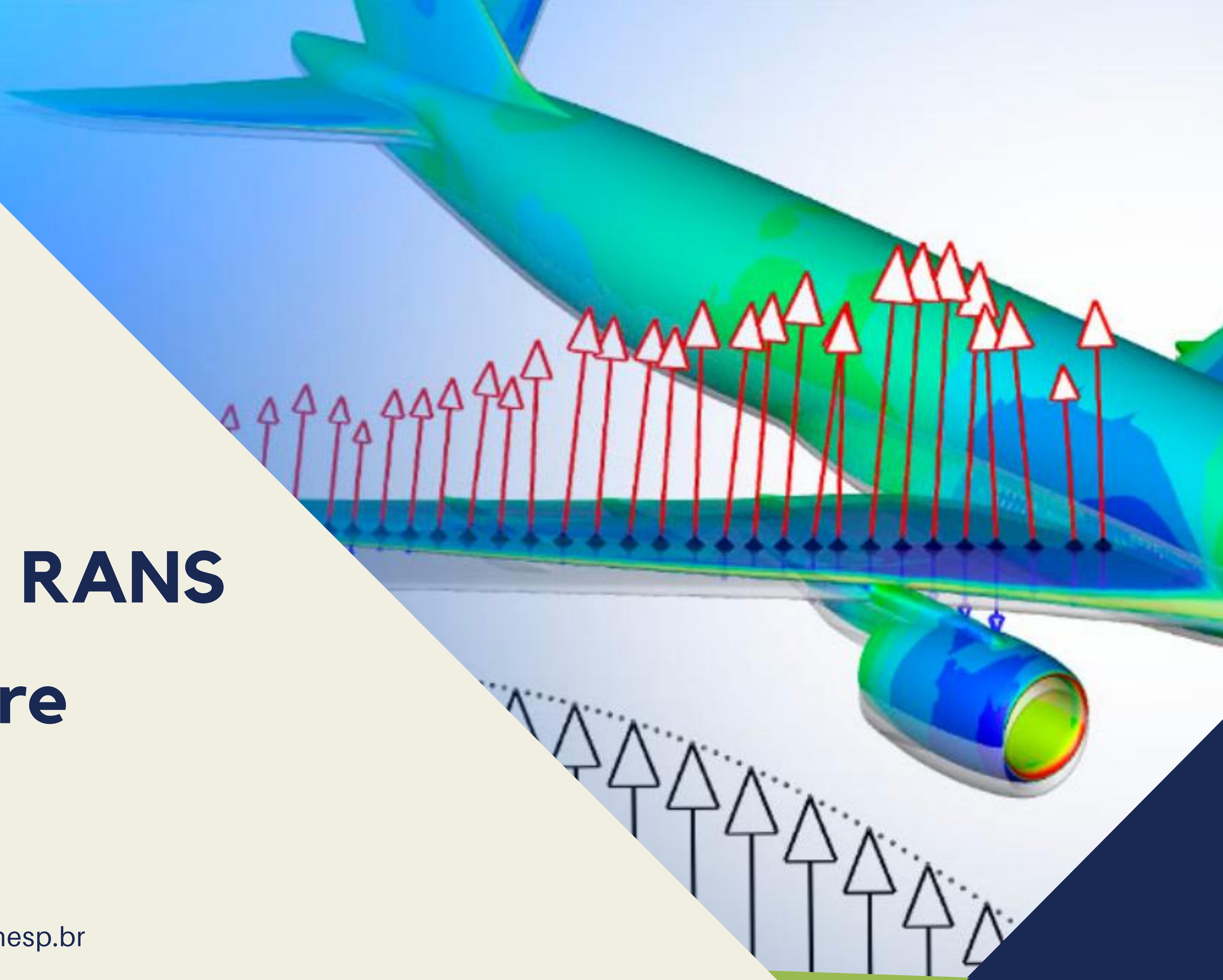

2D Flutter Analysis using RANS Equations in SU2 Software

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AGENDA

1 Test Case

2 Methodology

3 Results

4 Conclusion

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Test Case

High-Angle Working Group – Case 3

2D BSCW flutter prediction
Mach 0.80
Angle-of-attack sweep: 0° - 6°

Fonzi et al. (2022)

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Structural Dynamics

Extended capabilities for high-fidelity fluid-structure simulations

Fonzi *et al.*, 2022

MSC Nastran™

Industry Leading Multidisciplinary FEA Solution

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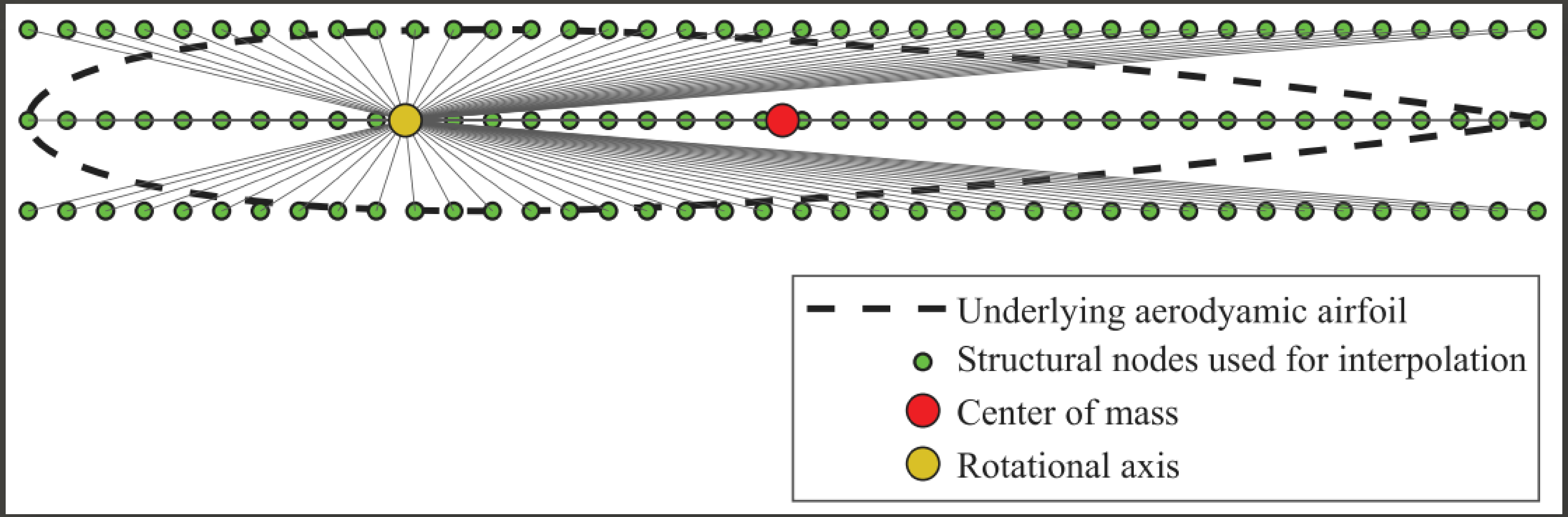

