

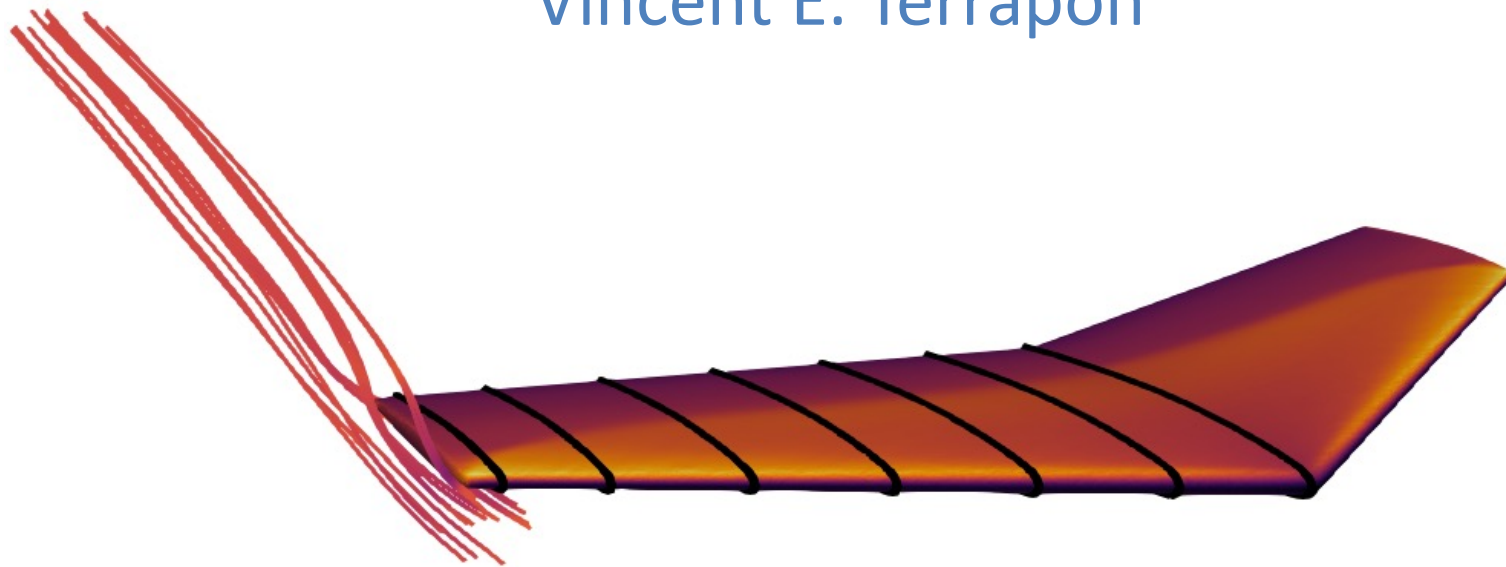
Aerostructural analysis and optimization using Viscous-Inviscid Interaction

Paul Dechamps

Adrien Crovato

Grigorios Dimitriadis

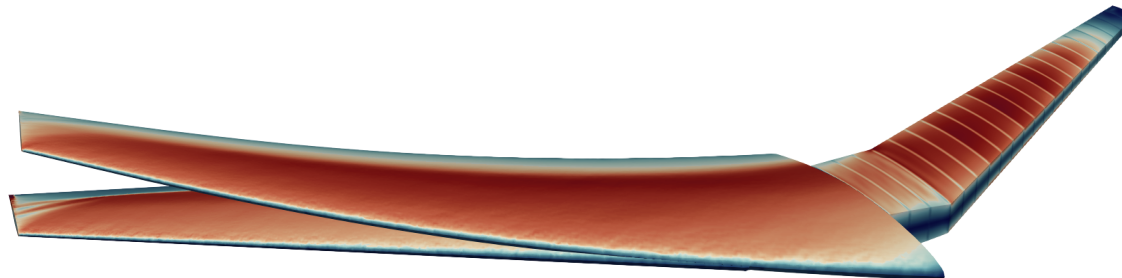
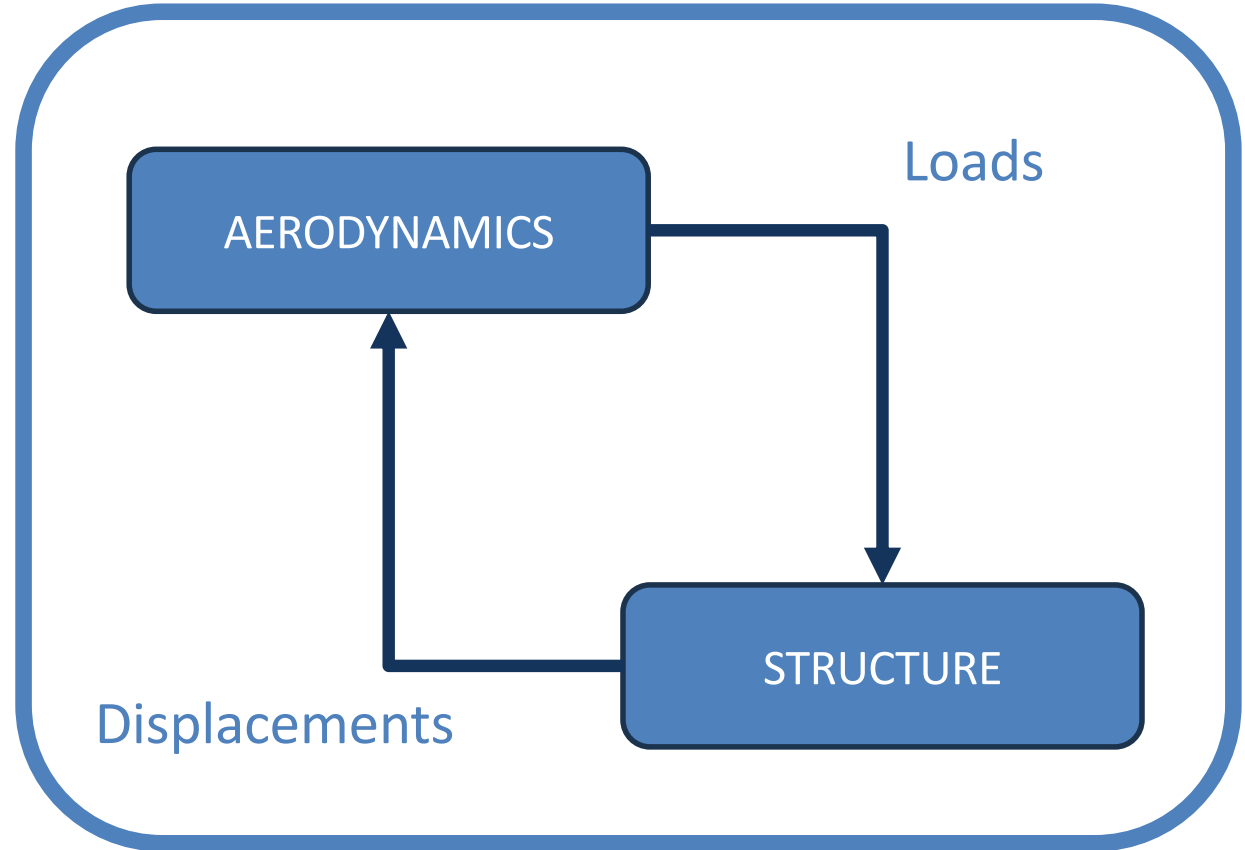
Vincent E. Terrapon



June 2026

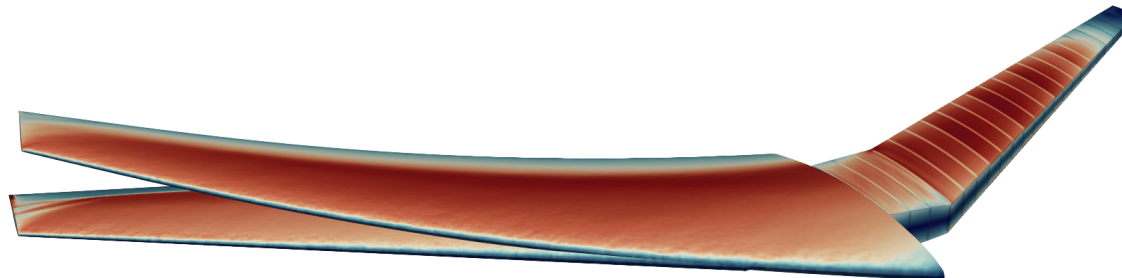
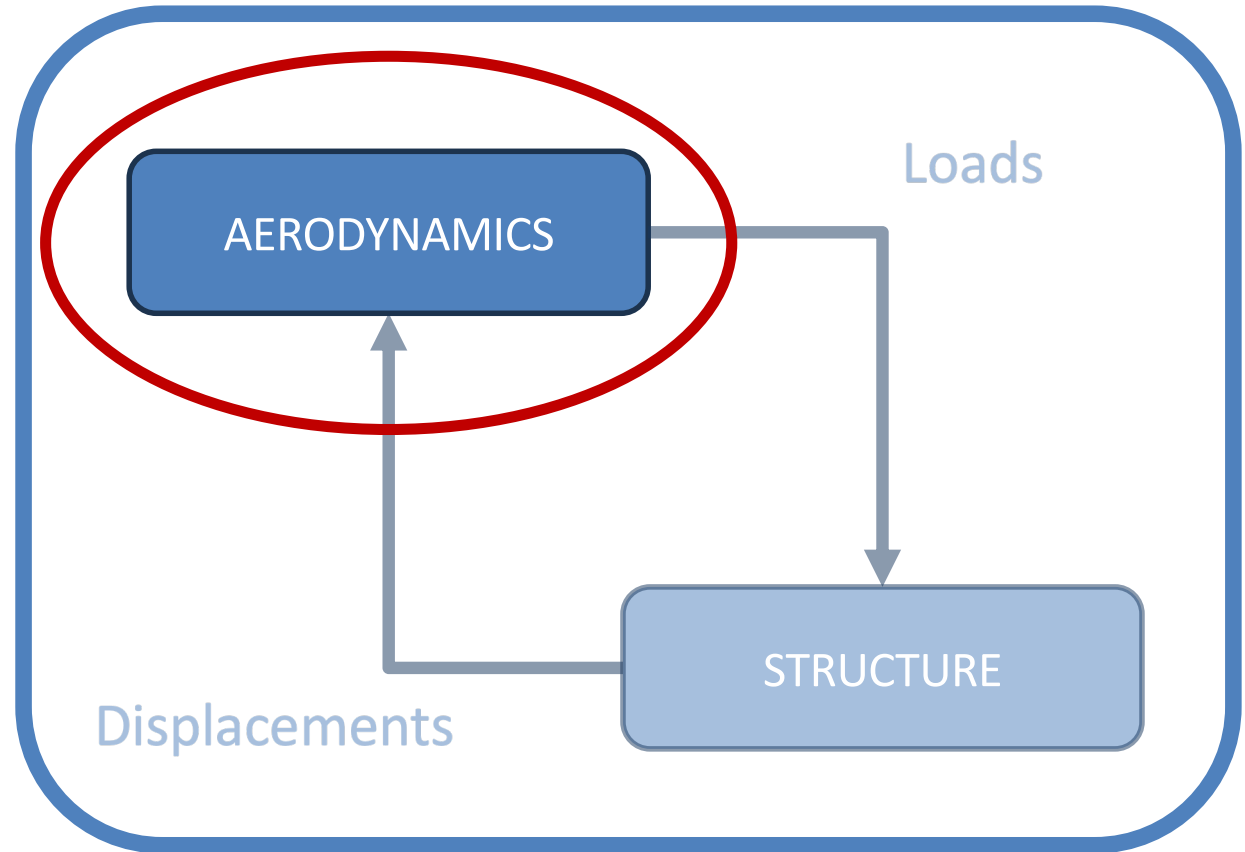
Aeroelastic optimization

Design variables
Constraints
Flow conditions



Aeroelastic optimization

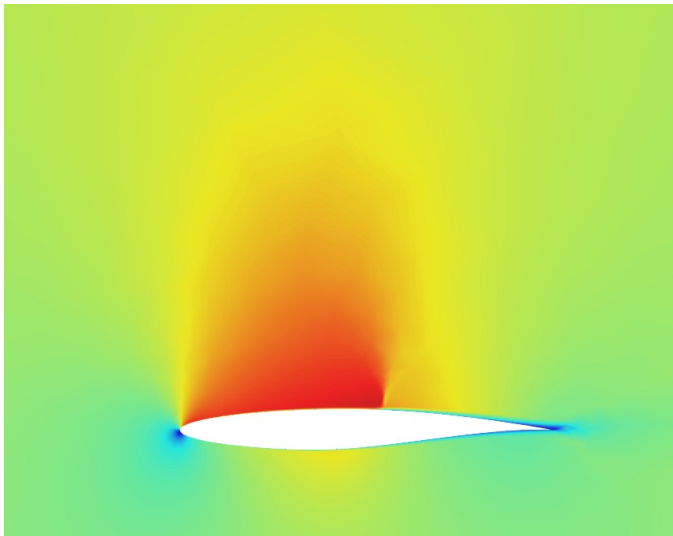
Design variables
Constraints
Flow conditions



