Structural Mechanics Analysis and Shape Determination of the Orion Spacecraft Drogue Parachute

T★AFSM

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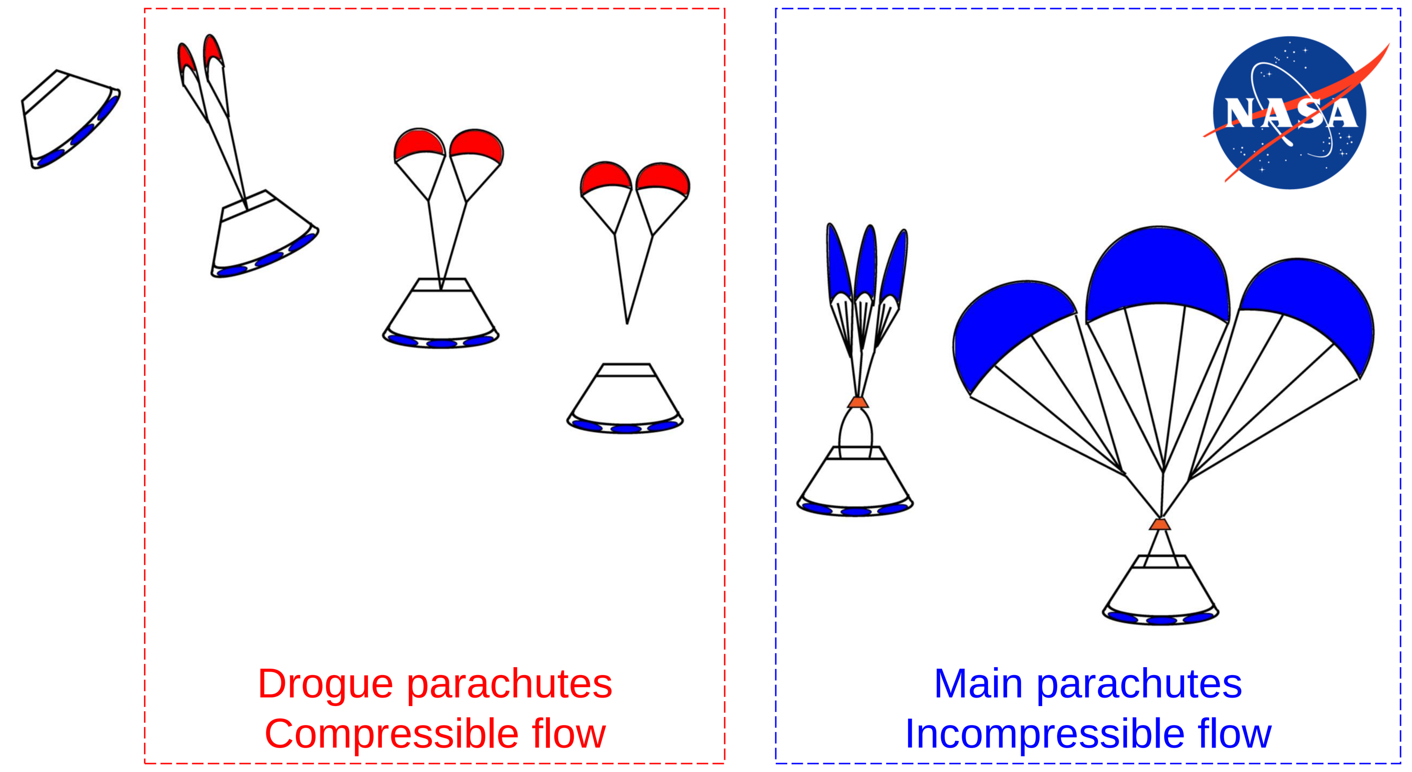
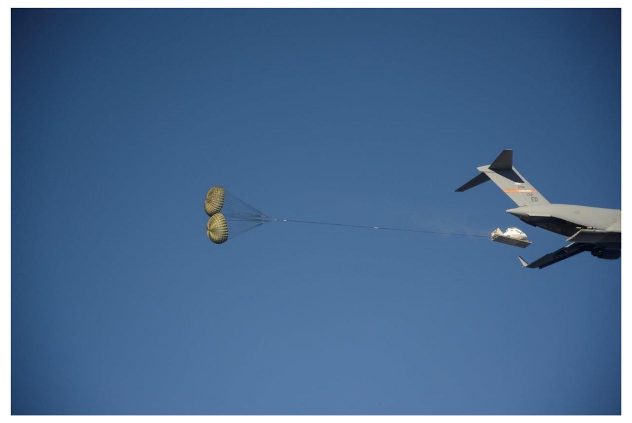
Background

