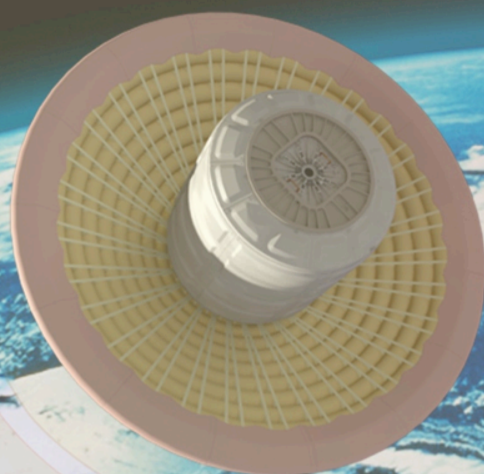
High Energy Atmospheric Reentry Test (HEART)

Overview of Proposed Flight Test

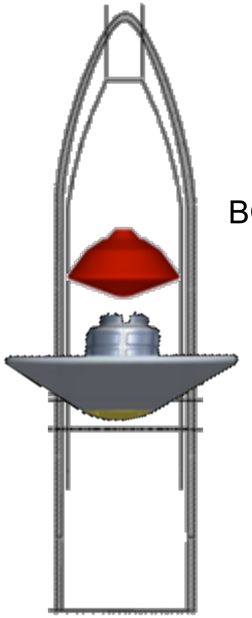


21 June 2012

Henry Wright
Dr. F. McNeil Cheatwood

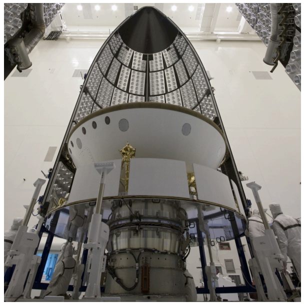
Motivation for HIAD

- Aeroshell size limited by Launch Vehicle fairing. HIAD could reduce constraints of launch vehicle fairing on entry system size.
- Lower ballistic coefficient from increased drag area allows higher altitude deceleration (aerocapture or entry) providing access to higher surface elevations and/or increased landed mass (MSR, Robotic Precursor missions to Mars)
- Increased time for EDL sequence to allow for additional maneuvering – either deceleration for larger payloads and/or precision landing
- Mars thin atmosphere makes it difficult to decelerate large masses and limits accessible surface altitudes. HIAD could provide access to higher elevation terrain (such as Mars Southern Highlands)
- Improved payload access

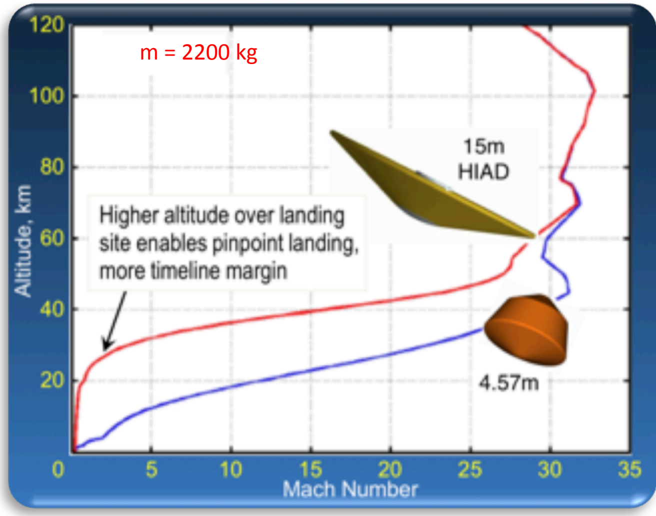


Comparable Entry Masses

MSL	HEART
m=3300 kg	3500 kg
D=4.5 m	8.5 m
BC=125 kg/m^2	40 kg/m^2



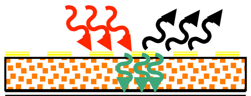
MSL in Launch Vehicle Fairing
(http://marsprogram.jpl.nasa.gov/msl/multimedia/images/?ImageID=3684)



Overview of HIAD Activities

System Development and Qualification

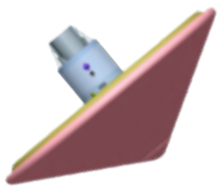
TPS



Inflatable Structures

Development and ground testing of HIAD components.

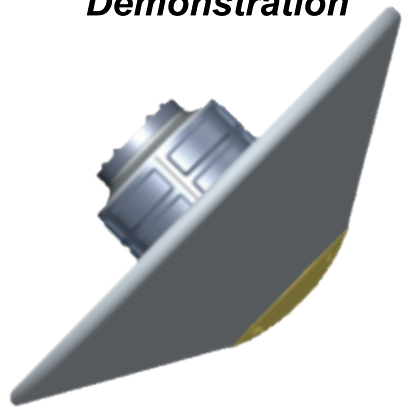
Sub-Orbital Flight Testing



IRVE-3 & 4

Sub-orbital flight tests on a cost-effective test platform (heating, lift, maneuverability).

System Demonstration



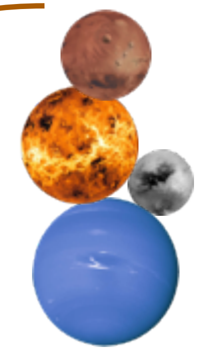
High-Energy Atmospheric Reentry Test

Flight test to demonstrate system performance at relevant scales and environments.

