Module Manual

Master of Science (M.Sc.)

Aircraft Systems Engineering

Cohort: Winter Term 2019

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Table of Contents

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, scientifical 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	
Knowledge	• 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.
Skills	• 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	
Social Competence	• Students are able to communicate in small interdisciplinary groups and to jointly develop solutions for complex problems
Autonomy	• 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	
Knowledge	**The Nontechnical Academic Programms (NTA)** 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. **The Learning Architecture** 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. 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". 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. **Teaching and Learning Arrangements** 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. **Fields of Teaching** 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. 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. **The Competence Level** 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. 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. **Specialized Competence (Knowledge)** Students can • 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.
Skills	**Professional Competence (Skills)** In selected sub-areas students can • 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 sucsessful manner, • justify their decisions on forms of organization and application in practical questions in contexts that go beyond the technical relationship to the subject.
Personal Competence	
Social Competence	**Personal Competences (Social Skills)** Students will be able • 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.
	Personal Competences (Self-reliance) Students are able in selected areas • to reflect on their own profession and professionalism in the context of real-life fields of application

Autonomy	• 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 writen form or verbaly • to organize themselves as an entrepreneurial subject country (as far as this study-focus would be chosen)
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 M0763: Aircraft Systems I

Courses

Title	Typ		Hrs/wk	CP
Aircraft Systems I (L0735)	Lecture		3	4
Aircraft Systems I (L0739)	Recitation (large)	Section	2	2

Module Responsible	Prof. Frank Thielecke
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Hydraulics • Control Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: • Describe essential components and design points of hydraulic, electrical and high-lift systems • Give an overview of the functionality of air conditioning systems • Explain the need for high-lift systems such as ist functionality and effects • Assess the challenge during the design of supply systems of an aircraft
Skills	Students are able to: • Design hydraulic and electric supply systems of aircrafts • Design high-lift systems of aircrafts • Analyze the thermodynamic behaviour of air conditioning systems
Personal Competence	
Social Competence	Students are able to: • Perform system design in groups and present and discuss results
Autonomy	Students are able to: • Reflect the contents of lectures autonomously
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: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

Course L0735: Aircraft Systems I	
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	• 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	• 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 Systems I	
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 (large)	Section	1	1

Module Responsible	Prof. Frank Thielecke
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Aviation
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	
Skills	
Personal Competence	
Social Competence	
Autonomy	
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 Theoretical Mechanical Engineering: Technical Complementary Course: 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, Mike Montel
Language	DE
Cycle	WiSe
Content	• 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	• 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, Mike Montel
Language	DE
Cycle	SoSe
Content	• stationary asymmetric flight • dynamics of lateral movement • methods of flight simulation • eyperimental methods of flight mechanics • model validation using system identification • wind tunnel techniques
Literature	• 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, Mike Montel
Language	DE
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Module M0812: Aircraft Design

Courses

Title	Typ		Hrs/wk	CP
Aircraft Design I (L0820)	Lecture		2	2
Aircraft Design I (L0834)	Recitation (large)	Section	1	1
Aircraft Design II (Conceptual Design of Rotorcraft, special operations aircraft, UAV) (L0844)	Lecture		2	2
Aircraft Design II (Conceptual Design of Rotorcraft, special operations aircraft, UAV) (L0847)	Recitation (large)	Section	1	1

Module Responsible	Prof. Volker Gollnick
Admission Requirements	None
Recommended Previous Knowledge	• Bachelor Mech. Eng. • Vordiplom Mech. Eng. • Module Air Transport Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	1. Principle understanding of integrated aircraft design 2. Understanding of the interactions and contributions of the various disciplines 3. Impact of the relevant design parameter on the aircraft design 4. Introduction of the principle design methods
Skills	Understanding and application of design and calculation methods Understanding of interdisciplinary and integrative interdependencies
Personal Competence	
Social Competence	Working in interdisciplinary teams Communication
Autonomy	Organization of workflows and -strategies
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 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 Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

Course L0820: Aircraft Design I	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	WiSe
Content	Introduction into the aircraft design process 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. Principles of aircraft performance design (stability, V-n-diagramme) 5. Principles of aerodynamic aircraft design (polar, geometry, 2D/3D aerodynamics) 6. Principles of structural fuselage and wing design (mass analysis, beam/tube models, geometry) 7. Principles of engine design and integration 8. Cruise design 9. Design of runway and landing field length 10. Cabin design (fuselage dimensioning, cabin interior, loading systems) 11. System- and equipment aspects 12. Design variations and operating cost calculation
Literature	J. Roskam: "Airplane Design" D.P. Raymer: "Aircraft Design - A Conceptual Approach" J.P. Fielding: "Intorduction to Aircraft Design" Jenkinson, Simpkon, Rhods: "Civil Jet Aircraft Design"

Course L0834: Aircraft Design I	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	WiSe
Content	Training in applying MatLab Application of design methods for civil aircraft concerning: Fuselage and Cabin sizing and design Calculation of aircraft masses Aerodynamic and geometric wing design TakeOff, landing cruise performance calculation Manoevre and gust load calculation
Literature	J. Roskam: "Airplane Design" D.P. Raymer: "Aircraft Design - A Conceptual Approach" J.P. Fielding: "Intorduction to Aircraft Design" Jenkinson, Simpkon, Rhods: "Civil Jet Aircraft Design"

Course L0844: Aircraft Design II (Conceptual Design of Rotorcraft, special operations aircraft, UAV)	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Volker Gollnick, Dr. Bernd Liebhardt
Language	DE/EN
Cycle	SoSe
Content	Take Off and landing Loads on Aircraft Operation Cost Principles of Rotorcraft Design Principles of high performance aircraft design Principles of special operations aircraft design Principles of Unmanned Air Systems design
Literature	Gareth Padfield: Helicopter Flight Dynamics Raymond Prouty: Helicopter Performance Stability and Control Klaus Hünecke: Das Kampfflugzeug von Heute

Course L0847: Aircraft Design II (Conceptual Design of Rotorcraft, special operations aircraft, UAV)	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Volker Gollnick, Dr. Bernd Liebhardt
Language	DE/EN
Cycle	SoSe
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 (large)	Section	1	2

Module Responsible	Prof. Ralf God
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: • 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
Skills	Students are able to: • 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
Personal Competence	
Social Competence	Students are able to: • understand existing system solutions and discuss their ideas with experts
Autonomy	Students are able to: • Reflect the contents of lectures and expert presentations self-dependent
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	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

the Following Curricula	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 Theoretical Mechanical Engineering: Technical Complementary Course: 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	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. 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: • 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	- 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 M0764: Aircraft Systems II

Courses

Title	Typ		Hrs/wk	CP
Aircraft Systems II (L0736)	Lecture		3	4
Aircraft Systems II (L0740)	Recitation (large)	Section	2	2

Module Responsible	Prof. Frank Thielecke
Admission Requirements	None
Recommended Previous Knowledge	basic knowledge of: • mathematics • mechanics • thermo dynamics • electronics • fluid technology • control technology
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to… • describe the structure of primary flight control systems as well as actuation-, avionic-, fuel- and landing gear-systems in general along with corresponding properties and applications. • explain different configurations and designs and their origins • explain atmospheric conditions for icing such as the functionality of anti-ice systems
Skills	Students are able to… • size primary flight control actuation systems • perform a controller design process for the flight control actuators • design high-lift kinematics • design and analyse landing gear systems • design anti-ice systems
Personal Competence	
Social Competence	Students are able to: • Develop joint solutions in mixed teams
Autonomy	Students are able to: • derive requirements and perform appropriate yet simplified design processes for aircraft systems from complex issues and circumstances 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: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

Course L0736: Aircraft Systems II	
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	• 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-skit 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	• Moir, Seabridge: Aircraft Systems • Torenbek: Synthesis of Subsonic Airplane Design • Curry: Aircraft Landing Gear Design: Principles and Practices

Course L0740: Aircraft Systems II	
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 (large)	Section	1	2

Module Responsible	Prof. Ralf God
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems Previous knowledge in: • Aircraft Cabin Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: • 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)
Skills	Students are able to: • 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	
Social Competence	Students are able to: • understand their responsibilities within a development team and integrate themselves with their role in the overall process
Autonomy	Students are able to: • interact and communicate in a development team which has distributed tasks
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and	120 Minutes

scale	
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: Technical Complementary Course: 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	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. 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: • 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	- Skript zur Vorlesung - diverse Normen und Richtlinien (EASA, FAA, RTCA, SAE) - Hauschildt, J., Salomo, S.: Innovationsmanagement. Vahlen, 5. Auflage, 2010 - NASA Systems Engineering Handbook, National Aeronautics and Space Administration, 2007 - Hinsch, M.: Industrielles Luftfahrtmanagement: Technik und Organisation luftfahrttechnischer Betriebe. Springer, 2010 - De Florio, P.: Airworthiness: An Introduction to Aircraft Certification. Elsevier Ltd., 2010 - Pohl, K.: Requirements Engineering. Grundlagen, Prinzipien, Techniken. 2. korrigierte Auflage, dpunkt.Verlag, 2008

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 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: • Mathematics • Mechanics • Electrical Engineering • Control Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to… • Name and explain all phases of the systems engineering process (V-Model) • Describe tools for systems engineering
Skills	Students are able to… • 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	
Social Competence	Students are able to… • 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
Autonomy	Students are able to… • 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: Elective 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 M1404: Research Project Aircraft-System-Engineering

Courses			
Title	**Typ**	**Hrs/wk**	**CP**

Module Responsible	Dozenten des SD M
Admission Requirements	None
Recommended Previous Knowledge	• Bachelor Mechanical Engineering • Aircraft Systems I+II • Cabin Systems • Aircraft Design
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	The students are able to demonstrate their detailed knowledge in the field of Aircraft Systems Engineering. They can exemplify the state of technology and application and discuss critically in the context of actual problems and general conditions of science and society. The students can develop solving strategies and approaches for fundamental and practical problems in Aircraft Systems Engineering. They may apply theory based procedures and integrate safety-related, ecological, ethical, and economic view points of science and society. Scientific work techniques that are used can be described and critically reviewed.
Skills	The students are able to independently select methods for the project work and to justify this choice. They can explain how these methods relate to the field of work and how the context of application has to be adjusted. General findings and further developments may essentially be outlined.
Personal Competence	
Social Competence	The students are able to condense the relevance and the structure of the project work, the work steps and the sub-problems for the presentation and discussion in front of a bigger group. They can lead the discussion and give a feedback on the project to their colleagues.
Autonomy	Die Studierenden sind fähig, die zur Bearbeitung der Projektarbeit notwendigen Arbeitsschritte und Abläufe selbständig unter Berücksichtigung vorgegebener Fristen zu planen und zu dokumentieren. Hierzu gehört, dass sie sich aktuelle wissenschaftliche Informationen zielorientiert beschaffen können. Ferner sind sie in der Lage, bei Fachexperten Rückmeldungen zum Arbeitsfortschritt einzuholen, um hochwertige, auf den Stand von Wissenschaft und Technik bezogene Arbeitsergebnisse zu erreichen.
Workload in Hours	Independent Study Time 360, Study Time in Lecture 0
Credit points	12
Course achievement	None
Examination	Study work
Examination duration and scale	approx. 60 - 150 pages
Assignment for	

the Following Curricula	Aircraft Systems Engineering: Core qualification: Elective Compulsory

Specialization Avionic Systems

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: • Mathematics • Electrical Engineering • Informatics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can: • 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
Skills	Students can ... • 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	
Social Competence	Students can: • jointly develop solutions in inhomogeneous teams • exchange information formally with other teams • present development results in a convenient way
Autonomy	Students can: • 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: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: 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	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. Content: 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	• 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 M0836: Communication Networks

Courses

Title	Typ	Hrs/wk	CP
Analysis and Structure of Communication Networks (L0897)	Lecture	2	2
Selected Topics of Communication Networks (L0899)	Project-/problem-based Learning	2	2
Communication Networks Excercise (L0898)	Project-/problem-based Learning	1	2

Module Responsible	Prof. Andreas Timm-Giel
Admission Requirements	None
Recommended Previous Knowledge	• 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	
Knowledge	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.
Skills	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	
Social Competence	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.
Autonomy	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.
	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems:

Assignment for the Following Curricula	Elective Compulsory Computational Science and Engineering: Specialisation I. Computer Science: Elective Compulsory Information and Communication Systems: Specialisation Secure and Dependable IT Systems, Focus Networks: Elective Compulsory Information and Communication Systems: Specialisation Communication Systems: Elective Compulsory Mechatronics: Technical Complementary Course: Elective Compulsory Microelectronics and Microsystems: Specialisation Communication and Signal Processing: Elective Compulsory

Course L0897: Analysis and Structure of 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
Language	EN
Cycle	WiSe
Content	
Literature	• Skript des Instituts für Kommunikationsnetze • Tannenbaum, Computernetzwerke, Pearson-Studium Further literature is announced at the beginning of the lecture.