☐ Orion Drogue Parachute



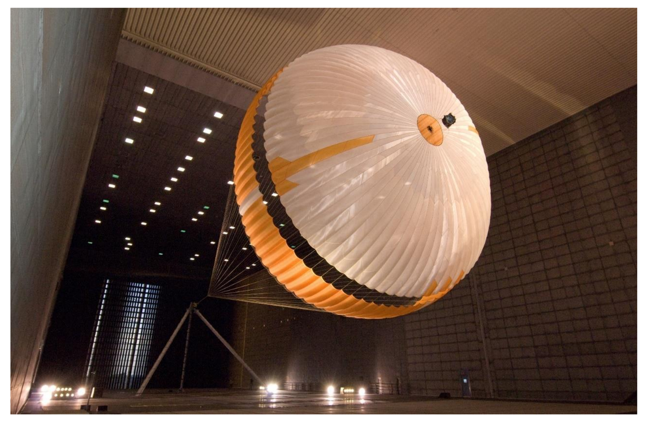
Orion parachute sequence From NASA site

☐ Field Tests



A drop test From NASA site

Cost is about a million dollar for each test.

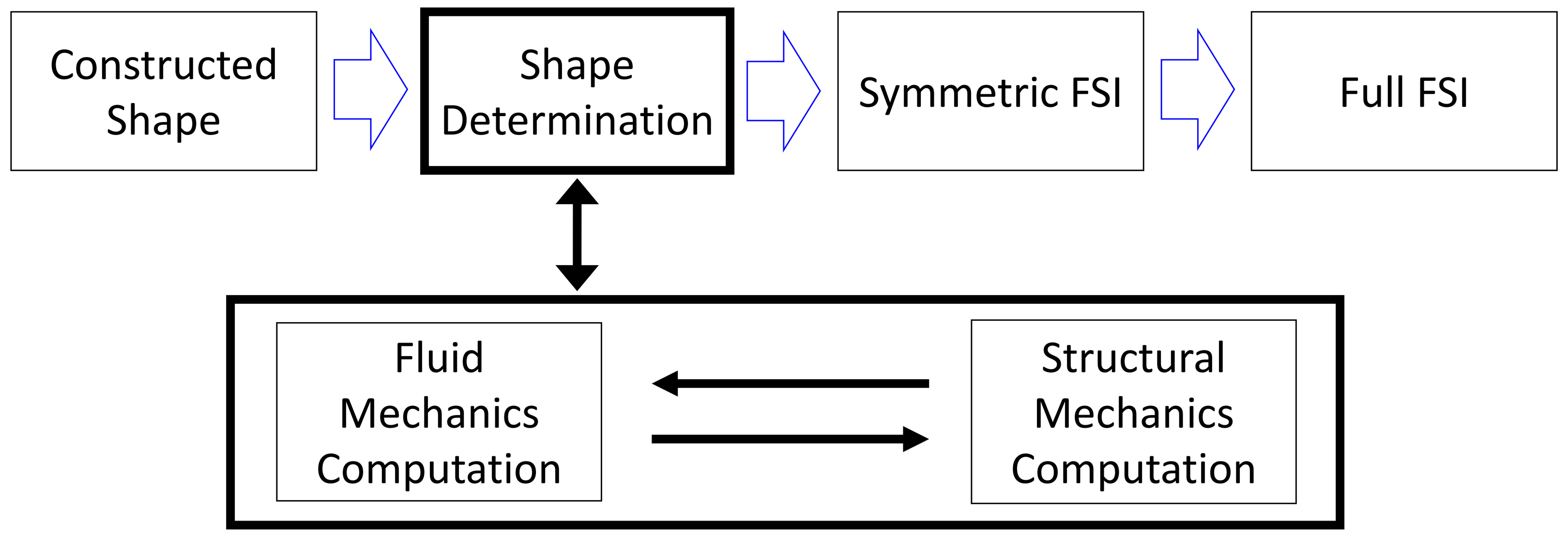


A wind-tunnel test From NASA site

Scaling challenge due to interaction between the canopy deformation and the airflow.