ARMD and OCT investments spans these elements

Potential on-ramps for future investments.

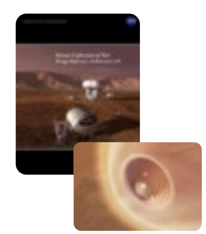
6 – 25 meter HIAD Class



Robotic Missions
(entry or aerocapture):
- *Mars*
- *Venus*
- *Titan*
- *Neptune (and other gas giants)*

Robotic or Crewed Earth Return
(entry or aerocapture):
- *LEO (including ISS)*
- *GEO, NEO, Lunar*

DoD Applications



Technology Development & Risk Reduction for Human Mars Missions

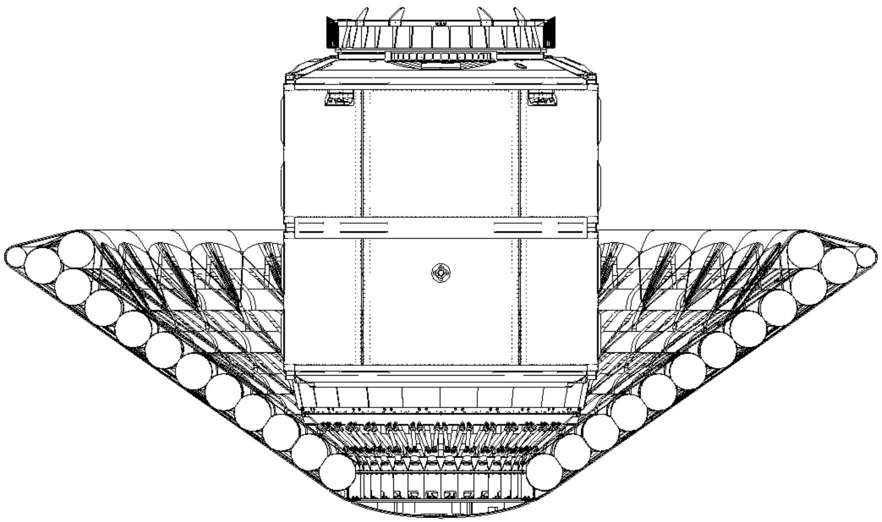
HEART Summary

HEART is a Flight Test…

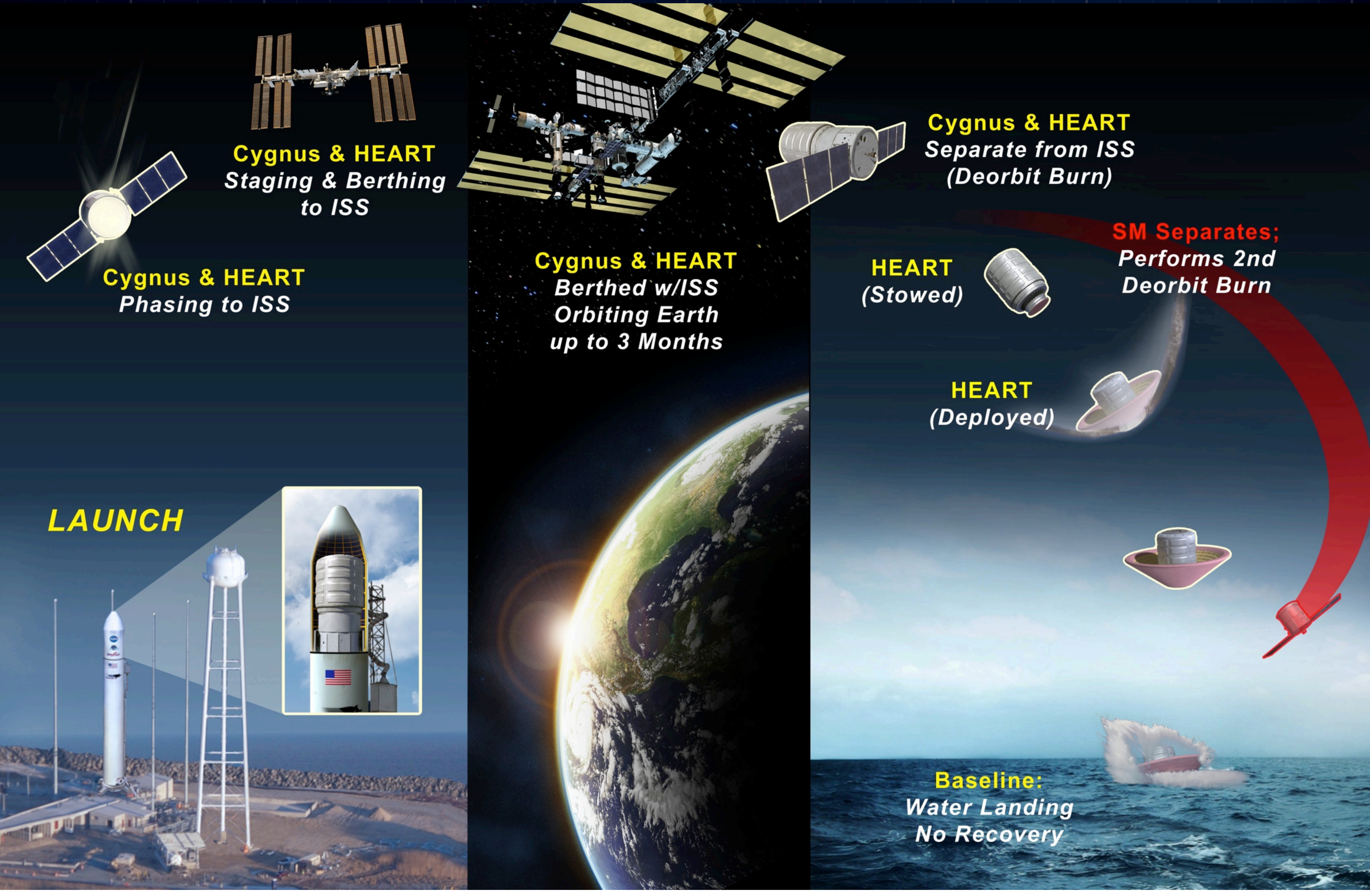
- To demonstrate performance in an environment relevant for robotic Earth and Planetary entry (Mars & Titan)
- To demonstrate effects of scale on development and performance
- Provide data needed to correlate and update high fidelity predictive models (environments, TPS, structures, etc.)
- To demonstrate the ability to be integrated into existing spacecraft without wholesale changes in capability

