Fluid and Structural Mechanics Analysis of the Orion Spacecraft Drogue Parachute in Compressible-Flow Regime

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Background

- Orion Drogue Parachute

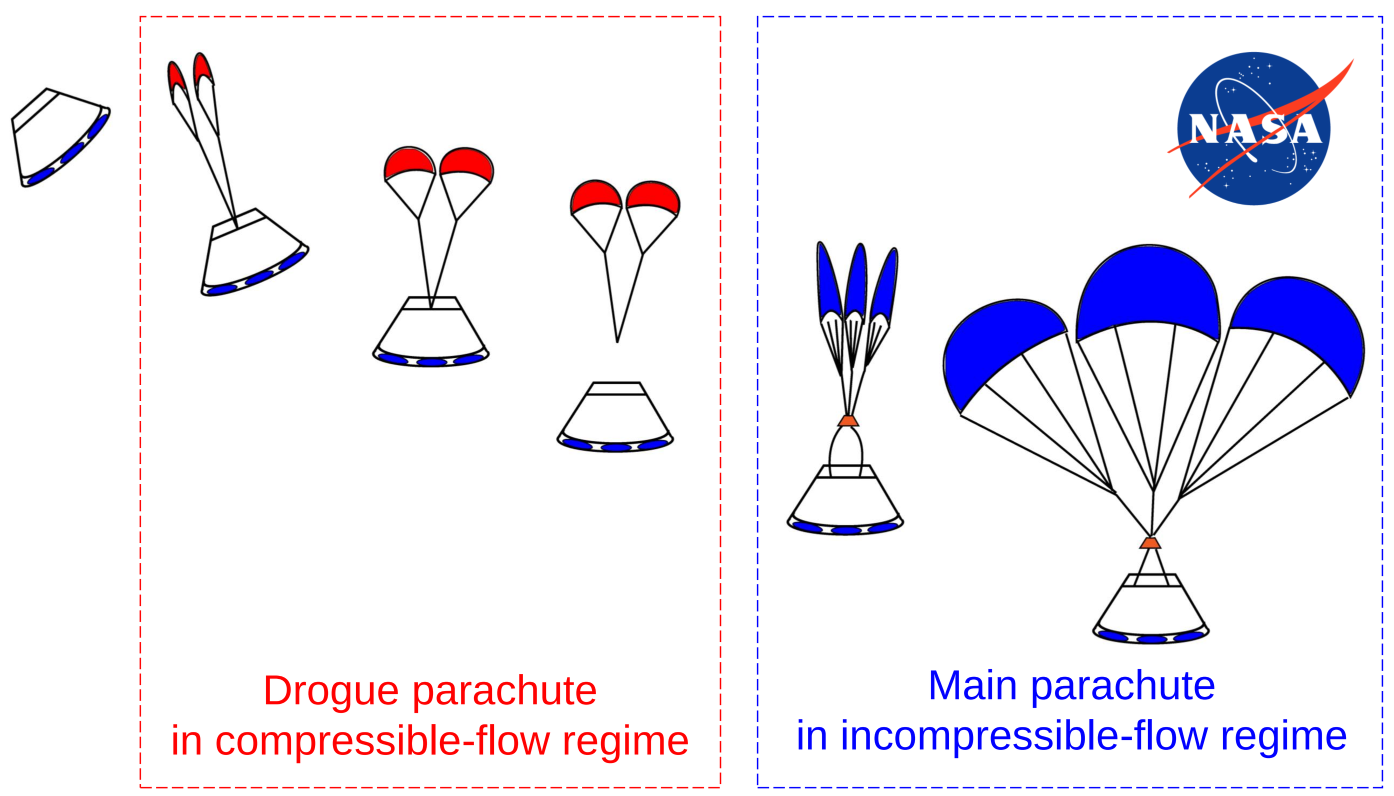


Figure: Orion parachute sequence From NASA site

- Field Tests

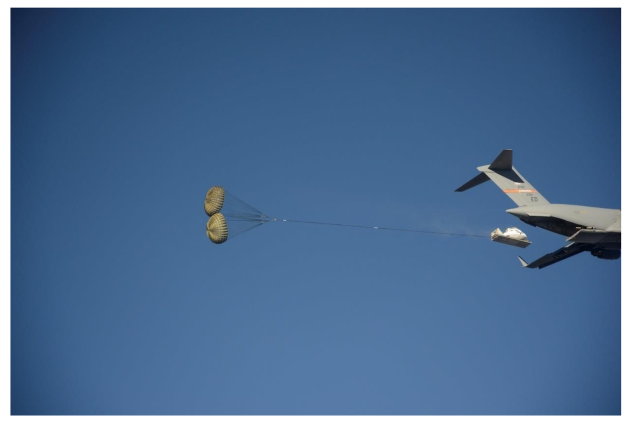


Figure: A drop test From NASA site

Cost is about a million dollar for each test.

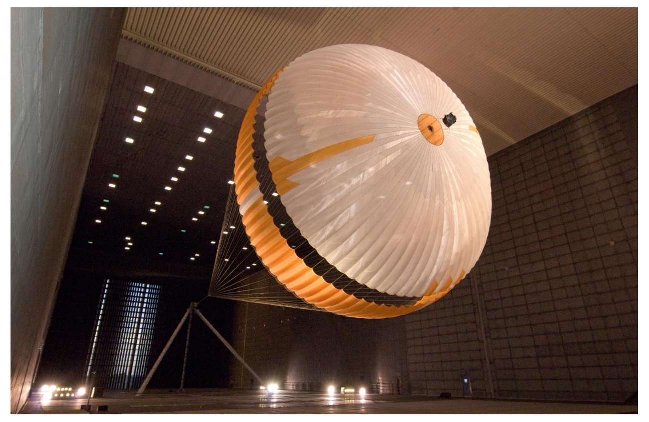


Figure: A wind-tunnel test From NASA site

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

Computational analysis
is expected to serve as a practical alternative.

Objective

