HIAD INFLATABLE STRUCTURE DESIGN AND PROTOTYPE DEVELOPMENT FOR THE EFESTO PROJECT

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The thin blue line of Earth's atmosphere photographed from ISS. *NASA image.*

HIAD – Hypersonic Inflatable Aerodynamic Decelerator

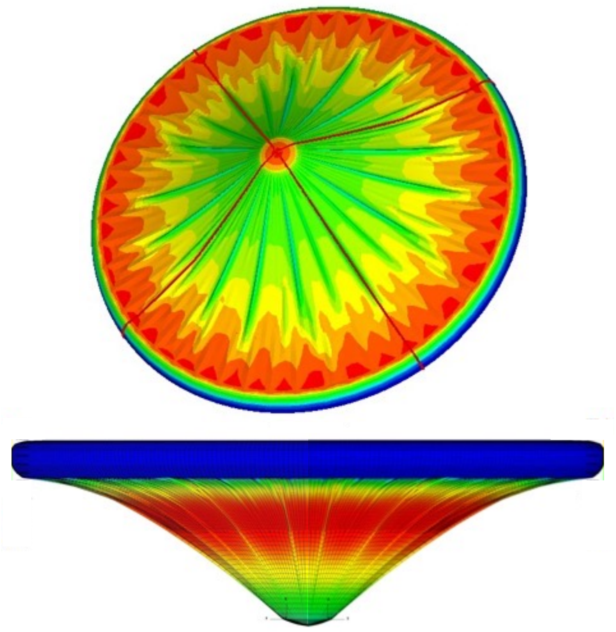
WE NEED…

VERY BIG DECELERATORS to accommodate atmospheric entry of BIG PAYLOADS

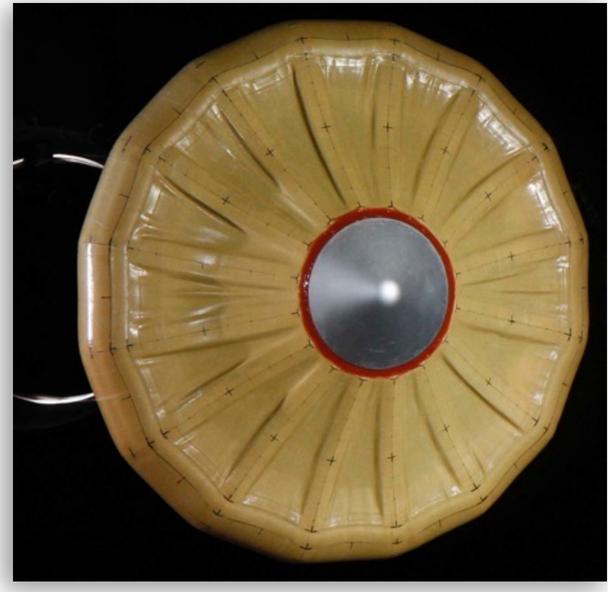
—VASTLY LARGER DIMENSIONS THAN LAUNCH VEHICLE PAYLOAD FAIRINGS CAN PROVIDE…

- To create the requisite drag, IAD's must present unprecedented frontal area
- But they also need to package small and weigh as little as absolutely possible, yet be immensely stiff and robust
- The IAD shall be scalable–with performance that can be characterized using analysis and subscale test articles
- We need to be able to build the design—and build it reproducibly, without compromising the predictive attributes

- Inflatable decelerator architectures have been investigated for six decades.
- Configurations abound—each with conspicuous benefits—and drawbacks
- Of these, perhaps the most appealing is the simple Tension Cone—using a single inflatable torus to define the decelerator drag "footprint" and support a conic fabric membrane



Analysis Graphics courtesy *Reuben Rohrschneider*. "Variable-fidelity hypersonic aeroelastic analysis of thin-film ballutes for aerocapture"

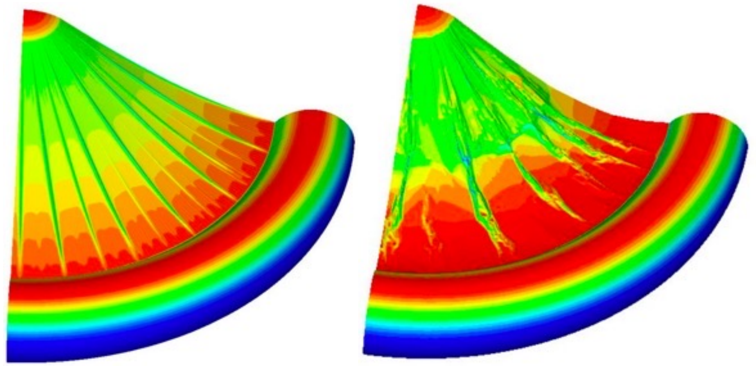


Courtesy Ian Clark. *Aerodynamic design, analysis, and validation of a supersonic inflatable decelerator.* 2009

HIAD – Where do we stand?

