MADELEINE

Final Workshop

Multidisciplinary Adjoint-Based Optimisations in MADELEINE:

Introduction to the Project

Virtual Event

25th / 26th of November 2021

Coordinator:
Michaël Méheut (ONERA)

MADELEINE project,
Grant Agreement No 769025

Consortium MADELEINE

MADELEINE	**Multidisciplinary ADjoint-based Enablers for LargE-scale Industrial desigN in aEronautics**
Call H2020-Transport 2017-MG 1.3	Industrial competitiveness
Coordinator	ONERA THE FRENCH AEROSPACE LAB
15 partners	AIRBUS, Rolls-Royce, DASSAULT AVIATION, esi, OPTIMAD ENGINEERING, DLR, nlr, IRT SAINT EXUPÉRY, Università di Cagliari, University of Southampton, The University Of Sheffield, Technische Universität München, National Technical University of Athens, UP
Duration	42 months (June 2018 – November 2021)
EU funding	5.8 M€

Current use of MDO in industry

MDO and/or **adjoint-based optimisation** using **high-fidelity** simulations	Often **limited** to **single disciplines**: ✓ *Aerodynamics* ✓ *Acoustics* ✓ *Thermics* ✓ *Structural analysis*
Multi-Disciplinary analysis during **design** campaign	**Iterative process** from **one discipline** to the other

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Limitations and **drawbacks** of the current approach	Significant **time delays** to the overall process Difficulties to exploit **multi-disciplinary trade-off**

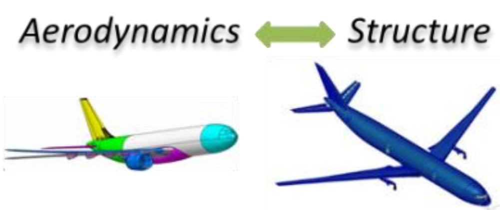
Overall objectives of MADELEINE

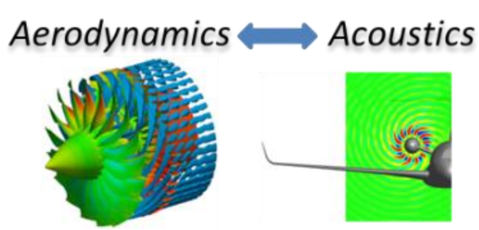
Meet short, medium and long-terms industrial objectives	✓ **Competitiveness** - By *reducing development time* and *costs* (incl. *manufacturing*) ✓ **Environment** - By *designing more efficient configurations* with better *multidisciplinary compromises*
Address the industrial needs to produce competitive design	✓ Extend the scope of **MDO** to include ***HiFi* simulations** (*CFD, CSM, CAA, CHT)* ✓ Fully **exploit** the **adjoint capability** to solve design problems with **hundreds or thousands** of design parameters ✓ Increase the **reliability** of the **adjoint** solvers ✓ Extend MDO to efficiently include **manufacturing criteria**

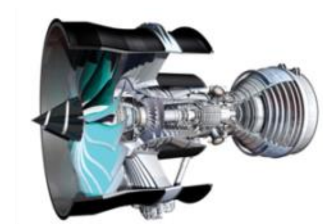
Overall objectives of MADELEINE

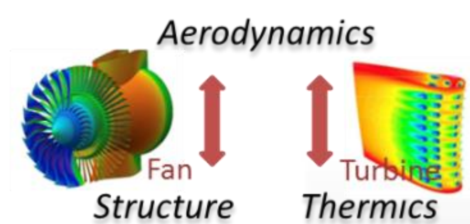
Demonstrate the **benefits of adjoint-based MDO**

Airframe	***Airframe/engine interactions***	***Engine***
Wing/fuselage aero-structure interactions	*Air inlet, propeller or fan blades aero-acoustics interactions*	*Fan and high-pressure turbine with very stringent aero-structure and aero-thermal interactions*









Success Criteria (SC) to measure the impact

3 main pillars : CAPABILITY, EFFICIENCY, USABILITY

CAPABILITY

SC1	**Adjoint of multi-physics equations and solvers** ➡ *Multi-physics adjoint sensitivities verified (maximum relative error of 5% in the norm of the gradient)*
SC2	**Manufacturability oriented design to faster integrate new materials or new manufacturing processes (*UQ* and manufacturing process modelling)** ➡ *Impact of manufacturing criterion in the MDO process on performance*
SC3	**Efficient exploration** of **large design space** ➡ *Removal of constraints on design space exploration (topology optimisation and/or by using mesh deformation schemes allowing large deformations)*

