10th International Planetary Probe Workshop
San Jose State University, 17th - 21st June 2013

Dual Body Hypersonic Inflatable Decelerator for Atmospheric Entry

Sajjad Reza[1], Suraj Rawal[1], Maxim de Jong[2], Brian Aiken[2], Essam Sheta[3] and Sami Habchi[3]

[1]Lockheed Martin Space Systems Co

[2]Thin Red Line Aerospace

[3]CFD Research Corporation

Hypersonic Inflatable Aerodynamic Decelerator (HIAD) Objectives

NASA has identified the development of Hypersonic Inflatable Aerodynamic Decelerators (HIADs) as core technology for future robotic and human missions

- **Inflatable decelerators** provide increased surface-area footprint, reduced heat flux and induced temperatures, and are stowable in a compact volume within a launch vehicle payload fairing and spacecraft
- **Task Objectives: Develop a Conceptual Design for a 10m diameter HIAD** (NASA sponsored conceptual design development effort*)
  - Address Materials, Structural, Manufacturing, Inflation Pressure, Leakage, Shape Stability, TPS, and Vehicle Integration Aspects
- **Team of Lockheed Martin Space Systems Company, Thin Red Line Aerospace, and CFDRC developed innovative Inflatable Structure (IS) concepts based on an proven Ultra High Performance Vessel (UHPV) design.**
- **The UHPV based design offers low mass, unlimited scalability, design simplicity with reduced manufacturing complexity, and simple integration of flexible TPS. Leveraging developmental hardware validated by test and analysis, UHPV design architecture can produce highly predictable, scalable performance configurations that exhibit stable in-flight performance.**
- **A Dual Body Inflatable structure was developed featuring an annular primary inflatable supporting a secondary sphere cone inflatable.** The higher pressure annular structure (~5 psi /35kPa) provides a large diameter footprint for the lower pressure (~1.5 psi, 10.3kPA) sphere cone's secondary volume that is the primary drag surface.
- **This poster presents an overview of the "Dual body" HIAD design concept, and its key advantages for use as part of a planetary entry system.**

HIAD Configuration Evaluation Metrics
- Drag performance
- Aerodynamic stability/off-axis performance
- Body Flex/shape deformation
- Scalability/Performance predictability
- Mass efficiency/specific stiffness
- Manufacturing complexity
- Vehicle and TPS attachment
- Inflation pressure/leakage
- Vehicle integration

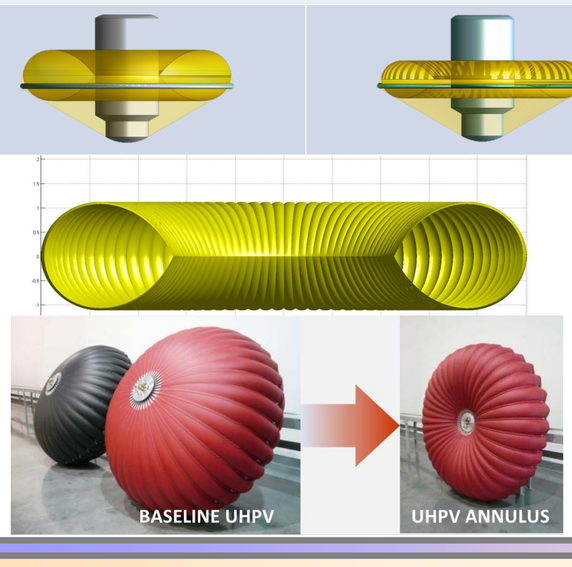
Configurations Capable of Producing 60°Sphere Cone
- Tension Cone
- Stacked Torus
- Isotensoid
- **Oblate Spheroid (UHPV)**

Oblate Spheroid (UHPV) Downselection: Key Attributes
- Highest **mass efficiency**
- **Scalable, predictable performance**
- **Minimum leakage** due to planar seams, low pressurization levels and low surface area to volume ratio
- **Low inflation pressure** requirements based on test and analysis results
- Planar 2D construction results in **simplistic fabrication methods** without complex tooling fixtures
- Accurate control of tendon length assures accurate inflated geometry
- **All seals are planar**
- Tendons facilitate **ease of attachment to vehicle structure and TPS**
- **Architectural diversity**: including bi-conic and asymmetrical geometries

