Module Overview

Module 1	Aerospace Systems Engineering
Content	**Day 1: Aviation requirements** • Business requirements Aviation business: airlines, OEMs, suppliers, MRO, new markets and players Strengths and weaknesses of the industry in Germany and Baden-Württemberg • Environmental protection requirements Environmental impact of aviation Risks and opportunities (EU and global) • Regulatory requirements Laws and authorities in the EU and USA Building regulations and standards Recommendations and standards • Safety requirements Acceptable probability of failure, why so extreme? Sources of danger (technical failure, human factors, environmental effects, security) • Basics of safety analysis **Day 2: Aerospace Management** • Aircraft System Development Process (oriented to SAE ARP-4754) • Aerospace Management and Leadership (practical aspects) • Safety vs. Compliance • Safety vs. Security • V-Modell vs. Agility • Human Factors **Day 3: Aircraft Safety Assessment** • Aircraft Safety Assessment (oriented to SAE ARP-4761) **Day 4: Flight System Technology and Control** • Overview of aircraft structure • Aerodynamics • Flight Mechanics and Control • Flight Control System • Auto Flight System **Day 5: Hydraulic and Navigation** • Hydraulic Power System Airbus A320 Airbus A380 • Navigation System Cockpit Systems Air Data and Inertial Sensors Air Data and Inertial Reference Systems (ADC/CADC/ADIRU) Radio Navigation (Radar, ILS, GNSS) **Day 6: Communication** • Communication media cable / fibre optics /wireless • Communication patterns CSMA / P2P • Protocols ARINC 429-629 / AFDX / PCIeX/ MIL-STD 1773 **Day 7: Degrees of Redundancy**

	• Dual Simplex Redundancy • Duplex Redundancy • Triplex • Quadruplex • Multi-Duplex / Multi-Triplex
Self-study phase	Material (literature, videos, simulations, etc.) is made available on an e-learning platform for self-study between the classroom sessions
Project work	Independent design of a primary/secondary flight control system for a future aircraft
Prerequisites	Bachelor's degree or relevant professional work experience
Learning objectives / applicability	• Design expertise in avionics technologies and architectures • Comprehensibility of specifications and framework conditions • Decision-making competence with regard to safety and security processes and methods (finding compromises)
Dates	11.10.25, 08.11.25, 06.12.25, 30.01.26, 31.01.26, 27.02.26, 28.02.26

Module 2	**Fundamentals of Spacecraft Technology**

Content	**Day 1: Fundamentals of Space Engineering**
	• Fundamentals of Space Mission Design, Operations and Mission Control
	    ○ Definition of a Space Mission & Key Actors
	    ○ Space Mission Types & Objectives
	    ○ Space Mission Destinations
	    ○ Key Elements of a Space Mission
	    ○ Space Mission Requirements & System Drivers
	    ○ Overview Spacecraft Subsystems
	    ○ Overview Space Mission Development Phases
	    ○ Overview Space Mission Operations
	• Basics of Launcher and Space Vehicle Propulsion
	    ○ Basic Performance Requirements of Space Propulsion
	    ○ The Rocket Equation and Important Rocket Parameters
	    ○ Chemical Propellant Rockets
	    ○ The Staging Principle
	    ○ Electrical Thrusters
	    ○ Alternative Propulsion Concepts
	• General Definitions and Unperturbed Orbital Motion (Day 2)
	    ○ Coordinate Frames and General Definitions
	    ○ The Two-Body Problem
	    ○ Orbit Geometry
	    ○ Space Velocities
	Day 2: Space Environment and its Impacts
	• The Space Environment
	    ○ Major Factors of Influence on the Space Environment
	    ○ Gravitational Fields
	    ○ Atmospheres and Ionospheres
	    ○ Magnetic Fields
	    ○ Electromagnetic and Particle Radiation
	    ○ Solid Matter
	• Impacts of Space Environment on Spacecraft and Mission Design
	    ○ Overview of Design Issues in Pre-operational Phase
	    ○ Impacts of the Space Environment
	        ▪ Overview
	        ▪ Gravitational Fields / Microgravity
	        ▪ Vacuum, Atmospheres and Ionospheres
	        ▪ Radiation / Magnetic Fields
	        ▪ Solid Matter