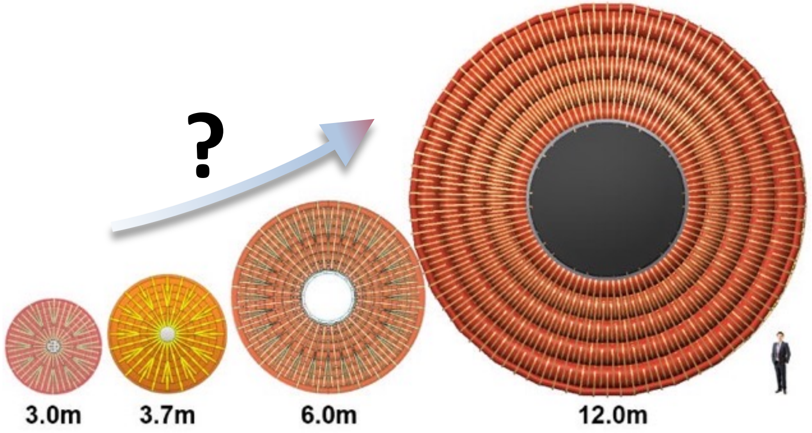
Despite its geometric simplicity, ***stable inflatable torus architecture is notoriously challenging to develop*** due to complex geometric instabilities

Furthermore, ***due largely to indeterminate global "cupping" and wrinkling of the fabric cone***, the Tension Cone falls prey to embedded shock formation, dynamic oscillations, and heating indeterminacy



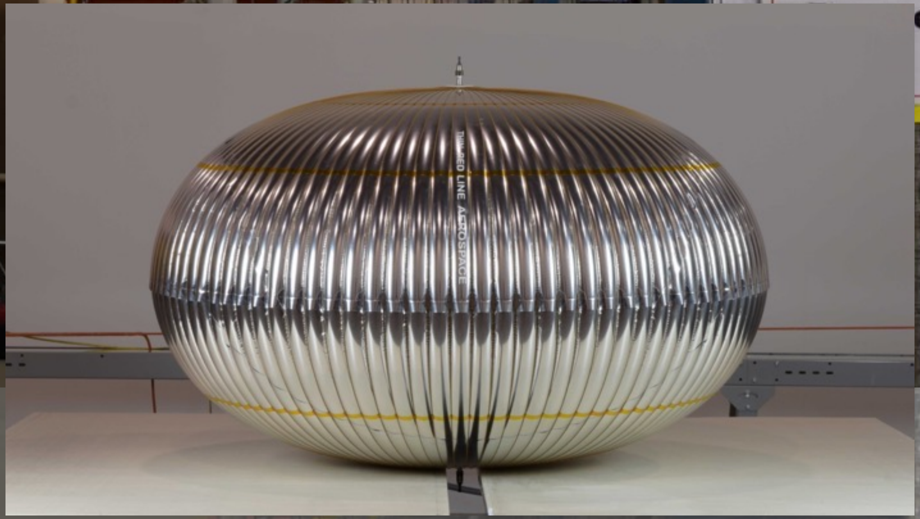
NASA's Stacked Torus HIAD solved the two big Tension Cone problems:

1. ***Buckling was eliminated*** by stacking a family of interconnected concentric tori
2. The torus stack provides a conic substrate that ***eliminated global TPS "cupping"***



The potential alternate HIAD architecture described in the following slides seeks architectural simplification through structural determinism and the uncoupling of primary load-bearing structures

