MDO 2022 POSTERS SESSIONS

Bussemaker Jasper, DLR	**The Influence of Architectural Design Decisions on the Formulation of MDAO Problems** Formulating system architecture design problems as optimization problems has the potential to help reduce bias in searching the combinatorial design space, and help find novel system architectures to better meet the challenges of the future. Typical types of design decisions present in architecture optimization problems, however, pose some special challenges to currently existing MDO problem formulations. Design variables are mixed-discrete, a hierarchy might exist between design variables where one design variable can deactivate another, and there might be multiple conflicting objectives to optimize for simultaneously. This poster explores some of the impacts these effects can have on MDO problems, in particular regarding the inclusion or exclusion of analysis blocks.
Hammami Omar, ENSTA Paris	**UAV System Modeling with MDO Down to Additive Manufacturing** UAV system modeling and optimization is extended to additive manufacturing to integrate in a unique flow both modeling, simulation and manufacturing. MDO is a must in this context.
Hammami Omar, ENSTA Paris	**Pushing Down System Design Cost with System Engineering and MDO: A CAse Study in Autonomous Robotics with Reverse Engineering** Increasing system complexity is pushing for higher cost and product delivery delay. For these reasons design space size is rarely adressed properly resulting in largely suboptimal system designs. In this work we demonstrate the use of MDO as a way to simultaneously optimize system design, pushing down cost and reducing design delays. As a proof of concept we apply our approach to an existing robot through reverse engineering resulting in automatic optimized redesign of susbsystem parts and overall system design. Multiphysics MDO coupled with low power embedded system design results in increasing power autonomy.
Tiziano Ghisu, Rolls Royce	**High-fidelity CFD Analysis of In-serviced Shrouded High-Pressure Turbine Rotor Blades** In-service deterioration can lead to undesired shape variations on high-pressure turbine rotor blades. This can have a significant impact on efficiency, power generation and component life. The aim of this study is to provide a high-fidelity flow simulation of a large number of in-serviced shrouded high-pressure turbine blades of a modern jet engine. In order to establish a digital model of the shape variation, a novel reverse engineering procedure is carried out, leading to a parametrized definition of each blade's variations from nominal including any observable damage. The investigation of residual performance is conducted by means of an in-house, full 3D steady-state RANS simulation of the flow around a series of damaged rotor blade geometries, which are obtained through high-resolution GOM scans. The analysis shows that the aerodynamic performance of

	the HPT rotor blades under investigation is primarily sensitive to shroud damage, which is found to account for efficiency losses often greater than 3%, and for more than 80% of the total performance loss. A secondary role on efficiency is found to be played by the blade shape deviation. A highly linear correlation is found between HPT stage efficiency and a combination of shroud damage parameters. *Diego Lopez, Tiziano Ghisu, Shahrokh Shahpar*
Tiziano Ghisu, **Rolls Royce**	**Extending Highly Loaded Axial Fan Stability Range Through Novel Blade Design** The tip clearance size has historically been considered the main factor affecting stability range in axial fan and compressors. This work reveals that the stall characteristics are defined by the axial momentum flux of the tip leakage flow and that tip clearance is primarily a strong driver for this metric. An advanced three-dimensional design approach is used to modify the axial momentum, enabling a higher degree of control over the stability range. The effect of the axial momentum on efficiency is also addressed and the trade-off between operability range and design point performance derived. The results show that that the conditions for optimal stability differ from those for optimal efficiency and that control over the axial momentum enables tuning the design for a desired exchange. *Diego Lopez, Tiziano Ghisu, Timoleon Kipouros, Shahrokh Shahpar, Mark J. Wilson*
Volle Fabian, DLR	**High-Fidelity Industry-Scale Aerostructural Optimisation Design Chain Using Airbus Lagrange and DLR Tau** The progress of simultaneous shape and structure sizing optimisation with aeroelastic analysis utilising a full adjoint for high-fidelity structure and aerodynamic simulation of industry scale problems is showcased. The Airbus Defence and Space tools Lagrange as a structural solver with analytical sensitivities and Descartes as a parametric model generator are coupled with DLR's FlowSimulator including TAU (high-fidelity fluid solver with adjoint sensitivities). A CSM model is generated with Descartes using the CPACS format. Thereby the vast capabilities of Lagrange for differentiated consideration of strength, buckling instability and manufacturing constraints are demonstrated. The local surface pressure of the CFD simulation is interpolated on the CSM mesh of the wing. The displacements of the FE simulation of trimmed flight conditions, balancing the aerodynamic and inertia loads, are propagated on the CFD surface mesh and to the volume mesh. The loop is iterated while the design variables of external shape and internal structure e.g. stinger cross sections, material thicknesses and composite ply layup are optimised for maximum aircraft performance.
Degrassi Gabrielle, ESTECO	**MDO workflow for adaptive sampling techniques to improve POD-based Reduced Order Models** The research aims to find a proper method to improve sampling efficiency for Reduced Order Models creation and this was done using a combination of ESTECO SPDM technology and OPTIMAD ROM technology, taking advantage of an MDO workflow to orchestrate the whole process to analyze the sampling methods.