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	• see lecture

Course L0898: Communication Networks Excercise	
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	• announced during lecture

Module M0565: Mechatronic Systems

Courses

Title	Typ	Hrs/wk	CP
Electro- and Contromechanics (L0174)	Lecture	2	2
Electro- and Contromechanics (L1300)	Recitation Section (small)	1	2
Mechatronics Laboratory (L0196)	Project-/problem-based Learning	2	2

Module Responsible	Prof. Uwe Weltin
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of mechanics, electromechanics and control theory
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe methods and calculations to design, model, simulate and optimize mechatronic systems and can repeat methods to verify and validate models.
Skills	Students are able to plan and execute mechatronic experiments. Students are able to model mechatronic systems and derive simulations and optimizations.
Personal Competence	
Social Competence	Students are able to work goal-oriented in small mixed groups, learning and broadening teamwork abilities and define task within the team.
Autonomy	Students are able to solve individually exercises related to this lecture with instructional direction. Students are able to plan, execute and summarize a mechatronic experiment.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / None / Subject theoretical and practical work
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Mechatronics: Core qualification: Compulsory

Course L0174: Electro- and Contromechanics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	SoSe
Content	Introduction to methodical design of mechatronic systems: • Modelling • System identification • Simulation • Optimization
Literature	Denny Miu: Mechatronics, Springer 1992 Rolf Isermann: Mechatronic systems : fundamentals, Springer 2003

Course L1300: Electro- and Contromechanics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0196: Mechatronics Laboratory	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Uwe Weltin
Language	DE/EN
Cycle	SoSe
Content	Modeling in MATLAB® und Simulink® Controller Design (Linear, Nonlinear, Observer) Parameter identification Control of a real system with a realtimeboard and Simulink® RTW
Literature	- Abhängig vom Versuchsaufbau - Depends on the experiment

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	• Knowledge of computer and communication networks • Basic programming skills
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to explain the necessary stochastics, the discrete event simulation technology and modelling of networks for performance evaluation.
Skills	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	
Social Competence	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.
Autonomy	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	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Specialisation Information and Communication Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: 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

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	• Skript des Instituts für Kommunikationsnetze Further literature is announced at the beginning of the lecture.

Module M1043: Aircraft Systems Engineering

Courses

Title	Typ	Hrs/wk	CP
Fatigue & Damage Tolerance (L0310)	Lecture	2	3
Lightweight Construction with Fibre Reinforced Rolymers - Structural Mechanics (L1514)	Lecture	2	3
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
Mechanisms, Systems and Processes of Materials Testing (L0950)	Lecture	2	2
Turbo Jet Engines (L0908)	Lecture	2	3
System Simulation (L1820)	Lecture	2	2
System Simulation (L1821)	Recitation Section (large)	1	2
Materials Testing (L0949)	Lecture	2	2
Reliability in Engineering Dynamics (L0176)	Lecture	2	2
Reliability in Engineering Dynamics (L1303)	Recitation Section (small)	1	2
Reliability of avionics assemblies (L1554)	Lecture	2	2
Reliability of avionics assemblies (L1555)	Recitation Section (small)	1	1
Reliability of Aircraft Systems (L0749)	Lecture	2	3

Module Responsible	Prof. Frank Thielecke
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Hydraulics • Control Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• 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.
Skills	Students are able to apply basic methods in selected areas of engineering.
Personal Competence	
Social Competence	
Autonomy	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: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

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. Kluver Academic Puplisher, Dordrecht, 2001 E. Haibach. Betriebsfestigkeit Verfahren und Daten zur Bauteilberechnung. VDI-Verlag, Düsseldorf, 1989

Course L1514: Lightweight Construction with Fibre Reinforced Rolymers - Structural Mechanics	
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	DE
Cycle	WiSe
	Fundamentals of Anisotropic Elasticity Displacements, strains and stresses; Equilibrium equations; Kinematics; Hooke’s generalized law **Behaviour of a single laminate layer** Material law of a single laminate layer; Full anisotropy and coupling effects; Material symmetries; Engineering constants; Plane state of stress; Transformation rules **Fundamentals of Micromechanics of a laminate layer**

Content	Representative unit cell; Determination of effective material constants; Effective stiffness properties of a single layer **Classical Laminate Plate Theory** Notations and laminate code; Kinematics and displacement field; Strains and stresses, stress resultants; Constitutive equations and coupling effects; Special laminates and their behavior; Effective laminate properties **Strength of Laminated Plates** Fundamental concept; Phenomenological failure criteria: maximum stresses, maximum strains, Tsai-Hill, Tsai-Wu, Puck, Hashin **Bending of Composite Laminated Plates** Differential Equations; Boundary Conditions; Navier-type solutions; Lévy-type solutions **Stress Concentration Problems** Free-edge effects; Stress concentrations at holes, cracks, delaminations; Aspects of failure analysis **Stability of Thin-Walled Composite Structures** Buckling of anisotropic plates and shells; Influence of loading conditions; Influence of boundary conditions; Exact transcendental solutions and their evaluation; Buckling of stiffened composite plates; Minimum stiffness requirements; Local buckling of stiffener profiles **Written exercise (report required)** Assessment of a thin-walled composite laminated beam taking several different dimensioning criteria into account
Literature	• 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 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	Development of a sandwich structure made of fibre reinforced plastics • 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	• Schürmann, H., „Konstruieren mit Faser-Kunststoff-Verbunden“, Springer, Berlin, 2005. • Puck, A., „Festigkeitsanalsyse 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	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. 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: • 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	- Skript zur Vorlesung - Giemulla, E.M., Rothe B.R. (Hrsg.): Handbuch Luftsicherheit. Universitätsverlag TU Berlin, 2011 - Thomas, A.R. (Ed.): Aviation Security Management. Praeger Security International, 2008

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	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. 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: • 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	- Skript zur Vorlesung - Giemulla, E.M., Rothe B.R. (Hrsg.): Handbuch Luftsicherheit. Universitätsverlag TU Berlin, 2011 - Thomas, A.R. (Ed.): Aviation Security Management. Praeger Security International, 2008

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	Application, analysis and discussion of basic and advanced testing methods to ensure correct selection of applicable testing procedure for investigation of part/materials deficiencies • 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	• E. Macherauch: Praktikum in Werkstoffkunde, Vieweg • G. E. Dieter: Mechanical Metallurgy, McGraw-Hill • R. Bürgel: Lehr- und Übungsbuch Festigkeitslehre, Vieweg • R. Bürgel: Werkstoffe sícher 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	• 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	• Bräunling: Flugzeugtriebwerke • Engmann: Technologie des Fliegens • Kerrebrock: Aircraft Engines and Gas Turbines

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
Language	DE
Cycle	WiSe
Content	All participants must bring a notebook, to install and use the software OpenModelica. • 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: Heat transfer • Example: System with different subsystems
Literature	[1] Modelica Association: "Modelica Language Specification - Version 3.3", Linköping, Sweden, 2 0 1 2 [2] M. Tiller: “Modelica by Example", http://book.xogeny.com, 2014. [3] M. Otter, H. Elmqvist, et al.: "Objektorientierte Modellierung Physikalischer Systeme", at- Automatisierungstechnik (german), Teil 1 - 17, Oldenbourg Verlag, 1999 - 2000. [4] P. Fritzson: "Principles of Object-Oriented Modeling and Simulation with Modelica 3.3", Wiley-IEEE Press, New York, 2015. [5] P. Fritzson: “Introduction to Modeling and Simulation of Technical and Physical Systems with Modelica”, Wiley, New York, 2011.

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
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	Application and analysis of basic mechanical as well as non-destructive testing of materials • 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	E. Macherauch: Praktikum in Werkstoffkunde, Vieweg G. E. Dieter: Mechanical Metallurgy, McGraw-Hill

Course L0176: 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. Uwe Weltin
Language	EN
Cycle	SoSe
Content	Method for calculation and testing of reliability of dynamic machine systems • Modeling • System identification • Simulation • Processing of measurement data • Damage accumulation • Test planning and execution
Literature	Bertsche, B.: Reliability in Automotive and Mechanical Engineering. Springer, 2008. ISBN: 978-3-540-33969-4 Inman, Daniel J.: Engineering Vibration. Prentice Hall, 3rd Ed., 2007. ISBN-13: 978-0132281737 Dresig, H., Holzweißig, F.: Maschinendynamik, Springer Verlag, 9. Auflage, 2009. ISBN 3540876936. VDA (Hg.): Zuverlässigkeitssicherung bei Automobilherstellern und Lieferanten. Band 3 Teil 2, 3. überarbeitete Auflage, 2004. ISSN 0943-9412

Course L1303: 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. Uwe Weltin
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L1554: Reliability of avionics assemblies	
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	SoSe
Content	The objective of the lecture with the corresponding exercise is the acquisition of knowledge for development, electronic packaging technology and the production of electronic components for safety-critical applications. On an item, component and system level it is shown, how the specified safety objectives for electronics in aircraft can be achieved. Current challenges, such as availability of components, component counterfeiting and the use of components off-the-shelf (COTS) will be discussed: • Survey of the role of electronics in aviation • System levels: From silicon to mechatronic systems • Semiconductor components, assemblies, systems • Challenges of electronic packaging technology (AVT) • System integration in electronics: Requirements for AVT • Methods and techniques of AVT • Error patterns for assemblies and avoidance of errors • Reliability analysis for printed circuit boards (PCBs) • Reliability of Avionics • COTS, ROTS, MOTS and the F ^{3}I concept • Future challenges for electronics
Literature	- Skript zur Vorlesung Hanke, H.-J.: Baugruppentechnologie der Elektronik. Leiterplatten. Verlag Technik, 1994 Scheel, W.: Baugruppentechnologie der Elektronik. Montage. Verlag Technik, 1999

Course L1555: Reliability of avionics assemblies	
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	SoSe
Content	The objective of the lecture with the corresponding exercise is the acquisition of knowledge for development, electronic packaging technology and the production of electronic components for safety-critical applications. On an item, component and system level it is shown, how the specified safety objectives for electronics in aircraft can be achieved. Current challenges, such as availability of components, component counterfeiting and the use of components off-the-shelf (COTS) will be discussed: • Survey of the role of electronics in aviation • System levels: From silicon to mechatronic systems • Semiconductor components, assemblies, systems • Challenges of electronic packaging technology (AVT) • System integration in electronics: Requirements for AVT • Methods and techniques of AVT • Error patterns for assemblies and avoidance of errors • Reliability analysis for printed circuit boards (PCBs) • Reliability of Avionics • COTS, ROTS, MOTS and the F ^{3}I concept • Future challenges for electronics
Literature	- Skript zur Vorlesung Hanke, H.-J.: Baugruppentechnologie der Elektronik. Leiterplatten. Verlag Technik, 1994 Scheel, W.: Baugruppentechnologie der Elektronik. Montage. Verlag Technik, 1999

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	• 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	• CS 25.1309 • SAE ARP 4754 • SAE ARP 4761

Module M0803: Embedded Systems

Courses

Title	Typ		Hrs/wk	CP
Embedded Systems (L0805)	Lecture		3	4
Embedded Systems (L0806)	Recitation (small)	Section	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	
Knowledge	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). Another part covers the hardware of embedded systems: Sonsors, 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.
Skills	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.
Personal Competence	
Social Competence	Students are able to solve similar problems alone or in a group and to present the results accordingly.
Autonomy	Students are able to acquire new knowledge from specific literature and to associate this knowledge with other classes.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
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: Elective Compulsory Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Electrical Engineering: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory Computational Science and 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	4
Workload in Hours	Independent Study Time 78, Study Time in Lecture 42
Lecturer	Prof. Heiko Falk
Language	EN
Cycle	SoSe
Content	• Introduction • Specifications and Modeling • Embedded/Cyber-Physical Systems Hardware • System Software • Evaluation and Validation • Mapping of Applications to Execution Platforms • Optimization
Literature	• 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 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 (small)	Section	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	
Knowledge	• 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
	• 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 the state space representation of spatially invariant distributed systems that are discretized according to an actuator/sensor array • They can explain (in outline) the extension of the bounded real lemma to such distributed systems and the associated synthesis conditions for distributed controllers
Skills	• Students are capable of constructing 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 are able to use standard software tools (Matlab robust control toolbox) for these tasks
	• Students are able to design distributed formation controllers for groups of agents with either LTI or LPV dynamics, using Matlab tools provided

	• Students are able to design distributed controllers for spatially interconnected systems, using the Matlab MD-toolbox
Personal Competence	
Social Competence	Students can work in small groups and arrive at joint results.
Autonomy	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	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic Systems: 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: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: 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	• Linear Parameter-Varying (LPV) Gain Scheduling - 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 - 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 • Control of Spatially Interconnected Systems - Multidimensional signals, l2 and L2 signal norm - Multidimensional systems in Roesser state space form - Extension of real-bounded lemma to spatially interconnected systems - LMI-based synthesis of distributed controllers - Spatial LPV control of spatially varying systems - Applications: control of temperature profiles, vibration damping for an actuated beam
Literature	• 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 M1091: Flight Guidance and Control