Thin Red Line UHPV* Inflatable Architecture

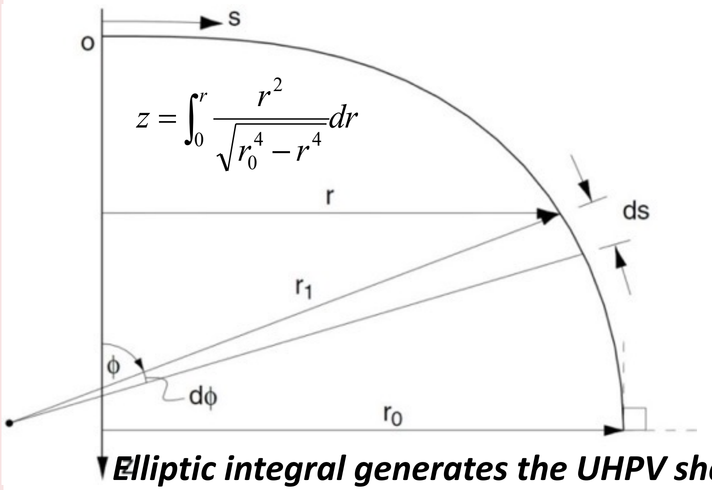


* Ultra High-Performance Vessel

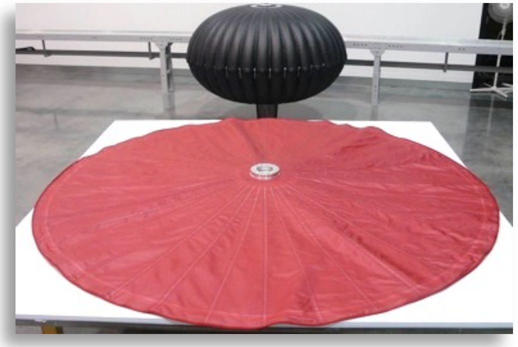
“LISA” INFLATABLE AIRLOCK

UHPV Inflatable Architecture Attributes

- Minimum Mass option
- Scalable & Structurally Determinate
- Packaged volume is an absolute minimum
- 3-D geometry to be constructed as a single, planar envelope: Problems associated with conventional, gore-based construction of 3-D fabric shells are eliminated

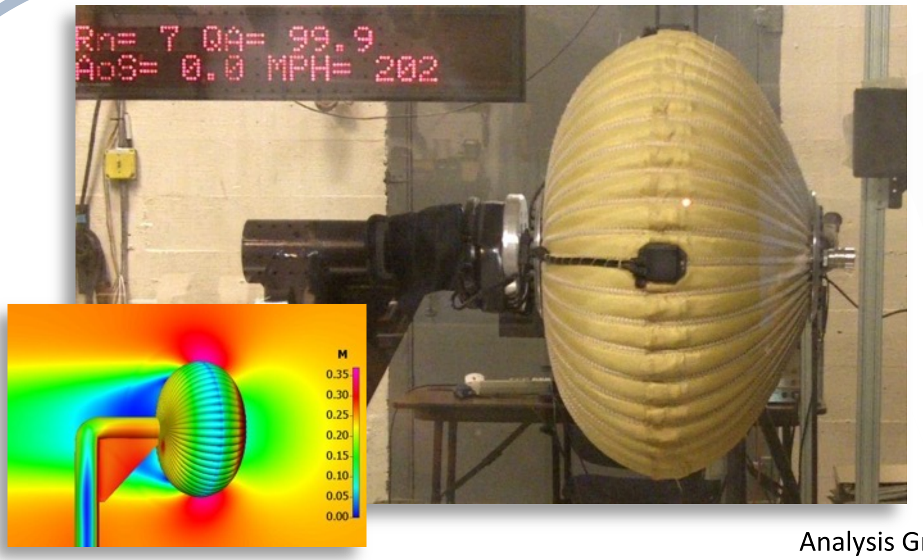


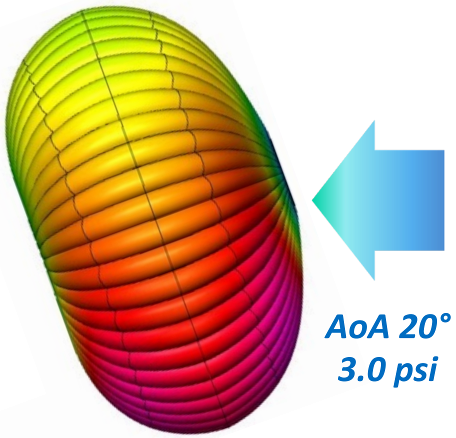
Elliptic integral generates the UHPV shape



Planar fabrication

UHPV also presents *remarkable* resistance to deflection…





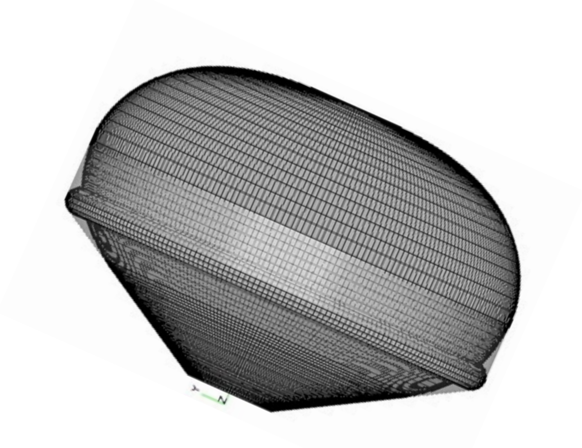
Analysis Graphics courtesy *CFD Research Corp*.

