



Module Manual

Master of Science (M.Sc.)

Aircraft Systems Engineering

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Program description

Content

The consecutive Master program „Aircraft System Engineering“ prepares participating students for diverse kind of professions in the field of aviation and related industries. During studies the technical, mathematical and natural science orientated Bachelor of Engineering is deepened. Competences for the systematical, scientific and independent solution of responsible tasks in industry and research are taught.

Students learn how to use typical methods of systems engineering as well as the application of modern, computer-based techniques for system design, analysis and evaluation. This count among others methods such as model based systems engineering or model based / virtual testing. Furthermore required knowledge from different fields of aviation including aircraft systems, cabin systems, air transportation system, preliminary aircraft design, flight physics and material science is discussed.

Additionally students get insight into current research activities, e.g. in the area of fuel cells and electrical energy supply, actuators, virtual integration and aircraft level evaluation, avionics systems and software, hydraulic energy supply and integrated aircraft design.

Students are specializing in one of three fields of specialization and gaining the competence to work at the interfaces between these fields. According to their individual focuses students can adjust their studies very flexible due to the various numbers of offered elective courses.

Career prospects

The consecutive Master program „Aircraft System Engineering“ prepares participating students for diverse kind of professions in the field of aviation and related industries. Graduates can, due to their specialization in one of the fields of Aircraft Systems Engineering, Cabin Systems, Air Transportation System or Preliminary Aircraft Design, work directly in one of these. Furthermore they have various methodically and interdisciplinary knowledge, so that they are prepared for multidisciplinary kind of jobs.

Graduates can work at Universities or other research institutes or apply directly for jobs in the industry. There they can start a carrier as a technical expert or qualify, with growing experiences, for technical management jobs such as project, group, team or development manager.

Besides starting their career in the aviation industry the master program allows, due to its system technical character, graduates to apply for jobs in other industries like the automotive or wind energy industry.

Learning target

Graduates can:

- Analyze and solve problems in a scientific way, even if they are defined unusual or incomplete and having competitive specifications;
- Abstract and formulate complex problems from a new or developing part of their discipline;
- Apply innovative methods to fundamental problems and develop new scientific methods;
- Recognize information demand, find and supply information;
- Plan and conduct theoretical and experimental analysis;
- Interpret data in a critical way and draw conclusions from them;
- Investigate and evaluate the application of emerging technologies;

Graduates are able to:

- Develop concepts and solutions for fundamental, partly unusual problems if necessary by involving other disciplines;
- Create and develop new products, processes and methods;
- Use engineering judgment in order to work with complex, potentially incomplete information, recognize contradictions and deal with them;
- Classify methodically and combine systematically knowledge from different disciplines and deal with complexity;
- Work themselves systematically into new tasks within a short period of time;
- Reflect non-technical effects of engineers work systematically and take them responsible into account;
- Work out solutions that have a demand for depend methodical competences;
- Work scientifically with the goal to achieve a PhD degree.

Program structure

The master program „Aircraft Systems Engineering“ is designed modular and oriented at the university wide program structure with an unified module size (multiples of six ECTS). It consists of a 60 ECTS curriculum of key qualifications that has to be taken by all students. It includes, among other, a so called system development project. Furthermore students have to choose one of the three offered curricula of specialization (30 ECTS), containing one obligatory module and a catalog of elective modules. The master program is completed by a master thesis.

All obligatory modules of the curriculum of key qualification and curricula of specializations are offered in the first two semesters of studies. The third semester only contains elective modules, which ease students to plan a semester abroad.

Core Qualification

The students extend their knowledge and skills in advanced engineering, aviation related subjects. Besides technical knowledge students strengthen their methodical skills in the fields of Aircraft Systems Engineering, Cabin Systems, Aircraft Design, Flight Physics and Systems Engineering. By performing the Systems Engineering Development Project, students apply their acquired skills in teams on a practical engineering problem.

Module M0523: Business & Management

Module Responsible	Prof. Matthias Meyer
Admission Requirements	None
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence <i>Knowledge</i> <ul style="list-style-type: none"> • Students are able to find their way around selected special areas of management within the scope of business management. • Students are able to explain basic theories, categories, and models in selected special areas of business management. • Students are able to interrelate technical and management knowledge. <i>Skills</i> <ul style="list-style-type: none"> • Students are able to apply basic methods in selected areas of business management. • Students are able to explain and give reasons for decision proposals on practical issues in areas of business management. Personal Competence <i>Social Competence</i> <ul style="list-style-type: none"> • Students are able to communicate in small interdisciplinary groups and to jointly develop solutions for complex problems <i>Autonomy</i> <ul style="list-style-type: none"> • Students are capable of acquiring necessary knowledge independently by means of research and preparation of material. 	
Workload in Hours	Depends on choice of courses
Credit points	6

Courses

Information regarding lectures and courses can be found in the corresponding module handbook published separately.

Module M0524: Non-technical Courses for Master	
Module Responsible	Dagmar Richter
Admission Requirements	None
Recommended Previous Knowledge	None
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence <i>Knowledge</i>	<p>The Nontechnical Academic Programms (NTA)</p> <p>imparts skills that, in view of the TUHH's training profile, professional engineering studies require but are not able to cover fully. Self-reliance, self-management, collaboration and professional and personnel management competences. The department implements these training objectives in its teaching architecture, in its teaching and learning arrangements, in teaching areas and by means of teaching offerings in which students can qualify by opting for specific competences and a competence level at the Bachelor's or Master's level. The teaching offerings are pooled in two different catalogues for nontechnical complementary courses.</p> <p>The Learning Architecture</p> <p>consists of a cross-disciplinarily study offering. The centrally designed teaching offering ensures that courses in the nontechnical academic programms follow the specific profiling of TUHH degree courses.</p> <p>The learning architecture demands and trains independent educational planning as regards the individual development of competences. It also provides orientation knowledge in the form of "profiles".</p> <p>The subjects that can be studied in parallel throughout the student's entire study program - if need be, it can be studied in one to two semesters. In view of the adaptation problems that individuals commonly face in their first semesters after making the transition from school to university and in order to encourage individually planned semesters abroad, there is no obligation to study these subjects in one or two specific semesters during the course of studies.</p> <p>Teaching and Learning Arrangements</p> <p>provide for students, separated into B.Sc. and M.Sc., to learn with and from each other across semesters. The challenge of dealing with interdisciplinarity and a variety of stages of learning in courses are part of the learning architecture and are deliberately encouraged in specific courses.</p> <p>Fields of Teaching</p> <p>are based on research findings from the academic disciplines cultural studies, social studies, arts, historical studies, communication studies, migration studies and sustainability research, and from engineering didactics. In addition, from the winter semester 2014/15 students on all Bachelor's courses will have the opportunity to learn about business management and start-ups in a goal-oriented way.</p> <p>The fields of teaching are augmented by soft skills offers and a foreign language offer. Here, the focus is on encouraging goal-oriented communication skills, e.g. the skills required by outgoing engineers in international and intercultural situations.</p> <p>The Competence Level</p> <p>of the courses offered in this area is different as regards the basic training objective in the Bachelor's and Master's fields. These differences are reflected in the practical examples used, in content topics that refer to different professional application contexts, and in the higher scientific and theoretical level of abstraction in the B.Sc.</p> <p>This is also reflected in the different quality of soft skills, which relate to the different team positions and different group leadership functions of Bachelor's and Master's graduates in their future working life.</p> <p>Specialized Competence (Knowledge)</p> <p>Students can</p> <ul style="list-style-type: none"> • explain specialized areas in context of the relevant non-technical disciplines, • outline basic theories, categories, terminology, models, concepts or artistic techniques in the disciplines represented in the learning area, • different specialist disciplines relate to their own discipline and differentiate it as well as make connections, • sketch the basic outlines of how scientific disciplines, paradigms, models, instruments, methods and forms of representation in the specialized sciences are subject to individual and socio-cultural interpretation and historicity, • Can communicate in a foreign language in a manner appropriate to the subject.
Professional Competence <i>Skills</i>	<p>Professional Competence (Skills)</p> <p>In selected sub-areas students can</p> <ul style="list-style-type: none"> • apply basic and specific methods of the said scientific disciplines, • aquestion a specific technical phenomena, models, theories from the viewpoint of another, aforementioned specialist discipline, • to handle simple and advanced questions in aforementioned scientific disciplines in a successful manner, • justify their decisions on forms of organization and application in practical questions in contexts that go beyond the technical relationship to the subject.

<p>Personal Competence <i>Social Competence</i></p>	<p>Personal Competences (Social Skills)</p> <p>Students will be able</p> <ul style="list-style-type: none"> • to learn to collaborate in different manner, • to present and analyze problems in the abovementioned fields in a partner or group situation in a manner appropriate to the addressees, • to express themselves competently, in a culturally appropriate and gender-sensitive manner in the language of the country (as far as this study-focus would be chosen), • to explain nontechnical items to auditorium with technical background knowledge.
<p><i>Autonomy</i></p>	<p>Personal Competences (Self-reliance)</p> <p>Students are able in selected areas</p> <ul style="list-style-type: none"> • to reflect on their own profession and professionalism in the context of real-life fields of application • to organize themselves and their own learning processes • to reflect and decide questions in front of a broad education background • to communicate a nontechnical item in a competent way in written form or verbally • to organize themselves as an entrepreneurial subject country (as far as this study-focus would be chosen)
<p>Workload in Hours</p>	<p>Depends on choice of courses</p>
<p>Credit points</p>	<p>6</p>

Courses

Information regarding lectures and courses can be found in the corresponding module handbook published separately.

Module M0763: Aircraft Energy Systems				
Courses				
Title		Typ	Hrs/wk	CP
Aircraft Energy Systems (L0735)		Lecture	3	4
Aircraft Energy Systems (L0739)		Recitation Section (large)	2	2
Module Responsible	Prof. Frank Thielecke			
Admission Requirements	None			
Recommended Previous Knowledge	Basic knowledge in: <ul style="list-style-type: none"> • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Fluid mechanics 			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<p><i>Knowledge</i> Students are able to:</p> <ul style="list-style-type: none"> • Assess challenges during the design of aircraft energy systems • Describe essential components and design points of hydraulic and electrical supply systems • Give an overview of the functionality of air conditioning systems • Describe different system concepts for de-icing • Identify constraints for the electrification of aircraft systems, and evaluate possible concepts and limitations • Describe architectures for fuel supply systems and illustrate design examples • Explain possible approaches for the integration of fuel cell systems and evaluate zero-emission concepts <p><i>Skills</i> Students are able to:</p> <ul style="list-style-type: none"> • Design hydraulic and electric supply systems of aircrafts • Analyze the thermodynamic behavior of air conditioning systems • Design ice protection systems • Apply possible electrification concepts to existing aircraft systems • Design fuel supply systems • Perform the design of a fuel cell system <p>Personal Competence</p> <p><i>Social Competence</i> Students are able to:</p> <ul style="list-style-type: none"> • Perform system design in groups and present and discuss results • Present systems engineering problems and discuss solutions with experts <p><i>Autonomy</i> Students are able to:</p> <ul style="list-style-type: none"> • Reflect on the content of lectures autonomously • Apply methods learned in the course of exercises to more advanced problems • Identify complex system dependencies autonomously and abstract simplified models and design processes 			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	165 Minutes			
Assignment for the Following Curricula	Energy Systems: Specialisation Energy Systems: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory			

Course L0735: Aircraft Energy Systems	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Frank Thielecke
Language	DE
Cycle	WiSe
Content	<ul style="list-style-type: none"> Hydraulic Energy Systems (Fluids; pressure loss in valves and pipes; components of hydraulic systems like pumps, valves, etc.; pressure/flow characteristics; actuators; tanks; power and heat balances; emergency power) Electric Energy Systems (Generators; constant-speed-drives; DC and AC converters; electrical power distribution; bus systems; monitoring; load analysis) High Lift Systems (Principles; investigation of loads and system actuation power; principles and sizing of actuation and positioning systems; safety requirements and devices) Environmental Control Systems (Thermodynamic analysis; expansion and compression cooling systems; control strategies; cabin pressure control systems)
Literature	<ul style="list-style-type: none"> Moir, Seabridge: Aircraft Systems Green: Aircraft Hydraulic Systems Torenbek: Synthesis of Subsonic Airplane Design SAE1991: ARP; Air Conditioning Systems for Subsonic Airplanes

Course L0739: Aircraft Energy Systems	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Frank Thielecke
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0771: Flight Physics			
Courses			
Title	Typ	Hrs/wk	CP
Aerodynamics and Flight Mechanics I (L0727)	Lecture	3	3
Flight Mechanics II (L0730)	Lecture	2	2
Flight Mechanics II (L0731)	Recitation Section (large)	1	1
Module Responsible	Prof. Frank Thielecke		
Admission Requirements	None		
Recommended Previous Knowledge	Basic knowledge in: <ul style="list-style-type: none"> • Mathematics • Mechanics • Thermodynamics • Aviation 		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p><i>Knowledge</i> Students are able to...</p> <ul style="list-style-type: none"> • Describe the fundamental equations of aerodynamics for compressible, incompressible and frictional flow • Explain the principles of wings and profiles • Explain the aircraft equations of motion • Evaluate aircraft performance and stability • Describe the dynamics of the longitudinal and lateral motion • Describe methods of flight simulation and airborne measurement technology <p><i>Skills</i> Students are able to...</p> <ul style="list-style-type: none"> • Perform flight mechanic simulations • Derive flight mechanic relations from virtual and real flight test data <p>Personal Competence</p> <p><i>Social Competence</i> Students are able to:</p> <ul style="list-style-type: none"> • Perform simulations in groups and discuss results • Evaluate flight test data in groups, discuss and present the results <p><i>Autonomy</i> Students are able to:</p> <ul style="list-style-type: none"> • Process teaching content independently • Prepare, work out and process simulation models independently • Apply teaching content on virtual and real flight test data 		
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84		
Credit points	6		
Course achievement	None		
Examination	Written exam		
Examination duration and scale	120 Minutes (WS) + 90 Minutes (SS)		
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory		

Course L0727: Aerodynamics and Flight Mechanics I	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Frank Thielecke, Dr. Ralf Heinrich
Language	DE
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Aerodynamics (fundamental equations of aerodynamics; compressible and incompressible flows; airfoils and wings; viscous flows) • Flight Mechanics (Equations of motion; flight performance; control surfaces; derivatives; lateral stability and control; trim conditions; flight maneuvers)
Literature	<ul style="list-style-type: none"> • Schlichting, H.; Truckenbrodt, E.: Aerodynamik des Flugzeuges I und II • Etkin, B.: Dynamics of Atmospheric Flight • Sachs/Hafer: Flugmechanik • Brockhaus: Flugregelung • J.D. Anderson: Introduction to flight

Course L0730: Flight Mechanics II	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Frank Thielecke
Language	DE
Cycle	SoSe
Content	<ul style="list-style-type: none"> • stationary asymmetric flight • dynamics of lateral movement • methods of flight simulation • experimental methods of flight mechanics • model validation using system identification • wind tunnel techniques
Literature	<ul style="list-style-type: none"> • Schlichting, H.; Truckenbrodt, E.: Aerodynamik des Flugzeuges I und II • Etkin, B.: Dynamics of Atmospheric Flight • Sachs/Hafer: Flugmechanik • Brockhaus: Flugregelung • J.D. Anderson: Introduction to flight

Course L0731: Flight Mechanics II	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Frank Thielecke
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0812: Aircraft Design I (Civil Aircraft Design)				
Courses				
Title	Typ	Hrs/wk	CP	
Aircraft Design I (Design of Transport Aircraft) (L0820)	Lecture	3	3	
Aircraft Design I (Design of Transport Aircraft) (L0834)	Recitation Section (large)	2	3	
Module Responsible	Prof. Volker Gollnick			
Admission Requirements	None			
Recommended Previous Knowledge	<ul style="list-style-type: none"> • Bachelor Mech. Eng. • Bachelor Traffic Systems • Vordiplom Mech. Eng. • Module Air Transport Systems 			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<p><i>Knowledge</i></p> <ol style="list-style-type: none"> 1. Principle understanding of integrated and civil aircraft design 2. Understanding of the interactions and contributions of the various disciplines 3. Impact of the relevant design parameter on the civil aircraft design 4. Introduction of the principle design methods <p><i>Skills</i></p> <p>Understanding and application of design and calculation methods</p> <p>Understanding of interdisciplinary and integrative interdependencies</p> <p>Personal Competence</p> <p><i>Social Competence</i></p> <p>Working in interdisciplinary teams</p> <p>Communication</p> <p><i>Autonomy</i></p> <p>Organization of workflows and -strategies</p>			
Workload in Hours				
Credit points				
Course achievement				
Examination	Written exam			
Examination duration and scale	180 min			
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory			

Course L0820: Aircraft Design I (Design of Transport Aircraft)	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Volker Gollnick, Jens Thöben
Language	DE
Cycle	WiSe
Content	<p>Introduction into the aircraft design process</p> <ol style="list-style-type: none"> 1. Introduction/process of aircraft design/various aircraft configurations 2. Requirements and design objectives, main design parameter (u.a. payload-range-diagramme) 3. Statistical methods in overall aircraft design/data base methods 4. Cabin design (fuselage sizing, cabin interior, loading systems) 5. Principles of aerodynamic aircraft design (polar, geometry, 2D/3D aerodynamics) 6. Wing Design 7. Tail wings and landing gear 8. Principles of engine design and integration 9. Flight performance in cruise 10. Take off and landing field length 11. Loads and V-n-diagramme 12. Operating cost calculation
Literature	<p>J. Roskam: "Airplane Design"</p> <p>D.P. Raymer: "Aircraft Design - A Conceptual Approach"</p> <p>J.P. Fielding: "Introduction to Aircraft Design"</p> <p>Jenkinson, Simpkon, Rhods: "Civil Jet Aircraft Design"</p>

Course L0834: Aircraft Design I (Design of Transport Aircraft)	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Volker Gollnick, Jens Thöben
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1155: Aircraft Cabin Systems				
Courses				
Title	Typ	Hrs/wk	CP	
Aircraft Cabin Systems (L1545)	Lecture	3	4	
Aircraft Cabin Systems (L1546)	Recitation Section (large)	1	2	
Module Responsible	Prof. Ralf God			
Admission Requirements	None			
Recommended Previous Knowledge	Basic knowledge in: <ul style="list-style-type: none"> • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems 			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<p><i>Knowledge</i> Students are able to:</p> <ul style="list-style-type: none"> • describe cabin operations, equipment in the cabin and cabin Systems • explain the functional and non-functional requirements for cabin Systems • elucidate the necessity of cabin operating systems and emergency Systems • assess the challenges human factors integration in a cabin environment <p><i>Skills</i> Students are able to:</p> <ul style="list-style-type: none"> • design a cabin layout for a given business model of an Airline • design cabin systems for safe operations • design emergency systems for safe man-machine interaction • solve comfort needs and entertainment requirements in the cabin <p>Personal Competence</p> <p><i>Social Competence</i> Students are able to:</p> <ul style="list-style-type: none"> • comprehend existing system solutions and explain them on the basis of existing requirements • discuss with experts in technical language • explain system functions • classify the criticality of functions • describe systems as is <p><i>Autonomy</i> Students are able to:</p> <ul style="list-style-type: none"> • independently reflect on lecture content and expert presentations • independently develop more in-depth content • recognize further areas of knowledge 			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	120 Minutes			
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Energy Systems: Specialisation Energy Systems: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory			

Course L1545: Aircraft Cabin Systems	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Ralf God
Language	DE
Cycle	WiSe
Content	<p>The objective of the lecture with the corresponding exercise is the acquisition of knowledge about aircraft cabin systems and cabin operations. A basic understanding of technological and systems engineering effort to maintain an artificial but comfortable and safe travel and working environment at cruising altitude is to be achieved.</p> <p>The course provides a comprehensive overview of current technology and cabin systems in modern passenger aircraft. The fulfillment of requirements for the cabin as the central system of work are covered on the basis of the topics comfort, ergonomics, human factors, operational processes, maintenance and energy supply:</p> <ul style="list-style-type: none"> • Materials used in the cabin • Ergonomics and human factors • Cabin interior and non-electrical systems • Cabin electrical systems and lights • Cabin electronics, communication-, information- and IFE-systems • Cabin and passenger process chains • RFID Aircraft Parts Marking • Energy sources and energy conversion
Literature	<ul style="list-style-type: none"> - Skript zur Vorlesung - Jenkinson, L.R., Simpkin, P., Rhodes, D.: Civil Jet Aircraft Design. London: Arnold, 1999 - Rossow, C.-C., Wolf, K., Horst, P. (Hrsg.): Handbuch der Luftfahrzeugtechnik. Carl Hanser Verlag, 2014 - Moir, I., Seabridge, A.: Aircraft Systems: Mechanical, Electrical and Avionics Subsystems Integration, Wiley 2008 - Davies, M.: The standard handbook for aeronautical and astronautical engineers. McGraw-Hill, 2003 - Kompendium der Flugmedizin. Verbesserte und ergänzte Neuauflage, Nachdruck April 2006. Fürstenfeldbruck, 2006 - Campbell, F.C.: Manufacturing Technology for Aerospace Structural Materials. Elsevier Ltd., 2006