2 – DOF system

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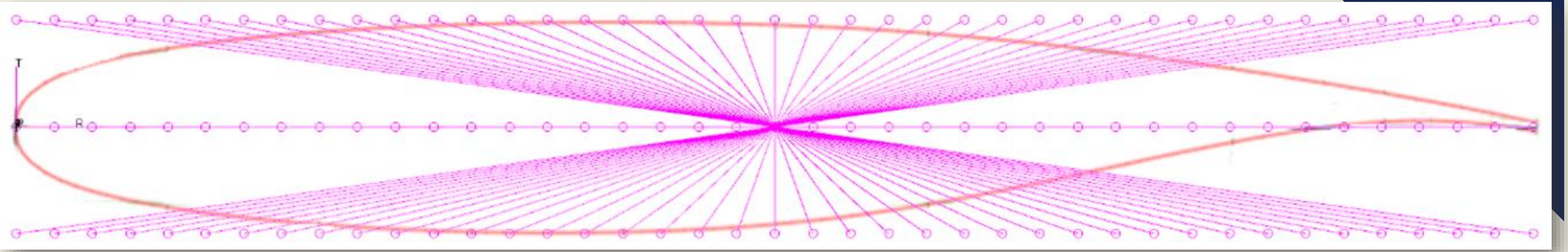
Mesh

Structural nodes for interpolation



Wind-off characteristics of primary modes

	Frequency	Stiffness	Structural Damping, g	Generalized Mass
Plunge	3.32 Hz	2637 lb/ft	0.002	6.1 slugs
Pitch	5.25 Hz	2964 ft-lb/rad	0.002	2.7 slug-ft^2

Source: Dansberry *et al.* (1993)

Fine-tuned Generalized Mass

Plunge - 6.054 slugs

Pitch - 2.724 slug-ft^2

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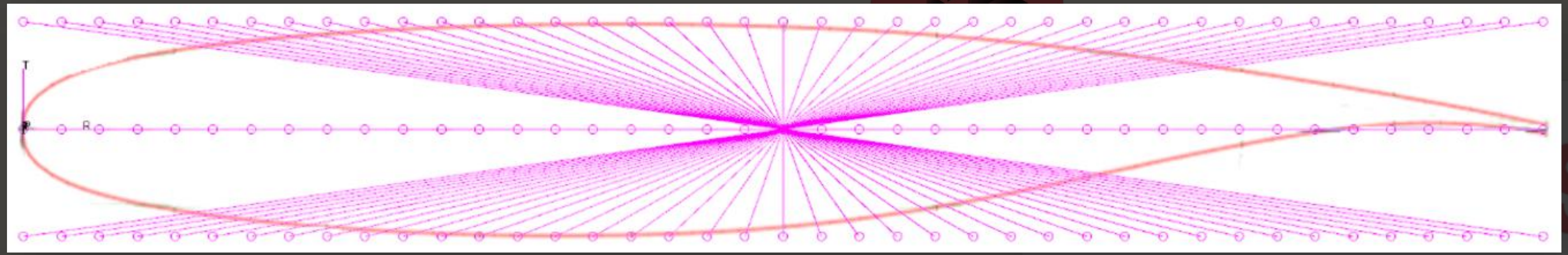

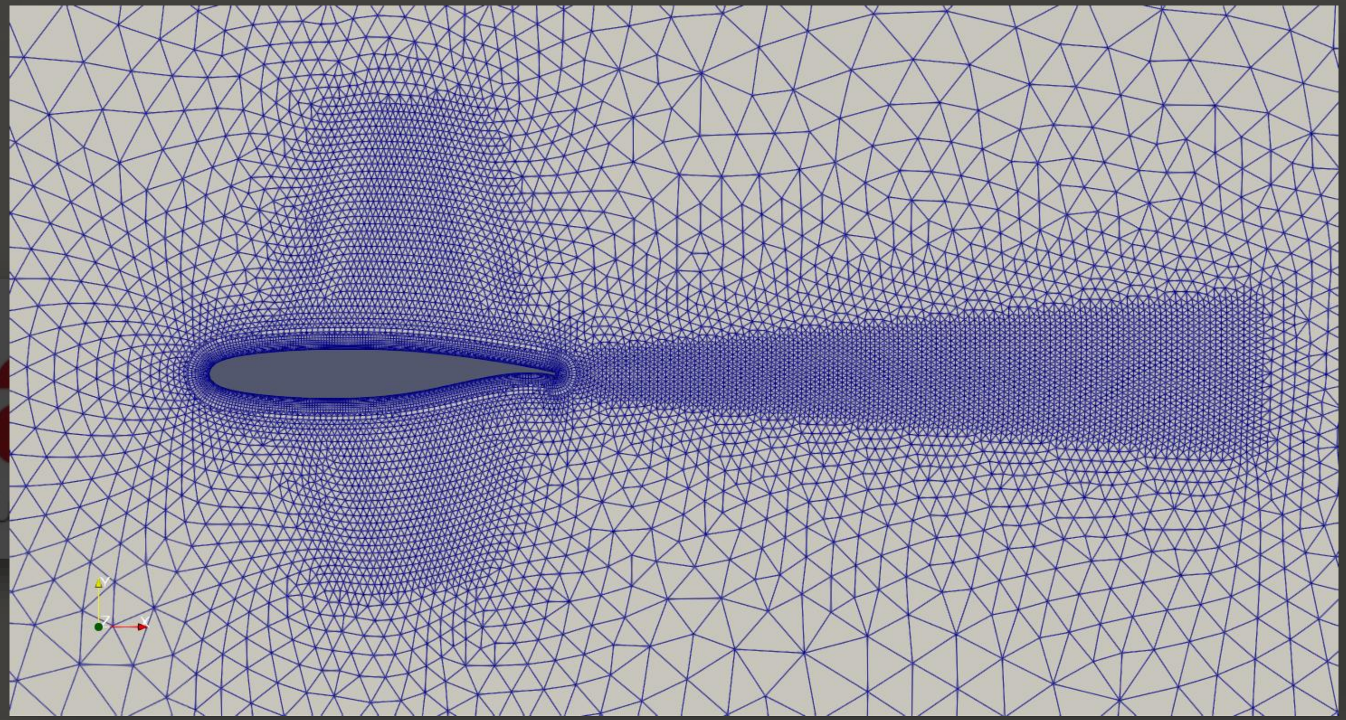

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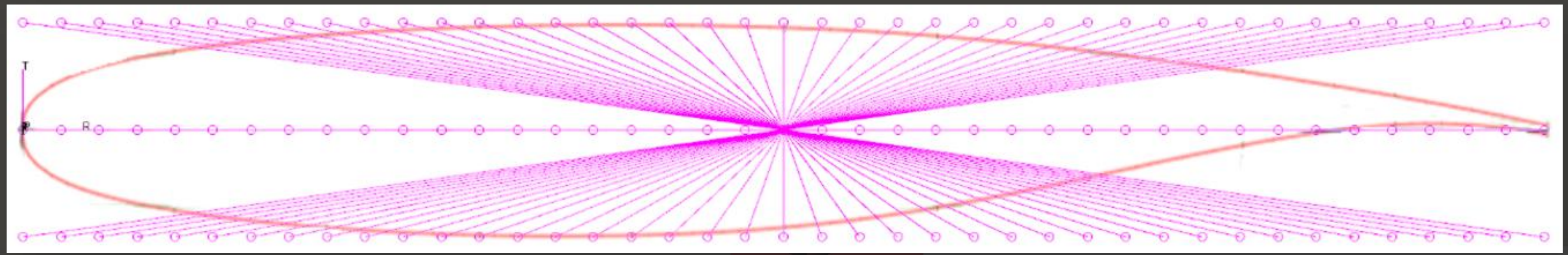

