Establishing a Joint Research-Industry MDO Benchmark Based on the DLR-F25 Aircraft Configuration

Definition of the first task: Sensitivity and Trade Studies

DLR
M. Abu-Zurayk, Č. Ilić, P. Wegener, J. Himisch, M. Schulze, S. Wöhler, J. Häßy, S. Dähne , S. Geisbauer, S. Görtz

AIRBUS DEFENCE & SPACE
Ö. Petersson

Bombardier
A. DeBlois, J. Singh

AIRBUS
J. Brezillon, R. Llamas, C. Conlan-Smith

NASA
B. D. Phillips, E. Aretskin-Hariton J. Chapman

ONERA THE FRENCH AEROSPACE LAB
C. Blondeau, M. Méheut

This document aims to define the initial task of the MDO benchmark, which was developed through collaborative efforts between research and industry, and was presented at the AIAA SciTech conference in 2026. To facilitate a smooth introduction to the MDO benchmark, the authors propose a series of simple optimization tasks, along with sensitivity and trade studies, designed to help participants adequately prepare their tools and capabilities. These studies will enable participants to validate the first-order effects of their tools while also allowing for the comparison of trends and outputs with those of other participants.

The sensitivity and trade studies will be conducted on four distinct variations applied to the DLR-F25 baseline geometry. The initial variation focuses on the wing's **aspect ratio**, while the second addresses the **wing sweep**. The third variation applies to the **wing tip twist**, and the fourth tackles the overall **profile thickness** of the wing. Per variation, participants will receive a CAD model in STEP format along with a corresponding set of CFD grids for the wing-body-tail configuration, as well as a CSM structural analysis model for the full configuration. Those requiring the CFD grids in an alternative format are encouraged to reach out to mohammed.abu-zurayk@dlr.de. Additionally, if the full configuration (Wing-Body-Tail-Pylon-Nacelle) is needed, participants may also reach out to the same email address to acquire the CAD models in STEP format along with a set of engine decks.

The four variations are defined as follows:

1. **Variation of the Wing Aspect Ratio as delta to baseline [-3, -2, -1, 0, +1]**

2. **Variation of the Wing Sweep Angle as delta to the baseline [-2°, 0°, +2°]**
   While changing the wing sweep, the mean aerodynamic chord (MAC) is kept fixed. This results in a slight change in the wing position (along the fuselage), and a corresponding movement (extension for higher wing sweep) in the forward part of the belly fairing.

3. **Variation of the Wing-tip Twist Angle as delta to the baseline [-2°, 0°, +2°]**
   Here the twist change is linearly propagated along the whole wing and the deflection in twist is weighted by spanwise-position; @ wing tip (with full angle deflection) scaling down to the root section (with 0° deflection)

4. **Variation of the Wing-profile Thickness (t/c) as delta to the baseline [-10%, 0, +10%]**

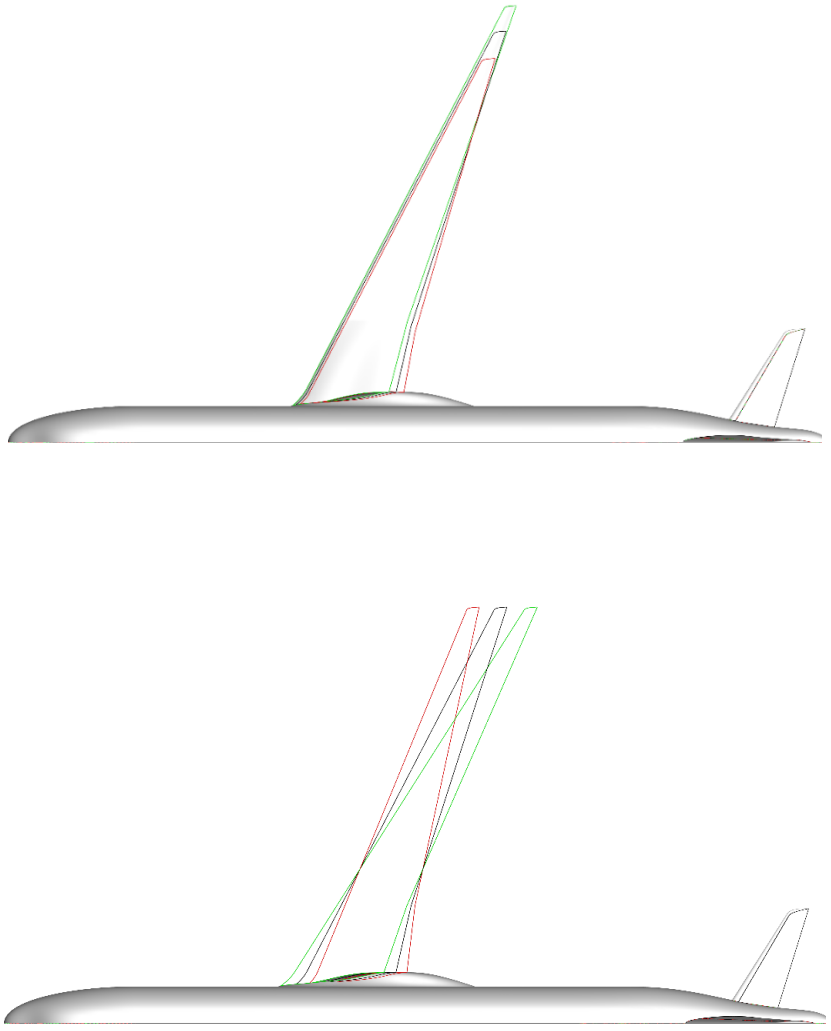
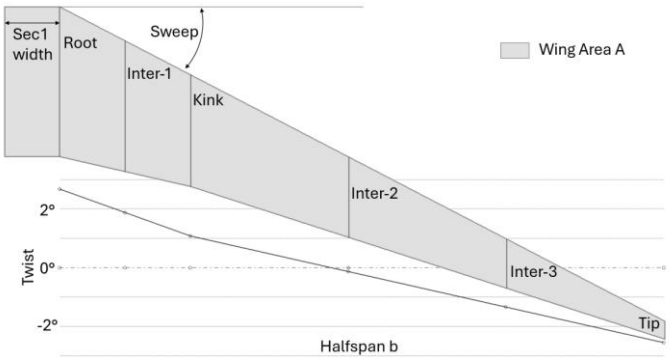


