Comparing Two Multidisciplinary Optimization Formulations of Trimmed Aircraft Subject to Industry-relevant Loads and Constraints

M. Abu-Zurayk, A. Merle, C. Ilic, J. Feldwisch , M. Schulze, J. Häßy
German Aerospace Center (DLR)

M. De Lozzo, F. Gallard, A.Gazaix
Institut de Recherche et Technologie Antoine de Saint Exupéry (IRT)

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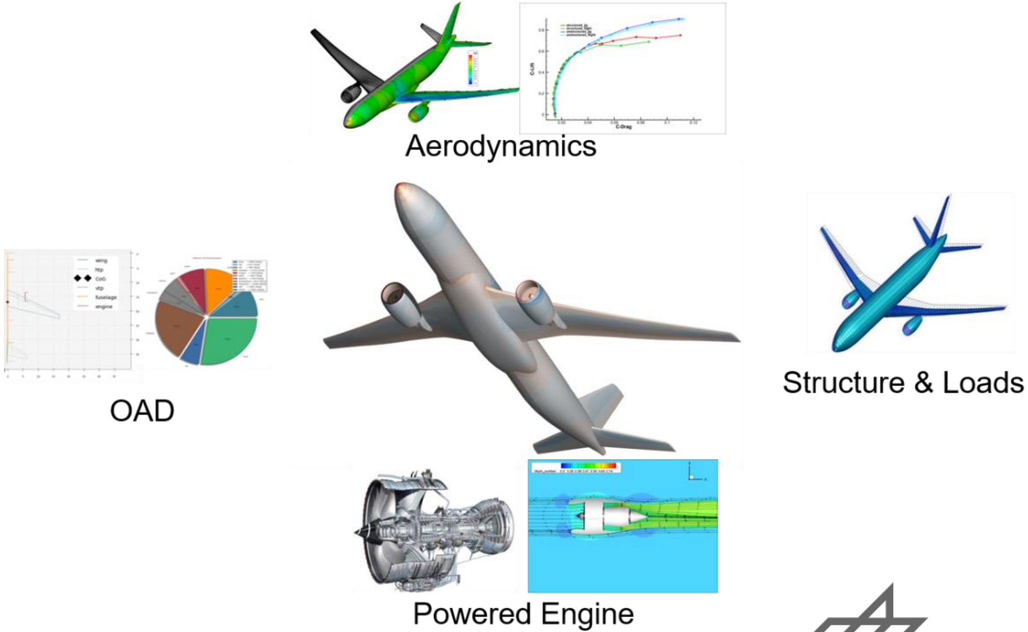
Introduction

- MDO of industry-relevant test cases is computationally costly



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Introduction

- MDO of industry-relevant test cases is computationally costly

  → one main target in this field is looking for approaches to increase its efficiency

  - Use of the efficient gradient-based algorithms
  - Understand the best way in which the different disciplinary solvers are connected
    - Study different MDO formulations
    - Compare and validate a data-driven approach for studying the efficiency of MDO formulations

    - In the industry, pragmatism is often required and *ad-hoc* formulations are developed to best meet business requirements and constraints
    - One cannot count on the common MDO formulations studied within academic circles, since their requirements are not available for practitioners in industry.

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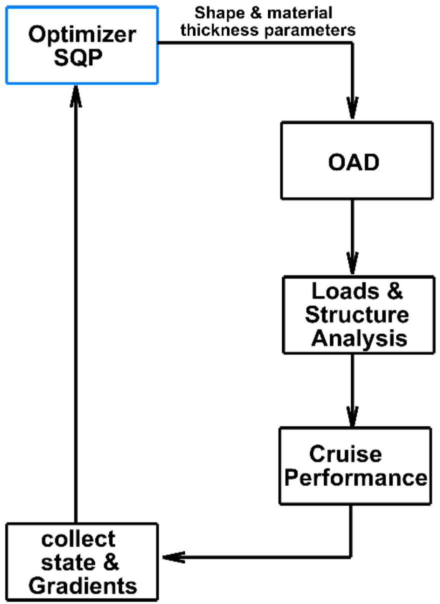
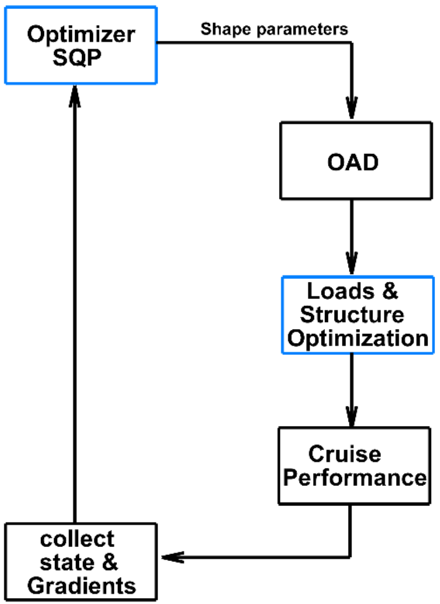
Two MDO Formulations



