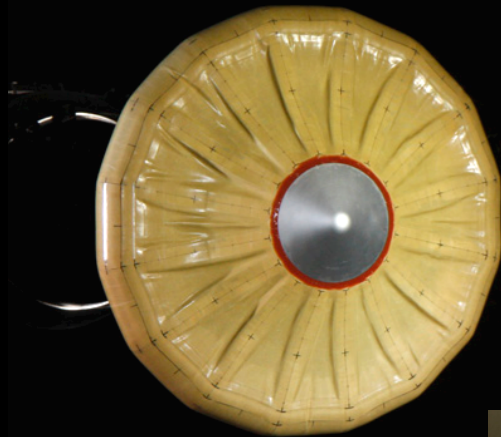


Wind Tunnel Testing of Tension Cone and Isotensoid Inflatable Aerodynamic Decelerators



Juan R. Cruz
Monica F. Hughes
NASA LaRC



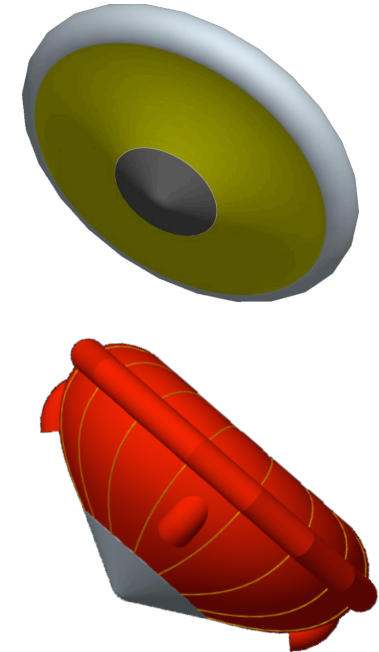
Ian G. Clark
NASA JPL

Christopher L. Tanner
Robert D. Braun
Georgia Tech

Background

Supersonic Inflatable Aerodynamic Decelerators

- Textile drag device
- Intended to be deployed at supersonic speeds ($M < 5$)
 - After peak aeroheating on entry systems
 - Against high dynamic pressure
- Inflated by internal gas generator and/or ram-air pressure
- Numerous configurations have been proposed



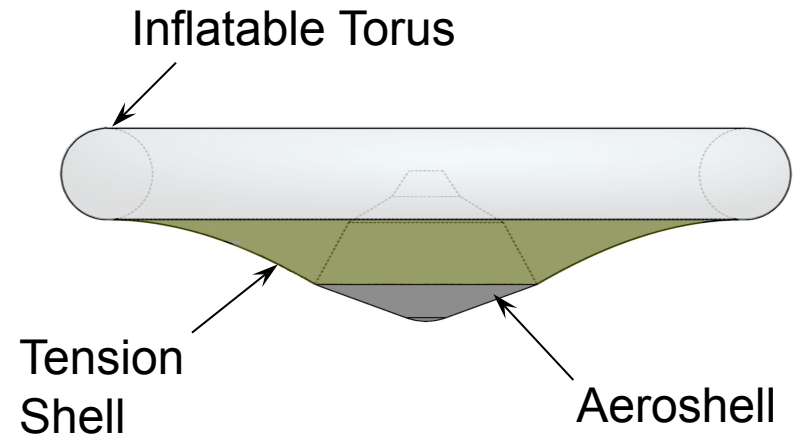
Previous Research

- Basic structural theories (linear) developed in the 1960's
- Some wind tunnel testing at supersonic speeds with rigid and textile models
- Numerous design studies quantifying benefits for EDL of high ballistic coefficient vehicles operating in low-density atmospheres.

Background

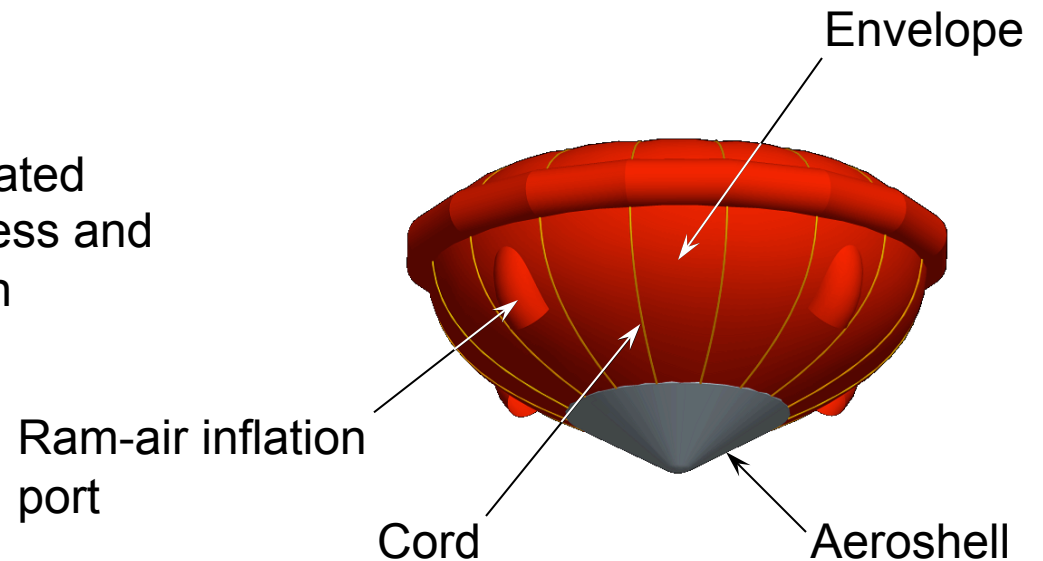
Tension Cone

- Type of IAD consisting of an inflated torus attached to an aeroshell through a single-surface tension shell.
- Inflated by internal gas generators

