CLEAN AVIATION

U-HARWARD

HIGH-FIDELITY STRUCTURAL AND AERODYNAMIC EVALUATIONS OF STRUT BRACED WING CONFIGURATION

May 24, 2023
ONLINE WORKSHOP

Co-funded by the European Union

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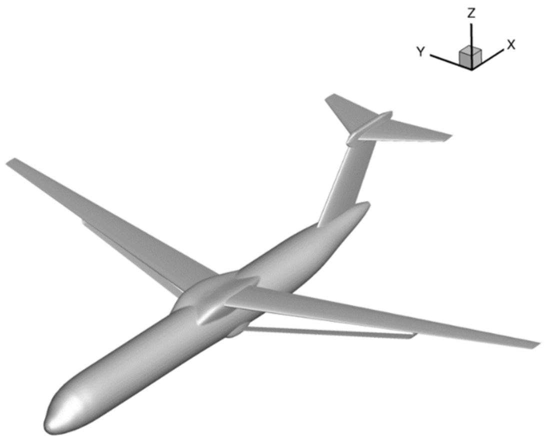
REFERENCE SBW CONFIGURATIONS FROM FAST-OAD



Reproduction of optimum SBW configuration from FAST-OAD

Wing planform characteristics		
Parameter	Symbol	Value
Wing area	S_{ref}	160 m^2
Wing span	b	55.14 m
Mean Aerodynamic Chord	MAC	3.20 m
Aspect ratio	AR	19
Taper Ratio	TR	0.3
Sweep angle	φ	19°
Root Profile Characteristics		
Chord	c	4.3 m
Relative thickness	t/c	0.1
Position in y	y	1.96 m
Tip Profile Characteristics		
Chord	c	1.29 m
Relative thickness	t/c	0.1
Position in y	y	27.57 m
Strut planform characteristics		
Chord	c	1.0 m
junction	y/b	65 %
Sweep angle	φ	13 °

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AEROELASTIC ANALYSIS

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AEROELASTIC ANALYSIS MODEL GENERATION