Course L1546: Aircraft Cabin Systems	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Ralf God
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0846: Control Systems Theory and Design				
Courses				
Title		Typ	Hrs/wk	CP
Control Systems Theory and Design (L0656)		Lecture	2	4
Control Systems Theory and Design (L0657)		Recitation Section (small)	2	2
Module Responsible	Prof. Herbert Werner			
Admission Requirements	None			
Recommended Previous Knowledge	Introduction to Control Systems			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<ul style="list-style-type: none"> Students can explain how linear dynamic systems are represented as state space models; they can interpret the system response to initial states or external excitation as trajectories in state space They can explain the system properties controllability and observability, and their relationship to state feedback and state estimation, respectively They can explain the significance of a minimal realisation They can explain observer-based state feedback and how it can be used to achieve tracking and disturbance rejection They can extend all of the above to multi-input multi-output systems They can explain the z-transform and its relationship with the Laplace Transform They can explain state space models and transfer function models of discrete-time systems They can explain the experimental identification of ARX models of dynamic systems, and how the identification problem can be solved by solving a normal equation They can explain how a state space model can be constructed from a discrete-time impulse response 			
<i>Knowledge</i>				
<i>Skills</i>				
Personal Competence				
<i>Social Competence</i>	Students can work in small groups on specific problems to arrive at joint solutions.			
<i>Autonomy</i>	Students can obtain information from provided sources (lecture notes, software documentation, experiment guides) and use it when solving given problems. They can assess their knowledge in weekly on-line tests and thereby control their learning progress.			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	120 min			
Assignment for the Following Curricula	Electrical Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Computer Science in Engineering: Specialisation II. Engineering Science: Elective Compulsory International Management and Engineering: Specialisation II. Electrical Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory			

Course L0656: Control Systems Theory and Design	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe
Content	<p>State space methods (single-input single-output)</p> <ul style="list-style-type: none"> • State space models and transfer functions, state feedback • Coordinate basis, similarity transformations • Solutions of state equations, matrix exponentials, Caley-Hamilton Theorem • Controllability and pole placement • State estimation, observability, Kalman decomposition • Observer-based state feedback control, reference tracking • Transmission zeros • Optimal pole placement, symmetric root locus <p>Multi-input multi-output systems</p> <ul style="list-style-type: none"> • Transfer function matrices, state space models of multivariable systems, Gilbert realization • Poles and zeros of multivariable systems, minimal realization • Closed-loop stability • Pole placement for multivariable systems, LQR design, Kalman filter <p>Digital Control</p> <ul style="list-style-type: none"> • Discrete-time systems: difference equations and z-transform • Discrete-time state space models, sampled data systems, poles and zeros • Frequency response of sampled data systems, choice of sampling rate <p>System identification and model order reduction</p> <ul style="list-style-type: none"> • Least squares estimation, ARX models, persistent excitation • Identification of state space models, subspace identification • Balanced realization and model order reduction <p>Case study</p> <ul style="list-style-type: none"> • Modelling and multivariable control of a process evaporator using Matlab and Simulink <p>Software tools</p> <ul style="list-style-type: none"> • Matlab/Simulink
Literature	<ul style="list-style-type: none"> • Werner, H., Lecture Notes „Control Systems Theory and Design“ • T. Kailath "Linear Systems", Prentice Hall, 1980 • K.J. Astrom, B. Wittenmark "Computer Controlled Systems" Prentice Hall, 1997 • L. Ljung "System Identification - Theory for the User", Prentice Hall, 1999

Course L0657: Control Systems Theory and Design	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1738: Selected Topics of Aeronautical Systems Engineering (Alternative B: 12 LP)			
Courses			
Title	Typ	Hrs/wk	CP
Advanced Training Course SE-ZERT (L2739)	Project-/problem-based Learning	2	3
Airline Operations (L1310)	Lecture	3	3
Fatigue & Damage Tolerance (L0310)	Lecture	2	3
Flight Guidance I (Introduction) (L0848)	Lecture	2	2
Flight Guidance I (Introduction) (L0854)	Recitation Section (large)	1	1
Flight Guidance II (Flight Control) (L2374)	Lecture	2	2
Flight Guidance II (Flight Control) (L2375)	Recitation Section (small)	1	1
Airport Operations (L1276)	Lecture	3	3
Airport Planning (L1275)	Lecture	2	2
Airport Planning (L1469)	Recitation Section (small)	1	1
Lightweight Design Practical Course (L1258)	Project-/problem-based Learning	3	3
Aviation Security (L1549)	Lecture	2	2
Aviation Security (L1550)	Recitation Section (small)	1	1
Aviation and Environment (L2376)	Lecture	3	3
Machine Learning in Safety-Critical Cyber-Physical Systems (L2934)	Lecture	2	2
Machine Learning in Safety-Critical Cyber-Physical Systems (L2935)	Recitation Section (small)	1	1
Mechanisms, Systems and Processes of Materials Testing (L0950)	Lecture	2	2
Turbo Jet Engines (L0908)	Lecture	2	3
Structural Mechanics of Fibre Reinforced Composites (L1514)	Lecture	2	3
Structural Mechanics of Fibre Reinforced Composites (L1515)	Recitation Section (large)	1	1
System Simulation (L1820)	Lecture	2	2
System Simulation (L1821)	Recitation Section (large)	1	2
Materials Testing (L0949)	Lecture	2	2
Reliability in Engineering Dynamics (L2994)	Lecture	2	2
Reliability in Engineering Dynamics (L2995)	Recitation Section (small)	1	2
Reliability of Aircraft Systems (L0749)	Lecture	2	3
Module Responsible	Prof. Frank Thielecke		
Admission Requirements	None		
Recommended Previous Knowledge	Basic knowledge in: <ul style="list-style-type: none"> • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Hydraulics • Control Systems 		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<ul style="list-style-type: none"> • Students are able to find their way through selected special areas within systems engineering, air transportation system and material science • Students are able to explain basic models and procedures in selected special areas. • Students are able to interrelate scientific and technical knowledge. 		
<i>Knowledge</i>			
<i>Skills</i>	Students are able to apply basic methods in selected areas of engineering.		
Personal Competence			
<i>Social Competence</i>			
<i>Autonomy</i>	Students can chose independently, in which fields they want to deepen their knowledge and skills through the election of courses.		
Workload in Hours	Depends on choice of courses		
Credit points	12		
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory		

Course L2739: Advanced Training Course SE-ZERT	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	120 min
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	
Literature	INCOSE Systems Engineering Handbuch - Ein Leitfaden für Systemlebenszyklus-Prozesse und -Aktivitäten, GfSE (Hrsg. der deutschen Übersetzung), ISBN 978-3-9818805-0-2. ISO/IEC 15288 System- und Software-Engineering - System-Lebenszyklus-Prozesse (Systems and Software Engineering - System Life Cycle Processes).

Course L1310: Airline Operations	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Volker Gollnick, Dr. Karl Echtermeyer
Language	DE
Cycle	SoSe
Content	<ol style="list-style-type: none"> 1. Introduction and overview 2. Airline business models 3. Interdependencies in flight planning (network management, slot management, network structures, aircraft circulation) 4. Operative flight preparation (weight & balance, payload/range, etc.) 5. fleet policy 6. Aircraft assessment and fleet planning 7. Airline organisation 8. Aircraft maintenance, repair and overhaul
Literature	Volker Gollnick, Dieter Schmitt: The Air Transport System, Springer Berlin Heidelberg New York, 2014 Paul Clark: "Buying the Big Jets", Ashgate 2008 Mike Hirst: The Air Transport System, AIAA, 2008

Course L0310: Fatigue & Damage Tolerance	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 min
Lecturer	Dr. Martin Flamm
Language	EN
Cycle	WiSe
Content	Design principles, fatigue strength, crack initiation and crack growth, damage calculation, counting methods, methods to improve fatigue strength, environmental influences
Literature	Jaap Schijve, Fatigue of Structures and Materials. Kluwer Academic Puplicher, Dordrecht, 2001 E. Haibach. Betriebsfestigkeit Verfahren und Daten zur Bauteilberechnung. VDI-Verlag, Düsseldorf, 1989

Course L0848: Flight Guidance I (Introduction)	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	WiSe
Content	<p>Introduction and motivation Flight guidance principles (airspace structures, organization of air navigation services, etc.)</p> <p>Cockpit systems and Avionics (cockpit design, cockpit equipment, displays, computers and bus systems)</p> <p>Principles of flight measurement techniques (Measurement of position (geometric methods, distance measurement, direction measurement) Determination of the aircraft attitude (magnetic field- and inertial sensors) Measurement of speed</p> <p>Principles of Navigation</p> <p>Radio navigation</p> <p>Satellite navigation</p> <p>Airspace surveillance (radar systems)</p> <p>Communication systems</p> <p>Integrated Navigation and Guidance Systems</p>
Literature	<p>Rudolf Brockhaus, Robert Luckner, Wolfgang Alles: "Flugregelung", Springer Berlin Heidelberg New York, 2011</p> <p>Holger Flühr: "Avionik und Flugsicherungssysteme", Springer Berlin Heidelberg New York, 2013</p> <p>Volker Gollnick, Dieter Schmitt "Air Transport Systems", Springer Berlin Heidelberg New York, 2016</p> <p>R.P.G. Collinson „Introduction to Avionics“, Springer Berlin Heidelberg New York 2003</p>

Course L0854: Flight Guidance I (Introduction)	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L2374: Flight Guidance II (Flight Control)	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	SoSe
Content	
Literature	<p>Brockhaus, Alles, Luckner: Flugregelung, Springer Verlag, 2011</p> <p>R.P.G Collinson: Introduction to Avionics Systems, Springer Verlag, 2011</p>

Course L2375: Flight Guidance II (Flight Control)	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L1276: Airport Operations	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Volker Gollnick, Dr. Peter Willems
Language	DE
Cycle	WiSe
Content	FA-F Flight Operations Flight Operations - Production Infrastructures Operations Planning Master plan Airport capacity Ground handling Terminal operations
Literature	Richard de Neufville, Amedeo Odoni: Airport Systems, McGraw Hill, 2003

Course L1275: Airport Planning	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick, Dr. Ulrich Hüp
Language	DE
Cycle	WiSe
Content	<ol style="list-style-type: none"> 1. Introduction, definitions, overview 2. Runway systems 3. Air space structures around airports 4. Airfield lightings, marking and information 5. Airfield and terminal configuration
Literature	N. Ashford, Martin Stanton, Clifton Moore: Airport Operations, John Wiley & Sons, 1991 Richard de Neufville, Amedeo Odoni: Airport Systems, Aviation Week Books, MacGraw Hill, 2003

Course L1469: Airport Planning	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick, Dr. Ulrich Hüp
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1258: Lightweight Design Practical Course	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Dieter Krause
Language	DE/EN
Cycle	SoSe
Content	<p>Development of a sandwich structure made of fibre reinforced plastics</p> <ul style="list-style-type: none"> • getting familiar with fibre reinforced plastics as well as lightweight design • Design of a sandwich structure made of fibre reinforced plastics using finite element analysis (FEA) • Determination of material properties based on sample tests • manufacturing of the structure in the composite lab • Testing of the developed structure • Concept presentation • Self-organised teamwork
Literature	<ul style="list-style-type: none"> • Schürmann, H., „Konstruieren mit Faser-Kunststoff-Verbunden“, Springer, Berlin, 2005. • Puck, A., „Festigkeitsanalyse von Faser-Matrix-Laminaten“, Hanser, München, Wien, 1996. • R&G, „Handbuch Faserverbundwerkstoffe“, Waldenbuch, 2009. • VDI 2014 „Entwicklung von Bauteilen aus Faser-Kunststoff-Verbund“ • Ehrenstein, G. W., „Faserverbundkunststoffe“, Hanser, München, 2006. • Klein, B., „Leichtbau-Konstruktion“, Vieweg & Sohn, Braunschweig, 1989. • Wiedemann, J., „Leichtbau Band 1: Elemente“, Springer, Berlin, Heidelberg, 1986. • Wiedemann, J., „Leichtbau Band 2: Konstruktion“, Springer, Berlin, Heidelberg, 1986. • Backmann, B.F., „Composite Structures, Design, Safety and Innovation“, Oxford (UK), Elsevier, 2005. • Krause, D., „Leichtbau“, In: Handbuch Konstruktion, Hrsg.: Rieg, F., Steinhilper, R., München, Carl Hanser Verlag, 2012. • Schulte, K., Fiedler, B., „Structure and Properties of Composite Materials“, Hamburg, TUHH - TuTech Innovation GmbH, 2005.

Course L1549: Aviation Security	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 Minuten
Lecturer	Prof. Ralf God
Language	DE
Cycle	WiSe
Content	<p>The objective of the lecture with the corresponding exercise is the acquisition of knowledge about tasks and measures for protection against attacks on the security of the commercial air transport system. Tasks and measures will be elicited in the context of the three system components man, technology and organization.</p> <p>The course teaches the basics of aviation security. Aviation security is a necessary prerequisite for an economically successful air transport system. Risk management for the entire system can only be successful in an integrated approach, considering man, technology and organization:</p> <ul style="list-style-type: none"> • Historical development • The special role of air transport • Motive and attack vectors • The human factor • Threats and risk • Regulations and law • Organization and implementation of aviation security tasks • Passenger and baggage checks • Cargo screening and secure supply chain • Safety technologies
Literature	<p>- Skript zur Vorlesung</p> <p>- Giemulla, E.M., Rothe B.R. (Hrsg.): Handbuch Luftsicherheit. Universitätsverlag TU Berlin, 2011</p> <p>- Thomas, A.R. (Ed.): Aviation Security Management. Praeger Security International, 2008</p>

Course L1550: Aviation Security	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	90 Minuten
Lecturer	Prof. Ralf God
Language	DE
Cycle	WiSe
Content	<p>The objective of the lecture with the corresponding exercise is the acquisition of knowledge about tasks and measures for protection against attacks on the security of the commercial air transport system. Tasks and measures will be elicited in the context of the three system components man, technology and organization.</p> <p>The course teaches the basics of aviation security. Aviation security is a necessary prerequisite for an economically successful air transport system. Risk management for the entire system can only be successful in an integrated approach, considering man, technology and organization:</p> <ul style="list-style-type: none"> • Historical development • The special role of air transport • Motive and attack vectors • The human factor • Threats and risk • Regulations and law • Organization and implementation of aviation security tasks • Passenger and baggage checks • Cargo screening and secure supply chain • Safety technologies
Literature	<p>- Skript zur Vorlesung</p> <p>- Giemulla, E.M., Rothe B.R. (Hrsg.): Handbuch Luftsicherheit. Universitätsverlag TU Berlin, 2011</p> <p>- Thomas, A.R. (Ed.): Aviation Security Management. Praeger Security International, 2008</p>

Course L2376: Aviation and Environment	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	SoSe
Content	<p>The lecture provides the necessary basics and methods for understanding the interactions between air traffic and the environment, both in terms of the effects of weather / climate on flying and with regard to the effects of air traffic on pollutant emissions, noise and climate.</p> <p>The following topics are covered:</p> <ul style="list-style-type: none"> • Atmospheric physics / chemistry <ul style="list-style-type: none"> ◦ Structure and statics ◦ Dynamics (water cycle, formation of weather events, high and low pressure areas, wind, gusts and turbulence) ◦ Cloud physics (thermodynamics, contrails) ◦ Radiation physics (energy balance, greenhouse effect) ◦ Photochemistry (ozone chemistry) • Impact of weather on flying <ul style="list-style-type: none"> ◦ Atmospheric influences on flight performance ◦ Flight planning ◦ Disturbances due to weather, e.g. thunderstorms, winter weather (icing), clear air turbulence, visibility ◦ Effects of climate change and adaptation • Effects of air traffic on the environment and climate <ul style="list-style-type: none"> ◦ Aviation pollutant emissions ◦ Effect of emissions on concentrations in the atmosphere ◦ Climate metrics / models and background scenarios ◦ Emissions inventories • Mitigation measures <ul style="list-style-type: none"> ◦ Technological measures, e.g. climate-optimized aircraft design ◦ Alternative fuels ◦ Operational measures, e.g. climate-optimized flight planning ◦ Environmental policy measures, e.g. EU-ETS, CORSIA ◦ Potentials and comparison, concept of eco-efficiency • Local environmental impacts <ul style="list-style-type: none"> ◦ Local air quality (particulate matter, other emissions near the ground) ◦ Noise (noise sources, noise metrics, noise impact, measurement, certification, psychoacoustics, noise mitigation) ◦ Health effects • Aspects of sustainability <ul style="list-style-type: none"> ◦ Other aspects, including life cycle emissions, disposal/recycling ◦ Relation to global goals, e.g. United Nations goals for sustainable development, Paris climate agreement
Literature	<ul style="list-style-type: none"> • Ruijgrok, G.: Elements of Aircraft Pollution, Delft University Press, 2005 • Friedrich, R., Reis, S.: Emissions of Air Pollutants, Springer 2004 • Janic, M.: The Sustainability of Air Transportation, Ashgate, 2007 • Schumann, U. (ed.): Atmospheric Physics: Background - Methods - Trends, Springer, Berlin, Heidelberg, 2012 • Spiridonov, V., Curic, M.: Fundamentals of Meteorology, Springer, 2021 • Kaltschmitt, M., Neuling, U.: Biokerosene - Status and Prospects, Springer, 2018 • Roedel, W., Wagner, T.: Physik unserer Umwelt: Die Atmosphäre, Springer, 2017 • W. Bräunling: Flugzeugtriebwerke. Springer-Verlag Berlin, Deutschland, 2009 • G. Brüning, X. Hafer, G. Sachs: Flugleistungen, Springer, 1993

Course L2934: Machine Learning in Safety-Critical Cyber-Physical Systems	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	90 min
Lecturer	Prof. Ralf God
Language	DE
Cycle	WiSe
Content	<p>The use of machine learning enables many highly complex applications, for example in autonomous systems. However, the application in safety-critical systems offers special challenges and makes special demands on the development.</p> <p>The course teaches the necessary basics and methods in the context of systems engineering for the use of data science, machine learning and AI in safety-critical systems. In addition, current areas of application and the current state of research are discussed.</p> <p>The following topics will be dealt with in detail:</p> <ul style="list-style-type: none"> • Introduction and motivation <ul style="list-style-type: none"> ◦ Safety-critical cyber-physical systems and systems of systems ◦ Methods of modelling in systems engineering ◦ Challenges in the use of machine learning in safety-critical systems • Systems engineering and safety-critical systems <ul style="list-style-type: none"> ◦ Safety and machine learning ◦ Machine learning lifecycle ◦ Methods ◦ Data set optimization ◦ Robust learning ◦ Quantification of uncertainty ◦ Adversarial attacks ◦ Interpretability ◦ Securing the overall system • The latest from research
Literature	- J. Holt, S. A. Perry, M. Brownsword. Model-Based Requirements Engineering. Institution Engineering & Tech, 2011. - S. Houben et al. Inspect, Understand, Overcome: A Survey of Practical Methods for AI Safety. arXiv, 2021. - A. Schwaiger. Machine Learning in sicherheitskritischen Systemen. Embedded Software Engineering Kongress, 2020. - A. Pereira, C. Thomas. Challenges of Machine Learning Applied to Safety-Critical Cyber-Physical Systems. Mach. Learn. Knowl. Extr., 2, 579-602, 2020.

Course L2935: Machine Learning in Safety-Critical Cyber-Physical Systems	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	90 min
Lecturer	Prof. Ralf God
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0950: Mechanisms, Systems and Processes of Materials Testing	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 Minuten
Lecturer	Dr. Jan Oke Peters
Language	DE
Cycle	SoSe
Content	<p>Application, analysis and discussion of basic and advanced testing methods to ensure correct selection of applicable testing procedure for investigation of part/materials deficiencies</p> <ul style="list-style-type: none"> • Stress-strain relationships • Strain gauge application • Visko elastic behavior • Tensile test (strain hardening, necking, strain rate) • Compression test, bending test, torsion test • Crack growth upon static loading (J-Integral) • Crack growth upon cyclic loading (micro- und macro cracks) • Effect of notches • Creep testing (physical creep test, influence of stress and temperature, Larson Miller parameter) • Wear testing • Non destructive testing application for overhaul of jet engines
Literature	<ul style="list-style-type: none"> • E. Macherauch: Praktikum in Werkstoffkunde, Vieweg • G. E. Dieter: Mechanical Metallurgy, McGraw-Hill • R. Bürgel: Lehr- und Übungsbuch Festigkeitslehre, Vieweg • R. Bürgel: Werkstoffe sicher beurteilen und richtig einsetzen, Vieweg

Course L0908: Turbo Jet Engines	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 min
Lecturer	Dr. Burkhard Andrich
Language	DE
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Cycle of the gas turbine • Thermodynamics of gas turbine components • Wing-, grid- and stage-sizing • Operating characteristics of gas turbine components • Sizing criteria's for jet engines • Development trends of gas turbines and jet engines • Maintenance of jet engines
Literature	<ul style="list-style-type: none"> • Bräunling: Flugzeugtriebwerke • Engmann: Technologie des Fliegens • Kerrebrock: Aircraft Engines and Gas Turbines

Course L1514: Structural Mechanics of Fibre Reinforced Composites	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Benedikt Kriegesmann
Language	EN
Cycle	WiSe
Content	Classical laminate theory Rules of mixture Failure mechanisms and criteria of composites Boundary value problems of isotropic and anisotropic shells Stability of composite structures Optimization of laminated composites Modelling composites in FEM Numerical multiscale analysis of textile composites Progressive failure analysis
Literature	<ul style="list-style-type: none"> • Schürmann, H., „Konstruieren mit Faser-Kunststoff-Verbunden“, Springer, Berlin, aktuelle Auflage. • Wiedemann, J., „Leichtbau Band 1: Elemente“, Springer, Berlin, Heidelberg, , aktuelle Auflage. • Reddy, J.N., „Mechanics of Composite Laminated Plates and Shells“, CRC Publishing, Boca Raton et al., current edition. • Jones, R.M., „Mechanics of Composite Materials“, Scripta Book Co., Washington, current edition. • Timoshenko, S.P., Gere, J.M., „Theory of elastic stability“, McGraw-Hill Book Company, Inc., New York, current edition. • Turvey, G.J., Marshall, I.H., „Buckling and postbuckling of composite plates“, Chapman and Hall, London, current edition. • Herakovich, C.T., „Mechanics of fibrous composites“, John Wiley and Sons, Inc., New York, current edition. • Mittelstedt, C., Becker, W., „Strukturmechanik ebener Laminat“, aktuelle Auflage.