	- Overview of Design Issues for Post-Operational Phase
	- Summary
	Day 3: Spacecraft Subsystems
	• Concepts of Spacecraft Structures and Materials
	  - Spacecraft Structures
	    ▪ Tasks and Categories
	    ▪ Structural Loads During Mission Phases
	    ▪ Key Characteristics and Design Process
	  - Spacecraft Materials
	    ▪ Selection Criteria
	    ▪ Material Erosion Examples
	• Concepts of Spacecraft Thermal Control
	  - Thermal Environment & Objectives of Thermal Control
	    ▪ External Heat Loads
	    ▪ Internal Heat Loads
	    ▪ Objectives of Thermal Control
	  - Thermal Analysis and Tests
	    ▪ Heat Transfer Mechanism
	    ▪ Heat Balance Equation for Spacecraft
	    ▪ Thermal Analysis and Tests
	  - Thermal Control Hardware
	    ▪ Passive Thermal Control
	    ▪ Active Thermal Control
	• Fundamental Concepts of Communication in Space
	  - Important Definitions and Boundary Conditions
	  - Electromagnetic Waves & Basics for Space Communication
	  - Modulation, Coding, Protocols
	  - Important System Components
	  - Link Budget
	  - Important Aspects Human Spaceflight
	  - Examples
	• Concepts of Spacecraft Power Systems
	  - Power system – functions and configuration
	  - Primary energy sources and energy conversion
	    ▪ Overview
	    ▪ Solar power
	    ▪ Radioisotope Thermoelectric Generator (RTG)
	    ▪ Nuclear reactors in space
	  - Energy storage systems
	    ▪ Overview
	    ▪ Secondary batteries
	    ▪ Regenerative fuel cells
	  - Power systems selection criteria
	Day 4: Translational Motion (Orbit Control)
	• Perturbed Orbital Motion
	  - Variations in the Orbital Elements due to General Perturbing Forces
	  - Perturbing Forces Acting on a Satellite
	  - Effects of Atmospheric Drag on the Satellite Orbit
	  - Nodal Precession
	• Orbital Manoeuvres and Interorbital Transfers
	  - One-Impulse Manoeuvres
	  - Two- and Three-Impulse Manoeuvres
	  - Continuous Thrust Manoeuvres
	  - Effects of Impulsive Manoeuvres on the ISS Orbit
	Day 5: Rotational Motion (Attitude Control)
	• Fundamentals of Attitude Determination and Control

	- One-Impulse Manoeuvres - Two- and Three-Impulse Manoeuvres - Continuous Thrust Manoeuvres - Effects of Impulsive Manoeuvres on the ISS Orbit **Day 6: Applied Orbital Mechanics for Vehicle Operations** - Access to Space (Day 5) - Launch Sites and Launch Directions - Launch Window and Launch Time - Launch Profile - Launch Abort Modes - Fundamentals of Rendezvous, Departure and Relative Motion - Launch and Orbit Insertion - Phasing - Far Range Rendezvous - Close Range Rendezvous - Final Approach and Docking - Departure - Deorbit, Reentry and Landing - Overview & General Aspects - Undocking & Deorbit - Re-entry - Types & Energies of Atmospheric Entry Maneuvers - Important Parameters & Definitions - Ballistic, Lift-assisted & Skip-assisted Re-entry - Re-entry Trajectory & Corridor - Remarks Stability & Thermal Protection System - Landing - Disposal Aspects **Day 7: Exploration** - Introduction to Exploration Flight Dynamics and Navigation - Possible destinations and their features - Basic concepts - Mission to the Moon - Interplanetary missions - Communication and navigation methods - Interstellar Spaceflight Visions - Dimensions, Energies, Relativity - Why? Where Do We Stand? - Concepts
Self-study phase	Material (literature, videos, simulations, etc.) is made available on an e-learning platform for self-study between the classroom sessions
Project work	Topics will be announced during the course
Prerequisites	Bachelor's degree or relevant professional work experience
Learning objectives / applicability	- Comprehensive overview of all key elements of a space mission and knowledge of the interrelationships. - Understanding of the space environment and its impact on the spacecraft and the mission. - Comprehensive overview of all relevant subsystems of a spacecraft. - Understanding of the physical laws of orbital mechanics and their practical effects, the most relevant perturbations and knowledge of various possibilities for orbit modification, including their advantages and disadvantages. - Basic understanding of the attitude dynamics of spacecraft and an overview of the possibilities of active and passive attitude control. - Understanding of the background to central space manoeuvres (rocket launch, rendezvous with a space station, re-entry) and classification of these.