Courses

Title	Typ		Hrs/wk	CP
Airline Operations (L1310)	Lecture		3	3
Introduction to Flight Guidance (L0848)	Lecture		3	2
Introduction to Flight Guidance (L0854)	Recitation (large)	Section	1	1
Flight Control (L2374)	Lecture		2	2
Flight Control (L2375)	Recitation (small)	Section	1	1

Module Responsible	Prof. Volker Gollnick
Admission Requirements	None
Recommended Previous Knowledge	• Bachelor Mech. Eng. • Vordiplom Mech. Eng. • Lecture Air Transportation Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	1. Principles of Air Traffic Management and technologies 2. Design and modelling of traffic flows, avionics and sensor systems, cockpit design 3. Principles of flight control systems development 4. Air vehicle description as control path (fixed wing, rotary wing, special) 5. Characteristics of control elements 6. Flight control systems design für stabilization, path control, navigation
Skills	• Understanding and application of different interdisciplinary interdependencies • Integration and assessment of new technologies in the air transportation system • Modelling and assessment of flight guidance systems • Airline fleet planning and fleet operation
Personal Competence	
Social Competence	• Working in interdisciplinary teams • Communication
Autonomy	Organization of workflows and -strategies
Workload in Hours	Independent Study Time 40, Study Time in Lecture 140
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	180 min
	Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems:

Assignment for the Following Curricula	Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic Systems: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory

Course L1310: Airline Operations	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Volker Gollnick, Dr. Karl Echtermeyer
Language	DE
Cycle	SoSe
Content	1. Introdution and overview 2. Airline business models 3. Interdependencies in flight planning (network management, slot management, netzwork 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 L0848: Introduction to Flight Guidance	
Typ	Lecture
Hrs/wk	3
CP	2
Workload in Hours	Independent Study Time 18, Study Time in Lecture 42
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	WiSe
Content	Introduction and motivation Flight guidance principles (airspace structures, organization of air navigation services, etc.) Navigation Radio navigation Satellite navigation 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 Airspace surveillance (radar systems) Commuication systems Avionics architectures (computer systems, bus systems) Cockpit systems and displays (cockpit design, cockpit equipment)
Literature	Rudolf Brockhaus, Robert Luckner, Wolfgang Alles: "Flugregelung", Springer Berlin Heidelberg New York, 2012 Holger Flühr: "Avionik und Flugsicherungssysteme", Springer Berlin Heidelberg New York, 2013 Volker Gollnick, Dieter Schmitt "Air Transport Systems", Springer Berlin Heidelberg New York, 2014

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

Course L2374: Flight Control	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	SoSe
Content	The course will provide knowledge how to describe flight vehicle as a control system. Further it gives inside into the design, layout and optimization of controller for stabilisation and control of flight states and guidance modes. The course is intended to enable participants in the layout of flight control systems presenting the major methods and tools
Literature	Brockhaus, Alles, Luckner: Flugregelung, Springer Verlag, 2011 R.P.G Collinson: Introduction to Avionics Systems, Springer Verlag, 2011

Course L2375: Flight Control	
Typ	Recitation Section (small)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	SoSe
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	
Knowledge	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.
Skills	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	
Social Competence	Students are able to solve similar problems alone or in a group and to present the results accordingly.
Autonomy	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"
	General Engineering Science (German program, 7 semester): Specialisation Computer Science: Elective Compulsory

Assignment for the Following Curricula	Computer Science: Specialisation Computer and Software Engineering: Elective Compulsory Computer Science: Specialisation I. Computer and Software Engineering: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic Systems: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Computer Science: Elective Compulsory Computational Science and Engineering: Specialisation I. Computer Science: Elective Compulsory Computational Science and Engineering: Specialisation 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	• Introduction • VHDL Basics • Programming Models • Realization of Elementary Data Types • Dynamic Scheduling • Branch Prediction • Superscalar Machines • Memory Hierarchies 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.
Literature	• 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

Specialization Aircraft Systems

By specializing in Aircraft Systems Engineering students learn how to work on complex system design problems in an analytical and methodical way. They are deepening existing and getting new competences in the field of control design, simulation, system modelling and other parts of system design. Choosing an open module allows students furthermore to participate in various lectures in the field of aviation.

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 (small)	Section	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	
Knowledge	• 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
Skills	• Students can transform transfer function models into state space models and vice versa • They can assess controllability and observability and construct minimal realisations • They can design LQG controllers for multivariable plants • They can carry out a controller design both in continuous-time and discrete-time domain, and decide which is appropriate for a given sampling rate • They can identify transfer function models and state space models of dynamic systems from experimental data • They can carry out all these tasks using standard software tools (Matlab Control Toolbox, System Identification Toolbox, Simulink)

Personal Competence	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	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	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Core qualification: Compulsory Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory Computational Science and 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	State space methods (single-input single-output) • 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 Multi-input multi-output systems • 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 Digital Control • 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 System identification and model order reduction • Least squares estimation, ARX models, persistent excitation • Identification of state space models, subspace identification • Balanced realization and model order reduction Case study • Modelling and multivariable control of a process evaporator using Matlab and Simulink Software tools • Matlab/Simulink
Literature	• 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 M0721: Air Conditioning

Courses

Title	Typ		Hrs/wk	CP
Air Conditioning (L0594)	Lecture		3	5
Air Conditioning (L0595)	Recitation (large)	Section	1	1

Module Responsible	Prof. Gerhard Schmitz
Admission Requirements	None
Recommended Previous Knowledge	Technical Thermodynamics I, II, Fluid Dynamics, Heat Transfer
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students know the different kinds of air conditioning systems for buildings and mobile applications and how these systems are controlled. They are familiar with the change of state of humid air and are able to draw the state changes in a h1+x,x-diagram. They are able to calculate the minimum airflow needed for hygienic conditions in rooms and can choose suitable filters. They know the basic flow pattern in rooms and are able to calculate the air velocity in rooms with the help of simple methods. They know the principles to calculate an air duct network. They know the different possibilities to produce cold and are able to draw these processes into suitable thermodynamic diagrams. They know the criteria for the assessment of refrigerants.
Skills	Students are able to configure air condition systems for buildings and mobile applications. They are able to calculate an air duct network and have the ability to perform simple planning tasks, regarding natural heat sources and heat sinks. They can transfer research knowledge into practice. They are able to perform scientific work in the field of air conditioning.
Personal Competence	
Social Competence	The students are able to discuss in small groups and develop an approach.
Autonomy	Students are able to define independently tasks, to get new knowledge from existing knowledge as well as to find ways to use the knowledge in practice.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and	60 min

scale	
Assignment for the Following Curricula	Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory Energy Systems: Specialisation Energy Systems: Elective Compulsory Energy Systems: Specialisation Marine Engineering: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0594: Air Conditioning	
Typ	Lecture
Hrs/wk	3
CP	5
Workload in Hours	Independent Study Time 108, Study Time in Lecture 42
Lecturer	Prof. Gerhard Schmitz
Language	DE
Cycle	SoSe
Content	1. Overview 1.1 Kinds of air conditioning systems 1.2 Ventilating 1.3 Function of an air condition system 2. Thermodynamic processes 2.1 Psychrometric chart 2.2 Mixer preheater, heater 2.3 Cooler 2.4 Humidifier 2.5 Air conditioning process in a Psychrometric chart 2.6 Desiccant assisted air conditioning 3. Calculation of heating and cooling loads 3.1 Heating loads 3.2 Cooling loads 3.3 Calculation of inner cooling load 3.4 Calculation of outer cooling load 4. Ventilating systems 4.1 Fresh air demand 4.2 Air flow in rooms 4.3 Calculation of duct systems

	4.4 Fans 4.5 Filters 5. Refrigeration systems 5.1. compression chillers 5.2Absorption chillers
Literature	• Schmitz, G.: Klimaanlagen, Skript zur Vorlesung • VDI Wärmeatlas, 11. Auflage, Springer Verlag, Düsseldorf 2013 • Herwig, H.; Moschallski, A.: Wärmeübertragung, Vieweg+Teubner Verlag, Wiesbaden 2009 • Recknagel, H.; Sprenger, E.; Schrammek, E.-R.: Taschenbuch für Heizung- und Klimatechnik 2013/2014, 76. Auflage, Deutscher Industrieverlag, 2013

Course L0595: Air Conditioning	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Gerhard Schmitz
Language	DE
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	• Calculus • Linear Algebra • Engineering Mechanics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to reflect existing terms and concepts in Nonlinear Dynamics and to develop and research new terms and concepts.
Skills	Students are able to apply existing methods and procesures of Nonlinear Dynamics and to develop novel methods and procedures.
Personal Competence	
Social Competence	Students can reach working results also in groups.
Autonomy	Students are able to approach given research tasks individually and 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: Specialisation Aircraft Systems: 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: Technical Complementary Course: 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	Fundamentals of Nonlinear Dynamics.
Literature	S. Strogatz: Nonlinear Dynamics and Chaos. Perseus, 2013.

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 (small)	Section	2	3

Module Responsible	Prof. Herbert Werner
Admission Requirements	None
Recommended Previous Knowledge	• 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	
Knowledge	• 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.
Skills	• 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	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	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	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: 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: Technical Complementary Course: 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	• 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	• 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. Postlewhaite "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 M1043: Aircraft Systems Engineering

Courses

Title	Typ	Hrs/wk	CP
Fatigue & Damage Tolerance (L0310)	Lecture	2	3
Lightweight Construction with Fibre Reinforced Rolymers - Structural Mechanics (L1514)	Lecture	2	3
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
Mechanisms, Systems and Processes of Materials Testing (L0950)	Lecture	2	2
Turbo Jet Engines (L0908)	Lecture	2	3
System Simulation (L1820)	Lecture	2	2
System Simulation (L1821)	Recitation Section (large)	1	2
Materials Testing (L0949)	Lecture	2	2
Reliability in Engineering Dynamics (L0176)	Lecture	2	2
Reliability in Engineering Dynamics (L1303)	Recitation Section (small)	1	2
Reliability of avionics assemblies (L1554)	Lecture	2	2
Reliability of avionics assemblies (L1555)	Recitation Section (small)	1	1
Reliability of Aircraft Systems (L0749)	Lecture	2	3

Module Responsible	Prof. Frank Thielecke
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Hydraulics • Control Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• 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.
Skills	Students are able to apply basic methods in selected areas of engineering.
Personal Competence	
Social Competence	
Autonomy	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: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

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. Kluver Academic Puplisher, Dordrecht, 2001 E. Haibach. Betriebsfestigkeit Verfahren und Daten zur Bauteilberechnung. VDI-Verlag, Düsseldorf, 1989

Course L1514: Lightweight Construction with Fibre Reinforced Rolymers - Structural Mechanics	
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	DE
Cycle	WiSe
	Fundamentals of Anisotropic Elasticity Displacements, strains and stresses; Equilibrium equations; Kinematics; Hooke’s generalized law **Behaviour of a single laminate layer** Material law of a single laminate layer; Full anisotropy and coupling effects; Material symmetries; Engineering constants; Plane state of stress; Transformation rules **Fundamentals of Micromechanics of a laminate layer**

Content	Representative unit cell; Determination of effective material constants; Effective stiffness properties of a single layer **Classical Laminate Plate Theory** Notations and laminate code; Kinematics and displacement field; Strains and stresses, stress resultants; Constitutive equations and coupling effects; Special laminates and their behavior; Effective laminate properties **Strength of Laminated Plates** Fundamental concept; Phenomenological failure criteria: maximum stresses, maximum strains, Tsai-Hill, Tsai-Wu, Puck, Hashin **Bending of Composite Laminated Plates** Differential Equations; Boundary Conditions; Navier-type solutions; Lévy-type solutions **Stress Concentration Problems** Free-edge effects; Stress concentrations at holes, cracks, delaminations; Aspects of failure analysis **Stability of Thin-Walled Composite Structures** Buckling of anisotropic plates and shells; Influence of loading conditions; Influence of boundary conditions; Exact transcendental solutions and their evaluation; Buckling of stiffened composite plates; Minimum stiffness requirements; Local buckling of stiffener profiles **Written exercise (report required)** Assessment of a thin-walled composite laminated beam taking several different dimensioning criteria into account
Literature	• 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 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	Development of a sandwich structure made of fibre reinforced plastics • 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	• Schürmann, H., „Konstruieren mit Faser-Kunststoff-Verbunden“, Springer, Berlin, 2005. • Puck, A., „Festigkeitsanalsyse 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	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. 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: • 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	- Skript zur Vorlesung - Giemulla, E.M., Rothe B.R. (Hrsg.): Handbuch Luftsicherheit. Universitätsverlag TU Berlin, 2011 - Thomas, A.R. (Ed.): Aviation Security Management. Praeger Security International, 2008

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	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. 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: • 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	- Skript zur Vorlesung - Giemulla, E.M., Rothe B.R. (Hrsg.): Handbuch Luftsicherheit. Universitätsverlag TU Berlin, 2011 - Thomas, A.R. (Ed.): Aviation Security Management. Praeger Security International, 2008

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	Application, analysis and discussion of basic and advanced testing methods to ensure correct selection of applicable testing procedure for investigation of part/materials deficiencies • 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	• E. Macherauch: Praktikum in Werkstoffkunde, Vieweg • G. E. Dieter: Mechanical Metallurgy, McGraw-Hill • R. Bürgel: Lehr- und Übungsbuch Festigkeitslehre, Vieweg • R. Bürgel: Werkstoffe sícher 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	• 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	• Bräunling: Flugzeugtriebwerke • Engmann: Technologie des Fliegens • Kerrebrock: Aircraft Engines and Gas Turbines

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
Language	DE
Cycle	WiSe
Content	All participants must bring a notebook, to install and use the software OpenModelica. • 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: Heat transfer • Example: System with different subsystems
Literature	[1] Modelica Association: "Modelica Language Specification - Version 3.3", Linköping, Sweden, 2 0 1 2 [2] M. Tiller: “Modelica by Example", http://book.xogeny.com, 2014. [3] M. Otter, H. Elmqvist, et al.: "Objektorientierte Modellierung Physikalischer Systeme", at- Automatisierungstechnik (german), Teil 1 - 17, Oldenbourg Verlag, 1999 - 2000. [4] P. Fritzson: "Principles of Object-Oriented Modeling and Simulation with Modelica 3.3", Wiley-IEEE Press, New York, 2015. [5] P. Fritzson: “Introduction to Modeling and Simulation of Technical and Physical Systems with Modelica”, Wiley, New York, 2011.