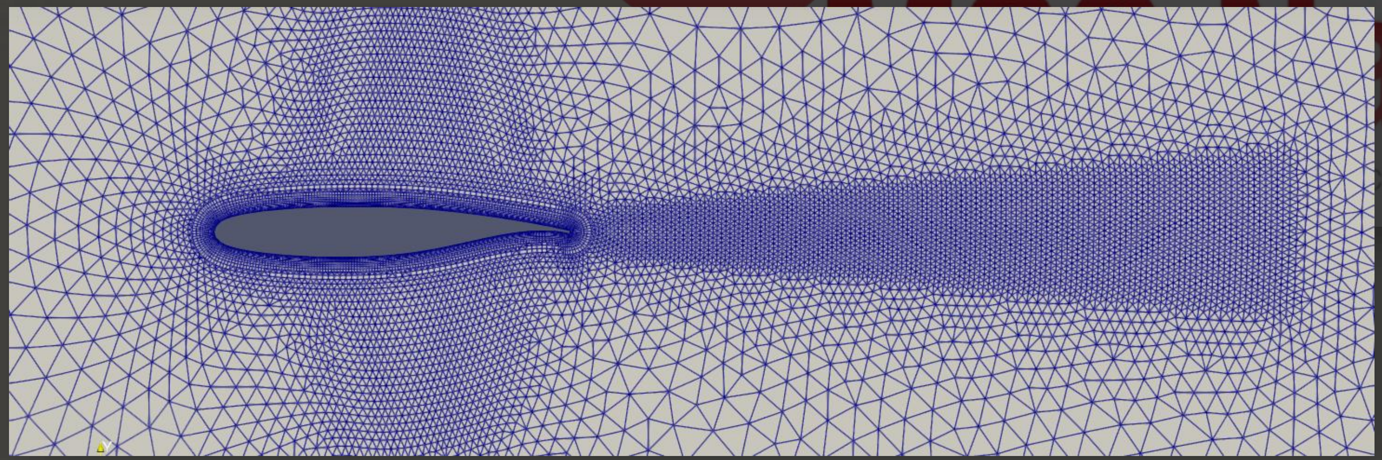

RBF – Radial Basis Function

RANS Level 1 mesh provided by NASA

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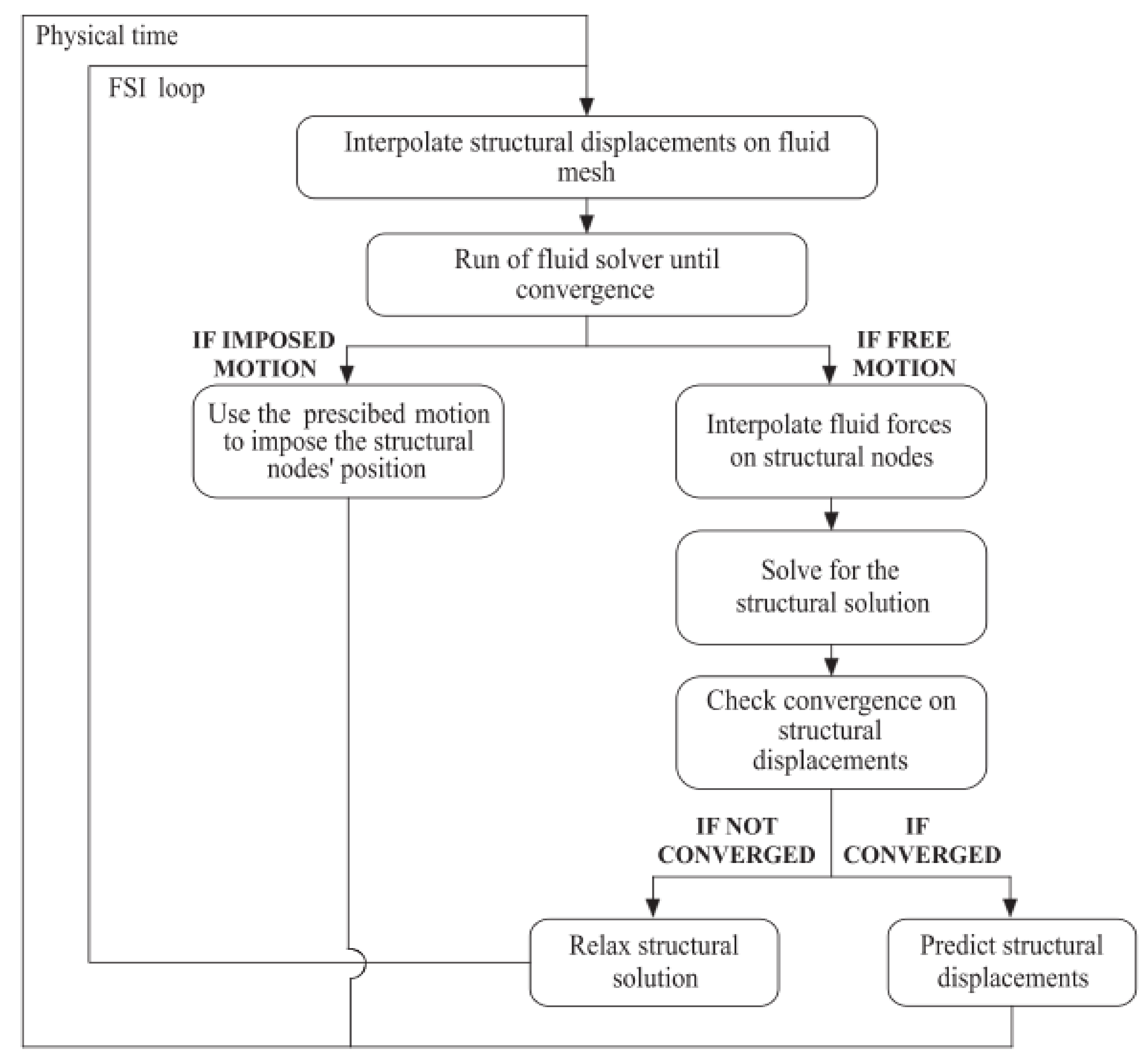
FSI Solution Process

Extended capabilities for high-fidelity fluid-structure simulations
Fonzi *et al.*, 2022