	• Overview of the requirements for exploration missions that differ from earthbound missions as well as space visions and their categorisation.
Dates	03.11.25, 04.11.25, 05.11.25, 10.11.25, 11.11.25, 12.11.25, 13.11.25

Module 3	**Aerospace Sensors and Radar**
Content	**Day 1:** • **Radio-frequency (RF) basics** Line theory, scattering parameters, Smith chart, practical work: simulations with LTSpice and ADS • **Realisation of passive RF components** Strip lines, couplers, filters • **RF measurement technology - network analyser** Introduction to network analyser, practical work: measurements with network analyser (NWA) and on the topics of radio-frequency fundamentals, filters, couplers **Day 2:** • **Active RF-components** Transceiver architectures, noise, non-linearities • **Signal generation** Oscillator, PLL, phase noise • **RF-Measurement Technology – Spektrum analysator** Introduction to spectrum analyser, practical work: Measurements on a mixer and with a spectrum analyser (SA) **Day 3:** • **What is Radar?** Frequency ranges, technologies, wave propagation, what does a radar sensor see?, resolution and accuracy • **Radar equation and RCS** Radar equation for different targets, target properties • **Modulation methods** Introduction to modulation and continuous wave radar, pulse modulation **Day 4:** • **Angular radar systems** Fundamentals of angulation, phased arrays, antennas for radar systems, practical boundary conditions • **Synthetic aperture radar (SAR)** Functionality, application examples and limitations • **New trends in radar sensor technology** **Day 5:** • **Digital signal processing for radar** Distance estimation, improving resolution in the distance direction • **Simulations for signal processing** Practical work: FFT for distance estimation, distance resolution, accuracy, influence of SNR • **Radar measurements with a 77 GHz sensor** Practical work on real hardware and with real signals **Day 6:** • **Digital signal processing in radar** Velocity estimation, angle estimation, multi-antenna systems, MIMO, beamforming • **Simulations for signal processing** Practical work: speed estimation with 2D and 3D FFT • **Design of the FMCW multi-ramp method** System analysis for a real sensor, practical work: commissioning of 60 GHz radar sensors **Day 7:** • **Signal evaluation with radar**

	CFAR, clustering, tracking, practical work on CFAR, automotive radar toolbox, tracking toolbox • **Measurements with a 60 GHz FMCW radar** Practical work: distance, speed and angle measurements, discussion of the measurement results • **Final discussion**
Self-study phase	Material (literature, videos, simulations, etc.) is made available on an e-learning platform for self-study between the classroom sessions
Project work	Current topic of radar technology in aerospace or implementation and evaluation of real radar measurements for distance, speed and angle determination.
Prerequisites	Bachelor's degree or relevant professional work experience
Learning objectives / applicability	• General and specialised knowledge in the field of radar technology at system and component level • Fundamentals of high-frequency technology and its significance at system level • Evaluation of radar signals across the entire processing chain
Dates	22.09.25, 23.09.25, 08.10.25, 09.10.25, 13.10.25, 14.10.25, 21.10.25