Course L1515: Structural Mechanics of Fibre Reinforced Composites	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Benedikt Kriegesmann
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1820: System Simulation	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Dr. Stefan Wischhusen, Dr. Johannes Brunnemann
Language	DE
Cycle	WiSe
Content	<p>Lecture about equation-based, physical modelling using the modelling language Modelica and the free simulation tool OpenModelica 1.17.0.</p> <ul style="list-style-type: none"> • Instruction and modelling of physical processes • Modelling and limits of model • Time constant, stiffness, stability, step size • Terms of object orientated programming • Differential equations of simple systems • Introduction into Modelica • Introduction into simulation tool • Example:Hydraulic systems and heat transfer • Example: System with different subsystems
Literature	<p>[1] Modelica Association: "Modelica Language Specification - Version 3.5", Linköping, Sweden, 2021.</p> <p>[2] OpenModelica: OpenModelica 1.17.0, https://www.openmodelica.org (siehe Download), 2021.</p> <p>[3] M. Tiller: "Modelica by Example", https://book.xogeny.com, 2014.</p> <p>[4] M. Otter, H. Elmqvist, et al.: "Objektorientierte Modellierung Physikalischer Systeme", at- Automatisierungstechnik (german), Teil 1 - 17, Oldenbourg Verlag, 1999 - 2000.</p> <p>[5] P. Fritzson: "Principles of Object-Oriented Modeling and Simulation with Modelica 3.3", Wiley-IEEE Press, New York, 2015.</p> <p>[6] P. Fritzson: "Introduction to Modeling and Simulation of Technical and Physical Systems with Modelica", Wiley, New York, 2011.</p>

Course L1821: System Simulation	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Dr. Stefan Wischhusen, Dr. Johannes Brunnemann
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0949: Materials Testing	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 Minuten
Lecturer	Dr. Jan Oke Peters
Language	DE
Cycle	WiSe
Content	<p>Application and analysis of basic mechanical as well as non-destructive testing of materials</p> <ul style="list-style-type: none"> • Determination elastic constants • Tensile test • Fatigue test (testing with constant stress, strain, or plastiv strain amplitude, low and high cycle fatigue, mean stress effect) • Crack growth upon static loading (stress intensity factor, fracture toughness) • Creep test • Hardness test • Charpy impact test • Non destructive testing
Literature	<p>E. Macherauch: Praktikum in Werkstoffkunde, Vieweg G. E. Dieter: Mechanical Metallurgy, McGraw-Hill</p>

Course L2994: Reliability in Engineering Dynamics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Benedikt Kriegesmann
Language	EN
Cycle	SoSe
Content	<p>Method for calculation and testing of reliability of dynamic machine systems</p> <p>Modeling</p> <p>System identification</p> <p>Simulation</p> <p>Processing of measurement data</p> <p>Damage accumulation</p> <p>Test planning and execution</p>
Literature	<p>Bertsche, B.: Reliability in Automotive and Mechanical Engineering. Springer, 2008. ISBN: 978-3-540-33969-4</p> <p>Inman, Daniel J.: Engineering Vibration. Prentice Hall, 3rd Ed., 2007. ISBN-13: 978-0132281737</p> <p>Dresig, H., Holzweißig, F.: Maschinendynamik, Springer Verlag, 9. Auflage, 2009. ISBN 3540876936.</p> <p>VDA (Hg.): Zuverlässigkeitssicherung bei Automobilherstellern und Lieferanten. Band 3 Teil 2, 3. überarbeitete Auflage, 2004. ISSN 0943-9412</p>

Course L2995: Reliability in Engineering Dynamics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Benedikt Kriegesmann
Language	EN
Cycle	SoSe
Content	<p>Method for calculation and testing of reliability of dynamic machine systems</p> <p>Modeling</p> <p>System identification</p> <p>Simulation</p> <p>Processing of measurement data</p> <p>Damage accumulation</p> <p>Test planning and execution</p>
Literature	<p>Bertsche, B.: Reliability in Automotive and Mechanical Engineering. Springer, 2008. ISBN: 978-3-540-33969-4</p> <p>Inman, Daniel J.: Engineering Vibration. Prentice Hall, 3rd Ed., 2007. ISBN-13: 978-0132281737</p> <p>Dresig, H., Holzweißig, F.: Maschinendynamik, Springer Verlag, 9. Auflage, 2009. ISBN 3540876936.</p> <p>VDA (Hg.): Zuverlässigkeitssicherung bei Automobilherstellern und Lieferanten. Band 3 Teil 2, 3. überarbeitete Auflage, 2004. ISSN 0943-9412</p>

Course L0749: Reliability of Aircraft Systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 Minuten
Lecturer	Prof. Frank Thielecke, Dr. Andreas Vahl, Dr. Uwe Wieczorek
Language	DE
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Functions of reliability and safety (regulations, certification requirements) • Basics methods of reliability analysis (FMEA, fault tree, functional hazard assessment) • Reliability analysis of electrical and mechanical systems
Literature	<ul style="list-style-type: none"> • CS 25.1309 • SAE ARP 4754 • SAE ARP 4761

Module M1193: Cabin Systems Engineering				
Courses				
Title	Typ	Hrs/wk	CP	
Computer and communication technology in cabin electronics and avionics (L1557)	Lecture	2	2	
Computer and communication technology in cabin electronics and avionics (L1558)	Recitation Section (small)	1	1	
Model-Based Systems Engineering (MBSE) with SysML/UML (L1551)	Project-/problem-based Learning	3	3	
Module Responsible	Prof. Ralf God			
Admission Requirements	None			
Recommended Previous Knowledge	Basic knowledge in: <ul style="list-style-type: none"> • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems Previous knowledge in: <ul style="list-style-type: none"> • Systems Engineering 			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<p><i>Knowledge</i> Students are able to:</p> <ul style="list-style-type: none"> • describe the structure and operation of computer architectures • explain the structure and operation of digital communication Networks • explain architectures of cabin electronics, integrated modular avionics (IMA) and Aircraft Data Communication Network (ADCN) • understand the approach of Model-Based Systems Engineering (MBSE) in the design of hardware and software-based cabin systems <p><i>Skills</i> Students are able to:</p> <ul style="list-style-type: none"> • understand, operate and maintain a Minicomputer • build up a network communication and communicate with other network participants • connect a minicomputer with a cabin management system (A380 CIDS) and communicate over a AFDX®-Network • model system functions by means of formal languages SysML/UML and generate software code from the models • execute software code on a minicomputer <p>Personal Competence</p> <p><i>Social Competence</i> Students are able to:</p> <ul style="list-style-type: none"> • form teams of two or small groups for the practical work • work out partial results themselves and combine them with others to form an overall solution • represent and contribute their own solution • take over the guidance of the team • contribute in the team <p><i>Autonomy</i> Students are able to:</p> <ul style="list-style-type: none"> • organize and plan their practical tasks • further develop their own skills • take their own initiative • explore their own new ways of solving problems 			
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	120 minutes			
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory			

Course L1557: Computer and communication technology in cabin electronics and avionics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Ralf God
Language	DE
Cycle	WiSe
Content	<p>The objective of the lecture with the corresponding exercise is the acquisition of knowledge of computer and communication technology in electronic systems in the cabin and in aircraft. For the system engineer the strong interaction of software, mechanical and electronic system components nowadays requires a basic understanding of cabin electronics and avionics.</p> <p>The course teaches the basics of design and functionality of computers and data networks. Subsequently it focuses on current principles and applications in integrated modular avionics (IMA), aircraft data communication networks (ADCN), cabin electronics and cabin networks:</p> <ul style="list-style-type: none"> • History of computer and network technology • Layer model in computer technology • Computer architectures (PC, IPC, Embedded Systems) • BIOS, UEFI and operating system (OS) • Programming languages (machine code and high-level languages) • Applications and Application Programming Interfaces • External interfaces (serial, USB, Ethernet) • Layer model in network technology • Network topologies • Network components • Bus access procedures • Integrated Modular Avionics (IMA) and Aircraft Data Communication Networks (ADCN) • Cabin electronics and cabin networks
Literature	<p>- Skript zur Vorlesung</p> <p>- Schnabel, P.: Computertechnik-Fibel: Grundlagen Computertechnik, Mikroprozessortechnik, Halbleiterspeicher, Schnittstellen und Peripherie. Books on Demand; 1. Auflage, 2003</p> <p>- Schnabel, P.: Netzwerktechnik-Fibel: Grundlagen, Übertragungstechnik und Protokolle, Anwendungen und Dienste, Sicherheit. Books on Demand; 1. Auflage, 2004</p> <p>- Wüst, K.: Mikroprozessortechnik: Grundlagen, Architekturen und Programmierung von Mikroprozessoren, Mikrocontrollern und Signalprozessoren. Vieweg Verlag; 2. aktualisierte und erweiterte Auflage, 2006</p>

Course L1558: Computer and communication technology in cabin electronics and avionics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Ralf God
Language	DE
Cycle	WiSe
Content	<p>The objective of the lecture with the corresponding exercise is the acquisition of knowledge of computer and communication technology in electronic systems in the cabin and in aircraft. For the system engineer the strong interaction of software, mechanical and electronic system components nowadays requires a basic understanding of cabin electronics and avionics.</p> <p>The course teaches the basics of design and functionality of computers and data networks. Subsequently it focuses on current principles and applications in integrated modular avionics (IMA), aircraft data communication networks (ADCN), cabin electronics and cabin networks:</p> <ul style="list-style-type: none"> • History of computer and network technology • Layer model in computer technology • Computer architectures (PC, IPC, Embedded Systems) • BIOS, UEFI and operating system (OS) • Programming languages (machine code and high-level languages) • Applications and Application Programming Interfaces • External interfaces (serial, USB, Ethernet) • Layer model in network technology • Network topologies • Network components • Bus access procedures • Integrated Modular Avionics (IMA) and Aircraft Data Communication Networks (ADCN) • Cabin electronics and cabin networks
Literature	<p>- Skript zur Vorlesung</p> <p>- Schnabel, P.: Computertechnik-Fibel: Grundlagen Computertechnik, Mikroprozessortechnik, Halbleiterspeicher, Schnittstellen und Peripherie. Books on Demand; 1. Auflage, 2003</p> <p>- Schnabel, P.: Netzwerktechnik-Fibel: Grundlagen, Übertragungstechnik und Protokolle, Anwendungen und Dienste, Sicherheit. Books on Demand; 1. Auflage, 2004</p> <p>- Wüst, K.: Mikroprozessortechnik: Grundlagen, Architekturen und Programmierung von Mikroprozessoren, Mikrocontrollern und Signalprozessoren. Vieweg Verlag; 2. aktualisierte und erweiterte Auflage, 2006</p>

Course L1551: Model-Based Systems Engineering (MBSE) with SysML/UML	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	<p>Objectives of the problem-oriented course are the acquisition of knowledge on system design using the formal languages SysML/UML, learning about tools for modeling and finally the implementation of a project with methods and tools of Model-Based Systems Engineering (MBSE) on a realistic hardware platform (e.g. Arduino®, Raspberry Pi®):</p> <ul style="list-style-type: none"> • What is a model? • What is Systems Engineering? • Survey of MBSE methodologies • The modelling languages SysML /UML • Tools for MBSE • Best practices for MBSE • Requirements specification, functional architecture, specification of a solution • From model to software code • Validation and verification: XIL methods • Accompanying MBSE project
Literature	<p>- Skript zur Vorlesung</p> <p>- Weilkens, T.: Systems Engineering mit SysML/UML: Modellierung, Analyse, Design. 2. Auflage, dpunkt.Verlag, 2008</p> <p>- Holt, J., Perry, S.A., Brownsword, M.: Model-Based Requirements Engineering. Institution Engineering & Tech, 2011</p>

Module M0832: Advanced Topics in Control			
Courses			
Title	Typ	Hrs/wk	CP
Advanced Topics in Control (L0661)	Lecture	2	3
Advanced Topics in Control (L0662)	Recitation Section (small)	2	3
Module Responsible	Prof. Herbert Werner		
Admission Requirements	None		
Recommended Previous Knowledge	H-infinity optimal control, mixed-sensitivity design, linear matrix inequalities		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p><i>Knowledge</i></p> <ul style="list-style-type: none"> • Students can explain the advantages and shortcomings of the classical gain scheduling approach • They can explain the representation of nonlinear systems in the form of quasi-LPV systems • They can explain how stability and performance conditions for LPV systems can be formulated as LMI conditions • They can explain how gridding techniques can be used to solve analysis and synthesis problems for LPV systems • They are familiar with polytopic and LFT representations of LPV systems and some of the basic synthesis techniques associated with each of these model structures <p><i>Skills</i></p> <ul style="list-style-type: none"> • Students can explain how graph theoretic concepts are used to represent the communication topology of multiagent systems • They can explain the convergence properties of first order consensus protocols • They can explain analysis and synthesis conditions for formation control loops involving either LTI or LPV agent models • Students can explain concepts behind linear and qLPV Model Predictive Control (MPC) • Students can construct LPV models of nonlinear plants and carry out a mixed-sensitivity design of gain-scheduled controllers; they can do this using polytopic, LFT or general LPV models • They can use standard software tools (Matlab robust control toolbox) for these tasks • Students can design distributed formation controllers for groups of agents with either LTI or LPV dynamics, using Matlab tools provided • Students can design MPC controllers for linear and non-linear systems using Matlab tools <p>Personal Competence</p> <p><i>Social Competence</i> Students can work in small groups and arrive at joint results.</p> <p><i>Autonomy</i> Students can find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.</p>		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Credit points	6		
Course achievement	None		
Examination	Oral exam		
Examination duration and scale	30 min		
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory		

Course L0661: Advanced Topics in Control	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Linear Parameter-Varying (LPV) Gain Scheduling <ul style="list-style-type: none"> - Linearizing gain scheduling, hidden coupling - Jacobian linearization vs. quasi-LPV models - Stability and induced L2 norm of LPV systems - Synthesis of LPV controllers based on the two-sided projection lemma - Simplifications: controller synthesis for polytopic and LFT models - Experimental identification of LPV models - Controller synthesis based on input/output models - Applications: LPV torque vectoring for electric vehicles, LPV control of a robotic manipulator • Control of Multi-Agent Systems <ul style="list-style-type: none"> - Communication graphs - Spectral properties of the graph Laplacian - First and second order consensus protocols - Formation control, stability and performance - LPV models for agents subject to nonholonomic constraints - Application: formation control for a team of quadrotor helicopters • Linear and Nonlinear Model Predictive Control based on LMIs
Literature	<ul style="list-style-type: none"> • Werner, H., Lecture Notes "Advanced Topics in Control" • Selection of relevant research papers made available as pdf documents via StudIP

Course L0662: Advanced Topics in Control	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1744: Selected Topics of Aeronautical Systems Engineering (Alternative A: 6 LP)			
Courses			
Title	Typ	Hrs/wk	CP
Advanced Training Course SE-ZERT (L2739)	Project-/problem-based Learning	2	3
Airline Operations (L1310)	Lecture	3	3
Fatigue & Damage Tolerance (L0310)	Lecture	2	3
Flight Guidance I (Introduction) (L0848)	Lecture	2	2
Flight Guidance I (Introduction) (L0854)	Recitation Section (large)	1	1
Flight Guidance II (Flight Control) (L2374)	Lecture	2	2
Flight Guidance II (Flight Control) (L2375)	Recitation Section (small)	1	1
Airport Operations (L1276)	Lecture	3	3
Airport Planning (L1275)	Lecture	2	2
Airport Planning (L1469)	Recitation Section (small)	1	1
Lightweight Design Practical Course (L1258)	Project-/problem-based Learning	3	3
Aviation Security (L1549)	Lecture	2	2
Aviation Security (L1550)	Recitation Section (small)	1	1
Aviation and Environment (L2376)	Lecture	3	3
Machine Learning in Safety-Critical Cyber-Physical Systems (L2934)	Lecture	2	2
Machine Learning in Safety-Critical Cyber-Physical Systems (L2935)	Recitation Section (small)	1	1
Mechanisms, Systems and Processes of Materials Testing (L0950)	Lecture	2	2
Turbo Jet Engines (L0908)	Lecture	2	3
Structural Mechanics of Fibre Reinforced Composites (L1514)	Lecture	2	3
Structural Mechanics of Fibre Reinforced Composites (L1515)	Recitation Section (large)	1	1
System Simulation (L1820)	Lecture	2	2
System Simulation (L1821)	Recitation Section (large)	1	2
Materials Testing (L0949)	Lecture	2	2
Reliability in Engineering Dynamics (L2994)	Lecture	2	2
Reliability in Engineering Dynamics (L2995)	Recitation Section (small)	1	2
Reliability of Aircraft Systems (L0749)	Lecture	2	3
Module Responsible	Prof. Frank Thielecke		
Admission Requirements	None		
Recommended Previous Knowledge	Basic knowledge in: <ul style="list-style-type: none"> • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Hydraulics • Control Systems 		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<ul style="list-style-type: none"> • Students are able to find their way through selected special areas within systems engineering, air transportation system and material science • Students are able to explain basic models and procedures in selected special areas. • Students are able to interrelate scientific and technical knowledge. 		
<i>Knowledge</i>			
<i>Skills</i>	Students are able to apply basic methods in selected areas of engineering.		
Personal Competence			
<i>Social Competence</i>			
<i>Autonomy</i>	Students can chose independently, in which fields they want to deepen their knowledge and skills through the election of courses.		
Workload in Hours	Depends on choice of courses		
Credit points	6		
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory		

Course L2739: Advanced Training Course SE-ZERT	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	120 min
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	
Literature	INCOSE Systems Engineering Handbuch - Ein Leitfaden für Systemlebenszyklus-Prozesse und -Aktivitäten, GfSE (Hrsg. der deutschen Übersetzung), ISBN 978-3-9818805-0-2. ISO/IEC 15288 System- und Software-Engineering - System-Lebenszyklus-Prozesse (Systems and Software Engineering - System Life Cycle Processes).