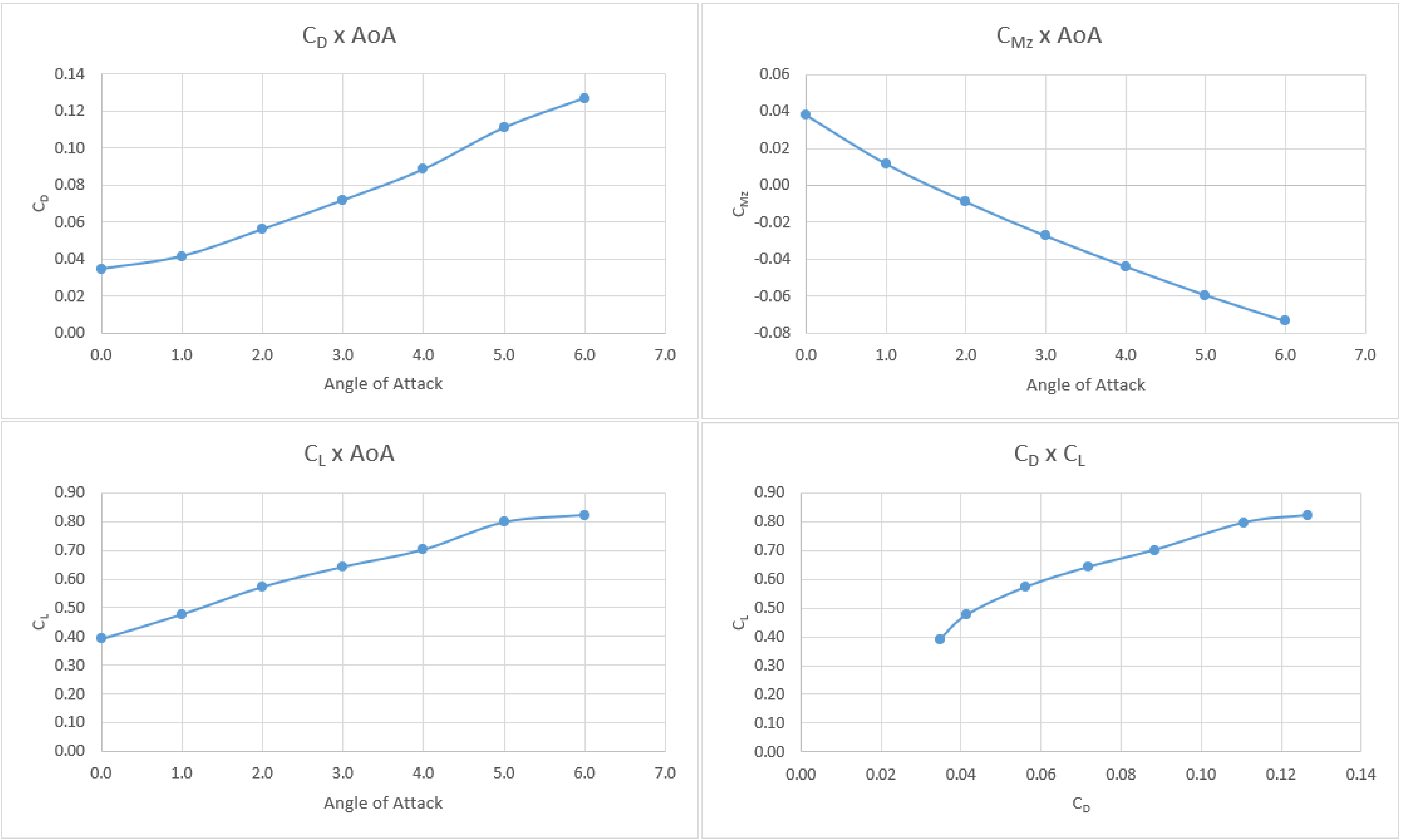
SU2 code

1. Solid: Structural model with wind-off results (NASTRAN)
2. Fluid: Mach, P, T e AoA
   - T = 300.15 K
   - Fluid – Air
   - *Dual Time Step* – 50 internal iterations
   - *Time Step* – 10^{-3} sec
   - Total – 4 seconds
   - Limiter – Venkatakrishnan
   - Turbulence Model: SST $k-\omega$
3. FSI: RBF and fluid/solid files (w/ 20 FSI sub-iterations)

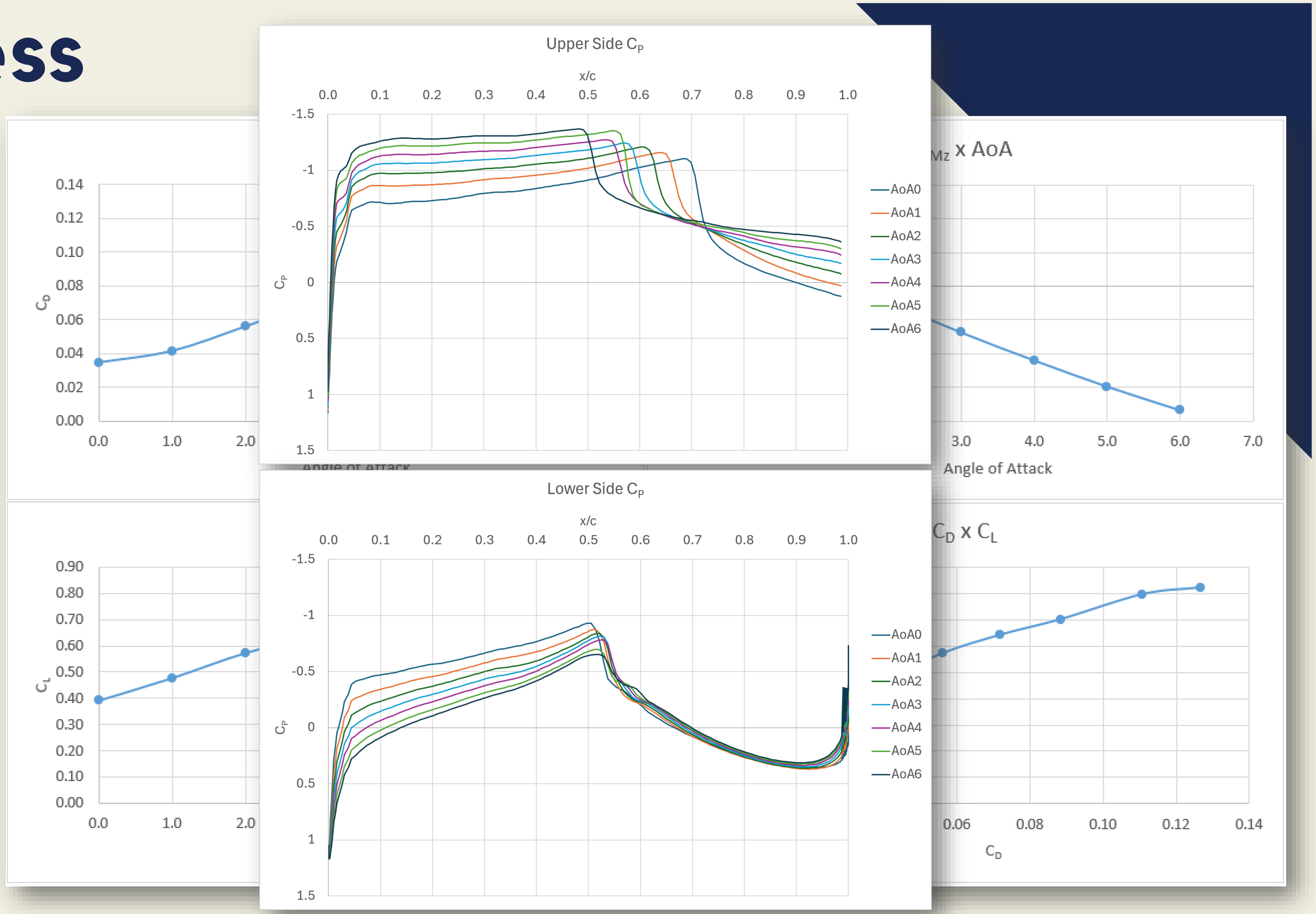
Solution process

Initialization

- Steady Rigid restart flow
- Incrementally increasing dynamic pressure up to flutter onset