One-Optimizer Formulation



Two-Optimizers Formulation

Which formulation is more efficient?

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MDO Task Definition

- **Objective function**: 1/*SR*; $SR = \frac{C_L}{C_D} * \frac{mass\_empty\_ref}{mass\_empty}$

- **Design parameters**:

Parameter	*Type*	*Quantity*
Wing sweep	planform	1
Aspect ratio	planform	1
Twists	sectional	11
Chord length	sectional	2
Belly Fairing	control points	8
Profile shape	sectional	126
Structure material	thickness	392
	Sum	541

- **Design constraints:**

Constraint	*Type*	*Discipline*	*Quantity*
$\sum F_{x,y,z} = 0$ $\sum M_{x,y,z} = 0$	Aircraft Trimming	RANS-based Aerodynamics	6
Take-off field length (@MTOW) Landing field length (@MLW)	Preliminary Sizing	Overall aircraft design	2
Longitudinal tip-over Lateral tip-over Nose landing gear effectiveness	Landing gear integration	Overall aircraft design	3
Static stability margin	Stability	Overall aircraft design	1
Approach speed (ICAO Category C) Wing span (ICAO Code E)	Airport requirements	Overall aircraft design	2
Flutter Structural strength Structural buckling Control surface efficiency	Structure related constraints	Structure Mechanics	20 15,680 15,680 1

- **Sizing Loads:**

6 pull up maneuver (nz=2,5)
- **3 subsonic, 3 transonic**

4 push down maneuver (nz=-1)
- **2 subsonic, 2 transonic**

18 Roll maneuvers (nz=0, nz=1,67)
- **Initialize roll: 1 subsonic, 2 transonic**
- **Steady roll: 1 subsonic, 2 transonic**
- **Revert roll: 1 subsonic, 2 transonic**

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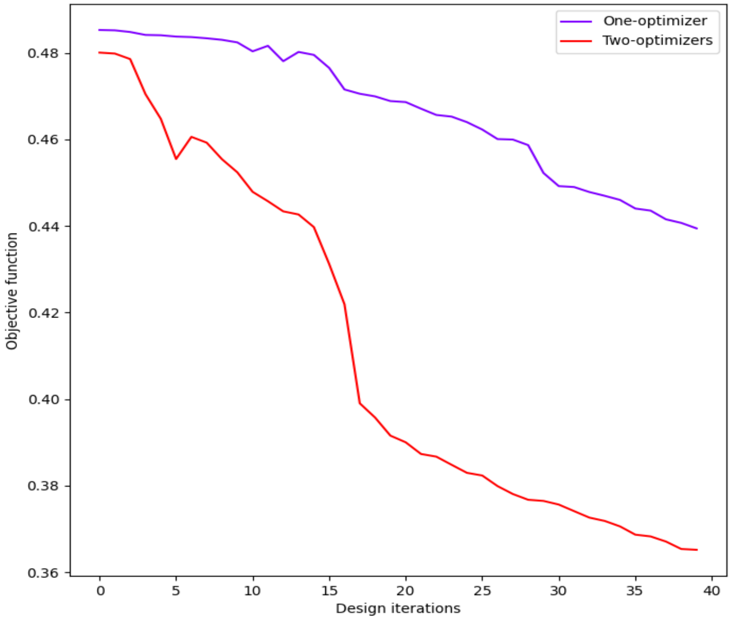
Data-driven approach results