HEART by the numbers…

- Entry Mass: 3500 - 5500 kg
- Downmass: 0 – 2000 kg
- Ballistic Coeff.: 40 – 80 kg/m^2
- 8-10 m diameter HIAD
  (55-60 deg sphere cone)



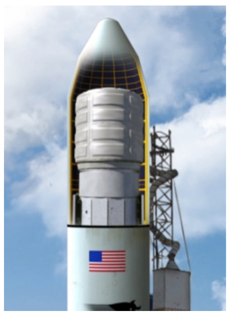
HEART Concept of Operations

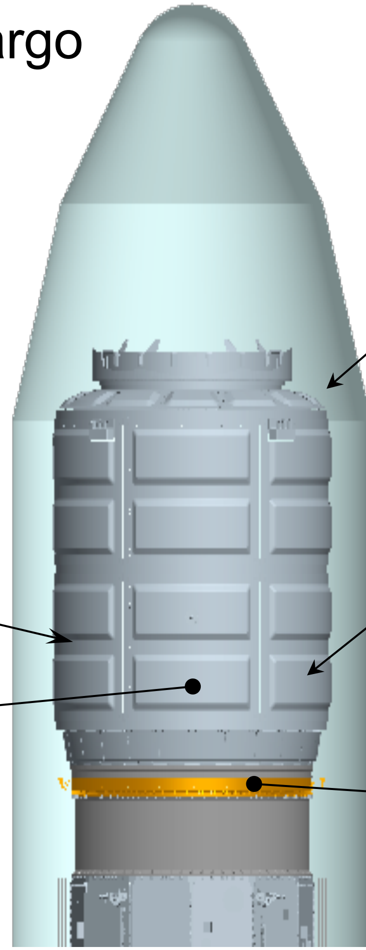


Launch Configurations – Cygnus with HEART

Launch Configuration: HEART and Cygnus

- Cygnus SM + Interstage + Stowed HIAD Module + Flight restraint with cover + PCM + Upmass Cargo