- To improve parachute performance, including stability
- To obtain the parachute shape and flow field for fluid–structure interaction (FSI) [1] of NASA's Orion spacecraft parachute

Method/Conditions

- Governing Equations
  Compressible Navier–Stokes equations
- Discretization and Stabilization Technique
  Compressible-flow SUPG method

Table: Flight conditions

Mach number M	0.3	0.5	0.7
Dynamic pressure (kPa)	1.50	4.17	8.17
Reynolds number Re (×10⁷)	1.65	2.75	3.85
Altitude (ft)		35,000	

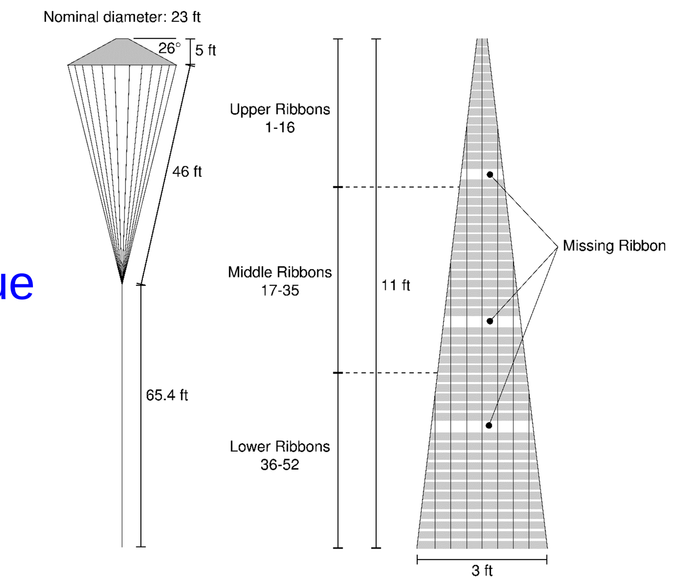
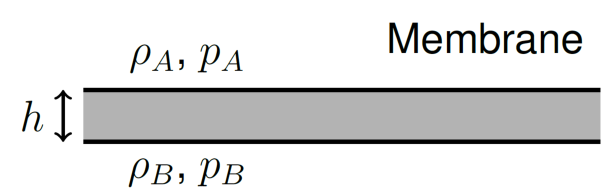


Figure: Parachute configuration

Porosity Model for Compressible-Flow Computations

Estimate mass flow rate across the membrane[2].