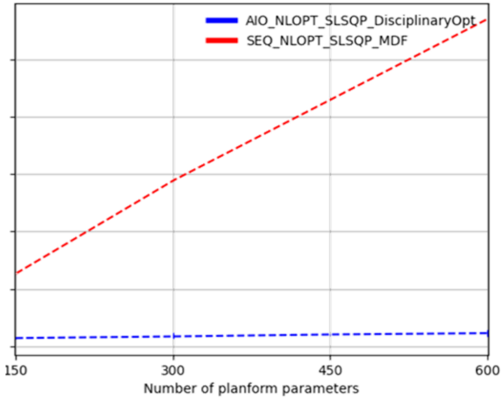


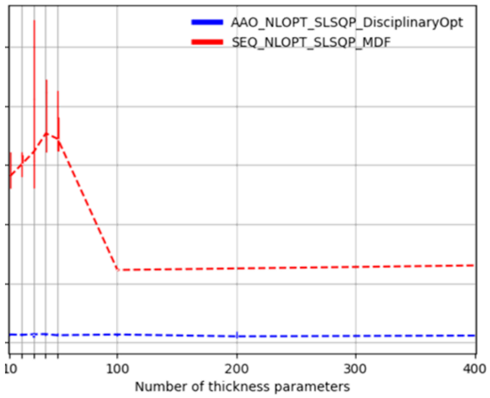
Optimizer	Planform Parameters	Shape Parameters & Thicknesses	Shape Parameters & Thicknesses
Global aircraft constraints	**OAD**		
Mass & Structure constraints		**Structure Process**	Mass
Cl, Cd			**AeroElastic-Performance Analysis**

One-optimizer

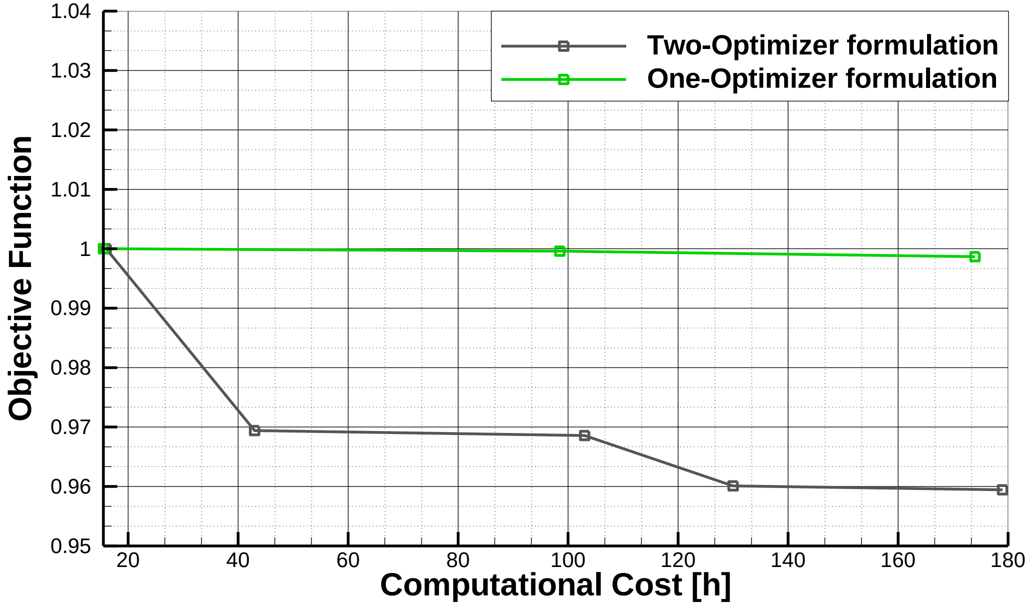
Optimizer	Planform Parameters	Shape Parameters	Shape Parameters
Global aircraft constraints	**OAD**		
Mass		**Structure Process**	Thicknesses & Mass
Cl, Cd			**AeroElastic-Performance Analysis**