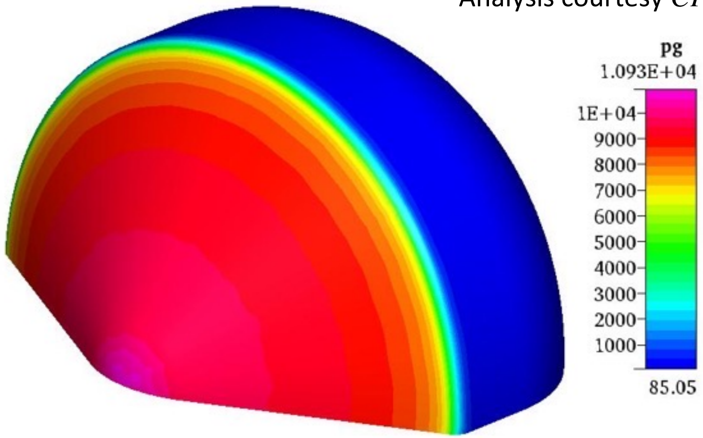
Single-Body UHPV Sphere-Cone

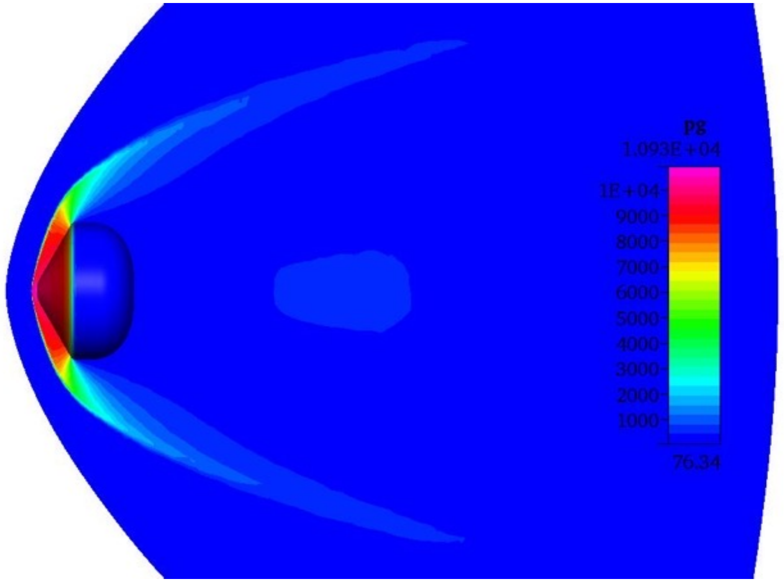
HIAD TYPE	C_D VALUE
Thin Red Line SINGLE BODY Sphere-Cone	1.432
NASA IRVE-2	1.382
NASA IRVE-3	1.472

The Single Body Sphere-Cone's distinctive frontal surface geometry is readily obtained by manipulation of a baseline UHPV through adjustment of the lengths of circumferential tendons

Analysis courtesy *CFD Research Corp*.







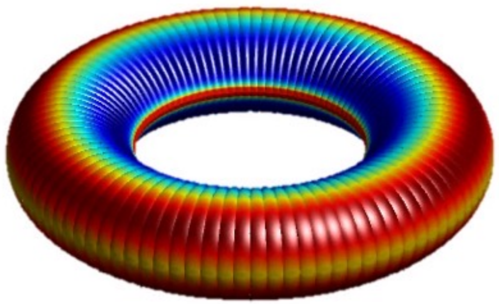
Even with very low 2 to 3 psig (14 to 21 kPa) inflation pressure, analysis shows promising CD values