$$\frac{\gamma}{\gamma-1}\left|\rho_A p_A - \rho_B p_B\right| = \frac{\mu}{D}|\dot{m}| + \beta|\dot{m}|^2$$

γ: ratio of specific heat, ρ: density, p: pressure, $\dot{m}$: momentum, μ/D and β: porosity coefficients

Generate Mesh

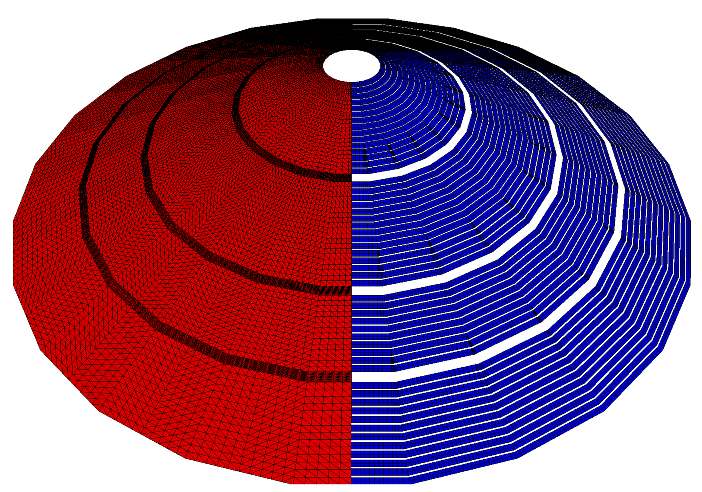


Figure: Fluid-interface mesh (left) and structural mechanics mesh (right)