Solution process



Initialization

- Steady Rigid restart flow
- Incrementally increasing dynamic pressure up to flutter onset

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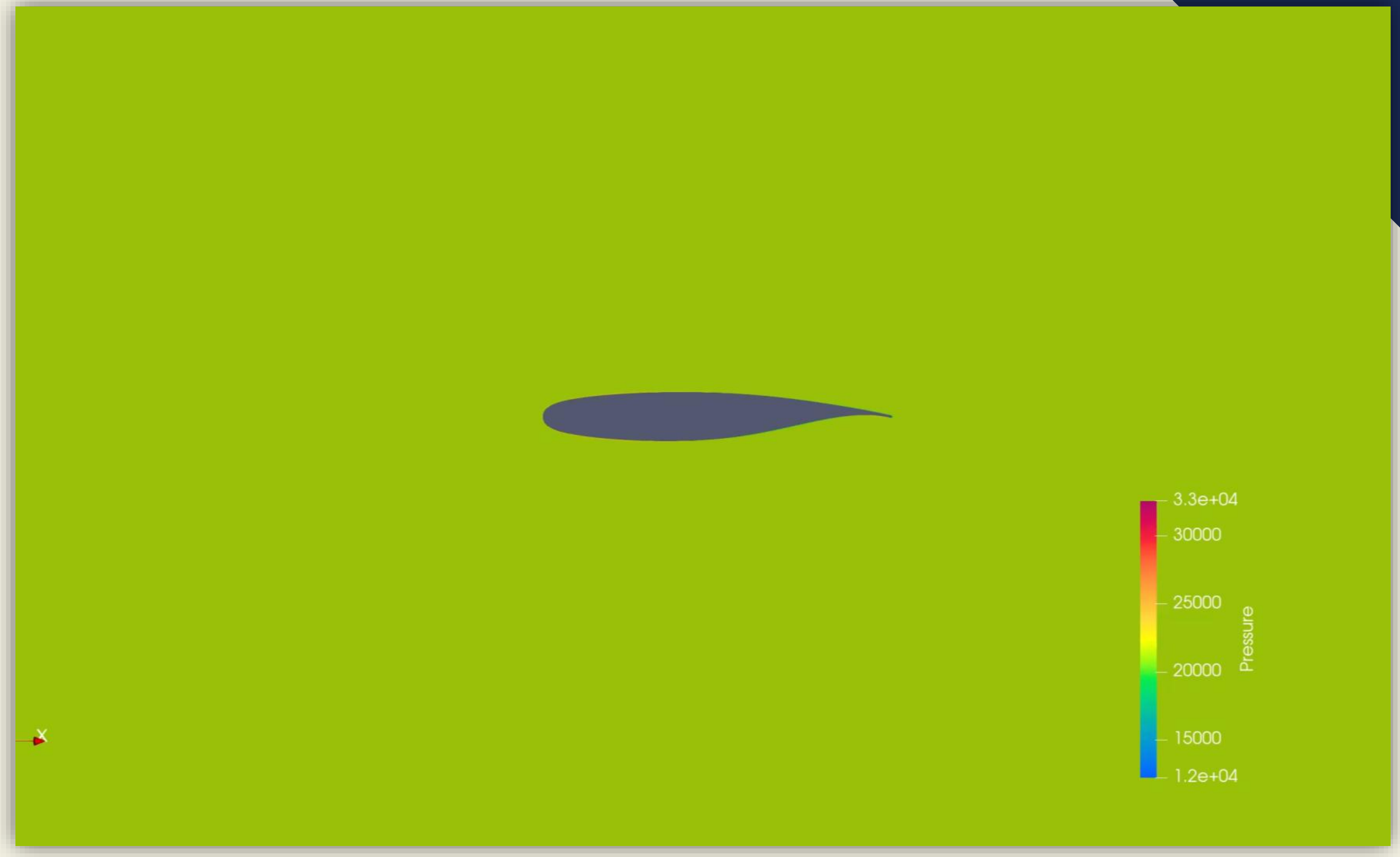
Solution process

Initialization

- Steady Rigid restart flow
- Incrementally increasing dynamic pressure up to flutter onset

Initial perturbation

- Jig-shape release method



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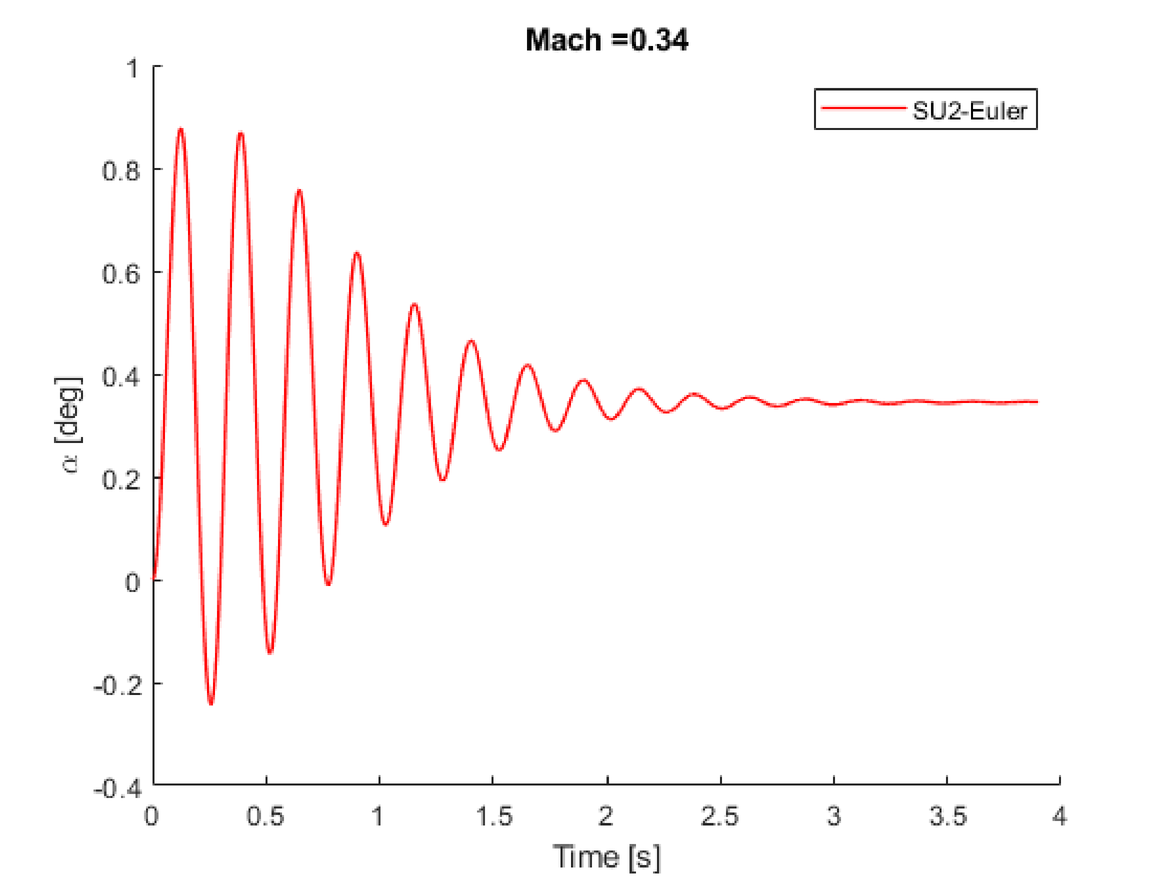
System Identification