Thin Red Line ***Dual-Body*** IAD

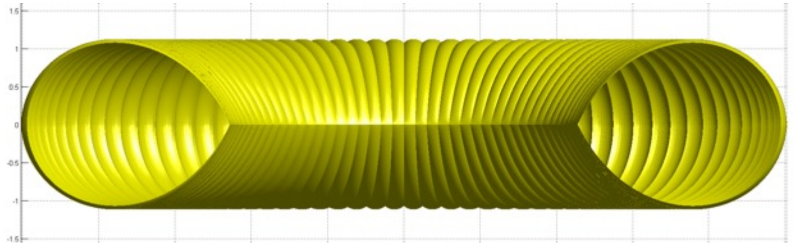
Dual Body **Inflatable Architecture =**

Large diameter <u>UHPV Toroidal Annulus</u> supporting a <u>Conic Volume</u>

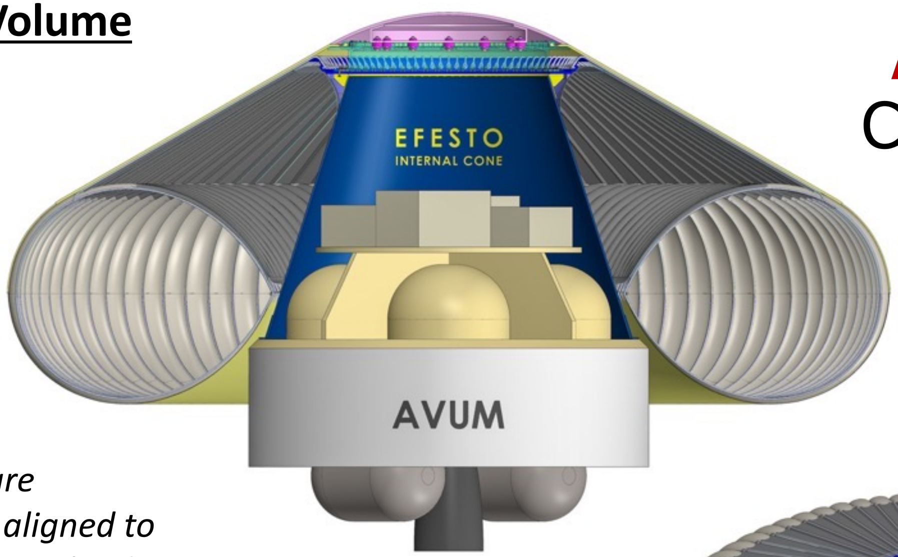
- **<u>ANNULUS</u> provides large diameter drag “footprint”**
- **<u>Low-pressure CONE</u> volume provides the frontal Sphere-Cone surface geometry**
  —a counterpart of the NASA HIAD torus stack