Success Criteria (SC) to measure the impact

3 main pillars : CAPABILITY, EFFICIENCY, USABILITY

EFFICIENCY

SC4	**Fast** and **robust adjoint-based MDO capability** for **large industrial test cases** → ***MDO adjoint solvers*** *as* ***robust and fast*** *as direct disciplinary solvers on heterogeneous HPC systems,* ***mesh morphing less than 10%*** *of* ***primal solver*** *in terms of computational time.*
SC5	**Industry-compatible development time** → ***Reduction of MDO development time*** *for industrial deployment* ***by a factor of 10.***

Success Criteria (SC) to measure the impact

3 main pillars : CAPABILITY, EFFICIENCY, USABILITY

USABILITY

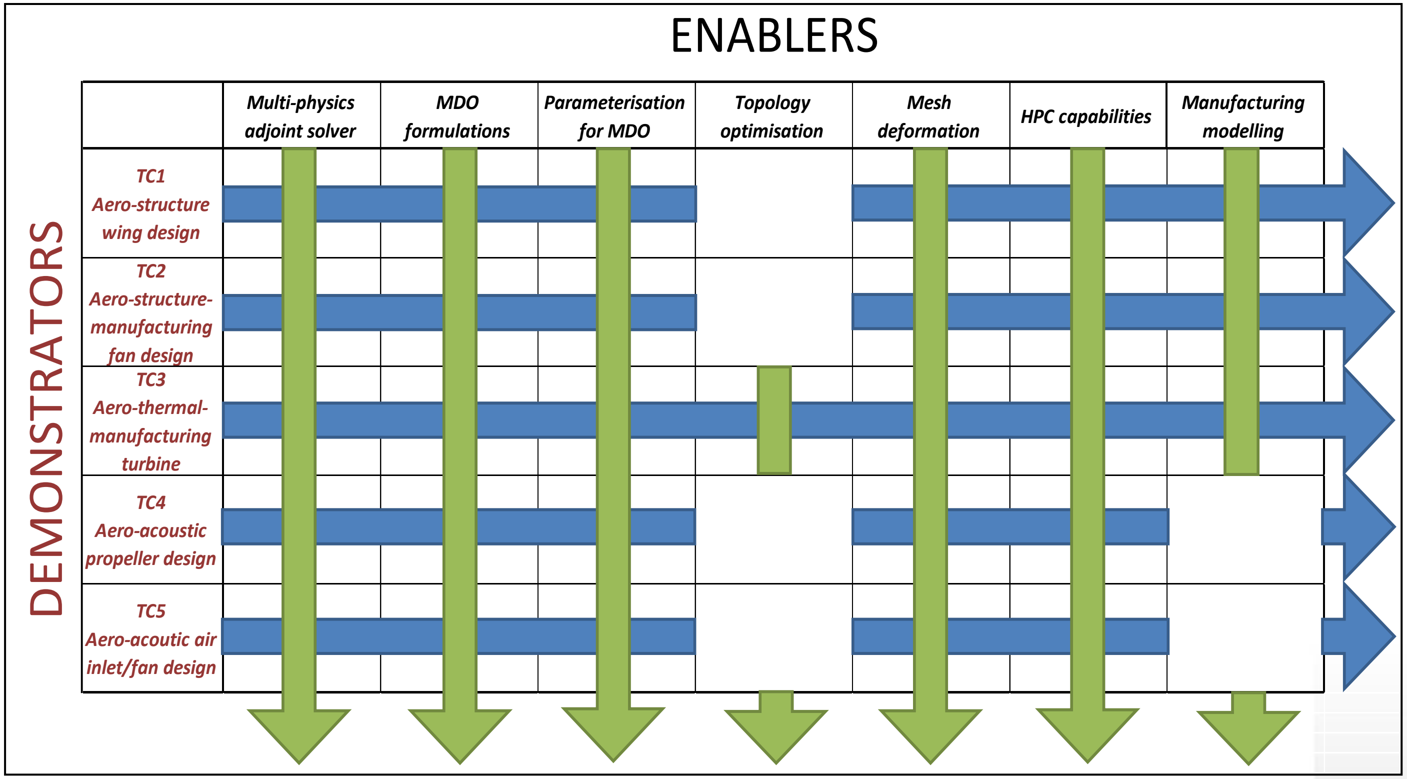
SC6	**Physics-based parametrisations and graphical environment to facilitate the definition of geometric constraints (link with *CAD* (Computed-Aided Design)** ➡ *MDO parametrisations defined with and approved by industrial aircraft and engine designers*
SC7	**Appropriate end-user formulations for MDO problem exploiting shape gradients adapted to aircraft and engine design** ➡ *Comparison between results obtained through coupled adjoint-based MDO and sequential/uncoupled single objective optimisations*