Guillaume *et al.* (2003)

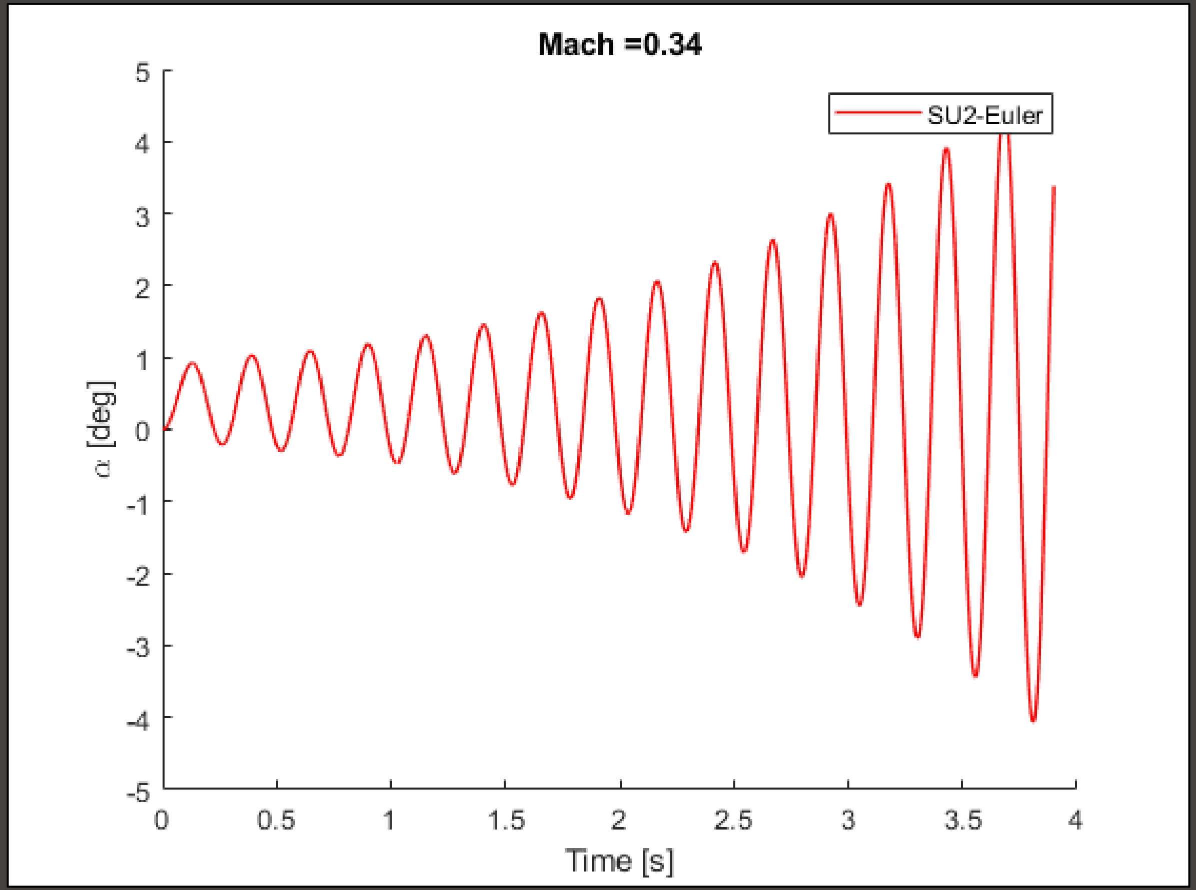
F

Least-

Pitch time response for Mach 0.34



Stable at 136 psf



Unstable at 144 psf

System Identification

Guillaume *et al.* (2003)