Capture relevant physics at low cost

RANS

High level of fidelity

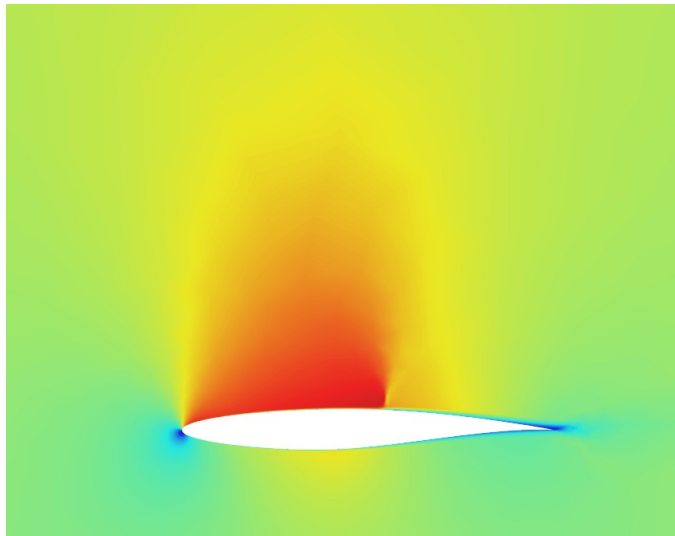


Mach number

Capture relevant physics at low cost

RANS

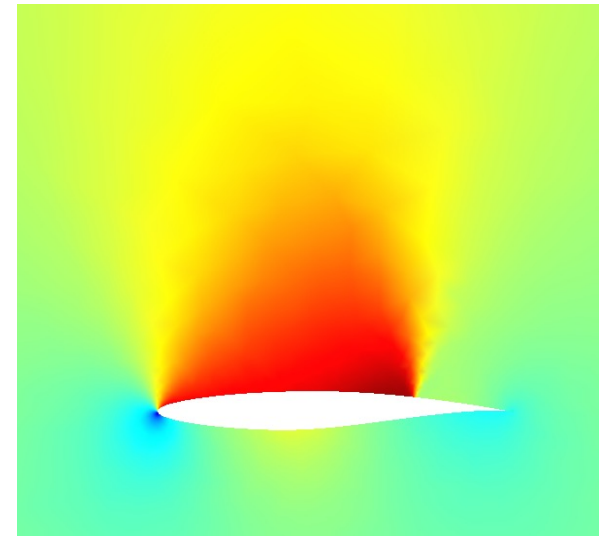
High level of fidelity



Mach number

Inviscid flow

Wrong shock location



Capture relevant physics at low cost

RANS

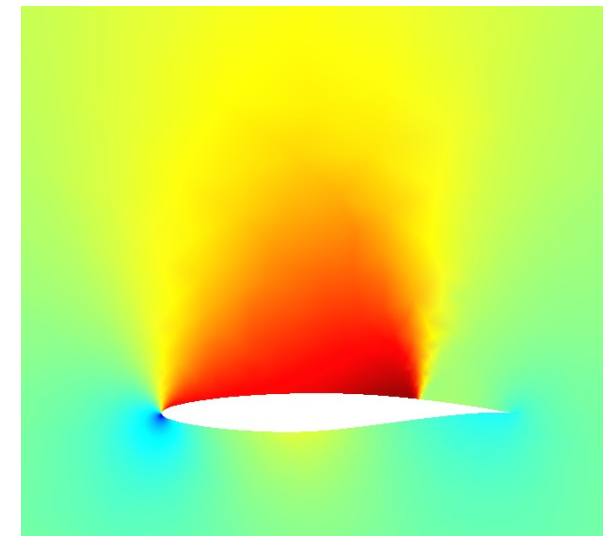
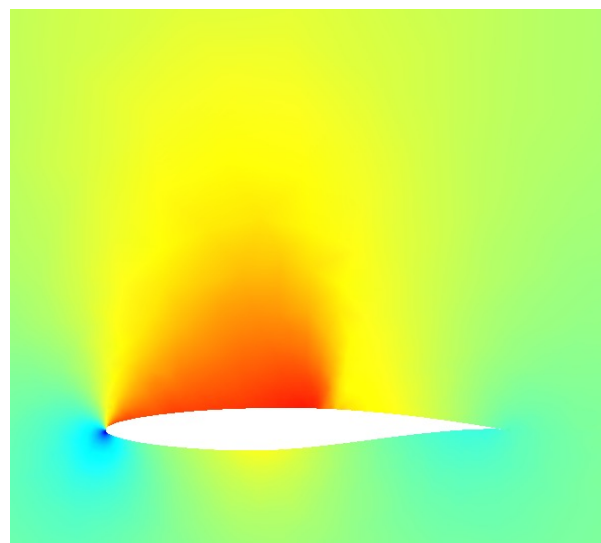
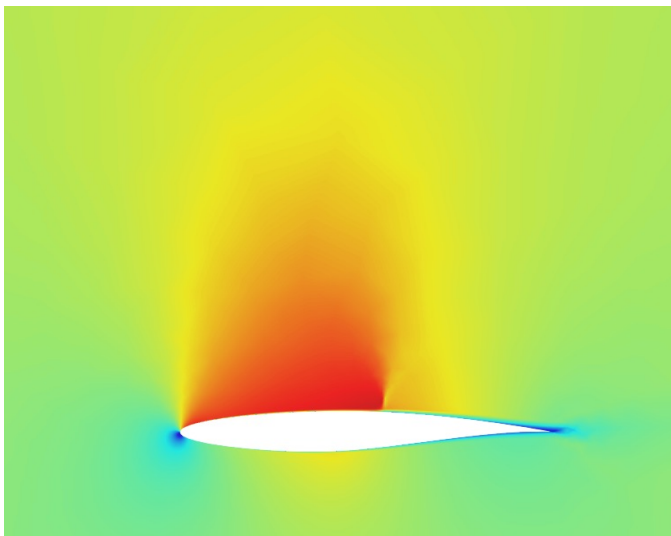
High level of fidelity

**Viscous inviscid
interaction**

Viscosity effects
Correct shock position

Inviscid flow

Wrong shock location



Mach number

Capture relevant physics at low cost

RANS

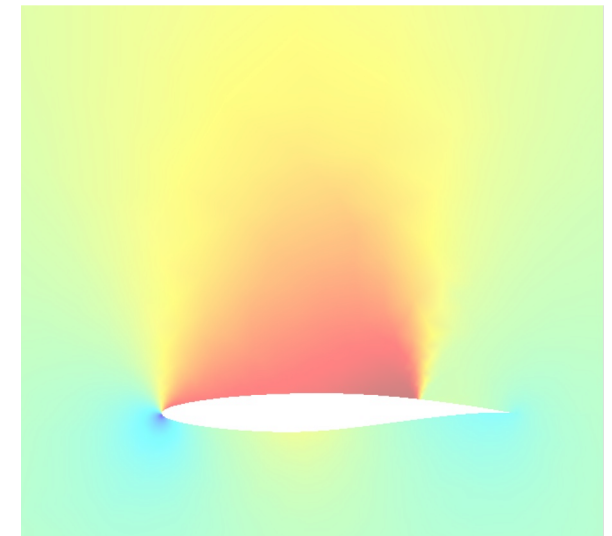
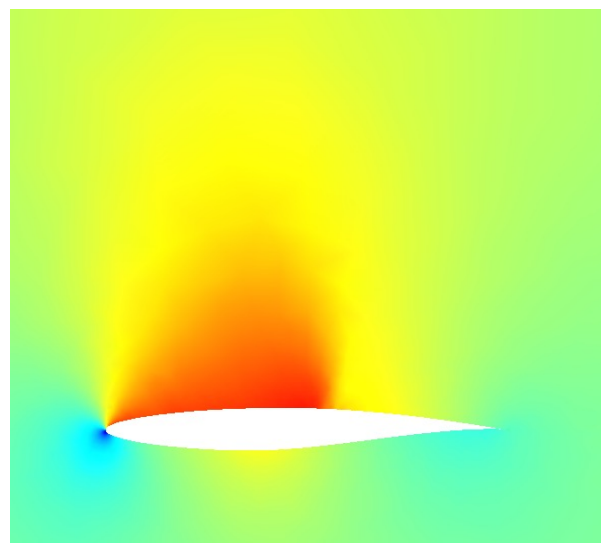
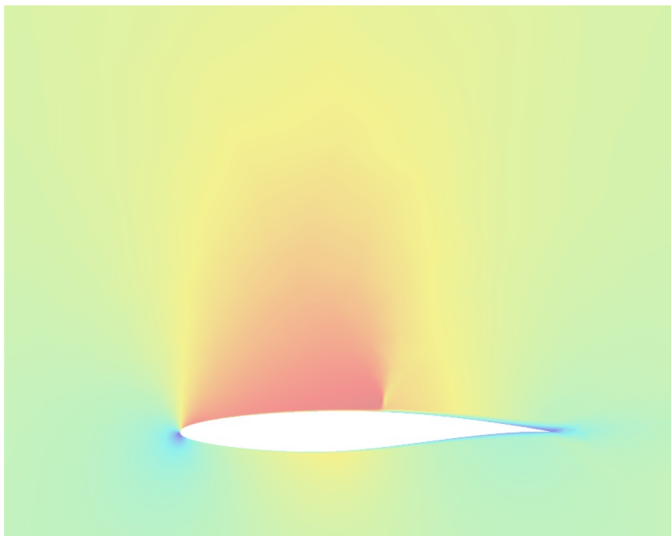
High level of fidelity

Viscous inviscid
interaction

Viscosity effects
Correct shock position

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Mach number

Capture relevant physics at low cost

RANS

High level of fidelity

Viscous inviscid
interaction

Viscosity effects
Correct shock position

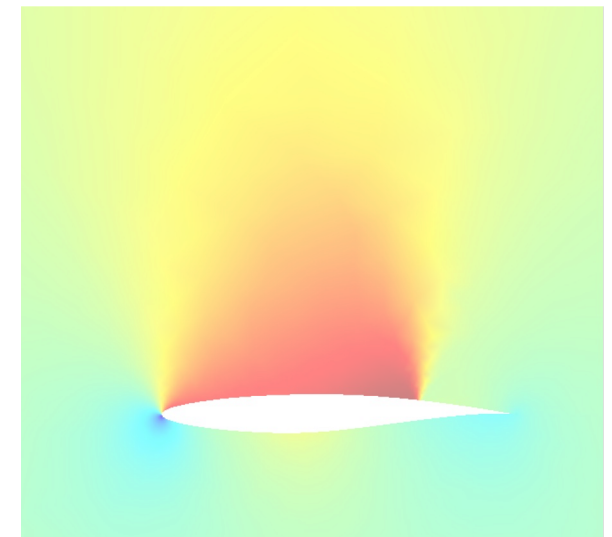
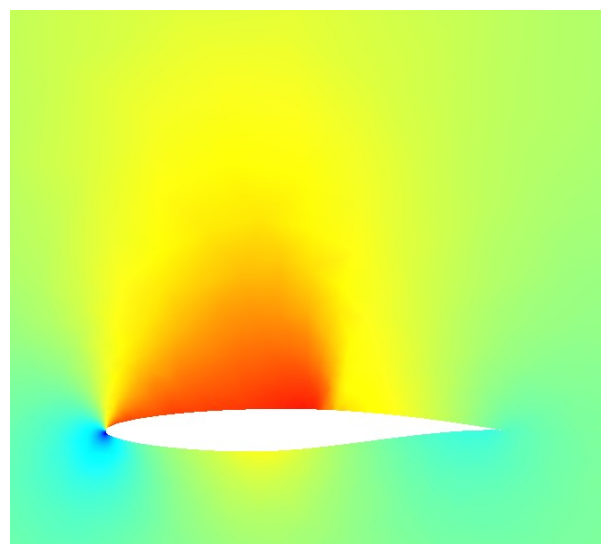
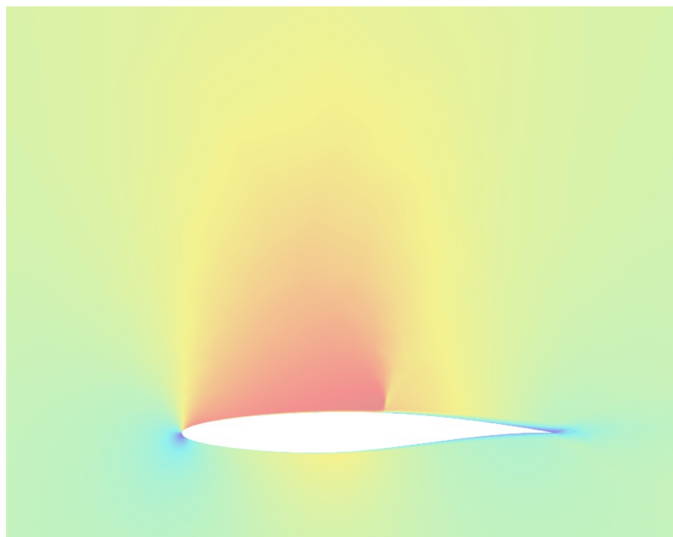
Inviscid flow