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
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	Application and analysis of basic mechanical as well as non-destructive testing of materials • 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	E. Macherauch: Praktikum in Werkstoffkunde, Vieweg G. E. Dieter: Mechanical Metallurgy, McGraw-Hill

Course L0176: 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. Uwe Weltin
Language	EN
Cycle	SoSe
Content	Method for calculation and testing of reliability of dynamic machine systems • Modeling • System identification • Simulation • Processing of measurement data • Damage accumulation • Test planning and execution
Literature	Bertsche, B.: Reliability in Automotive and Mechanical Engineering. Springer, 2008. ISBN: 978-3-540-33969-4 Inman, Daniel J.: Engineering Vibration. Prentice Hall, 3rd Ed., 2007. ISBN-13: 978-0132281737 Dresig, H., Holzweißig, F.: Maschinendynamik, Springer Verlag, 9. Auflage, 2009. ISBN 3540876936. VDA (Hg.): Zuverlässigkeitssicherung bei Automobilherstellern und Lieferanten. Band 3 Teil 2, 3. überarbeitete Auflage, 2004. ISSN 0943-9412

Course L1303: 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. Uwe Weltin
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L1554: Reliability of avionics assemblies	
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	SoSe
Content	The objective of the lecture with the corresponding exercise is the acquisition of knowledge for development, electronic packaging technology and the production of electronic components for safety-critical applications. On an item, component and system level it is shown, how the specified safety objectives for electronics in aircraft can be achieved. Current challenges, such as availability of components, component counterfeiting and the use of components off-the-shelf (COTS) will be discussed: • Survey of the role of electronics in aviation • System levels: From silicon to mechatronic systems • Semiconductor components, assemblies, systems • Challenges of electronic packaging technology (AVT) • System integration in electronics: Requirements for AVT • Methods and techniques of AVT • Error patterns for assemblies and avoidance of errors • Reliability analysis for printed circuit boards (PCBs) • Reliability of Avionics • COTS, ROTS, MOTS and the F ^{3}I concept • Future challenges for electronics
Literature	- Skript zur Vorlesung Hanke, H.-J.: Baugruppentechnologie der Elektronik. Leiterplatten. Verlag Technik, 1994 Scheel, W.: Baugruppentechnologie der Elektronik. Montage. Verlag Technik, 1999

Course L1555: Reliability of avionics assemblies	
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	SoSe
Content	The objective of the lecture with the corresponding exercise is the acquisition of knowledge for development, electronic packaging technology and the production of electronic components for safety-critical applications. On an item, component and system level it is shown, how the specified safety objectives for electronics in aircraft can be achieved. Current challenges, such as availability of components, component counterfeiting and the use of components off-the-shelf (COTS) will be discussed: • Survey of the role of electronics in aviation • System levels: From silicon to mechatronic systems • Semiconductor components, assemblies, systems • Challenges of electronic packaging technology (AVT) • System integration in electronics: Requirements for AVT • Methods and techniques of AVT • Error patterns for assemblies and avoidance of errors • Reliability analysis for printed circuit boards (PCBs) • Reliability of Avionics • COTS, ROTS, MOTS and the F ^{3}I concept • Future challenges for electronics
Literature	- Skript zur Vorlesung Hanke, H.-J.: Baugruppentechnologie der Elektronik. Leiterplatten. Verlag Technik, 1994 Scheel, W.: Baugruppentechnologie der Elektronik. Montage. Verlag Technik, 1999

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	• 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	• CS 25.1309 • SAE ARP 4754 • SAE ARP 4761

Module M0565: Mechatronic Systems

Courses

Title	Typ	Hrs/wk	CP
Electro- and Contromechanics (L0174)	Lecture	2	2
Electro- and Contromechanics (L1300)	Recitation Section (small)	1	2
Mechatronics Laboratory (L0196)	Project-/problem-based Learning	2	2

Module Responsible	Prof. Uwe Weltin
Admission Requirements	None
Recommended Previous Knowledge	Fundamentals of mechanics, electromechanics and control theory
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to describe methods and calculations to design, model, simulate and optimize mechatronic systems and can repeat methods to verify and validate models.
Skills	Students are able to plan and execute mechatronic experiments. Students are able to model mechatronic systems and derive simulations and optimizations.
Personal Competence	
Social Competence	Students are able to work goal-oriented in small mixed groups, learning and broadening teamwork abilities and define task within the team.
Autonomy	Students are able to solve individually exercises related to this lecture with instructional direction. Students are able to plan, execute and summarize a mechatronic experiment.
Workload in Hours	Independent Study Time 110, Study Time in Lecture 70
Credit points	6
Course achievement	**Compulsory** / **Bonus** / **Form** / **Description** Yes / None / Subject theoretical and practical work
Examination	Written exam
Examination duration and scale	90 min
Assignment for the Following Curricula	Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Mechatronics: Core qualification: Compulsory

Course L0174: Electro- and Contromechanics	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	SoSe
Content	Introduction to methodical design of mechatronic systems: • Modelling • System identification • Simulation • Optimization
Literature	Denny Miu: Mechatronics, Springer 1992 Rolf Isermann: Mechatronic systems : fundamentals, Springer 2003

Course L1300: Electro- and Contromechanics	
Typ	Recitation Section (small)
Hrs/wk	1
CP	2
Workload in Hours	Independent Study Time 46, Study Time in Lecture 14
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L0196: Mechatronics Laboratory	
Typ	Project-/problem-based Learning
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Uwe Weltin
Language	DE/EN
Cycle	SoSe
Content	Modeling in MATLAB® und Simulink® Controller Design (Linear, Nonlinear, Observer) Parameter identification Control of a real system with a realtimeboard and Simulink® RTW
Literature	- Abhängig vom Versuchsaufbau - Depends on the experiment

Module M0714: Numerical Treatment of 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 (small)	Section	2	3

Module Responsible	Prof. Sabine Le Borne
Admission Requirements	None
Recommended Previous Knowledge	• Mathematik I, II, III für Ingenieurstudierende (deutsch oder englisch) oder Analysis & Lineare Algebra I + II sowie Analysis III für Technomathematiker • Basic MATLAB knowledge
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to • list numerical methods for the solution of ordinary differential equations and explain their core ideas, • repeat convergence statements for the treated numerical methods (including the prerequisites tied to the underlying problem), • explain aspects regarding the practical execution of a method. • select the appropriate numerical method for concrete problems, implement the numerical algorithms efficiently and interpret the numerical results
Skills	Students are able to • implement (MATLAB), apply and compare numerical methods for the solution of ordinary differential equations, • to justify the convergence behaviour of numerical methods with respect to the posed problem and selected algorithm, • for a given problem, develop a suitable solution approach, if necessary by the composition of several algorithms, to execute this approach and to critically evaluate the results.
Personal Competence	
Social Competence	Students are able to • 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.
Autonomy	Students are capable • to assess whether the supporting theoretical and practical excercises 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 Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Mathematical Modelling in Engineering: Theory, Numerics, Applications: Specialisation I. Numerics (TUHH): 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. Sabine Le Borne, Dr. Christian Seifert
Language	DE/EN
Cycle	SoSe
Content	Numerical methods for Initial Value Problems • single step methods • multistep methods • stiff problems • differential algebraic equations (DAE) of index 1 Numerical methods for Boundary Value Problems • multiple shooting method • difference methods • variational methods
Literature	• 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

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. Sabine Le Borne, Dr. Christian Seifert
Language	DE/EN
Cycle	SoSe
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 (large)	Section	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	
Knowledge	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.
Skills	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	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	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
	Civil Engineering: Core qualification: Compulsory Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective

Assignment for the Following Curricula	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	- 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 M1091: Flight Guidance and Control

Courses

Title	Typ		Hrs/wk	CP
Airline Operations (L1310)	Lecture		3	3
Introduction to Flight Guidance (L0848)	Lecture		3	2
Introduction to Flight Guidance (L0854)	Recitation (large)	Section	1	1
Flight Control (L2374)	Lecture		2	2
Flight Control (L2375)	Recitation (small)	Section	1	1

Module Responsible	Prof. Volker Gollnick
Admission Requirements	None
Recommended Previous Knowledge	• Bachelor Mech. Eng. • Vordiplom Mech. Eng. • Lecture Air Transportation Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	1. Principles of Air Traffic Management and technologies 2. Design and modelling of traffic flows, avionics and sensor systems, cockpit design 3. Principles of flight control systems development 4. Air vehicle description as control path (fixed wing, rotary wing, special) 5. Characteristics of control elements 6. Flight control systems design für stabilization, path control, navigation
Skills	• Understanding and application of different interdisciplinary interdependencies • Integration and assessment of new technologies in the air transportation system • Modelling and assessment of flight guidance systems • Airline fleet planning and fleet operation
Personal Competence	
Social Competence	• Working in interdisciplinary teams • Communication
Autonomy	Organization of workflows and -strategies
Workload in Hours	Independent Study Time 40, Study Time in Lecture 140
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	180 min
	Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems:

Assignment for the Following Curricula	Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic Systems: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory

Course L1310: Airline Operations	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Volker Gollnick, Dr. Karl Echtermeyer
Language	DE
Cycle	SoSe
Content	1. Introdution and overview 2. Airline business models 3. Interdependencies in flight planning (network management, slot management, netzwork 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 L0848: Introduction to Flight Guidance	
Typ	Lecture
Hrs/wk	3
CP	2
Workload in Hours	Independent Study Time 18, Study Time in Lecture 42
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	WiSe
Content	Introduction and motivation Flight guidance principles (airspace structures, organization of air navigation services, etc.) Navigation Radio navigation Satellite navigation 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 Airspace surveillance (radar systems) Commuication systems Avionics architectures (computer systems, bus systems) Cockpit systems and displays (cockpit design, cockpit equipment)
Literature	Rudolf Brockhaus, Robert Luckner, Wolfgang Alles: "Flugregelung", Springer Berlin Heidelberg New York, 2012 Holger Flühr: "Avionik und Flugsicherungssysteme", Springer Berlin Heidelberg New York, 2013 Volker Gollnick, Dieter Schmitt "Air Transport Systems", Springer Berlin Heidelberg New York, 2014

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

Course L2374: Flight Control	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	SoSe
Content	The course will provide knowledge how to describe flight vehicle as a control system. Further it gives inside into the design, layout and optimization of controller for stabilisation and control of flight states and guidance modes. The course is intended to enable participants in the layout of flight control systems presenting the major methods and tools
Literature	Brockhaus, Alles, Luckner: Flugregelung, Springer Verlag, 2011 R.P.G Collinson: Introduction to Avionics Systems, Springer Verlag, 2011

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

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: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems Previous knowledge in: • Systems Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: • 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
Skills	Students are able to: • 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
Personal Competence	
Social Competence	Students are able to: • elaborate partial results and merge with others to form a complete solution
Autonomy	Students are able to: • organize and schedule their practical tasks
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: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: 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: Technical Complementary Course: 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	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. 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: • 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	- Skript zur Vorlesung - Schnabel, P.: Computertechnik-Fibel: Grundlagen Computertechnik, Mikroprozessortechnik, Halbleiterspeicher, Schnittstellen und Peripherie. Books on Demand; 1. Auflage, 2003 - Schnabel, P.: Netzwerktechnik-Fibel: Grundlagen, Übertragungstechnik und Protokolle, Anwendungen und Dienste, Sicherheit. Books on Demand; 1. Auflage, 2004 - Wüst, K.: Mikroprozessortechnik: Grundlagen, Architekturen und Programmierung von Mikroprozessoren, Mikrocontrollern und Signalprozessoren. Vieweg Verlag; 2. aktualisierte und erweiterte Auflage, 2006