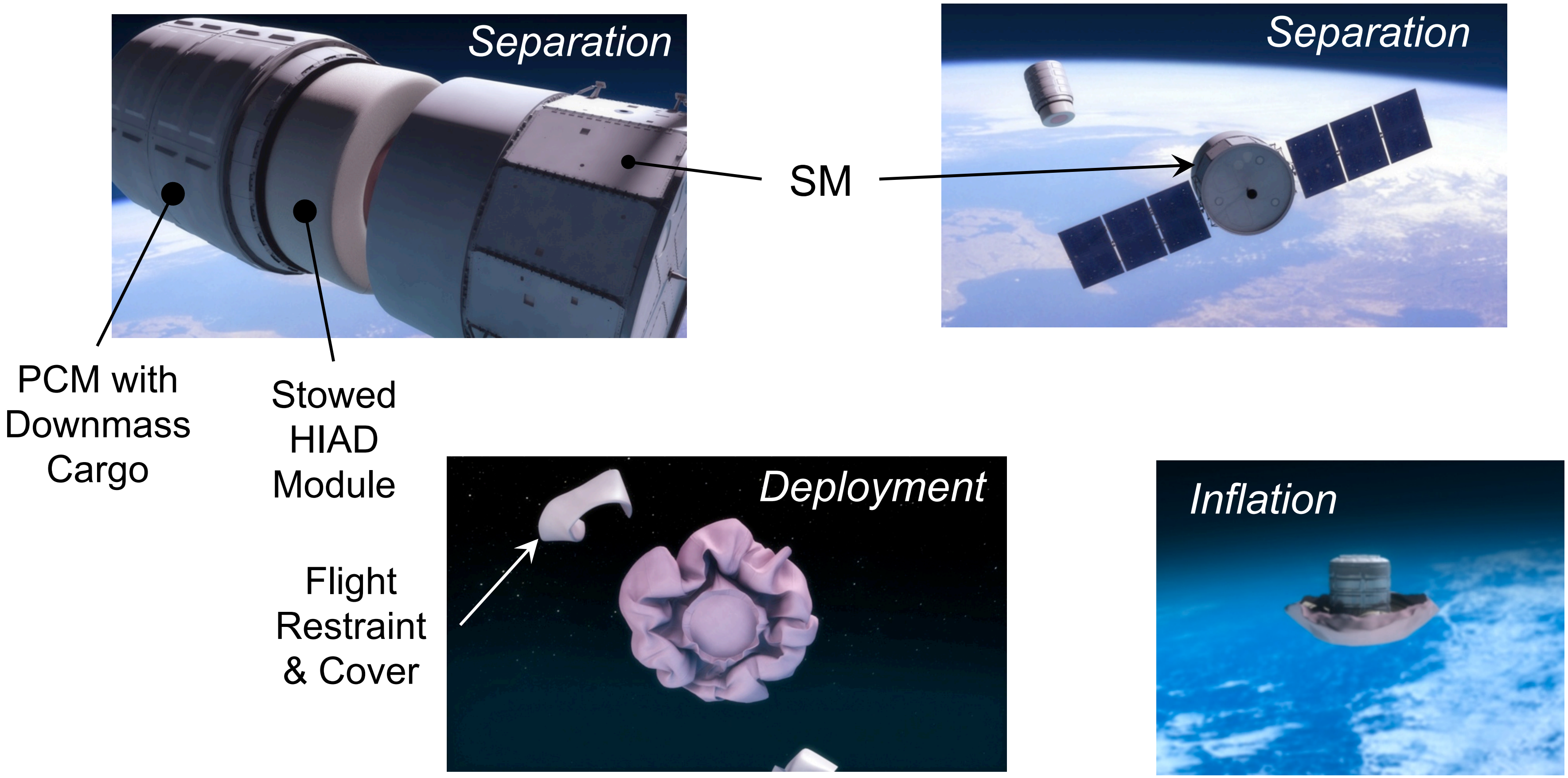




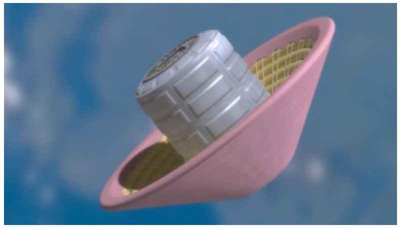
Deployment Configurations

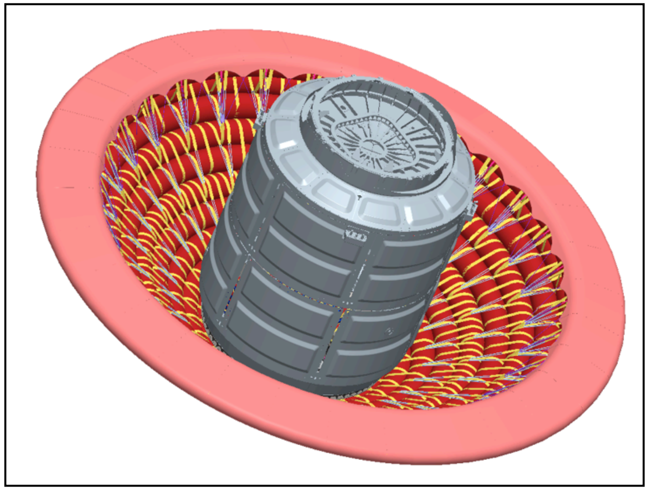
Separation & Deployment Configuration: HEART and Cygnus