Wrong shock location

Time

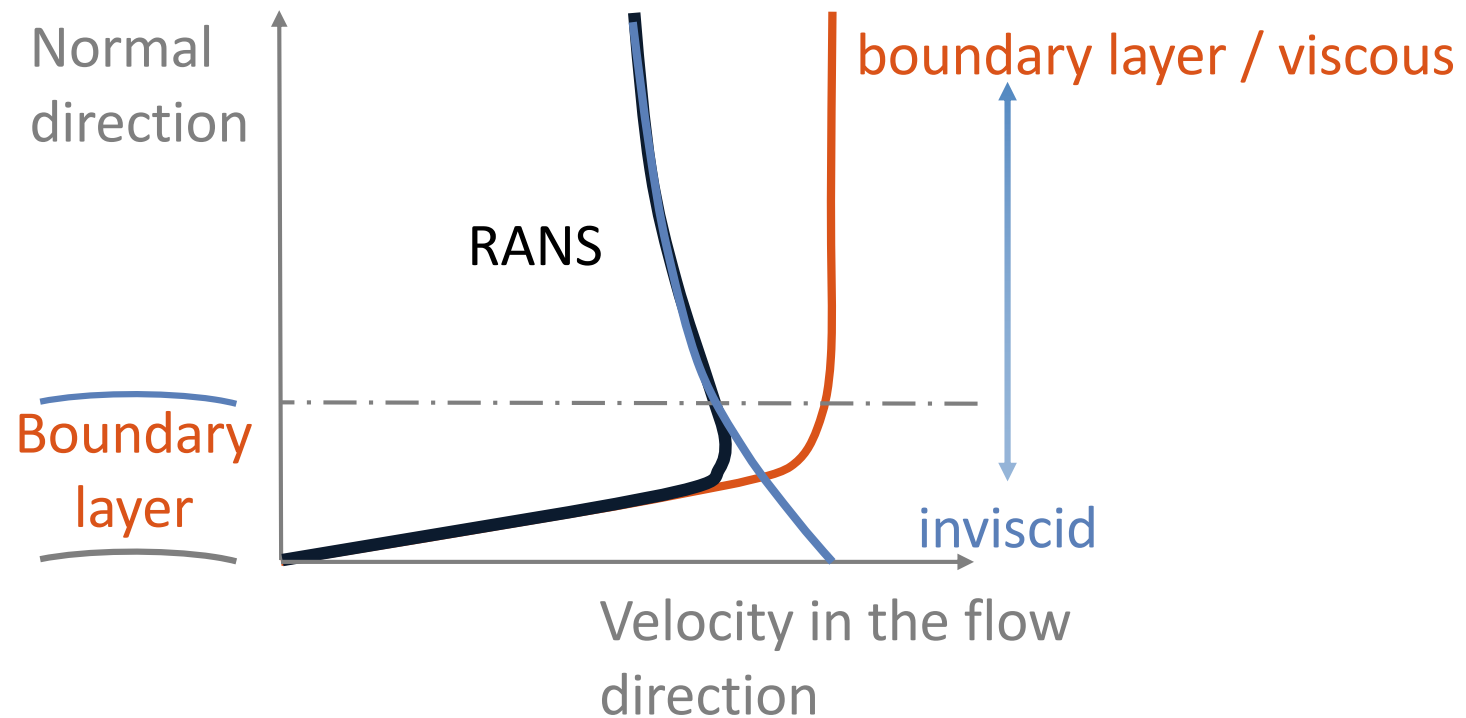
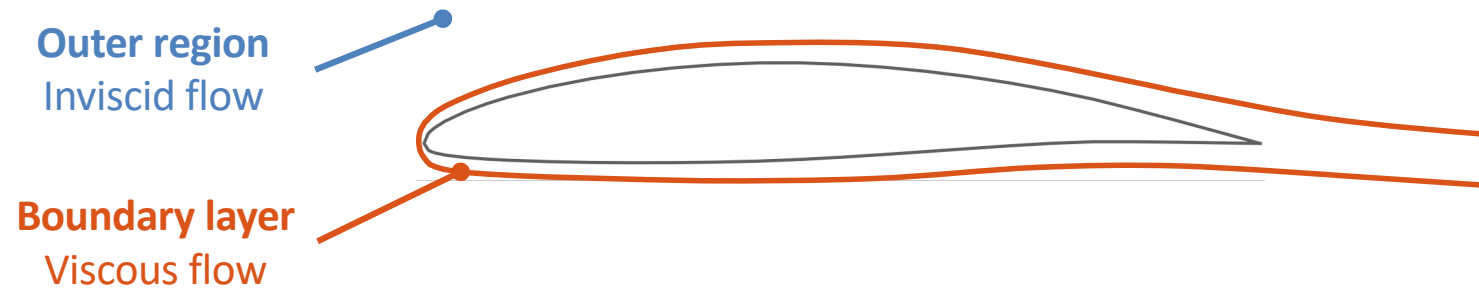
x1000

x10

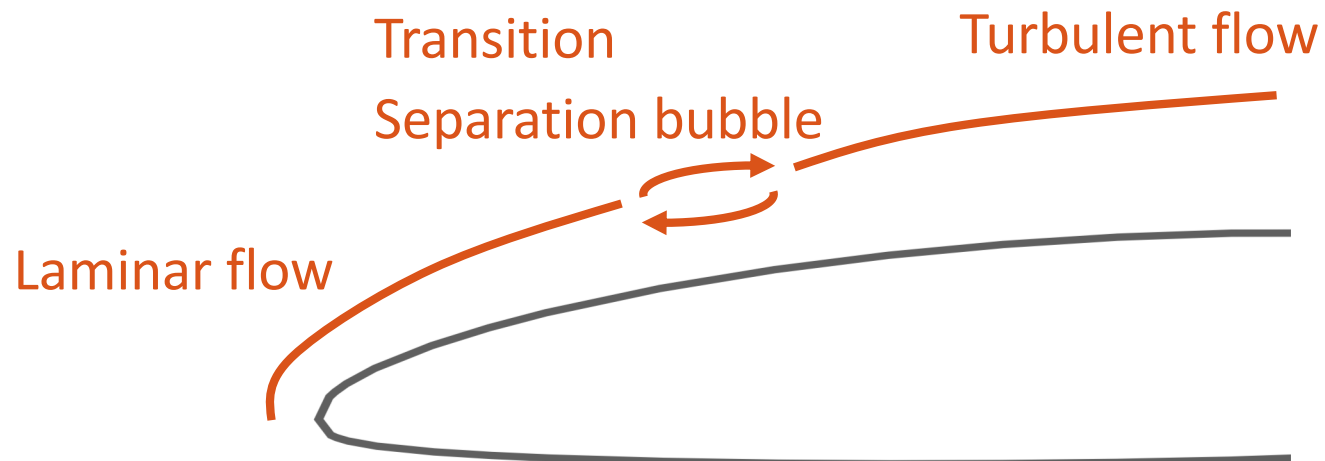
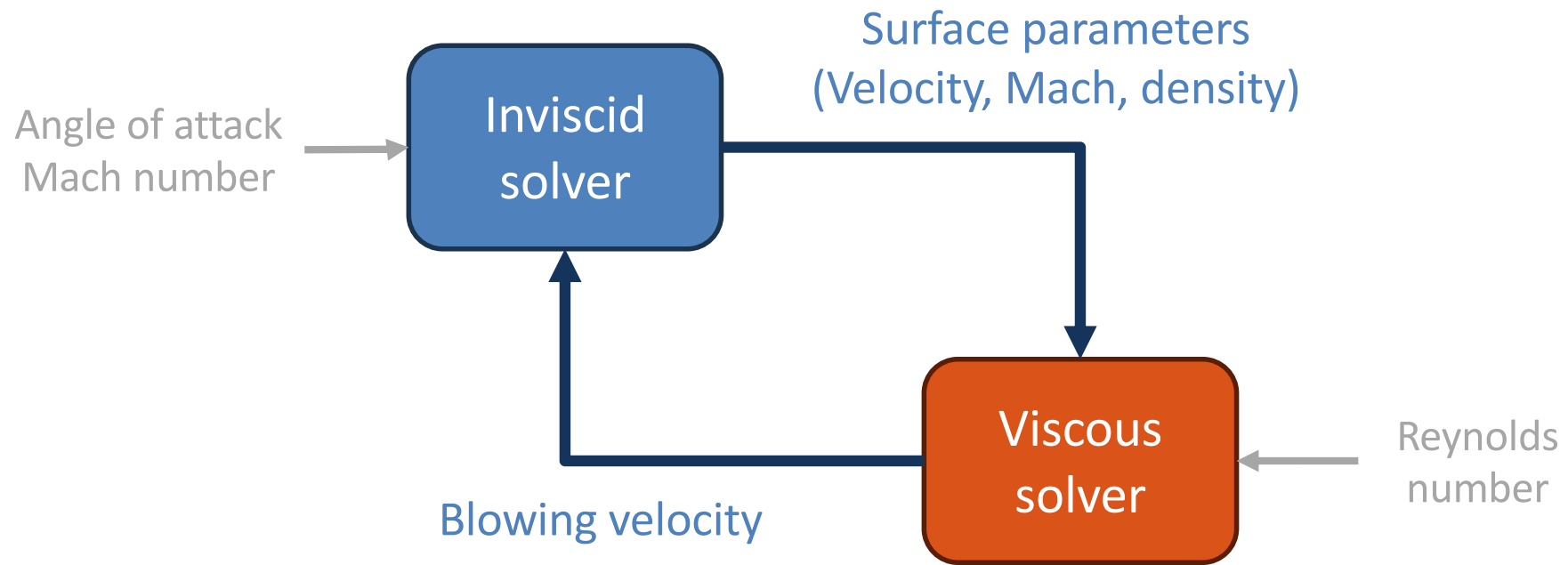


Mach number

Viscous-Inviscid Interaction



Sequential interaction between solvers

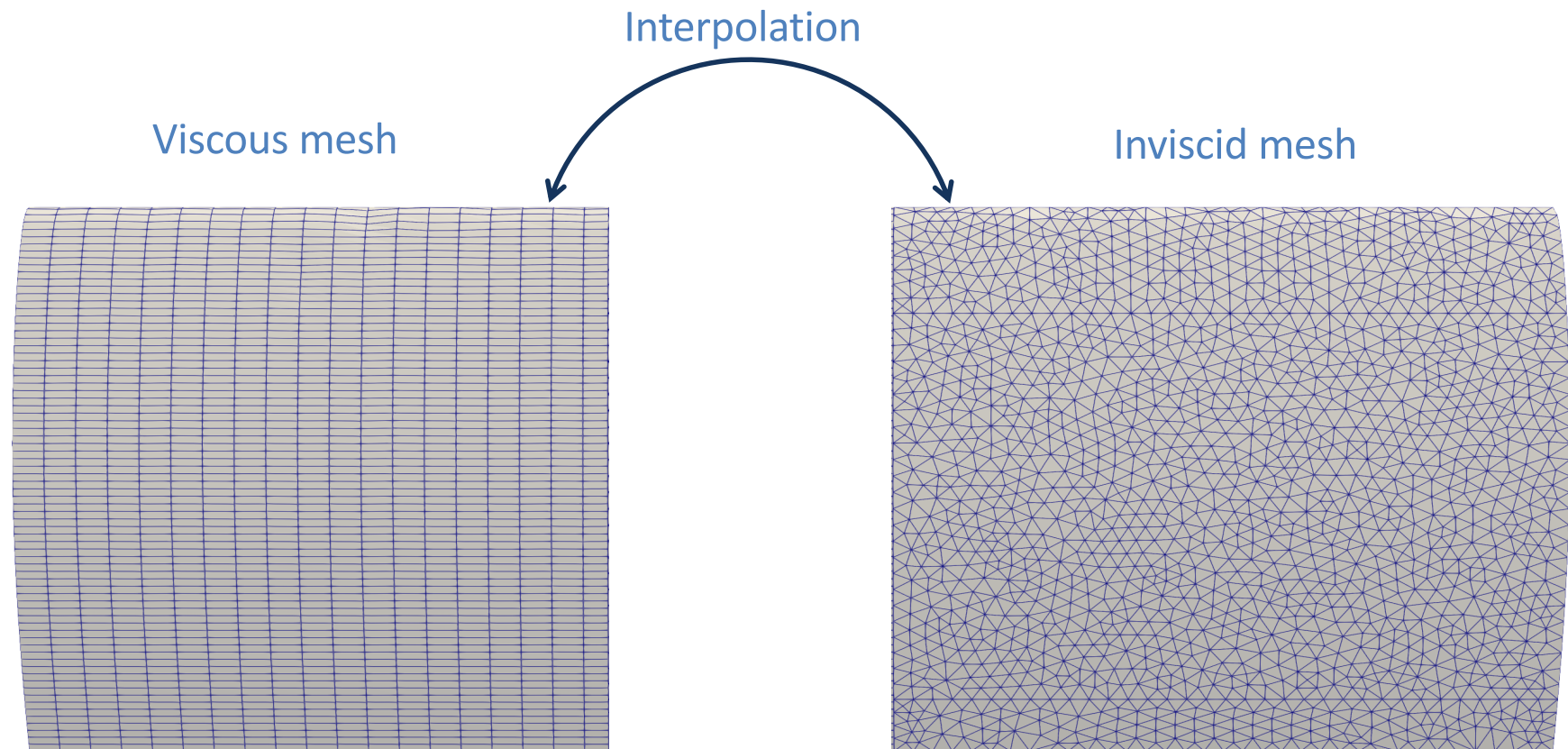
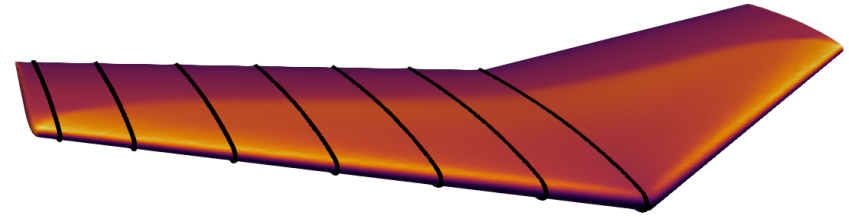


