PILLARS

Plume-deployed Inflatable for Launch and Landing Abrasive Regolith Shielding

California Institute of Technology

OVERVIEW

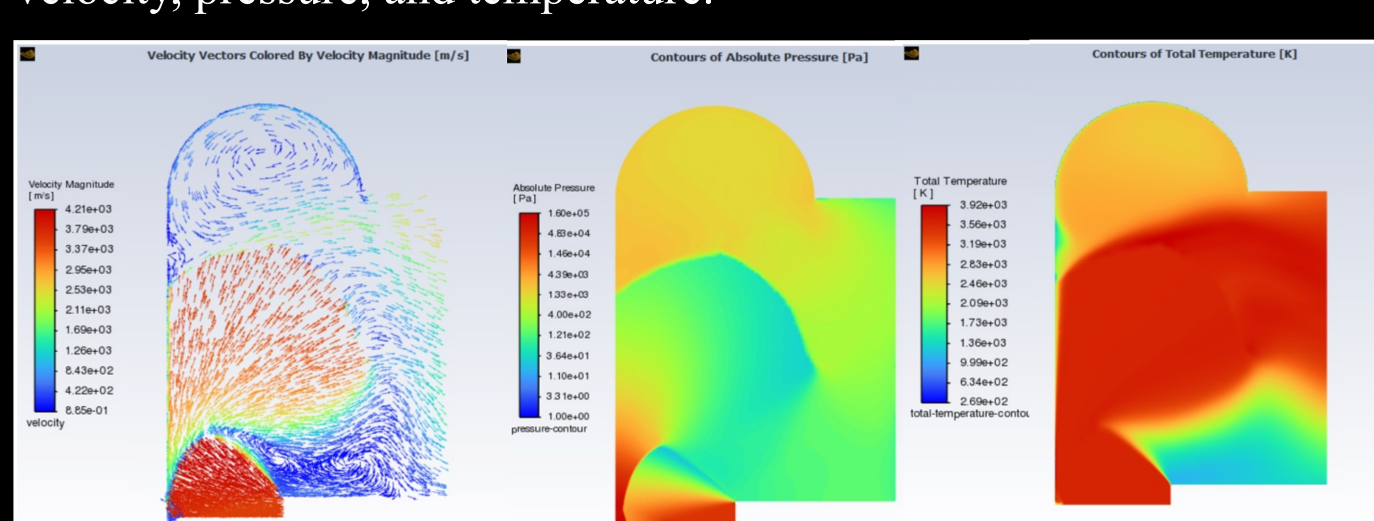
NASA's Artemis missions aim to establish a long-term lunar habitat through a continuous human presence and supporting infrastructure. Resulting landings and launches of heavy-duty landers will generate lunar regolith dust ejecta, impacting nearby infrastructure. To mitigate the damage caused by ejected regolith, we developed PILLARS, a simple, toroidal membrane structure designed to withstand the extreme conditions of direct rocket fire and regolith blasting. The shield is deployed autonomously by a single-use skeletal bladder inflation, and then performs shielding operations passively. Unlike traditional berm solutions, PILLARS lays flat once the plume dissipates, providing easy cargo access. Minimal implementation complexity and cost compared to other solutions make this robust solution significantly more feasible for enabling early infrastructure development. PILLARS provides maximum mass and power savings with a stow volume orders of magnitude smaller than the deployed volume and serves as a long-term dust shielding solution for the lunar surface.

REQUIREMENTS

PILLARS must consider the various environmental and technical challenges. The material needs to withstand the ambient lunar temperature range and radiation environment, high plume temperature and velocity, and high-velocity impacts of sharp regolith and micrometeoroids. It must be stiff enough to maintain the shape of PILLARS when inflated, but also be lightweight to maintain the low-SWaP nature of PILLARS.