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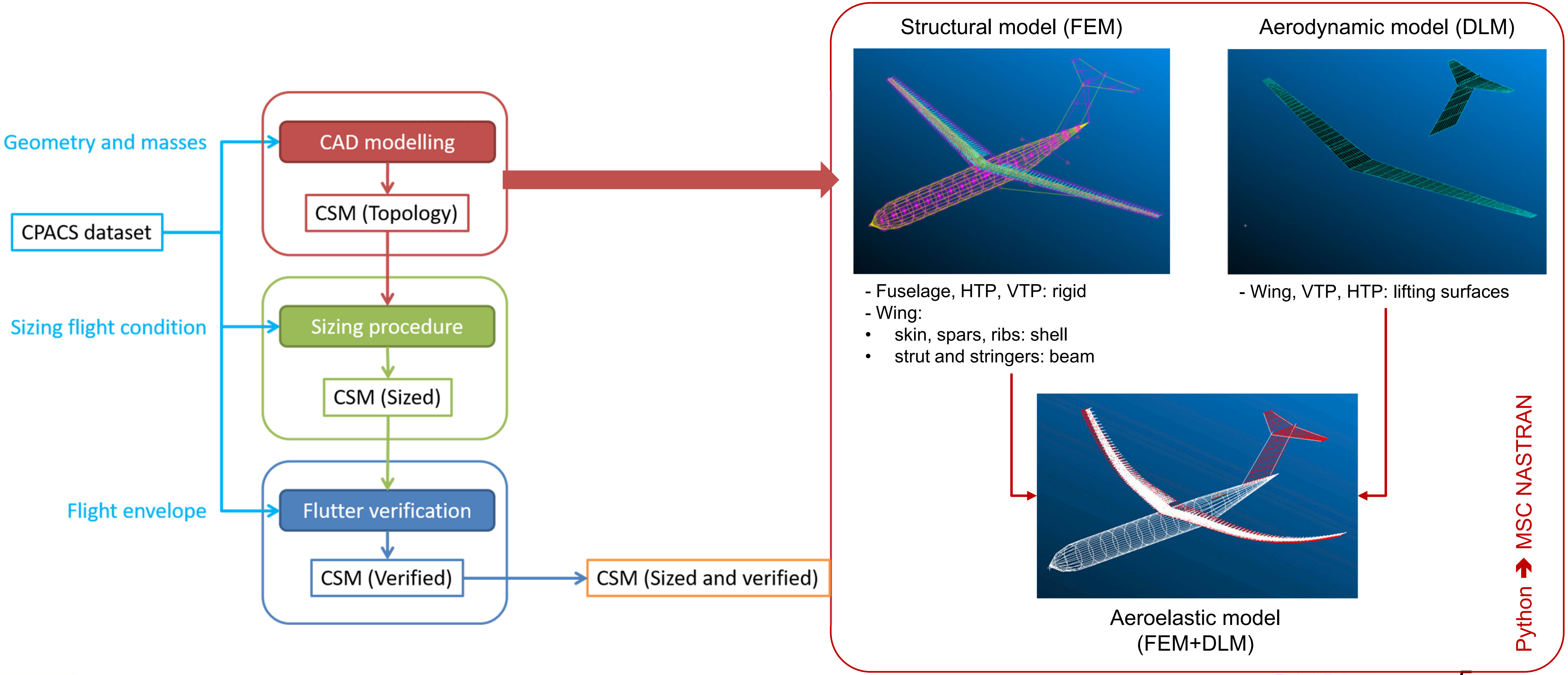
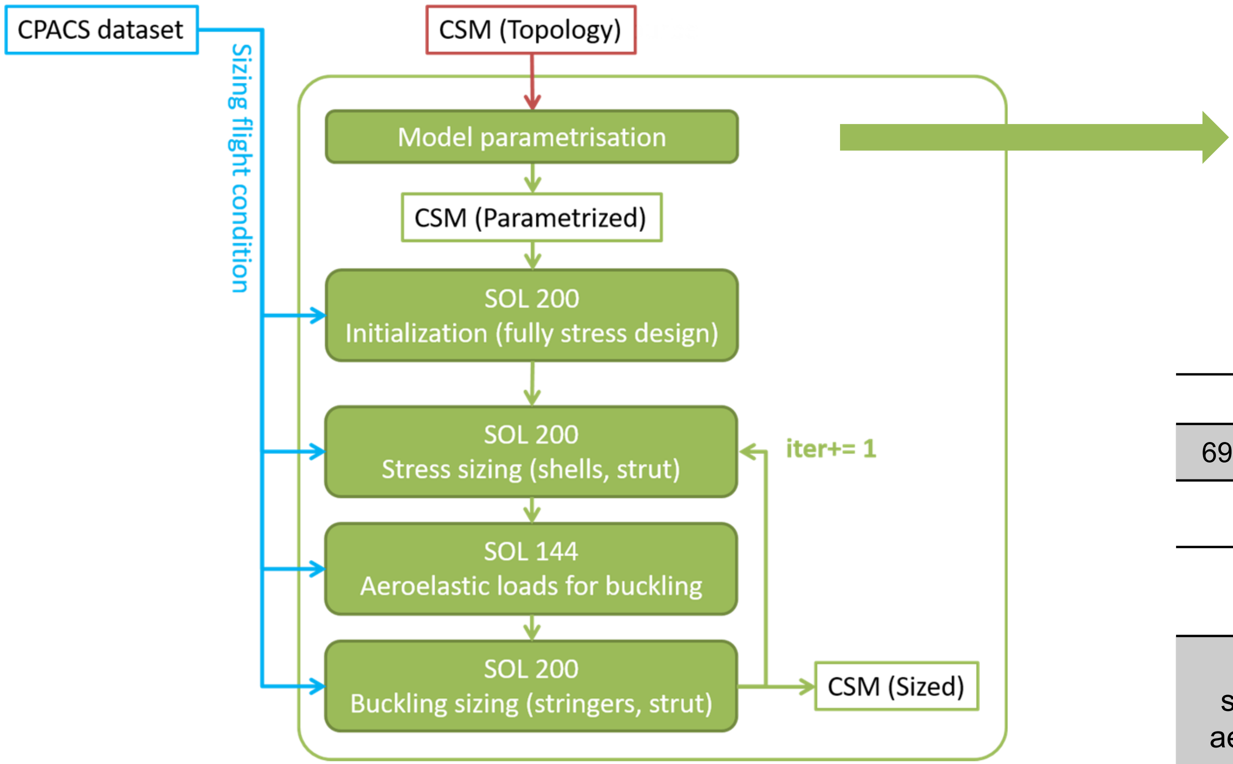
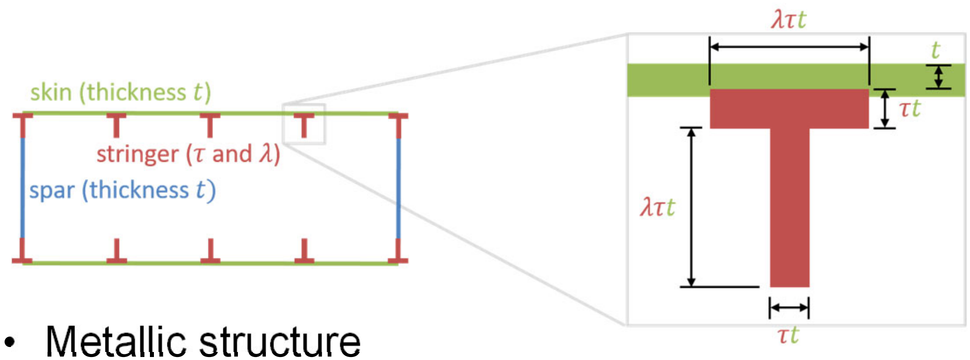


AEROELASTIC ANALYSIS SIZING PROCEDURE



- Wingbox parametrisation



- Metallic structure

E	ν	ρ	$\sigma_{t,lim}$	$\sigma_{c,lim}$	$\sigma_{s,lim}$
69 GPa	0.30	2700 kg/m^3	270 MPa	270 MPa	200 MPa

- Load cases

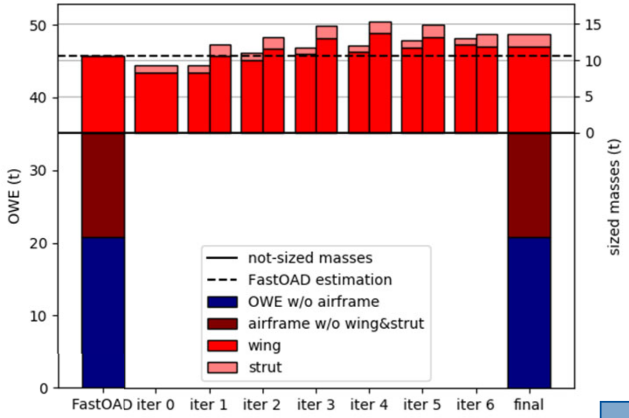
$$\{\sigma_I, \sigma_{II}, \sigma_S\} < \frac{\{\sigma_t, \sigma_c, \sigma_s\}}{\text{s.f.}}$$