Bruggeman Anne-Liza, Delft University	**Design for Manufacturing and Assembly in Early Aircraft Design Stages : A New Methodological Approach** The simultaneous design of an aircraft system and its corresponding production processes is a complex and challenging task. It consists of two different systems that are tightly connected, each putting requirements on the other. Furthermore, each production process has different design variables and constraints and many production processes may be required to produce one aircraft system. The goal of the research is to develop a new methodological approach to obtain the best combination of aircraft system design, production processes and materials according to the stakeholders' needs. This will be achieved by combining, amongst others, Model-Based Systems Engineering with Multidisciplinary Design Analysis and Optimization. The result is a modular and flexible framework that enables the optimization of different combinations of design and production processes while maintaining transparency and traceability. This will support in making better trade-offs and thus obtaining improved product designs.
Pretsch Lisa, University of Munich	**Interdisciplinary design optimization of aircraft engine compressor blades using low- and high-fidelity models** The application of multidisciplinary design optimization (MDO) in an industrial context poses challenges concerning computational effort and integration into company structures. Low-fidelity models are commonly used to speed up computations. We propose a multi-fidelity approach, which also reduces the required exchange of data, complex models, and simulation tools between disciplinary design teams. The interdisciplinary rather than multidisciplinary design optimization involves a distinction between high-fidelity main discipline and low- fidelity side discipline. The latter is modelled using Kriging and proper-orthogonal decomposition (POD). The proposed approach is illustrated by a weakly coupled aero-structural compressor blade optimization. It is shown to yield a valid blade design at significantly reduced computational cost. The interdisciplinary multi-fidelity optimization has the potential to consider the effects of all involved disciplines at little additional cost and organizational complexity, while keeping the focus on the main discipline.
Anhichem Mehdi, University of Liverpool	**Multifidelity Data Fusion Applied to Aircraft Wing Pressure Distributions** Designing an aircraft and analysing its performance requires uncertainty-aware and robust aerodynamic data. The three principal ways of acquiring such aerodynamic data are flight testing, wind tunnel testing and numerical analysis. They all can be expensive and are subject to multiple sources of uncertainty. A multifidelity data fusion framework applied to surface pressure data of a large aircraft wing model obtained from experiment and simulation is developed in this project with the ambition to enhance its intended use in optimising wind tunnel campaigns. Static pressure tapping and dynamic pressure sensitive paint are exploited to obtain experimental data sets of different quality and quantity. These are complemented by numerical data ranging from a linear potential panel method to non-linear RANS simulations. The data fusion approach introduced by Lam, Allaire and Willcox (2015) and revisited here is non-hierarchical, meaning there is not an absolute hierarchy in terms of accuracy between the information sources. The confidence in an information source over the parameter space is defined through a fidelity function. The project aims to introduce a reliable definition of the physical accuracy through this fidelity function. The approach uses Gaussian processes to enable the fusion of experimental and numerical data into a single multifidelity surrogate model. An additional analysis of the Gaussian process formulation is performed here in order to select a