Figure 1: Visual example of shape (upper: aspect-ratio, lower: sweep) variations

The expected outputs are summarized in table

Geometrical Results	
Fuel tank volume	Provide the fuel tanks volume (See Appendix A.)
Wing flight shape	Provide bending and twist data at the sections (root, inter-1, kink, inter-2, inter-3, tip) defined in Figure 2
Aerodynamics Results	
Aerodynamic Polars	Run aerodynamic polars (α: [0.0° - 3.6°; @ Δ α =0.2°] for Ma: [0.76, 0.78, 0.80]) and provide C_D, C_L, C_{My}
Flow separation indication	Provide the approximate separation point (simply defined at C_{FX}=0) along the chord per span position defined in Figure 2 (Root, Inter-1, Kink, Inter-2, Inter-3) in addition to two equidistant sections between Kink and Inter-2 (called inter-2a, inter-2b), two equidistant sections between inter-2 and inter-3 (called inter-2x, inter-2y) and two equidistant sections between inter-3 and tip (called inter-3x and inter-3y)
Structure Results	
Masses	Provide wing empty mass, operating empty mass, mass breakdown per component (skin, spar,rib,..)
Material thickness	Provide the material thickness distribution along the wing span for the upper and lower skin, the ribs and the spars
Overall Aircraft Design Results	
Performance Assessment	C_L/C_D mid cruise (whole Aircraft); Drag breakdown mid cruise (Whole Aircraft); Component-wise Drag breakdown; Component-wise Pitching-Moment breakdown; Analyze the buffet onset curve (Ma over C_L); Mach Drag-Divergence (@C_{Dw}=20 drag counts);

Table 1: Expected outputs to be compared among participants



name	root	inter-1	kink	inter-2	inter-3	tip
index k	0	1	2	3	4	5
abs. position [mm]	1867.5					
rel. position half-span						1.0000
rel. position root-to-tip[a]			0.2165			
rel. position root-to-kink[b]		0.5000				
rel. position kink-to-tip[c]				0.3333	0.6667	

[a] relative in the extent from root to tip section [b] ... from root to kink section [c] ... from kink to tip section

Figure 2: Definition of the parameterized wing sections

Per geometry variation, the following **general tasks** are expected:

a) For the given shape variations, provide the aerodynamic results presented in table 1 for:

i. Rigid CFD computations

ii. CFD-CSM coupling (while using the provided corresponding CSM models)

b) For the given shape variations, size the wing structure and provide the structure results presented in table 1

c) For the given shape variations, run a rigid, high speed, multipoint ([*Mach, Lift Coefficient, Weighting Factor*]: [Ma=0.78, C_L=0.59, ω =0.4], [Ma=0.80, C_L=0.585, ω=0.2], [Ma=0.78, C_L =0.55, ω=0.4]), aerodynamic profile optimization at fixed maximum t/c and provide the final optimized shape and the aerodynamic results presented in table 1.

d) Evaluate the performance assessment data outlined in table 1.

Additionally, the following **variation-specific tasks** are expected:

1. Per variation in **Wing Aspect Ratio**:
   within point b) from the general tasks, size the structure for the following 3 setups: number of ribs = [given # of ribs, given # of ribs ±1; see Appendix B.], while using the same provided set of load cases (see Appendix D.)