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	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. 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: • 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	- Skript zur Vorlesung - Schnabel, P.: Computertechnik-Fibel: Grundlagen Computertechnik, Mikroprozessortechnik, Halbleiterspeicher, Schnittstellen und Peripherie. Books on Demand; 1. Auflage, 2003 - Schnabel, P.: Netzwerktechnik-Fibel: Grundlagen, Übertragungstechnik und Protokolle, Anwendungen und Dienste, Sicherheit. Books on Demand; 1. Auflage, 2004 - Wüst, K.: Mikroprozessortechnik: Grundlagen, Architekturen und Programmierung von Mikroprozessoren, Mikrocontrollern und Signalprozessoren. Vieweg Verlag; 2. aktualisierte und erweiterte Auflage, 2006

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, Dr. Sylvia Melzer
Language	DE
Cycle	SoSe
Content	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®): • 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	- Skript zur Vorlesung - Weilkiens, T.: Systems Engineering mit SysML/UML: Modellierung, Analyse, Design. 2. Auflage, dpunkt.Verlag, 2008 - Holt, J., Perry, S.A., Brownsword, M.: Model-Based Requirements Engineering. Institution Engineering & Tech, 2011

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	• 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	
Knowledge	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.
Skills	Students are able + to think holistically + to independently, securly 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	
Social Competence	Students are able to + solve problems in heterogeneous groups and to document the corresponding results.
Autonomy	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: Specialisation Aircraft Systems: 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 Theoretical Mechanical Engineering: Technical Complementary Course: 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	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	Schwertassek, R. und Wallrapp, O.: Dynamik flexibler Mehrkörpersysteme. Braunschweig, Vieweg, 1999. Seifried, R.: Dynamics of Underactuated Multibody Systems, Springer, 2014. Shabana, A.A.: Dynamics of Multibody Systems. Cambridge Univ. Press, Cambridge, 2004, 3. Auflage.

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
Language	DE
Cycle	WiSe
Content	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	Bestle, D.: Analyse und Optimierung von Mehrkörpersystemen. Springer, Berlin, 1994. Nocedal, J. , Wright , S.J. : Numerical Optimization. New York: Springer, 2006.

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: • Mathematics • Electrical Engineering • Informatics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can: • 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
Skills	Students can ... • 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	
Social Competence	Students can: • jointly develop solutions in inhomogeneous teams • exchange information formally with other teams • present development results in a convenient way
Autonomy	Students can: • 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: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic Systems: Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: 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	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. Content: 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	• 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 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 (small)	Section	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	
Knowledge	• 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
	• 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 the state space representation of spatially invariant distributed systems that are discretized according to an actuator/sensor array • They can explain (in outline) the extension of the bounded real lemma to such distributed systems and the associated synthesis conditions for distributed controllers
Skills	• Students are capable of constructing 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 are able to use standard software tools (Matlab robust control toolbox) for these tasks
	• Students are able to design distributed formation controllers for groups of agents with either LTI or LPV dynamics, using Matlab tools provided

	• Students are able to design distributed controllers for spatially interconnected systems, using the Matlab MD-toolbox
Personal Competence	
Social Competence	Students can work in small groups and arrive at joint results.
Autonomy	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	Computer Science: Specialisation Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic Systems: 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: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Core qualification: 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	• Linear Parameter-Varying (LPV) Gain Scheduling - 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 - 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 • Control of Spatially Interconnected Systems - Multidimensional signals, l2 and L2 signal norm - Multidimensional systems in Roesser state space form - Extension of real-bounded lemma to spatially interconnected systems - LMI-based synthesis of distributed controllers - Spatial LPV control of spatially varying systems - Applications: control of temperature profiles, vibration damping for an actuated beam
Literature	• 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 M0563: Robotics

Courses

Title	Typ		Hrs/wk	CP
Robotics: Modelling and Control (L0168)	Lecture		3	3
Robotics: Modelling and Control (L1305)	Recitation (small)	Section	2	3

Module Responsible	Prof. Uwe Weltin
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	
Knowledge	Students are able to describe fundamental properties of robots and solution approaches for multiple problems in robotics.
Skills	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	
Social Competence	Students are able to work goal-oriented in small mixed groups.
Autonomy	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 110, Study Time in Lecture 70
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	120 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation Aircraft Systems: 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: 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: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Robotics and Computer Science: Elective Compulsory

Course L0168: Robotics: Modelling and Control	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Uwe Weltin
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	Recitation Section (small)
Hrs/wk	2
CP	3
Workload in Hours	Independent Study Time 62, Study Time in Lecture 28
Lecturer	Prof. Uwe Weltin
Language	EN
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

Specialization Cabin Systems

In the specialization in cabin systems, students learn to systematically deal with issues related to the development of aircraft cabin systems, the use of these systems and their application in an operational environment. The aircraft cabin with the cabin management system represents the central working system of an airline during passenger transport. The focus of the specialization is the design of electronic cabin and communication systems using the methodology of Model-Based Systems Engineering (MBSE). Environmental control systems, acoustics, design methods related to composite materials and for integrated product development are further important aspects in the specialization for aircraft cabin development. Airport operations and operations of an airline with respective procedures and systems round off the context of the aircraft cabin. Students have broad knowledge on development methods for complex systems. The can draft requirements, functions and architectures for hardware- and software-based systems, and model and simulate solutions. They know about appropriate tools and methods and master the overall system development process from system design via system implementation and system integration, right up to validation and verification.

Module M1032: Airport Planning and Operations

Courses

Title	Typ		Hrs/wk	CP
Airport Operations (L1276)	Lecture		3	3
Airport Planning (L1275)	Lecture		2	2
Airport Planning (L1469)	Recitation (small)	Section	1	1

Module Responsible	Prof. Volker Gollnick
Admission Requirements	None
Recommended Previous Knowledge	• Bachelor Mech. Eng. • Vordiplom Mech. Eng. • Lecture Air Transportation Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	1. Regulatory principles of airport planning and operations 2. Design of an airport incl. Regulatory baselines 3. Airport operation in the terminal and at the airfield
Skills	• Understanding of different interdisciplinary interdependencies • Planning and design of an airport • Modelling and assessment of airport operation
Personal Competence	
Social Competence	• Working in interdisciplinary teams • Communication
Autonomy	Organization of workflows and -strategies

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 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory

Course L1276: Airport Operations	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Volker Gollnick, Peter Willems (geb. Bießlich)
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
Lecturer	Prof. Volker Gollnick, Dr. Ulrich Häp
Language	DE
Cycle	WiSe
Content	1. Introduction, definitions, overviewg 2. Runway systems 3. Air space strucutres 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
Lecturer	Prof. Volker Gollnick, Dr. Ulrich Häp
Language	DE
Cycle	WiSe
Content	See interlocking course
Literature	See interlocking course

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: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems Previous knowledge in: • Systems Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: • 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
Skills	Students are able to: • 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
Personal Competence	
Social Competence	Students are able to: • elaborate partial results and merge with others to form a complete solution
Autonomy	Students are able to: • organize and schedule their practical tasks
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: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: 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: Technical Complementary Course: 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	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. 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: • 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	- Skript zur Vorlesung - Schnabel, P.: Computertechnik-Fibel: Grundlagen Computertechnik, Mikroprozessortechnik, Halbleiterspeicher, Schnittstellen und Peripherie. Books on Demand; 1. Auflage, 2003 - Schnabel, P.: Netzwerktechnik-Fibel: Grundlagen, Übertragungstechnik und Protokolle, Anwendungen und Dienste, Sicherheit. Books on Demand; 1. Auflage, 2004 - Wüst, K.: Mikroprozessortechnik: Grundlagen, Architekturen und Programmierung von Mikroprozessoren, Mikrocontrollern und Signalprozessoren. Vieweg Verlag; 2. aktualisierte und erweiterte Auflage, 2006

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	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. 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: • 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	- Skript zur Vorlesung - Schnabel, P.: Computertechnik-Fibel: Grundlagen Computertechnik, Mikroprozessortechnik, Halbleiterspeicher, Schnittstellen und Peripherie. Books on Demand; 1. Auflage, 2003 - Schnabel, P.: Netzwerktechnik-Fibel: Grundlagen, Übertragungstechnik und Protokolle, Anwendungen und Dienste, Sicherheit. Books on Demand; 1. Auflage, 2004 - Wüst, K.: Mikroprozessortechnik: Grundlagen, Architekturen und Programmierung von Mikroprozessoren, Mikrocontrollern und Signalprozessoren. Vieweg Verlag; 2. aktualisierte und erweiterte Auflage, 2006

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, Dr. Sylvia Melzer
Language	DE
Cycle	SoSe
Content	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®): • 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	- Skript zur Vorlesung - Weilkiens, T.: Systems Engineering mit SysML/UML: Modellierung, Analyse, Design. 2. Auflage, dpunkt.Verlag, 2008 - Holt, J., Perry, S.A., Brownsword, M.: Model-Based Requirements Engineering. Institution Engineering & Tech, 2011

Module M1091: Flight Guidance and Airline Operations

Courses

Title	Typ		Hrs/wk	CP
Airline Operations (L1310)	Lecture		3	3
Introduction to Flight Guidance (L0848)	Lecture		3	2
Introduction to Flight Guidance (L0854)	Recitation (large)	Section	1	1
Flight Control (L2374)	Lecture		2	2
Flight Control (L2375)	Recitation (small)	Section	1	1

Module Responsible	Prof. Volker Gollnick
Admission Requirements	None
Recommended Previous Knowledge	• Bachelor Mech. Eng. • Vordiplom Mech. Eng. • Lecture Air Transportation Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	1. Principles of Air Traffic Management and technologies 2. Design and modelling of traffic flows, avionics and sensor systems, cockpit design 3. Principles of Airline organization and business 4. Fleet setup, fleet operation, aircraft selection, maintenance, repair overhaul technologies and business
Skills	• Understanding and application of different interdisciplinary interdependencies • Integration and assessment of new technologies in the air transportation system • Modelling and assessment of flight guidance systems • Airline fleet planning and fleet operation
Personal Competence	
Social Competence	• Working in interdisciplinary teams • Communication
Autonomy	Organization of workflows and -strategies
Workload in Hours	Independent Study Time 40, Study Time in Lecture 140
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	180 min
	Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Compulsory

Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory

Course L1310: Airline Operations	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Volker Gollnick, Dr. Karl Echtermeyer
Language	DE
Cycle	SoSe
Content	1. Introdution and overview 2. Airline business models 3. Interdependencies in flight planning (network management, slot management, netzwork 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 L0848: Introduction to Flight Guidance	
Typ	Lecture
Hrs/wk	3
CP	2
Workload in Hours	Independent Study Time 18, Study Time in Lecture 42
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	WiSe
Content	Introduction and motivation Flight guidance principles (airspace structures, organization of air navigation services, etc.) Navigation Radio navigation Satellite navigation 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 Airspace surveillance (radar systems) Commuication systems Avionics architectures (computer systems, bus systems) Cockpit systems and displays (cockpit design, cockpit equipment)
Literature	Rudolf Brockhaus, Robert Luckner, Wolfgang Alles: "Flugregelung", Springer Berlin Heidelberg New York, 2012 Holger Flühr: "Avionik und Flugsicherungssysteme", Springer Berlin Heidelberg New York, 2013 Volker Gollnick, Dieter Schmitt "Air Transport Systems", Springer Berlin Heidelberg New York, 2014

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

Course L2374: Flight Control	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	SoSe
Content	The course will provide knowledge how to describe flight vehicle as a control system. Further it gives inside into the design, layout and optimization of controller for stabilisation and control of flight states and guidance modes. The course is intended to enable participants in the layout of flight control systems presenting the major methods and tools
Literature	Brockhaus, Alles, Luckner: Flugregelung, Springer Verlag, 2011 R.P.G Collinson: Introduction to Avionics Systems, Springer Verlag, 2011

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

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	
Knowledge	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.
Skills	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	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	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: Specialisation Cabin Systems: 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: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: 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	- Introduction and Motivation - Acoustic quantities - Acoustic waves - Sound sources, sound radiation - Sound engergy 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 M1043: Aircraft Systems Engineering

Courses

Title	Typ	Hrs/wk	CP
Fatigue & Damage Tolerance (L0310)	Lecture	2	3
Lightweight Construction with Fibre Reinforced Rolymers - Structural Mechanics (L1514)	Lecture	2	3
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
Mechanisms, Systems and Processes of Materials Testing (L0950)	Lecture	2	2
Turbo Jet Engines (L0908)	Lecture	2	3
System Simulation (L1820)	Lecture	2	2
System Simulation (L1821)	Recitation Section (large)	1	2
Materials Testing (L0949)	Lecture	2	2
Reliability in Engineering Dynamics (L0176)	Lecture	2	2
Reliability in Engineering Dynamics (L1303)	Recitation Section (small)	1	2
Reliability of avionics assemblies (L1554)	Lecture	2	2
Reliability of avionics assemblies (L1555)	Recitation Section (small)	1	1
Reliability of Aircraft Systems (L0749)	Lecture	2	3

