FY23 Strategic University Research Partnership (SURP)

Verification and Validation of High-Fidelity Supersonic Parachute Deployment Modeling

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Objectives:

This project leveraged investments in the Stanford-developed AERO computational suite that focused on creating the capability to model supersonic parachute inflations. Specifically, this SURP focused on code validation using existing experimental data (MSL, ASPIRE, and M2020 flight-data), and on uncertainty quantification. This has allowed JPL and Stanford to, for the first time, quantify the effect of modeling uncertainties for supersonic parachute inflations, and to understand parachute design and modeling sensitivities.

Background:

The structural failure of the supersonic parachutes on two flight tests during the Low-Density Supersonic Decelerator (LDSD) project was not predicted by traditional parachute design methods which were considered industry standard and had been used for nearly 40 years.

High-fidelity modeling of fluid-structure interactions (FSI) is a topic of great interest at JPL. Validating existing modeling tools is important due to the cost, difficulties, and test-as-you-fly exceptions associated with Mars-relevant parachute testing. The ASPIRE tests have provided a unique data set with high-resolution images and temporally resolved integrated loads of full-scale supersonic parachute inflations, yet no FSI simulations have been completed prior to this effort to model these experiments.

Approach and Results:

Year 3 of this effort focused on simulations of the ASPIRE SR-03 flight, with both refinements to the modeling approach and investigation into the effects of several modeling parameters on inflation results. One key update this year was to better model the initial inflation by further collapsing the parachute into a "line stretch" configuration (see Fig. 1). It was found that this updated configuration provided a better match to the drag profile see in the ASPIRE flights. This year incorporated the best practices found in previous years, and added new parameter assumptions to investigate as shown in Fig. 2. Results for some of these simulations are shown in Figs. 3-4. Overall, these results help validate key modeling assumptions needed to provide accurate simulation of the initial inflation drag rise as well as long-term drag trend of the parachute.