3D Methodology

Generate sections on the wing

Solve the **2D boundary layer equations** on sections

Interpolate the correction on the inviscid mesh



High modularity – Different inviscid solver

Level of fidelity



Hess-Smith

SDPM

Linear potential



Full potential

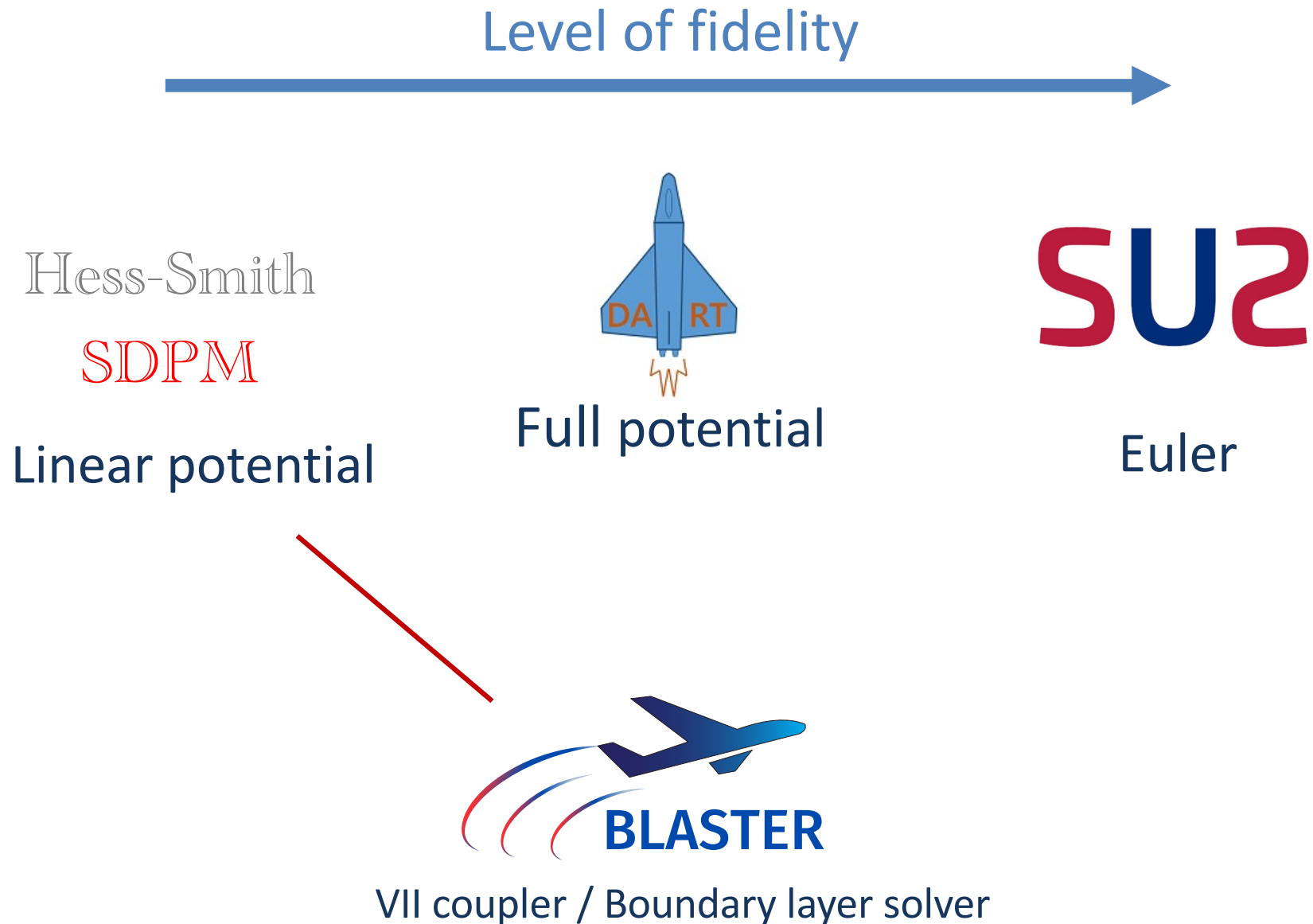
SU2

Euler

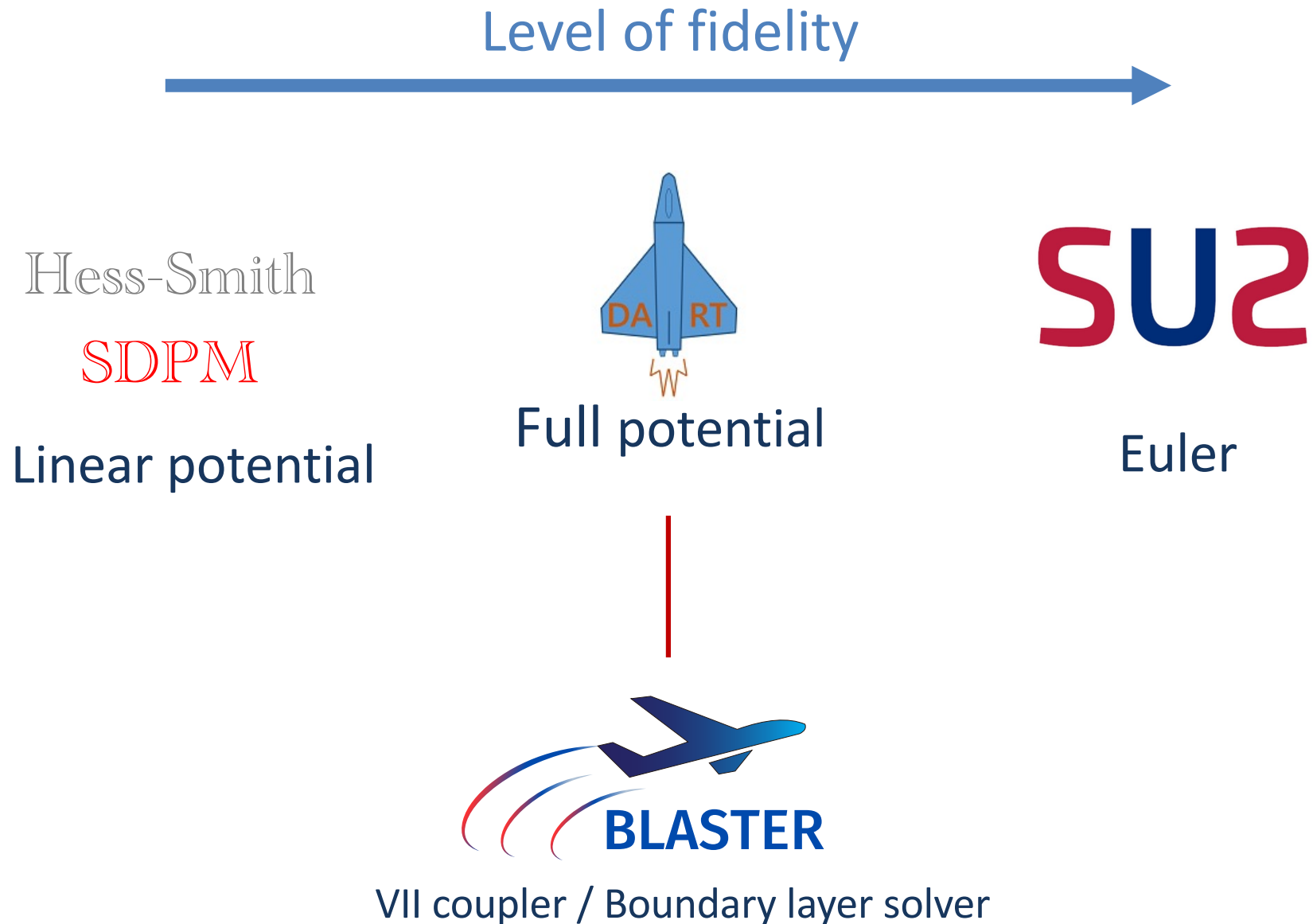


VII coupler / Boundary layer solver

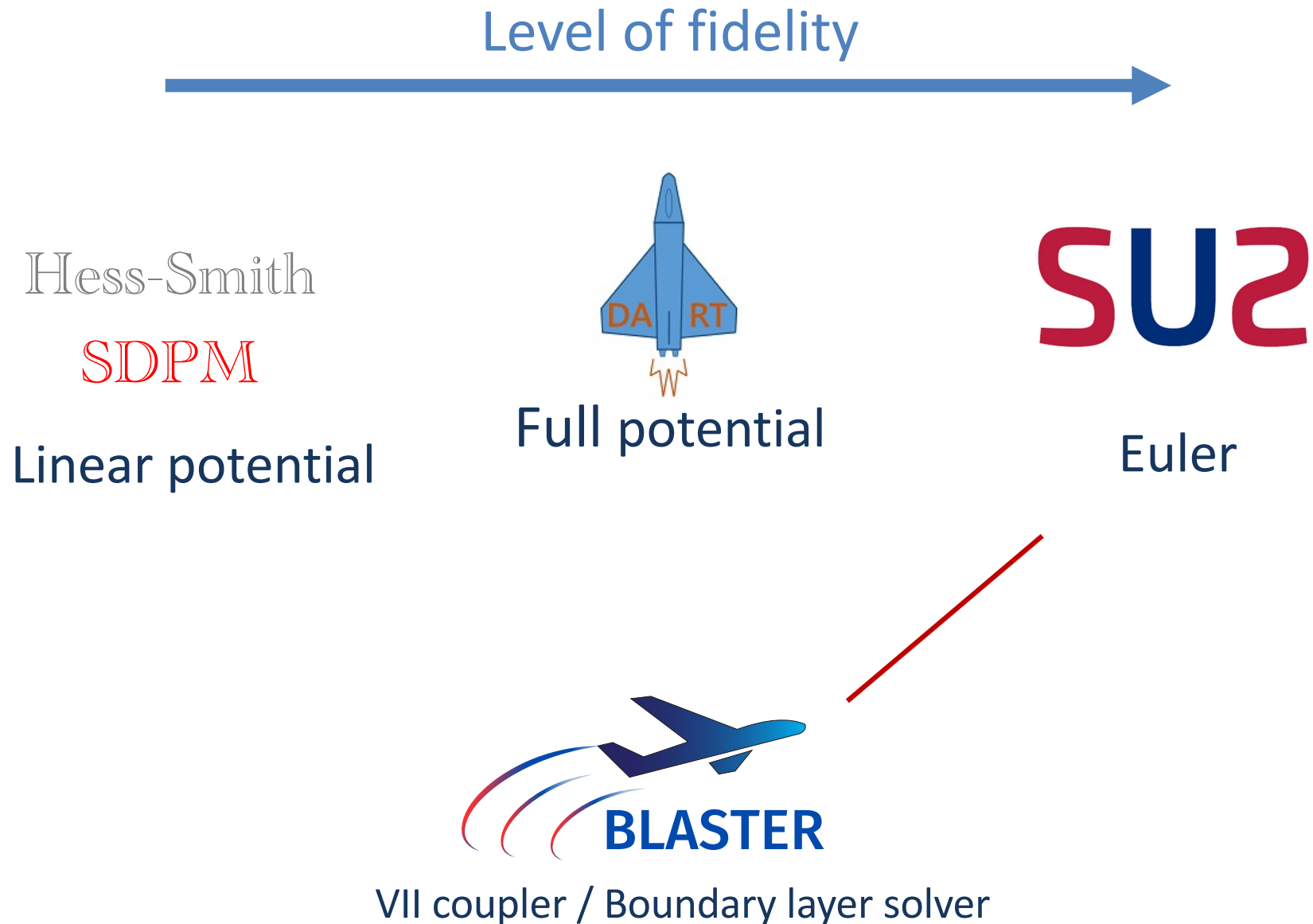
High modularity – Different inviscid solver



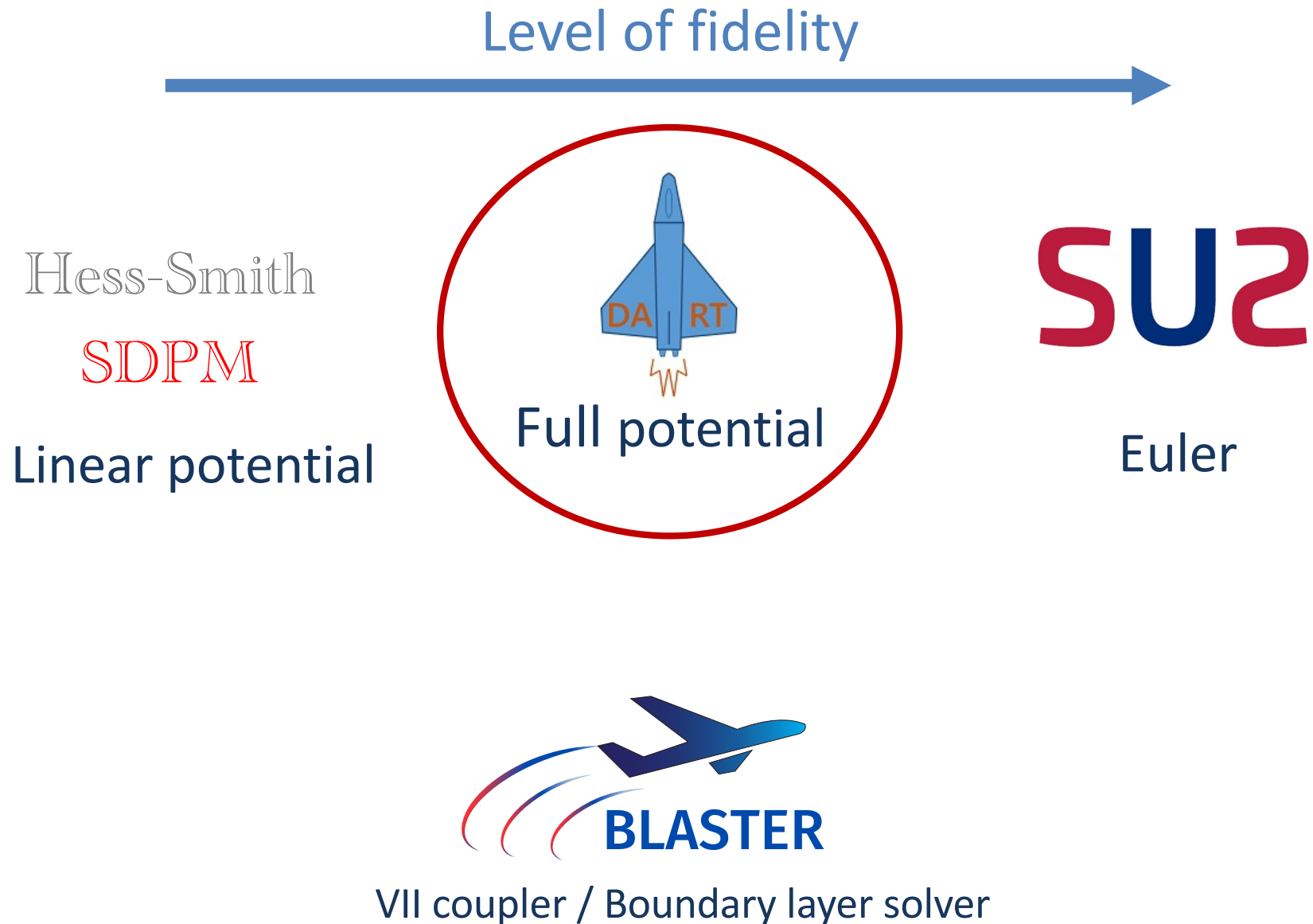
High modularity – Different inviscid solver