Module 4	**Aerospace Software Engineering**
Content	**Day 1:** • **Overview of the specifications** SAE ARP-4754A: System Development Process SAE ARP-4761: Safety Assessment & Functional Hazard Analysis RTCA DO-178C: Software Development & Certification RTCA DO-330: Tool Qualification RTCA DO-331/332/333: Model-Based, Object-Oriented, Formal Methods RTCA DO-254: Hardware Design Assurance RTCA DO-160: Environmental Conditions & Testing RTCA DO-326A / DO-356A: Airborne Security (Cybersecurity Guidelines) • **Aerospace Software Project Management** Aerospace Software Project Management Project life cycle in the aviation context Roles: Certification Authority, Design Assurance Engineer, Project Manager Requirements for traceability, documentation, process maturity Differences to classical/agile SW projects Version Management / Configuration Management Introduction to Configuration Management (CM) What is CM and why is it critical in aerospace? Overview of configuration objects: Code, requirements, tests, documents Lifecycle of a configuration item (Create - Modify - Release - Archive) Aviation requirements for a KM system Clear identification and versioning Change tracking and release processes Auditability and baseline control (e.g. configuration status accounting) Evidence in DO-178C & DO-254 (e.g. Configuration Management Plan) Tools for use Comparison: Git, Subversion (SVN), ClearCase Industry-standard tools: GitLab, IBM Rational, Polarion, Helix Core Introduction to Git (hands-on/overview) Repositories, commits, branches, tags Best practices for structured KM in Git (e.g. Git Flow) Toolchain e.g. Git Flow) Toolchain integration (e.g. Git + Jenkins + DOORS) Problem Reporting & Change Management (approx. 60 min) Problem Reporting Classification of bugs

	Traceable bug lifecycle (Detection → Logging → Tracking → Resolution) Tools: JIRA, Bugzilla, Polarion ALM, gitlab, github Change management Change request, impact analysis, approval workflows Connection with traceability and safety assessment Review & approval in DO-178 environment Risk management in aviation projects (approx. 45-60 min) Systematic risk identification (e.g. technical, scheduling, safety-related risks) Methods: FMEA, FTA, hazard analysis (ARP-4761) Risk treatment: avoidance, mitigation, acceptance Risk management documentation & review Dissimilarity Definition: What does 'dissimilar software' mean in the context of safety & certification? Use in redundancy architectures (e.g. various implementations, different tools/compilers) Advantages: Fault independence, increased fault tolerance Challenges: Verification, costs, maintenance Conclusion / summary Review of the standards landscape and their interaction Discussion of typical practical problems with KM, change management, dissimilarity Q&A **Day 2:** **V-Model Development process (RTCA DO-178)** Introduction: DO-178C and the V-Modell Structure of the development process Requirements development in the V-Modell Software design in a safety-critical environment Implementation and integration Traceability & artefact structure Exemplary documents and artefacts Practical exercise / workshop part Summary & reflection Optional: In-depth topics Comparison with ISO 26262 (e.g. automotive vs. aviation) **Day 3:** **V-Model V&V-Process (DAL-A)** Introduction to the V-Modell Verification and validation in the V-Modell Introduction to DAL (Design Assurance Levels) according to DO-178C V&V process at DAL-A in detail Tools and techniques for V&V at DAL-A Example scenario / mini-workshop Conclusion / reflection Checklist for V&V at DAL-A What distinguishes DAL-A from lower levels (e.g. B/C)? Typical audit questions / preparation for certification Q&A session & summary Optional bonus topic (if there is time): Tool qualification according to DO-330 Differences to ISO 26262 / IEC 61508 **Day 4 and 5:** **Software Architecture** IMA ARINC-653+ARINC-664