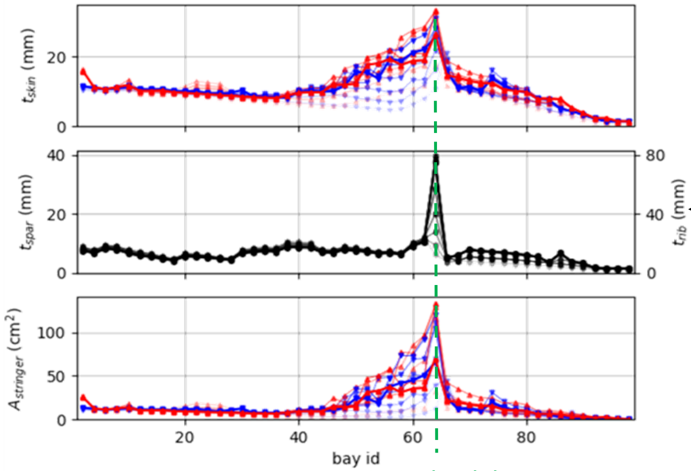
static aeroel. trim	M = 0.78 FL310	MTOW	+1.0 g	s.f.=1.5
			+2.5 g	s.f.=1.2
			-1.0 g	s.f.=1.2

AEROELASTIC ANALYSIS SIZED MODEL

Sizing results

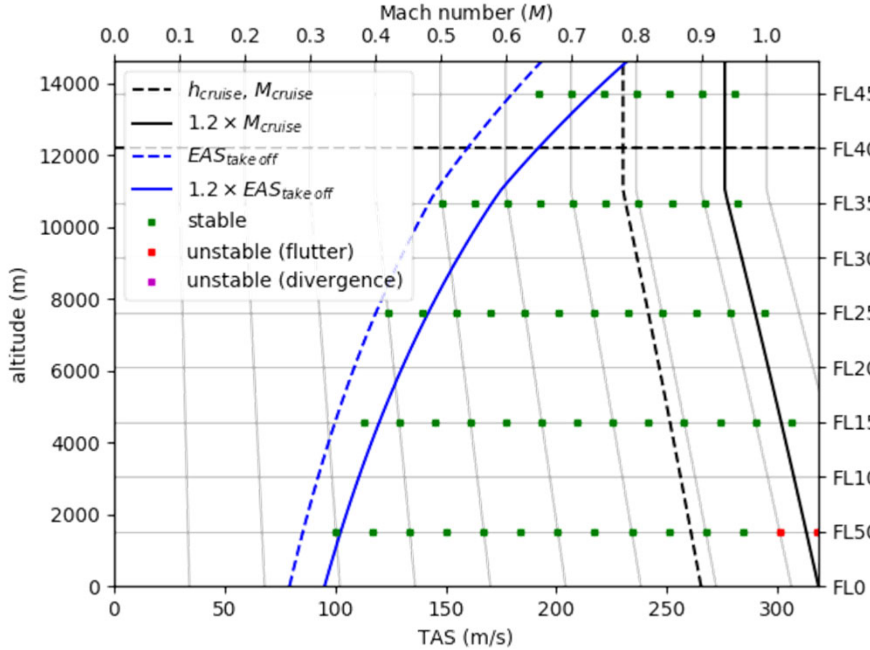
- Initial fully-stress design (iter 0) consistent with FastOAD
- Mass added by the aeroelastic coupling





Spanwise variation of the structural design variables

Preliminary flutter verification (no pre-stress) ☑



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AERODYNAMIC AUTOMATIC OPTIMISATION STUDY

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AUTOMATIC DESIGN PROCESS

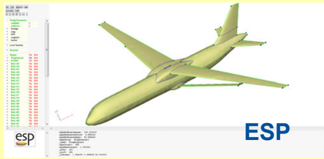
Input File (.csm)

Parameterized geometry description (script)

ESP/EGADS

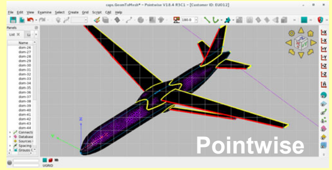
Parametric geometry

Use of Plugs



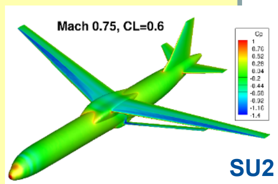
CAPS/AIM/Pointwise Module
or
CAPS/AIM/AFLR Module

Automated CFD mesh generation (Euler or RANS)



CAPS/AIM/SU2 or esIA Module

CFD Euler or CFD RANS



CAPS/AIM/FRICTION Module

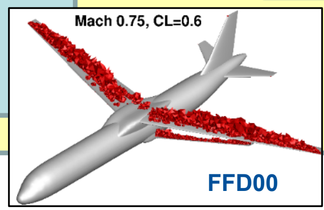
Viscous drag estimation module based on geometry and analytical methods

Far field Drag breakdown Module

ONERA post-processor FFD00

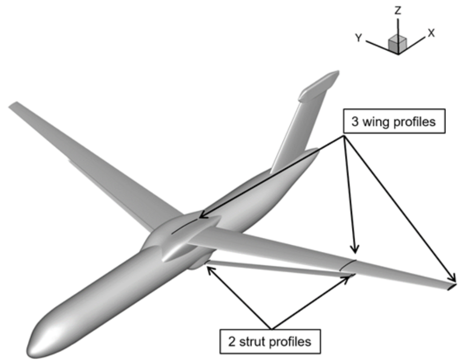
Drag breakdown:
CDinduced + CDwave (+ CDviscous)

