Interaction of Wind Gust and Airfoil with Active Flap

As the influence of wind gusts on aircraft is a major factor increasing the unsteady loads, a way to mitigate the influence of gusts is sought. We aim to achieve this by controlling the airfoil lift using a fast response actuated trailing-edge flap. An active pitching wing is available as gust generator, which produces a wind gust-like unsteady vortex. In the planned wind tunnel experiments, several measurement techniques, such as hot wire, time-resolved pressure and particle image velocimetry (PIV) measurements will be employed to further characterize both, simulated wind gust and wing flow.

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Hysteresis behaviour of a Dual-Bell nozzle

The nozzle design of a space launcher has a strong influence on the effectiveness of the propulsion system. The main engine usually uses chemical propulsion. With this kind of propulsion, the expansion ratio determines the maximum available thrust. Commonly used nozzle types employ truncated ideal contour (TIC) or thrust optimised shapes. With these nozzle concepts the maximum area ratio is limited to prevent flow separation inside the nozzle. This issue is avoided with the use of altitude compensating nozzles, such as the dual-bell nozzle. The dual-bell nozzle is a one-step altitude compensating nozzle and comprises of a sea-level and altitude operating mode. The transition from sea-level to altitude mode is the most critical phase in the operation of a dual-bell nozzle since high side loads can be generated. A retransition to sea-level mode should be avoided during flight. A hysteresis between transition and retransition exists for the dual-bell nozzle that naturally prevents retransition. The purpose of this work is to quantify the hysteresis of a dual-bell nozzle and to characterise the influence of an outer flow on the hysteresis. This will be accomplished by numerical simulations on a generic space launcher configuration.

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Fig. 1: Dual-Bell nozzle in altitude mode (top) and during transition (bottom)
Investigation of Aerodynamic Effects on Novel Engine Integration Concepts

Studies in the framework of the Collaborative Research Centre (CRC) SFB 880 are focusing on novel engine integration concepts to achieve reduction in noise emission and fuel consumption. Within these concepts engine nacelles are on the wing (OWN) offer enough space for growing engine sizes when increasing the bypass ratio (BPR) of turbofan engines while having simultaneously a positive effect on the aircraft noise due to e.g. shielding effects. A major drawback of OWN arrangements is the aerodynamic behavior which is known to lead to a higher overall airframe drag with respect to common under-the-wing turbofan installations. Recent studies have shown, though, that OWN can offer the potential to improve aerodynamic performance especially for rising BPR and corresponding increasing engine dimensions (Hooker et al., 2013). When the nacelle is placed at the wing’s trailing edge at high cruise velocities the air sucked in by the engine strongly influences the flow field of the wing by slowing down the approaching flow. As a result, the strength of the shock that is observed on the suction side of the wing for the clean wing configuration at the cruise Mach number will be reduced.

On the other hand, utilizing such novel integration concepts requires careful analysis and consideration of local aerodynamic effects. This hold especially true for the nacelle-to-wing connection of the embedded-engine as well as for local fan aerodynamic effects occurring as a consequence of the incoming boundary layer and circulation from the upper wing flow (see marked area in figure). Within the project such local effects shall be investigated using RANS analysis. This includes parameter studies for different nacelle-to-wing intersections and the resulting fan sensitivities as well as 3D-shaping of the local nacelle geometry. Second part of the work will be an aerodynamic analysis in order to explain the observed effects and to derive design rules for local geometry adaption.

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Simulation of the Deformation of Aluminum Foams

To reduce the noise of aircrafts, aluminum foams can be applied to the trailing edge of the wing. The pores allow air to flow between the upper and the lower side of the wing and thus reduce the pressure drop and noise production compared to a sharp edge. The microstructure of these foams can be controlled by a rolling process to compress the pores in the foam. In this project, the deformation of a porous aluminium foam is simulated in a finite element model. The influence of different rolling parameters on the foam deformation is then evaluated to predict the deformation of the foam and the shape of the pores.

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Fig. 1: Finite element simulation of a rolling process.
Improvement of the Oxidation Resistance of Titanium Alloys

Even if Titanium alloys show outstanding specific fatigue properties, their application in aircraft engines is limited due to their poor oxidation resistance. Above 550°C the protective TiO$_2$ oxide layer becomes permeable for Oxygen leading to severe oxidation at the oxide-metal-interface. The addition of Niobium and Silicon to Titanium alloys leads to reduced oxidation whereas the underlying mechanisms are not yet well understood.

In the current work, different binary and ternary Titanium alloys will produced and analysed with respect to their oxidations resistance by means of optical microscopy, scanning electron microscopy and micro-focused hard X-ray phase analyses, see figure 1.

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![Figure 1](image.png)

**Fig. 1:** Micro-focused hard X-ray experiment carried out at the synchrotron PETRA III of HASYLAB, DESY. Different zones are detected by phase analyses at Ti 2Nb alloy after oxidation at 800°C for 96 hours.
Verification of the open source orbital propagator NEPTUNE

The backbone of every SST (Space, Surveillance and Tracking) system is a suitable propagator. This is a software that provides a mathematical model to predict future positions of objects in orbit. In the past, the Institute of Space Systems has developed to propagator NEPTUNE. It considers all relevant perturbations in earth orbit (geopotential, atmospheric resistance, third body interference, etc.) and uses a Störmer-Cowell integrator to integrate the equations of motion. In addition to pure position extrapolation, propagators are used in statistical orbit determination. Here they serve as a mathematical model to adapt the state description of the object to actual observations. For the adaptation there are different methods available, examples are Least-Square methods or different Kalman filters.