Module Responsible	Prof. Frank Thielecke
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Hydraulics • Control Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• 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.
Skills	Students are able to apply basic methods in selected areas of engineering.
Personal Competence	
Social Competence	
Autonomy	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: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

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. Kluver Academic Puplisher, Dordrecht, 2001 E. Haibach. Betriebsfestigkeit Verfahren und Daten zur Bauteilberechnung. VDI-Verlag, Düsseldorf, 1989

Course L1514: Lightweight Construction with Fibre Reinforced Rolymers - Structural Mechanics	
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	DE
Cycle	WiSe
	Fundamentals of Anisotropic Elasticity Displacements, strains and stresses; Equilibrium equations; Kinematics; Hooke’s generalized law **Behaviour of a single laminate layer** Material law of a single laminate layer; Full anisotropy and coupling effects; Material symmetries; Engineering constants; Plane state of stress; Transformation rules **Fundamentals of Micromechanics of a laminate layer**

Content	Representative unit cell; Determination of effective material constants; Effective stiffness properties of a single layer **Classical Laminate Plate Theory** Notations and laminate code; Kinematics and displacement field; Strains and stresses, stress resultants; Constitutive equations and coupling effects; Special laminates and their behavior; Effective laminate properties **Strength of Laminated Plates** Fundamental concept; Phenomenological failure criteria: maximum stresses, maximum strains, Tsai-Hill, Tsai-Wu, Puck, Hashin **Bending of Composite Laminated Plates** Differential Equations; Boundary Conditions; Navier-type solutions; Lévy-type solutions **Stress Concentration Problems** Free-edge effects; Stress concentrations at holes, cracks, delaminations; Aspects of failure analysis **Stability of Thin-Walled Composite Structures** Buckling of anisotropic plates and shells; Influence of loading conditions; Influence of boundary conditions; Exact transcendental solutions and their evaluation; Buckling of stiffened composite plates; Minimum stiffness requirements; Local buckling of stiffener profiles **Written exercise (report required)** Assessment of a thin-walled composite laminated beam taking several different dimensioning criteria into account
Literature	• 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 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	Development of a sandwich structure made of fibre reinforced plastics • 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	• Schürmann, H., „Konstruieren mit Faser-Kunststoff-Verbunden“, Springer, Berlin, 2005. • Puck, A., „Festigkeitsanalsyse 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	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. 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: • 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	- Skript zur Vorlesung - Giemulla, E.M., Rothe B.R. (Hrsg.): Handbuch Luftsicherheit. Universitätsverlag TU Berlin, 2011 - Thomas, A.R. (Ed.): Aviation Security Management. Praeger Security International, 2008

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	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. 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: • 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	- Skript zur Vorlesung - Giemulla, E.M., Rothe B.R. (Hrsg.): Handbuch Luftsicherheit. Universitätsverlag TU Berlin, 2011 - Thomas, A.R. (Ed.): Aviation Security Management. Praeger Security International, 2008

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	Application, analysis and discussion of basic and advanced testing methods to ensure correct selection of applicable testing procedure for investigation of part/materials deficiencies • 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	• E. Macherauch: Praktikum in Werkstoffkunde, Vieweg • G. E. Dieter: Mechanical Metallurgy, McGraw-Hill • R. Bürgel: Lehr- und Übungsbuch Festigkeitslehre, Vieweg • R. Bürgel: Werkstoffe sícher 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	• 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	• Bräunling: Flugzeugtriebwerke • Engmann: Technologie des Fliegens • Kerrebrock: Aircraft Engines and Gas Turbines

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
Language	DE
Cycle	WiSe
Content	All participants must bring a notebook, to install and use the software OpenModelica. • 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: Heat transfer • Example: System with different subsystems
Literature	[1] Modelica Association: "Modelica Language Specification - Version 3.3", Linköping, Sweden, 2 0 1 2 [2] M. Tiller: “Modelica by Example", http://book.xogeny.com, 2014. [3] M. Otter, H. Elmqvist, et al.: "Objektorientierte Modellierung Physikalischer Systeme", at- Automatisierungstechnik (german), Teil 1 - 17, Oldenbourg Verlag, 1999 - 2000. [4] P. Fritzson: "Principles of Object-Oriented Modeling and Simulation with Modelica 3.3", Wiley-IEEE Press, New York, 2015. [5] P. Fritzson: “Introduction to Modeling and Simulation of Technical and Physical Systems with Modelica”, Wiley, New York, 2011.

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
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	Application and analysis of basic mechanical as well as non-destructive testing of materials • 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	E. Macherauch: Praktikum in Werkstoffkunde, Vieweg G. E. Dieter: Mechanical Metallurgy, McGraw-Hill

Course L0176: 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. Uwe Weltin
Language	EN
Cycle	SoSe
Content	Method for calculation and testing of reliability of dynamic machine systems • Modeling • System identification • Simulation • Processing of measurement data • Damage accumulation • Test planning and execution
Literature	Bertsche, B.: Reliability in Automotive and Mechanical Engineering. Springer, 2008. ISBN: 978-3-540-33969-4 Inman, Daniel J.: Engineering Vibration. Prentice Hall, 3rd Ed., 2007. ISBN-13: 978-0132281737 Dresig, H., Holzweißig, F.: Maschinendynamik, Springer Verlag, 9. Auflage, 2009. ISBN 3540876936. VDA (Hg.): Zuverlässigkeitssicherung bei Automobilherstellern und Lieferanten. Band 3 Teil 2, 3. überarbeitete Auflage, 2004. ISSN 0943-9412

Course L1303: 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. Uwe Weltin
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L1554: Reliability of avionics assemblies	
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	SoSe
Content	The objective of the lecture with the corresponding exercise is the acquisition of knowledge for development, electronic packaging technology and the production of electronic components for safety-critical applications. On an item, component and system level it is shown, how the specified safety objectives for electronics in aircraft can be achieved. Current challenges, such as availability of components, component counterfeiting and the use of components off-the-shelf (COTS) will be discussed: • Survey of the role of electronics in aviation • System levels: From silicon to mechatronic systems • Semiconductor components, assemblies, systems • Challenges of electronic packaging technology (AVT) • System integration in electronics: Requirements for AVT • Methods and techniques of AVT • Error patterns for assemblies and avoidance of errors • Reliability analysis for printed circuit boards (PCBs) • Reliability of Avionics • COTS, ROTS, MOTS and the F ^{3}I concept • Future challenges for electronics
Literature	- Skript zur Vorlesung Hanke, H.-J.: Baugruppentechnologie der Elektronik. Leiterplatten. Verlag Technik, 1994 Scheel, W.: Baugruppentechnologie der Elektronik. Montage. Verlag Technik, 1999

Course L1555: Reliability of avionics assemblies	
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	SoSe
Content	The objective of the lecture with the corresponding exercise is the acquisition of knowledge for development, electronic packaging technology and the production of electronic components for safety-critical applications. On an item, component and system level it is shown, how the specified safety objectives for electronics in aircraft can be achieved. Current challenges, such as availability of components, component counterfeiting and the use of components off-the-shelf (COTS) will be discussed: • Survey of the role of electronics in aviation • System levels: From silicon to mechatronic systems • Semiconductor components, assemblies, systems • Challenges of electronic packaging technology (AVT) • System integration in electronics: Requirements for AVT • Methods and techniques of AVT • Error patterns for assemblies and avoidance of errors • Reliability analysis for printed circuit boards (PCBs) • Reliability of Avionics • COTS, ROTS, MOTS and the F ^{3}I concept • Future challenges for electronics
Literature	- Skript zur Vorlesung Hanke, H.-J.: Baugruppentechnologie der Elektronik. Leiterplatten. Verlag Technik, 1994 Scheel, W.: Baugruppentechnologie der Elektronik. Montage. Verlag Technik, 1999

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	• 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	• CS 25.1309 • SAE ARP 4754 • SAE ARP 4761

Module M1343: Fibre-polymer-composites

Courses

Title	Typ	Hrs/wk	CP
Structure and properties of fibre-polymer-composites (L1894)	Lecture	2	3
Design with fibre-polymer-composites (L1893)	Lecture	2	3

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	
Knowledge	Students can use the knowledge of fiber-reinforced composites (FRP) and its constituents to play (fiber / matrix) and define the necessary testing and analysis. 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).
Skills	Students are capable of • 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	
Social Competence	Students can • arrive at funded work results in heterogenius groups and document them. • provide appropriate feedback and handle feedback on their own performance constructively.
Autonomy	Students are able to - 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 124, Study Time in Lecture 56
Credit points	6
Course achievement	None

Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: 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 Theoretical Mechanical Engineering: Technical Complementary Course: 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	- 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 Deckker, New York

Course L1893: Design with 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	Designing with Composites: Laminate Theory; Failure Criteria; Design of Pipes and Shafts; Sandwich Structures; Notches; Joining Techniques; Compression Loading; Examples
Literature	Konstruieren mit Kunststoffen, Gunter Erhard , Hanser Verlag

Module M0721: Air Conditioning

Courses

Title	Typ		Hrs/wk	CP
Air Conditioning (L0594)	Lecture		3	5
Air Conditioning (L0595)	Recitation (large)	Section	1	1

Module Responsible	Prof. Gerhard Schmitz
Admission Requirements	None
Recommended Previous Knowledge	Technical Thermodynamics I, II, Fluid Dynamics, Heat Transfer
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students know the different kinds of air conditioning systems for buildings and mobile applications and how these systems are controlled. They are familiar with the change of state of humid air and are able to draw the state changes in a h1+x,x-diagram. They are able to calculate the minimum airflow needed for hygienic conditions in rooms and can choose suitable filters. They know the basic flow pattern in rooms and are able to calculate the air velocity in rooms with the help of simple methods. They know the principles to calculate an air duct network. They know the different possibilities to produce cold and are able to draw these processes into suitable thermodynamic diagrams. They know the criteria for the assessment of refrigerants.
Skills	Students are able to configure air condition systems for buildings and mobile applications. They are able to calculate an air duct network and have the ability to perform simple planning tasks, regarding natural heat sources and heat sinks. They can transfer research knowledge into practice. They are able to perform scientific work in the field of air conditioning.
Personal Competence	
Social Competence	The students are able to discuss in small groups and develop an approach.
Autonomy	Students are able to define independently tasks, to get new knowledge from existing knowledge as well as to find ways to use the knowledge in practice.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and	60 min

scale	
Assignment for the Following Curricula	Energy and Environmental Engineering: Specialisation Energy and Environmental Engineering: Elective Compulsory Energy Systems: Specialisation Energy Systems: Elective Compulsory Energy Systems: Specialisation Marine Engineering: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory International Management and Engineering: Specialisation II. Energy and Environmental Engineering: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Energy Systems: Elective Compulsory Process Engineering: Specialisation Process Engineering: Elective Compulsory

Course L0594: Air Conditioning	
Typ	Lecture
Hrs/wk	3
CP	5
Workload in Hours	Independent Study Time 108, Study Time in Lecture 42
Lecturer	Prof. Gerhard Schmitz
Language	DE
Cycle	SoSe
Content	1. Overview 1.1 Kinds of air conditioning systems 1.2 Ventilating 1.3 Function of an air condition system 2. Thermodynamic processes 2.1 Psychrometric chart 2.2 Mixer preheater, heater 2.3 Cooler 2.4 Humidifier 2.5 Air conditioning process in a Psychrometric chart 2.6 Desiccant assisted air conditioning 3. Calculation of heating and cooling loads 3.1 Heating loads 3.2 Cooling loads 3.3 Calculation of inner cooling load 3.4 Calculation of outer cooling load 4. Ventilating systems 4.1 Fresh air demand 4.2 Air flow in rooms 4.3 Calculation of duct systems

	4.4 Fans 4.5 Filters 5. Refrigeration systems 5.1. compression chillers 5.2Absorption chillers
Literature	• Schmitz, G.: Klimaanlagen, Skript zur Vorlesung • VDI Wärmeatlas, 11. Auflage, Springer Verlag, Düsseldorf 2013 • Herwig, H.; Moschallski, A.: Wärmeübertragung, Vieweg+Teubner Verlag, Wiesbaden 2009 • Recknagel, H.; Sprenger, E.; Schrammek, E.-R.: Taschenbuch für Heizung- und Klimatechnik 2013/2014, 76. Auflage, Deutscher Industrieverlag, 2013

Course L0595: Air Conditioning	
Typ	Recitation Section (large)
Hrs/wk	1
CP	1
Workload in Hours	Independent Study Time 16, Study Time in Lecture 14
Lecturer	Prof. Gerhard Schmitz
Language	DE
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 (small)	Section	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	
Knowledge	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: - 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
Skills	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 Compatibilty to the development of electrical components and systems.
Personal Competence	
Social Competence	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).
Autonomy	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.