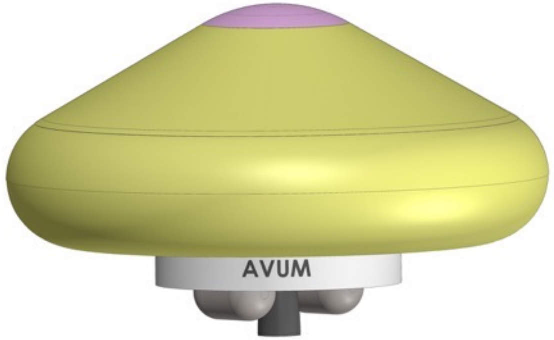
UHPV Annulus

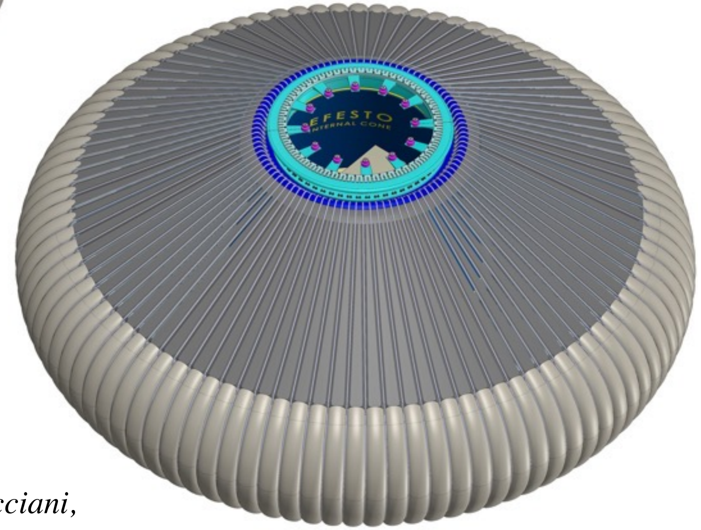


EFESTO
Dual Body
Configuration



Tendons are favorably aligned to bear dynamic loads



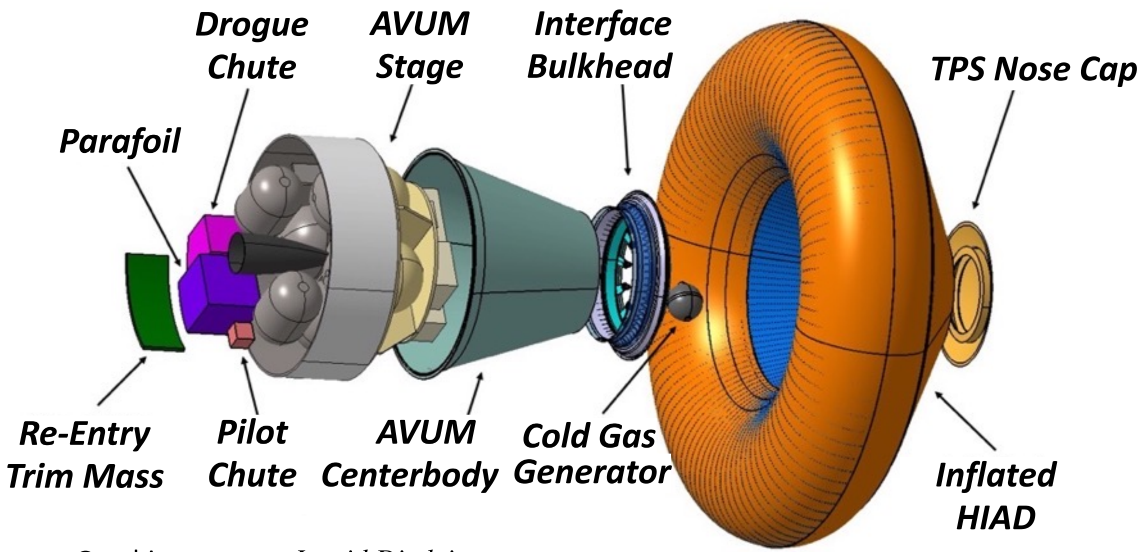


Graphics courtesy *Giovanni Gambacciani*, AVIOSPACE SRL for EFESTO

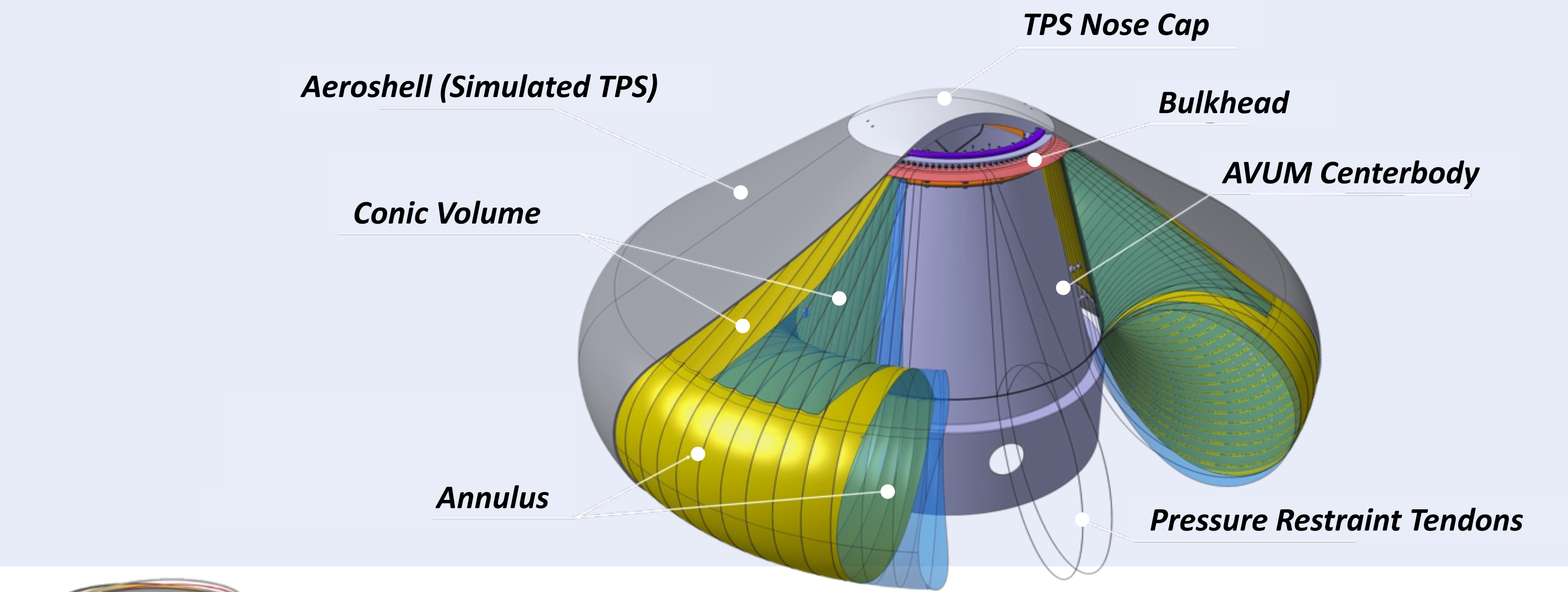
Prototype ***Dual-Body*** IAD

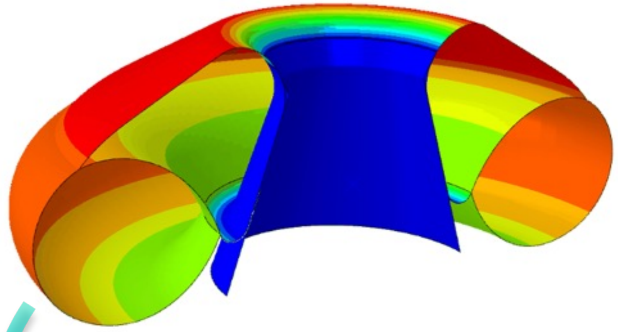
