# MADELEINE STANDS FOR "MULTIDISCIPLINARY ADJOINT-BASED ENABLERS FOR LARGE-SCALE INDUSTRIAL DESIGN IN AERONAUTICS".

**The project focuses on the development and validation of multidisciplinary design tools for optimisation.**

Special attention is given to:

- multidisciplinary optimisation
- understanding of multi-physics phenomena
- simulation of manufacturing processes
- transition to High-Performance Computing

*Our media releases include interviews with project partners to let you discover how they cooperate to achieve the project objectives. The "Get Together" section will show you when we disseminate the MADELEINE results. This is in case you feel like meeting with us! Meanwhile, we invite you to visit our website at www.madeleine-project.eu and follow us on Linkedin via #madeleineproject*

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# Interview With The Team Of The Aerodynamics and Flow Technology Institute, German Aerospace Center (DLR)

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**Question 1 (Q1):** DLR is the leader of the work package entitled "Wing design" in MADELEINE. Can you describe the structure and objectives of this work package?

**Answer 1 (A1):** In this work package, the various partners from academia, research centres and industry join forces in order to push the current technology readiness level (TRL 3-4) of the targeted wing design tools to the next level (TRL 4-5), and get the tools into the hands of wing design practitioners. In order to achieve that, two main milestones need to be achieved. Firstly, to prove the feasibility of these methods for daily use in aircraft design, and secondly, to prove and highlight that these methods offer new capabilities that are beyond the ones wing designers master today. The main objectives of this work package in MADELEINE are thus to:

1) Validate the implementation of the coupled adjoint approach among partners on the same test cases.
2) Increase the readiness level of the numerical tools developed in the work package "Methods and Tools"[1] and test them on industry-relevant test cases.
3) Understand and quantify the benefit of engaging the multidisciplinary (aerostructural) coupled adjoint approach in wing design.

**Q2:** What were the main steps in optimising the wing design?

**A2:** To be more accurate in answering this question, we need to clarify that here we discuss the automatic numerical wing design process that we developed and set up in this work package, and that we discuss multidisciplinary design in terms of two disciplines only: aerodynamics and structures. These two disciplines affect two important aspects in wing design, namely the aerodynamic performance in terms of lift and drag, as well as the structural integrity and mass of the wing.

In this context, the first step lies in obtaining a parametric Computer Aided Design (CAD) model of the wing, the generation of which has to be robust in the defined bounds of the design space for all engaged disciplines. After obtaining the parametric CAD models, multidisciplinary analysis on both ends of the aero-structure problem - static aeroelastic performance and structural sizing including extensive loads analysis - take place. Then, since we deal with gradient-based optimization algorithms, our tools have to compute the design sensitivities, i.e. gradients, of the cost functions engaged in the design task with respect to the design parameters. These design sensitivities are forwarded to the optimizer. After combining this information with the current states of the tightly coupled multidisciplinary analysis, the optimizer suggests new design parameters. This process is repeated automatically without any need for user interaction as long as more improvements are obtained.

**Q3:** What are the main achievements today?

**A3:** So far, we were able to define two test cases with requirements coming from the industrial partners. Then, we validated the partners' implementations of the multidisciplinary aeroelastic coupled adjoint in two groups. Each group includes three partners that work on a specific aircraft configuration. The validation showed a very good match of the design sensitivities that include interdisciplinary effects among the different partners. After that, each partner performed an aeroelastic optimization where the effect of the structure's elasticity is considered but the structural model of the wing itself is not

[1] Refer to the MADELEINE Media Release from June 2020.

updated with the new design variables, i.e. is not parametric. This step is very helpful for testing our implementations on a simple case (i.e. wing-body configurations) and starting collecting some best-practice knowledge that will be necessary when setting up and running the final aerostructural optimizations on the industry-relevant test cases.

**Q4:** What were the challenges that the project partners met while performing the aerostructural wing optimisations?

**A4:** There are two main types of challenges that one meets when running or working with Multidisciplinary Optimisation (MDO). The first type of challenges is related to communication between experts from different engineering backgrounds and disciplines. This challenge is even larger when one team engages different disciplinary experts from different organizations in Europe. An example of that is, when the aerodynamicist is located in Athens and the structural expert works in Paris, and both require inputs from one another to run one MDO that includes interdisciplinary effects. To overcome such challenges, one needs to spend a considerable amount of time in communication and on unifying terms and definitions while setting up the design task. This part of the challenge should not be underestimated in terms of importance or time.

The second type of challenges lies in setting up a robust optimization chain with tools that are partly foreign to the engineers. Firstly, because they come from different disciplines and secondly because they come from different organizations. So, considerable energy needs to be spent on making the computers and the different tools communicate via clear and well-defined interfaces for robust automatic process chains for optimization.

**Q5:** Real industrial test cases have been set up to evaluate the benefit of engaging multi-disciplinary adjoint formulations. What were the criteria for choosing each aircraft configuration as a test case in MADELEINE?

**A5:** Since we are talking about the benefit of aerostructural optimization with the coupled adjoint approach in this work package, the elasticity of the wing plays a considerable role. Hence, we chose two different aircraft configurations. On the one hand, a wide body long-range transport aircraft with a relatively elastic wing and an underwing podded engine. On the other hand, a business jet configuration with a lower span clean wing, where the engine is mounted at the rear of the fuselage. It is interesting to know if the coupled adjoint approach is useful for designing both types of configurations, which have different wing stiffnesses, and different effects of elasticity on the flight performance.