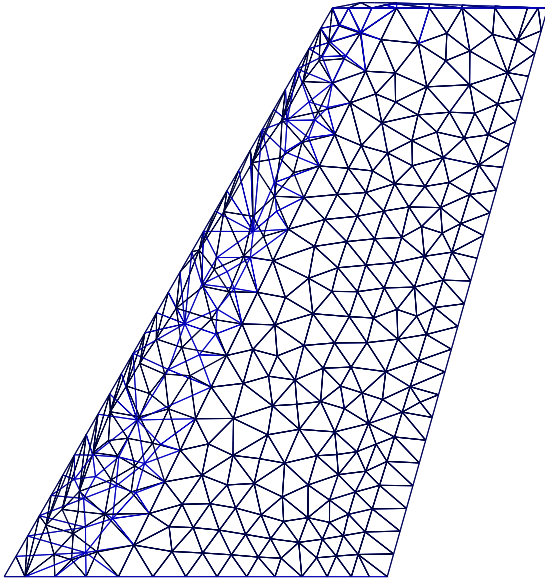
High modularity – Different inviscid solver



High modularity – Different inviscid solver



DART inviscid solver



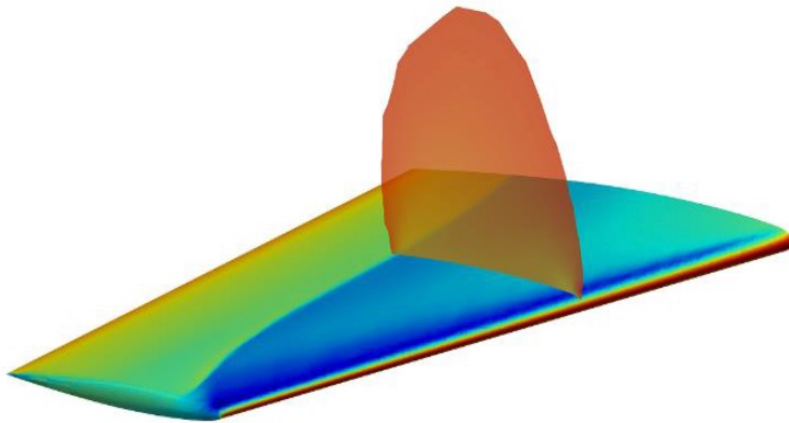
Steady full potential formulation

Finite element discretization

Unstructured tetrahedral grid

Analytical discrete adjoint

L



Dr. Adrien Crovato

2D VII

$$\alpha = 2.80^\circ$$

$$M = 0.73$$

$$Re = 6 \text{ millions}$$

$$c_l = 0.82$$

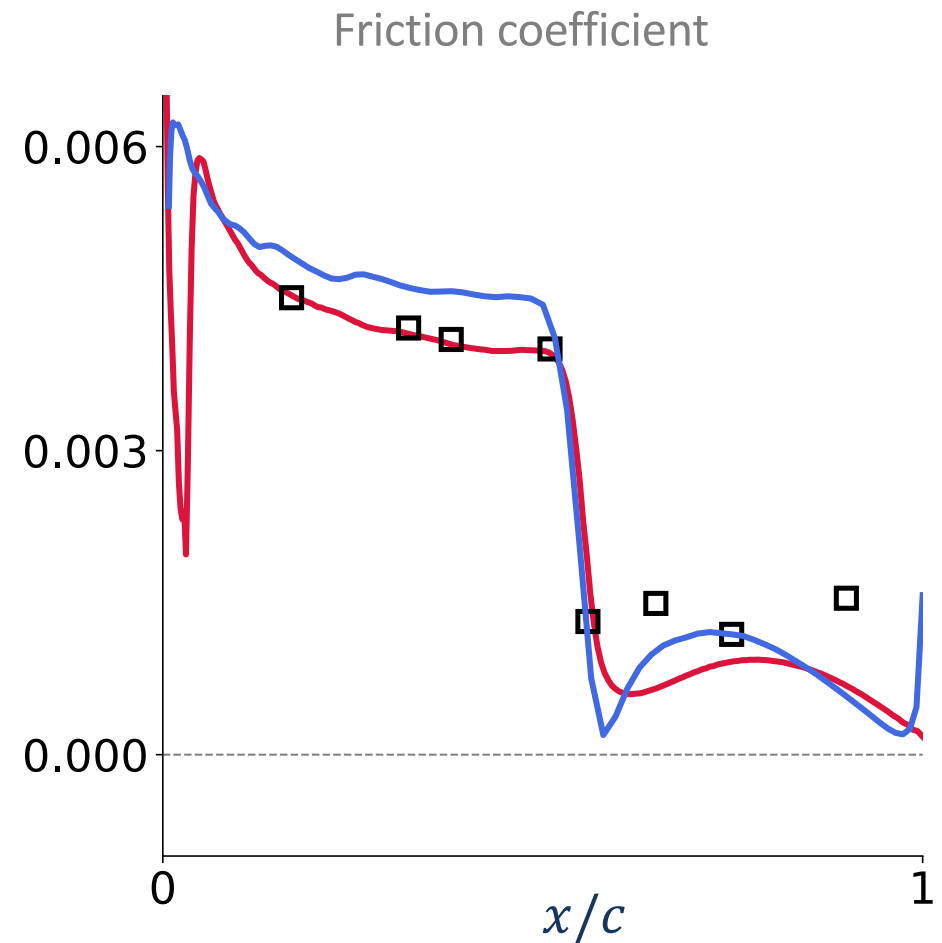
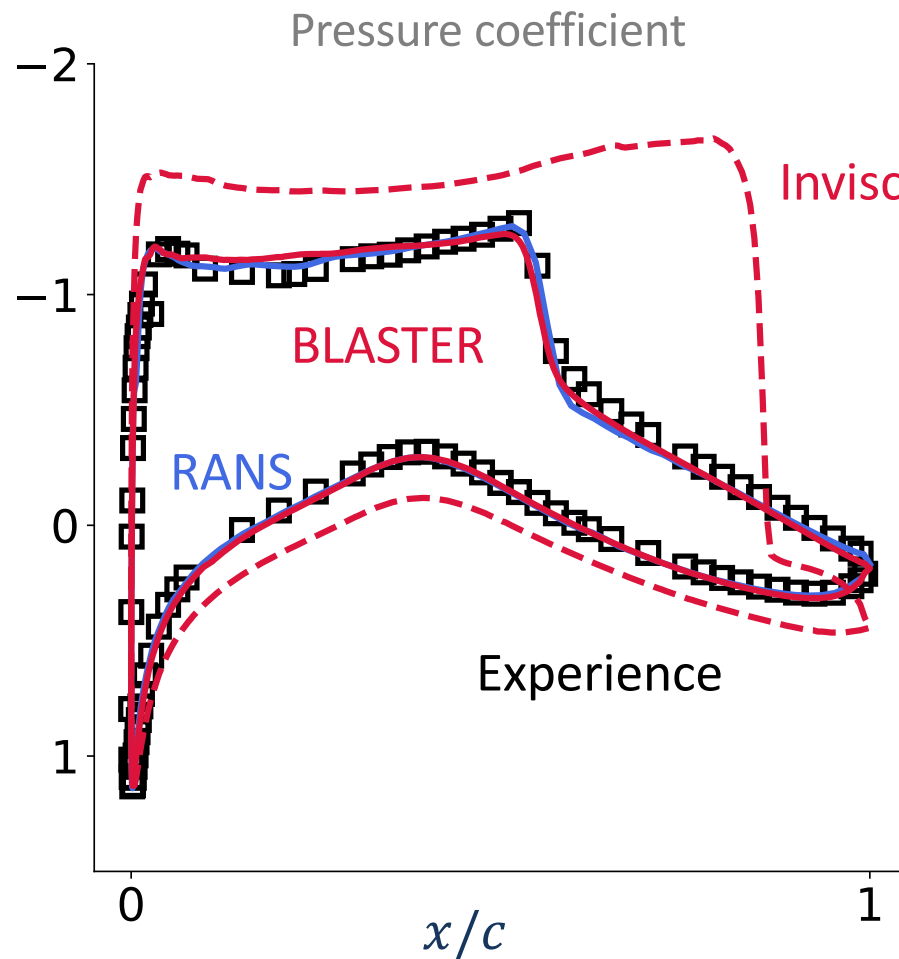
$$c_d = 0.017$$

Case 9 Cook et. al. 1979

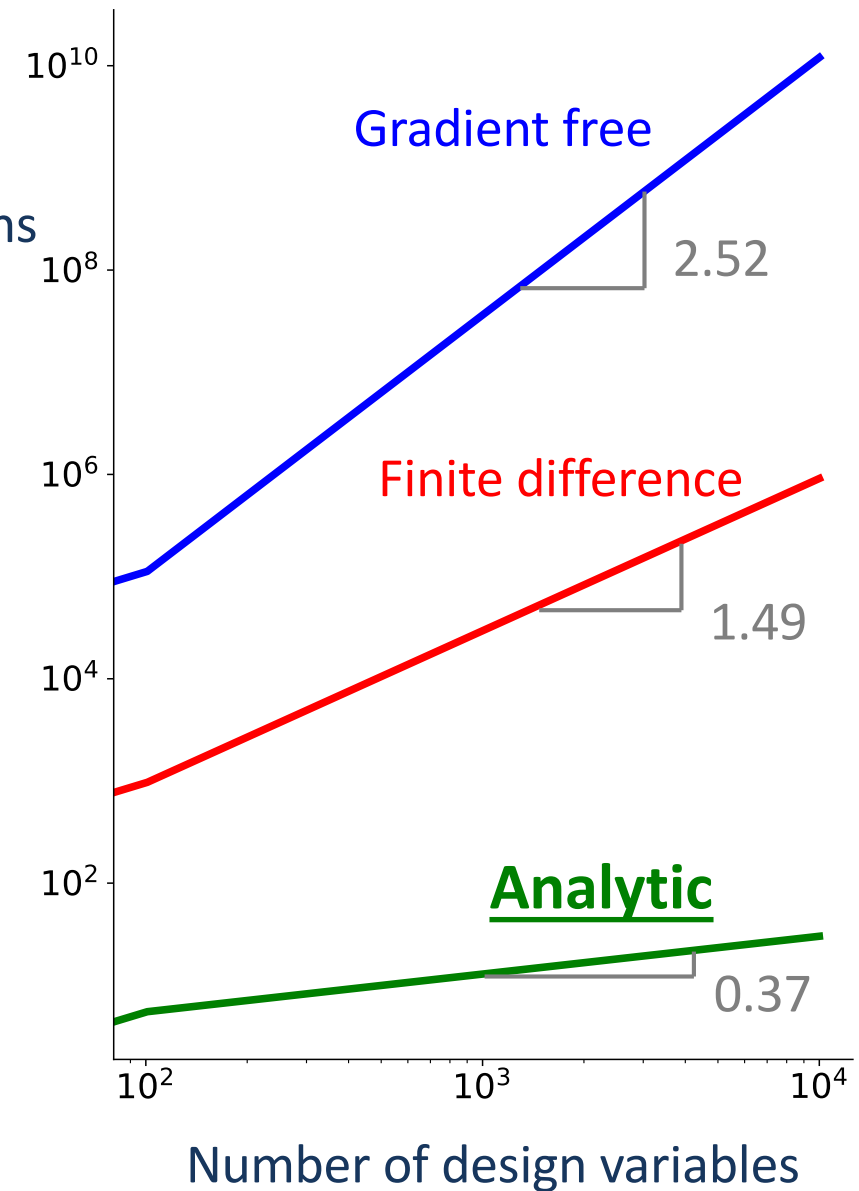
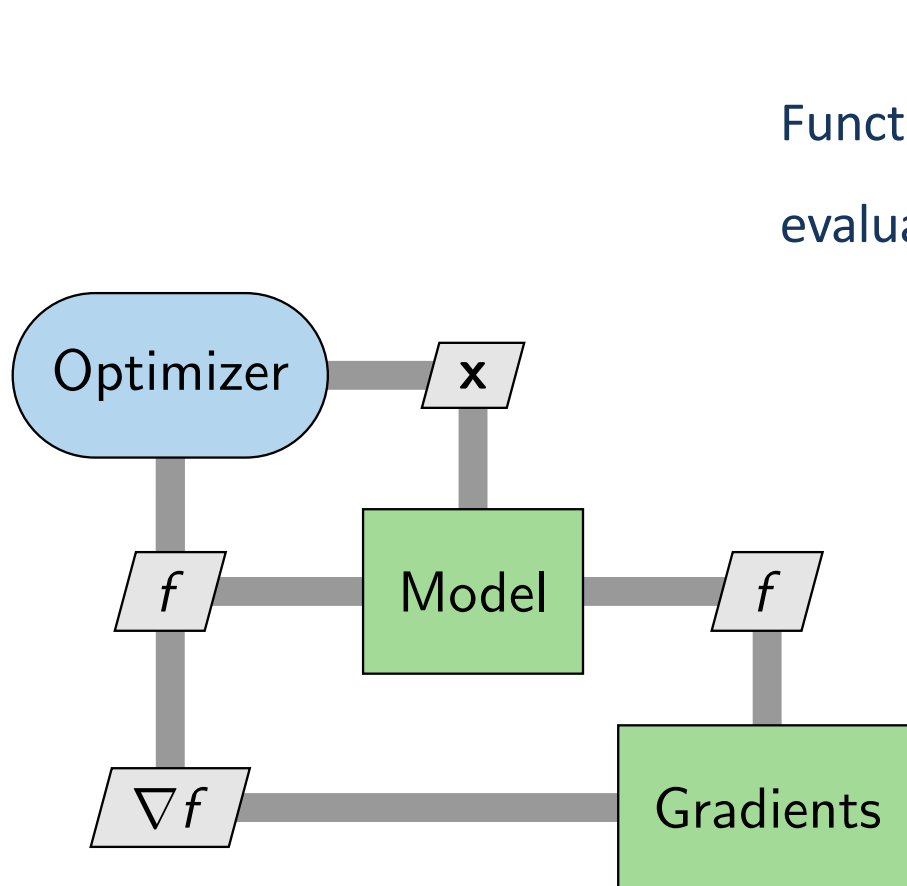
CPU time