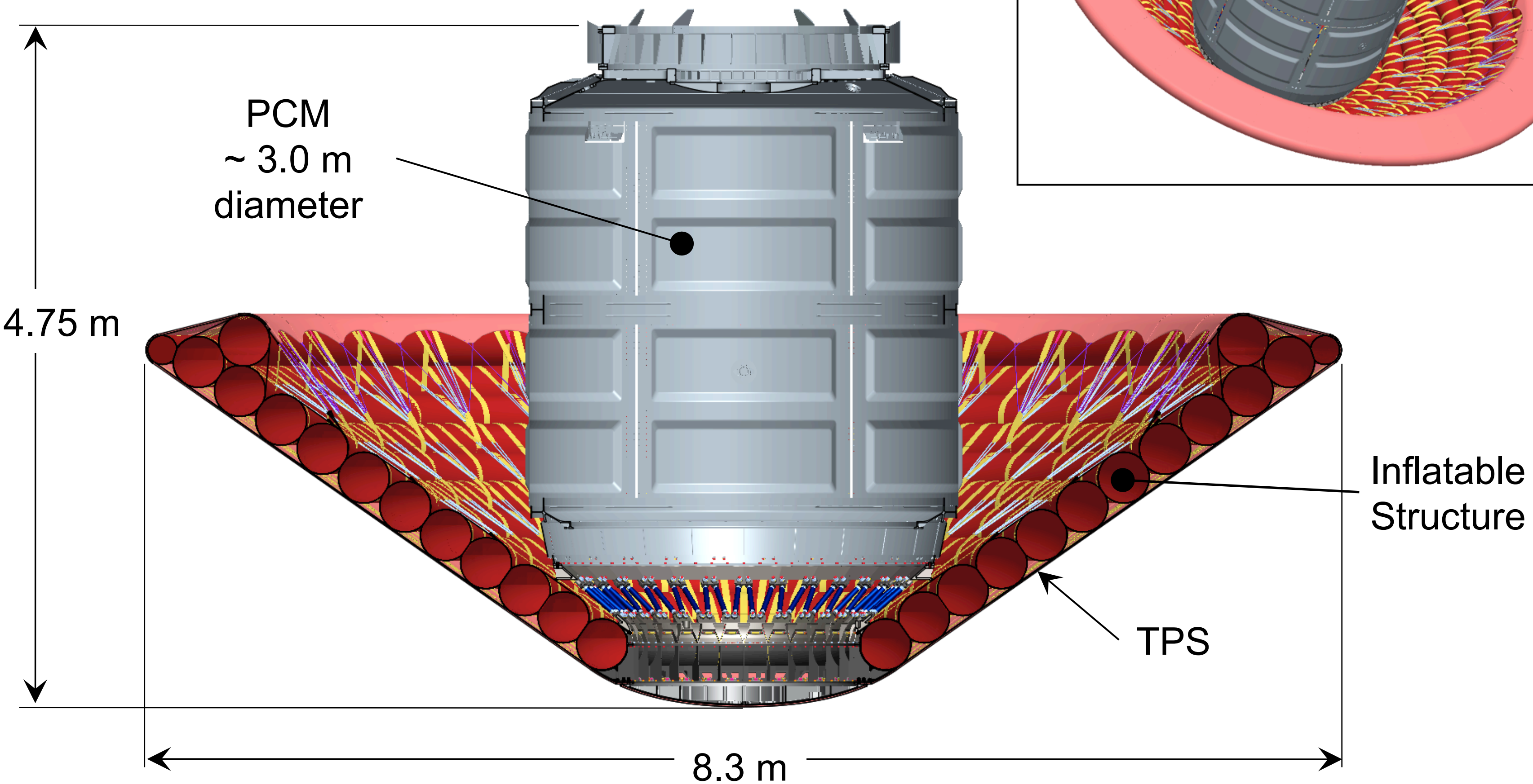
- Cygnus SM + Interstage + Stowed HIAD Module + Flight restraint with cover + PCM + Downmass Cargo