Remove spurious drag

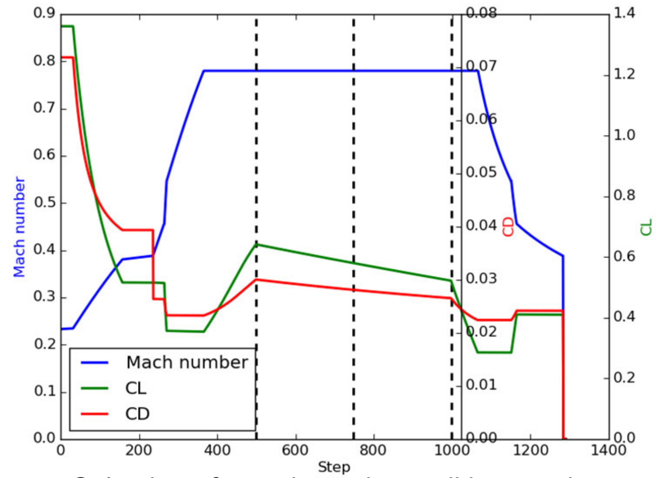


AERODYNAMIC OPTIMISATION PROBLEM

MM1



Parameterization of the profiles



Selection of aerodynamic conditions and constraints

Parameterization:

- Twist law along the wing and strut span
- CST parameterization of the wing and strut profiles using 14 variables (7 for thickness and 7 for camber for each section) starting from the ALBATROS profiles => 87 parameters

Optimization conditions:

- 3 cruise conditions at M = 0.75:

- beginning	CL = 0.642
- middle	CL = 0.58
- end	CL = 0.523

$$Objective : \min\left(\sum_{k=1}^{N} C_{Dk}\right)$$

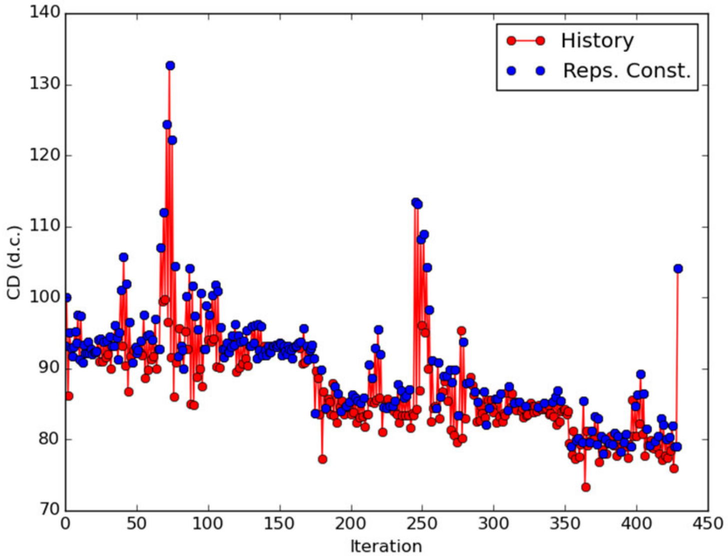
$$w.r.t.:\ C_{Lk\,obj} = C_{Lk\,flight}$$

Diapositiva 10

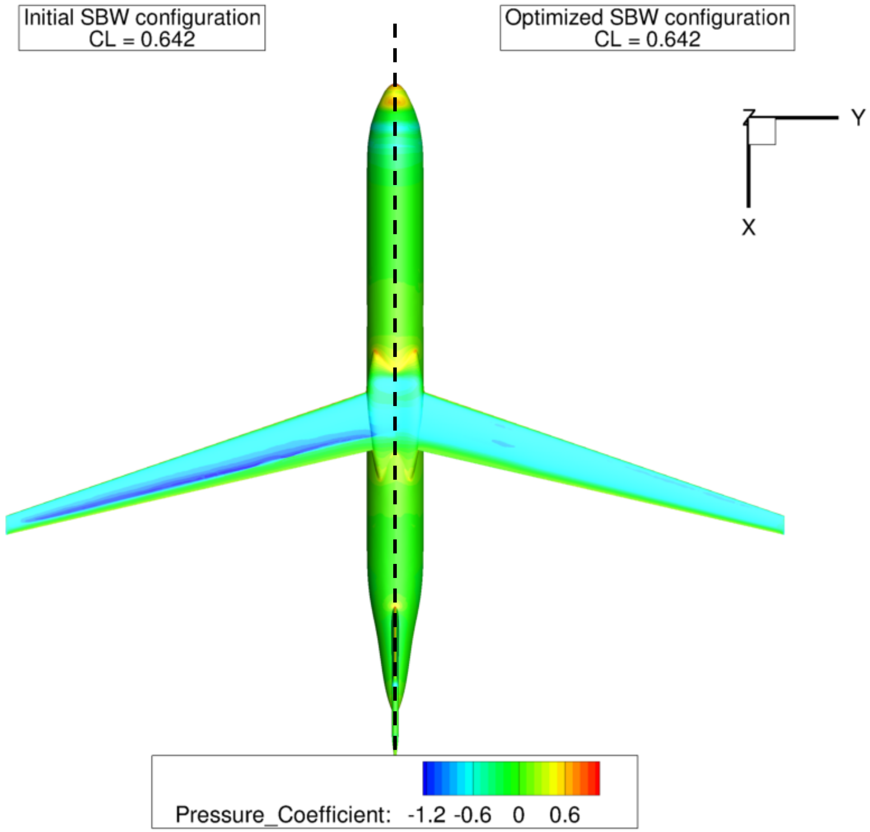
MM1 M=0.78 sur le graph mais design fait à M=0.75...
Sais-tu ce que montre Christophe pour être cohérent?
Meheut Michael; 22/05/2023