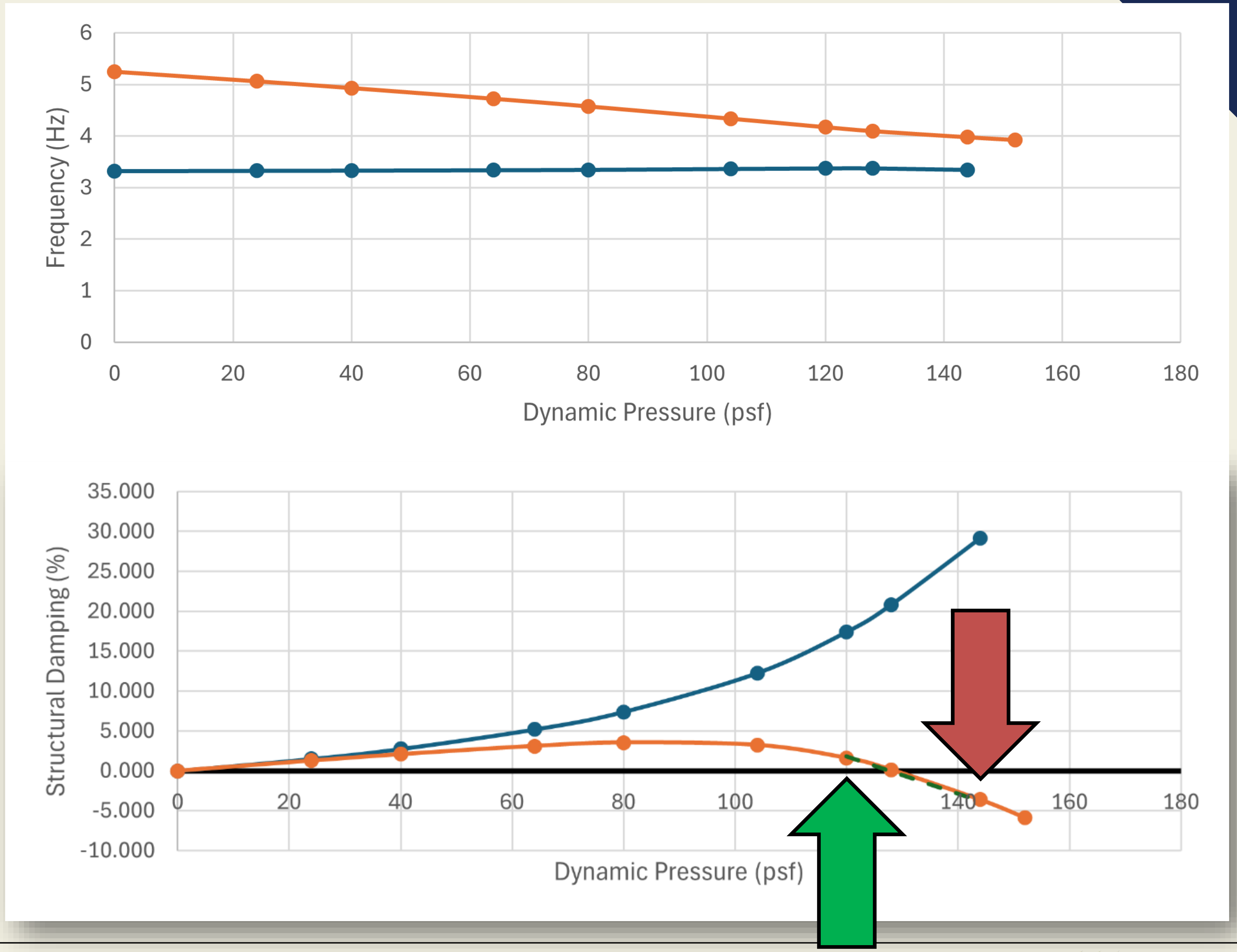
Frequency Domain

Least-Squared Complex Frequency – LSCF

ω_n – *natural frequency*

ζ – modal damping ratio

V-g-f for Mach 0.34



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Results

Workstation UNESP - 15 cores

Dynamic Pressure [psf]	Angle of Attack						
	0° [hour:minute]	1° [hour:minute]	2° [hour:minute]	3° [hour:minute]	4° [hour:minute]	5° [hour:minute]	6° [hour:minute]
137.3							01:06
154.5							01:07
171.7						01:06	01:14
188.8		00:44	00:50	00:55	00:59	01:08	01:14
206.0		00:44	00:49	00:54	00:59	01:10	
223.1		00:45	00:49	00:54	01:03		
240.3		00:46	00:47	00:53	01:04		
257.5		00:47	00:46	00:53	01:06		
274.6		00:48		00:59	01:11		
291.8		00:50	00:50	01:04			
309.0		00:55	00:57	01:07			
326.1		00:51	01:05	01:10			
343.3		01:06	01:07				
360.5		01:04	01:09				
377.6		01:07					

Wall times

Green indicates a stable time response

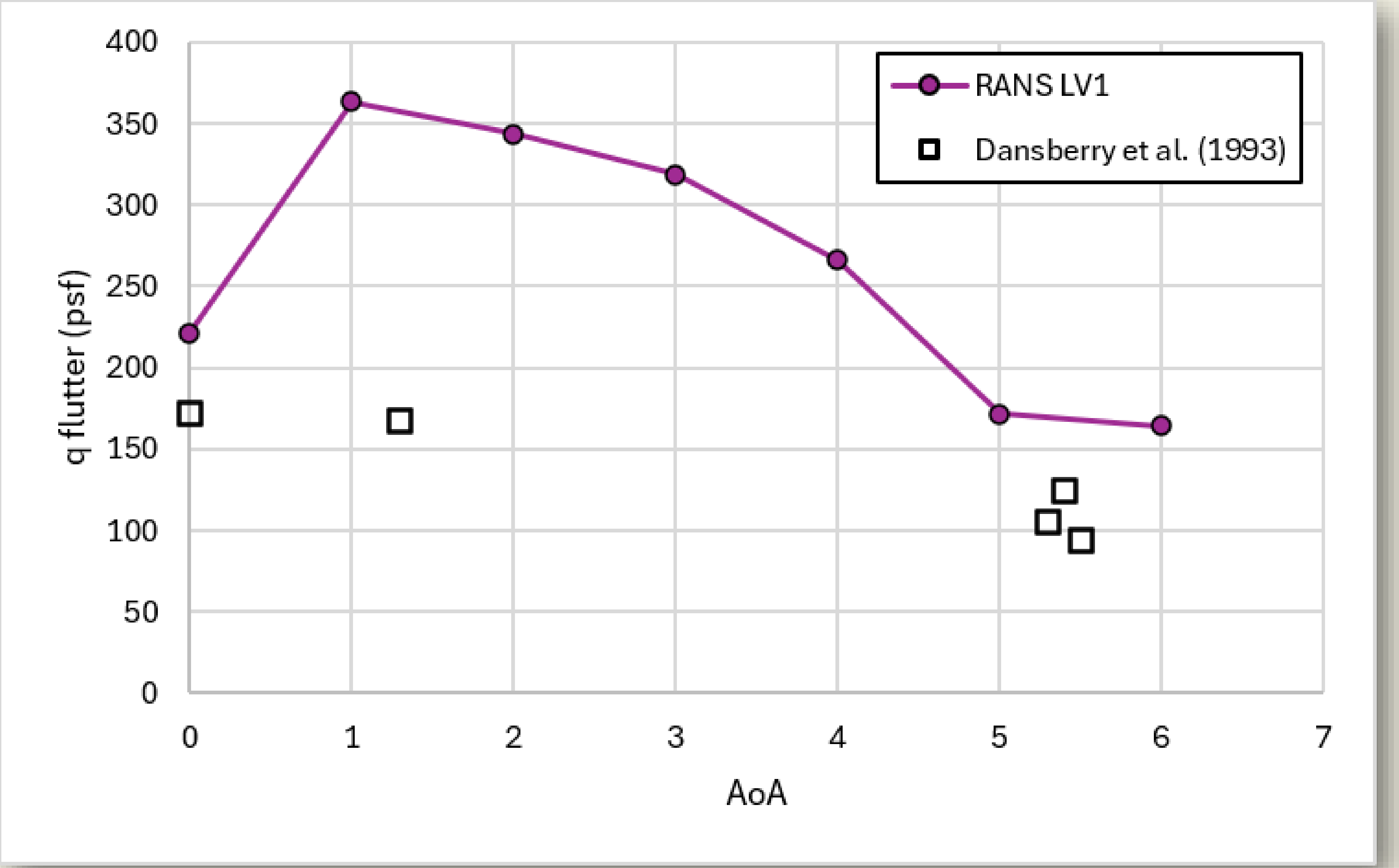
Orange indicates an unstable time response

Wall-time summary

Model	Wall time [hour:minute]		
	Minimum	Maximum	Average
URANS Lv. 1	00:44	01:14	00:58

