Eurogen 2019

12-14 September 2019

Guimaraes, Portugal

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 EXUPERY, Università di Cagliari, UNIVERSITY OF Southampton, The University Of Sheffield, TECHNISCHE UNIVERSITÄT MÜNCHEN, National Technical University of Athens, UP
Duration	36 months (June 2018 – May 2021)
EU funding	5.8 M€

Current use of MDO in industry

MDO and/or **adjoint-based optimization** 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**

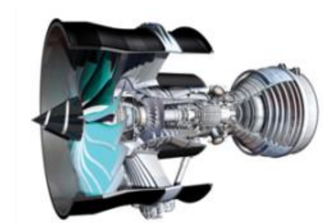
Overall objectives of MADELEINE

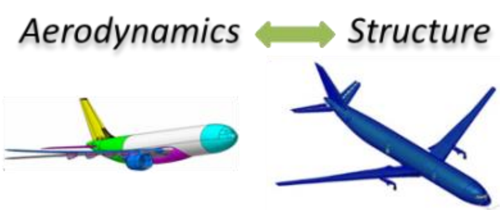
Meet short, medium and long-terms industrial objectives	✓ **Competitiveness** - By *reducing development time* and *costs* (incl. *manufacturing*) ✓ **Environment** - By *designing more efficient configurations* with better *multidisciplinary compromises*
Address the industrial needs of competitive design	✓ 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**

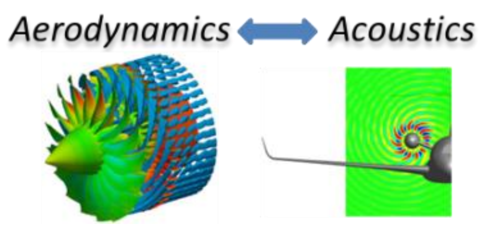
Overall objectives of MADELEINE

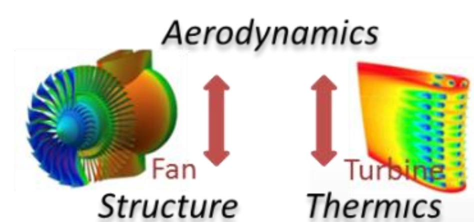
Demonstrate the **benefits of adjoint-based MDO**

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*



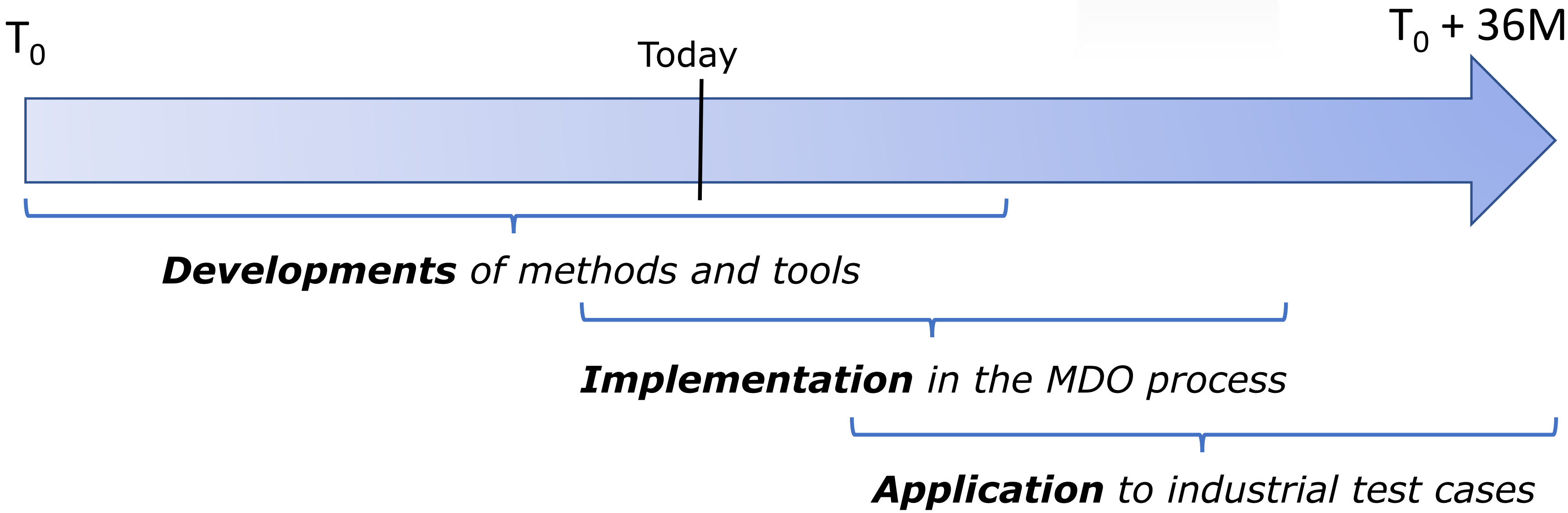






Implementation of MADELEINE

MADELEINE is organised in **3 main phases**



All **activities** are done around **three main pillars**:

Capability ***Efficiency*** ***Usability***

3 main pillars of MADELEINE

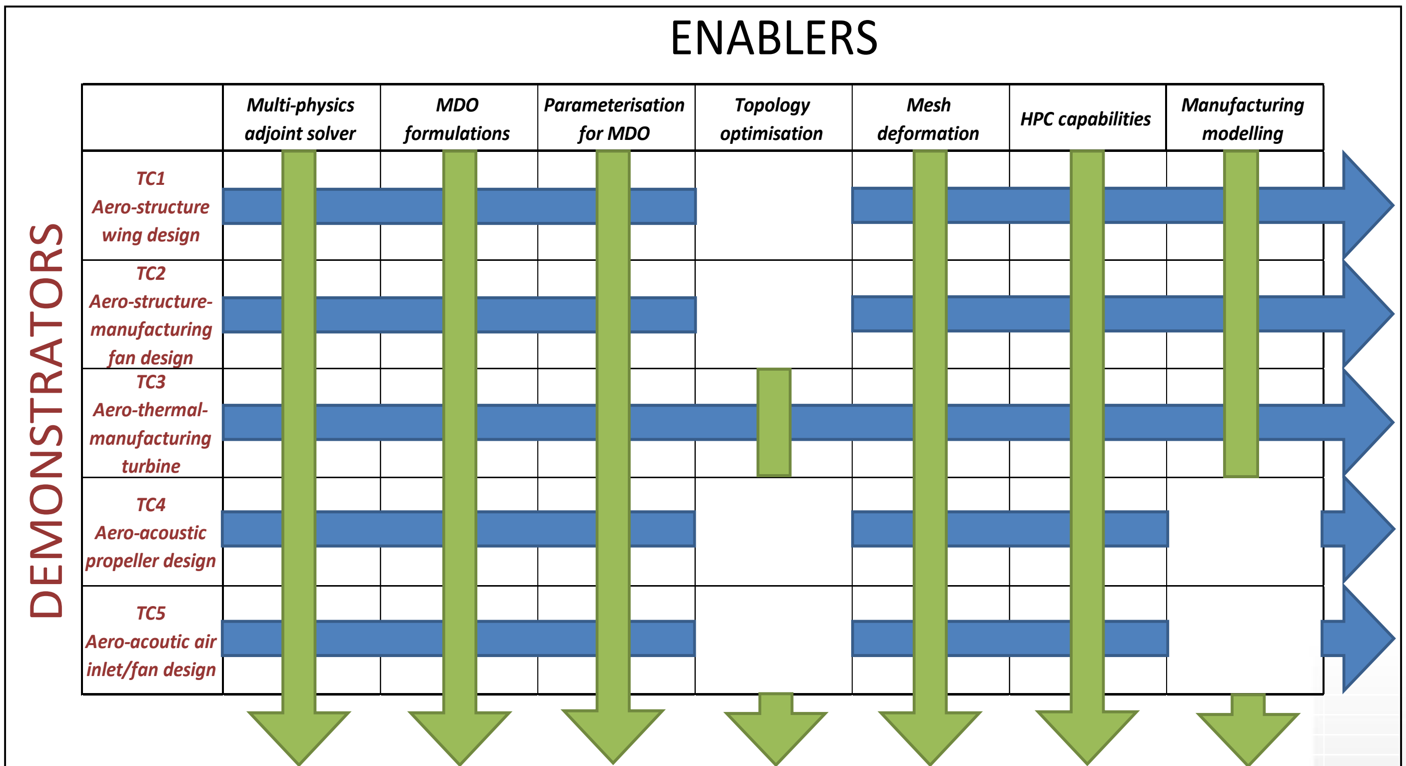
Capability	✓ **Robustness** and **accuracy** of **multi-physics adjoint** solvers ✓ **Efficient exploration** of large design space ✓ **Manufacturability** oriented design
Efficiency	✓ **Fast adjoint-based MDO capability** for **large industrial test cases** on next generation **HPC** infrastructure ✓ Industry-compatible **development time**
Usability	✓ **Physics-based parameterisations** (link with *CAD*) ✓ Appropriate end-user **MDO formulations**