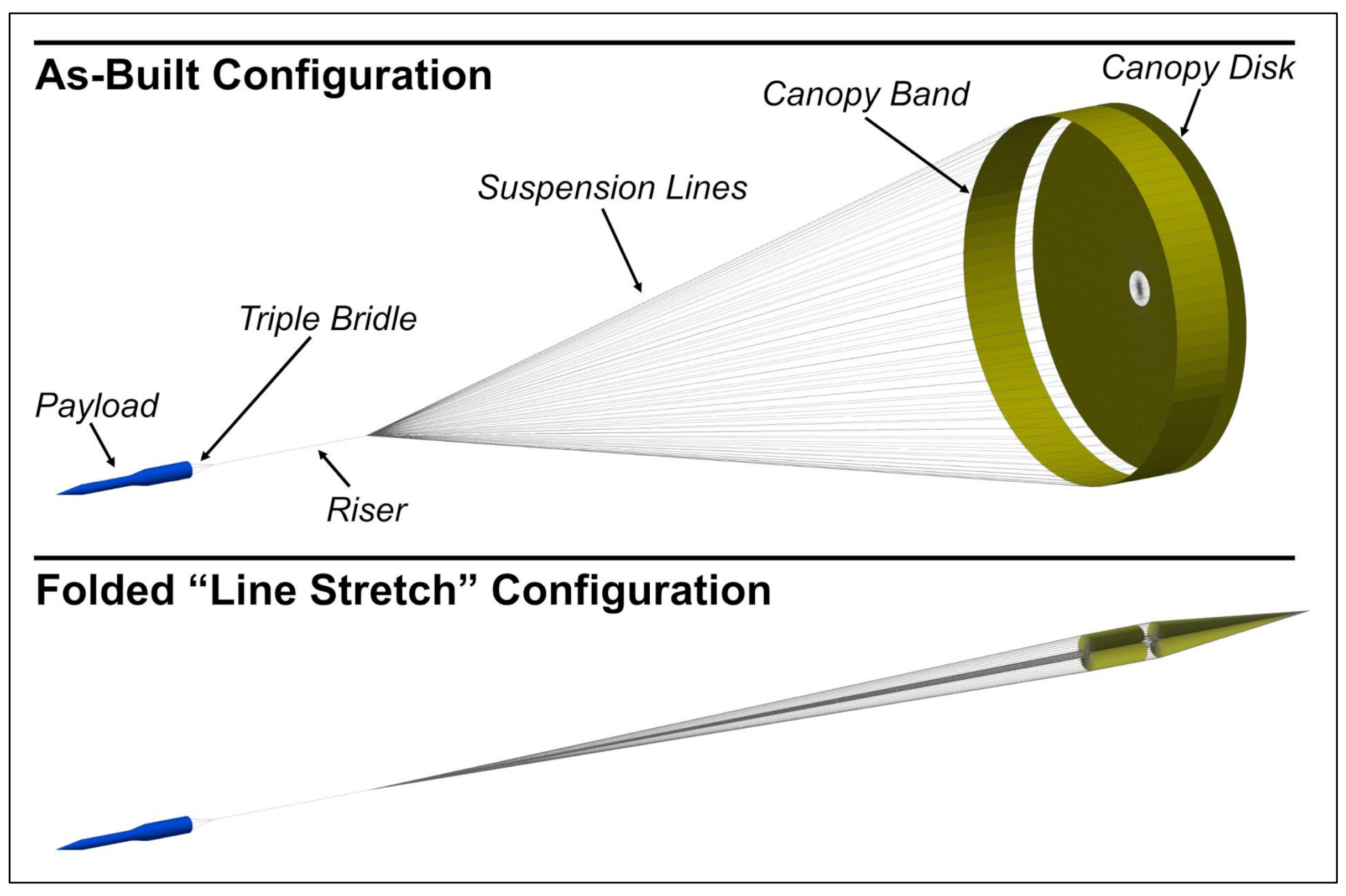


Fig. 1: *ASPIRE configuration showing as-built and folded (i.e. simulation start) shapes.*

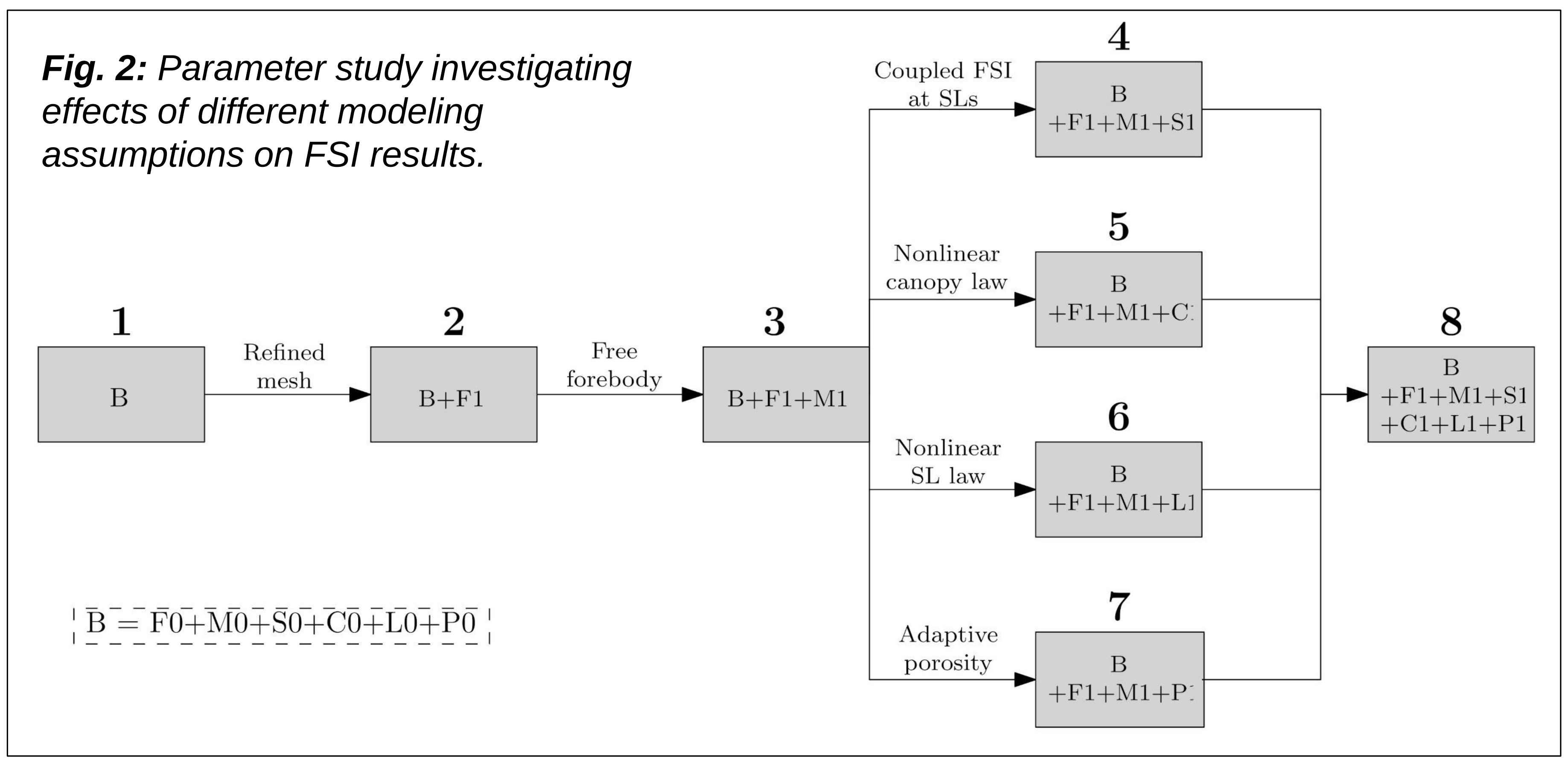


Fig. 2: *Parameter study investigating effects of different modeling assumptions on FSI results.*