Computational analysis
can serve as a practical alternative.

☐ Complete Fluid–Structure Interaction (FSI) Process



Objective

- ☐ Find the condition that can shorten the computation time to determine the starting shape for symmetric FSI.
- ☐ Improve the parachute performance, including stability.

Methods

☐ Governing Equations

Structural mechanics equations[1]

☐ Spatial Discretization

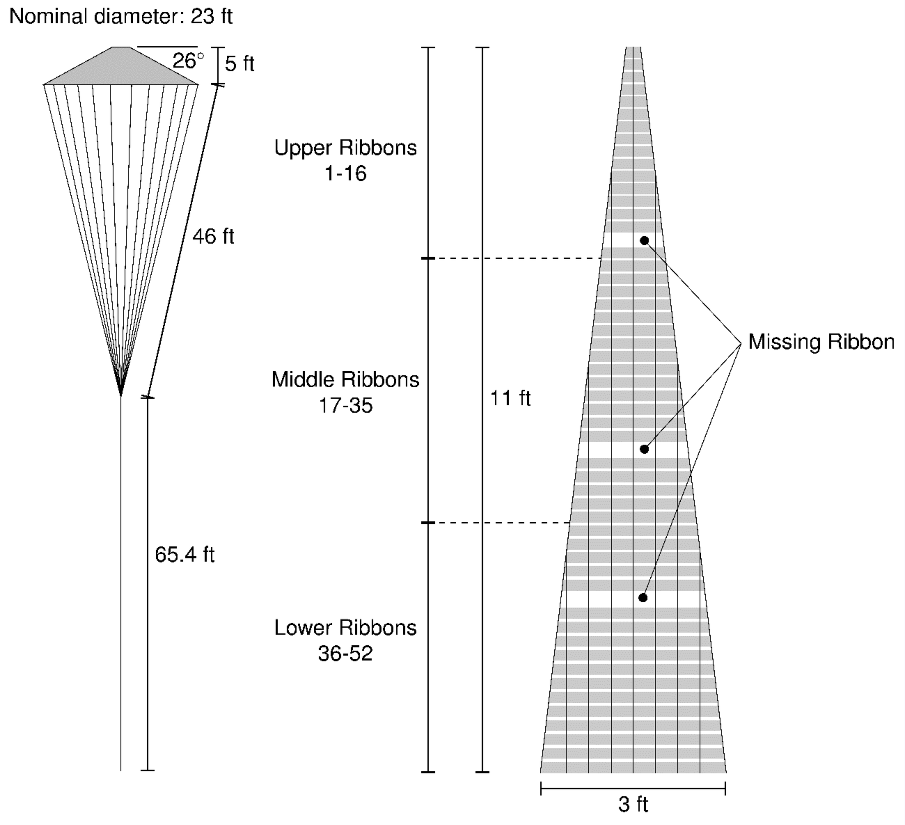
Finite element method (FEM)[1]

☐ Rayleigh Damping

$$\mathbf{Ma} + \mathbf{Cu} + \mathbf{Ky} = \mathbf{0}$$

$$\mathbf{C} = \eta\mathbf{M} + \zeta\mathbf{K}$$

$\mathbf{M}$: mass, $\mathbf{C}$: viscous damping, $\mathbf{K}$: stiffness
$\mathbf{a}$: acceleration, $\mathbf{u}$: velocity, $\mathbf{y}$: displacement



