
Learning outcome	After the course the students will be able to • discuss and apply professional codes of ethics • distinguish normative from descriptive judgements • describe basic norms, values and ethical theories • determine conditions of responsibility • apply norms and theories to concrete cases in engineering and identify ethical issues at different stages
Workload / **credit points**	Total working hours: 90 h • presence (L): 28 h (2 h x 14 weeks) • preparation and follow-up: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr. Dagmar Borchers, M.A. Björn Haferkamp Module section / Elective Courses
Compulsory / optional	Optional
Offered frequency	Annually / summer semester
Duration / semester	1 semester (1st or 2nd academic year)
ECTS	3 CP
Semester Weekly Hours	2 semester weekly hours
Course and examination performance, type of exam	Module exam Examination performance: written summary and oral exam (will be announced by the lecturer)
Literature	Will be announced in the respective course

Code no.	01-29-03-RingSp-V
Module title /	Fascination Space – On the scientific and practical use of astronautics
Assignment to study programmes	Optional for MSc Space Sciences and Technologies
Requirements for participation	None
Content	Experts from academia and industry give lectures on different topics in space research and applications. The list of speakers varies from semester to semester.
Learning outcome	The students will learn about science missions in space, in particular the science case, the mission scenario and the technological challenges. Furthermore, they gain an understanding of how certain aspects of space research are transferred into everyday life and practical use. And they will get an overview on past, current and future space missions.
Workload / credit points	3 CP, 90 h • presence (L): 14 h (2 SWH x 7 weeks) • follow-up and protocols: 14 h (2 SWH x 7 weeks) • preparation of a seminar talk and an essay: 62 h
Course language	English
Responsible for the module, lecturers / Module assignment	Prof. Dr. Claus Lämmerzahl, PD Dr. Annette Ladstätter-Weißenmayer Experts from the field of space research and applications serve as guest lecturers. Module section / Elective Courses
Compulsory / optional	Optional
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (1st or 3rd academic year)
ECTS	3 CP
Semester Weekly Hours	2 semester hours every other week
Course and examination performance, type of exam	Study performances: A report/protocol of every lecture, one essay
Literature	• will be announced at the beginning of the semester

Code no.	01-15-03-InS-V
Module title	Integrated Circuits
Assignment to study programmes	Optional for MSc Space Sciences and Technologies Compulsory / optional compulsory for MSc Elektrotechnik und Informationstechnik Compulsory for MSc Systems Engineering Compulsory for MSc Electrical Engineer with Management Optional for MSc CIT Compulsory for MSc CMM
Requirements for participation	Basics of electrical engineering and analog integrated circuits
Content	• Noise • gm/Id Method • Mismatch • two pole opamps (OTA) • feedback
Learning outcome	After this course, students are able to: • describe and characterize noise in electronics circuits • apply the gm/Id sizing method to design amplifier circuits for advance CMOS technologies • deal with process variations and mismatch • understand the frequency behaviour of amplifier circuits • understand and size compensation networks • use feedback to modify circuit characteristics.
Workload	Total working hours: 90 h • Presence (L + EC): 42 h (3 SWH x 14 weeks) • Preparation, learning and exercises: 14h (1 h/week x 14 weeks) • Preparation for exam: 34 h
Course language	English
Responsible for the module, lecturers	Prof. Dr.-Ing. Steffen Paul
Compulsory / optional	Optional
Offered frequency	Annually, winter semester
Duration/ semester	1 Semester/ 1st semester
ECTS	3 CP
SWH	3 SWS (2 SWS Vorlesung & 1 SWS Übung)
Course and examination performance / type of exam	Module Exam (MP) / oral examination (30 minutes)
Literature	• T. Carusone: Analog integrated circuit design. • W. Sansen: Analog Design essentials.

Code no.	04-M30-CEM-SFI-1
Module title /	On-Board Data Handling
Assignment to study programmes	Optional for MSc Space Sciences and Technologies
Requirements for participation	Basics of electrical engineering and analog integrated circuits
Content	On-Board Data Handling (OBDH) includes all aspects from payload data processing to mission critical control tasks. The OBDH system can in principle be considered as an embedded system that is subject to strong requirements with respect to reliability and availability in harsh environments with minimal or no maintenance. The lecture considers various aspects from general mission scenarios and their impact on the OBDH system, examples for typical architecture, techniques for Failure Detection Isolation and Recovery (FDIR) and approaches for guaranteeing functional correctness of the hardware and/or software. Relevant standards are introduced. A coarse table of contents reads as follows: • Mission scenarios and implications on the OBDH system • Tasks for OBDH • Standards for space applications • Architectures for OBDH system considered as embedded systems • Hardware and software solutions • Functional correctness
Learning outcome	The students should be able to explain typical scenarios for space missions, to understand and derive mission-specific requirements for the On-Board Data Handling (OBDH) system, to explain relevant standards, to explain and justify typical test approaches for OBDH systems, to understanding approaches for Failure Detection Isolation and Recovery (FDIR) and to have the ability to specify an OBDH system.
Workload / **credit points**	3 CP, 90 h • presence (L + EC): 42 h (3 SWH x 14 weeks) in the clean room • preparation, learning + exercises: 28 h (2 SWH x 14 weeks) • preparation for exam: 20 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr. Claus Braxmaier, Dr. Fank Dannemann Module section / Elective Courses
Compulsory / optional	Optional
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (1st academic year)
ECTS	3 CP
Semester Weekly Hours	(3 semester weekly hours (SWH) / 2x lecture (L) + 1x exercise classes (EC))
Course and examination performance, type of exam	Module exam Examination performance: Oral exam
Literature	A list of references will be given in the lecture