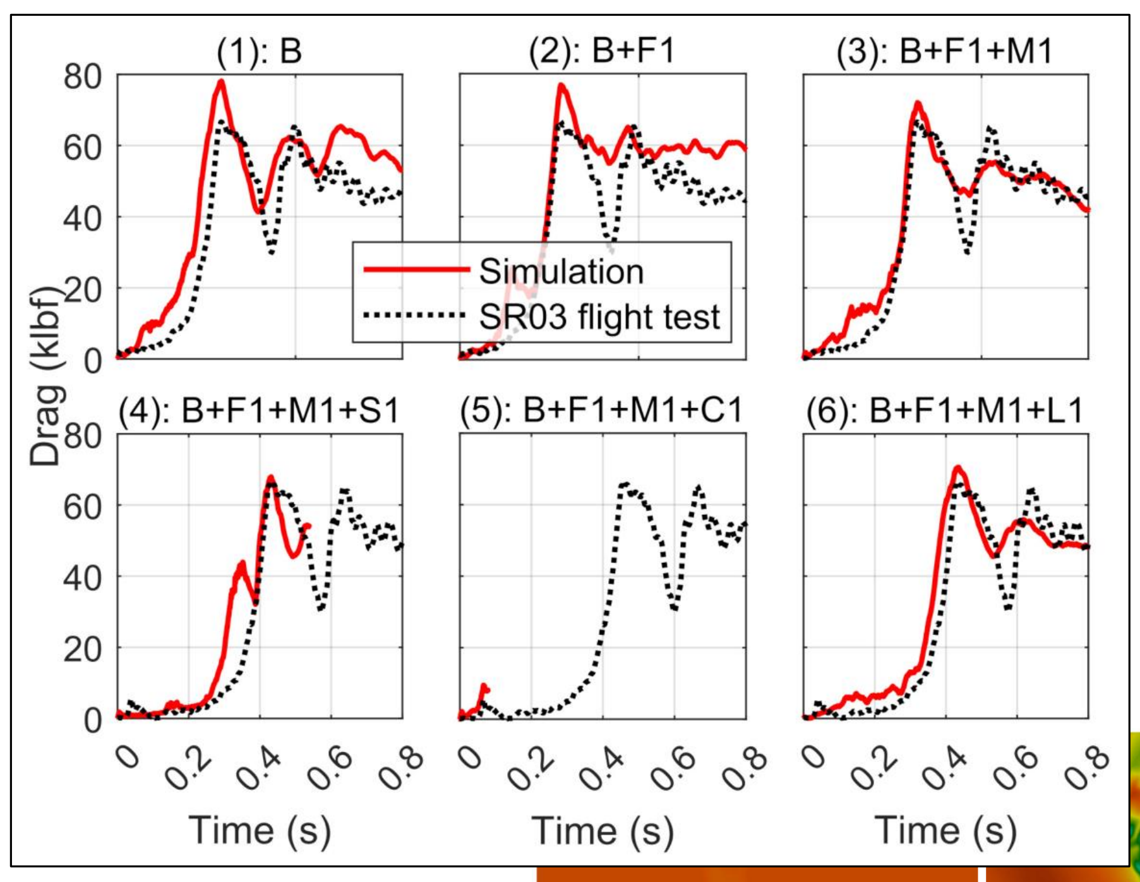
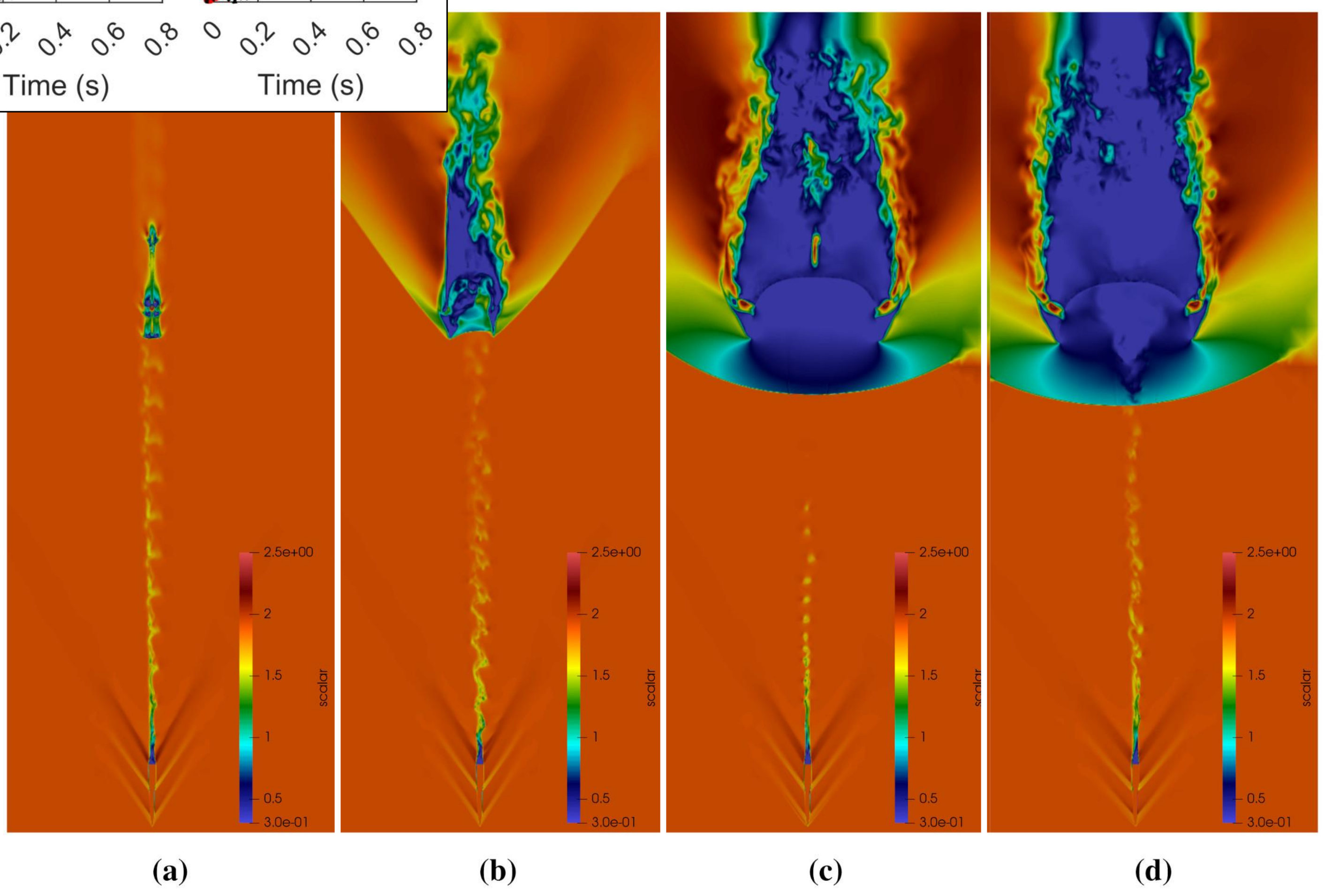