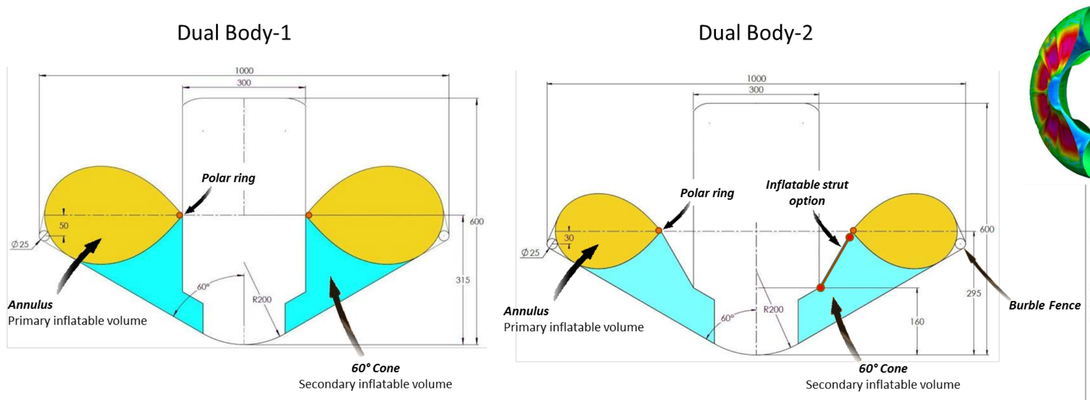
10m Dual Body (DB) Ultra-High Performance Vessel (UHPV) HIAD

- **Annulus ring Primary Volume**
- **CONIC Secondary Volume**
- **DB1 and DB2 Configurations**

UHPV Dual Body 1	UHPV Dual Body 2
Advantages: • Benefits from limited Centerbody contact to couple Sphere Cone and Centerbody orientation; also minimizing body flex • Design simplicity • Off-axis stability	***Advantages:*** • No contact with payload Centerbody • High aspect ratio annulus reduces volume and mass and improves aft geometry • Annulus ID and volume can be modified to optimize mass, stiffness, and drag effect
Disadvantages: • Centerbody contact considerations • Larger volume and mass than Dual Body 2	***Disadvantages:*** • Potential requirement of **deployment assist mechanisms!**



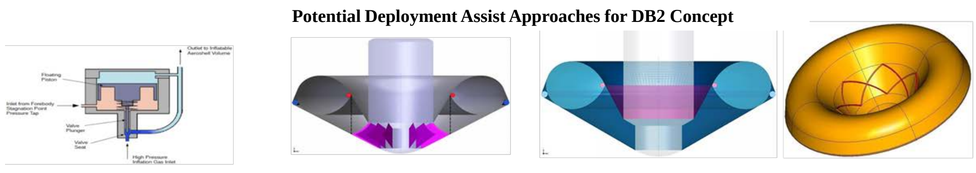
Meridional tendons enveloping oversized gas barrier externally reinforced with robust carrier fabric



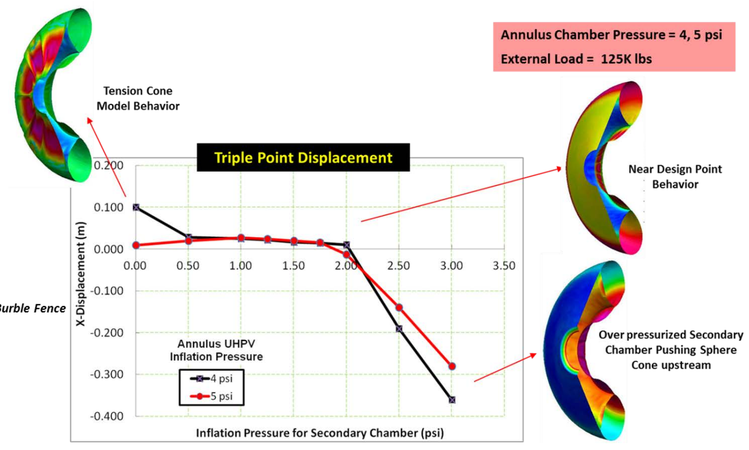
Low Mass, Scalable, Planar Construction, Structural Determinism, High Drag