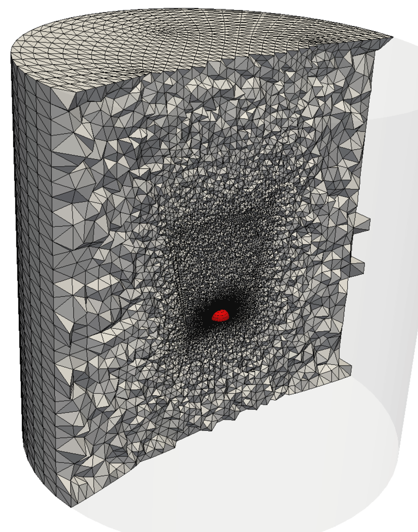


Figure: Fluid-volume mesh

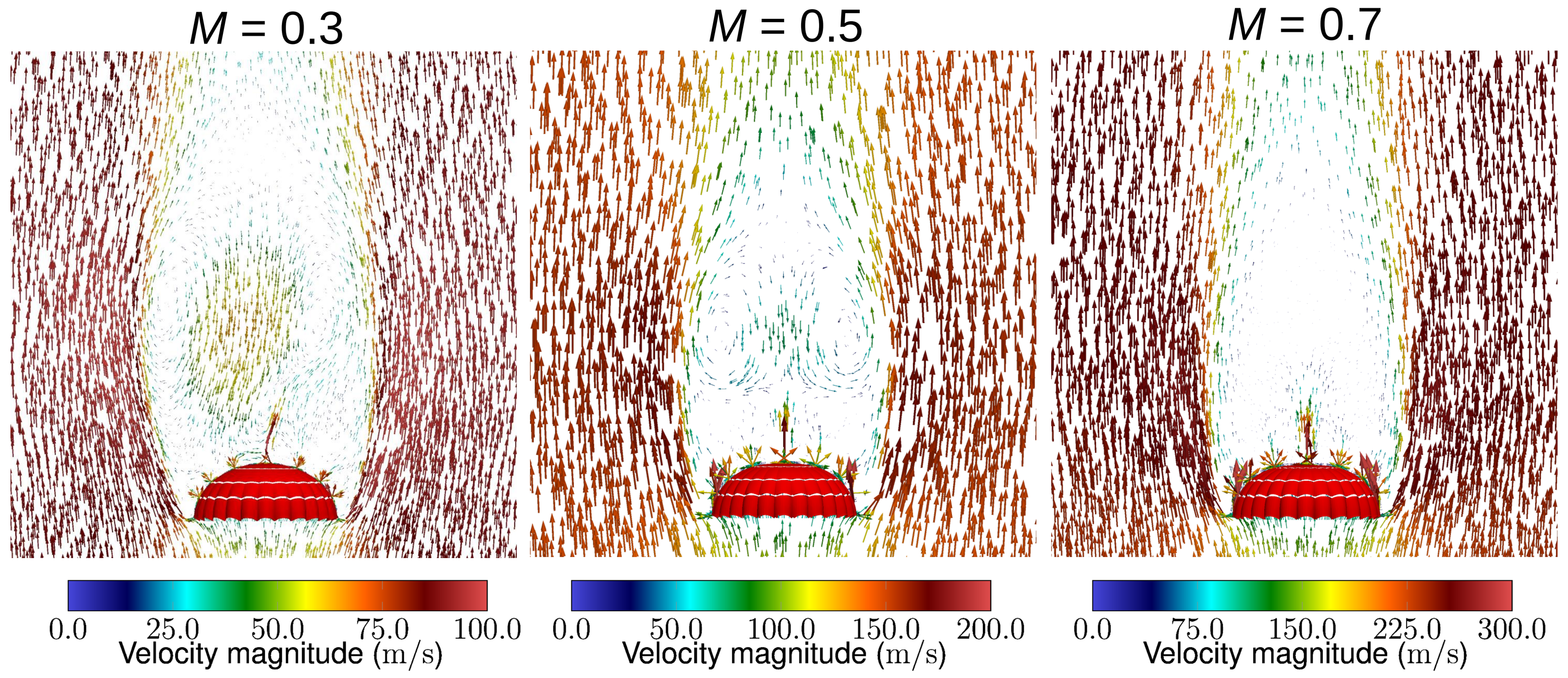
Table: Mesh size

M		(×10⁶)
0.3	nn	1.01
	ne	6.00
0.5	nn	0.92
	ne	5.45
0.7	nn	0.90
	ne	5.35

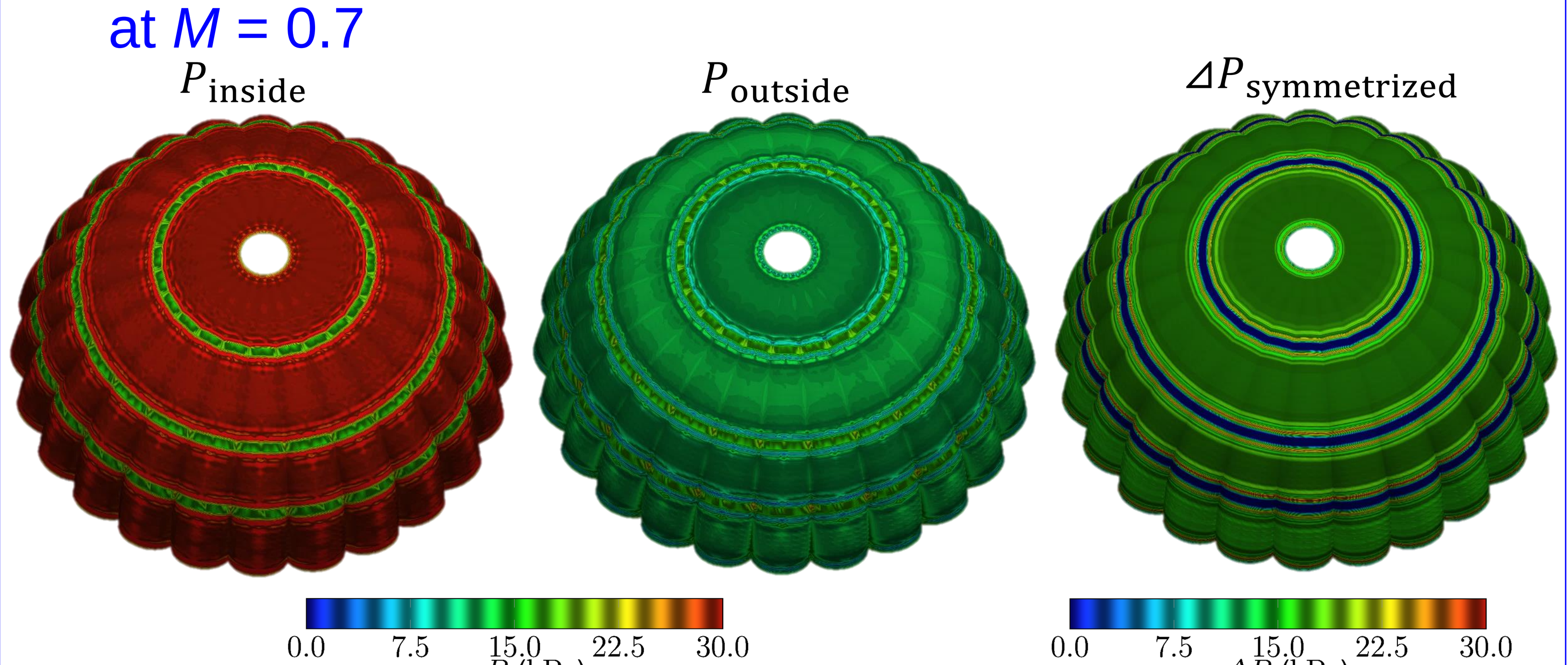
nn: Number of nodes
ne: Number of elements