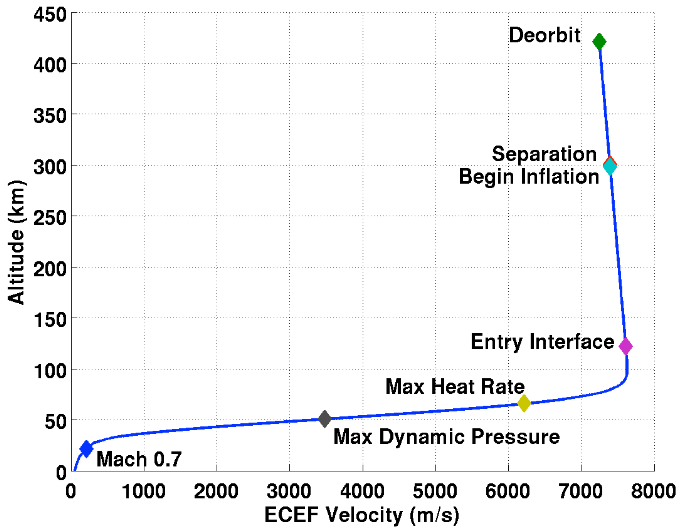
HEART Entry Configuration



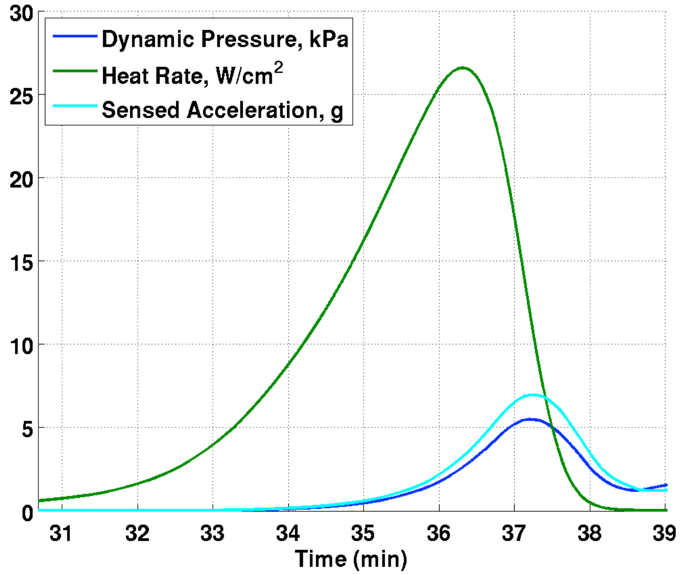




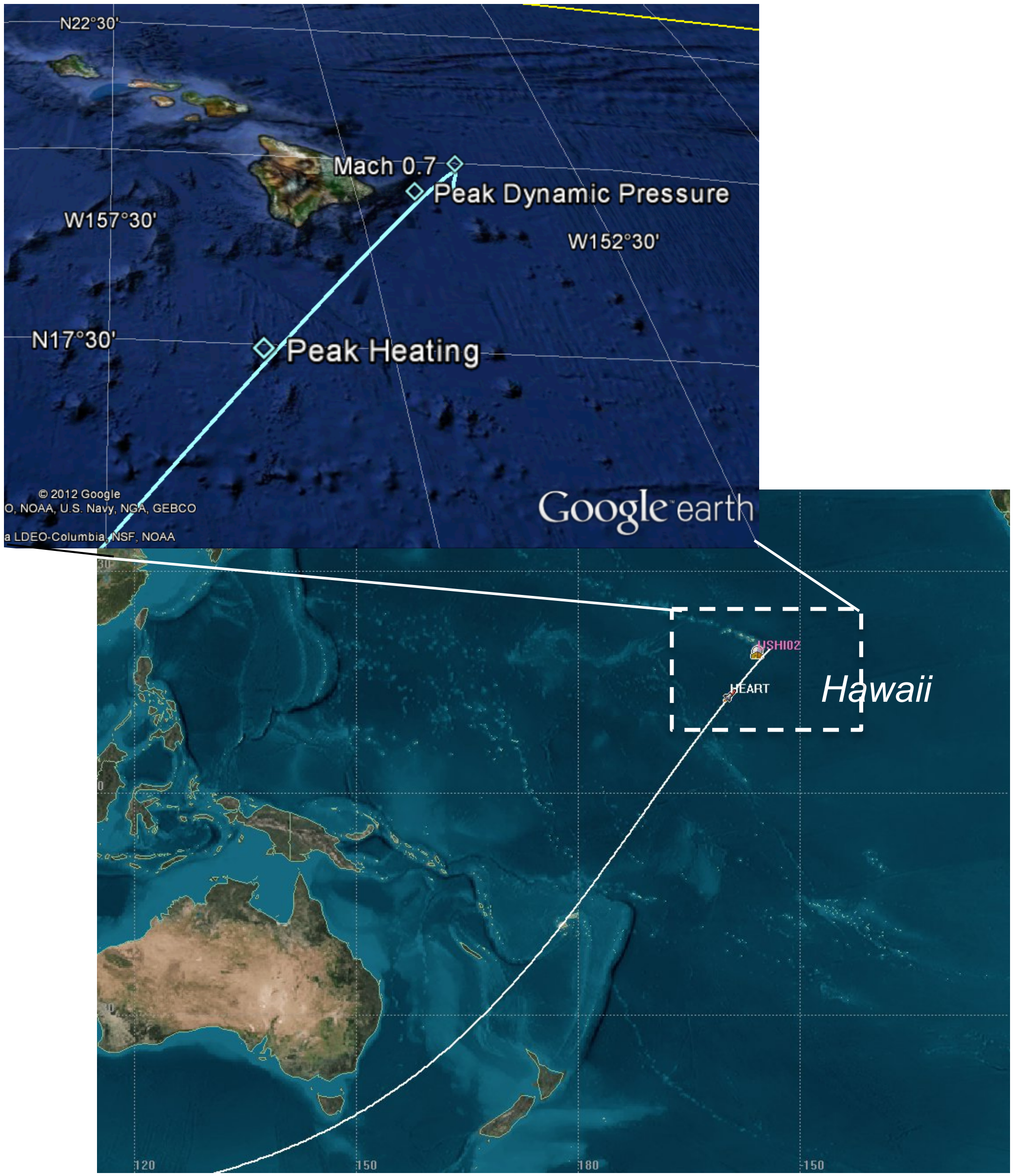
Trajectory



Deorbit
Separation
Begin Inflation
Entry Interface
Max Heat Rate
Max Dynamic Pressure
Mach 0.7
Altitude (km)
ECEF Velocity (m/s)
0
50
100
150
200
250
300
350
400
450
0
1000
2000
3000
4000
5000
6000
7000
8000



Dynamic Pressure, kPa
Heat Rate, W/cm²
Sensed Acceleration, g
Time (min)
0
5
10
15
20
25
30
31
32
33
34
35
36
37
38
39



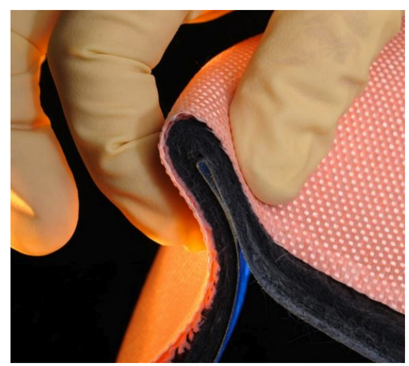
N22°30'
Mach 0.7
Peak Dynamic Pressure
W157°30'
W152°30'
N17°30'
Peak Heating
© 2012 Google
Google earth
USHI02
HEART
Hawaii
120
150
180
-150