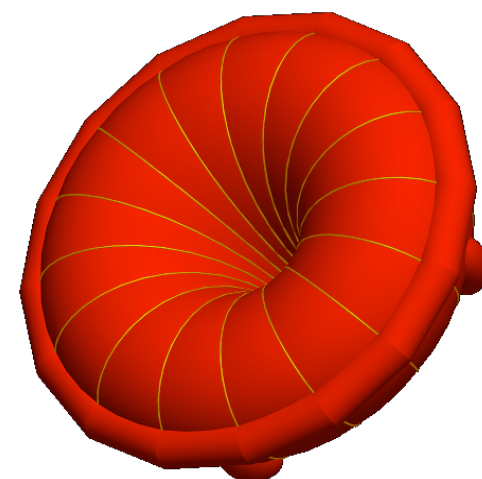
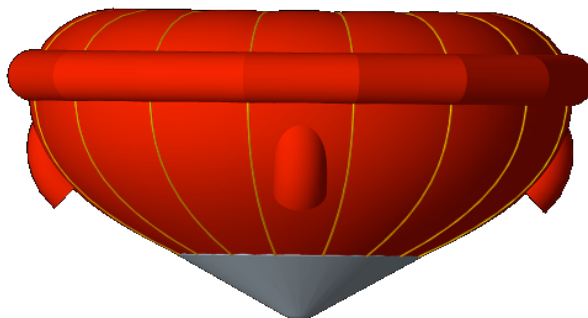
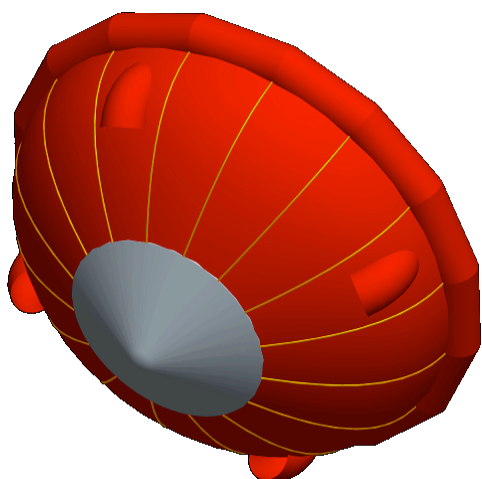
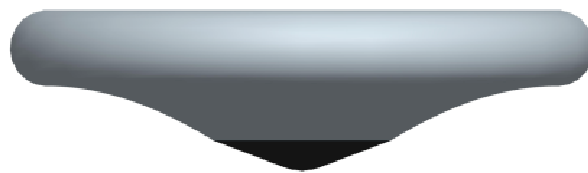
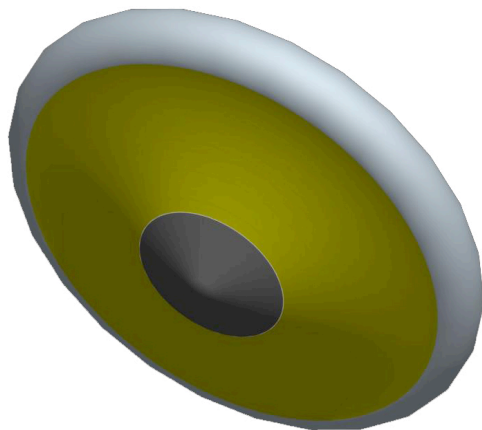


Isotenoid

- Type of IAD consisting of an inflated envelope with uniform fabric stress and constant meridional cord tension
- Ram-air inflated



Background

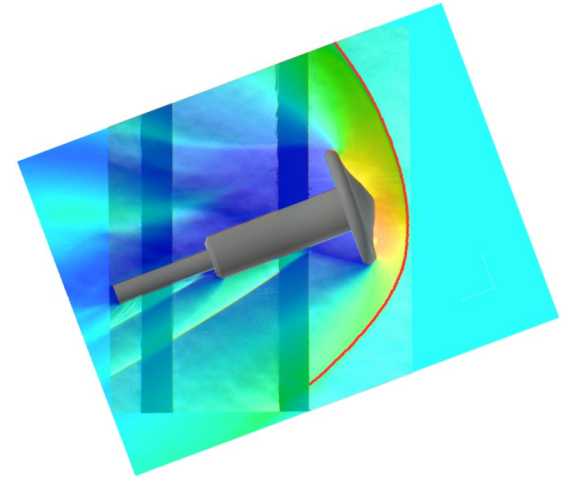


Present Research

Objectives: Characterize the aerodynamic and structural performance of tension cone and isotenoid IADs

Fill in gaps in experimental database

Validate CFD, FEA, and FSI codes for use in the analysis and design of IADs



LaRC Unitary Wind Tunnel Test Program

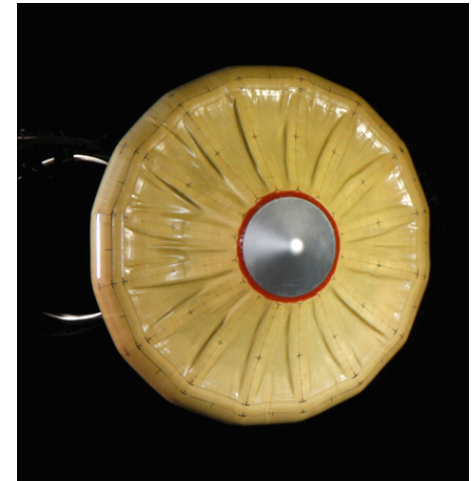
- Tension cone rigid models
- Force/moment and surface pressures
- $1.65 \leq M \leq 4.5$
- Aerodynamic performance
- CFD validation



Present Research

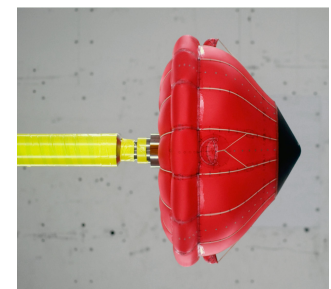
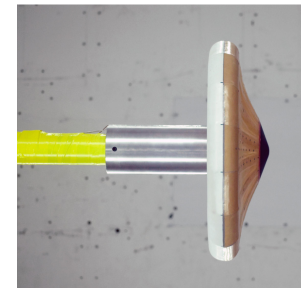
GRC 10- by 10-ft Supersonic Wind Tunnel Test Program

- Tension cone inflatable and semi-rigid models
- Force/moment, deployment, reqd. inflation pressure
- $2.0 \leq M \leq 2.5$
- Aerodynamic and structural performance
- CFD, FEA, and FSI validation