Prototype Dual-Body IAD Pressure Restraint Frontal Surface

EFESTO Dual-Body HIAD Configuration

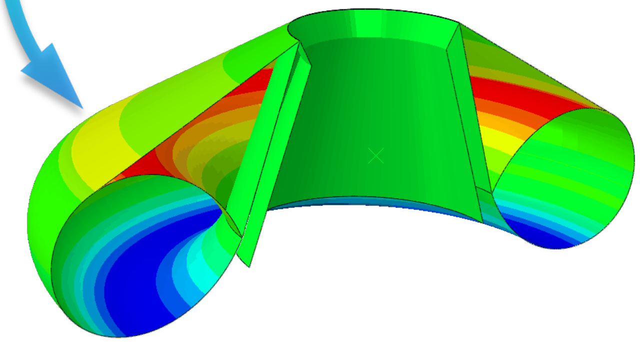


Graphics courtesy *Ingrid Dietlein*,
Deutsches Zentrum für Luft- Und Raumfahrt e.V. (DLR) for EFESTO





Annulus pressure = 27 kPa
Cone pressure = 5 kPa
Dynamic Pressure = 0 kPa



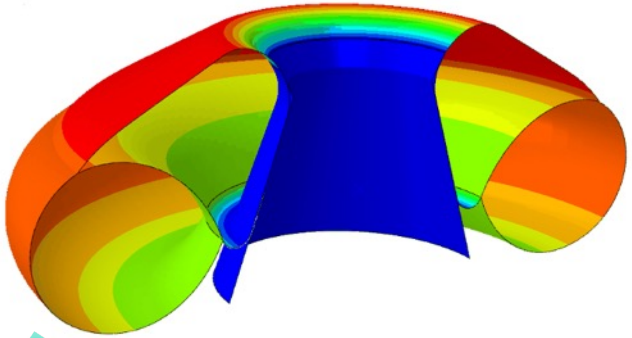
Annulus pressure = 27 kPa
Cone pressure = 5 kPa
Dynamic Pressure = 10 kPa