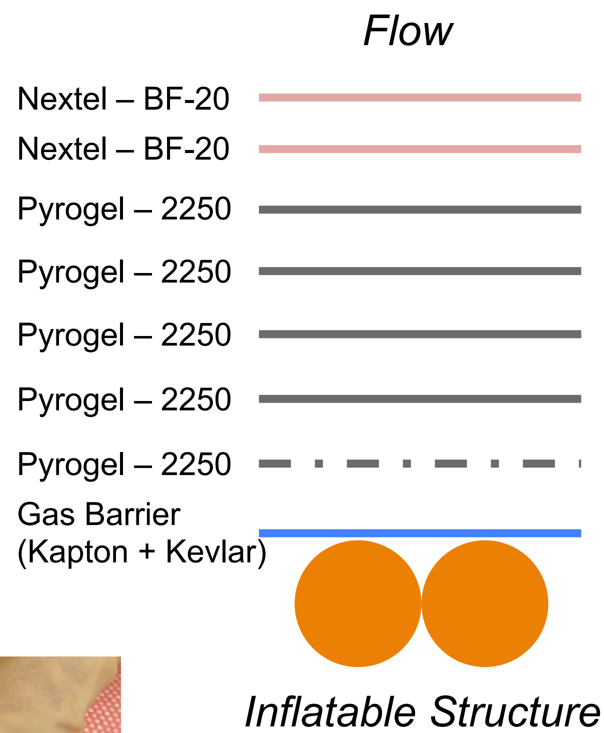
Inflatable Structure Test Article (6 m)

6m Test Article before June 5 Tests

Thermal Protection System

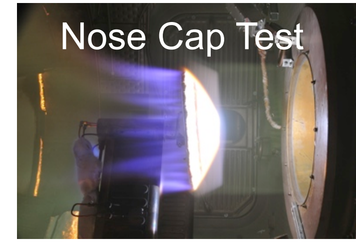
TPS – Flexible, Insulating, Multi-Layer Laminate





HEART TPS Maturation (HIAD 1st Generation TPS)

Characterize 1st Generation Flex. TPS Performance: smooth, seams, stagnation, shear, age



Develop Physics Based Analytical Model

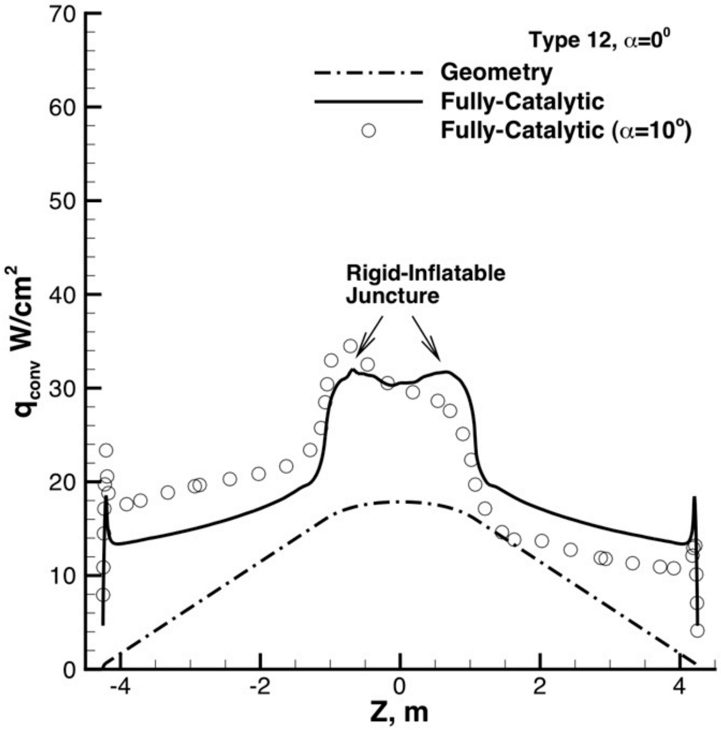
Develop Flexible TPS Margin Policy

Update HEART Baseline TPS

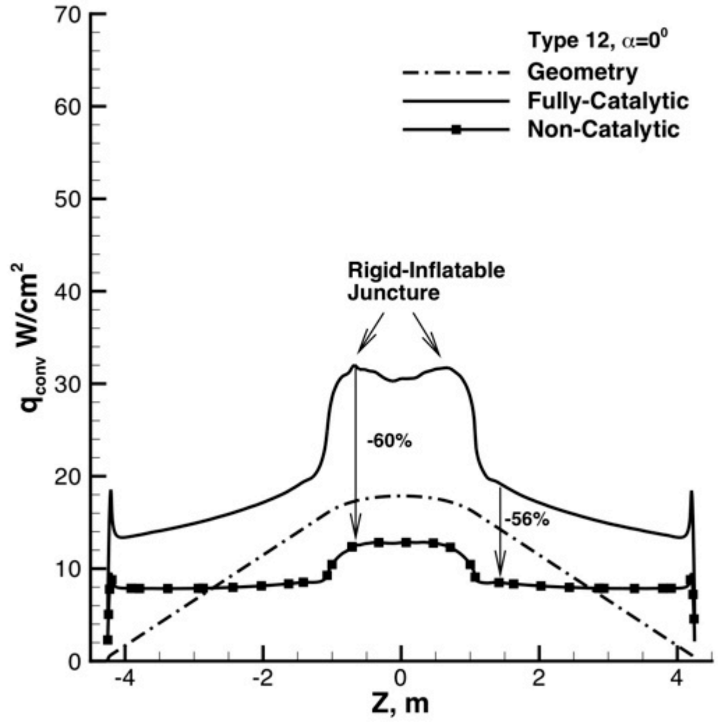
Characterize 1st Generation Flex. TPS thermophysical properties