Neptune has been used very successfully in many simulation campaigns, and currently, it is in the process of being released as open source software. However, so far a comprehensive verification of is missing. Verification means that simulated results are compared with those of actual objects in Earth orbit and the resulting deviation is described. This shall be done for the orbit prediction as well as for a part of existing orbit determination methods. In detail the following points are to be worked on:

- Familiarize with the topics of orbit propagation and statistical orbit determination.
- Research of available reference data, both for orbit determination and propagation (e.g. ESA Satellite, Laser-Ranging data, etc.).
- Perform simulations based on the researched data.
- Comparison of results and documentation.
- Depending on the duration of stay and resources available: planning and execution of own measurement campaigns with the help of sensors available from partners (telescopes, laser ranging systems).

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Dimensional analysis for CubeSat design and dynamics mapping

Experimental validation is the final step in the development of systems and algorithms in aerospace engineering. To fulfil its purpose, the experimental environment and the test object should replicate the real world as faithfully as possible. That means ideally that the test mockup should be exactly the same system supposed to fly and the experimental environment exactly the same mission environment. This is often not the case, meaning that experimental validation does not include the validation of flight hardware/software but is only limited to method-validation.

The Institute of Space Systems (IRAS) is building an air-bearing testbed to validate flight hardware/software. Therefore it’s necessary to replicate real subsystems on the test mockup and real orbital mechanics on experimental environment. In this work the powerful technique of dimensional analysis should be analyzed and assessed in its suitability to perform the following tasks:

- **Test mockup design**: Satellite subsystem design by means of the Buckingham-Pi-Theorem. The idea is to identify relevant ratios and non-dimensional parameters and “quickly” design a new CubeSat based on former designs. The SQL-Based CubeSat Analyse and Design Tool (QuSAD) contains an SQL database with available commercial off the shelf (COTS) CubeSat components, which will be used in this study.

- **Experimental environment**: The experimental reproducing of orbital mechanics in an air-bearing test environment. That means that the dynamics of motion, especially formation flight (Clohessy Wiltshire equations), and atmospheric perturbations has to be mapped into a planar 7m x 4m motion. The problem of accurate actuation should be investigated.

![Figure 1: The free floating environment at IRAS](image-url)

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Middleware enabling interconnectivity of simulation components

The Institute of Flight Guidance operates two fixed-base flight simulators, a cabin simulator and two generic air traffic controller working positions. Each of the simulators runs within its own network environment. The future goal is to connect each component within an integrated simulation infrastructure. This would allow a joint simulation operation while maintaining the possibility to use each component separately. This study should identify and verify potential middleware solutions to enable data access across the simulation environment.

The following steps describe the task in more detail:

- Literature research regarding current middleware solutions
- Conception of a network architecture
- Implementation of a demonstrator to verify the middleware solutions

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Low-level jet occurrence at different sites - statistics, formation mechanisms and potential impact on wind energy

The Institute of Flight Guidance has operated a wind lidar for wind profiles up to 500 m. Based on the data sets of different sites, analysis on specific wind phenomena like the low-level jet are possible. The comparison allows investigating formation mechanisms and the impact on wind energy.

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Implementation and Validation of a Finite Element-based Partitioned Fluid-structure Interaction Solver for Strongly Coupled Problems using FEniCS

Introduction:
At the Institute of Aircraft Design and Lightweight Structures novel simulation-based approaches to the analysis of aircraft ditching are developed as part of the collaborative EU project „Increased Safety and robust certification for ditching of aircraft and helicopters“.

The process of ditching is characterized by a significant interaction between fluid and structure and accompanied by a strong effect of added mass effect of the fluid on the structure. As shown in [1], this causes numerical difficulties if densities of fluid and structure are comparable and the structure is slender. For efficient high-fidelity ditching simulations, robust partitioned coupling procedures are desirable. Such procedures have to be carefully designed in order to preserve numerical stability and accuracy of the overall simulation.

Tasks
At the beginning of the project, available literature on partitioned simulation methods for FSI problems involving strong interaction shall be reviewed. Furthermore, the student will be given the opportunity to become acquainted with the automated programming environment FEniCS [2], which will be used in this work. Afterwards, the iterative coupling procedure described in [3] shall be re-implemented within FEniCS and validated using the Turek-Hron FSI3 benchmark case (see [4]). The procedure should then be extended by a convergence acceleration technique, for instance Aitken’s relaxation. Optionally, one selected simple staggered procedure from [5] shall be implemented and compared to the iterative method in terms of accuracy and computational effort.

References
Accuracy Studies of Structural Analyses of an Aircraft Wing with an UHBR Engine

At the Institute of Aircraft Design and Lightweight Structures wing designs made out of fibre-reinforced composites are investigated within Finite Element Analysis (FEA). Using algorithms for the structural dimensioning and optimization, the FE-model is adapted to the occurring loads during aircraft operation.

The Finite Element (FE) model for an aircraft wing with an Ultra High Bypass Ratio engine is generated by a parametrized wing generator-routine utilizing MSC Patran. Within this routine, the CAD wing model is created and each wing part is meshed for FEA successively. The aim of this work is to perform different levels of mesh refinements for the FE wing model. Subsequently FE-computations should be performed to compare the obtained results on the differently refined meshes. The FE meshes should be compared in terms of accuracy and computation time. The differently refined meshes should also be used within a structural dimensioning routine. The results should be compared to analyze the impact of the mesh refinement onto the structural dimensioning of the wing. Finally, a best practice for an appropriate mesh detailing level for aircraft wings should be deduced.