Analysis Graphics courtesy *Pietro Pasolini*,
SRS Engineering Design for EFESTO

EFESTO Dual-Body HIAD – GTU* Aft View

* Ground Test Unit

EFESTO Dual-Body IAD – Pre Dynamic Loading



Annulus pressure = 27 kPa
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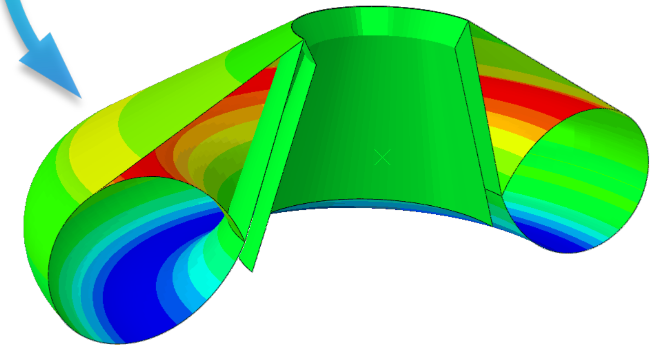
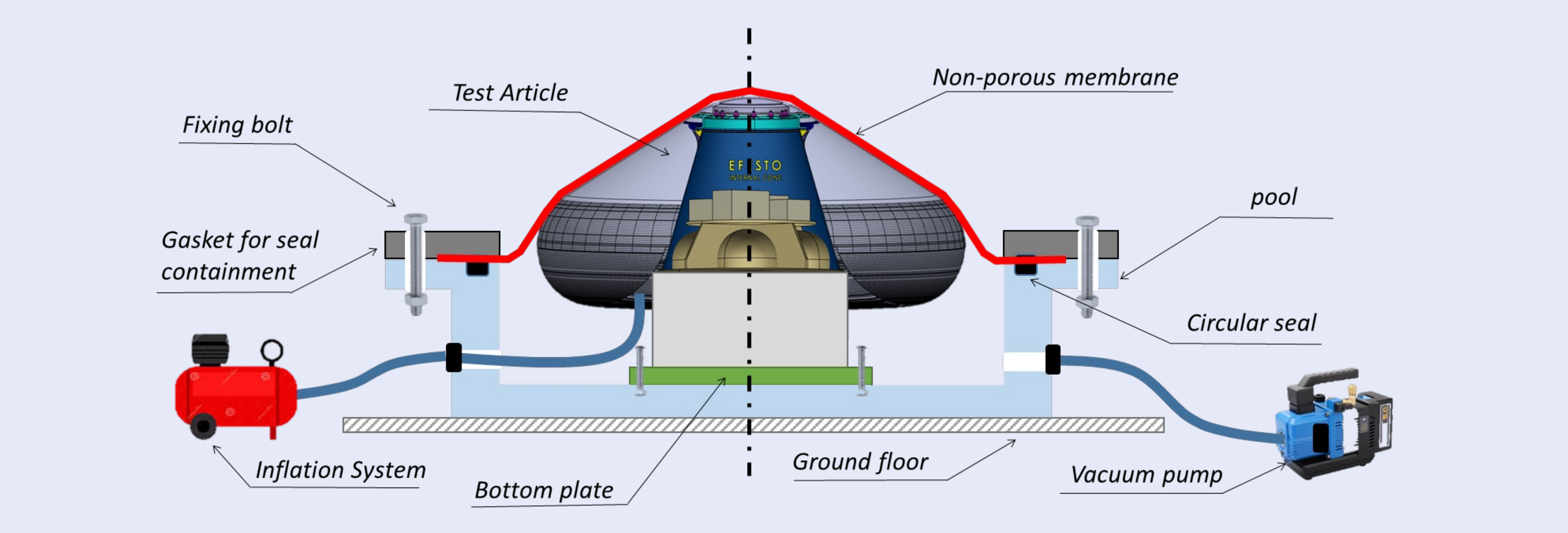


Annulus pressure = 27 kPa
Cone pressure = 5 kPa
Dynamic Pressure = 10 kPa

EFESTO Dual-Body HIAD – Next Steps

- Packaging & Deployment
- Static Deflection Testing
- Advanced investigation and characterization of Annulus behavior under external loads



EFESTO

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deimos elecnor group

CIRA Italian Aerospace Research Centre

ALI Aerospace Laboratory for Innovative components S.c.a r.l.

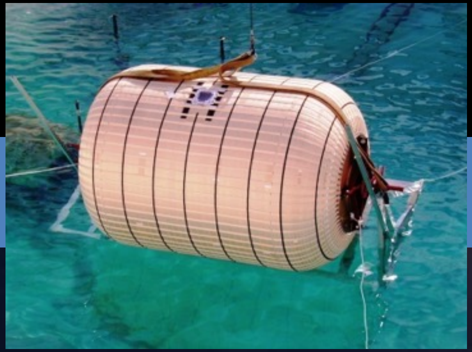
ONERA THE FRENCH AEROSPACE LAB

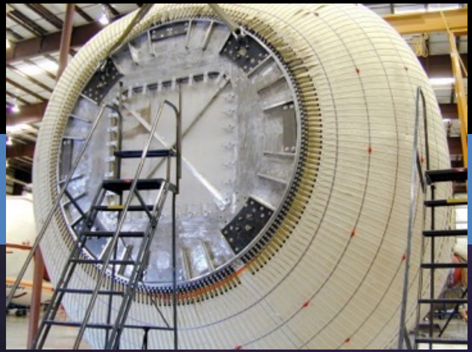
aviospace

DLR Deutsches Zentrum für Luft- und Raumfahrt

Politecnico di Torino 1859

THIN RED LINE AEROSPACE





TPS, MMOD, MLI
DECELERATORS
ULA VULCAN
HABITATION
BALLOONS
NASA SLS