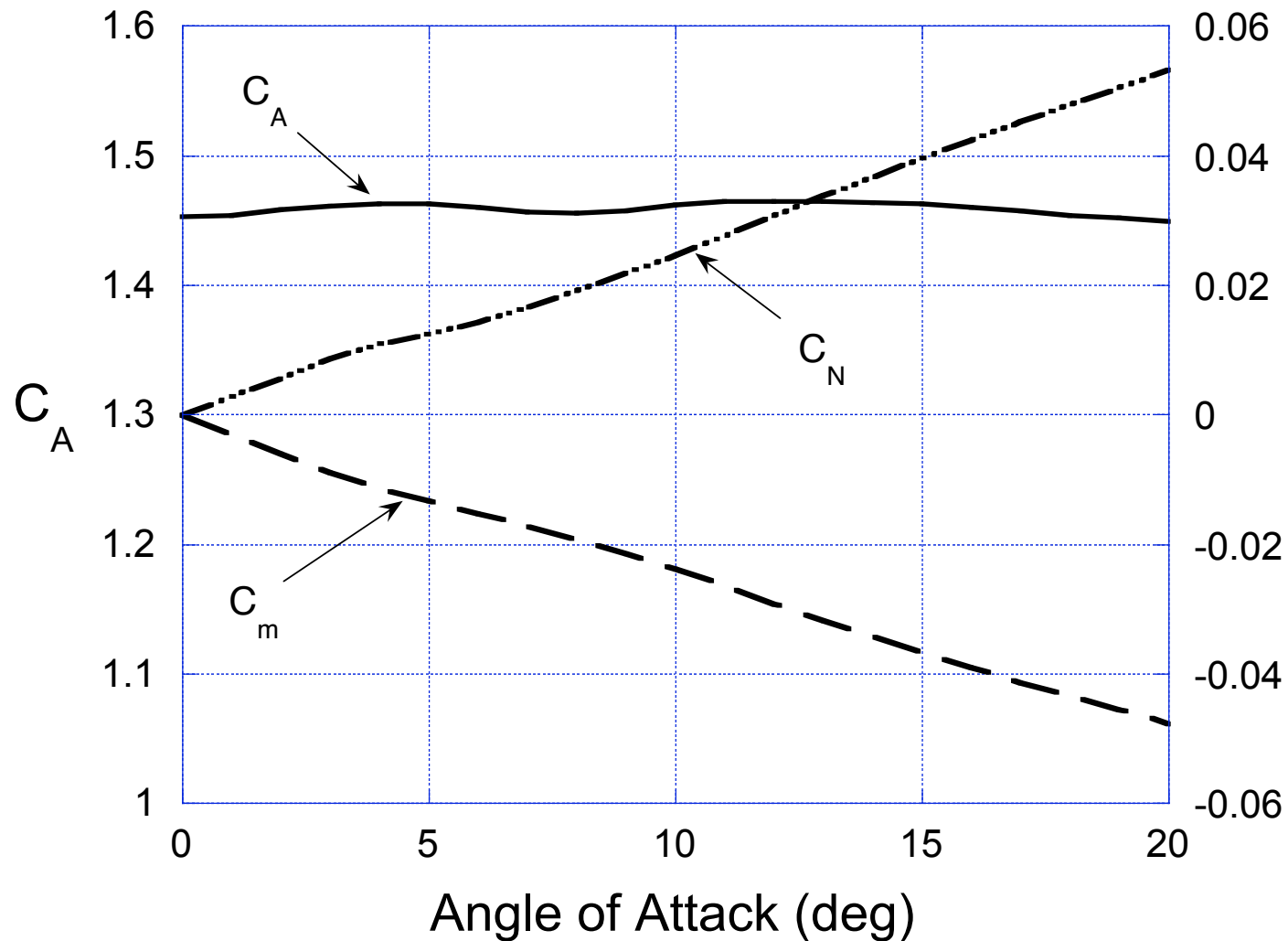
LaRC Transonic Dynamics Tunnel Test Program

- Tension cone semi-rigid models
- Isotenoid inflatable models
- Force/moment
- $0.30 \leq M \leq 1.08$
- Aerodynamic and structural performance
- CFD, FEA, and FSI validation