BLASTER 11.2 sec

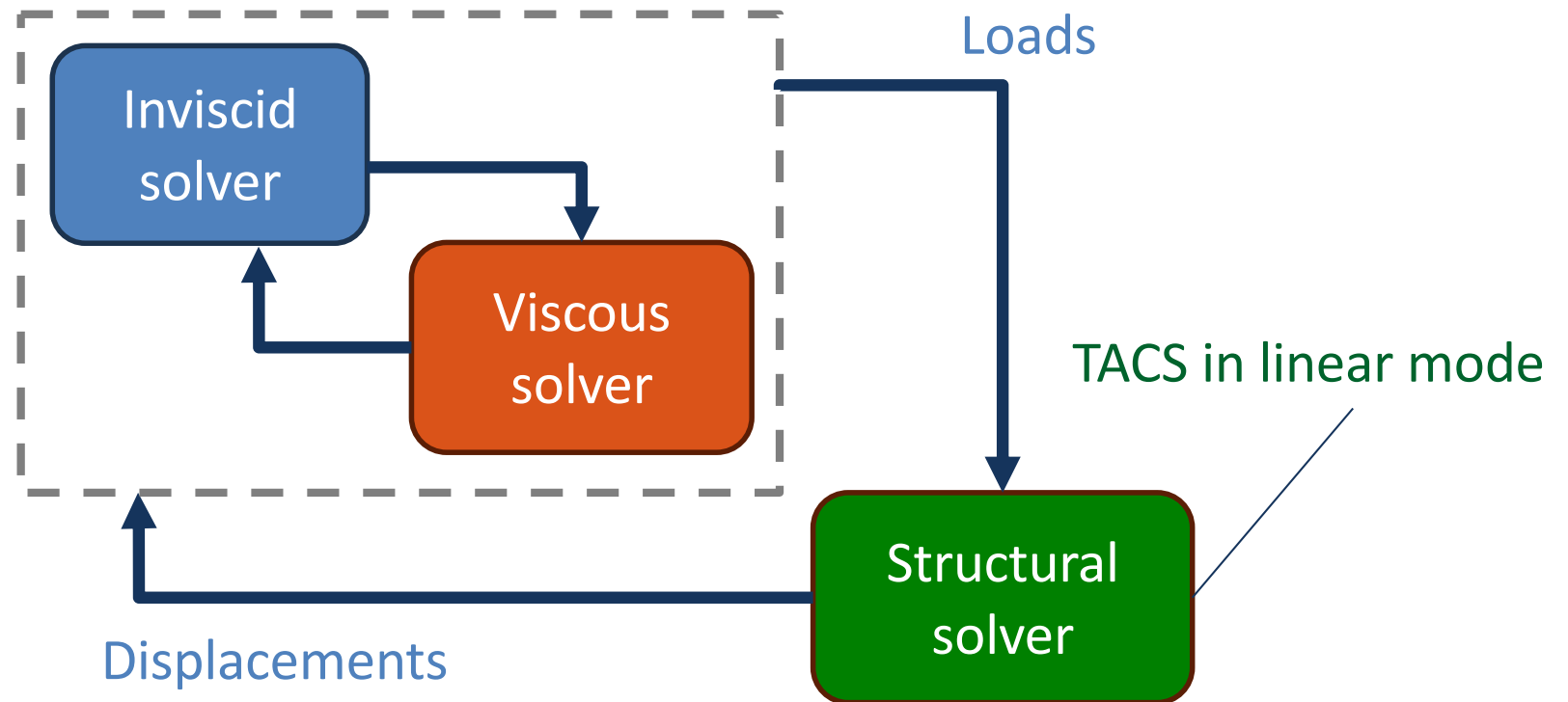
RANS 61 min



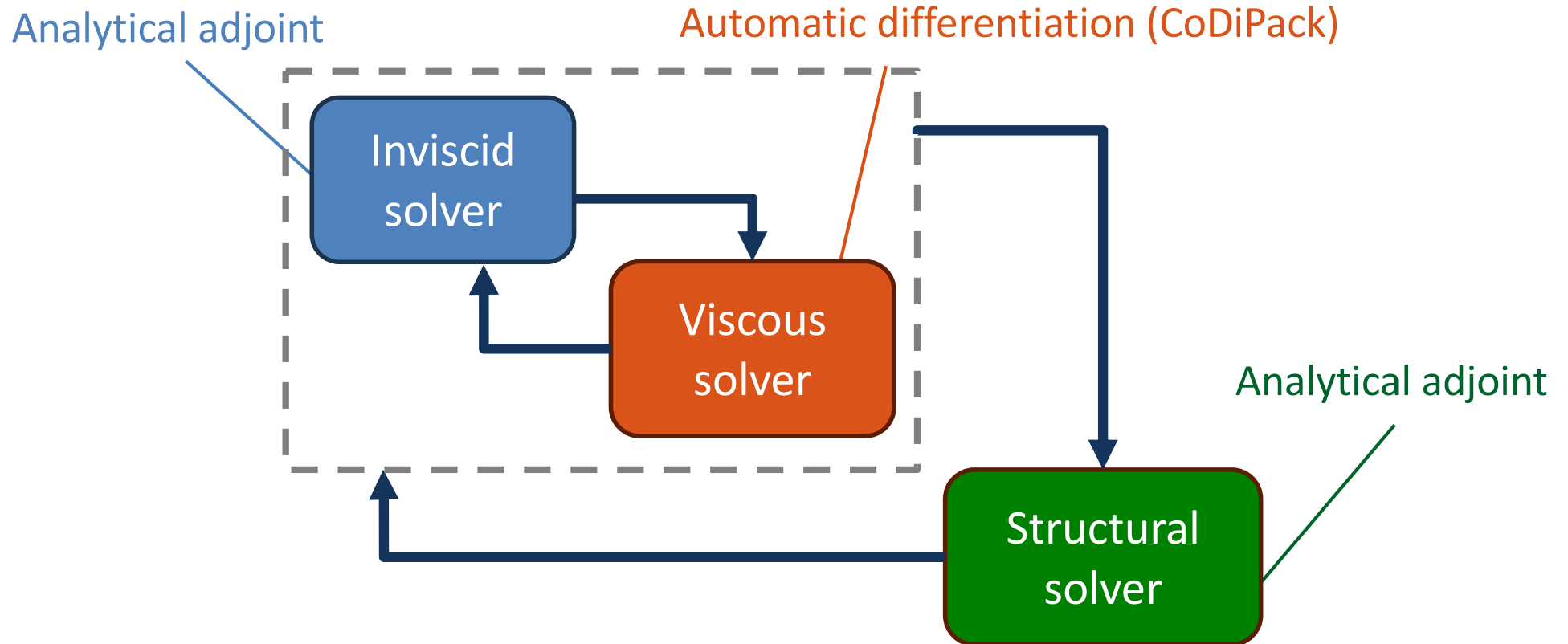
Aeroelastic gradient based optimization



Aerostructural model



Computing derivatives



Coupled adjoint system solved by 

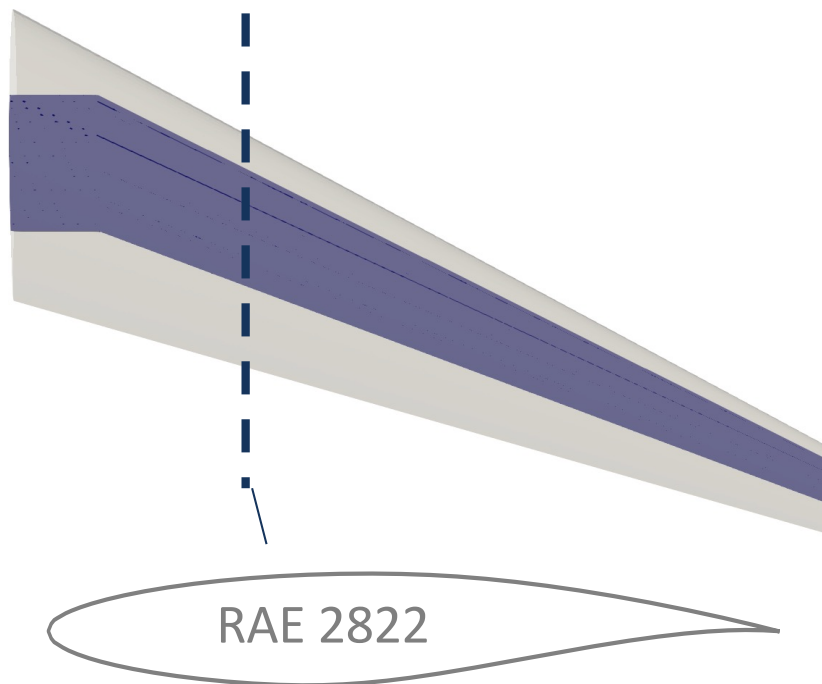
Simple Transonic Wing

Proposed aeroelastic analysis and
several optimization cases

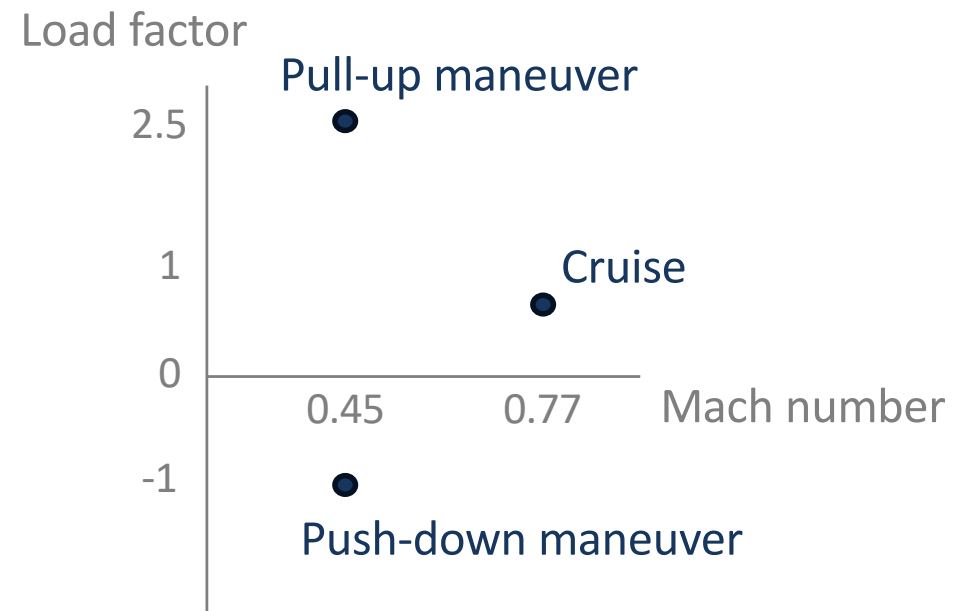
Available high-fidelity data

Wing model based on Boeing 717

Conformal composite wingbox



3 flight conditions

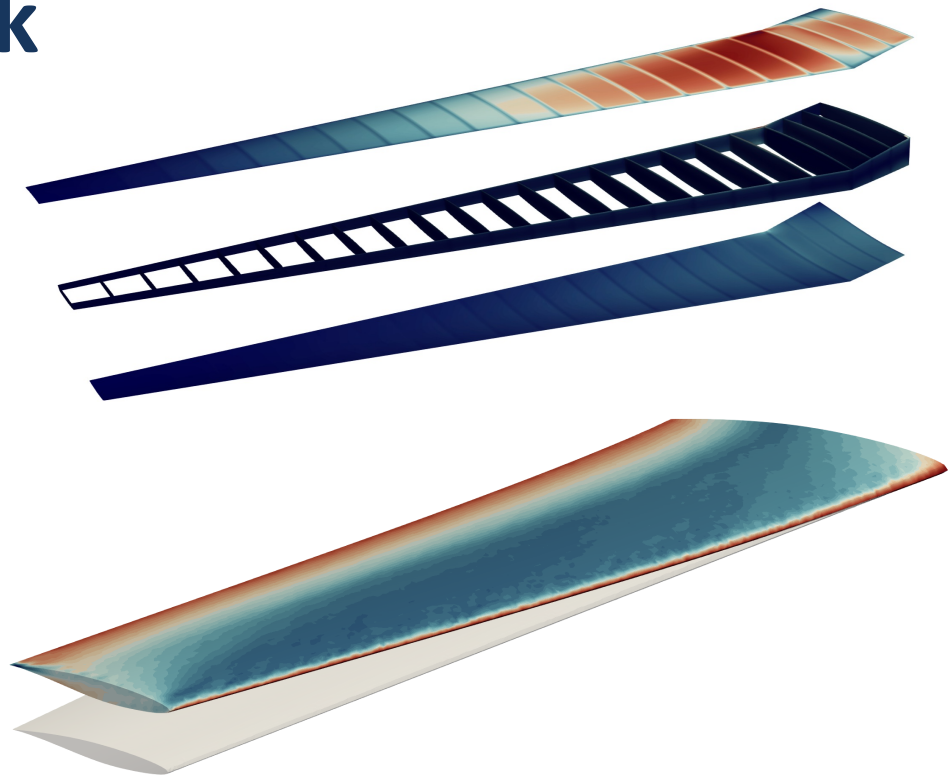


Aeroelastic benchmark

Mach 0.77

Load factor 1

Angle of attack 3.25°



	DART (Potential)	BLASTER (VII)	ADflow (RANS)
C_L	0.57	0.54	0.54
C_D	0.0151	0.0208	0.0191
Tip deflection (m)	0.73	0.65	0.68
Tip twist (°)	1.78	1.53	1.55
Material failure (-)	0.56	0.41	0.41