Results from Fluid Mechanics Computations

- Velocity Field at M = 0.3–0.7

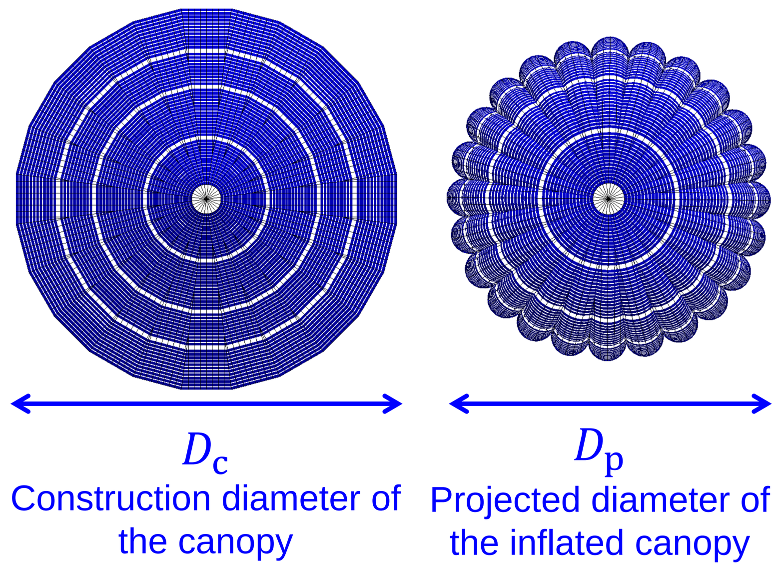


- Symmetrize Cross-Membrane Pressure Difference at M = 0.7



Results from Structural Mechanics Computations

Apply symmetrized pressure difference from fluid mechanics computations to structural mechanics computations.