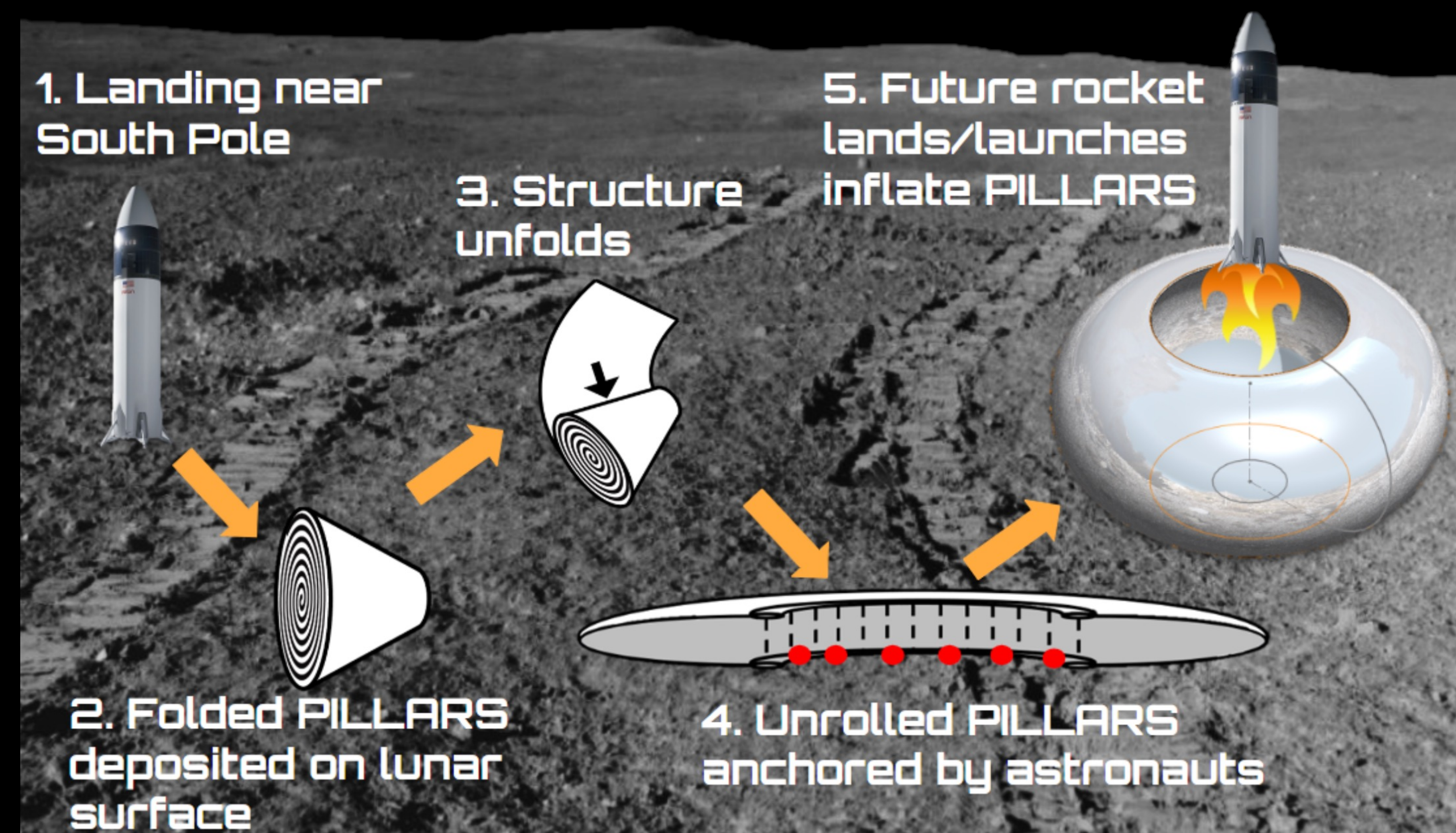
SIMULATIONS

We conducted simulations to balance the trade-off between reliable inflation reduced thermal stresses. Using Ansys, we evaluated pressure and temperature effects on a Kevlar structure at various rocket heights and radii. Shown are visuals for simulations of plume velocity, pressure, and temperature.



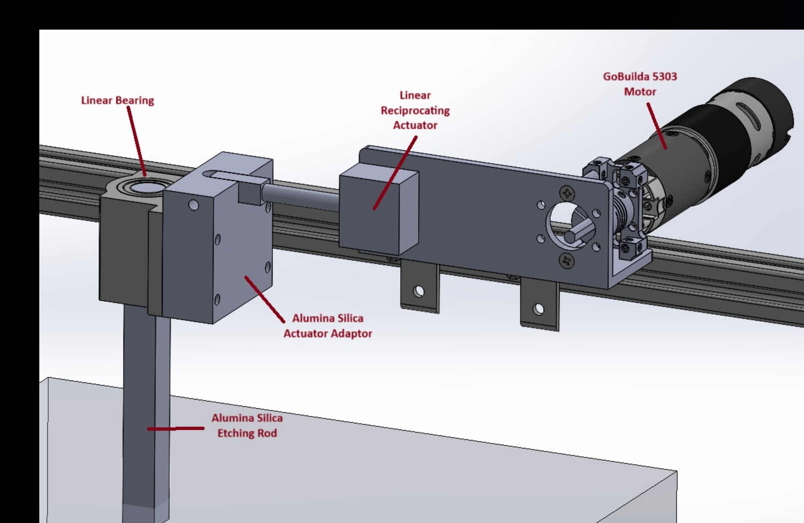
Velocity | Absolute Pressure | Temperature