Course L1310: Airline Operations	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Volker Gollnick, Dr. Karl Echtermeyer
Language	DE
Cycle	SoSe
Content	<ol style="list-style-type: none"> 1. Introduction and overview 2. Airline business models 3. Interdependencies in flight planning (network management, slot management, network structures, aircraft circulation) 4. Operative flight preparation (weight & balance, payload/range, etc.) 5. fleet policy 6. Aircraft assessment and fleet planning 7. Airline organisation 8. Aircraft maintenance, repair and overhaul
Literature	Volker Gollnick, Dieter Schmitt: The Air Transport System, Springer Berlin Heidelberg New York, 2014 Paul Clark: "Buying the Big Jets", Ashgate 2008 Mike Hirst: The Air Transport System, AIAA, 2008

Course L0310: Fatigue & Damage Tolerance	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 min
Lecturer	Dr. Martin Flamm
Language	EN
Cycle	WiSe
Content	Design principles, fatigue strength, crack initiation and crack growth, damage calculation, counting methods, methods to improve fatigue strength, environmental influences
Literature	Jaap Schijve, Fatigue of Structures and Materials. Kluwer Academic Puplicher, Dordrecht, 2001 E. Haibach. Betriebsfestigkeit Verfahren und Daten zur Bauteilberechnung. VDI-Verlag, Düsseldorf, 1989

Course L0848: Flight Guidance I (Introduction)	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	WiSe
Content	<p>Introduction and motivation Flight guidance principles (airspace structures, organization of air navigation services, etc.)</p> <p>Cockpit systems and Avionics (cockpit design, cockpit equipment, displays, computers and bus systems)</p> <p>Principles of flight measurement techniques (Measurement of position (geometric methods, distance measurement, direction measurement) Determination of the aircraft attitude (magnetic field- and inertial sensors) Measurement of speed</p> <p>Principles of Navigation</p> <p>Radio navigation</p> <p>Satellite navigation</p> <p>Airspace surveillance (radar systems)</p> <p>Communication systems</p> <p>Integrated Navigation and Guidance Systems</p>
Literature	<p>Rudolf Brockhaus, Robert Luckner, Wolfgang Alles: "Flugregelung", Springer Berlin Heidelberg New York, 2011</p> <p>Holger Flühr: "Avionik und Flugsicherungssysteme", Springer Berlin Heidelberg New York, 2013</p> <p>Volker Gollnick, Dieter Schmitt "Air Transport Systems", Springer Berlin Heidelberg New York, 2016</p> <p>R.P.G. Collinson „Introduction to Avionics“, Springer Berlin Heidelberg New York 2003</p>

Course L0854: Flight Guidance I (Introduction)	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L2374: Flight Guidance II (Flight Control)	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	SoSe
Content	
Literature	<p>Brockhaus, Alles, Luckner: Flugregelung, Springer Verlag, 2011</p> <p>R.P.G Collinson: Introduction to Avionics Systems, Springer Verlag, 2011</p>

Course L2375: Flight Guidance II (Flight Control)	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L1276: Airport Operations	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Volker Gollnick, Dr. Peter Willems
Language	DE
Cycle	WiSe
Content	FA-F Flight Operations Flight Operations - Production Infrastructures Operations Planning Master plan Airport capacity Ground handling Terminal operations
Literature	Richard de Neufville, Amedeo Odoni: Airport Systems, McGraw Hill, 2003

Course L1275: Airport Planning	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick, Dr. Ulrich Hüp
Language	DE
Cycle	WiSe
Content	<ol style="list-style-type: none"> 1. Introduction, definitions, overview 2. Runway systems 3. Air space structures around airports 4. Airfield lightings, marking and information 5. Airfield and terminal configuration
Literature	N. Ashford, Martin Stanton, Clifton Moore: Airport Operations, John Wiley & Sons, 1991 Richard de Neufville, Amedeo Odoni: Airport Systems, Aviation Week Books, MacGraw Hill, 2003

Course L1469: Airport Planning	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	60 min
Lecturer	Prof. Volker Gollnick, Dr. Ulrich Hüp
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1258: Lightweight Design Practical Course	
Typ	Project-/problem-based Learning
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Dieter Krause
Language	DE/EN
Cycle	SoSe
Content	<p>Development of a sandwich structure made of fibre reinforced plastics</p> <ul style="list-style-type: none"> • getting familiar with fibre reinforced plastics as well as lightweight design • Design of a sandwich structure made of fibre reinforced plastics using finite element analysis (FEA) • Determination of material properties based on sample tests • manufacturing of the structure in the composite lab • Testing of the developed structure • Concept presentation • Self-organised teamwork
Literature	<ul style="list-style-type: none"> • Schürmann, H., „Konstruieren mit Faser-Kunststoff-Verbunden“, Springer, Berlin, 2005. • Puck, A., „Festigkeitsanalyse von Faser-Matrix-Laminaten“, Hanser, München, Wien, 1996. • R&G, „Handbuch Faserverbundwerkstoffe“, Waldenbuch, 2009. • VDI 2014 „Entwicklung von Bauteilen aus Faser-Kunststoff-Verbund“ • Ehrenstein, G. W., „Faserverbundkunststoffe“, Hanser, München, 2006. • Klein, B., „Leichtbau-Konstruktion“, Vieweg & Sohn, Braunschweig, 1989. • Wiedemann, J., „Leichtbau Band 1: Elemente“, Springer, Berlin, Heidelberg, 1986. • Wiedemann, J., „Leichtbau Band 2: Konstruktion“, Springer, Berlin, Heidelberg, 1986. • Backmann, B.F., „Composite Structures, Design, Safety and Innovation“, Oxford (UK), Elsevier, 2005. • Krause, D., „Leichtbau“, In: Handbuch Konstruktion, Hrsg.: Rieg, F., Steinhilper, R., München, Carl Hanser Verlag, 2012. • Schulte, K., Fiedler, B., „Structure and Properties of Composite Materials“, Hamburg, TUHH - TuTech Innovation GmbH, 2005.

Course L1549: Aviation Security	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 Minuten
Lecturer	Prof. Ralf God
Language	DE
Cycle	WiSe
Content	<p>The objective of the lecture with the corresponding exercise is the acquisition of knowledge about tasks and measures for protection against attacks on the security of the commercial air transport system. Tasks and measures will be elicited in the context of the three system components man, technology and organization.</p> <p>The course teaches the basics of aviation security. Aviation security is a necessary prerequisite for an economically successful air transport system. Risk management for the entire system can only be successful in an integrated approach, considering man, technology and organization:</p> <ul style="list-style-type: none"> • Historical development • The special role of air transport • Motive and attack vectors • The human factor • Threats and risk • Regulations and law • Organization and implementation of aviation security tasks • Passenger and baggage checks • Cargo screening and secure supply chain • Safety technologies
Literature	<p>- Skript zur Vorlesung</p> <p>- Giemulla, E.M., Rothe B.R. (Hrsg.): Handbuch Luftsicherheit. Universitätsverlag TU Berlin, 2011</p> <p>- Thomas, A.R. (Ed.): Aviation Security Management. Praeger Security International, 2008</p>

Course L1550: Aviation Security	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	90 Minuten
Lecturer	Prof. Ralf God
Language	DE
Cycle	WiSe
Content	<p>The objective of the lecture with the corresponding exercise is the acquisition of knowledge about tasks and measures for protection against attacks on the security of the commercial air transport system. Tasks and measures will be elicited in the context of the three system components man, technology and organization.</p> <p>The course teaches the basics of aviation security. Aviation security is a necessary prerequisite for an economically successful air transport system. Risk management for the entire system can only be successful in an integrated approach, considering man, technology and organization:</p> <ul style="list-style-type: none"> • Historical development • The special role of air transport • Motive and attack vectors • The human factor • Threats and risk • Regulations and law • Organization and implementation of aviation security tasks • Passenger and baggage checks • Cargo screening and secure supply chain • Safety technologies
Literature	<p>- Skript zur Vorlesung</p> <p>- Giemulla, E.M., Rothe B.R. (Hrsg.): Handbuch Luftsicherheit. Universitätsverlag TU Berlin, 2011</p> <p>- Thomas, A.R. (Ed.): Aviation Security Management. Praeger Security International, 2008</p>

Course L2376: Aviation and Environment	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	SoSe
Content	<p>The lecture provides the necessary basics and methods for understanding the interactions between air traffic and the environment, both in terms of the effects of weather / climate on flying and with regard to the effects of air traffic on pollutant emissions, noise and climate.</p> <p>The following topics are covered:</p> <ul style="list-style-type: none"> • Atmospheric physics / chemistry <ul style="list-style-type: none"> ◦ Structure and statics ◦ Dynamics (water cycle, formation of weather events, high and low pressure areas, wind, gusts and turbulence) ◦ Cloud physics (thermodynamics, contrails) ◦ Radiation physics (energy balance, greenhouse effect) ◦ Photochemistry (ozone chemistry) • Impact of weather on flying <ul style="list-style-type: none"> ◦ Atmospheric influences on flight performance ◦ Flight planning ◦ Disturbances due to weather, e.g. thunderstorms, winter weather (icing), clear air turbulence, visibility ◦ Effects of climate change and adaptation • Effects of air traffic on the environment and climate <ul style="list-style-type: none"> ◦ Aviation pollutant emissions ◦ Effect of emissions on concentrations in the atmosphere ◦ Climate metrics / models and background scenarios ◦ Emissions inventories • Mitigation measures <ul style="list-style-type: none"> ◦ Technological measures, e.g. climate-optimized aircraft design ◦ Alternative fuels ◦ Operational measures, e.g. climate-optimized flight planning ◦ Environmental policy measures, e.g. EU-ETS, CORSIA ◦ Potentials and comparison, concept of eco-efficiency • Local environmental impacts <ul style="list-style-type: none"> ◦ Local air quality (particulate matter, other emissions near the ground) ◦ Noise (noise sources, noise metrics, noise impact, measurement, certification, psychoacoustics, noise mitigation) ◦ Health effects • Aspects of sustainability <ul style="list-style-type: none"> ◦ Other aspects, including life cycle emissions, disposal/recycling ◦ Relation to global goals, e.g. United Nations goals for sustainable development, Paris climate agreement
Literature	<ul style="list-style-type: none"> • Ruijgrok, G.: Elements of Aircraft Pollution, Delft University Press, 2005 • Friedrich, R., Reis, S.: Emissions of Air Pollutants, Springer 2004 • Janic, M.: The Sustainability of Air Transportation, Ashgate, 2007 • Schumann, U. (ed.): Atmospheric Physics: Background - Methods - Trends, Springer, Berlin, Heidelberg, 2012 • Spiridonov, V., Curic, M.: Fundamentals of Meteorology, Springer, 2021 • Kaltschmitt, M., Neuling, U.: Biokerosene - Status and Prospects, Springer, 2018 • Roedel, W., Wagner, T.: Physik unserer Umwelt: Die Atmosphäre, Springer, 2017 • W. Bräunling: Flugzeugtriebwerke. Springer-Verlag Berlin, Deutschland, 2009 • G. Brüning, X. Hafer, G. Sachs: Flugleistungen, Springer, 1993

Course L2934: Machine Learning in Safety-Critical Cyber-Physical Systems	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	90 min
Lecturer	Prof. Ralf God
Language	DE
Cycle	WiSe
Content	<p>The use of machine learning enables many highly complex applications, for example in autonomous systems. However, the application in safety-critical systems offers special challenges and makes special demands on the development.</p> <p>The course teaches the necessary basics and methods in the context of systems engineering for the use of data science, machine learning and AI in safety-critical systems. In addition, current areas of application and the current state of research are discussed.</p> <p>The following topics will be dealt with in detail:</p> <ul style="list-style-type: none"> • Introduction and motivation <ul style="list-style-type: none"> ◦ Safety-critical cyber-physical systems and systems of systems ◦ Methods of modelling in systems engineering ◦ Challenges in the use of machine learning in safety-critical systems • Systems engineering and safety-critical systems <ul style="list-style-type: none"> ◦ Safety and machine learning ◦ Machine learning lifecycle ◦ Methods ◦ Data set optimization ◦ Robust learning ◦ Quantification of uncertainty ◦ Adversarial attacks ◦ Interpretability ◦ Securing the overall system • The latest from research
Literature	- J. Holt, S. A. Perry, M. Brownsword. Model-Based Requirements Engineering. Institution Engineering & Tech, 2011. - S. Houben et al. Inspect, Understand, Overcome: A Survey of Practical Methods for AI Safety. arXiv, 2021. - A. Schwaiger. Machine Learning in sicherheitskritischen Systemen. Embedded Software Engineering Kongress, 2020. - A. Pereira, C. Thomas. Challenges of Machine Learning Applied to Safety-Critical Cyber-Physical Systems. Mach. Learn. Knowl. Extr., 2, 579-602, 2020.

Course L2935: Machine Learning in Safety-Critical Cyber-Physical Systems	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Schriftliche Ausarbeitung
Examination duration and scale	90 min
Lecturer	Prof. Ralf God
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0950: Mechanisms, Systems and Processes of Materials Testing	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 Minuten
Lecturer	Dr. Jan Oke Peters
Language	DE
Cycle	SoSe
Content	<p>Application, analysis and discussion of basic and advanced testing methods to ensure correct selection of applicable testing procedure for investigation of part/materials deficiencies</p> <ul style="list-style-type: none"> • Stress-strain relationships • Strain gauge application • Visko elastic behavior • Tensile test (strain hardening, necking, strain rate) • Compression test, bending test, torsion test • Crack growth upon static loading (J-Integral) • Crack growth upon cyclic loading (micro- und macro cracks) • Effect of notches • Creep testing (physical creep test, influence of stress and temperature, Larson Miller parameter) • Wear testing • Non destructive testing application for overhaul of jet engines
Literature	<ul style="list-style-type: none"> • E. Macherauch: Praktikum in Werkstoffkunde, Vieweg • G. E. Dieter: Mechanical Metallurgy, McGraw-Hill • R. Bürgel: Lehr- und Übungsbuch Festigkeitslehre, Vieweg • R. Bürgel: Werkstoffe sicher beurteilen und richtig einsetzen, Vieweg

Course L0908: Turbo Jet Engines	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	45 min
Lecturer	Dr. Burkhard Andrich
Language	DE
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Cycle of the gas turbine • Thermodynamics of gas turbine components • Wing-, grid- and stage-sizing • Operating characteristics of gas turbine components • Sizing criteria's for jet engines • Development trends of gas turbines and jet engines • Maintenance of jet engines
Literature	<ul style="list-style-type: none"> • Bräunling: Flugzeugtriebwerke • Engmann: Technologie des Fliegens • Kerrebrock: Aircraft Engines and Gas Turbines

Course L1514: Structural Mechanics of Fibre Reinforced Composites	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Benedikt Kriegesmann
Language	EN
Cycle	WiSe
Content	Classical laminate theory Rules of mixture Failure mechanisms and criteria of composites Boundary value problems of isotropic and anisotropic shells Stability of composite structures Optimization of laminated composites Modelling composites in FEM Numerical multiscale analysis of textile composites Progressive failure analysis
Literature	<ul style="list-style-type: none"> • Schürmann, H., „Konstruieren mit Faser-Kunststoff-Verbunden“, Springer, Berlin, aktuelle Auflage. • Wiedemann, J., „Leichtbau Band 1: Elemente“, Springer, Berlin, Heidelberg, , aktuelle Auflage. • Reddy, J.N., „Mechanics of Composite Laminated Plates and Shells“, CRC Publishing, Boca Raton et al., current edition. • Jones, R.M., „Mechanics of Composite Materials“, Scripta Book Co., Washington, current edition. • Timoshenko, S.P., Gere, J.M., „Theory of elastic stability“, McGraw-Hill Book Company, Inc., New York, current edition. • Turvey, G.J., Marshall, I.H., „Buckling and postbuckling of composite plates“, Chapman and Hall, London, current edition. • Herakovich, C.T., „Mechanics of fibrous composites“, John Wiley and Sons, Inc., New York, current edition. • Mittelstedt, C., Becker, W., „Strukturmechanik ebener Laminate“, aktuelle Auflage.

Course L1515: Structural Mechanics of Fibre Reinforced Composites	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Prof. Benedikt Kriegesmann
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1820: System Simulation	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Dr. Stefan Wischhusen, Dr. Johannes Brunnemann
Language	DE
Cycle	WiSe
Content	<p>Lecture about equation-based, physical modelling using the modelling language Modelica and the free simulation tool OpenModelica 1.17.0.</p> <ul style="list-style-type: none"> • Instruction and modelling of physical processes • Modelling and limits of model • Time constant, stiffness, stability, step size • Terms of object orientated programming • Differential equations of simple systems • Introduction into Modelica • Introduction into simulation tool • Example:Hydraulic systems and heat transfer • Example: System with different subsystems
Literature	<p>[1] Modelica Association: "Modelica Language Specification - Version 3.5", Linköping, Sweden, 2021.</p> <p>[2] OpenModelica: OpenModelica 1.17.0, https://www.openmodelica.org (siehe Download), 2021.</p> <p>[3] M. Tiller: "Modelica by Example", https://book.xogeny.com, 2014.</p> <p>[4] M. Otter, H. Elmqvist, et al.: "Objektorientierte Modellierung Physikalischer Systeme", at- Automatisierungstechnik (german), Teil 1 - 17, Oldenbourg Verlag, 1999 - 2000.</p> <p>[5] P. Fritzson: "Principles of Object-Oriented Modeling and Simulation with Modelica 3.3", Wiley-IEEE Press, New York, 2015.</p> <p>[6] P. Fritzson: "Introduction to Modeling and Simulation of Technical and Physical Systems with Modelica", Wiley, New York, 2011.</p>

Course L1821: System Simulation	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Examination Form	Mündliche Prüfung
Examination duration and scale	30 min
Lecturer	Dr. Stefan Wischhusen, Dr. Johannes Brunnemann
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L0949: Materials Testing	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 Minuten
Lecturer	Dr. Jan Oke Peters
Language	DE
Cycle	WiSe
Content	<p>Application and analysis of basic mechanical as well as non-destructive testing of materials</p> <ul style="list-style-type: none"> • Determination elastic constants • Tensile test • Fatigue test (testing with constant stress, strain, or plastiv strain amplitude, low and high cycle fatigue, mean stress effect) • Crack growth upon static loading (stress intensity factor, fracture toughness) • Creep test • Hardness test • Charpy impact test • Non destructive testing
Literature	<p>E. Macherauch: Praktikum in Werkstoffkunde, Vieweg G. E. Dieter: Mechanical Metallurgy, McGraw-Hill</p>

Course L2994: Reliability in Engineering Dynamics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Benedikt Kriegesmann
Language	EN
Cycle	SoSe
Content	<p>Method for calculation and testing of reliability of dynamic machine systems</p> <p>Modeling</p> <p>System identification</p> <p>Simulation</p> <p>Processing of measurement data</p> <p>Damage accumulation</p> <p>Test planning and execution</p>
Literature	<p>Bertsche, B.: Reliability in Automotive and Mechanical Engineering. Springer, 2008. ISBN: 978-3-540-33969-4</p> <p>Inman, Daniel J.: Engineering Vibration. Prentice Hall, 3rd Ed., 2007. ISBN-13: 978-0132281737</p> <p>Dresig, H., Holzweißig, F.: Maschinendynamik, Springer Verlag, 9. Auflage, 2009. ISBN 3540876936.</p> <p>VDA (Hg.): Zuverlässigkeitssicherung bei Automobilherstellern und Lieferanten. Band 3 Teil 2, 3. überarbeitete Auflage, 2004. ISSN 0943-9412</p>

Course L2995: Reliability in Engineering Dynamics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Examination Form	Klausur
Examination duration and scale	90 min
Lecturer	Prof. Benedikt Kriegesmann
Language	EN
Cycle	SoSe
Content	<p>Method for calculation and testing of reliability of dynamic machine systems</p> <p>Modeling</p> <p>System identification</p> <p>Simulation</p> <p>Processing of measurement data</p> <p>Damage accumulation</p> <p>Test planning and execution</p>
Literature	<p>Bertsche, B.: Reliability in Automotive and Mechanical Engineering. Springer, 2008. ISBN: 978-3-540-33969-4</p> <p>Inman, Daniel J.: Engineering Vibration. Prentice Hall, 3rd Ed., 2007. ISBN-13: 978-0132281737</p> <p>Dresig, H., Holzweißig, F.: Maschinendynamik, Springer Verlag, 9. Auflage, 2009. ISBN 3540876936.</p> <p>VDA (Hg.): Zuverlässigkeitssicherung bei Automobilherstellern und Lieferanten. Band 3 Teil 2, 3. überarbeitete Auflage, 2004. ISSN 0943-9412</p>

Course L0749: Reliability of Aircraft Systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Examination Form	Klausur
Examination duration and scale	90 Minuten
Lecturer	Prof. Frank Thielecke, Dr. Andreas Vahl, Dr. Uwe Wiecek
Language	DE
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Functions of reliability and safety (regulations, certification requirements) • Basics methods of reliability analysis (FMEA, fault tree, functional hazard assessment) • Reliability analysis of electrical and mechanical systems
Literature	<ul style="list-style-type: none"> • CS 25.1309 • SAE ARP 4754 • SAE ARP 4761

Module M0764: Flight Control Systems				
Courses				
Title	Typ	Hrs/wk	CP	
Flight Control Systems (L0736)	Lecture	3	4	
Flight Control Systems (L0740)	Recitation Section (large)	2	2	
Module Responsible	Prof. Frank Thielecke			
Admission Requirements	None			
Recommended Previous Knowledge	basic knowledge of: <ul style="list-style-type: none"> • mathematics • mechanics • thermo dynamics • electronics • fluid mechanics • control theory 			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<p><i>Knowledge</i> Students are able to...</p> <ul style="list-style-type: none"> • describe the structure and the functioning of primary flight control systems as well as actuation-, avionic-, high lift systems of aircrafts in general along with corresponding properties and applications. • give an overview over the functioning and the structure of landing gears and landing gear systems • explain different configurations and designs and their origins <p><i>Skills</i> Students are able to...</p> <ul style="list-style-type: none"> • size primary flight control actuation systems • perform a controller design process for the flight control actuators • design high-lift systems and high-lift kinematics • size landing gear components 			
Personal Competence	<p><i>Social Competence</i> Students are able to:</p> <ul style="list-style-type: none"> • Develop joint solutions in mixed teams • Present and explain developed solutions in front of other students • Discuss developed solutions with experts <p><i>Autonomy</i> Students are able to:</p> <ul style="list-style-type: none"> • derive requirements and perform appropriate yet simplified design processes for aircraft systems from complex issues and circumstances in a self-reliant manner • apply new skills and methods in the context of exercises in a self-reliant manner 			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	165 Minutes			
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory			