Two-optimizer





Two MDO Formulations - Convergence



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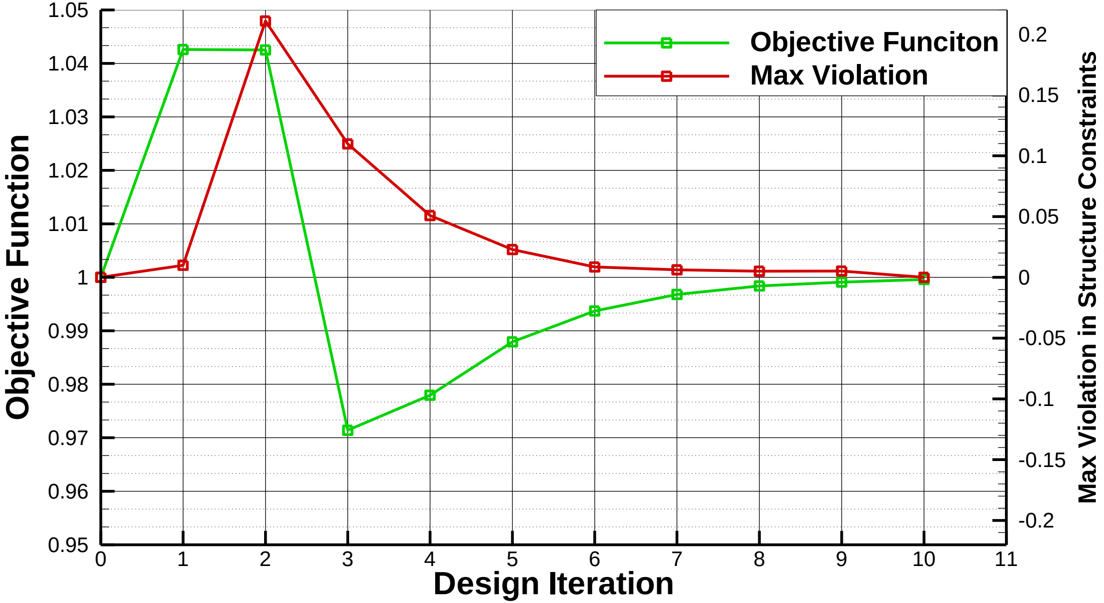

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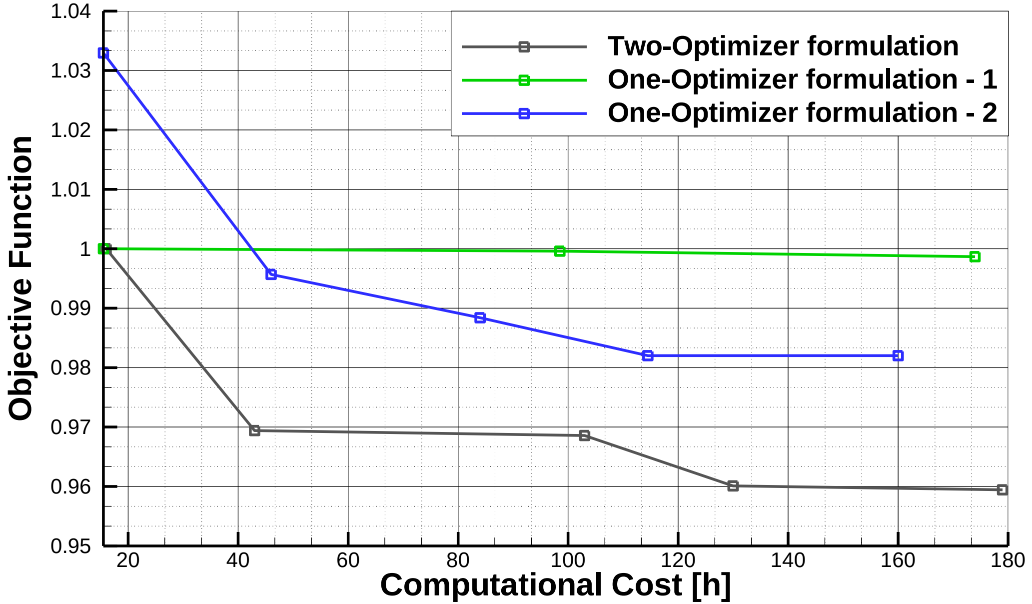
Two MDO Formulations - Convergence



The Conclusions

- Two MDO formulations were tested and their efficiency was investigated.
- The Two-optimizer approach turned out to be practically more efficient due to the optimization algorithm employed.
- The data driven scalable model approach showed that the two formulations are not mathematically equivalent.
- Data driven approach shows that the one-optimizer approach would be more efficient when one considers the exact set of gradients.

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