	structure suitable for aerodynamics application. Lastly, the generated (and required) volume of data to study the surface flow and distributed aerodynamic loads on an aircraft wing leads to scalability issues. A suitable extension of Gaussian process regression based on stochastic variational inference has been adopted alongside the use of GPU architecture to enable the application of the data fusion framework on large data sets. The approach provides a surrogate model with a quantified uncertainty from uncertainty-aware disparate data sources. We explore (and adapt) the framework for a high-dimensional practical data set generated through industrial wind tunnel testing and numerical flow analysis.
Saves Paul, ONERA	**Multidisciplinary design optimization with mixed categorical variables: application to DRAGON an hybrid electric propulsion aircraft** MDO methods aim at adapting numerical optimization techniques to the design of engineering systems involving multiple disciplines or components. In our study, the system of interest being an aircraft,the resolution of the MDA will be provided by the Future Aircraft Sizing Tool with Overall Aircraft Design (FAST-OAD), a point mass approach that estimates the required fuel and energy consumption for a given set of top-level aircraft requirements. In this context, a large number of mixed continuous, integer and categorical variables that arise from aircraft design has to be tackled by the optimization process. Recently, there has been a growing interest in mixed variables constrained Bayesian optimization based on Gaussian process surrogate models. In this work, we consider an adapated covariance kernel for the Gaussian process model that depends on only a few hyper-parameters. The obtained numerical results lead to interesting results for the optimization of a baseline aircraft and to reduce the fuel consumption of "DRAGON", a new hybrid electric propulsion aircraft, with a high number of mixed variables and for a small budget of time-consuming evaluations.
Espoeys Romain, ONERA	**Overview and comparison of reliability analysis techniques based on different multi-fidelity Gaussian Processes in MDAO context** The design and analysis of complex systems in the presence of uncertainties is a challenging task. Taking into account various uncertainties (aleatory or epistemic) in the design of complex systems (e.g., aerospace vehicles, wind turbines, seawalls) often involves Multidisciplinary Design Analysis and Optimization under uncertainty problems (MDAO). The satisfaction of constraints can then require the calculation of failure probabilities (e.g., the probability to exceed a target threshold), thus needing repeated reliability analyses during the optimization problem. The designer can have at his disposal both precise but expensive and cheap but inaccurate codes. Multi-fidelity modeling is a way to aggregate information from different fidelity models in order to provide accurate results with a limited computational cost. In the literature, different surrogate-based techniques have been developed and follow this procedure : a surrogate model is built using a limited dataset of high-fidelity model evaluations, and then is enriched by adding new data in the based on an infill criterion, in order to improve its prediction. The purpose of this benchmark is to evaluate the behaviour of the multi-fidelity adaptive reliability analysis techniques with respect to two main axes: the refinement technique and the multi-fidelity model. The different combinations of multi-fidelity

	techniques and refinement strategies will be tested on two analytical test cases, as well as on two physical cases: a test case on a sounding rocket and a hydraulic test case on the dike failure due to river flooding.
Aziz Alaoui Amine, IRT Saint-Exupery	**A scalable problem to benchmark robust multidisciplinary** A scalable problem to benchmark robust multidisciplinary design optimization algorithms is proposed. This allows the user to choose the number of disciplines and the dimensions of the coupling and design variables. After a description of the mathematical background, a deterministic version of the scalable problem is built and conditions on the existence and uniqueness of the solution are given. Then, random variables are added to the coupling equations to generate uncertainty. Under specific hypotheses, it is possible to guarantee a unique solution for the uncertain problem which is easily computable with a quadratic programming algorithm. This solution will then serve as a reference to test the accuracy of conventional methods used in the context of robust multidisciplinary design optimization. This scalable problem is then implemented in the open-source software GEMSEO and used to compare two techniques of statistics estimation: Monte-Carlo sampling and Taylor polynomials.
Daniel Simanowitsch DLR	**Adjoint-Based Airfoil Shape Optimization Coupled with Parabolized Stability Equations** Airfoil shape optimization to reduce total drag is a key step towards sustainable aviation. At the DLR, a gradient-based optimization toolchain has been extended for optimizing transitional airfoils via the use of Linear Stability Theory. The gradients are efficiently obtained via the adjoint RANS equations. For an optimization that explicitly aims at increasing laminar length, coupling with direct and adjoint transition models is necessary. At the German Cluster SE^2A on sustainable and energy-efficient aviation, we work on the coupling with direct and adjoint Parabolized Stability Equations. Once implemented, the influence of shape modifications on the transition location and thus total drag will be reflected in the gradients obtained from the coupled, iterative toolchain, allowing efficient design of laminar airfoils.