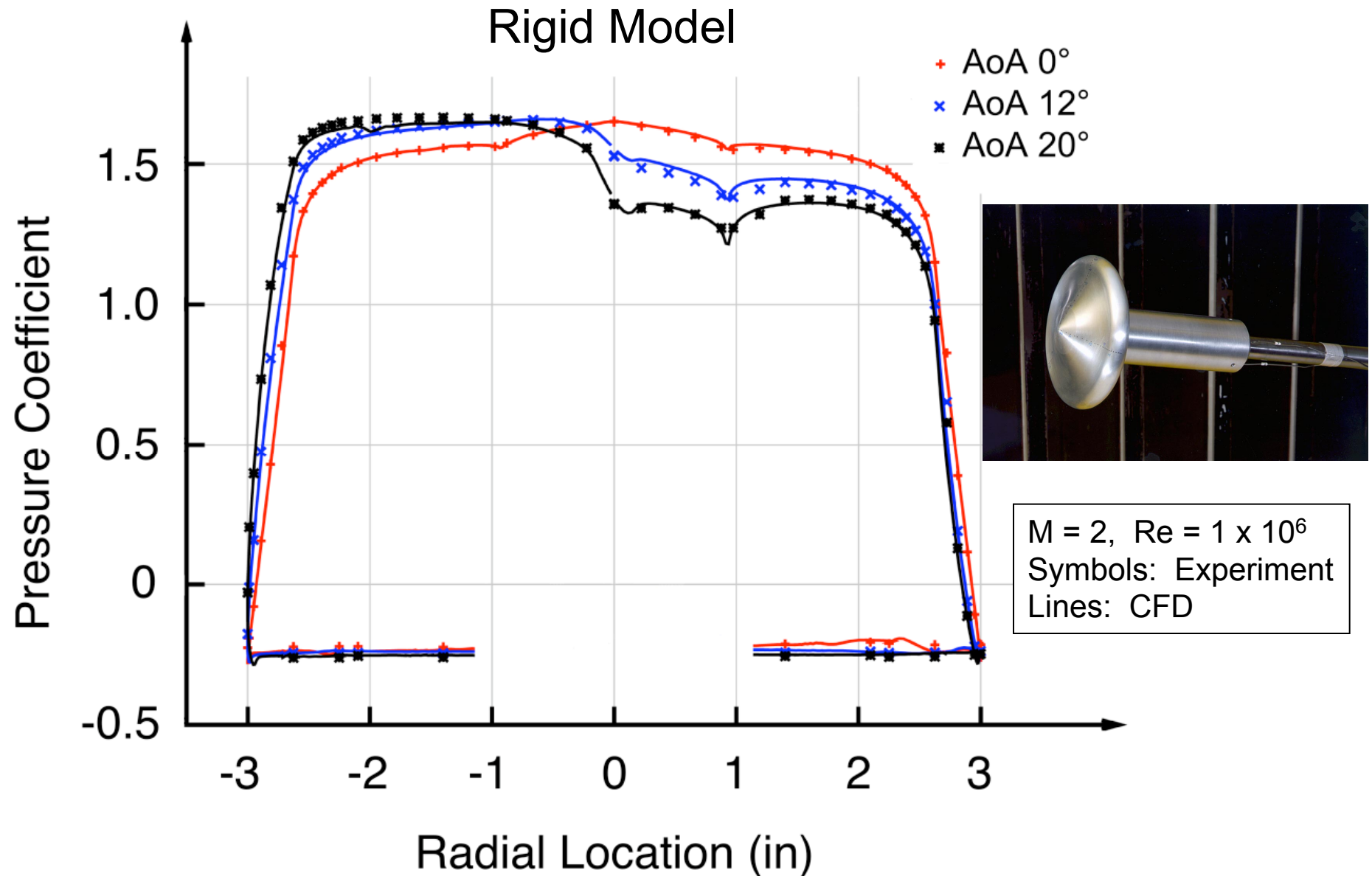
Force and Moment Results

Rigid Model
 $M = 2$, $Re = 1 \times 10^6$



C_N & C_m

Surface Pressures Results



GRC 10- by 10-ft SWT Test Setup

Test Parameters

Mach: 2 to 2.5

AoA: -6° to 18°

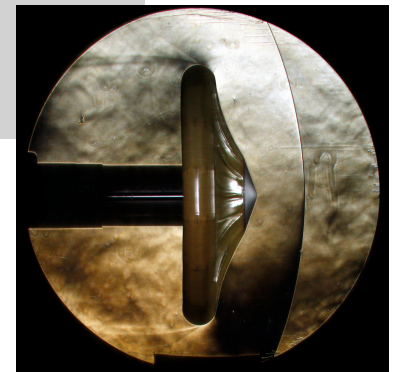
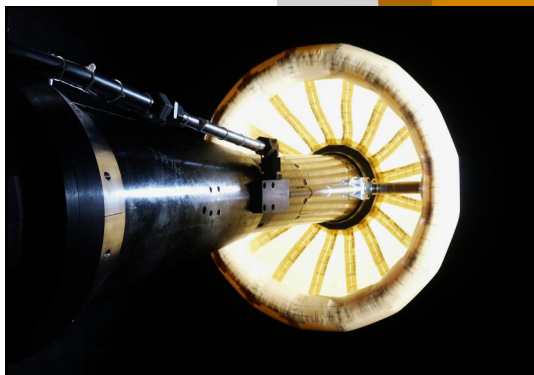
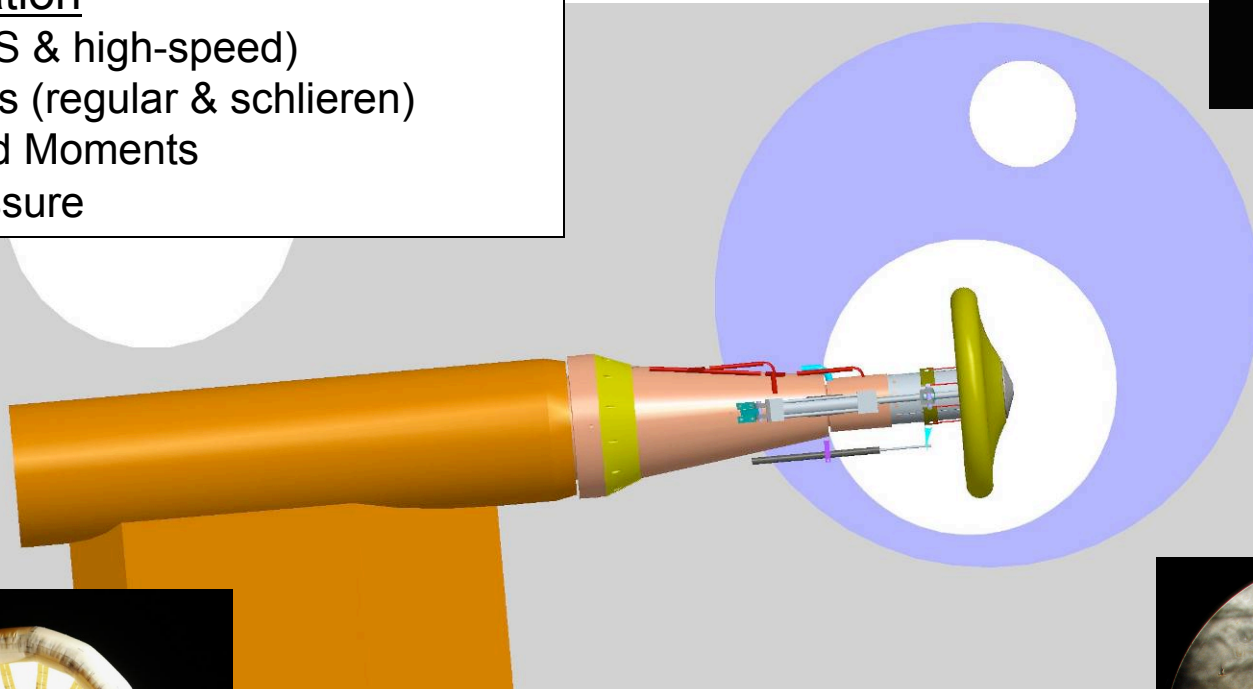
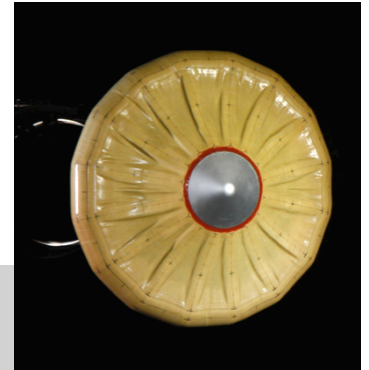
Instrumentation

Video (VHS & high-speed)

Still Images (regular & schlieren)