2. Per variation in **Wing sweep**:
   - within point a) i. from the general tasks, run the rigid CFD computations for trimmed state (HTP & Engine-if employed)
   - within point b) from the general tasks, size the structure for the following 2 lamination layup setups

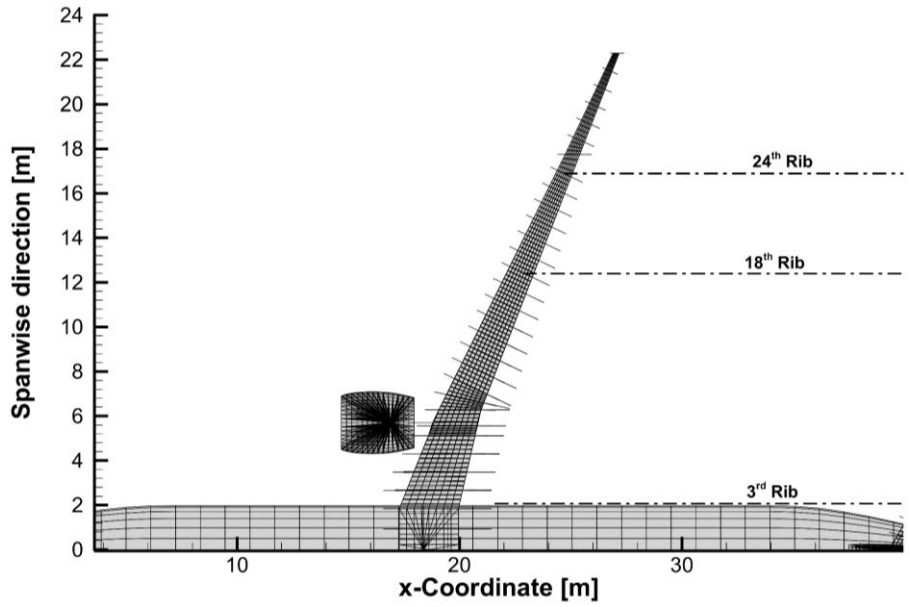
[0° 60 / 90° 10 / ±45° 30] Skin	[0° 40 / 90° 10 / ±45° 50] Skin
[0° 20 / 90° 20 / ±45° 60] Spars & Ribs	[0° 20 / 90° 20 / ±45° 60] Spars & Ribs

3. Per variation in **Wing-tip Twist** and in **Wing-Profile thickness**
   1. within point a) from the general tasks, extract the maximum value of the boundary layer shape factors H_{12}
   2. within point b) from the general tasks, size the structure:
      i. for the provided set of load cases
      ii. While recomputing/reselecting the sizing load cases

Finally, perform the **Baseline-Specific structure optimization** task, defined in Appendix C.

Appendix:

A. **Fuel Tanks Volume**:
- The central fuel tank is enclosed between 1st and 3rd ribs, and front and rear spars
- The wing-inner fuel tank is enclosed between the 3rd and the 18th ribs and the front and rear spars
- The wing-outer fuel tank is enclosed between the 18th and the 24th ribs and the front and rear spars
- Actually, the wing-outer fuel tank shall not exceed the 17-meter half span limit (at the trailing edge), nevertheless, this is neglected for this level of complexity, and will be considered at next stages.



B. **Changing number of Ribs**:
While modifying the number of ribs, the inner set of ribs (between Root and Kink) are fixed and kept constant, the changes shall apply only to the outer set of ribs enclosed between the Kink and the Tip sections.

C. **Structure optimization Task for Baseline**:

Two structure models for the baseline configuration are provided in a sub-package called *TheBaselineStructureOptimizationTask*. The package contains additionally a set of static loads (forces and moments) that are defined at a loads reference axis. For at least one of the two models and the given static loads (forces and moments):

1. Optimize the thicknesses of skin (min thicknesses are described in the paper). In this introductory structure optimization task, the stiffeners are kept constant and no planform changes are applied. The following information are to be considered:
   - Ramp rate is 1:20 in spanwise direction
   - Spacing = 250mm
   - Plyshare :
     - for skin: 60/30/10,
     - and for stiffener: 60/30/10
   - Stiffener concept: T – stiffened panel,
     - t_web = 2*t_foot ≥ 6mm
     - Foot width ≤ 120mm
     - Height ≤ 80mm
   - Structure Sizing Criteria:
     - Strength
       - Classical strength (e.g. Tsai Wu)
       - Max strain (follow data in Table below, taken from the SciTech paper)

	Compression	**Tension**
Spar to cover bolted interfaces	-3500$\mu\epsilon$	5000$\mu\epsilon$
Skin or stringer free edges	-4800$\mu\epsilon$	5000$\mu\epsilon$