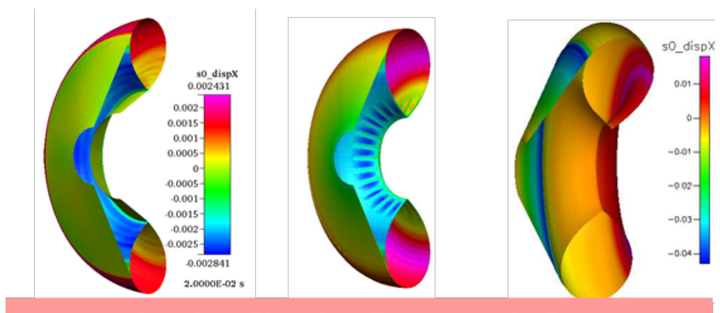
Model Description	Cd (Perfect Gas)	Cd (Finite Rate Chemistry)
UHPV Dual Body 1	1.466	1.512
UHPV Dual Body 2	1.467	1.512
IRVE-3	1.465	1.505

Potential Deployment Assist Approaches for DB2 Concept



Pressure Analysis @ 125k lbs External Load Low Inflation pressures

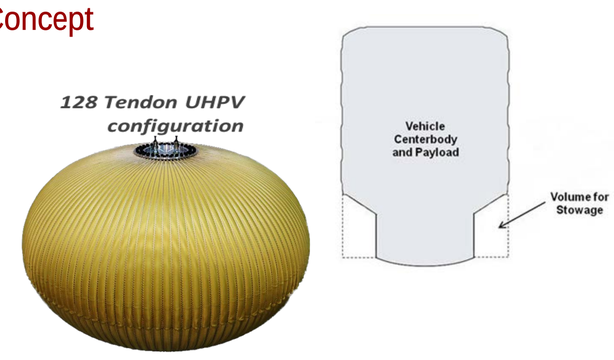


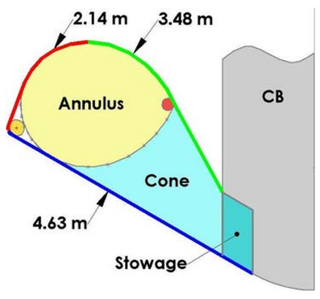


Annulus Chamber Pressure: 4 - 5 psi
Secondary Chamber Pressure = 1.0 - 1.5 psi

Packaging/Stowage & Materials

- ✓ Robust Simple Stowage & Packing Concept
- ✓ Proven Packing Methods
- ✓ Packing Density > 200 kg/m³
- ✓ Packing Volume < 3.95 to 4.09 m³





CARRIER STRUCTURE
Kevlar® variant (250°C class HIAD)
PBO (Zylon® 300 and 400°C class)

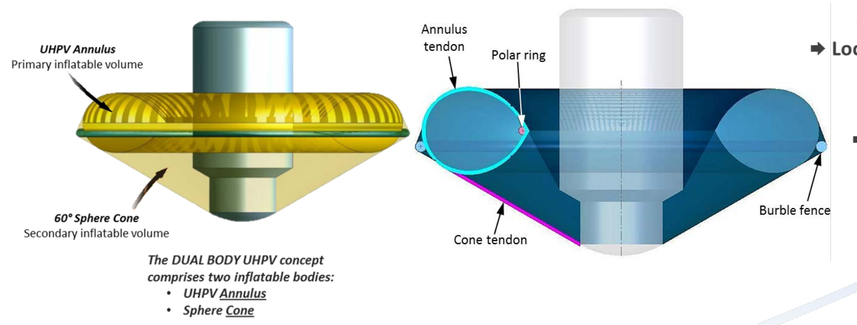
PRESSURE RESTRAINT TENDONS
Aramid (250°C class HIAD)
PBO (Zylon® 300 and 400°C class)