**Q6:** How have you organised the work around each test case?

**A6:** The business jet case involves three partners: Dassault Aviation, National Technical University of Athens (NTUA) and ESI Group. Dassault Aviation provided the parametric geometry and defined the design task including the flight conditions and the sizing loads. Dassault Aviation and NTUA engaged their aerodynamic solvers to compute the flow. ESI Group built the wing's structural model, based on the loads provided and solved by the structural part of the multidisciplinary design task.

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The XRF-1 research aircraft configuration engages three partners: AIRBUS, Office National D'Études et de Recherches Aérospatiales (ONERA) and DLR. AIRBUS provided the parametric geometry and defined the design task. ONERA and DLR each engaged their own flow solver. Furthermore, DLR engaged its structural generation and sizing tool which is shared with ONERA.

In both test cases, the industrial partners are interested in performing aeroelastic optimizations, with frozen structural parameters, whereas the other partners are also interested in performing aerostructural optimizations where the structure of the wing is being optimized throughout the optimization.

**Q7:** Are the two test cases interacting with each other? What kind of information is being exchanged?

**A7:** The two cases are not interacting technically speaking. However, the engineers from both groups are highly interacting and communicating with each other on the basis of regular common meetings to discuss, for example, the results of the validation, or the results of the aeroelastic optimizations. This communication and exchange of experiences and opinions is extremely helpful. The more different the engineering backgrounds of the communicating partners, the more useful the discussions are. This is MDO.

**Q8:** How will the industrial partners measure the impact of the coupled aero-structure design approach compared to the current, step-by-step, disciplinary design process?

**A8:** This is an interesting question, since the answer to it is not straight forward. Besides the conclusion on whether the method has a beneficial impact on the design process in terms of cost, there are other elements to consider. Decision makers in industry consider other factors in order to decide if it is worth to modify an existing design process. These factors include, for example, the amount of training the engineers need to take in order to be able to use the new numerical tools correctly and robustly. However, if we put these factors, which are outside the scope of the project, aside, then what we need to look at is twofold. First, the potential reduction in development time for new aircraft designs and re-designs. Second, the additional improvement obtained in terms of design cost, compared to the current design process.

Gradient-based algorithms can be used to automatize parts of the design process efficiently. Since the coupled adjoint approach feeds these algorithms with the required gradients, it is expected that designers will be able to perform design trade studies more efficiently. Moreover, the coupled adjoint approach helps revealing and catching interdisciplinary effects, that are supposed to produce designs which are less intuitive to disciplinary experts. This holds true especially for novel aircraft configurations where previous experience is missing. So, what we will do in this work package is to solve the design tasks provided by the industry partners twice. Once, using the coupled adjoint approach and taking the interdisciplinary effects into account, and once while neglecting the interdisciplinary effects, which is more comparable to the current way aircraft are designed. By comparing the optimization costs and solutions, we will be able to conclude on the two points mentioned above; if the design is obtained more time-efficiently and if it achieved more improvement.

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# Get Together

Get Together selects the events at which MADELEINE will be represented in 2021.

### ETC14, 12-16 APRIL 2021, VIRTUAL

The 14th European Turbomachinery Conference covers the scientific and engineering outcomes concerning the fluid dynamic, thermodynamic, performance and stability aspects in the design, development and operation of axial, mixed flow and radial turbomachines. **The MADELEINE partner National Technical University of Athens (NTUA) will give a presentation entitled "Continuous Adjoint Shape Optimization Of Internally Cooled Turbine Blade".**
More information: ETC14

### TURBO EXPO 2021, 7-11 JUNE 2021, VIRTUAL

The Turbomachinery Technical Conference and Exposition will be an all-virtual event as part of the "ASME Anywhere" initiative to ensure the growing global community can stay connected and achieve their goals in 2021 without disruption. **Two presentations from MADELEINE will be prepared by the project partners the University of Cagliari, University of Sheffield and Rolls Royce.**
More information: Turbo Expo 2021

### EUROGEN 2021, 28-30 JUNE 2021, VIRTUAL

14th International Conference on Evolutionary and Deterministic Methods for Design, Optimization and Control is an ECCOMAS thematic conference. EUROGEN 2021 will be streamed from Athens. It will consist of live sessions and on demand pre-recorded presentations. **Several presentations from MADELEINE will disseminate the project results.**
More information: EUROGEN 2021

### AIAA AVIATION 2021, 2-6 AUGUST 2021, VIRTUAL

The annual AIAA Aviation and Aeronautics Forum and Exposition draws participants from around the globe. The MADELEINE partners are organising a **special session** dedicated to the project. **Eleven presentations and papers by the MADELEINE partners will showcase the latest achievements.**
More information: AIAA Aviation Forum 2021

We hope to meet you soon during virtual moments of exchange!


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## MADELEINE in a nutshell:

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| **GRANT AGREEMENT NUMBER:** 769025 | **15** PARTNERS | 6 **EUROPEAN** COUNTRIES | CALL: **H2020-MG-2016-2017** |
| 50 RESEARCHERS AND ENGINEERS | **RESEARCH & INNOVATION** ACTION | TOTAL MANPOWER: 631 PERSON-MONTHS | TOTAL BUDGET: **5 815 181 EUROS** |
| **36** MONTHS | **TOPIC:** MG-1.3-2017 | PROJECT COORDINATOR: **MICHAËL MEHEUT** (ONERA) | PROJECT OFFICER: **MIGUEL-ANGEL MARTI-VIDAL** (INEA) |

## MADELEINE consortium:


MADELEINE

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