     - Stability if possible
       - Global
       - Local (e.g. skin between stiffener, web, …)
   - Material and allowable are defined in the CPACS file (within the package), the provided Nastran files and in the SciTech paper

2. Optimize stiffener thicknesses as well

3. Perform composite optimization for quad laminates (0°, +-45° and 90°) and symmetric balanced including 10% rule, based on available composite parametrization:

D. **Selected Load Cases for Structure Sizing**:
The load cases definitions are presented below (Table 3), based on the definition of the initial mass cases defined in Table 2:

ID	MCRUa	MCRUb	MCRUc	MOOee	MZOAe	MTOAa	MTOfF	MFOef
Mass [kg]	71240	76209	81179	46271	71271	85688	85688	66148
xCG [m]	20.3	20.33	20.37	20.16	19.8	19.8	20.51	20.51
Payload [kg]	20000	20000	20000	0	25000	25000	19540	0
Fuel [kg]	4969	9938	14907	0	0	14417	19877	19877

Table 2: Definition of the various initial mass cases used within the load analysis process

LOAD ID	LOAD CASE	MASS CASE	DESIGN SPEED	ALTITUDE [M]	MACH [-]	V_{EAS} [M/S]	COMPONENT
0001	Gust (H=30m)	MTOAa	VC	8000	0.82	165.4	Wing
0002	Gust (H=50m)	MTOAa	VC	8000	0.82	165.4	Wing
0003	2.5g Pull-Up	MTOAa	Va	8000	0.83	168	Wing
0004	2.5g Pull-Up	MTOAa	VD	8000	0.89	179.5	Wing, Fuselage
0005	-1g Push-Down	MTOAa	VC	8000	0.82	165.4	Wing
0006	-1gPush-Down	MTOAa	Vh	10668	0.70	115.6	Wing
0007	Gust (H=10m)	MTOAa	VC	2000	0.59	178.5	HTP
0008	-1gPush-Down	MTOAa	VC	0	0.53	180.1	HTP
0009	Yaw	MTOAa	VS	10668	0.55	91.2	VTP, Fuselage
0010	Gust (H=30m)	MZOAe	VC	8000	0.82	165.4	Wing
0011	Gust (H=30m)	MZOAe	VC	10000	0.82	142.8	Wing
0012	2.5gPull-Up	MZOAe	Va	4000	0.56	149.3	Wing
0013	2.5gPull-Up	MZOAe	Va	8000	0.72	145.6	Wing
0014	0g Push-Down	MZOAe	VD	8000	0.89	179.5	Wing, Fuselage
0015	Roll	MZOAe	VA	0	0.40	135.2	Wing
0016	2.5gPull-Up	MZOAe	Va	0	0.45	151.5	HTP
0017	Yaw	MZOAe	VD	0	0.62	209.6	VTP, Fuselage
0018	Gust (H=30m)	MZOAe	VC	4000	0.67	176.5	Fuselage
0019	2.5gPull-Up	MZOAe	VD	8000	0.89	179.5	Fuselage
0020	-1gPush-Down	MZOAe	Vh	0	0.32	108.6	Fuselage
0021	-1gPush-Down	MZOAe	Vh	10668	0.63	104.6	Fuselage
0022	2.5gPull-Up	MOOee	Va	0	0.332	113	Wing
0023	2.5gPull-Up	MOOee	VD	4000	0.757	245.7	HTP
0024	2.5gPull-Up	MOOee	VD	8000	0.89	179.5	HTP
0025	Gust (H=30m)	MOOee	VC	8000	0.82	165.4	Wing
0026	2.5gPull-Up	MFOeF	Va	0	0.42	143.4	HTP
0027	2.5gPull-Up	MFOeF	VD	4000	0.757	200.9	HTP
0028	2.5gPull-Up	MFOeF	VD	8000	0.89	179.5	HTP
0029	2.5gPull-Up	MTOfF	Va	0	0.52	178.8	HTP
0030	2.5gPull-Up	MTOfF	VD	0	0.60	205.6	HTP, Fuselage
0031	-1gPush-Down	MTOfF	VC	0	0.53	180	HTP
0032	0g Push-Down	MTOfF	VD	10668	0.89	146.9	HTP
0033	Yaw	MTOfF	VS	8000	0.57	176.2	Fuselage
0034	Yaw	MTOfF	VS	10668	0.70	208.5	VTP, Fuselage
0.35	Gust (H=30m)	MCRUc	VC	8000	0.82	165.4	HTP, VTP

Table 3: load case definition; row-separated by mass case

Speeds:

VC: design cruising speed
VS: 1g stall speed
Vh: -1g stall speed
VD: design dive speed
Va: 2.5g stall speed
VB: design gust speed