Code no.	01-01-03-PDAP-V
Module title /	Practical Data Analysis with Python
Assignment to study programmes	Optional for MSc Space Sciences and Technologies Optional for MSc Environmental Physics Optional for MSc Physik Optional for MSc Marine Geosciences
Requirements for participation	None
Content	The course will touch on the following subjects: • "But this worked yesterday, before I made some changes ..." or: An introduction to version control • Getting started: How to setup your own computer for data analysis in Python. • Hands-on introduction to the Python scientific ecosystem: Arrays and mathematical operations, using NumPy. • Labeled arrays or how to intuitively work with data, using Pandas and xarray. • Reading and writing data in common file formats. • Making both meaningful and beautiful plots, using matplotlib. • Statistical analysis in Python using the SciPy and Statsmodels packages. • Parameter estimation / regression using SciPy • An overview of the most common special-topic libraries for the research areas covered by the students' study programmes. • Working with geoscientific data and plotting maps, using Cartopy and Shapely. • Other data analysis tasks needed by the students for their study program, upon demand.
Learning outcome	Upon successful completion of this course, the student will be able to work with scientific data using the Python scientific programming ecosystem, including the whole scientific data lifecycle (reading data, statistical analysis, plotting, storing results), following modern scientific programming best practices (e.g., version control, reproducibility, documentation, …).
Workload / **credit points**	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + exercises: 26 h (2 SWH x 13 weeks) • preparation for exam: 36 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Dr. Andreas Hilboll
Compulsory / optional	Optional
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (1st academic year)
ECTS	3 CP
Semester Weekly Hours	(2 semester weekly hours (SWH) / 1x lecture (L) + 1x exercise classes (EC))
Course and examination performance, type of exam	Partial exam Examination performance: Two graded homework projects Course performance: Successful assessment of example classes and/or successful writing of an essay
Literature	VanderPlas, Jake: Python Data Science Handbook, O'Reilly, 2016 (freely available online at https://jakevdp.github.io/PythonDataScienceHandbook/)

Code no.	01-01-03-StEA-V
Module title /	Statistics and Error Analysis
Assignment to study programmes	Optional for MSc Space Sciences and Technologies Optional for MSc Environmental Physics Optional compulsory for MSc Physik Optional compulsory for MSc Marine Geosciences Optional compulsory for MSc Technomathematik
Requirements for participation	None
Content	Random variables, probability, density and distribution functions, expectation values, covariance and correlation, error propagation, statistical tests
Learning outcome	The participants have knowledge about statistics, error calculation and data analysis.
Workload / **credit points**	3 CP, 90 h • presence (L + EC): 28 h (2 SWH x 14 weeks) • preparation, learning + exercises: 28 h (2 SWH x 14 weeks) • preparation for exam: 34 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr. Reiner Schlitzer. Dr. Emily King Module section / Elective Courses
Compulsory / optional	Optional
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (1st academic year)
ECTS	3 CP
Semester Weekly Hours	(3 semester weekly hours (SWH) / 2x lecture (L) + 1x exercise classes (EC))
Course and examination performance, type of exam	Partial exam Examination performance: Written exam/oral exam (will be announced by the respective lecturer) Course performance: Successful assessment of example classes and/or successful writing of an essay
Literature	Will be announced in the respective course.

Code no.	01-15-03-WCom-V
Module title /	Wireless Communications
Assignment to study programmes	Optional for MSc Space Sciences and Technologies Compulsory for MSc CIT Compulsory for MSc IKT Optional compulsory for MSc. ME/KT Optional for MSc CMM
Requirements for participation	Basics of communications technologies, stochastic (digital) signal processing, system theory
Content	• Mobile Radio Channels: Power Delay Profile, Doppler Spectrum, Jakes-Spectrum, Channel Modelling, Rayleigh-Fading/Rician Channels • Multi-Carrier Transmission: Basics, Ambiguity-Function, F/T-Grid, Principles of CP-OFDM, Detectors for CP-OFDM, PAPR/Crest Factor, Out-of-Band radiation, LTE • CDMA: Principles, spreading sequence design system models, Single-User Machted Filter Bank, Rake Receiver, Multi-User Detection (MF, LS, MMSE), Radio System principles • MIMO: Principles and system model, spatial duplexing, BLAST
Learning outcome	After this course, the students will have a basic knowledge on wireless communications with the ability to design modern communication systems. In particular, they should be able to: • Model mobile radio channels, apply their expertise to perform analysis of digital wireless transmission • Apply knowledge on the design of modern solutions for mobiles (OFDM, CDMA, MIMO). • Combine existing Matlab-Modules for the simulation of mobile communication systems.
Workload / **credit points**	3 CP, 90 h • presence (L + EC): 42 h (3 SWH x 14 weeks) • preparation, learning + exercises: 28 h (2 SWH x 14 weeks) • preparation for exam: 20 h
Course language	English
Responsible for the module, lecturers / **Module assignment**	Prof. Dr.-Ing. A. Dekorsy Module section / Elective Courses
Compulsory / optional	Optional
Offered frequency	Annually / summer semester
Duration / semester	1 semester / summer semester (1st academic year)
ECTS	3 CP
Semester Weekly Hours	(3 semester weekly hours (SWH) / 2x lecture (L) + 1x exercise classes (EC))
Course and examination performance, type of exam	Module exam Examination performance: Written exam
Literature	• David Tse, Pramond Viswanath: Fundamentals of Wireless Communications. • J. Proakis: Digital Transmission • Goldsmith: Wireless Communications • Paulraj, Nabar, Gore: Introduction to Space-Time Wireless Communications.