Optimization case 1

Initial structural sizing

3 scenarios: Cruise, Maneuver 2.5g, Maneuver -1g

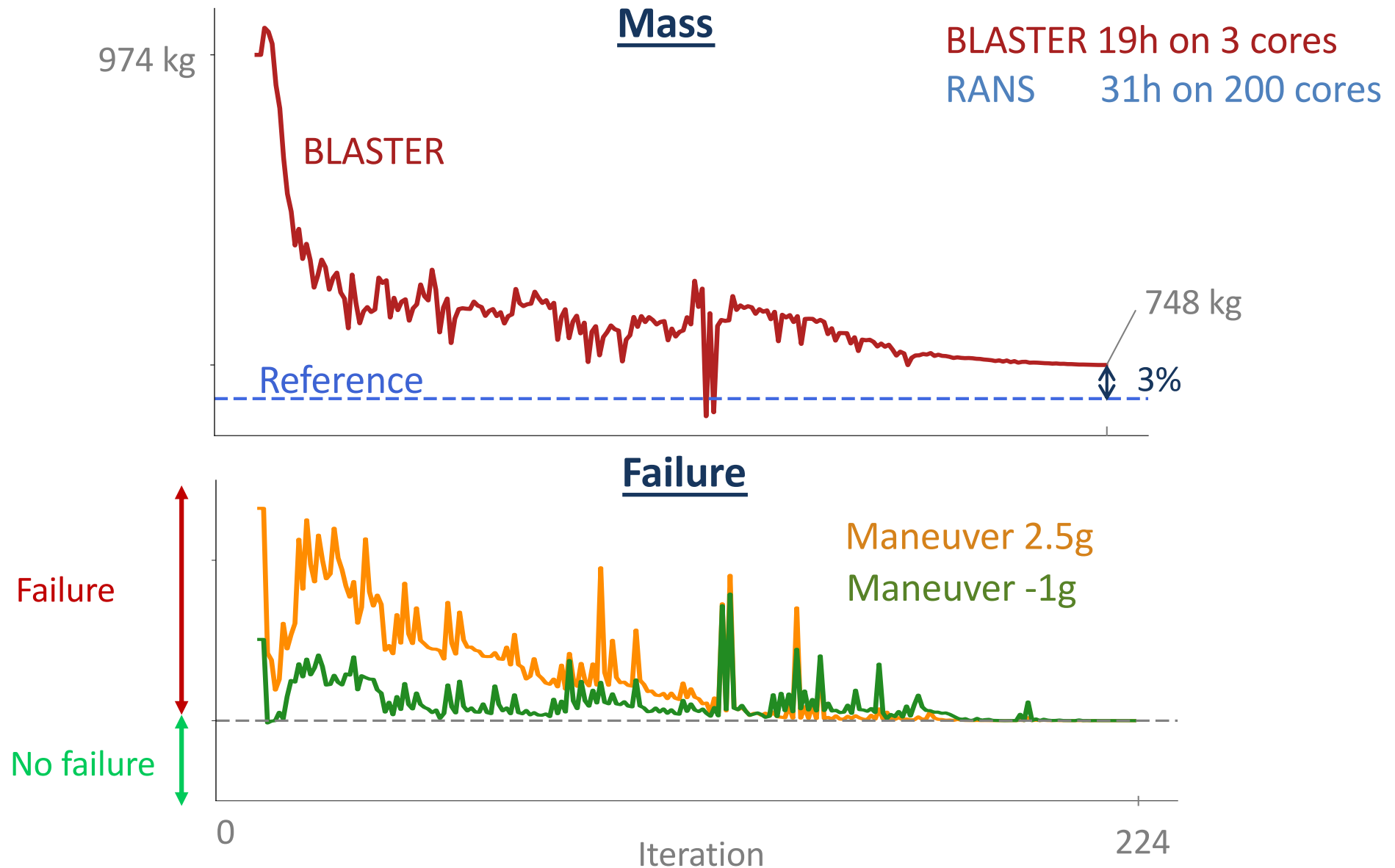
1 **Objective:** Wingbox mass minimization

446 **Design variables:** Skin panels & stiffeners thicknesses and lengths

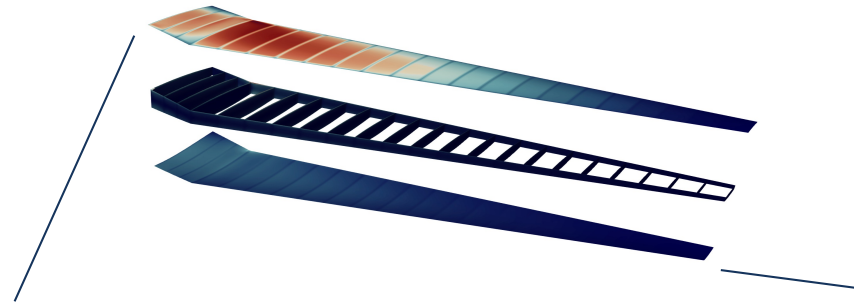
814 **Constraints:** No structural failure

Coherent composite structure (similar adjacent thicknesses)

Variation of the objective and constraints

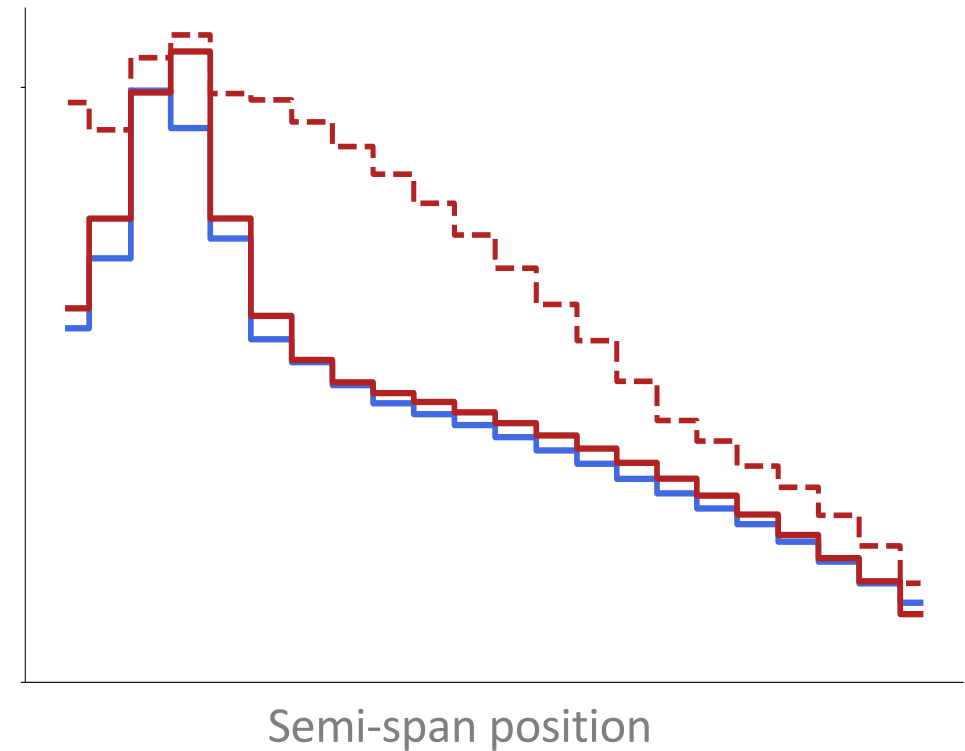
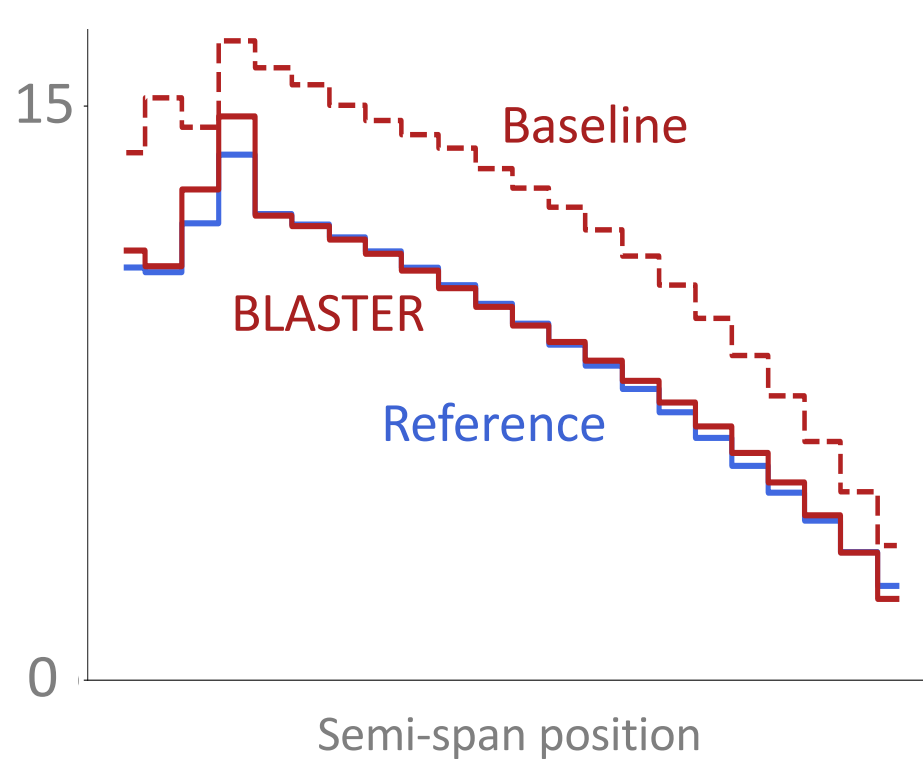


Similar structural metrics



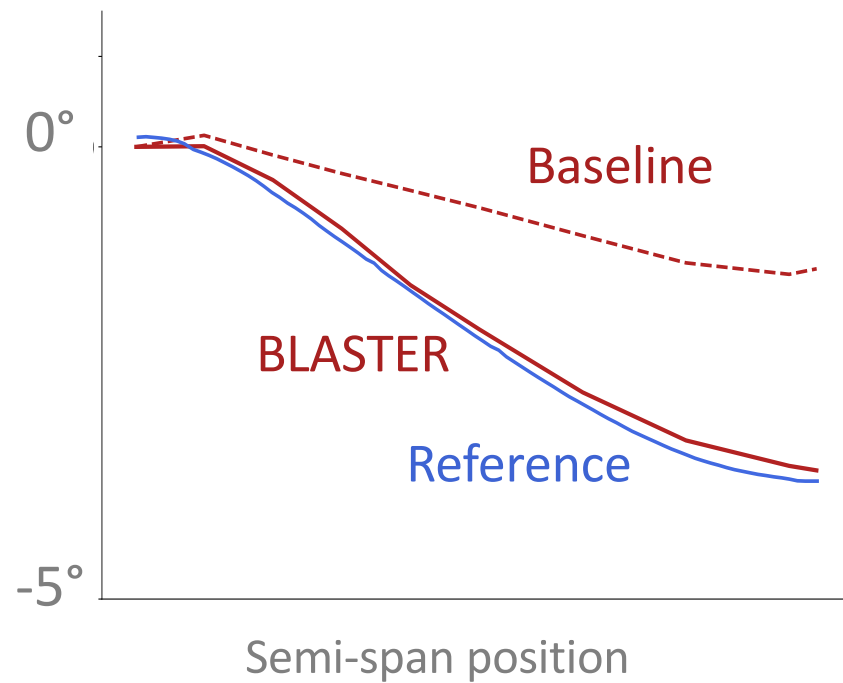
Upper skin thickness (mm)

Lower skin thickness (mm)

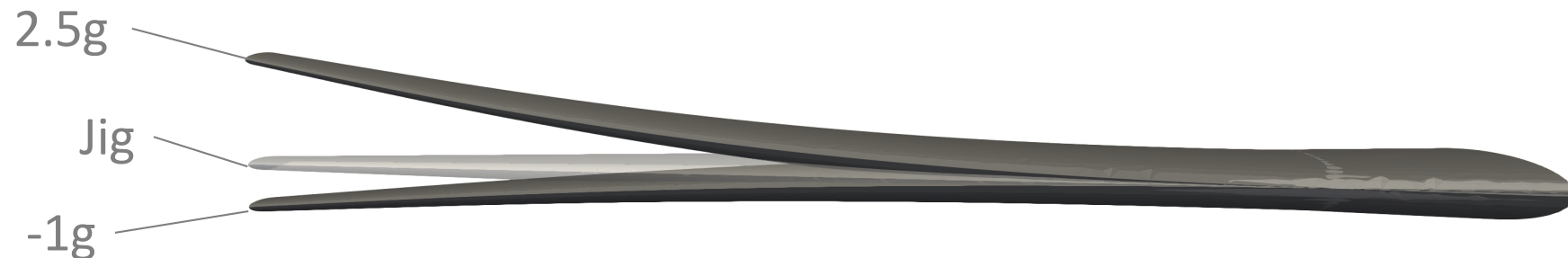
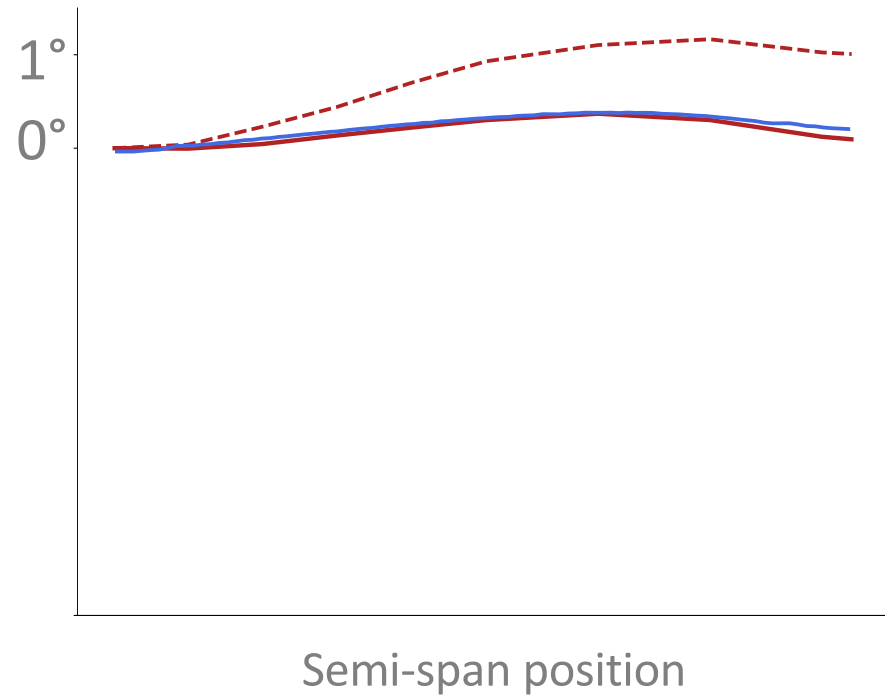