Parachute configuration

Conditions

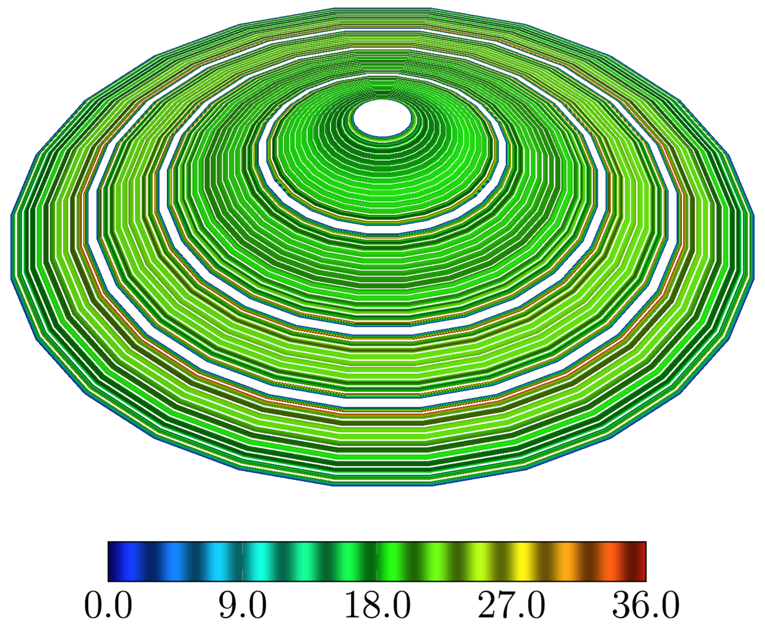
☐ Base Conditions

Mach number	0.7
Altitude (ft)	10,000
Reynolds number	1.23×10^6

☐ Conditions of Each Case

	Δt ($\times 10^{-3}$s)	η (1/s)	ζ ($\times 10^{-3}$s)
Case 0	1.0000	0	0
Case 1	0.5000	251.3	2.546
Case 2	0.2500	502.7	1.273
Case 3	0.0625	2011	0.318

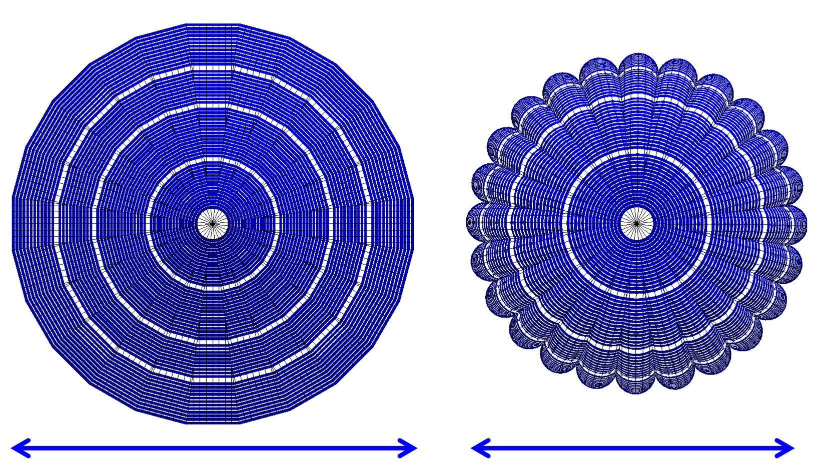
☐ Pressure Distribution on the Canopy



Pressure difference $\varDelta P$ (kPa)