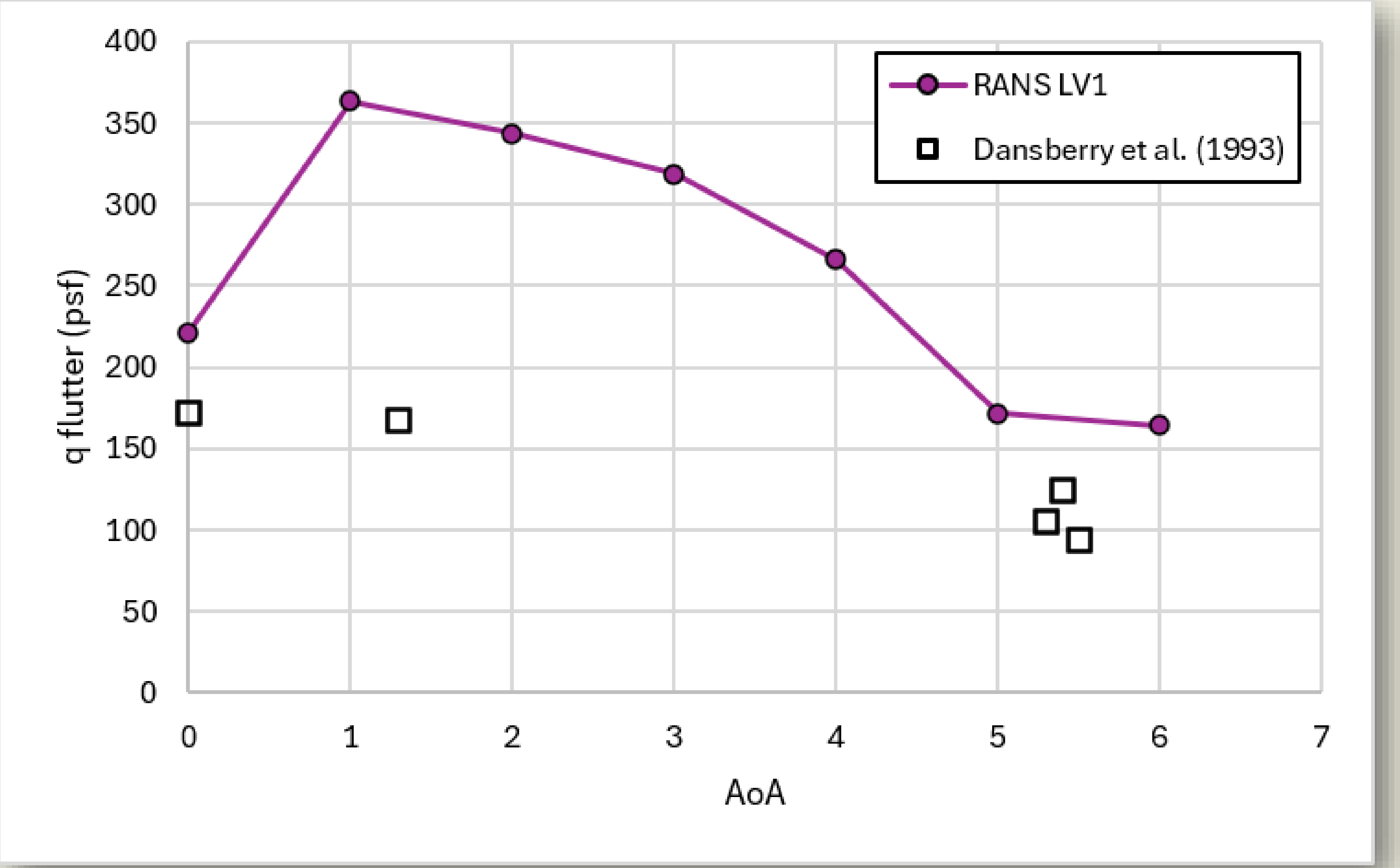
Results

Flutter dynamic pressure vs. Angle of attack for Mach 0.80



Results

Flutter dynamic pressure vs. Angle of attack for Mach 0.80



Concluding Remarks

Predicted flutter dynamic pressures are significantly higher than experimental data

Peak flutter dynamic pressure observed at 1° AoA

The applied computational framework yielded coherent behavior

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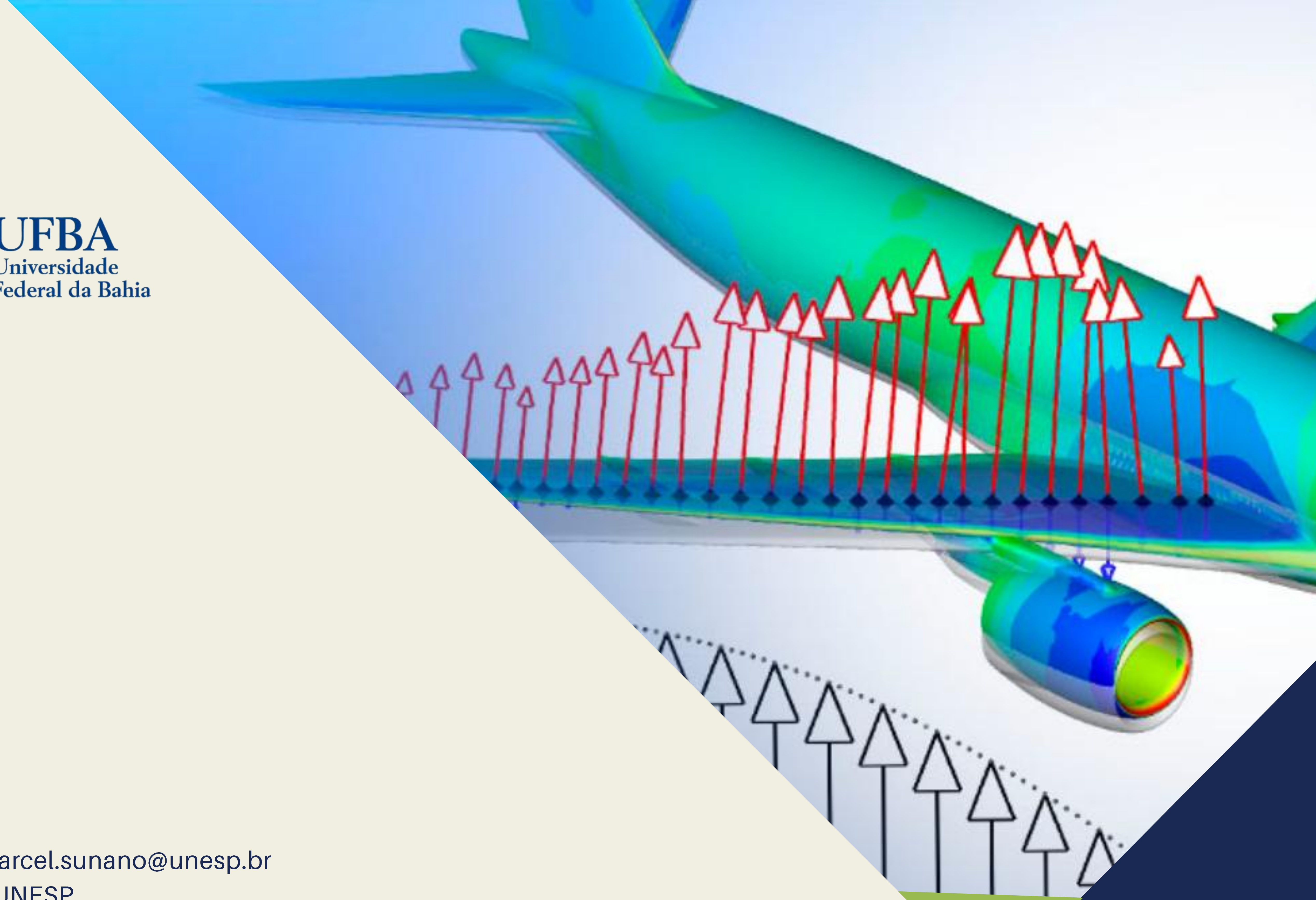

Thank you!

Obrigado!

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