Concept of MADELEINE

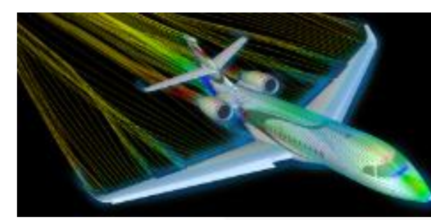
Focus on synergies between enablers and demonstrators

Enablers: methods and tools required to apply adjoint based MDO processes

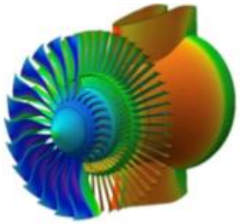
Demonstrators: test cases representative of multi-physics industrial design problems



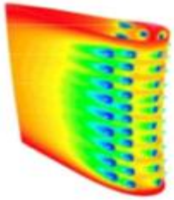
Aero-structure aircraft wing design

Challenge	Perform **aero-structure flexible wing optimisations** of modern transport aircraft in a **real industrial context**
Strategy	Apply of ***aerodynamic, aero-elastic and aero-structure adjoint solvers*** to measure the impact of multiphysics phenomena on the performance of optimised configurations
Configurations	A **large passenger aircraft** configuration (Airbus) *Partners: Airbus, ONERA, DLR, IRT*  A **business jet** configuration (Dassault) *Partners: Dassault, ESI, National Technical University of Athens* 

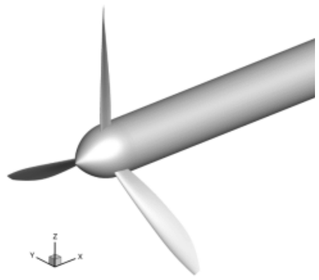
Aero-structure-manufacturing fan blade design

Challenge	Perform **aero-structure-manufacturing fan blade optimisations** of a Ultra-High-By-pass-Ratio modern engine
Strategy	Progressively include **manufacturing aspects** on the MDO process to avoid **accumulation of deviations** that can cause the blades to **deviate from the design intent** in terms of optimal **efficiency**
Configurations	3 levels of complexity from **generic configuration** (NASA rotor 37) to **complex industrial geometry** (confidential Rolls-Royce)  All configurations are **representative** of **modern aircraft engine** (Low-Pressure Fan) *Partners: Rolls-Royce, University of Sheffield, University of Cagliary*

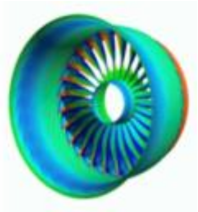
Aero-thermal-manufacturing turbine blade design

Challenge	Perform **aero-thermal-manufacturing turbine blade optimisations** of a Ultra-High-By-pass-Ratio modern engine
Strategy	Use **topology optimisation** methods for the definition of **cooling passages** Integrate of **specific manufacturing process** or **uncertainties** in the MDO loop to design configuration **robust** to **geometry deviations**
Configurations	3 levels of complexity from **generic configuration** (MT1) to **complex industrial geometry** (confidential Rolls-Royce)  All configurations are **representative** of **modern aircraft engine** (High-Pressure Turbine) *Partners: Rolls-Royce, University of Sheffield, University of Cagliari, ESI, OPTIMAD, National Technical University of Athens*

Aero-acoustic isolated propeller blade design

Challenge	Perform **aero-acoustic propeller blade optimisations** of modern turbo-propulsor engine
Strategy	Use **vertex morphing approach to open the design space** Apply **steady** and **unsteady aero-acoustic adjoint solvers** to minimise the **acoustic noise** while considering strong **aerodynamic constraints** (in terms of performance)
Configuration	Generic design complying with the requirements of **an electrical or hybrid CTOL/VTOL concept** using light propellers (ONERA)  *Partners: ONERA, NLR, Technical University of Munich*

Aero-acoustic air inlet and fan blade design

Challenge	Perform simultaneously **aero-acoustic air inlet** and **fan blade optimisations** of a Ultra-High-By-pass-Ratio modern engine
Strategy	Optimise the air inlet (including **acoustic liners**) and the fan blade in parallel with **a specific coupling interface** Apply **steady** and **unsteady aero-acoustic adjoint** solvers to improve **both aerodynamic** and **acoustic performance**
Configuration	**Generic air intake** adapted to the **VITAL fan blade** geometry  *Partners: Rolls-Royce, University of Southampton, National Technical University of Athens*

Meet with us And stay tuned!

Website: **https://www.madeleine-project.eu/**

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