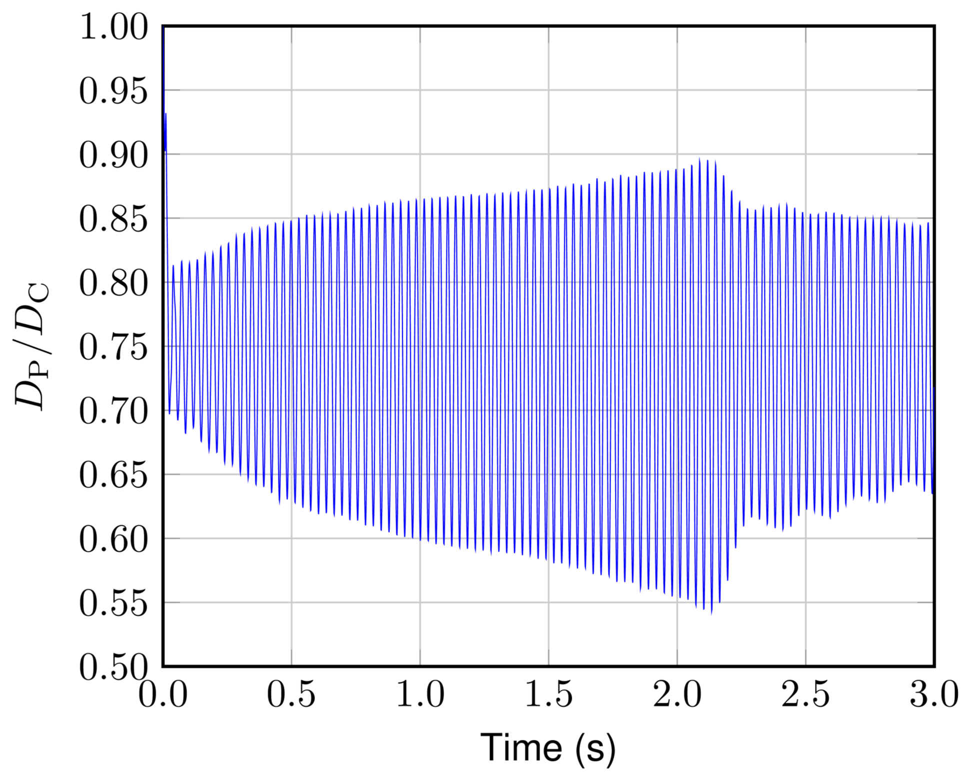
Results: The Need for Damping

☐ Case 0



D_C
Constructed diameter of the canopy

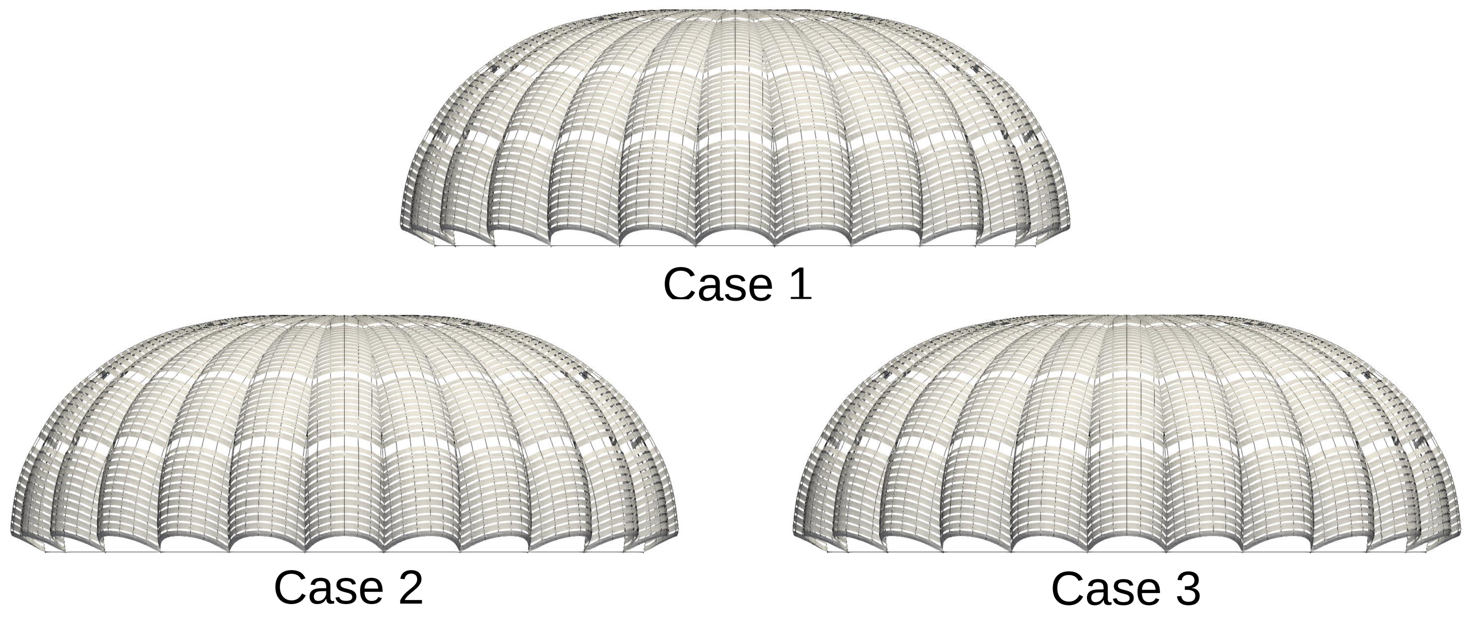
D_P
Projected diameter of the inflated canopy