OPTIMISATION OF THE PROFILES IN INITIAL CRUISE CONDITIONS

- Modification of the parameters and generation of the CFD mesh at each iteration
- Simulations of the flow using CFD Euler
- Reduction of the overall drag coefficient $\Delta C_D = -16\%$



Convergence of the optimisation process



Distribution of the pressure coefficient

OPTIMISATION OF THE PROFILES IN INITIAL CRUISE CONDITIONS

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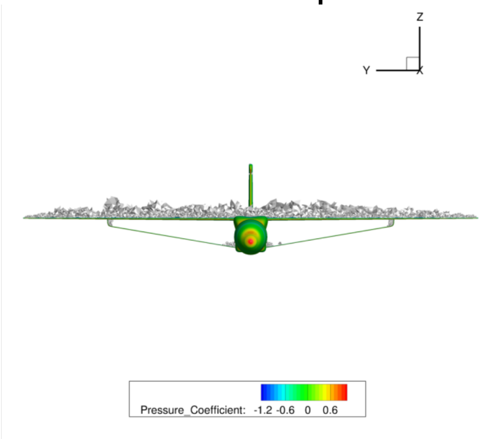
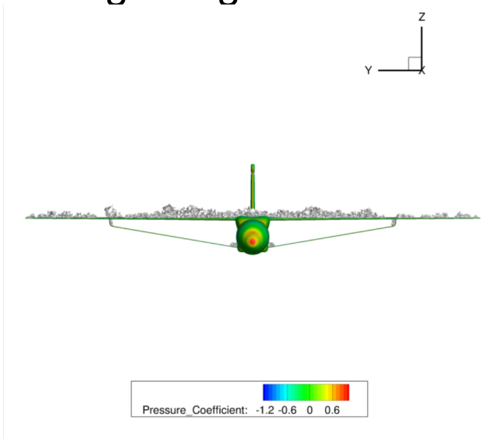
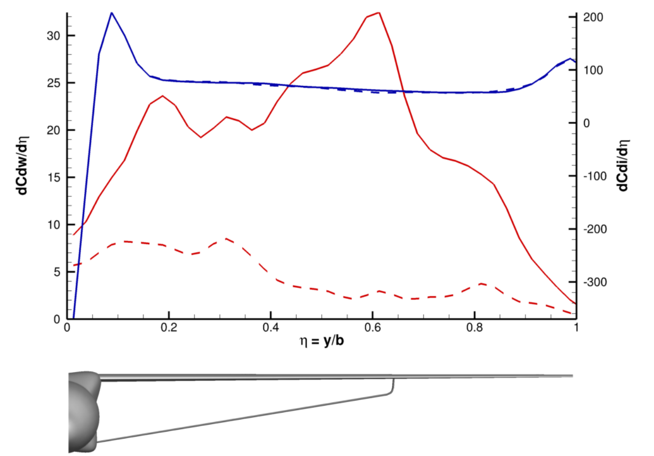
- Performance of the optimum design at the beginning of cruise



Wave drag integration contours initial design



Wave drag integration contours optimum design



Drag sources comparison along the spanwise direction

Optimization of the profiles and twist law at M = 0.75 for C_L = 0.642			
	Initial AR = 19 SBW configuration	Optimized AR = 19 SBW configuration	Delta (%)
Angle of attack (°)	1.25	1.26	
Wave drag (d. c.)	18.8	4.4	- 76.4
Induced drag (d. c.)	74.3	73.6	- 0.9
Far-Field drag (d. c.)	93.1	78.1	- 16.2
Oswald coefficient	0.930	0.937	+ 0.8

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MANUAL AERODYNAMIC DESIGN

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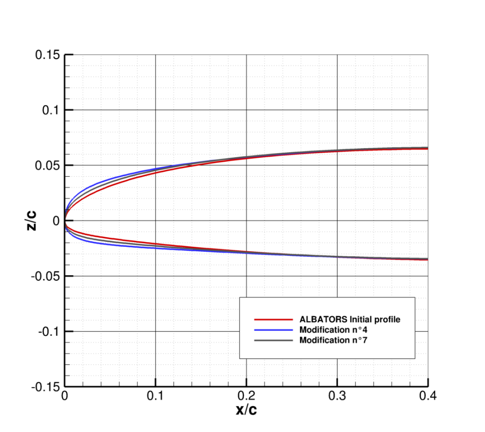
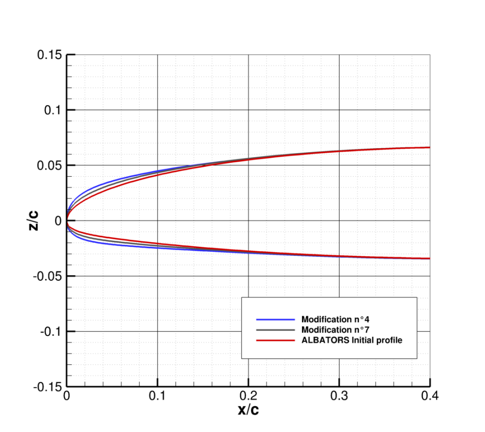
MANUAL DESIGN STEPS