Course L0736: Flight Control Systems	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Frank Thielecke
Language	DE
Cycle	SoSe
Content	<ul style="list-style-type: none"> • Actuation (Principles of actuators; electro-mechanical actuators; modeling, analysis and sizing of position control systems; hydro-mechanic actuation systems) • Flight Control Systems (control surfaces, hinge moments; requirements of stability and controllability, actuation power; principles of reversible and irreversible flight control systems; servo actuation systems) • Landing Gear Systems (Configurations and geometries; analysis of landing gear systems with respect to damper dynamics, dynamics of the breaking aircraft and power consumption; design and analysis of breaking systems with respect to energy and heat; anti-skid systems) • Fuel Systems (Architectures; aviation fuels; system components; fueling system; tank inerting system; fuel management; trim tank) • De- and Anti-Ice Systems: (Atmospheric icing conditions; principles of de- and anti-ice systems)
Literature	<ul style="list-style-type: none"> • Moir, Seabridge: Aircraft Systems • Torenbek: Synthesis of Subsonic Airplane Design • Curry: Aircraft Landing Gear Design: Principles and Practices

Course L0740: Flight Control Systems	
Typ	Recitation Section (large)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Frank Thielecke
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1156: Systems Engineering				
Courses				
Title	Typ	Hrs/wk	CP	
Systems Engineering (L1547)	Lecture	3	4	
Systems Engineering (L1548)	Recitation Section (large)	1	2	
Module Responsible	Prof. Ralf God			
Admission Requirements	None			
Recommended Previous Knowledge	Basic knowledge in: <ul style="list-style-type: none"> • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems Previous knowledge in: <ul style="list-style-type: none"> • Aircraft Cabin Systems 			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	Students are able to: <ul style="list-style-type: none"> • understand systems engineering process models, methods and tools for the development of complex Systems • describe innovation processes and the need for technology Management • explain the aircraft development process and the process of type certification for aircraft • explain the system development process, including requirements for systems reliability • identify environmental conditions and test procedures for airborne Equipment • value the methodology of requirements-based engineering (RBE) and model-based requirements engineering (MBRE) 			
<i>Knowledge</i>				
<i>Skills</i>	Students are able to: <ul style="list-style-type: none"> • plan the process for the development of complex Systems • organize the development phases and development Tasks • assign required business activities and technical Tasks • apply systems engineering methods and tools 			
Personal Competence	Students are able to: <ul style="list-style-type: none"> • understand and accept their tasks within a development team • be comfortable with their role their tasks within the overall process • understand and serve their suppliers and customers in large projects • assume responsibility for people and technology in the development of safety-critical systems 			
<i>Social Competence</i>				
<i>Autonomy</i>	Students are able to: <ul style="list-style-type: none"> • interact and communicate in a development team with division of tasks. • independently research and identify certification specifications • formulate requirements on their own • create test plans on their own and accompany certification processes 			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	120 Minutes			
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory			

Course L1547: Systems Engineering	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	<p>The objective of the lecture with the corresponding exercise is to accomplish the prerequisites for the development and integration of complex systems using the example of commercial aircraft and cabin systems. Competences in the systems engineering process, tools and methods is to be achieved. Regulations, guidelines and certification issues will be known.</p> <p>Key aspects of the course are processes for innovation and technology management, system design, system integration and certification as well as tools and methods for systems engineering:</p> <ul style="list-style-type: none"> • Innovation processes • IP-protection • Technology management • Systems engineering • Aircraft program • Certification issues • Systems development • Safety objectives and fault tolerance • Environmental and operating conditions • Tools for systems engineering • Requirements-based engineering (RBE) • Model-based requirements engineering (MBRE)
Literature	<p>- Skript zur Vorlesung</p> <p>- diverse Normen und Richtlinien (EASA, FAA, RTCA, SAE)</p> <p>- Hauschildt, J., Salomo, S.: Innovationsmanagement. Vahlen, 5. Auflage, 2010</p> <p>- NASA Systems Engineering Handbook, National Aeronautics and Space Administration, 2007</p> <p>- Hinsch, M.: Industrielles Luftfahrtmanagement: Technik und Organisation Luftfahrttechnischer Betriebe. Springer, 2010</p> <p>- De Florio, P.: Airworthiness: An Introduction to Aircraft Certification. Elsevier Ltd., 2010</p> <p>- Pohl, K.: Requirements Engineering. Grundlagen, Prinzipien, Techniken. 2. korrigierte Auflage, dpunkt.Verlag, 2008</p>

Course L1548: Systems Engineering	
Typ	Recitation Section (large)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Ralf God
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1339: Design optimization and probabilistic approaches in structural analysis			
Courses			
Title		Typ	Hrs/wk CP
Design Optimization and Probabilistic Approaches in Structural Analysis (L1873)		Lecture	2 3
Design Optimization and Probabilistic Approaches in Structural Analysis (L1874)		Recitation Section (large)	2 3
Module Responsible	Prof. Benedikt Kriegesmann		
Admission Requirements	None		
Recommended Previous Knowledge	<ul style="list-style-type: none"> • Technical mechanics • Higher math 		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<ul style="list-style-type: none"> • Design optimization <ul style="list-style-type: none"> ◦ Gradient based methods ◦ Genetic algorithms ◦ Optimization with constraints ◦ Topology optimization • Reliability analysis <ul style="list-style-type: none"> ◦ Stochastic basics ◦ Monte Carlo methods ◦ Semi-analytic approaches • robust design optimization <ul style="list-style-type: none"> ◦ Robustness measures ◦ Coupling of design optimization and reliability analysis 		
<i>Knowledge</i>			
<i>Skills</i>			
Personal Competence			
<i>Social Competence</i>	<ul style="list-style-type: none"> • Application of optimization algorithms and probabilistic methods in the design of structures • Programming with Matlab • Implementation of algorithms • Debugging 		
<i>Autonomy</i>	<ul style="list-style-type: none"> • Team work • Oral explanation of the the work 		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Credit points	6		
Course achievement	None		
Examination	Written elaboration		
Examination duration and scale	10 pages		
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory		

Course L1873: Design Optimization and Probabilistic Approaches in Structural Analysis	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Benedikt Kriegesmann
Language	DE
Cycle	SoSe
Content	<p>In the course the theoretic basics for design optimization and reliability analysis are taught, where the focus is on the application of such methods. The lectures will consist of presentations as well as computer exercises. In the computer exercises, the methods learned will be implemented in Matlab for understanding the practical realization.</p> <p>The following contents will be considered:</p> <ul style="list-style-type: none"> • Design optimization <ul style="list-style-type: none"> ◦ Gradient based methods ◦ Genetic algorithms ◦ Optimization with constraints ◦ Topology optimization • Reliability analysis <ul style="list-style-type: none"> ◦ Stochastic basics ◦ Monte Carlo methods ◦ Semi-analytic approaches • robust design optimization <ul style="list-style-type: none"> ◦ Robustness measures ◦ Coupling of design optimization and reliability analysis
Literature	<p>[1] Arora, Jasbir. Introduction to Optimum Design. 3rd ed. Boston, MA: Academic Press, 2011.</p> <p>[2] Haldar, A., and S. Mahadevan. Probability, Reliability, and Statistical Methods in Engineering Design. John Wiley & Sons New York/Chichester, UK, 2000.</p>

Course L1874: Design Optimization and Probabilistic Approaches in Structural Analysis	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Benedikt Kriegesmann
Language	DE
Cycle	SoSe
Content	Matlab exercises complementing the lecture
Literature	siehe Vorlesung

Module M1343: Structure and properties of fibre-polymer-composites			
Courses			
Title	Typ	Hrs/wk	CP
Structure and properties of fibre-polymer-composites (L1894)	Lecture	2	3
Structure and properties of fibre-polymer-composites (L2614)	Project-/problem-based Learning	2	2
Structure and properties of fibre-polymer-composites (L2613)	Recitation Section (large)	1	1
Module Responsible	Prof. Bodo Fiedler		
Admission Requirements	None		
Recommended Previous Knowledge	Basics: chemistry / physics / materials science		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p><i>Knowledge</i> Students can use the knowledge of fiber-reinforced composites (FRP) and its constituents to play (fiber / matrix) and define the necessary testing and analysis.</p> <p>They can explain the complex relationships structure-property relationship and the interactions of chemical structure of the polymers, their processing with the different fiber types, including to explain neighboring contexts (e.g. sustainability, environmental protection).</p> <p><i>Skills</i> Students are capable of</p> <ul style="list-style-type: none"> • using standardized calculation methods in a given context to mechanical properties (modulus, strength) to calculate and evaluate the different materials. • approximate sizing using the network theory of the structural elements implement and evaluate. • selecting appropriate solutions for mechanical recycling problems and sizing example stiffness, corrosion resistance. 		
Personal Competence	<p><i>Social Competence</i> Students can</p> <ul style="list-style-type: none"> • arrive at funded work results in heterogenius groups and document them. • provide appropriate feedback and handle feedback on their own performance constructively. <p><i>Autonomy</i> Students are able to</p> <ul style="list-style-type: none"> - assess their own strengths and weaknesses. - assess their own state of learning in specific terms and to define further work steps on this basis. - assess possible consequences of their professional activity. 		
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70		
Credit points	6		
Course achievement	None		
Examination	Written exam		
Examination duration and scale	90 min		
Assignment for the Following Curricula	Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Materials Science: Specialisation Engineering Materials: Elective Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Materials Science: Elective Compulsory		

Course L1894: Structure and properties of fibre-polymer-composites	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Bodo Fiedler
Language	EN
Cycle	SoSe
Content	<ul style="list-style-type: none"> - Microstructure and properties of the matrix and reinforcing materials and their interaction - Development of composite materials - Mechanical and physical properties - Mechanics of Composite Materials - Laminate theory - Test methods - Non destructive testing - Failure mechanisms - Theoretical models for the prediction of properties - Application
Literature	Hall, Clyne: Introduction to Composite materials, Cambridge University Press Daniel, Ishai: Engineering Mechanics of Composites Materials, Oxford University Press Mallick: Fibre-Reinforced Composites, Marcel Dekker, New York

Course L2614: Structure and properties of fibre-polymer-composites	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Bodo Fiedler
Language	DE/EN
Cycle	SoSe
Content	
Literature	

Course L2613: Structure and properties of fibre-polymer-composites	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Bodo Fiedler
Language	EN
Cycle	SoSe
Content	
Literature	

Module M1690: Aircraft Design II (Special Air Vehicle Design)				
Courses				
Title	Typ	Hrs/wk	CP	
Aircraft Design II (Conceptual Design of Rotorcraft, special operations aircraft, UAV) (L0844)	Lecture	3	3	
Aircraft Design II (Conceptual Design of Rotorcraft, special operations aircraft, UAV) (L0847)	Recitation Section (large)	2	3	
Module Responsible	Prof. Volker Gollnick			
Admission Requirements	None			
Recommended Previous Knowledge	Aircraft Design I (Design of Transport Aircraft) Air Transportation Systems			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<p><i>Knowledge</i></p> <p>Understanding of various flight systems and its special characteristics (supersonic aircraft, rotorcraft, high performance aircraft, unmanned air systems)</p> <p>Understanding of pro's and con's and physical characteristics of different air systems</p> <p>Understanding of special mission requirements and its impact on systems definition and conceptual design</p> <p>Intensified knowledge of performance design on various air systems</p> <p><i>Skills</i></p> <p>Understanding and application of design and calculation methods</p> <p>Understanding of interdisciplinary and integrative interdependencies</p> <p>mission oriented technical definition of air systems</p> <p>special conceptual calculation methods for special equipment characteristics</p> <p>assessment of different design solutions</p> <p>Personal Competence</p> <p><i>Social Competence</i></p> <p>Working in teams for focused solutions</p> <p>communication, assertiveness, technical persuasion</p> <p><i>Autonomy</i></p> <p>Organisation of workflows and strategies for solutions</p> <p>structured task analysis and definition of solutions</p>			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	180 min			
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory			

Course L0844: Aircraft Design II (Conceptual Design of Rotorcraft, special operations aircraft, UAV)	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Volker Gollnick, Dr. Bernd Liebhardt, Jens Thöben
Language	DE/EN
Cycle	SoSe
Content	<ol style="list-style-type: none"> 1. Design of supersonic civil aircraft 2. Principles of high performance and special operations aircraft design 3. Principles of Rotorcraft Design 4. Principles of Unmanned Air Systems design, air taxis, electric aircraft
Literature	<p>Gareth Padfield: Helicopter Flight Dynamics, Butterworth Ltd.</p> <p>Raymond Prouty: Helicopter Performance Stability and Control, Krieger Publ.</p> <p>Klaus Hünecke: Das Kampfflugzeug von Heute, Motorbuch Verlag</p> <p>Jay Gundelach: Designing Unmanned Aircraft Systems - Configurative Approach, AIAA</p>

Course L0847: Aircraft Design II (Conceptual Design of Rotorcraft, special operations aircraft, UAV)	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Volker Gollnick, Dr. Bernd Liebhardt, Jens Thöben
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1248: Compilers for Embedded Systems				
Courses				
Title		Typ	Hrs/wk	CP
Compilers for Embedded Systems (L1692)		Lecture	3	4
Compilers for Embedded Systems (L1693)		Project-/problem-based Learning	1	2
Module Responsible	Prof. Heiko Falk			
Admission Requirements	None			
Recommended Previous Knowledge	Module "Embedded Systems" C/C++ Programming skills			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<p><i>Knowledge</i></p> <p>The relevance of embedded systems increases from year to year. Within such systems, the amount of software to be executed on embedded processors grows continuously due to its lower costs and higher flexibility. Because of the particular application areas of embedded systems, highly optimized and application-specific processors are deployed. Such highly specialized processors impose high demands on compilers which have to generate code of highest quality. After the successful attendance of this course, the students are able</p> <ul style="list-style-type: none"> • to illustrate the structure and organization of such compilers, • to distinguish and explain intermediate representations of various abstraction levels, and • to assess optimizations and their underlying problems in all compiler phases. <p>The high demands on compilers for embedded systems make effective code optimizations mandatory. The students learn in particular,</p> <ul style="list-style-type: none"> • which kinds of optimizations are applicable at the source code level, • how the translation from source code to assembly code is performed, • which kinds of optimizations are applicable at the assembly code level, • how register allocation is performed, and • how memory hierarchies can be exploited effectively. <p>Since compilers for embedded systems often have to optimize for multiple objectives (e.g., average- or worst-case execution time, energy dissipation, code size), the students learn to evaluate the influence of optimizations on these different criteria.</p> <p><i>Skills</i></p> <p>After successful completion of the course, students shall be able to translate high-level program code into machine code. They will be enabled to assess which kind of code optimization should be applied most effectively at which abstraction level (e.g., source or assembly code) within a compiler.</p> <p>While attending the labs, the students will learn to implement a fully functional compiler including optimizations.</p> <p>Personal Competence</p> <p><i>Social Competence</i></p> <p>Students are able to solve similar problems alone or in a group and to present the results accordingly.</p> <p><i>Autonomy</i></p> <p>Students are able to acquire new knowledge from specific literature and to associate this knowledge with other classes.</p>			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Oral exam			
Examination duration and scale	30 min			
Assignment for the Following Curricula	Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory			

Course L1692: Compilers for Embedded Systems	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	SoSe
Content	<ul style="list-style-type: none"> • Introduction and Motivation • Compilers for Embedded Systems - Requirements and Dependencies • Internal Structure of Compilers • Pre-Pass Optimizations • HIR Optimizations and Transformations • Code Generation • LIR Optimizations and Transformations • Register Allocation • WCET-Aware Compilation • Outlook
Literature	<ul style="list-style-type: none"> • Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2nd Edition, Springer, 2012. • Steven S. Muchnick. Advanced Compiler Design and Implementation. Morgan Kaufmann, 1997. • Andrew W. Appel. Modern compiler implementation in C. Oxford University Press, 1998.

Course L1693: Compilers for Embedded Systems	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0803: Embedded Systems				
Courses				
Title		Typ	Hrs/wk	CP
Embedded Systems (L0805)		Lecture	3	3
Embedded Systems (L2938)		Project-/problem-based Learning	1	1
Embedded Systems (L0806)		Recitation Section (small)	1	2
Module Responsible	Prof. Heiko Falk			
Admission Requirements	None			
Recommended Previous Knowledge	Computer Engineering			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<p><i>Knowledge</i> Embedded systems can be defined as information processing systems embedded into enclosing products. This course teaches the foundations of such systems. In particular, it deals with an introduction into these systems (notions, common characteristics) and their specification languages (models of computation, hierarchical automata, specification of distributed systems, task graphs, specification of real-time applications, translations between different models).</p> <p>Another part covers the hardware of embedded systems: Sensors, A/D and D/A converters, real-time capable communication hardware, embedded processors, memories, energy dissipation, reconfigurable logic and actuators. The course also features an introduction into real-time operating systems, middleware and real-time scheduling. Finally, the implementation of embedded systems using hardware/software co-design (hardware/software partitioning, high-level transformations of specifications, energy-efficient realizations, compilers for embedded processors) is covered.</p> <p><i>Skills</i> After having attended the course, students shall be able to realize simple embedded systems. The students shall realize which relevant parts of technological competences to use in order to obtain a functional embedded systems. In particular, they shall be able to compare different models of computations and feasible techniques for system-level design. They shall be able to judge in which areas of embedded system design specific risks exist.</p> <p>Personal Competence</p> <p><i>Social Competence</i> Students are able to solve similar problems alone or in a group and to present the results accordingly.</p> <p><i>Autonomy</i> Students are able to acquire new knowledge from specific literature and to associate this knowledge with other classes.</p>			
<i>Knowledge</i>				
<i>Skills</i>				
Personal Competence				
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points	6			
Course achievement	Compulsory	Bonus	Form	Description
	Yes	10 %	Subject	theoretical and practical work
Examination	Written exam			
Examination duration and scale	90 minutes, contents of course and labs			
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Compulsory Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Electrical Engineering: Core Qualification: Elective Compulsory Engineering Science: Specialisation Mechatronics: Elective Compulsory Engineering Science: Specialisation Electrical Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Mechatronics: Elective Compulsory Computer Science in Engineering: Core Qualification: Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Microelectronics and Microsystems: Specialisation Embedded Systems: Elective Compulsory			

Course L0805: Embedded Systems	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Heiko Falk
Language	EN
Cycle	SoSe
Content	<ul style="list-style-type: none"> • Introduction • Specifications and Modeling • Embedded/Cyber-Physical Systems Hardware • System Software • Evaluation and Validation • Mapping of Applications to Execution Platforms • Optimization
Literature	<ul style="list-style-type: none"> • Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2nd Edition, Springer, 2012., Springer, 2012.

Course L2938: Embedded Systems	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Heiko Falk
Language	EN
Cycle	SoSe
Content	<ul style="list-style-type: none"> • Introduction • Specifications and Modeling • Embedded/Cyber-Physical Systems Hardware • System Software • Evaluation and Validation • Mapping of Applications to Execution Platforms • Optimization
Literature	<ul style="list-style-type: none"> • Peter Marwedel. Embedded System Design - Embedded Systems Foundations of Cyber-Physical Systems. 2nd Edition, Springer, 2012., Springer, 2012.

Course L0806: Embedded Systems	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Heiko Falk
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0752: Nonlinear Dynamics				
Courses				
Title	Typ	Hrs/wk	CP	
Nonlinear Dynamics (L0702)	Integrated Lecture	4	6	
Module Responsible	Prof. Norbert Hoffmann			
Admission Requirements	None			
Recommended Previous Knowledge	<ul style="list-style-type: none"> • Calculus • Linear Algebra • Engineering Mechanics 			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence <i>Knowledge</i>	<ul style="list-style-type: none"> • Students are able to reflect existing terms and concepts in Nonlinear Dynamics and to develop and research new terms and concepts. • Students are able to denote and expand methods of modeling and analysis for nonlinear dynamical systems. 			
<i>Skills</i>	<ul style="list-style-type: none"> • Students are able to apply existing methods and procedures of Nonlinear Dynamics. • Students are able to develop novel methods and procedures for nonlinear dynamical systems. 			
Personal Competence <i>Social Competence</i>	<ul style="list-style-type: none"> • Students can analyze problems of nonlinear dynamics also in groups. • Students can achieve solution procedures for problems of nonlinear dynamical systems also in groups. 			
<i>Autonomy</i>	<ul style="list-style-type: none"> • Students are able to approach given research tasks on the basis of given methods individually. • Students are able to identify and follow up novel research tasks by themselves. 			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	2 Hours			
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory			

Course L0702: Nonlinear Dynamics	
Typ	Integrated Lecture
Hrs/wk	4
CP	6
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Lecturer	Prof. Norbert Hoffmann
Language	DE/EN
Cycle	SoSe
Content	<p>Fundamentals of Nonlinear Dynamics</p> <ul style="list-style-type: none"> • One dimensional problems <ul style="list-style-type: none"> ◦ Linear Stability ◦ Local Bifurcations ◦ Synchronisation • Two dimensional problems <ul style="list-style-type: none"> ◦ Limit Cycles ◦ Global Bifurcations • Chaos <ul style="list-style-type: none"> ◦ Lorenz Equations ◦ Fractals and Strange Attractors ◦ Predictability and Horizons
Literature	Steven Strogatz: Nonlinear Dynamics and Chaos.