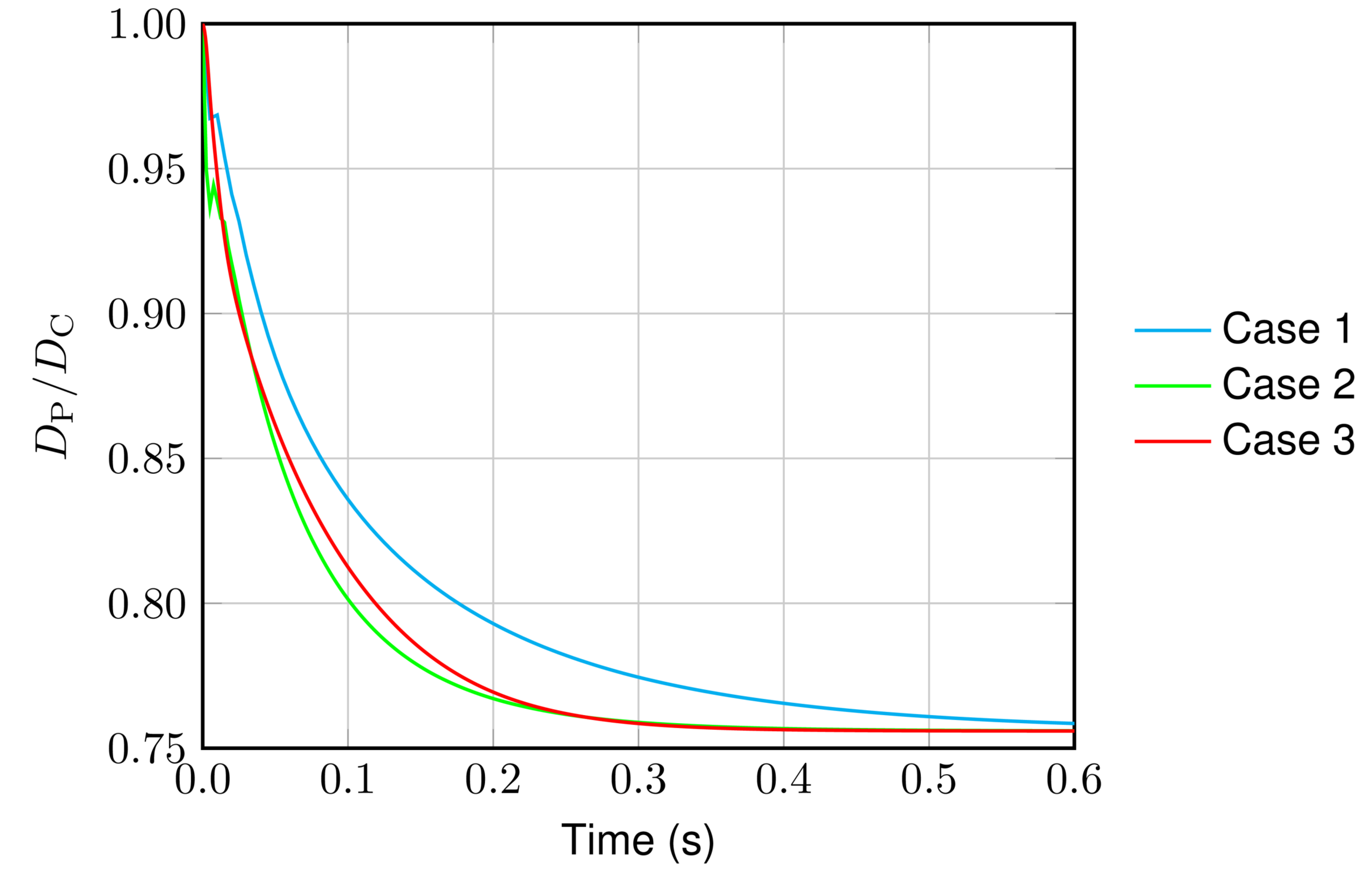
Time history of normalized diameter

Results: Comparison

☐ Case 1–3



Parachute canopy of each case at t = 0.6 s



Time history of normalized diameter

Concluding Remarks

- ☐ Cases 1 and 2 are good choices.
- ☐ Rayleigh damping helps to determine the parachute shape.

Future Directions

- ☐ Vary altitude and Mach number.
- ☐ Start symmetric FSI.
- ☐ Use Non-Uniform Rational B-Spline (NURBS) mesh.

Reference

[1] Y. Bazilevs, K. Takizawa and T. E. Tezduyar, "Computational Fluid–Structure Interaction: Methods and Applications", Wiley (2013).

Acknowledgement

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