Forces and Moments

Torus Pressure



Inflation

Inflatable Textile Model

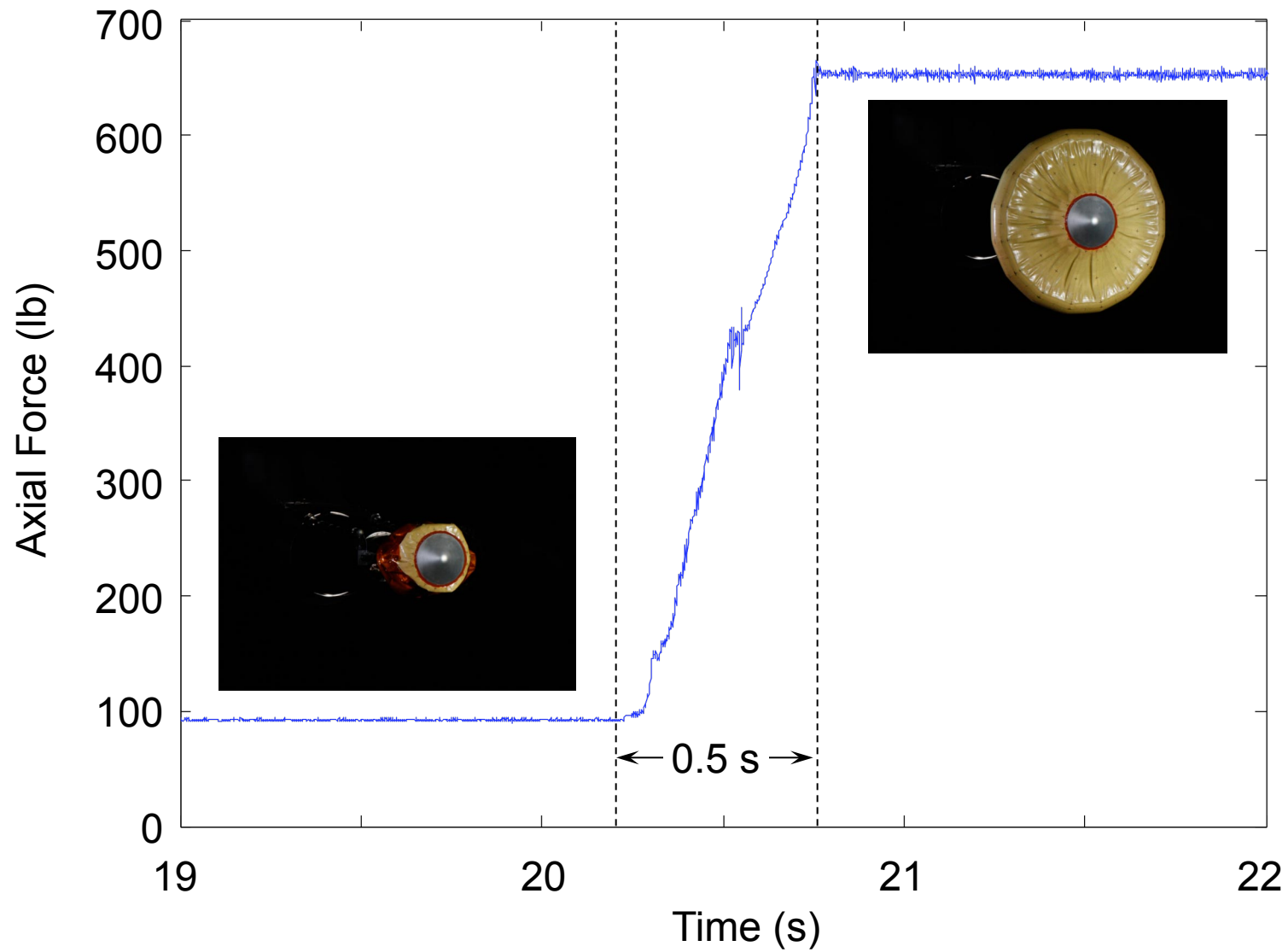


Real-Time Video

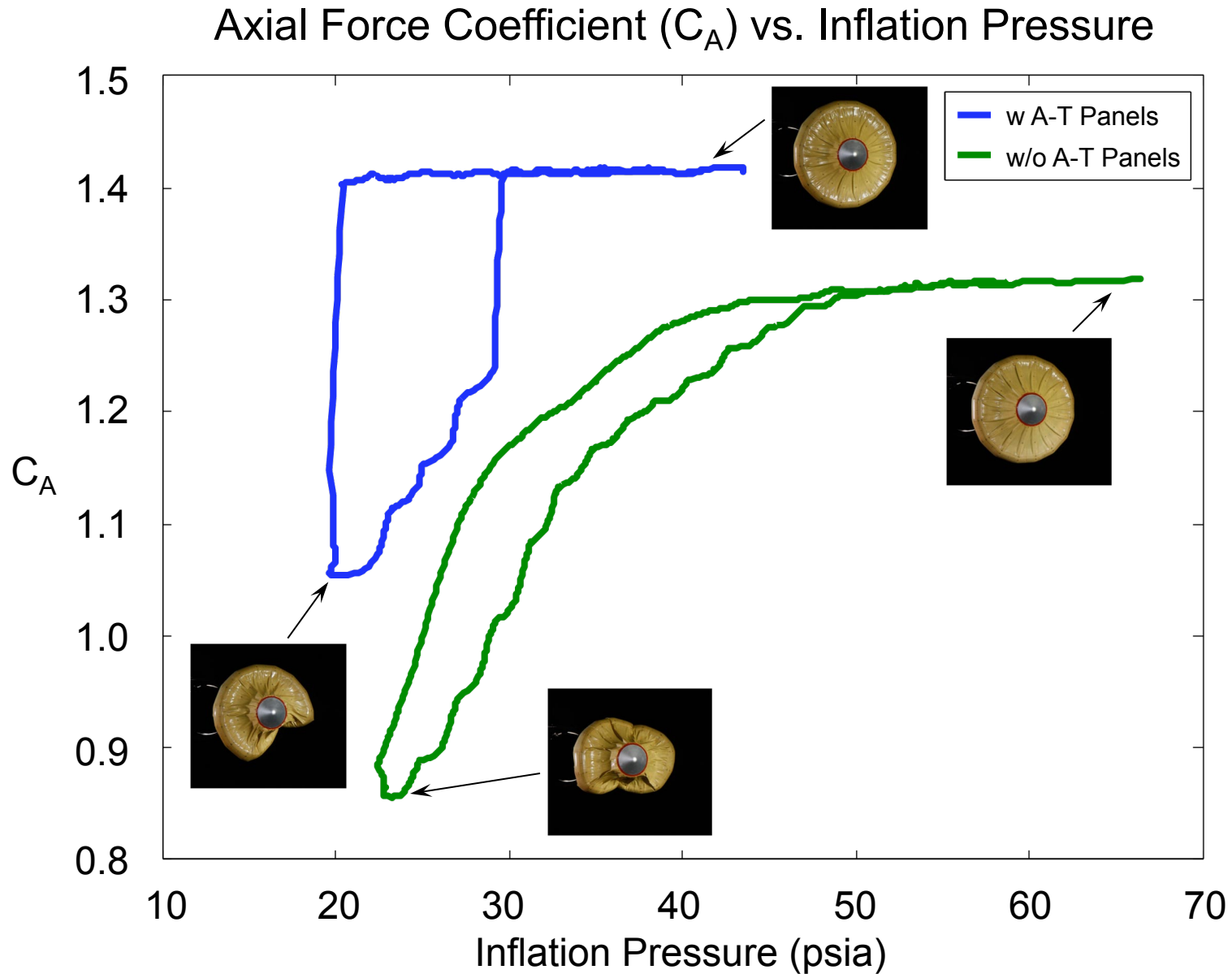


High-Speed Video

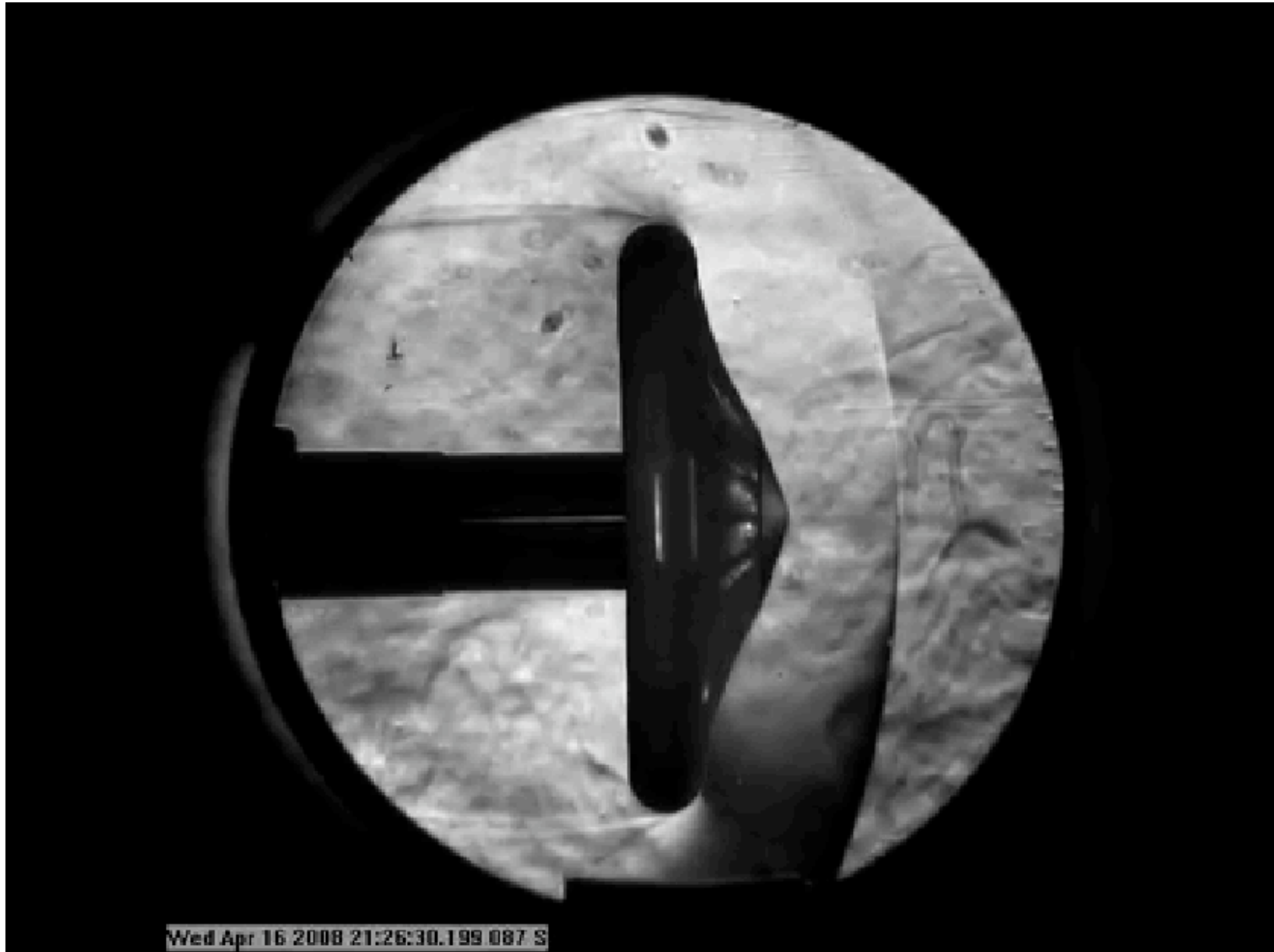