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: Compulsory General Engineering Science (German program, 7 semester): Specialisation Electrical Engineering: Elective Compulsory Electrical Engineering: Core qualification: Elective Compulsory Electrical Engineering: Core qualification: Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Electrical Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Electrical Engineering: Elective Compulsory Mechatronics: Specialisation System Design: 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	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. Topics: - 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	- 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 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 (large)	Section	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	
Knowledge	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.
Skills	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	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	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: Specialisation Cabin Systems: Elective Compulsory Mechatronics: Specialisation System Design: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Product Development and Production: 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	- 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 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	
Knowledge	After passing the module students are able to: • 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.
Skills	After passing the module students are able to: • 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.
Personal Competence	
Social Competence	After passing the module students are able to: • prepare and lead team meetings and moderation processes, • work in teams on complex tasks, • represent problems and solutions and advance ideas.
Autonomy	After passing the module students are able to: • give a structured feedback and accept a critical feedback, • implement the accepted feedback autonomous.
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
	Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory

Assignment for the Following Curricula	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: Technical Complementary Course: 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	**Lecture** 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. Topics of the course include in particular: • Methods of product development, • Presentation techniques, • Industrial Design, • Design for variety • Modularization methods, • Design catalogs, • Adapted QFD matrix, • Systematic material selection, • Assembly oriented design, Construction management • 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. **Exercise (PBL)** In the exercise the content presented in the lecture “Integrated Product Development II” and methods of product development and design management will be enhanced. 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.

Literature	• 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 M0633: Industrial Process Automation

Courses

Title	Typ		Hrs/wk	CP
Industrial Process Automation (L0344)	Lecture		2	3
Industrial Process Automation (L0345)	Recitation (small)	Section	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	
Knowledge	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'.
Skills	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.
Personal Competence	
Social Competence	The students work in teams to solve problems.
Autonomy	The students can reflect their knowledge and document the results of their work.
Workload in Hours	Independent Study Time 124, Study Time in Lecture 56
Credit points	6

Course achievement	Compulsory	Bonus	Form	Description
	No	10 %	Excercises	

Examination	Written exam
Examination duration and scale	90 minutes
	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:

Assignment for the Following Curricula	Elective Compulsory Computer Science: Specialisation II: Intelligence Engineering: Elective Compulsory Electrical Engineering: Specialisation Control and Power Systems Engineering: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: 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: Technical Complementary Course: 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	- 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	J. Lunze: „Automatisierungstechnik“, Oldenbourg Verlag, 2012 Reisig: Petrinetze: Modellierungstechnik, Analysemethoden, Fallstudien; Vieweg+Teubner 2010 Hrúz, Zhou: Modeling and Control of Discrete-event Dynamic Systems; Springer 2007 Li, Zhou: Deadlock Resolution in Automated Manufacturing Systems, Springer 2009 Pinedo: Planning and Scheduling in Manufacturing and Services, Springer 2009

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 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: • Mathematics • Electrical Engineering • Informatics
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students can: • 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
Skills	Students can ... • 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	
Social Competence	Students can: • jointly develop solutions in inhomogeneous teams • exchange information formally with other teams • present development results in a convenient way
Autonomy	Students can: • 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: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic Systems: Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: 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	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. Content: 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	• 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

Specialization Air Transportation Systems

The degree programme „Air Transportation Systems and Preliminary Aircraft Design“ provides a comprehensive understanding of operational aspects of air transport. Further students are educated in aircraft design methods based on operational requirements. The programme competences will extend and intensify the basic compentencies of the bachelor studies by specific methods in design and modelling of air transport systems and and aircraft a spart of it.

As a result graduates will be system analysts being able to design, integrate, model and assess complex systems like air transport including the related technologies.

Module M1091: Flight Guidance and Airline Operations

Courses

Title	Typ		Hrs/wk	CP
Airline Operations (L1310)	Lecture		3	3
Introduction to Flight Guidance (L0848)	Lecture		3	2
Introduction to Flight Guidance (L0854)	Recitation (large)	Section	1	1
Flight Control (L2374)	Lecture		2	2
Flight Control (L2375)	Recitation (small)	Section	1	1

Module Responsible	Prof. Volker Gollnick
Admission Requirements	None
Recommended Previous Knowledge	• Bachelor Mech. Eng. • Vordiplom Mech. Eng. • Lecture Air Transportation Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	1. Principles of Air Traffic Management and technologies 2. Design and modelling of traffic flows, avionics and sensor systems, cockpit design 3. Principles of Airline organization and business 4. Fleet setup, fleet operation, aircraft selection, maintenance, repair overhaul technologies and business
Skills	• Understanding and application of different interdisciplinary interdependencies • Integration and assessment of new technologies in the air transportation system • Modelling and assessment of flight guidance systems • Airline fleet planning and fleet operation
Personal Competence	
Social Competence	• Working in interdisciplinary teams • Communication
Autonomy	Organization of workflows and -strategies

Workload in Hours	Independent Study Time 40, Study Time in Lecture 140
Credit points	6
Course achievement	None
Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory

Course L1310: Airline Operations	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Volker Gollnick, Dr. Karl Echtermeyer
Language	DE
Cycle	SoSe
Content	1. Introdution and overview 2. Airline business models 3. Interdependencies in flight planning (network management, slot management, netzwork 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 L0848: Introduction to Flight Guidance	
Typ	Lecture
Hrs/wk	3
CP	2
Workload in Hours	Independent Study Time 18, Study Time in Lecture 42
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	WiSe
Content	Introduction and motivation Flight guidance principles (airspace structures, organization of air navigation services, etc.) Navigation Radio navigation Satellite navigation 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 Airspace surveillance (radar systems) Commuication systems Avionics architectures (computer systems, bus systems) Cockpit systems and displays (cockpit design, cockpit equipment)
Literature	Rudolf Brockhaus, Robert Luckner, Wolfgang Alles: "Flugregelung", Springer Berlin Heidelberg New York, 2012 Holger Flühr: "Avionik und Flugsicherungssysteme", Springer Berlin Heidelberg New York, 2013 Volker Gollnick, Dieter Schmitt "Air Transport Systems", Springer Berlin Heidelberg New York, 2014

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

Course L2374: Flight Control	
Typ	Lecture
Hrs/wk	2
CP	2
Workload in Hours	Independent Study Time 32, Study Time in Lecture 28
Lecturer	Prof. Volker Gollnick
Language	DE
Cycle	SoSe
Content	The course will provide knowledge how to describe flight vehicle as a control system. Further it gives inside into the design, layout and optimization of controller for stabilisation and control of flight states and guidance modes. The course is intended to enable participants in the layout of flight control systems presenting the major methods and tools
Literature	Brockhaus, Alles, Luckner: Flugregelung, Springer Verlag, 2011 R.P.G Collinson: Introduction to Avionics Systems, Springer Verlag, 2011

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

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: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Control Systems Previous knowledge in: • Systems Engineering
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	Students are able to: • 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
Skills	Students are able to: • 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
Personal Competence	
Social Competence	Students are able to: • elaborate partial results and merge with others to form a complete solution
Autonomy	Students are able to: • organize and schedule their practical tasks
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: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: 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: Technical Complementary Course: 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	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. 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: • 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	- Skript zur Vorlesung - Schnabel, P.: Computertechnik-Fibel: Grundlagen Computertechnik, Mikroprozessortechnik, Halbleiterspeicher, Schnittstellen und Peripherie. Books on Demand; 1. Auflage, 2003 - Schnabel, P.: Netzwerktechnik-Fibel: Grundlagen, Übertragungstechnik und Protokolle, Anwendungen und Dienste, Sicherheit. Books on Demand; 1. Auflage, 2004 - Wüst, K.: Mikroprozessortechnik: Grundlagen, Architekturen und Programmierung von Mikroprozessoren, Mikrocontrollern und Signalprozessoren. Vieweg Verlag; 2. aktualisierte und erweiterte Auflage, 2006

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	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. 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: • 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	- Skript zur Vorlesung - Schnabel, P.: Computertechnik-Fibel: Grundlagen Computertechnik, Mikroprozessortechnik, Halbleiterspeicher, Schnittstellen und Peripherie. Books on Demand; 1. Auflage, 2003 - Schnabel, P.: Netzwerktechnik-Fibel: Grundlagen, Übertragungstechnik und Protokolle, Anwendungen und Dienste, Sicherheit. Books on Demand; 1. Auflage, 2004 - Wüst, K.: Mikroprozessortechnik: Grundlagen, Architekturen und Programmierung von Mikroprozessoren, Mikrocontrollern und Signalprozessoren. Vieweg Verlag; 2. aktualisierte und erweiterte Auflage, 2006

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, Dr. Sylvia Melzer
Language	DE
Cycle	SoSe
Content	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®): • 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	- Skript zur Vorlesung - Weilkiens, T.: Systems Engineering mit SysML/UML: Modellierung, Analyse, Design. 2. Auflage, dpunkt.Verlag, 2008 - Holt, J., Perry, S.A., Brownsword, M.: Model-Based Requirements Engineering. Institution Engineering & Tech, 2011

Module M1043: Aircraft Systems Engineering

Courses

Title	Typ	Hrs/wk	CP
Fatigue & Damage Tolerance (L0310)	Lecture	2	3
Lightweight Construction with Fibre Reinforced Rolymers - Structural Mechanics (L1514)	Lecture	2	3
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
Mechanisms, Systems and Processes of Materials Testing (L0950)	Lecture	2	2
Turbo Jet Engines (L0908)	Lecture	2	3
System Simulation (L1820)	Lecture	2	2
System Simulation (L1821)	Recitation Section (large)	1	2
Materials Testing (L0949)	Lecture	2	2
Reliability in Engineering Dynamics (L0176)	Lecture	2	2
Reliability in Engineering Dynamics (L1303)	Recitation Section (small)	1	2
Reliability of avionics assemblies (L1554)	Lecture	2	2
Reliability of avionics assemblies (L1555)	Recitation Section (small)	1	1
Reliability of Aircraft Systems (L0749)	Lecture	2	3

Module Responsible	Prof. Frank Thielecke
Admission Requirements	None
Recommended Previous Knowledge	Basic knowledge in: • Mathematics • Mechanics • Thermodynamics • Electrical Engineering • Hydraulics • Control Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• 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.
Skills	Students are able to apply basic methods in selected areas of engineering.
Personal Competence	
Social Competence	
Autonomy	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: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Avionic and Embedded Systems: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: Elective Compulsory Theoretical Mechanical Engineering: Specialisation Aircraft Systems Engineering: Elective Compulsory

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. Kluver Academic Puplisher, Dordrecht, 2001 E. Haibach. Betriebsfestigkeit Verfahren und Daten zur Bauteilberechnung. VDI-Verlag, Düsseldorf, 1989

Course L1514: Lightweight Construction with Fibre Reinforced Rolymers - Structural Mechanics	
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	DE
Cycle	WiSe
	Fundamentals of Anisotropic Elasticity Displacements, strains and stresses; Equilibrium equations; Kinematics; Hooke’s generalized law **Behaviour of a single laminate layer** Material law of a single laminate layer; Full anisotropy and coupling effects; Material symmetries; Engineering constants; Plane state of stress; Transformation rules **Fundamentals of Micromechanics of a laminate layer**

Content	Representative unit cell; Determination of effective material constants; Effective stiffness properties of a single layer **Classical Laminate Plate Theory** Notations and laminate code; Kinematics and displacement field; Strains and stresses, stress resultants; Constitutive equations and coupling effects; Special laminates and their behavior; Effective laminate properties **Strength of Laminated Plates** Fundamental concept; Phenomenological failure criteria: maximum stresses, maximum strains, Tsai-Hill, Tsai-Wu, Puck, Hashin **Bending of Composite Laminated Plates** Differential Equations; Boundary Conditions; Navier-type solutions; Lévy-type solutions **Stress Concentration Problems** Free-edge effects; Stress concentrations at holes, cracks, delaminations; Aspects of failure analysis **Stability of Thin-Walled Composite Structures** Buckling of anisotropic plates and shells; Influence of loading conditions; Influence of boundary conditions; Exact transcendental solutions and their evaluation; Buckling of stiffened composite plates; Minimum stiffness requirements; Local buckling of stiffener profiles **Written exercise (report required)** Assessment of a thin-walled composite laminated beam taking several different dimensioning criteria into account
Literature	• 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 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	Development of a sandwich structure made of fibre reinforced plastics • 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	• Schürmann, H., „Konstruieren mit Faser-Kunststoff-Verbunden“, Springer, Berlin, 2005. • Puck, A., „Festigkeitsanalsyse 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	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. 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: • 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	- Skript zur Vorlesung - Giemulla, E.M., Rothe B.R. (Hrsg.): Handbuch Luftsicherheit. Universitätsverlag TU Berlin, 2011 - Thomas, A.R. (Ed.): Aviation Security Management. Praeger Security International, 2008

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	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. 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: • 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	- Skript zur Vorlesung - Giemulla, E.M., Rothe B.R. (Hrsg.): Handbuch Luftsicherheit. Universitätsverlag TU Berlin, 2011 - Thomas, A.R. (Ed.): Aviation Security Management. Praeger Security International, 2008

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	Application, analysis and discussion of basic and advanced testing methods to ensure correct selection of applicable testing procedure for investigation of part/materials deficiencies • 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	• E. Macherauch: Praktikum in Werkstoffkunde, Vieweg • G. E. Dieter: Mechanical Metallurgy, McGraw-Hill • R. Bürgel: Lehr- und Übungsbuch Festigkeitslehre, Vieweg • R. Bürgel: Werkstoffe sícher 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	• 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	• Bräunling: Flugzeugtriebwerke • Engmann: Technologie des Fliegens • Kerrebrock: Aircraft Engines and Gas Turbines

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
Language	DE
Cycle	WiSe
Content	All participants must bring a notebook, to install and use the software OpenModelica. • 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: Heat transfer • Example: System with different subsystems
Literature	[1] Modelica Association: "Modelica Language Specification - Version 3.3", Linköping, Sweden, 2 0 1 2 [2] M. Tiller: “Modelica by Example", http://book.xogeny.com, 2014. [3] M. Otter, H. Elmqvist, et al.: "Objektorientierte Modellierung Physikalischer Systeme", at- Automatisierungstechnik (german), Teil 1 - 17, Oldenbourg Verlag, 1999 - 2000. [4] P. Fritzson: "Principles of Object-Oriented Modeling and Simulation with Modelica 3.3", Wiley-IEEE Press, New York, 2015. [5] P. Fritzson: “Introduction to Modeling and Simulation of Technical and Physical Systems with Modelica”, Wiley, New York, 2011.