Module M0714: Numerical Methods for Ordinary Differential Equations				
Courses				
Title		Typ	Hrs/wk	CP
Numerical Treatment of Ordinary Differential Equations (L0576)		Lecture	2	3
Numerical Treatment of Ordinary Differential Equations (L0582)		Recitation Section (small)	2	3
Module Responsible	Prof. Daniel Ruprecht			
Admission Requirements	None			
Recommended Previous Knowledge	<ul style="list-style-type: none"> Mathematik I, II, III für Ingenieurstudierende (deutsch oder englisch) oder Analysis & Lineare Algebra I + II sowie Analysis III für Technomathematiker Basic knowledge of MATLAB, Python or a similar programming language 			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence				
<i>Knowledge</i>	Students are able to <ul style="list-style-type: none"> list numerical methods for the solution of ordinary differential equations and explain their core ideas, formulate convergence statements for the treated numerical methods (including the assumptions about the underlying problem), explain aspects regarding the practical realisation of a method. select the appropriate numerical method for concrete problems, implement the numerical algorithms efficiently and interpret the numerical results 			
<i>Skills</i>	Students are able to <ul style="list-style-type: none"> implement, apply and compare numerical methods for the solution of ordinary differential equations, justify the convergence behaviour of numerical methods with respect to the posed problem and selected algorithm, develop a suitable solution approach for a given problem, if necessary by combining of several algorithms, and to realise this approach and critically evaluate the results. 			
Personal Competence				
<i>Social Competence</i>	Students are able to <ul style="list-style-type: none"> work together in heterogeneously composed teams (i.e., teams from different study programs and background knowledge), explain theoretical foundations and support each other with practical aspects regarding the implementation of algorithms. 			
<i>Autonomy</i>	Students are capable <ul style="list-style-type: none"> to assess whether the supporting theoretical and practical exercises are better solved individually or in a team, to assess their individual progress and, if necessary, to ask questions and seek help. 			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	90 min			
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Computer Science: Specialisation III. Mathematics: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Interdisciplinary Mathematics: Specialisation II. Numerical - Modelling Training: Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Technomathematics: Specialisation I. Mathematics: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory			

Course L0576: Numerical Treatment of Ordinary Differential Equations	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Daniel Ruprecht
Language	DE/EN
Cycle	SoSe
Content	<p>Numerical methods for Initial Value Problems</p> <ul style="list-style-type: none"> • single step methods • multistep methods • stiff problems • differential algebraic equations (DAE) of index 1 <p>Numerical methods for Boundary Value Problems</p> <ul style="list-style-type: none"> • multiple shooting method • difference methods
Literature	<ul style="list-style-type: none"> • E. Hairer, S. Noersett, G. Wanner: Solving Ordinary Differential Equations I: Nonstiff Problems. • E. Hairer, G. Wanner: Solving Ordinary Differential Equations II: Stiff and Differential-Algebraic Problems. • D. Griffiths, D. Higham: Numerical Methods for Ordinary Differential Equations.

Course L0582: Numerical Treatment of Ordinary Differential Equations	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Daniel Ruprecht
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0840: Optimal and Robust Control				
Courses				
Title	Typ	Hrs/wk	CP	
Optimal and Robust Control (L0658)	Lecture	2	3	
Optimal and Robust Control (L0659)	Recitation Section (small)	2	3	
Module Responsible	Prof. Herbert Werner			
Admission Requirements	None			
Recommended Previous Knowledge	<ul style="list-style-type: none"> • Classical control (frequency response, root locus) • State space methods • Linear algebra, singular value decomposition 			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence <i>Knowledge</i>	<ul style="list-style-type: none"> • Students can explain the significance of the matrix Riccati equation for the solution of LQ problems. • They can explain the duality between optimal state feedback and optimal state estimation. • They can explain how the H2 and H-infinity norms are used to represent stability and performance constraints. • They can explain how an LQG design problem can be formulated as special case of an H2 design problem. • They can explain how model uncertainty can be represented in a way that lends itself to robust controller design • They can explain how - based on the small gain theorem - a robust controller can guarantee stability and performance for an uncertain plant. • They understand how analysis and synthesis conditions on feedback loops can be represented as linear matrix inequalities. 			
<i>Skills</i>	<ul style="list-style-type: none"> • Students are capable of designing and tuning LQG controllers for multivariable plant models. • They are capable of representing a H2 or H-infinity design problem in the form of a generalized plant, and of using standard software tools for solving it. • They are capable of translating time and frequency domain specifications for control loops into constraints on closed-loop sensitivity functions, and of carrying out a mixed-sensitivity design. • They are capable of constructing an LFT uncertainty model for an uncertain system, and of designing a mixed-objective robust controller. • They are capable of formulating analysis and synthesis conditions as linear matrix inequalities (LMI), and of using standard LMI-solvers for solving them. • They can carry out all of the above using standard software tools (Matlab robust control toolbox). 			
Personal Competence <i>Social Competence</i>	Students can work in small groups on specific problems to arrive at joint solutions.			
<i>Autonomy</i>	Students are able to find required information in sources provided (lecture notes, literature, software documentation) and use it to solve given problems.			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Oral exam			
Examination duration and scale	30 min			
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory			

Course L0658: Optimal and Robust Control	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	SoSe
Content	<ul style="list-style-type: none"> • Optimal regulator problem with finite time horizon, Riccati differential equation • Time-varying and steady state solutions, algebraic Riccati equation, Hamiltonian system • Kalman's identity, phase margin of LQR controllers, spectral factorization • Optimal state estimation, Kalman filter, LQG control • Generalized plant, review of LQG control • Signal and system norms, computing H2 and H∞ norms • Singular value plots, input and output directions • Mixed sensitivity design, H∞ loop shaping, choice of weighting filters • Case study: design example flight control • Linear matrix inequalities, design specifications as LMI constraints (H2, H∞ and pole region) • Controller synthesis by solving LMI problems, multi-objective design • Robust control of uncertain systems, small gain theorem, representation of parameter uncertainty
Literature	<ul style="list-style-type: none"> • Werner, H., Lecture Notes: "Optimale und Robuste Regelung" • Boyd, S., L. El Ghaoui, E. Feron and V. Balakrishnan "Linear Matrix Inequalities in Systems and Control", SIAM, Philadelphia, PA, 1994 • Skogestad, S. and I. Postlewaite "Multivariable Feedback Control", John Wiley, Chichester, England, 1996 • Strang, G. "Linear Algebra and its Applications", Harcourt Brace Jovanovic, Orlando, FA, 1988 • Zhou, K. and J. Doyle "Essentials of Robust Control", Prentice Hall International, Upper Saddle River, NJ, 1998

Course L0659: Optimal and Robust Control	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Herbert Werner
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0837: Simulation of Communication Networks				
Courses				
Title		Typ	Hrs/wk	CP
Simulation of Communication Networks (L0887)		Project-/problem-based Learning	5	6
Module Responsible	Prof. Andreas Timm-Giel			
Admission Requirements	None			
Recommended Previous Knowledge	<ul style="list-style-type: none"> • Knowledge of computer and communication networks • Basic programming skills 			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence				
<i>Knowledge</i>	Students are able to explain the necessary stochastics, the discrete event simulation technology and modelling of networks for performance evaluation.			
<i>Skills</i>	Students are able to apply the method of simulation for performance evaluation to different, also not practiced, problems of communication networks. The students can analyse the obtained results and explain the effects observed in the network. They are able to question their own results.			
Personal Competence				
<i>Social Competence</i>	Students are able to acquire expert knowledge in groups, present the results, and discuss solution approaches and results. They are able to work out solutions for new problems in small teams.			
<i>Autonomy</i>	Students are able to transfer independently and in discussion with others the acquired method and expert knowledge to new problems. They can identify missing knowledge and acquire this knowledge independently.			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points	6			
Course achievement	None			
Examination	Oral exam			
Examination duration and scale	30 min			
Assignment for the Following Curricula	Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory			
Course L0887: Simulation of Communication Networks				
Typ	Project-/problem-based Learning			
Hrs/wk	5			
CP	6			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Lecturer	Prof. Andreas Timm-Giel			
Language	EN			
Cycle	SoSe			
Content	In the course necessary basic stochastics and the discrete event simulation are introduced. Also simulation models for communication networks, for example, traffic models, mobility models and radio channel models are presented in the lecture. Students work with a simulation tool, where they can directly try out the acquired skills, algorithms and models. At the end of the course increasingly complex networks and protocols are considered and their performance is determined by simulation.			
Literature	<ul style="list-style-type: none"> • Skript des Instituts für Kommunikationsnetze Further literature is announced at the beginning of the lecture.			

Module M0805: Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics)				
Courses				
Title		Typ	Hrs/wk	CP
Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics) (L0516)		Lecture	2	3
Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics) (L0518)		Recitation Section (large)	2	3
Module Responsible	Prof. Otto von Estorff			
Admission Requirements	None			
Recommended Previous Knowledge	Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics, Kinematics, Dynamics) Mathematics I, II, III (in particular differential equations)			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence				
<i>Knowledge</i>	The students possess an in-depth knowledge in acoustics regarding acoustic waves, noise protection, and psycho acoustics and are able to give an overview of the corresponding theoretical and methodical basis.			
<i>Skills</i>	The students are capable to handle engineering problems in acoustics by theory-based application of the demanding methodologies and measurement procedures treated within the module.			
Personal Competence				
<i>Social Competence</i>	Students can work in small groups on specific problems to arrive at joint solutions.			
<i>Autonomy</i>	The students are able to independently solve challenging acoustical problems in the areas treated within the module. Possible conflicting issues and limitations can be identified and the results are critically scrutinized.			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	90 min			
Assignment for the Following Curricula	Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory			
Course L0516: Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics)				
Typ	Lecture			
Hrs/wk	2			
CP	3			
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28			
Lecturer	Prof. Otto von Estorff			
Language	EN			
Cycle	SoSe			
Content	<ul style="list-style-type: none"> - Introduction and Motivation - Acoustic quantities - Acoustic waves - Sound sources, sound radiation - Sound energy and intensity - Sound propagation - Signal processing - Psycho acoustics - Noise - Measurements in acoustics 			
Literature	Cremer, L.; Heckl, M. (1996): Körperschall. Springer Verlag, Berlin Veit, I. (1988): Technische Akustik. Vogel-Buchverlag, Würzburg Veit, I. (1988): Flüssigkeitsschall. Vogel-Buchverlag, Würzburg			

Course L0518: Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics)	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Otto von Estorff
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1616: Flight Control Law Design and Application				
Courses				
Title	Typ	Hrs/wk	CP	
Flight Control Law Design and Application (L2448)	Lecture	2	4	
Flight Control Law Design and Application (L2449)	Project-/problem-based Learning	2	2	
Module Responsible	Prof. Frank Thielecke			
Admission Requirements	None			
Recommended Previous Knowledge	Basic knowledge in: * mathematics (linear algebra and ordinary differential equations) * control systems (transfer functions and state space representation) * mechanics (rigid-body kinetics) * flight mechanics			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	Students are able to: * describe and understand flight dynamics models for control tasks * assess handling qualities and understand the need for augmentation through control systems * identify fundamental performance limitations of control laws			
<i>Knowledge</i>				
<i>Skills</i>	Students are able to: * design model-based control laws for stability augmentation * design model-based flight control laws * assess robustness and performance of control laws			
Personal Competence	Students are able to: * design control laws in groups as well as discuss the requirements and results			
<i>Social Competence</i>				
<i>Autonomy</i>	Students are able to: * reflect on the contents of lectures and extend their knowledge through literature research * solve control design tasks with software tools			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	Compulsory	Bonus	Form	Description
	Yes	None	Attestation	Die in der Vorlesung vermittelten Kenntnisse werden in einem semesterbegleitenden Projekt direkt auf das Modell eines Passagierflugzeugs angewendet.
Examination	Written exam			
Examination duration and scale	60 min			
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory			

Course L2448: Flight Control Law Design and Application	
Typ	Lecture
Hrs/wk	2
CP	4
Workload in Hours	Independent Study Time 92, Study Time in Lecture 28
Lecturer	Prof. Frank Thielecke
Language	EN
Cycle	SoSe
Content	<ul style="list-style-type: none"> * flight dynamics (equations of motion, trim and linearization, linear models of longitudinal and lateral-directional motion, eigenforms) * stability augmentation (modal dynamics, damper design with root-loci, pole placement and eigenstructure assignment) * primary flight control laws and autopilots * design of flight control laws (loopshaping design, robustness criteria and analysis, cascaded control loops, gain-scheduling) * verification of flight control laws in simulation
Literature	<p>J. Theis: Lecture Notes Flight Control Law Design</p> <p>D. Schmidt: Modern Flight Dynamics</p> <p>B. Stevens, F. Lewis: Aircraft Control and Simulation</p> <p>D. McGruer, D. Graham, I. Ashkenas: Aircraft Dynamics and Automatic Control</p> <p>SAE Aerospace Standard 94900 - Flight Control Systems</p> <p>The MathWorks: Control Systems Design Toolbox User Guide</p>

Course L2449: Flight Control Law Design and Application	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Frank Thielecke
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1340: Introduction to Waveguides, Antennas, and Electromagnetic Compatibility				
Courses				
Title		Typ	Hrs/wk	CP
Introduction to Waveguides, Antennas, and Electromagnetic Compatibility (L1669)		Lecture	3	4
Introduction to Waveguides, Antennas, and Electromagnetic Compatibility (L1877)		Recitation Section (small)	2	2
Module Responsible	Prof. Christian Schuster			
Admission Requirements	None			
Recommended Previous Knowledge	Basic principles of physics and electrical engineering			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<p><i>Knowledge</i> Students can explain the basic principles, relationships, and methods for the design of waveguides and antennas as well as of Electromagnetic Compatibility. Specific topics are:</p> <ul style="list-style-type: none"> - Fundamental properties and phenomena of electrical circuits - Steady-state sinusoidal analysis of electrical circuits - Fundamental properties and phenomena of electromagnetic fields and waves - Steady-state sinusoidal description of electromagnetic fields and waves - Useful microwave network parameters - Transmission lines and basic results from transmission line theory - Plane wave propagation, superposition, reflection and refraction - General theory of waveguides - Most important types of waveguides and their properties - Radiation and basic antenna parameters - Most important types of antennas and their properties - Numerical techniques and CAD tools for waveguide and antenna design - Fundamentals of Electromagnetic Compatibility - Coupling mechanisms and countermeasures - Shielding, grounding, filtering - Standards and regulations - EMC measurement techniques <p><i>Skills</i> Students know how to apply various methods and models for characterization and choice of waveguides and antennas. They are able to assess and qualify their basic electromagnetic properties. They can apply results and strategies from the field of Electromagnetic Compatibility to the development of electrical components and systems.</p> <p>Personal Competence</p> <p><i>Social Competence</i> Students are able to work together on subject related tasks in small groups. They are able to present their results effectively in English (e.g. during small group exercises).</p> <p><i>Autonomy</i> Students are capable to gather information from subject related, professional publications and relate that information to the context of the lecture. They are able to make a connection between their knowledge obtained in this lecture with the content of other lectures (e.g. theory of electromagnetic fields, fundamentals of electrical engineering / physics). They can discuss technical problems and physical effects in English.</p>			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points	6			
Course achievement	None			
Examination	Oral exam			
Examination duration and scale	45 min			
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Electrical Engineering: Elective Compulsory Electrical Engineering: Core Qualification: Elective Compulsory Engineering Science: Specialisation Electrical Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory			

Course L1669: Introduction to Waveguides, Antennas, and Electromagnetic Compatibility	
Typ	Lecture
Hrs/wk	3
CP	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	SoSe
Content	<p>This course is intended as an introduction to the topics of wave propagation, guiding, sending, and receiving as well as Electromagnetic Compatibility (EMC). It will be useful for engineers that face the technical challenge of transmitting high frequency / high bandwidth data in e.g. medical, automotive, or avionic applications. Both circuit and field concepts of wave propagation and Electromagnetic Compatibility will be introduced and discussed.</p> <p>Topics:</p> <ul style="list-style-type: none"> - Fundamental properties and phenomena of electrical circuits - Steady-state sinusoidal analysis of electrical circuits - Fundamental properties and phenomena of electromagnetic fields and waves - Steady-state sinusoidal description of electromagnetic fields and waves - Useful microwave network parameters - Transmission lines and basic results from transmission line theory - Plane wave propagation, superposition, reflection and refraction - General theory of waveguides - Most important types of waveguides and their properties - Radiation and basic antenna parameters - Most important types of antennas and their properties - Numerical techniques and CAD tools for waveguide and antenna design - Fundamentals of Electromagnetic Compatibility - Coupling mechanisms and countermeasures - Shielding, grounding, filtering - Standards and regulations - EMC measurement techniques
Literature	<ul style="list-style-type: none"> - Zinke, Brunswig, "Hochfrequenztechnik 1", Springer (1999) - J. Detlefsen, U. Siart, "Grundlagen der Hochfrequenztechnik", Oldenbourg (2012) - D. M. Pozar, "Microwave Engineering", Wiley (2011) - Y. Huang, K. Boyle, "Antenna: From Theory to Practice", Wiley (2008) - H. Ott, "Electromagnetic Compatibility Engineering", Wiley (2009) - A. Schwab, W. Kürner, "Elektromagnetische Verträglichkeit", Springer (2007)

Course L1877: Introduction to Waveguides, Antennas, and Electromagnetic Compatibility	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Christian Schuster
Language	DE/EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M1287: Risk Management, Hydrogen and Fuel Cell Technology			
Courses			
Title	Typ	Hrs/wk	CP
Applied Fuel Cell Technology (L1831)	Lecture	2	2
Risk Management in the Energy Industry (L1748)	Lecture	2	2
Hydrogen Technology (L0060)	Lecture	2	2
Module Responsible	Prof. Martin Kaltschmitt		
Admission Requirements	None		
Recommended Previous Knowledge	None		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p><i>Knowledge</i> With completion of this module students can explain basics of risk management involving thematical adjacent contexts and can describe an optimal management of energy systems.</p> <p>Furthermore, students can reproduce solid theoretical knowledge about the potentials and applications of new information technologies in logistics and explain technical aspects of the use, production and processing of hydrogen.</p> <p><i>Skills</i> With completion of this module students are able to evaluate risks of energy systems with respect to energy economic conditions in an efficient way. This includes that the students can assess the risks in operational planning of power plants from a technical, economic and ecological perspective.</p> <p>In this context, students can evaluate the potentials of logistics and information technology in particular on energy issues.</p> <p>In addition, students are able to describe the energy transfer medium hydrogen according to its applications, the given security and its existing service capacities and limits as well as to evaluate these aspects from a technical, environmental and economic perspective.</p>		
Personal Competence	<p><i>Social Competence</i> Students are able to discuss issues in the thematic fields in the renewable energy sector addressed within the module.</p> <p><i>Autonomy</i> Students can independently exploit sources on the emphasis of the lectures and acquire the contained knowledge. In this way, they can recognize their lacks of knowledge and can consequently define the further workflow.</p>		
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84		
Credit points	6		
Course achievement	None		
Examination	Written exam		
Examination duration and scale	3 hours written exam		
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory		

Course L1831: Applied Fuel Cell Technology	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Klaus Bonhoff
Language	DE
Cycle	SoSe
Content	The lecture provide an insight into the various possibilities of fuel cells in the energy system (electricity, heat and transport). These are presented and discussed for individual fuel types and application-oriented requirements; also compared with alternative technologies in the system. These different possibilities will be presented regardind the state-of-the-art development of the technologies and exemplary applications from Germany and worldwide. Also the emerging trends and lines of development will be discussed. Besides to the technical aspects, which are the focus of the event, also energy, environmental and industrial policy aspects are discussed - also in the context of changing circumstances in the German and international energy system.
Literature	Vorlesungsunterlagen

Course L1748: Risk Management in the Energy Industry	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Christian Wulf
Language	DE
Cycle	SoSe
Content	<ul style="list-style-type: none"> • Basics of risk management <ul style="list-style-type: none"> ◦ Definition of terms ◦ Risk types ◦ Risk management process ◦ Enterprise risk management • Markets and instruments in energy trading <ul style="list-style-type: none"> ◦ Basics of futures and spot trading ◦ Notation in energy markets ◦ Options • Kennzahlendefinition <ul style="list-style-type: none"> ◦ Assessing of market risks ◦ Assessing of credit risks ◦ Assessing of operational risks ◦ Assessing of liquidity risks • Risk monitoring and reporting • Risk treatment
Literature	<ul style="list-style-type: none"> • Roggi, O. (2012): Risk Taking: A Corporate Governance Perspective, International Finance Corporation, New York • Hull, J. C. (2012): Options, Futures, and other Derivatives, 8. Auflage, Pearson Verlag, New York • Albrecht, P.; Maurer, R. (2008): Investment- und Risikomanagement, 3. Auflage, Schäffer-Poeschel Verlag, Stuttgart • Rittenberg, L.; Martens, F. (2012): Understanding and Communicating Risk Appetite, Treadway Commission, Durham