	Fundamentals of IMA technologies
	    IMA platform concepts
	    IMA and aviation systems
	    ARINC 653 - API, operating system,
	    Development and realisation of an application with the ARINC 653 API
	    Signal processing and bus communication with AFDX
	    Design and verification of a system function
	Worst case execution time
	    WCET basics
	    Assessment of algorithms (O-notation)
	    Factors influencing the WCET
	    Measurement and procedure for determining the WCET
	    Static WCET analysis
	    Measurement-based WCET analysis
	    Tool support & frameworks
	    WCET in real-time systems
	    Challenges & limits
	    Application examples
	    Project or presentation
	Multi-core
	    Multicore basics Architecture
	    Parallelisation techniques
	    Thread programming
	    Synchronisation and memory access
	    Programming models for multicore
	    Multicore optimisation
	    Debugging & testing in multicore environments
	    Operating system support for multicore
	    Performance measurement and tuning
	    Applications of multicore programming
	    Bonus topics (advanced)
	Model-based software development
	Code generation
	    Basics and motivation
	    Types of code generation
	    Tools & frameworks for code generation
	    Advantages and disadvantages of code generation
	    Code generation in build processes
	    Template-based code generation
	    Domain-specific languages (DSLs)
	    Security & quality of generated code
	    Code generation in AI development
	    Reverse engineering and re-generation
	    Case studies and practical examples
	
	Day 6 and 7:
	Software Development
	Defensive programming and safe C
	    Error handling and exception handling
	    Validation of inputs
	    Contract-based programming (design by contract)
	    Unit testing & test-driven development (TDD)
	Code reviews & static code analysis
	Use of safe programming patterns
	Logging and monitoring
	Documentation and comprehensibility
	Defensive programming in a team context

	Comparison of different programming languages Defensive programming vs. offensive techniques Configuration Fundamentals of configurable systems Configurability vs. self-adaptation Problems of configurable/self-adaptable systems CI/CT Introduction: Continuous Integration (CI) & Continuous Testing (CT) Tool: Jenkins Git and Jenkins - interaction Setting up a workflow Code coverage Performance measurement in CI Expandable additional topics (optional) Security checks (SAST) Error and log analysis Containerisation & CI/CD Best practices & anti-patterns Presentation/project report AI in development Introduction to AI AI methods Retrieval-Augmented Generation (RAG) AI-supported tools in software development AI in CI/CD pipelines Challenges and risks Practical examples and tools Future & outlook Presentation or work: Software reuse / COTS What is software reuse Integration into the V-model Traceability Types of software reuse Evaluation and selection of COTS Quality aspects and risks of reuse Integration techniques Documentation and governance Cost-effectiveness of software reuse Practical examples µC / memory / ASIC / FPGA Design of an avionics computer Consideration of individual components
Self-study phase	Material (literature, videos, simulations, etc.) is made available on an e-learning platform for self-study between the classroom sessions
Project work/ exam	Project work and presentations by the participants during the week. At the end, a written exam of 2 hours: 1 hour online test with questions on the various topics; 1 hour working on a specific task using the methods and techniques learnt.
Prerequisites	Bachelor's degree or relevant professional work experience
Learning objectives / applicability	• Participants will be familiar with the most important aviation-specific standards (e.g. DO-178C, ARP-4754A) as well as their interrelationships and requirements for software development processes. They understand the basics of configuration, change and risk management and can categorize common tools such as Git and JIRA. • Participants understand the structured development process in the V-model in accordance with DO-178C, including the creation and documentation of requirements, software design

	and implementation. They know how these phases are linked and made traceable in safety-critical projects. • Participants know the requirements for verification and validation according to DO-178C for safety-critical software of class DAL-A. They know how verification is planned, carried out and documented, including the use of suitable tools and coverage metrics. • Participants understand the basics of IMA, ARINC-653/664 and the architecture of modern avionics systems. They can evaluate real-time conditions (e.g. WCET), multicore challenges and model-based development approaches in safety-relevant systems. • - Participants know the principles of defensive programming, configurable systems and CI/CT pipelines with tools such as Jenkins and Git. They will have an overview of AI-supported development methods, software reuse/COTS use and system integration on a µC, FPGA and ASIC basis.
Dates	25.10.25, 22.11.25, 20.12.25, 16.01.26, 17.01.26, 13.02.26, 14.02.26