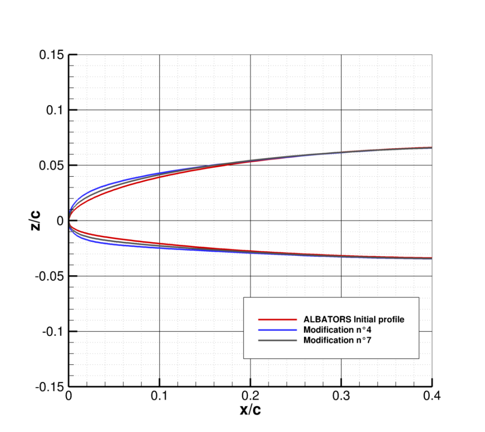
- Manual modification of the local thickness of the profiles $0\% < \frac{x}{c} < 40\%$



Modifications of the root profile



Modifications of the intermediate profile

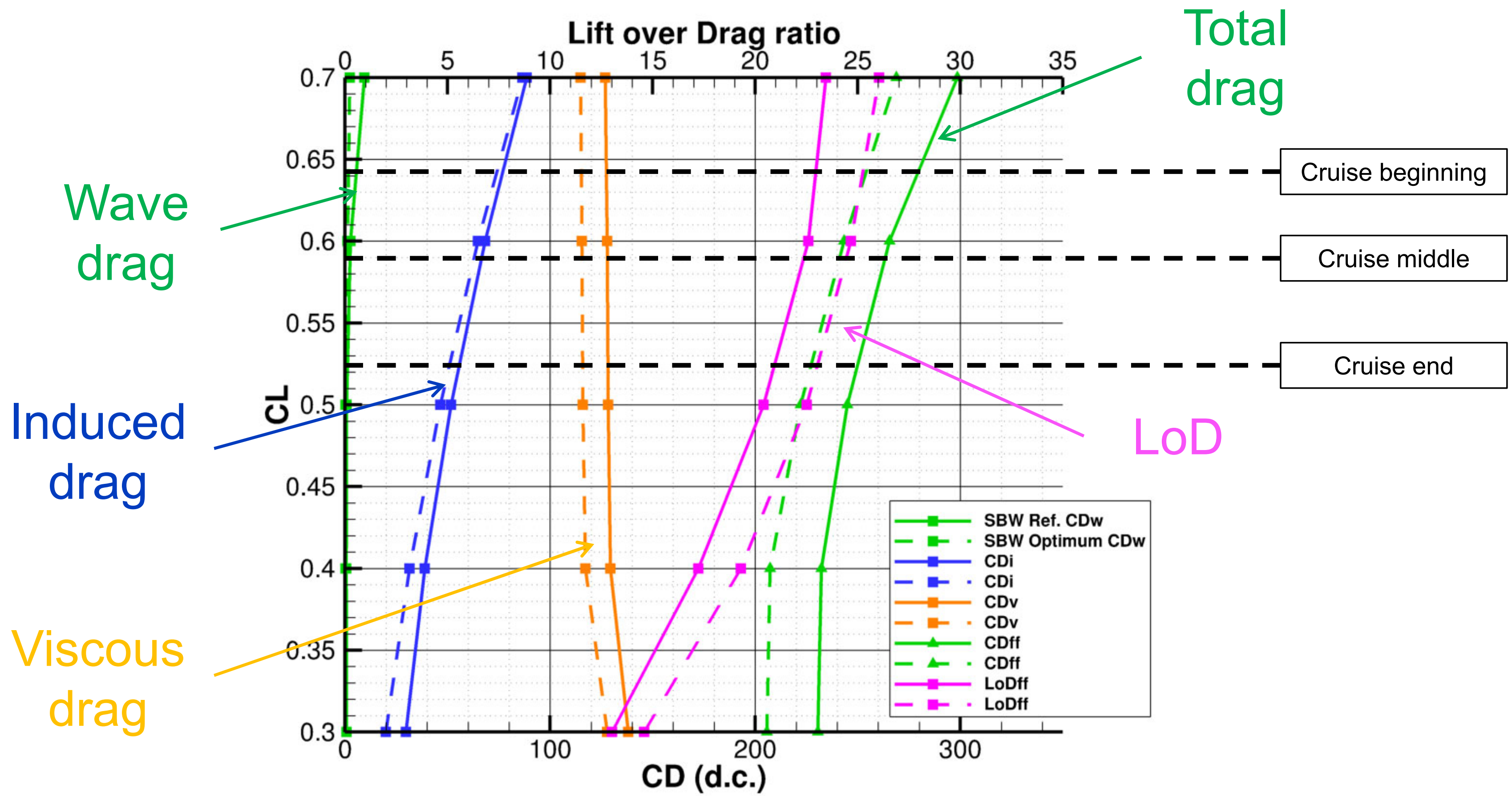


Modifications of the tip profile

- Validation of the wing surface curvature through CAD software

- High-Fidelity CFD RANS computations at $C_L = [0.3 ; 0.4 ; 0.5 ; 0.6 ; 0.7 ; 0.8]$