Inflation Force-Time History



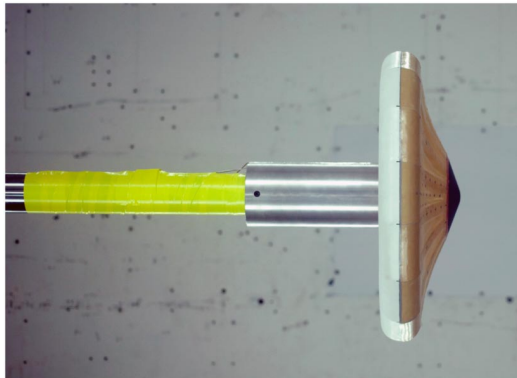
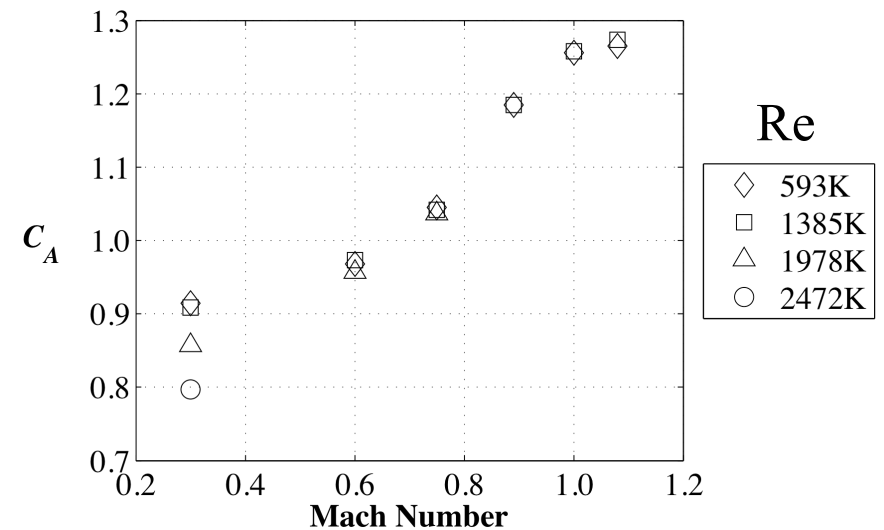
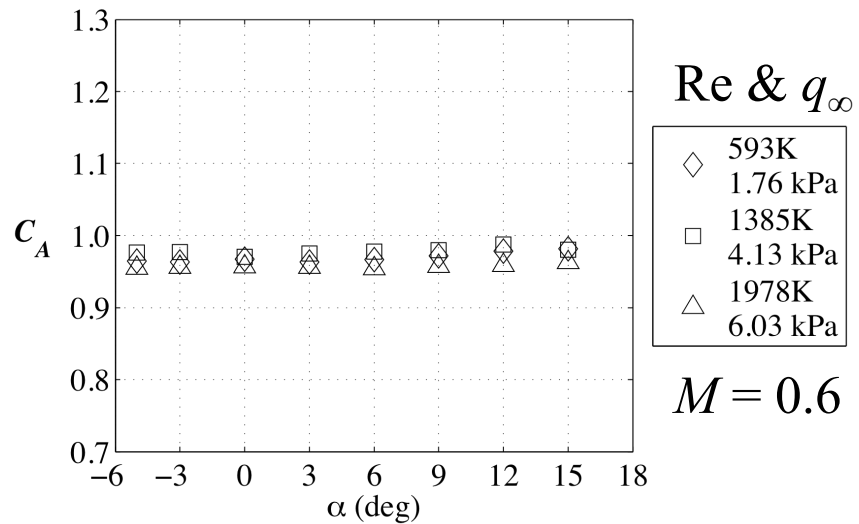
Pressure Sweep: Collapse and Re-Inflation