Course L0060: Hydrogen Technology	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	NN
Language	DE
Cycle	SoSe
Content	<ol style="list-style-type: none"> 1. Energy economy 2. Hydrogen economy 3. Occurrence and properties of hydrogen 4. Production of hydrogen (from hydrocarbons and by electrolysis) 5. Separation and purification Storage and transport of hydrogen 6. Security 7. Fuel cells 8. Projects
Literature	<ul style="list-style-type: none"> • Skriptum zur Vorlesung • Winter, Nitsch: Wasserstoff als Energieträger • Ullmann's Encyclopedia of Industrial Chemistry • Kirk, Othmer: Encyclopedia of Chemical Technology • Larminie, Dicks: Fuel cell systems explained

Module M0513: System Aspects of Renewable Energies				
Courses				
Title	Typ	Hrs/wk	CP	
Fuel Cells, Batteries, and Gas Storage: New Materials for Energy Production and Storage (L0021)	Lecture	2	2	
Energy Trading (L0019)	Lecture	1	1	
Energy Trading (L0020)	Recitation Section (small)	1	1	
Deep Geothermal Energy (L0025)	Lecture	2	2	
Module Responsible	Prof. Martin Kaltschmitt			
Admission Requirements	None			
Recommended Previous Knowledge	Module: Technical Thermodynamics I Module: Technical Thermodynamics II			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<p><i>Knowledge</i> Students are able to describe the processes in energy trading and the design of energy markets and can critically evaluate them in relation to current subject specific problems. Furthermore, they are able to explain the basics of thermodynamics of electrochemical energy conversion in fuel cells and can establish and explain the relationship to different types of fuel cells and their respective structure. Students can compare this technology with other energy storage options. In addition, students can give an overview of the procedure and the energetic involvement of deep geothermal energy.</p> <p><i>Skills</i> Students can apply the learned knowledge of storage systems for excessive energy to explain for various energy systems different approaches to ensure a secure energy supply. In particular, they can plan and calculate domestic, commercial and industrial heating equipment using energy storage systems in an energy-efficient way and can assess them in relation to complex power systems. In this context, students can assess the potential and limits of geothermal power plants and explain their operating mode.</p> <p>Furthermore, the students are able to explain the procedures and strategies for marketing of energy and apply it in the context of other modules on renewable energy projects. In this context they can unassistedly carry out analysis and evaluations of energie markets and energy trades.</p>			
Personal Competence				
<i>Social Competence</i>				
<i>Autonomy</i>	Students are able to discuss issues in the thematic fields in the renewable energy sector addressed within the module.			
<i>Autonomy</i>	Students can independently exploit sources , acquire the particular knowledge about the subject area and transform it to new questions.			
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84			
Credit points	6			
Course achievement	None			
Examination	Written exam			
Examination duration and scale	3 hours written exam			
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Renewable Energy: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Process Engineering and Biotechnology: Elective Compulsory Renewable Energies: Core Qualification: Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Environmental Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory Water and Environmental Engineering: Specialisation Water: Elective Compulsory Water and Environmental Engineering: Specialisation Environment: Elective Compulsory			

Course L0021: Fuel Cells, Batteries, and Gas Storage: New Materials for Energy Production and Storage	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Michael Fröba
Language	DE
Cycle	SoSe
Content	<ol style="list-style-type: none"> 1. Introduction to electrochemical energy conversion 2. Function and structure of electrolyte 3. Low-temperature fuel cell <ul style="list-style-type: none"> ◦ Types ◦ Thermodynamics of the PEM fuel cell ◦ Cooling and humidification strategy 4. High-temperature fuel cell <ul style="list-style-type: none"> ◦ The MCFC ◦ The SOFC ◦ Integration Strategies and partial reforming 5. Fuels <ul style="list-style-type: none"> ◦ Supply of fuel ◦ Reforming of natural gas and biogas ◦ Reforming of liquid hydrocarbons 6. Energetic Integration and control of fuel cell systems
Literature	<ul style="list-style-type: none"> • Hamann, C.; Vielstich, W.: Elektrochemie 3. Aufl.; Weinheim: Wiley - VCH, 2003

Course L0019: Energy Trading	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Michael Sagorje, Dr. Sven Orlowski
Language	DE
Cycle	SoSe
Content	<ul style="list-style-type: none"> • Basic concepts and tradable products in energy markets • Primary energy markets • Electricity Markets • European Emissions Trading Scheme • Influence of renewable energy • Real options • Risk management <p>Within the exercise the various tasks are actively discussed and applied to various cases of application.</p>
Literature	

Course L0020: Energy Trading	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Michael Sagorje, Dr. Sven Orlowski
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0025: Deep Geothermal Energy	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Ben Norden
Language	DE
Cycle	SoSe
Content	<ol style="list-style-type: none"> 1. Introduction to the deep geothermal use 2. Geological Basics I 3. Geological Basics II 4. Geology and thermal aspects 5. Rock Physical Aspects 6. Geochemical aspects 7. Exploration of deep geothermal reservoirs 8. Drilling technologies, piping and expansion 9. Borehole Geophysics 10. Underground system characterization and reservoir engineering 11. Microbiology and Upper-day system components 12. Adapted investment concepts, cost and environmental aspect
Literature	<ul style="list-style-type: none"> • Dipippo, R.: Geothermal Power Plants: Principles, Applications, Case Studies and Environmental Impact. Butterworth Heinemann; 3rd revised edition. (29. Mai 2012) • www.geo-energy.org • Edenhofer et al. (eds): Renewable Energy Sources and Climate Change Mitigation; Special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, 2012. • Kaltschmitt et al. (eds): Erneuerbare Energien: Systemtechnik, Wirtschaftlichkeit, Umweltaspekte. Springer, 5. Aufl. 2013. • Kaltschmitt et al. (eds): Energie aus Erdwärme. Spektrum Akademischer Verlag; Auflage: 1999 (3. September 2001) • Huenges, E. (ed.): Geothermal Energy Systems: Exploration, Development, and Utilization. Wiley-VCH Verlag GmbH & Co. KGaA; Auflage: 1. Auflage (19. April 2010)

Module M1213: Avionics for safety-critical Systems				
Courses				
Title		Typ	Hrs/wk	CP
Avionics of Safty Critical Systems (L1640)		Lecture	2	3
Avionics of Safty Critical Systems (L1641)		Recitation Section (small)	1	1
Avionics of Safty Critical Systems (L1652)		Practical Course	1	2
Module Responsible	Dr. Martin Halle			
Admission Requirements	None			
Recommended Previous Knowledge	Basic knowledge in: <ul style="list-style-type: none"> • Mathematics • Electrical Engineering • Informatics 			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence				
<i>Knowledge</i>	Students can: <ul style="list-style-type: none"> • describe the most important principles and components of safety-critical avionics • denote processes and standards of safety-critical software development • depict the principles of Integrated Modular Avionics (IMA) • can compare hardware and bus systems used in avionics • assess the difficulties of developing a safety-critical avionics system correctly 			
<i>Skills</i>	Students can ... <ul style="list-style-type: none"> • operate real-time hardware and simulations • program A653 applications • plan avionics architectures up to a certain extend • create test scripts and assess test results 			
Personal Competence				
<i>Social Competence</i>	Students can: <ul style="list-style-type: none"> • jointly develop solutions in inhomogeneous teams • exchange information formally with other teams • present development results in a convenient way 			
<i>Autonomy</i>	Students can: <ul style="list-style-type: none"> • understand the requirements for an avionics system • autonomously derive concepts for systems based on safety-critical avionics 			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	Compulsory	Bonus	Form	Description
	Yes	None	Subject	theoretical and practical work
Examination	Oral exam			
Examination duration and scale	30 min			
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory			

Course L1640: Avionics of Safty Critical Systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Dr. Martin Halle
Language	DE
Cycle	WiSe
Content	<p>Avionics are all kinds off flight electronics. Today there is no aircraft system function without avionics, and avionics are one main source of innovation in aerospace industry. Since many system functions are highly safety critical, the development of avionics hardware and software underlies mandatory constraints, technics, and processes. It is inevitable for system developers and computer engineers in aerospace industry to understand and master these. This lecture teaches the risks and techniques of developing safety critical hardware and software; major avionics components; integration; and test with a practical orientation. A focus is on Integrated Modular Avionics (IMA). The lecture is accompanied by a mandatory and laboratory exercises.</p> <p>Content:</p> <ol style="list-style-type: none"> 1. Introduction and Fundamentals 2. History and Flight Control 3. Concepts and Redundancy 4. Digital Computers 5. Interfaces and Signals 6. Busses 7. Networks 8. Aircraft Cockpit 9. Software Development 10. Model-based Development 11. Integrated Modular Avionics I 12. Integrated Modular Avionics II
Literature	<ul style="list-style-type: none"> • Moir, I.; Seabridge, A. & Jukes, M., Civil Avionics Systems Civil Avionics Systems, John Wiley & Sons, Ltd, 2013 • Spitzer, C. R. Spitzer, Digital Avionics Handbook, CRC Press, 2007 • FAA, Advanced Avionics Handbook U.S. Department of Transportation Federal Aviation Administration, 2009 • Moir, I. & Seabridge, A. Aircraft Systems, Wiley, 2008, 3

Course L1641: Avionics of Safty Critical Systems	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Martin Halle
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1652: Avionics of Safty Critical Systems	
Typ	Practical Course
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Dr. Martin Halle
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1204: Modelling and Optimization in Dynamics				
Courses				
Title		Typ	Hrs/wk	CP
Flexible Multibody Systems (L1632)		Lecture	2	3
Optimization of dynamical systems (L1633)		Lecture	2	3
Module Responsible	Prof. Robert Seifried			
Admission Requirements	None			
Recommended Previous Knowledge	<ul style="list-style-type: none"> • Mathematics I, II, III • Mechanics I, II, III, IV • Simulation of dynamical Systems 			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence				
<i>Knowledge</i>	Students demonstrate basic knowledge and understanding of modeling, simulation and analysis of complex rigid and flexible multibody systems and methods for optimizing dynamic systems after successful completion of the module.			
<i>Skills</i>	Students are able + to think holistically + to independently, securely and critically analyze and optimize basic problems of the dynamics of rigid and flexible multibody systems + to describe dynamics problems mathematically + to optimize dynamics problems			
Personal Competence				
<i>Social Competence</i>	Students are able to + solve problems in heterogeneous groups and to document the corresponding results.			
<i>Autonomy</i>	Students are able to + assess their knowledge by means of exercises. + acquaint themselves with the necessary knowledge to solve research oriented tasks.			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	None			
Examination	Oral exam			
Examination duration and scale	30 min			
Assignment for the Following Curricula	Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Elective Compulsory			

Course L1632: Flexible Multibody Systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Robert Seifried, Dr. Alexander Held
Language	DE
Cycle	WiSe
Content	<ol style="list-style-type: none"> 1. Basics of Multibody Systems 2. Basics of Continuum Mechanics 3. Linear finite element modelles and modell reduction 4. Nonlinear finite element Modelles: absolute nodal coordinate formulation 5. Kinematics of an elastic body 6. Kinetics of an elastic body 7. System assembly
Literature	<p>Schwertassek, R. und Wallrapp, O.: Dynamik flexibler Mehrkörpersysteme. Braunschweig, Vieweg, 1999.</p> <p>Seifried, R.: Dynamics of Underactuated Multibody Systems, Springer, 2014.</p> <p>Shabana, A.A.: Dynamics of Multibody Systems. Cambridge Univ. Press, Cambridge, 2004, 3. Auflage.</p>

Course L1633: Optimization of dynamical systems	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Robert Seifried, Dr. Alexander Held
Language	DE
Cycle	WiSe
Content	<ol style="list-style-type: none"> 1. Formulation and classification of optimization problems 2. Scalar Optimization 3. Sensitivity Analysis 4. Unconstrained Parameter Optimization 5. Constrained Parameter Optimization 6. Stochastic optimization 7. Multicriteria Optimization 8. Topology Optimization
Literature	<p>Bestle, D.: Analyse und Optimierung von Mehrkörpersystemen. Springer, Berlin, 1994.</p> <p>Nocedal, J. , Wright , S.J. : Numerical Optimization. New York: Springer, 2006.</p>

Module M0633: Industrial Process Automation				
Courses				
Title	Typ	Hrs/wk	CP	
Industrial Process Automation (L0344)	Lecture	2	3	
Industrial Process Automation (L0345)	Recitation Section (small)	2	3	
Module Responsible	Prof. Alexander Schlaefer			
Admission Requirements	None			
Recommended Previous Knowledge	mathematics and optimization methods principles of automata principles of algorithms and data structures programming skills			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	<p><i>Knowledge</i> The students can evaluate and assess discrete event systems. They can evaluate properties of processes and explain methods for process analysis. The students can compare methods for process modelling and select an appropriate method for actual problems. They can discuss scheduling methods in the context of actual problems and give a detailed explanation of advantages and disadvantages of different programming methods. The students can relate process automation to methods from robotics and sensor systems as well as to recent topics like 'cyberphysical systems' and 'industry 4.0'.</p> <p><i>Skills</i> The students are able to develop and model processes and evaluate them accordingly. This involves taking into account optimal scheduling, understanding algorithmic complexity, and implementation using PLCs.</p> <p>Personal Competence</p> <p><i>Social Competence</i> The students can independently define work processes within their groups, distribute tasks within the group and develop solutions collaboratively.</p> <p><i>Autonomy</i> The students are able to assess their level of knowledge and to document their work results adequately.</p>			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	Compulsory	Bonus	Form	Description
	No	10 %	Exercises	
Examination	Written exam			
Examination duration and scale	90 minutes			
Assignment for the Following Curricula	Bioprocess Engineering: Specialisation A - General Bioprocess Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Chemical and Bioprocess Engineering: Specialisation General Process Engineering: Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechanical Engineering and Management: Specialisation Mechatronics: Elective Compulsory Mechatronics: Specialisation Intelligent Systems and Robotics: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Process Engineering: Specialisation Chemical Process Engineering: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory			

Course L0344: Industrial Process Automation	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> - foundations of problem solving and system modeling, discrete event systems - properties of processes, modeling using automata and Petri-nets - design considerations for processes (mutex, deadlock avoidance, liveness) - optimal scheduling for processes - optimal decisions when planning manufacturing systems, decisions under uncertainty - software design and software architectures for automation, PLCs
Literature	<p>J. Lunze: „Automatisierungstechnik“, Oldenbourg Verlag, 2012</p> <p>Reisig: Petrinetze: Modellierungstechnik, Analysemethoden, Fallstudien; Vieweg+Teubner 2010</p> <p>Hrúz, Zhou: Modeling and Control of Discrete-event Dynamic Systems; Springer 2007</p> <p>Li, Zhou: Deadlock Resolution in Automated Manufacturing Systems, Springer 2009</p> <p>Pinedo: Planning and Scheduling in Manufacturing and Services, Springer 2009</p>

Course L0345: Industrial Process Automation	
Typ	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Alexander Schlaefer
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0791: Computer Architecture				
Courses				
Title		Typ	Hrs/wk	CP
Computer Architecture (L0793)		Lecture	2	3
Computer Architecture (L0794)		Project-/problem-based Learning	2	2
Computer Architecture (L1864)		Recitation Section (small)	1	1
Module Responsible	Prof. Heiko Falk			
Admission Requirements	None			
Recommended Previous Knowledge	Module "Computer Engineering"			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence				
<i>Knowledge</i>	This module presents advanced concepts from the discipline of computer architecture. In the beginning, a broad overview over various programming models is given, both for general-purpose computers and for special-purpose machines (e.g., signal processors). Next, foundational aspects of the micro-architecture of processors are covered. Here, the focus particularly lies on the so-called pipelining and the methods used for the acceleration of instruction execution used in this context. The students get to know concepts for dynamic scheduling, branch prediction, superscalar execution of machine instructions and for memory hierarchies.			
<i>Skills</i>	The students are able to describe the organization of processors. They know the different architectural principles and programming models. The students examine various structures of pipelined processor architectures and are able to explain their concepts and to analyze them w.r.t. criteria like, e.g., performance or energy efficiency. They evaluate different structures of memory hierarchies, know parallel computer architectures and are able to distinguish between instruction- and data-level parallelism.			
Personal Competence				
<i>Social Competence</i>	Students are able to solve similar problems alone or in a group and to present the results accordingly.			
<i>Autonomy</i>	Students are able to acquire new knowledge from specific literature and to associate this knowledge with other classes.			
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70			
Credit points	6			
Course achievement	Compulsory	Bonus	Form	Description
	No	15 %	Subject theoretical and practical work	
Examination	Written exam			
Examination duration and scale	90 minutes, contents of course and 4 attestations from the PBL "Computer architecture"			
Assignment for the Following Curricula	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Computer Science in Engineering: Specialisation I. Computer Science: Elective Compulsory Microelectronics and Microsystems: Specialisation Embedded Systems: Elective Compulsory			

Course L0793: Computer Architecture	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> • Introduction • VHDL Basics • Programming Models • Realization of Elementary Data Types • Dynamic Scheduling • Branch Prediction • Superscalar Machines • Memory Hierarchies <p>The theoretical tutorials amplify the lecture's content by solving and discussing exercise sheets and thus serve as exam preparation. Practical aspects of computer architecture are taught in the FPGA-based PBL on computer architecture whose attendance is mandatory.</p>
Literature	<ul style="list-style-type: none"> • D. Patterson, J. Hennessy. Rechnerorganisation und -entwurf. Elsevier, 2005. • A. Tanenbaum, J. Goodman. Computerarchitektur. Pearson, 2001.

Course L0794: Computer Architecture	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Course L1864: Computer Architecture	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Heiko Falk
Language	DE/EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0563: Robotics				
Courses				
Title		Typ	Hrs/wk	CP
Robotics: Modelling and Control (L0168)		Integrated Lecture	4	4
Robotics: Modelling and Control (L1305)		Project-/problem-based Learning	2	2
Module Responsible	Dr. Martin Gomse			
Admission Requirements	None			
Recommended Previous Knowledge	Fundamentals of electrical engineering Broad knowledge of mechanics Fundamentals of control theory			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence	Students are able to describe fundamental properties of robots and solution approaches for multiple problems in robotics. Students are able to derive and solve equations of motion for various manipulators. Students can generate trajectories in various coordinate systems. Students can design linear and partially nonlinear controllers for robotic manipulators.			
Personal Competence	Students are able to work goal-oriented in small mixed groups. Students are able to recognize and improve knowledge deficits independently. With instructor assistance, students are able to evaluate their own knowledge level and define a further course of study.			
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84			
Credit points	6			
Course achievement	Compulsory	Bonus	Form	Description
	Yes	None	Subject theoretical and practical work	Teilnahme an PBL-Einheiten sowie Erreichen des Gesamtziels und der jeweiligen Session-Ziele
Examination	Written exam			
Examination duration and scale	120 min			
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory Mechanical Engineering and Management: Core Qualification: Compulsory Mechatronics: Core Qualification: Compulsory Product Development, Materials and Production: Specialisation Product Development: Elective Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory			

Course L0168: Robotics: Modelling and Control	
Typ	Integrated Lecture
Hrs/wk	4
CP	4
Workload in Hours	Independent Study Time 64, Study Time in Lecture 56
Lecturer	Dr. Martin Gomse
Language	EN
Cycle	WiSe
Content	Fundamental kinematics of rigid body systems Newton-Euler equations for manipulators Trajectory generation Linear and nonlinear control of robots
Literature	Craig, John J.: Introduction to Robotics Mechanics and Control, Third Edition, Prentice Hall. ISBN 0201-54361-3 Spong, Mark W.; Hutchinson, Seth; Vidyasagar, M. : Robot Modeling and Control. WILEY. ISBN 0-471-64990-2

Course L1305: Robotics: Modelling and Control	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Martin Gomse
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0806: Technical Acoustics II (Room Acoustics, Computational Methods)			
Courses			
Title		Typ	Hrs/wk CP
Technical Acoustics II (Room Acoustics, Computational Methods) (L0519)		Lecture	2 3
Technical Acoustics II (Room Acoustics, Computational Methods) (L0521)		Recitation Section (large)	2 3
Module Responsible	Prof. Otto von Estorff		
Admission Requirements	None		
Recommended Previous Knowledge	Technical Acoustics I (Acoustic Waves, Noise Protection, Psycho Acoustics) Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics, Kinematics, Dynamics) Mathematics I, II, III (in particular differential equations)		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<i>Knowledge</i> The students possess an in-depth knowledge in acoustics regarding room acoustics and computational methods and are able to give an overview of the corresponding theoretical and methodical basis. <i>Skills</i> The students are capable to handle engineering problems in acoustics by theory-based application of the demanding computational methods and procedures treated within the module.		
Personal Competence	<i>Social Competence</i> Students can work in small groups on specific problems to arrive at joint solutions. <i>Autonomy</i> The students are able to independently solve challenging acoustical problems in the areas treated within the module. Possible conflicting issues and limitations can be identified and the results are critically scrutinized.		
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56		
Credit points	6		
Course achievement	None		
Examination	Oral exam		
Examination duration and scale	20-30 Minuten		
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Product Development, Materials and Production: Core Qualification: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Simulation Technology: Elective Compulsory		