OPTIMUM SBW CONFIGURATION DRAG BREAKDOWN



PRESSURE COEFFICIENTS
RANS AT CL = 0.7

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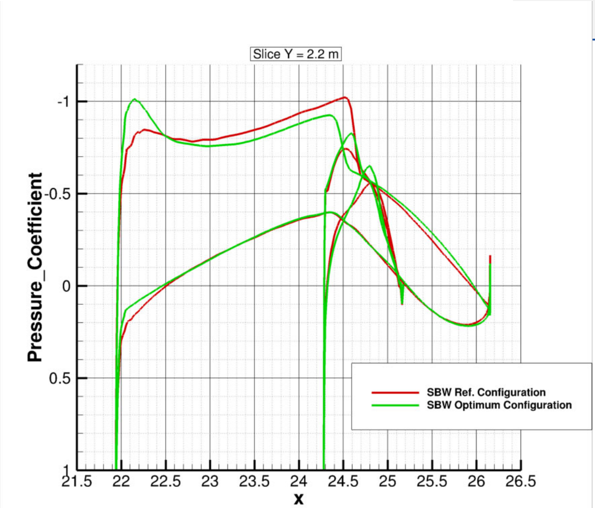
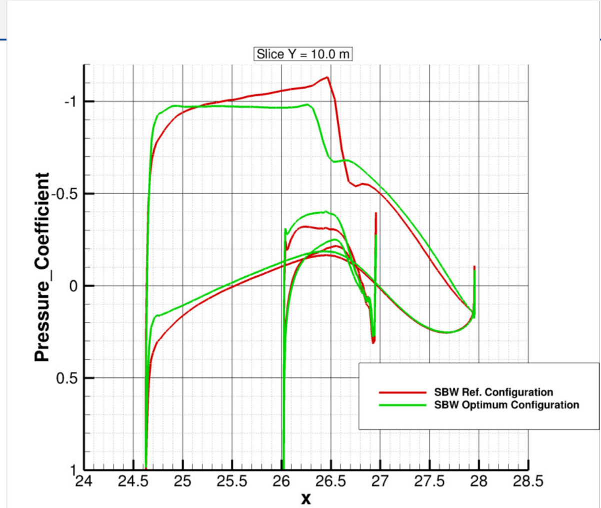
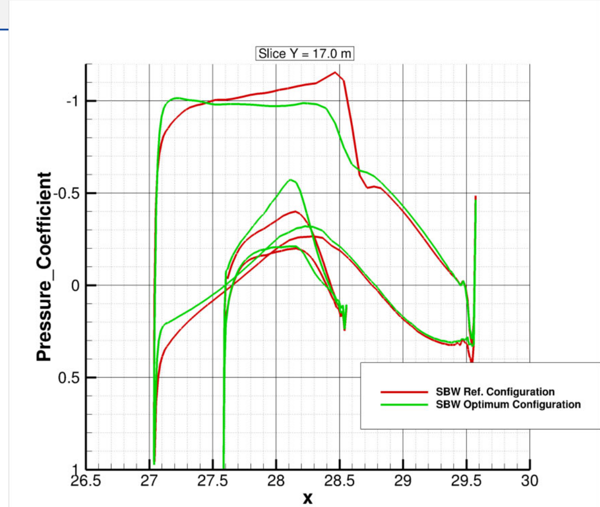
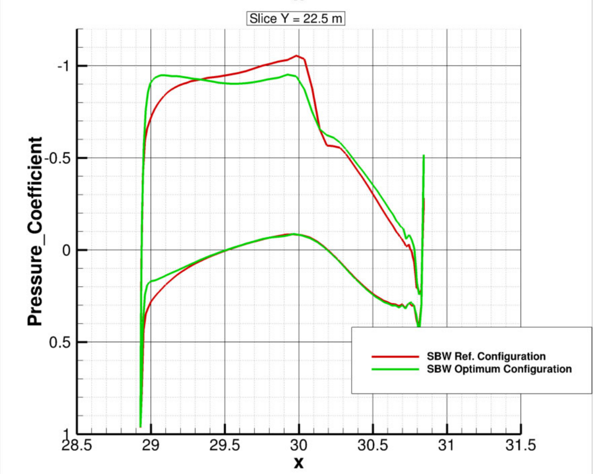
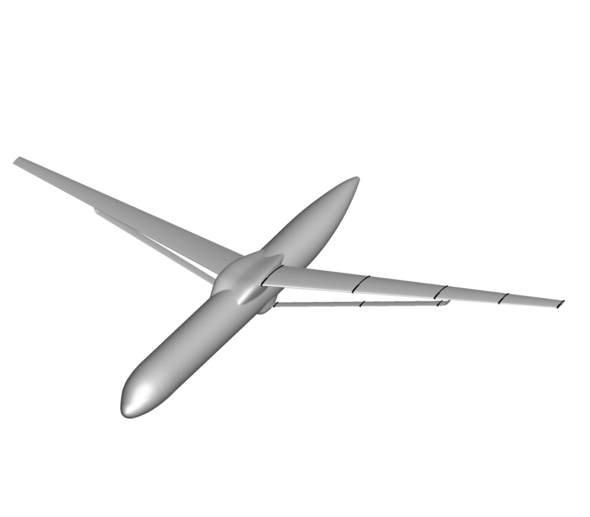
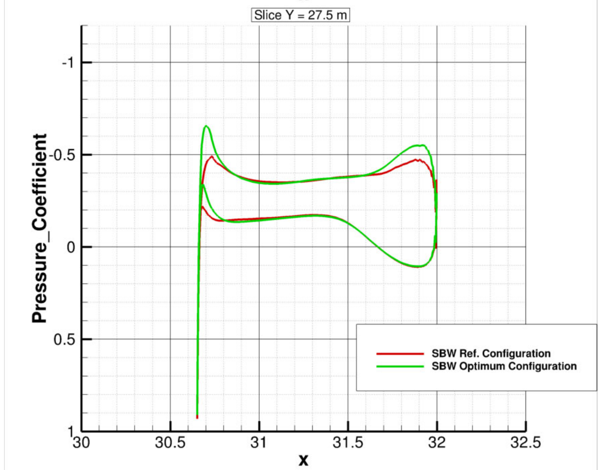