Similar aeroelastic twist

Maneuver 2.5g twist



Maneuver -1g twist



Optimization case 2

Fixed planform fuelburn minimization

3 scenarios: Cruise, Maneuver 2.5g, Maneuver -1g

1 **Objective:** Climb + cruise fuelburn (Breguet) minimization

532 **Design variables:** Structure + wing twists and shapes

947 **Constraints:** No structural failure

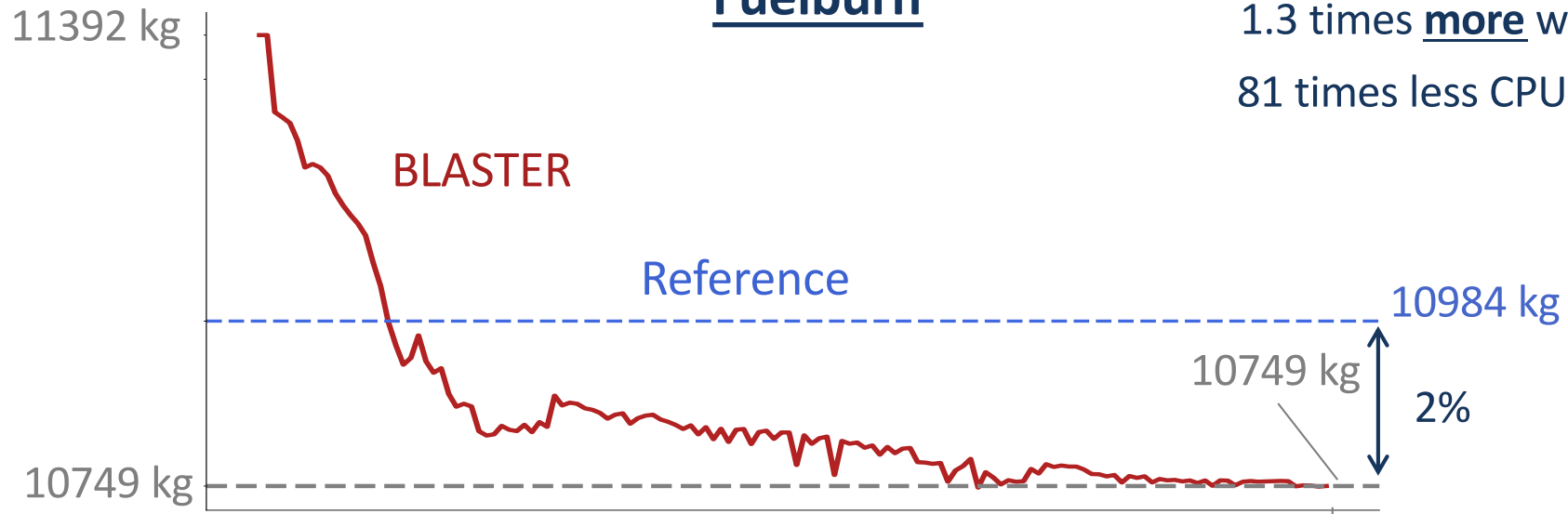
Coherent composite structure (similar adjacent
thicknesses)

Geometric feasibility

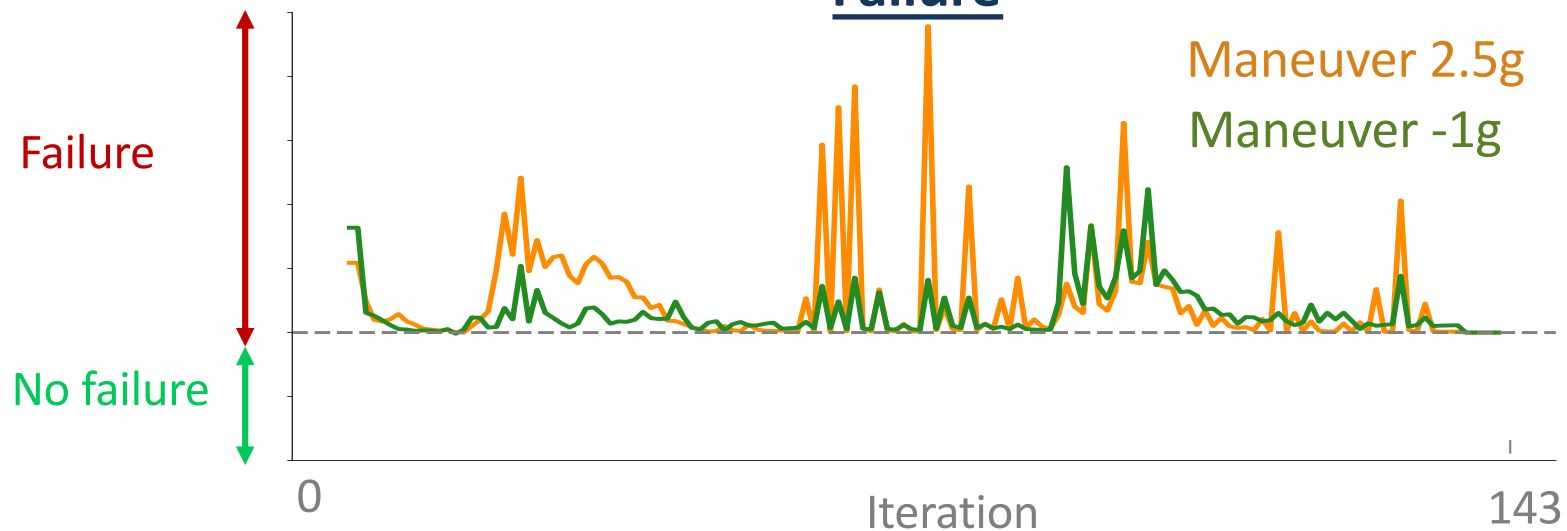
Variation of the objective and constraints

Fuelburn

1.3 times more wall time
81 times less CPU time

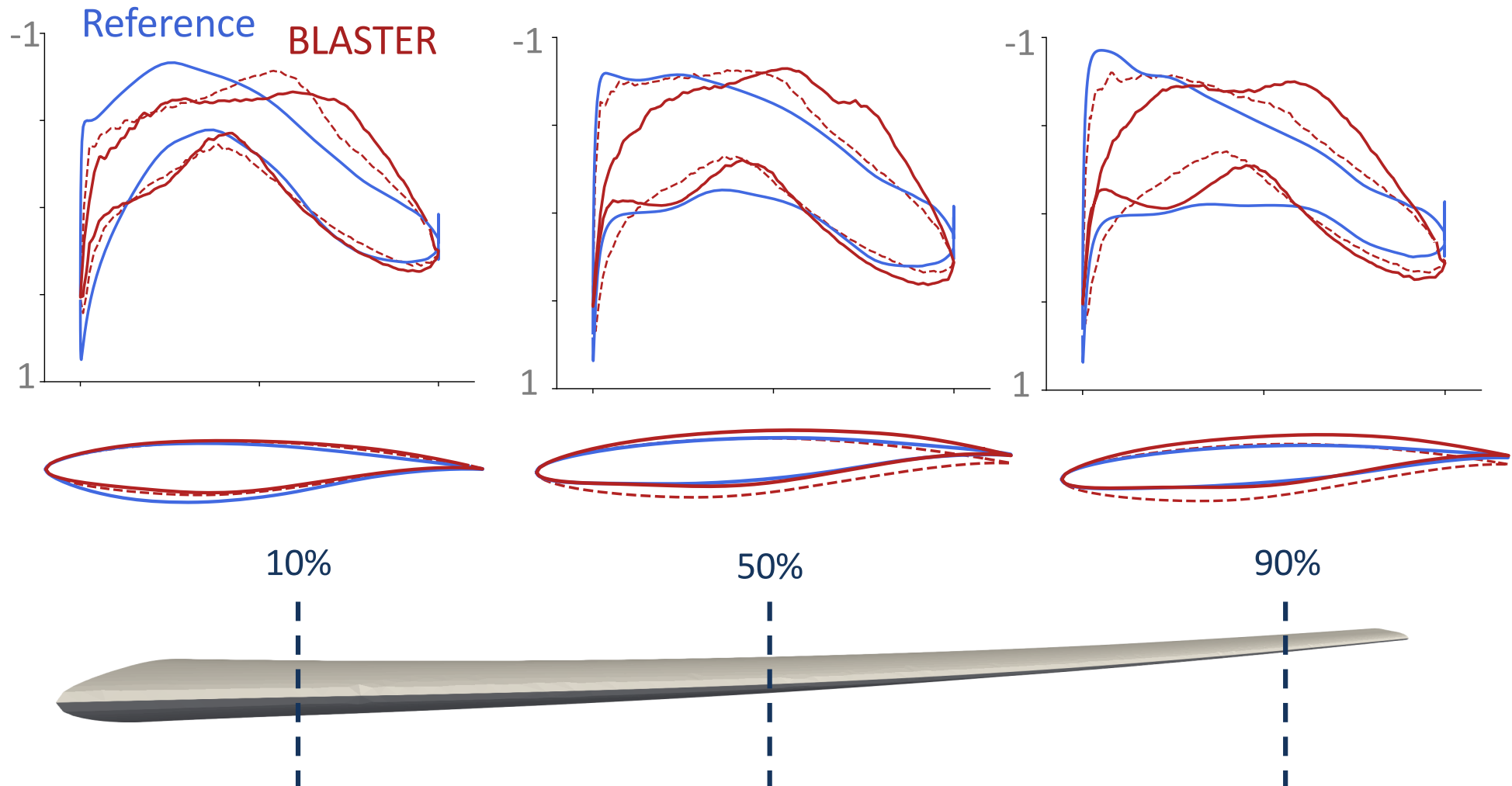


Failure



Different optimal designs

Our design is highly rear loaded



Our design is NOT better

	VII optimal design (this work)	RANS optimal design (reference)
VII Analysis	$L/D = 16.57$	$L/D = 16.05$
RANS Analysis	$L/D = 15.86$	$L/D = 16.17$

The problem may be linked to the inviscid potential solver

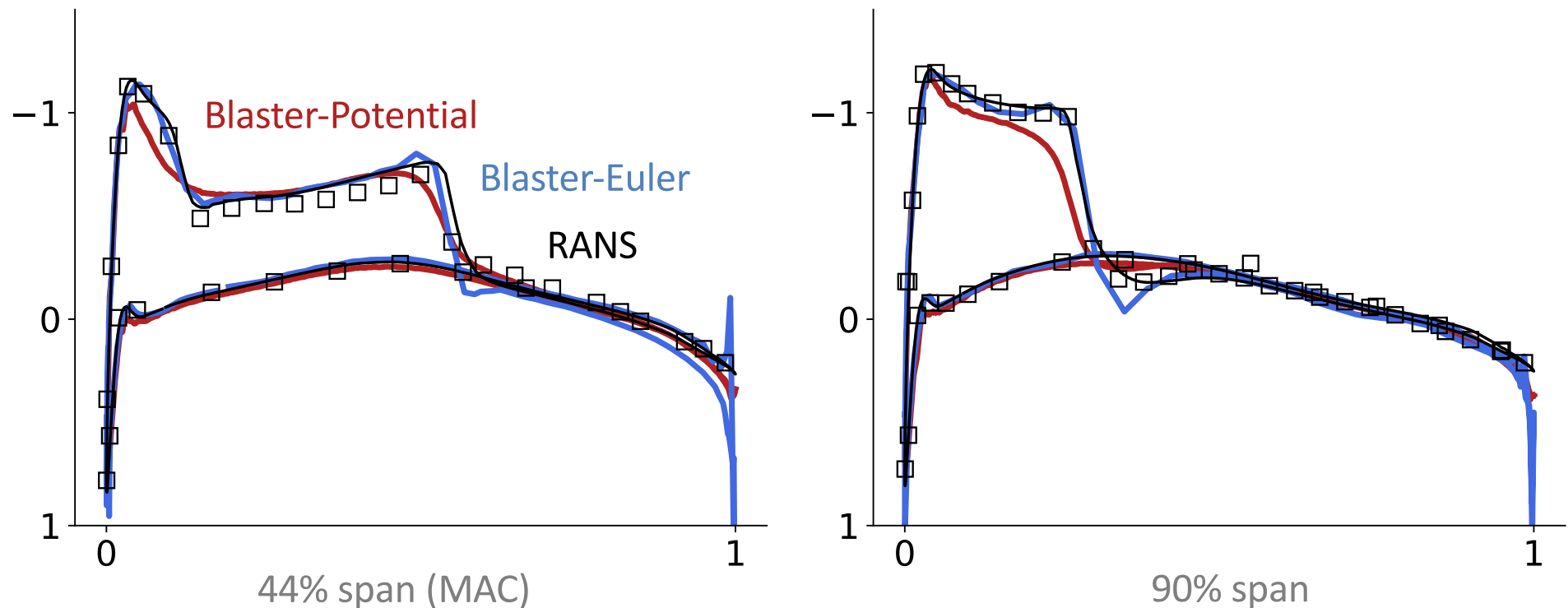
Future work: Consider an Euler inviscid solver

Blaster offers high flexibility and can be easily coupled to existing solvers

Euler solutions may provide adequate accuracy for the cases of interest

Correct adjoint implementation is required

Pressure coefficient on ONERA M6 wing



VII for aerostructural optimization

- Better aerostructural predictions than inviscid flow alone
- Structural optimization leads to a similar design than RANS
- Including shape design variables leads to a highly rear-loaded design
- Small discrepancies between VII and RANS lead to very different designs
- These differences can be investigated by using a higher fidelity Euler solver

IFASD

Aerostructural analysis and optimization using Viscous-Inviscid Interaction

Paul Dechamps – June 2026