KAPTON FILM GAS BARRIER

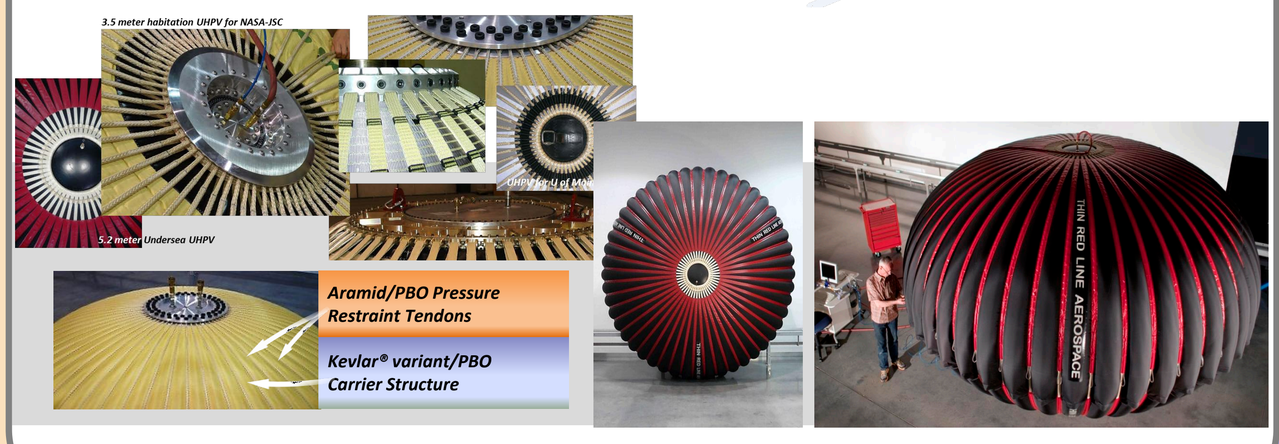
Structure/Centerbody Interface

- ✓ Tendons carry most load through anchor bolts
- ✓ Proven UHPV Interfaces
- ✓ Simple HIAD interface to rigid nose
- ✓ No Complex Straps or deployment mechanisms
- ✓ Seamless Transition from Flexible to Rigid Nose

DUAL BODY I.S
=
TENDON ARRAY
➡ Global pressure and dynamic load restraint
+
CARRIER STRUCTURE
➡ Local loads between tendons
+
BLADDER
➡ inflation gas barrier



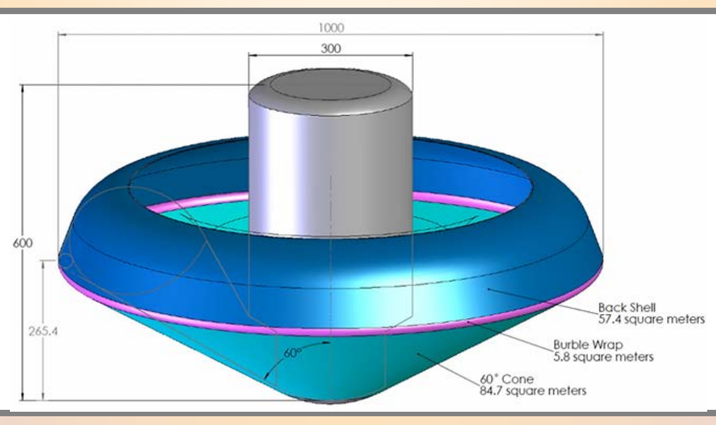
The DUAL BODY UHPV concept comprises two inflatable bodies:
- *UHPV Annulus*
- *Sphere Cone*



5.2 meter diameter UHPV baseline architecture

CONCLUSION & OUTLOOK

Developed Innovative Dual Body (DB) Design Configuration based on Ultra High Performance Pressure Vessel (UHPV)
- Low Mass, Minimal Parts Count, High Specific Stiffness
- Low Inflation Pressure, Minimum Leakage
- Analytically Predictable, Shape Stable Envelope
- Developed Approaches for Centerbody Interface, Stowage, Packaging, inflation, and TPS Integration
- Future Construction of 10m Diameter Test Model



Successful Development of 10 meter DB UHPV Design Concept for Potential HIAD Applications
- Design & Fabrication Simplicity, Planar Construction
- Ease of Scalability and Improved Packaged Density
- Amenable to Innovative Mission Configurations with Versatile Tendon-based, Hard-point Systems Integration
- UHPV-based architecture capable of multiple, structurally divergent Inflation Envelopes