CONOPS



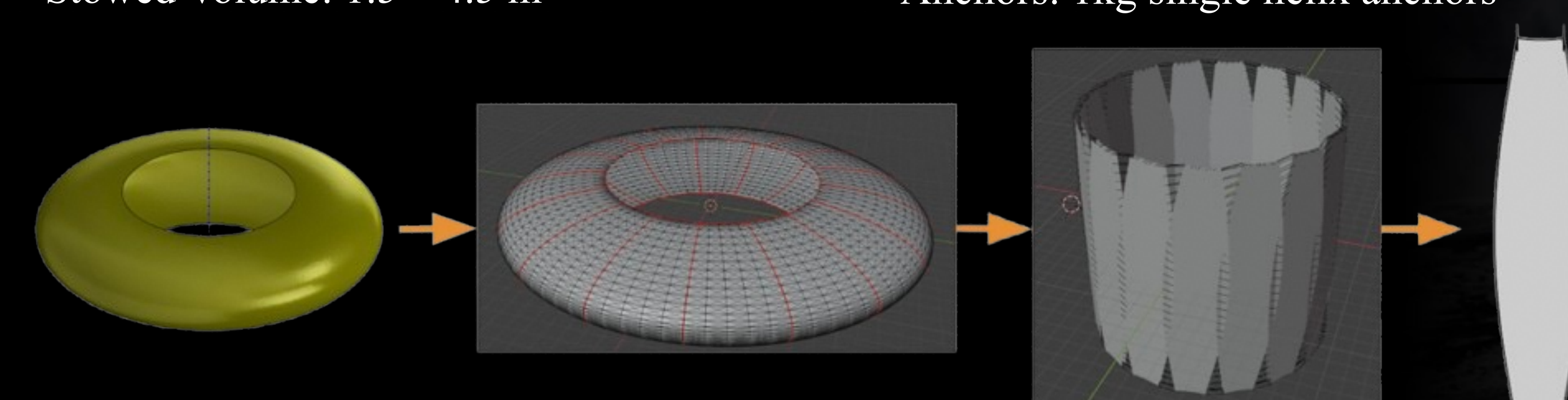
MATERIALS

Significant testing of materials was undergone for abrasion and temperature. Shown to the right is our abrasion testing setup, with an etching rod extending into a furnace holding the sample. This gives us an understanding of the behavior of different materials (mainly Kevlar) under abrasion at high temperatures.



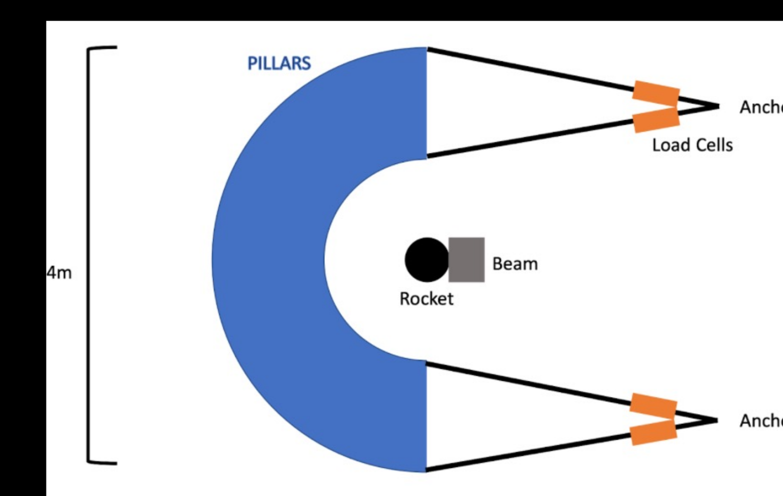
DESIGN

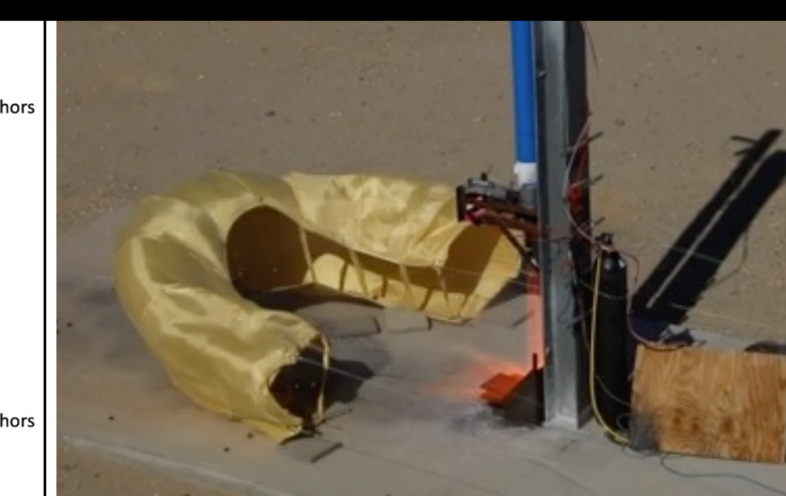
- Rocket Model: SpaceX' Starship
- Inner Diameter: 20 - 40 m
- Outer Diameter: 40 - 80 m
- Stowed Volume: 1.5 – 4.5 m^3
- Deployed Volume: 20,000 - 160,000 m^3
- Mass: 1,800 - 7,200 kg
- Material: Aluminized Kapton Kevlar
- Anchors: 1kg single helix anchors



FIELD TESTING

Diagram and photo of FAR test conducted on August 24, 2024. PILLARS is anchored to two points in the dirt behind the rocket launch pad with in-line load cells to measure tangent force and verify stresses in the shield. PILLARS inflated as expected before the ground anchors were blown away.





Above image created with AI assistance.

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