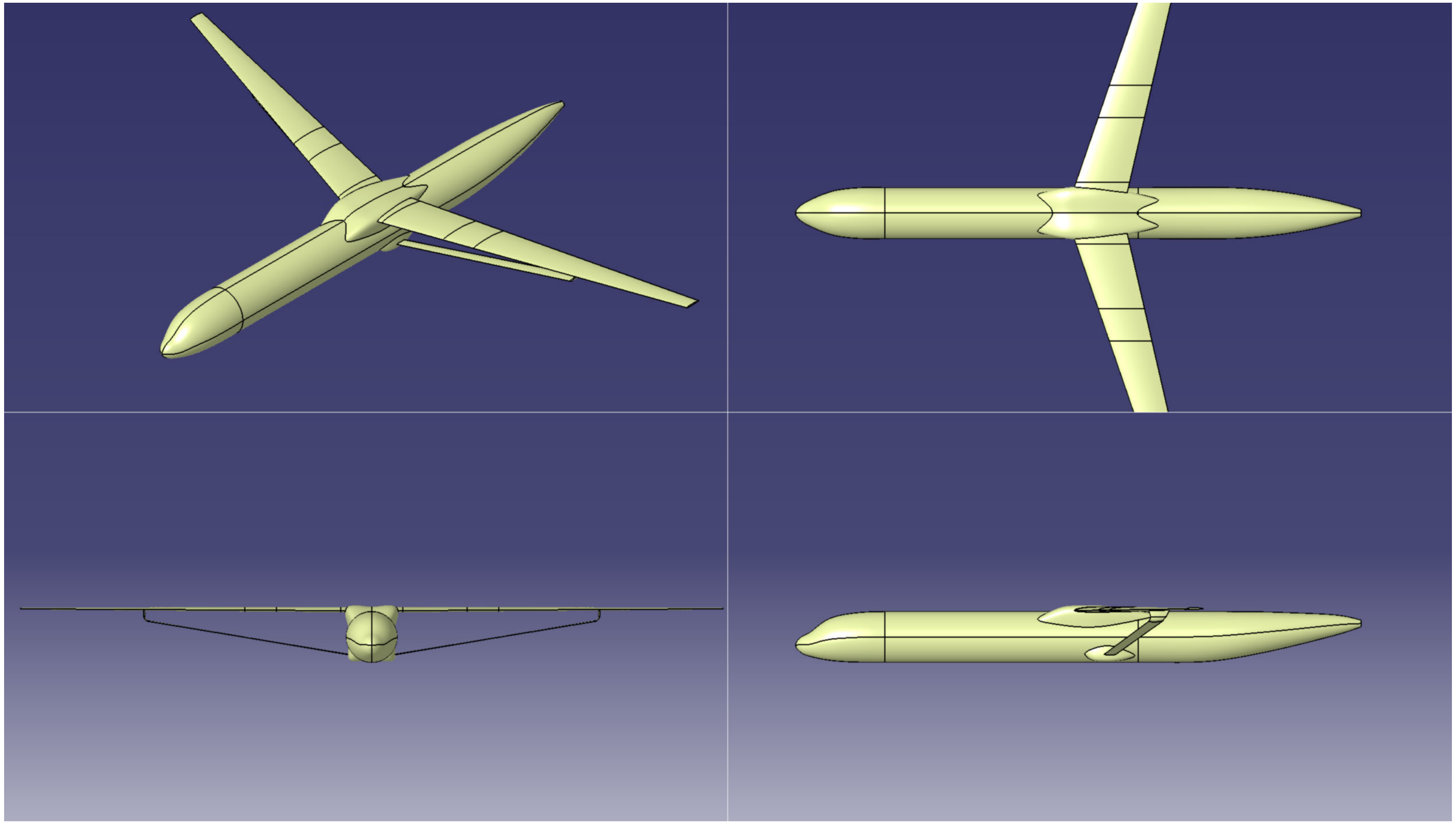








AERODYNAMIC MANUAL DESIGN PROCESS



SUMMARY AND PERSPECTIVES

- FAST-OAD process used to determine the preliminary shape of the aircraft with fast disciplinary modules

- Structural Design and aero-elastic analysis:
  - FIRST SIZING STRUCTURE WITH POTENTIAL ROOMS FOR IMPROVEMENT
  - FIRST ASSESSMENT OF THE FLUTTER RESPONSE
  - AIRCRAFT SIZING COHERENT WITH THE ASSUMPTIONS OF THE OAD PROCESS

- Aerodynamic design process:
  - AERODYNAMIC OPTIMIZATION BASED ON MEDIUM-FIDELITY (EULER) SIMULATIONS FOR THE CRUISE CONDITIONS
  - VALIDATION THROUGH HIGH-FIDELITY (RANS) COMPUTATIONS
  - FINAL MODIFICATION OF THE GEOMETRY USING A CAD SOFTWARE AND HIGH-FIDELITY CFD COMPUTATIONS RESULTING IN ~ 10% DRAG REDUCTION
  - CONFIGURATION USED AS BASELINE FOR CLEAN AVIATION ACAP AND UPWING PROJECTS

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