Fig. 3: *Comparison of drag results from simulation to flight experiment for several parameter cases.*

Fig. 4: *Example of Mach number contours for FSI simulation at times a) t=0.05s, b) t=0.2s, c) t=0.4s, and d) t=0.75s after "line stretch" condition used to start simulation.*



Significance/Benefits to JPL and NASA:

A validated FSI computational framework enables JPL to lead missions that use larger and more capable supersonic parachutes, improve our design for future parachutes and other deployable soft goods, and reduce the number of costly flight-like experiments required for future missions. Interaction with Prof. Farhat (a world leader in FSI and computational mechanics) has allowed JPL to continue to increase its ability to accurately model complex physical problems directly related to spacecraft. This partnership will also continue to encourage talented Stanford students to seek careers at JPL.

Acknowledgments:

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Publications:

1. As'ad, F., Avery, P., Farhat, C., Rabinovitch, J., and Lobbia, M., "Validation of a High-Fidelity Supersonic Parachute Inflation Dynamics Model and Best Practice," AIAA 2022-0351
2. Rabinovitcha Comput, J., As'ad, F., Avery, P., Farhat, C., Ataei, N., and Lobbia, M., "Update: Modeling Supersonic Parachute Inflations for Mars Spacecraft," AIAA 2022-2746
3. Lobbia, M., O'Farrell, C., Siegel, K., Leylek, E., Ataei, N., As'ad, F., Farhat, C., and Rabinovitch, J., "Supersonic Parachute Design and Analysis to Support Mars Sample Return," IPPW 2022
4. As'ad, F., Avery, P., Farhat, C., Lobbia, M., Ataei, N., and Rabinovitch, J., "Modeling and Validation of ational Framework for Supersonic Parachute Inflation Dynamics," accepted to AIAA SciTech 2024

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