Concept of MADELEINE

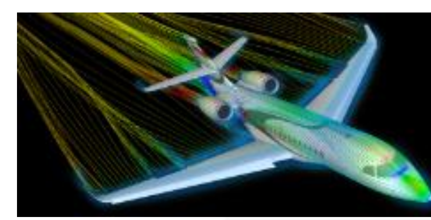
Focus on synergies between enablers and demonstrators

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

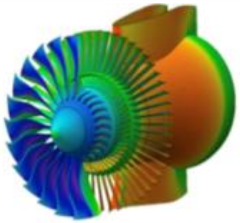
Demonstrators: test cases representative of multi-physics industrial design problems



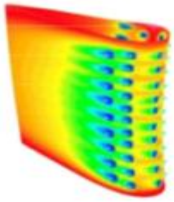
Aero-structure aircraft wing design

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 optimized 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* 

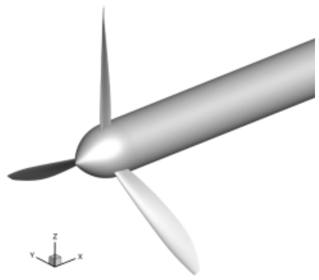
Aero-structure-manufacturing fan blade design

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*

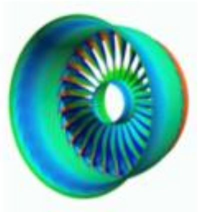
Aero-thermal-manufacturing turbine blade design

Challenge	Perform **aero-thermal-manufacturing turbine blade optimizations** of a Ultra-High-By-pass-Ratio modern engine
Strategy	Use **topology optimization** methods for the definition **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 Cagliary, 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*

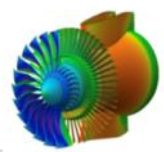
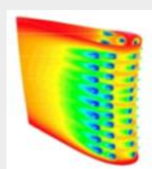
Aero-acoustic air inlet and fan blade design

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 of the fan blade performed 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*

Overview of the results achieved so far

Adjoint solvers	***Robustness*** and ***accuracy*** of the adjoint solvers First comparison of ***linear solvers*** dedicated to adjoint solver
MDO formulations	Development of ***scalable models*** representative of industrial optimisation problem that will be used to ***benchmark MDO formulations***
UQ and Robust Design	Integration of ***gradients*** in ***Non-Intrusive Polynomial Chaos*** methods and first validation on simplified test-cases
Parameterisation	Adaptation of ***topology optimisation*** methods for HP Turbine application ***Benchmark of parameterisation methods*** for fan blade optimisation Integration of ***geometric constraints*** in the ***Vertex Morphing*** approach
Mesh deformation	***Benchmark of mesh deformation*** techniques on generic test-cases
Time-efficiency of MDO process	Evaluation of different strategies to increase the ***time-efficiency of MDO*** process (by ***reducing the number of iterations*** or by ***improving*** the ***data transfer*** between the different solvers/tools used in the MDO process)

Overview of the results achieved so far

All test cases		Definition of **MDO problems** with a step by step approach (**Monodisciplinary** ➡ **Multidisciplinary**) Setup of **common MDO processes** or modules between partners
Aero-structure aircraft wing design		**Benchmark** of CFD codes on **wing/fuselage configurations** First optimisations using **rigid aerodynamic adjoint** solvers
Aero-structure-manufacturing fan blade design		**Aerodynamic adjoint-based** optimisations with different **parameterisations** and optimisations algorithms
Aero-thermal-manufacturing turbine blade design		**Aerodynamic adjoint-based optimisations** of the turbine tip with **topology optimisation** to create original shapes Optimisations (gradient-free and gradient-based) of the **casting (manufacturing) process** of turbine blade
Aero-acoustic isolated propeller blade design		**Performance assessment** of the baseline configuration (benchmark)
Aero-acoustic air inlet and fan blade design		**Rotor performance prediction** and rotor-alone tones analysis Development of a specific BC in CFD for **acoustic liners**

Meet with us

Next Minisymposium *at the* ***14th World Congress in Computational Mechanics and ECCOMAS Congress 2020***
Paris, 19-24 July 2020

ADJOINT METHODS FOR MULTI-PHYSICS, INCLUDING APPLICATIONS

Deadline for abstracts: December 15, 2019

And stay tuned!

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MADELEINE

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