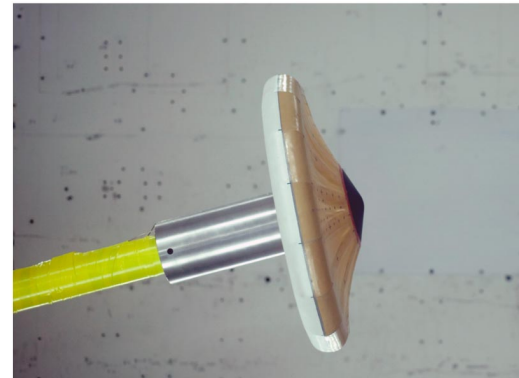
Flow Stability



Tension Cone - Subsonic and Transonic

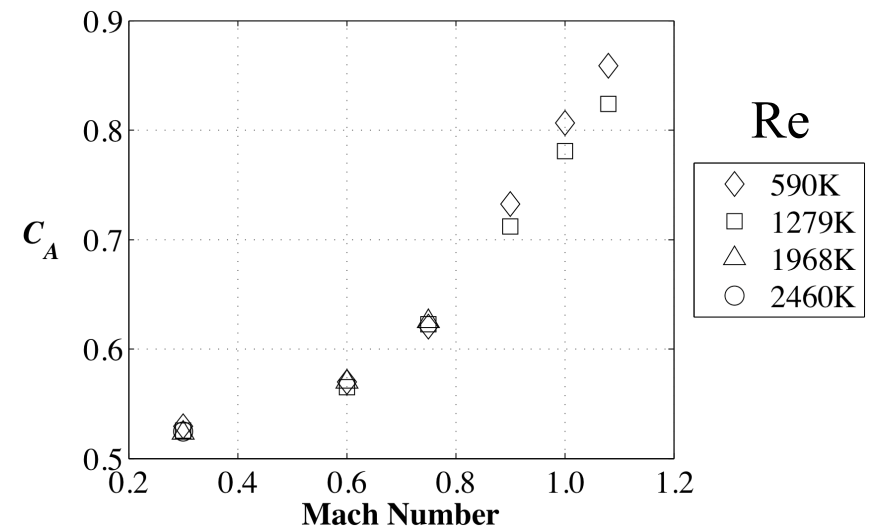
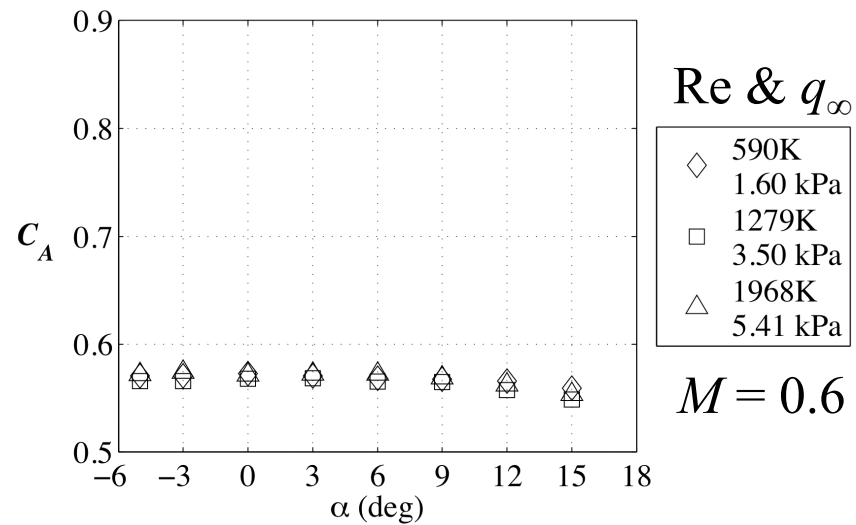