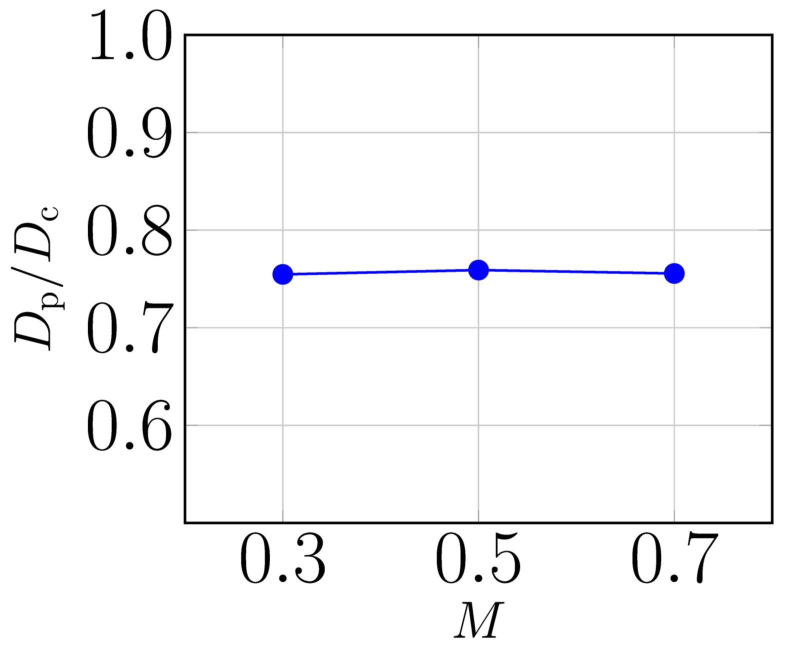
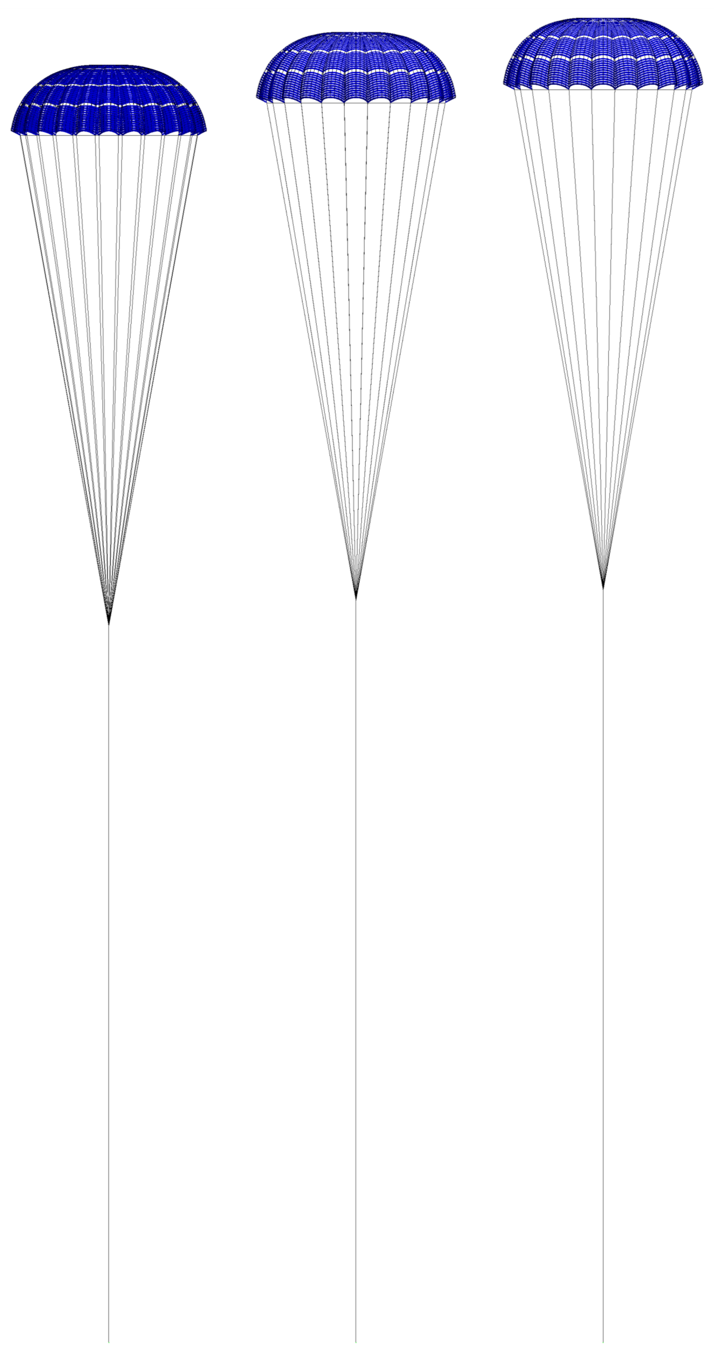


Figure: Parachute diameter



Concluding Remarks

- Method for calculating the FSI starting condition
- For M = 0.3–0.7, parachute diameter is almost constant with M

Future Directions

- Vary the altitude
- Start FSI analysis
- Improve the stability performance of the parachute

References

[1] K. Takizawa and T.E. Tezduyar, "Computational methods for parachute–structure interactions", Archives of Computational Methods in Engineering **19** (2012) 125–169.
[2] T. Kanai and K. Takizawa, "Geometric-Porosity Modeling for Ribbon-Parachute Compressible Flow", (2015) 17–18.

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