Course L0519: Technical Acoustics II (Room Acoustics, Computational Methods)	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Otto von Estorff
Language	EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> - Room acoustics - Sound absorber - Standard computations - Statistical Energy Approaches - Finite Element Methods - Boundary Element Methods - Geometrical acoustics - Special formulations - Practical applications - Hands-on Sessions: Programming of elements (Matlab)
Literature	Cremer, L.; Heckl, M. (1996): Körperschall. Springer Verlag, Berlin Veit, I. (1988): Technische Akustik. Vogel-Buchverlag, Würzburg Veit, I. (1988): Flüssigkeitsschall. Vogel-Buchverlag, Würzburg Gaul, L.; Fiedler, Ch. (1997): Methode der Randelemente in Statik und Dynamik. Vieweg, Braunschweig, Wiesbaden Bathe, K.-J. (2000): Finite-Elemente-Methoden. Springer Verlag, Berlin

Course L0521: Technical Acoustics II (Room Acoustics, Computational Methods)	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Otto von Estorff
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0808: Finite Elements Methods				
Courses				
Title		Typ	Hrs/wk	CP
Finite Element Methods (L0291)		Lecture	2	3
Finite Element Methods (L0804)		Recitation Section (large)	2	3
Module Responsible	Prof. Otto von Estorff			
Admission Requirements	None			
Recommended Previous Knowledge	Mechanics I (Statics, Mechanics of Materials) and Mechanics II (Hydrostatics, Kinematics, Dynamics) Mathematics I, II, III (in particular differential equations)			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence				
<i>Knowledge</i>	The students possess an in-depth knowledge regarding the derivation of the finite element method and are able to give an overview of the theoretical and methodical basis of the method.			
<i>Skills</i>	The students are capable to handle engineering problems by formulating suitable finite elements, assembling the corresponding system matrices, and solving the resulting system of equations.			
Personal Competence				
<i>Social Competence</i>	Students can work in small groups on specific problems to arrive at joint solutions.			
<i>Autonomy</i>	The students are able to independently solve challenging computational problems and develop own finite element routines. Problems can be identified and the results are critically scrutinized.			
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56			
Credit points	6			
Course achievement	Compulsory	Bonus	Form	Description
	No	20 %	Midterm	
Examination	Written exam			
Examination duration and scale	120 min			
Assignment for the Following Curricula	Civil Engineering: Core Qualification: Compulsory Energy Systems: Core Qualification: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Mechatronics: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechatronics: Core Qualification: Compulsory Biomedical Engineering: Specialisation Implants and Endoprostheses: Compulsory Biomedical Engineering: Specialisation Management and Business Administration: Elective Compulsory Biomedical Engineering: Specialisation Medical Technology and Control Theory: Elective Compulsory Biomedical Engineering: Specialisation Artificial Organs and Regenerative Medicine: Elective Compulsory Product Development, Materials and Production: Core Qualification: Compulsory Technomathematics: Specialisation III. Engineering Science: Elective Compulsory Theoretical Mechanical Engineering: Core Qualification: Compulsory			

Course L0291: Finite Element Methods	
Typ	Lecture
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Otto von Estorff
Language	EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> - General overview on modern engineering - Displacement method - Hybrid formulation - Isoparametric elements - Numerical integration - Solving systems of equations (statics, dynamics) - Eigenvalue problems - Non-linear systems - Applications - Programming of elements (Matlab, hands-on sessions) - Applications
Literature	Bathe, K.-J. (2000): Finite-Elemente-Methoden. Springer Verlag, Berlin

Course L0804: Finite Element Methods	
Typ	Recitation Section (large)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Otto von Estorff
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M1024: Methods of Integrated Product Development			
Courses			
Title	Typ	Hrs/wk	CP
Integrated Product Development II (L1254)	Lecture	3	3
Integrated Product Development II (L1255)	Project-/problem-based Learning	2	3
Module Responsible	Prof. Dieter Krause		
Admission Requirements	None		
Recommended Previous Knowledge	Basic knowledge of Integrated product development and applying CAE systems		
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<p><i>Knowledge</i> After passing the module students are able to:</p> <ul style="list-style-type: none"> • explain technical terms of design methodology, • describe essential elements of construction management, • describe current problems and the current state of research of integrated product development. <p><i>Skills</i> After passing the module students are able to:</p> <ul style="list-style-type: none"> • select and apply proper construction methods for non-standardized solutions of problems as well as adapt new boundary conditions, • solve product development problems with the assistance of a workshop based approach, • choose and execute appropriate moderation techniques. <p>Personal Competence</p> <p><i>Social Competence</i> After passing the module students are able to:</p> <ul style="list-style-type: none"> • prepare and lead team meetings and moderation processes, • work in teams on complex tasks, • represent problems and solutions and advance ideas. <p><i>Autonomy</i> After passing the module students are able to:</p> <ul style="list-style-type: none"> • give a structured feedback and accept a critical feedback, • implement the accepted feedback autonomously. 		
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70		
Credit points	6		
Course achievement	None		
Examination	Oral exam		
Examination duration and scale	30 Minuten		
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Product Development, Materials and Production: Specialisation Product Development: Compulsory Product Development, Materials and Production: Specialisation Production: Elective Compulsory Product Development, Materials and Production: Specialisation Materials: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory		

Course L1254: Integrated Product Development II	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Dieter Krause
Language	DE
Cycle	WiSe
Content	<p>Lecture</p> <p>The lecture extends and enhances the learned content of the module "Integrated Product Development and lightweight design" and is based on the knowledge and skills acquired there.</p> <p>Topics of the course include in particular:</p> <ul style="list-style-type: none"> • Methods of product development, • Presentation techniques, • Industrial Design, • Design for variety • Modularization methods, • Design catalogs, • Adapted QFD matrix, • Systematic material selection, • Assembly oriented design, <p>Construction management</p> <ul style="list-style-type: none"> • CE mark, declaration of conformity including risk assessment, • Patents, patent rights, patent monitoring • Project management (cost, time, quality) and escalation principles, • Development management for mechatronics, • Technical Supply Chain Management. <p>Exercise (PBL)</p> <p>In the exercise the content presented in the lecture "Integrated Product Development II" and methods of product development and design management will be enhanced.</p> <p>Students learn an independently moderated and workshop based approach through industry related practice examples to solve complex and currently existing issues in product development. They will learn the ability to apply important methods of product development and design management autonomous and acquire further expertise in the field of integrated product development. Besides personal skills, such as teamwork, guiding discussions and representing work results will be acquired through the workshop based structure of the event under its own planning and management.</p>
Literature	<ul style="list-style-type: none"> • Andreasen, M.M., Design for Assembly, Berlin, Springer 1985. • Ashby, M. F.: Materials Selection in Mechanical Design, München, Spektrum 2007. • Beckmann, H.: Supply Chain Management, Berlin, Springer 2004. • Hartmann, M., Rieger, M., Funk, R., Rath, U.: Zielgerichtet moderieren. Ein Handbuch für Führungskräfte, Berater und Trainer, Weinheim, Beltz 2007. • Pahl, G., Beitz, W.: Konstruktionslehre, Berlin, Springer 2006. • Roth, K.H.: Konstruieren mit Konstruktionskatalogen, Band 1-3, Berlin, Springer 2000. • Simpson, T.W., Siddique, Z., Jiao, R.J.: Product Platform and Product Family Design. Methods and Applications, New York, Springer 2013.

Course L1255: Integrated Product Development II	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Dieter Krause
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Module M0836: Communication Networks	
Courses	
Title	Typ Hrs/wk CP
Selected Topics of Communication Networks (L0899)	Project-/problem-based Learning 2 2
Communication Networks (L0897)	Lecture 2 2
Communication Networks Exercise (L0898)	Project-/problem-based Learning 1 2
Module Responsible	Prof. Andreas Timm-Giel
Admission Requirements	None
Recommended Previous Knowledge	<ul style="list-style-type: none"> Fundamental stochastics Basic understanding of computer networks and/or communication technologies is beneficial
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
<i>Knowledge</i>	Students are able to describe the principles and structures of communication networks in detail. They can explain the formal description methods of communication networks and their protocols. They are able to explain how current and complex communication networks work and describe the current research in these examples.
<i>Skills</i>	Students are able to evaluate the performance of communication networks using the learned methods. They are able to work out problems themselves and apply the learned methods. They can apply what they have learned autonomously on further and new communication networks.
Personal Competence	
<i>Social Competence</i>	Students are able to define tasks themselves in small teams and solve these problems together using the learned methods. They can present the obtained results. They are able to discuss and critically analyse the solutions.
<i>Autonomy</i>	Students are able to obtain the necessary expert knowledge for understanding the functionality and performance capabilities of new communication networks independently.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Presentation
Examination duration and scale	1.5 hours colloquium with three students, therefore about 30 min per student. Topics of the colloquium are the posters from the previous poster session and the topics of the module.
Assignment for the Following Curricula	Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Core Qualification: Elective Compulsory Computer Science in Engineering: Specialisation I. Computer Science: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory International Management and Engineering: Specialisation II. Information Technology: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L0899: Selected Topics of Communication Networks	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Andreas Timm-Giel
Language	EN
Cycle	WiSe
Content	Example networks selected by the students will be researched on in a PBL course by the students in groups and will be presented in a poster session at the end of the term.
Literature	<ul style="list-style-type: none"> see lecture

Course L0897: Communication Networks	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Andreas Timm-Giel, Dr.-Ing. Koojana Kuladinithi
Language	EN
Cycle	WiSe
Content	
Literature	<ul style="list-style-type: none"> • Skript des Instituts für Kommunikationsnetze • Tannenbaum, Computernetzwerke, Pearson-Studium <p>Further literature is announced at the beginning of the lecture.</p>

Course L0898: Communication Networks Exercise	
Typ	Project-/problem-based Learning
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Andreas Timm-Giel
Language	EN
Cycle	WiSe
Content	Part of the content of the lecture Communication Networks are reflected in computing tasks in groups, others are motivated and addressed in the form of a PBL exercise.
Literature	<ul style="list-style-type: none"> • announced during lecture

Module M1399: System Development Projekt				
Courses				
Title	Typ	Hrs/wk	CP	
Systems Engineering Development Project I+II (Block Event) (L1993)	Project-/problem-based Learning	12	12	
Module Responsible	Prof. Frank Thielecke			
Admission Requirements	None			
Recommended Previous Knowledge	Basic knowledge in: <ul style="list-style-type: none"> • Mathematics • Mechanics • Electrical Engineering • Control Systems 			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence				
<i>Knowledge</i>	Students are able to...			
	<ul style="list-style-type: none"> • Name and explain all phases of the systems engineering process (V-Model) • Describe tools for systems engineering 			
<i>Skills</i>	Students are able to...			
	<ul style="list-style-type: none"> • Define requirements for a system • Document and evaluate the system development process by using suitable tools • Design a system • Plan, execute and interpret system tests 			
Personal Competence				
<i>Social Competence</i>	Students are able to...			
	<ul style="list-style-type: none"> • Perform a complete system design in small groups • Develop technical solutions in small groups as well as discuss, prepare and present these solutions to a plenum • Lead team meetings and group work 			
<i>Autonomy</i>	Students are able to...			
	<ul style="list-style-type: none"> • Define tasks and tap required knowledge • Choose suitable methods for different systems engineering tasks 			
Workload in Hours	Independent Study Time 192, Study Time in Lecture 168			
Credit points	12			
Course achievement	None			
Examination	Written elaboration			
Examination duration and scale	approx. 60 - 200 pages			
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Compulsory			

Course L1993: Systems Engineering Development Project I+II (Block Event)	
Typ	Project-/problem-based Learning
Hrs/wk	12
CP	12
Workload in Hours	Independent Study Time 192, Study Time in Lecture 168
Lecturer	Prof. Frank Thielecke
Language	DE
Cycle	WiSe
Content	
Literature	Wird in der Veranstaltung bekannt gegeben

Module M1354: Advanced Fuels				
Courses				
Title		Typ	Hrs/wk	CP
Second generation biofuels and electricity based fuels (L2414)		Lecture	2	2
Carbon dioxide as an economic determinant in the mobility sector (L1926)		Lecture	1	1
Mobility and climate protection (L2416)		Recitation Section (small)	2	2
Sustainability aspects and regulatory framework (L2415)		Lecture	1	1
Module Responsible	Prof. Martin Kaltschmitt			
Admission Requirements	None			
Recommended Previous Knowledge	Bachelor degree in Process Engineering, Bioprocess Engineering or Energy- and Environmental Engineering			
Educational Objectives	After taking part successfully, students have reached the following learning results			
Professional Competence				
<i>Knowledge</i>	Within the module, students learn about different provision pathways for the production of advanced fuels (biofuels like e.g. alcohol-to-jet; electricity-based fuels like e.g. power-to-liquid). The different processes chains are explained and the regulatory framework for sustainable fuel production is examined. This includes, for example, the requirements of the Renewable Energies Directive II and the conditions and aspects for a market ramp-up of these fuels. For the holistic assessment of the various fuel options, they are also examined under environmental and economic factors.			
<i>Skills</i>	After successfully participating, the students are able to solve simulation and application tasks of renewable energy technology: <ul style="list-style-type: none"> • Module-spanning solutions for the design and presentation of fuel production processes resp. the fuel provision chains • Comprehensive analysis of various fuel production options in technical, ecological and economic terms Through active discussions of the various topics within the lectures and exercises of the module, the students improve their understanding and application of the theoretical foundations and are thus able to transfer the learned to the practice.			
Personal Competence				
<i>Social Competence</i>	The students can discuss scientific tasks in a subject-specific and interdisciplinary way and develop joint solutions.			
<i>Autonomy</i>	The students are able to access independent sources about the questions to be addressed and to acquire the necessary knowledge. They are able to assess their respective learning situation concretely in consultation with their supervisor and to define further questions and solutions.			
Workload in Hours	Independent Study Time 96, Study Time in Lecture 84			
Credit points	6			
Course achievement	Compulsory	Bonus	Form	Description
	Yes	20 %	Written elaboration	Details werden in der ersten Veranstaltung bekannt gegeben.
Examination	Written exam			
Examination duration and scale	2 hours written exam			
Assignment for the Following Curricula	Aircraft Systems Engineering: Core Qualification: Elective Compulsory Renewable Energies: Specialisation Bioenergy Systems: Elective Compulsory Renewable Energies: Specialisation Solar Energy Systems: Elective Compulsory Renewable Energies: Specialisation Wind Energy Systems: Elective Compulsory			

Course L2414: Second generation biofuels and electricity based fuels	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Martin Kaltschmitt
Language	DE/EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> • General overview of various power-based fuels and their process paths, including power-to-liquid process (Fischer-Tropsch synthesis, methanol synthesis), power-to-gas (Sabatier process) • Origin, production and use of these fuels
Literature	<ul style="list-style-type: none"> • Vorlesungsskript

Course L1926: Carbon dioxide as an economic determinant in the mobility sector	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Karsten Wilbrand
Language	DE/EN
Cycle	WiSe
Content	<ul style="list-style-type: none"> • General overview of various advanced biofuels and their process pathways (including gas-to-liquid, HEFA and Alcohol-to-Jet processes) • Origin, production and use of these fuels
Literature	<ul style="list-style-type: none"> • Babu, V.: Biofuels Production. Beverly, Mass: Scrivener [u.a.], 2013 • Olsson, L.: Biofuels. Berlin, Heidelberg: Springer-Verlag Berlin Heidelberg, 2007 • William, L. L.: Distillation Design and Control Using Aspen Simulation; ISBN-10: 0-471-77888-5 • Perry, R.; Green, R.: Perry's Chemical Engineers' Handbook, 8th Edition, McGraw Hill Professional, 20 • Sinnott, R. K.: Chemical Engineering Design, Elsevier, 2014 • Kaltschmitt, M.; Neuling, U. (Ed.): Biokerosene - Status and Prospects; Springer, Berlin, Heidelberg, 2018

Course L2416: Mobility and climate protection	
Typ	Recitation Section (small)
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Dr. Benedikt Buchspies, Dr. Karsten Wilbrand
Language	DE/EN
Cycle	WiSe
Content	<p>Application of the acquired theoretical knowledge from the respective lectures on the basis of concrete tasks from practice</p> <ul style="list-style-type: none"> • Design and simulation of sub-processes of production processes in Aspen Plus ® • Ecological and economic analysis of fuel supply paths • Classification of case studies into applicable regulations
Literature	<ul style="list-style-type: none"> • Skriptum zur Vorlesung • Aspen Plus® - Aspen Plus User Guide

Course L2415: Sustainability aspects and regulatory framework	
Typ	Lecture
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Dr. Benedikt Buchspies
Language	DE/EN
Cycle	WiSe
Content	<p>Holistic examination of the different fuel paths with the following main topics, among others:</p> <ul style="list-style-type: none"> • Consideration of the environmental impact of the various alternative fuels • Economic consideration of the different alternative fuels • Regulatory framework for alternative fuels • Certification of alternative fuels • Market introduction models of alternative fuels
Literature	<ul style="list-style-type: none"> • European Commission - Joint Research Center (2010): International Reference Life Cycle Data System (ILCD) Handbook - General guide for Life Cycle Assessment - Detailed guidance. Joint Research Center (JRC) Institut for Environment and Sustainability, Luxembourg • Richtlinie (EU) 2018/2001 des Europäischen Parlaments und des Rates vom 11. Dezember 2018 zur Förderung der Nutzung von Energie aus erneuerbaren Quellen

Thesis

In their master's thesis students work independently on research-oriented problems, structuring the task into different sub-aspects and apply systematically the specialized competences they have acquired in the course of the study program.

Special importance is attached to a scientific approach to the problem including, in addition to an overview of literature on the subject, its classification in relation to current issues, a description of the theoretical foundations, and a critical analysis and assessment of the results.

Module M-002: Master Thesis			
Courses			
Title	Typ	Hrs/wk	CP
Module Responsible	Professoren der TUHH		
Admission Requirements	<ul style="list-style-type: none"> According to General Regulations §21 (1): <p>At least 60 credit points have to be achieved in study programme. The examinations board decides on exceptions.</p>		
Recommended Previous Knowledge			
Educational Objectives	After taking part successfully, students have reached the following learning results		
Professional Competence	<ul style="list-style-type: none"> The students can use specialized knowledge (facts, theories, and methods) of their subject competently on specialized issues. The students can explain in depth the relevant approaches and terminologies in one or more areas of their subject, describing current developments and taking up a critical position on them. The students can place a research task in their subject area in its context and describe and critically assess the state of research. 		
<i>Knowledge</i>			
<i>Skills</i>	<p>The students are able:</p> <ul style="list-style-type: none"> To select, apply and, if necessary, develop further methods that are suitable for solving the specialized problem in question. To apply knowledge they have acquired and methods they have learnt in the course of their studies to complex and/or incompletely defined problems in a solution-oriented way. To develop new scientific findings in their subject area and subject them to a critical assessment. 		
Personal Competence	<p>Students can</p> <ul style="list-style-type: none"> Both in writing and orally outline a scientific issue for an expert audience accurately, understandably and in a structured way. Deal with issues competently in an expert discussion and answer them in a manner that is appropriate to the addressees while upholding their own assessments and viewpoints convincingly. 		
<i>Social Competence</i>			
<i>Autonomy</i>	<p>Students are able:</p> <ul style="list-style-type: none"> To structure a project of their own in work packages and to work them off accordingly. To work their way in depth into a largely unknown subject and to access the information required for them to do so. To apply the techniques of scientific work comprehensively in research of their own. 		
Workload in Hours	Independent Study Time 900, Study Time in Lecture 0		
Credit points	30		
Course achievement	None		
Examination	Thesis		
Examination duration and scale	According to General Regulations		
Assignment for the Following Curricula	Civil Engineering: Thesis: Compulsory Bioprocess Engineering: Thesis: Compulsory Chemical and Bioprocess Engineering: Thesis: Compulsory Computer Science: Thesis: Compulsory Digital Journalism: Thesis: Compulsory Electrical Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Global Innovation Management: Thesis: Compulsory Computer Science in Engineering: Thesis: Compulsory Information and Communication Systems: Thesis: Compulsory Interdisciplinary Mathematics: Thesis: Compulsory		

International Production Management: Thesis: Compulsory
International Management and Engineering: Thesis: Compulsory
Joint European Master in Environmental Studies - Cities and Sustainability: Thesis: Compulsory
Logistics, Infrastructure and Mobility: Thesis: Compulsory
Materials Science: Thesis: Compulsory
Mechanical Engineering and Management: Thesis: Compulsory
Mechatronics: Thesis: Compulsory
Biomedical Engineering: Thesis: Compulsory
Microelectronics and Microsystems: Thesis: Compulsory
Product Development, Materials and Production: Thesis: Compulsory
Renewable Energies: Thesis: Compulsory
Naval Architecture and Ocean Engineering: Thesis: Compulsory
Ship and Offshore Technology: Thesis: Compulsory
Teilstudiengang Lehramt Metalltechnik: Thesis: Compulsory
Theoretical Mechanical Engineering: Thesis: Compulsory
Process Engineering: Thesis: Compulsory
Water and Environmental Engineering: Thesis: Compulsory
Certification in Engineering & Advisory in Aviation: Thesis: Compulsory