0° AoA

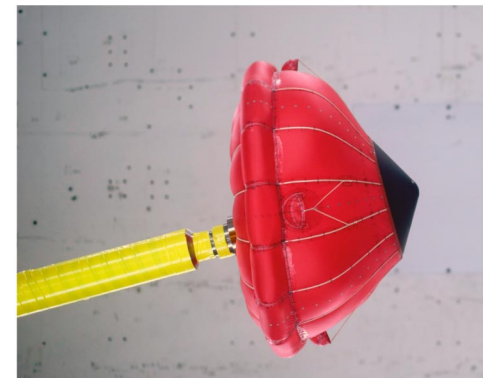


9° AoA

Isotensoid - Subsonic and Transonic



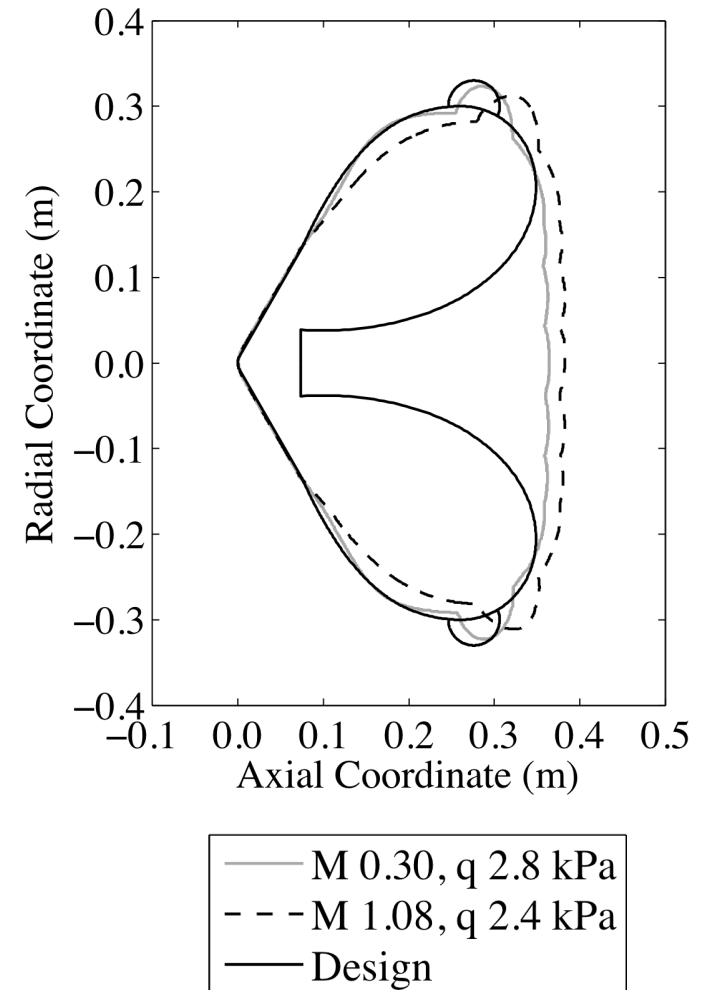
0° AoA



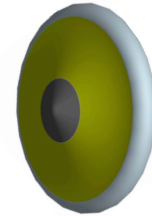
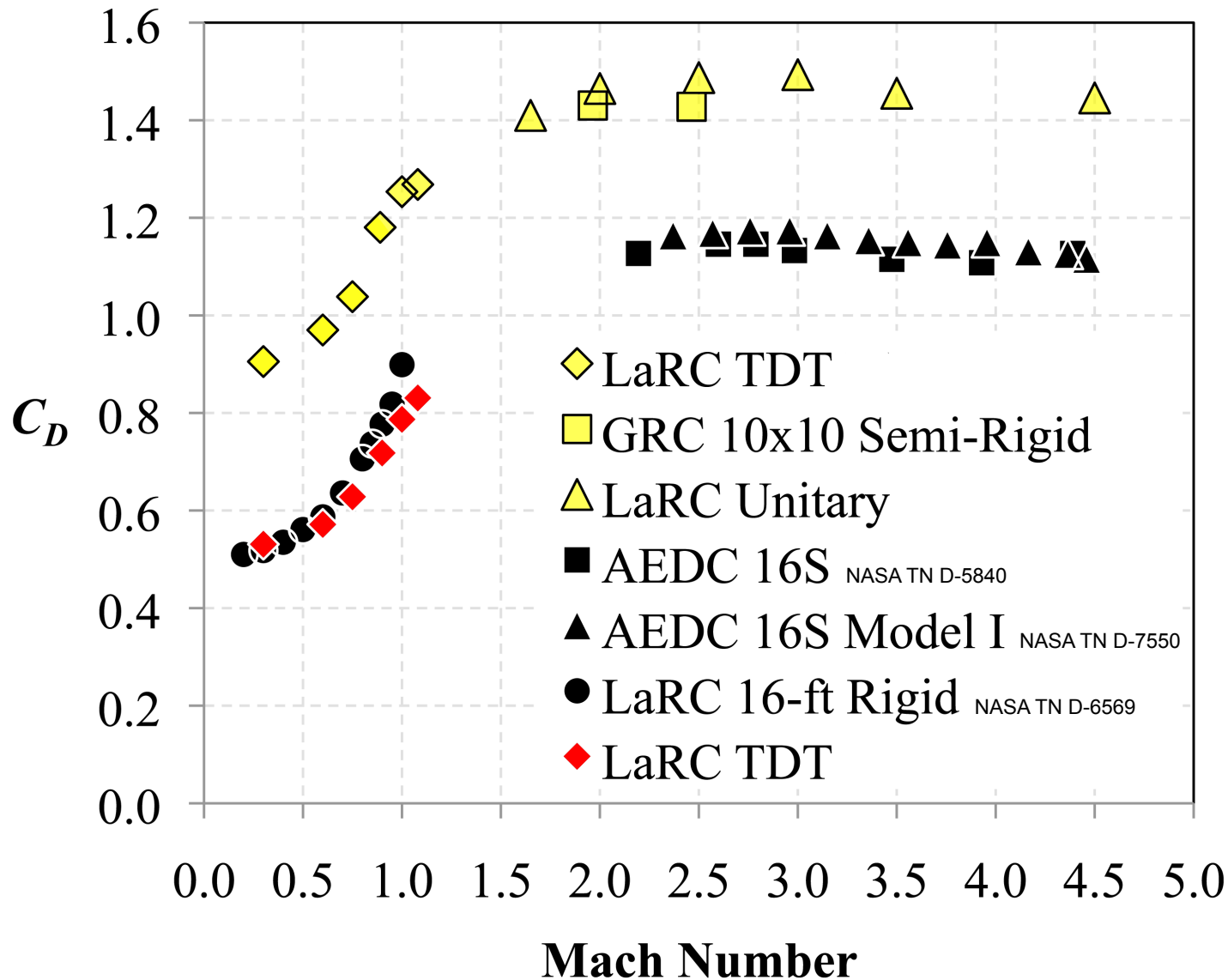
9° AoA

Isotenoid Inflated Shape – Subsonic and Transonic

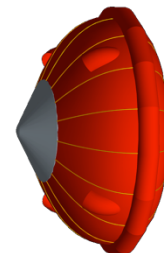
- Profiles extracted from high resolution images
- Isotenoid shape design at supersonic conditions
 - Subsonic shape very close to design shape
 - Transonic shape considerably different than design shape
- Shape is a function of internal pressure, windward pressure distribution, and back pressure



Drag Coefficient Summary



Tension Cone
Yellow Symbols



Isotenoid
Red Symbols

Heritage Data
Black Symbols

References and Contact Information

References

Clark, I. G., Cruz, J. R., Hughes, M. F., Ware, J. S., Madlangbayan, A., and Braun, R. D.: Aerodynamic and Aeroelastic Characteristics of a Tension Cone Inflatable Aerodynamic Decelerator, AIAA Paper 2009-2967, 2009.

Clark, I. G.: Aerodynamic Design, Analysis, and Validation of a Supersonic Inflatable Decelerator, Ph.D. Dissertation, Georgia Institute of Technology, August 2009.

Tanner, C. L., Cruz, J. R., Hughes, M. F., Clark, I. G., and Braun, R. D.: Subsonic and Transonic Wind Tunnel Testing of Two Inflatable Aerodynamic Decelerators, International Planetary Probe Workshop 7, Barcelona, Spain, June 12-18, 2010.

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