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
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	Application and analysis of basic mechanical as well as non-destructive testing of materials • 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	E. Macherauch: Praktikum in Werkstoffkunde, Vieweg G. E. Dieter: Mechanical Metallurgy, McGraw-Hill

Course L0176: 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. Uwe Weltin
Language	EN
Cycle	SoSe
Content	Method for calculation and testing of reliability of dynamic machine systems • Modeling • System identification • Simulation • Processing of measurement data • Damage accumulation • Test planning and execution
Literature	Bertsche, B.: Reliability in Automotive and Mechanical Engineering. Springer, 2008. ISBN: 978-3-540-33969-4 Inman, Daniel J.: Engineering Vibration. Prentice Hall, 3rd Ed., 2007. ISBN-13: 978-0132281737 Dresig, H., Holzweißig, F.: Maschinendynamik, Springer Verlag, 9. Auflage, 2009. ISBN 3540876936. VDA (Hg.): Zuverlässigkeitssicherung bei Automobilherstellern und Lieferanten. Band 3 Teil 2, 3. überarbeitete Auflage, 2004. ISSN 0943-9412

Course L1303: 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. Uwe Weltin
Language	EN
Cycle	SoSe
Content	See interlocking course
Literature	See interlocking course

Course L1554: Reliability of avionics assemblies	
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	SoSe
Content	The objective of the lecture with the corresponding exercise is the acquisition of knowledge for development, electronic packaging technology and the production of electronic components for safety-critical applications. On an item, component and system level it is shown, how the specified safety objectives for electronics in aircraft can be achieved. Current challenges, such as availability of components, component counterfeiting and the use of components off-the-shelf (COTS) will be discussed: • Survey of the role of electronics in aviation • System levels: From silicon to mechatronic systems • Semiconductor components, assemblies, systems • Challenges of electronic packaging technology (AVT) • System integration in electronics: Requirements for AVT • Methods and techniques of AVT • Error patterns for assemblies and avoidance of errors • Reliability analysis for printed circuit boards (PCBs) • Reliability of Avionics • COTS, ROTS, MOTS and the F ^{3}I concept • Future challenges for electronics
Literature	- Skript zur Vorlesung Hanke, H.-J.: Baugruppentechnologie der Elektronik. Leiterplatten. Verlag Technik, 1994 Scheel, W.: Baugruppentechnologie der Elektronik. Montage. Verlag Technik, 1999

Course L1555: Reliability of avionics assemblies	
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	SoSe
Content	The objective of the lecture with the corresponding exercise is the acquisition of knowledge for development, electronic packaging technology and the production of electronic components for safety-critical applications. On an item, component and system level it is shown, how the specified safety objectives for electronics in aircraft can be achieved. Current challenges, such as availability of components, component counterfeiting and the use of components off-the-shelf (COTS) will be discussed: • Survey of the role of electronics in aviation • System levels: From silicon to mechatronic systems • Semiconductor components, assemblies, systems • Challenges of electronic packaging technology (AVT) • System integration in electronics: Requirements for AVT • Methods and techniques of AVT • Error patterns for assemblies and avoidance of errors • Reliability analysis for printed circuit boards (PCBs) • Reliability of Avionics • COTS, ROTS, MOTS and the F ^{3}I concept • Future challenges for electronics
Literature	- Skript zur Vorlesung Hanke, H.-J.: Baugruppentechnologie der Elektronik. Leiterplatten. Verlag Technik, 1994 Scheel, W.: Baugruppentechnologie der Elektronik. Montage. Verlag Technik, 1999

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	• 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	• CS 25.1309 • SAE ARP 4754 • SAE ARP 4761

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 (large)	Section	2	3

Module Responsible	Prof. Benedikt Kriegesmann
Admission Requirements	None
Recommended Previous Knowledge	• Technical mechanics • Higher math
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	

Knowledge	• Design optimization
	  ◦ Gradient based methods
	  ◦ Genetic algorithms
	  ◦ Optimization with constraints
	  ◦ Topology optimization
	• Reliability analysis
	  ◦ Stochastic basics
	  ◦ Monte Carlo methods
	  ◦ Semi-analytic approaches
	• robust design optimization
	  ◦ Robustness measures
	  ◦ Coupling of design optimization and reliability analysis

Skills	• Application of optimization algorithms and probabilistic methods in the design of structures • Programming with Matlab • Implementation of algorithms • Debugging
Personal Competence	
Social Competence	• Team work • Oral explanation of the the work
Autonomy	• Application of methods learned in the framework of a home work • Familiarizing with source code provided • Description of approaches and results
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: Specialisation Air Transportation Systems: Elective Compulsory Product Development, Materials and Production: Core qualification: Elective Compulsory Theoretical Mechanical Engineering: Technical Complementary Course: 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	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.
	
	The following contents will be considered:
	
	• Design optimization
	  ◦ Gradient based methods
	  ◦ Genetic algorithms
	  ◦ Optimization with constraints
	  ◦ Topology optimization
	• Reliability analysis
	  ◦ Stochastic basics
	  ◦ Monte Carlo methods
	  ◦ Semi-analytic approaches
	• robust design optimization
	  ◦ Robustness measures
	  ◦ Coupling of design optimization and reliability analysis

Literature	[1] Arora, Jasbir. Introduction to Optimum Design. 3rd ed. Boston, MA: Academic Press, 2011. [2] Haldar, A., and S. Mahadevan. Probability, Reliability, and Statistical Methods in Engineering Design. John Wiley & Sons New York/Chichester, UK, 2000.

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: Fibre-polymer-composites

Courses

Title	Typ	Hrs/wk	CP
Structure and properties of fibre-polymer-composites (L1894)	Lecture	2	3
Design with fibre-polymer-composites (L1893)	Lecture	2	3

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	
Knowledge	Students can use the knowledge of fiber-reinforced composites (FRP) and its constituents to play (fiber / matrix) and define the necessary testing and analysis. 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).
Skills	Students are capable of • 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	
Social Competence	Students can • arrive at funded work results in heterogenius groups and document them. • provide appropriate feedback and handle feedback on their own performance constructively.
Autonomy	Students are able to - 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 124, Study Time in Lecture 56
Credit points	6
Course achievement	None

Examination	Written exam
Examination duration and scale	180 min
Assignment for the Following Curricula	Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: 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 Theoretical Mechanical Engineering: Technical Complementary Course: 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	- 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 Deckker, New York

Course L1893: Design with 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	Designing with Composites: Laminate Theory; Failure Criteria; Design of Pipes and Shafts; Sandwich Structures; Notches; Joining Techniques; Compression Loading; Examples
Literature	Konstruieren mit Kunststoffen, Gunter Erhard , Hanser Verlag

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 (small)	Section	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	
Knowledge	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: - 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
Skills	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 Compatibilty to the development of electrical components and systems.
Personal Competence	
Social Competence	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).
Autonomy	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.

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: Compulsory General Engineering Science (German program, 7 semester): Specialisation Electrical Engineering: Elective Compulsory Electrical Engineering: Core qualification: Elective Compulsory Electrical Engineering: Core qualification: Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory General Engineering Science (English program, 7 semester): Specialisation Electrical Engineering: Compulsory General Engineering Science (English program, 7 semester): Specialisation Electrical Engineering: Elective Compulsory Mechatronics: Specialisation System Design: 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	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. Topics: - 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	- 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 M1032: Airport Planning and Operations

Courses

Title	Typ		Hrs/wk	CP
Airport Operations (L1276)	Lecture		3	3
Airport Planning (L1275)	Lecture		2	2
Airport Planning (L1469)	Recitation (small)	Section	1	1

Module Responsible	Prof. Volker Gollnick
Admission Requirements	None
Recommended Previous Knowledge	• Bachelor Mech. Eng. • Vordiplom Mech. Eng. • Lecture Air Transportation Systems
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	1. Regulatory principles of airport planning and operations 2. Design of an airport incl. Regulatory baselines 3. Airport operation in the terminal and at the airfield
Skills	• Understanding of different interdisciplinary interdependencies • Planning and design of an airport • Modelling and assessment of airport operation
Personal Competence	
Social Competence	• Working in interdisciplinary teams • Communication
Autonomy	Organization of workflows and -strategies
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 min
Assignment for the Following Curricula	Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory International Management and Engineering: Specialisation II. Aviation Systems: Elective Compulsory Logistics, Infrastructure and Mobility: Specialisation Infrastructure and Mobility: Elective Compulsory

Course L1276: Airport Operations	
Typ	Lecture
Hrs/wk	3
CP	3
Workload in Hours	Independent Study Time 48, Study Time in Lecture 42
Lecturer	Prof. Volker Gollnick, Peter Willems (geb. Bießlich)
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
Lecturer	Prof. Volker Gollnick, Dr. Ulrich Häp
Language	DE
Cycle	WiSe
Content	1. Introduction, definitions, overviewg 2. Runway systems 3. Air space strucutres 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
Lecturer	Prof. Volker Gollnick, Dr. Ulrich Häp
Language	DE
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	
Knowledge	After passing the module students are able to: • 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.
Skills	After passing the module students are able to: • 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.
Personal Competence	
Social Competence	After passing the module students are able to: • prepare and lead team meetings and moderation processes, • work in teams on complex tasks, • represent problems and solutions and advance ideas.
Autonomy	After passing the module students are able to: • give a structured feedback and accept a critical feedback, • implement the accepted feedback autonomous.
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
	Aircraft Systems Engineering: Specialisation Cabin Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective Compulsory International Management and Engineering: Specialisation II. Product Development and Production: Elective Compulsory

Assignment for the Following Curricula	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: Technical Complementary Course: 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	**Lecture** 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. Topics of the course include in particular: • Methods of product development, • Presentation techniques, • Industrial Design, • Design for variety • Modularization methods, • Design catalogs, • Adapted QFD matrix, • Systematic material selection, • Assembly oriented design, Construction management • 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. **Exercise (PBL)** In the exercise the content presented in the lecture “Integrated Product Development II” and methods of product development and design management will be enhanced. 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.

Literature	• 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 M0808: Finite Elements Methods

Courses

Title	Typ		Hrs/wk	CP
Finite Element Methods (L0291)	Lecture		2	3
Finite Element Methods (L0804)	Recitation (large)	Section	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	
Knowledge	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.
Skills	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	
Social Competence	Students can work in small groups on specific problems to arrive at joint solutions.
Autonomy	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
	Civil Engineering: Core qualification: Compulsory Energy Systems: Core qualification: Elective Compulsory Aircraft Systems Engineering: Specialisation Aircraft Systems: Elective Compulsory Aircraft Systems Engineering: Specialisation Air Transportation Systems: Elective

Assignment for the Following Curricula	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	- 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

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	• According to General Regulations §21 (1): At least 60 credit points have to be achieved in study programme. The examinations board decides on exceptions.
Recommended Previous Knowledge	
Educational Objectives	After taking part successfully, students have reached the following learning results
Professional Competence	
Knowledge	• 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.
Skills	The students are able: • 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	
Social Competence	Students can • 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.

Autonomy	Students are able: • 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 Electrical Engineering: Thesis: Compulsory Energy and Environmental Engineering: Thesis: Compulsory Energy Systems: Thesis: Compulsory Environmental Engineering: Thesis: Compulsory Aircraft Systems Engineering: Thesis: Compulsory Global Innovation Management: Thesis: Compulsory Computational Science and Engineering: Thesis: Compulsory Information and Communication Systems: 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 Mathematical Modelling in Engineering: Theory, Numerics, Applications: 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