Fabricate 6 m size EDU TPS

Aeroheating Environments



Peak Heat Rate point (2255)
Modified configuration
Minor sensitivity (~10%) to angle of attack

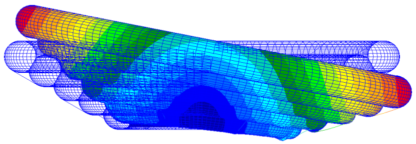
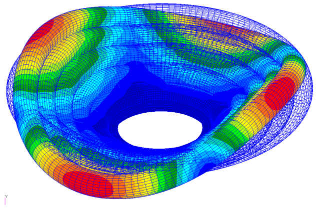


Peak Heat Rate point (2255)
Modified configuration
Unmargined heat rate for design assessments

Summary/Conclusion

- HEART flight test will demonstrate the readiness of HIAD for mission infusion
- HEART will demonstrate capabilities consistent with future robotic planetary missions
- HEART has a clear path for implementation
- ***HEART flight test is ready and relevant***

HEART Inflatable Structure Maturation (HIAD 1st Generation IS)

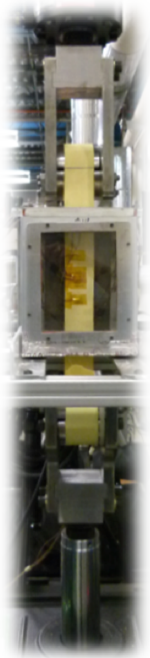
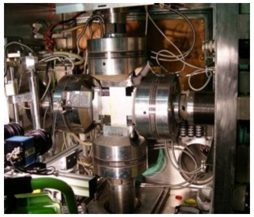
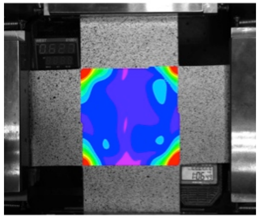



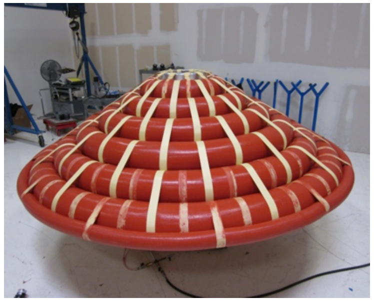
Develop Structural Modeling capability

Fabricate and test 3 m, 6 m, and 8 m EDU Inflatable Structures

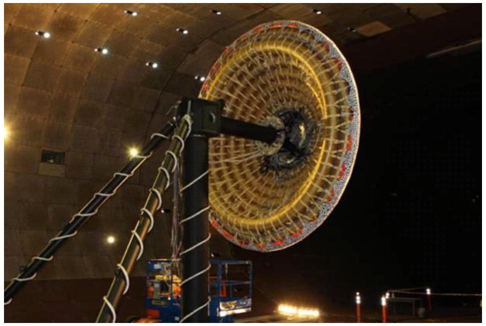
Update HEART Baseline IS

Characterize 1st Generation Inflatable Structure material properties

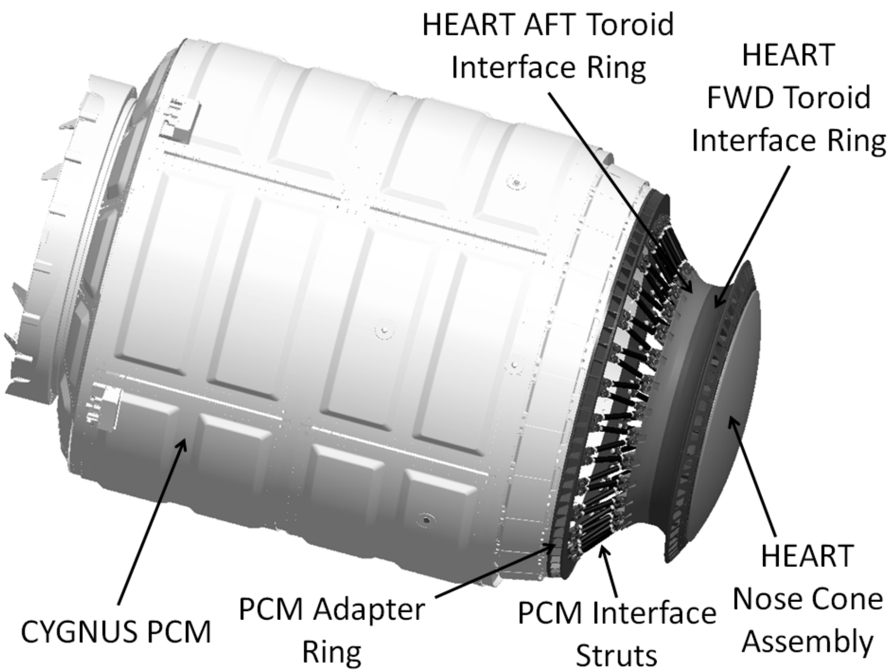


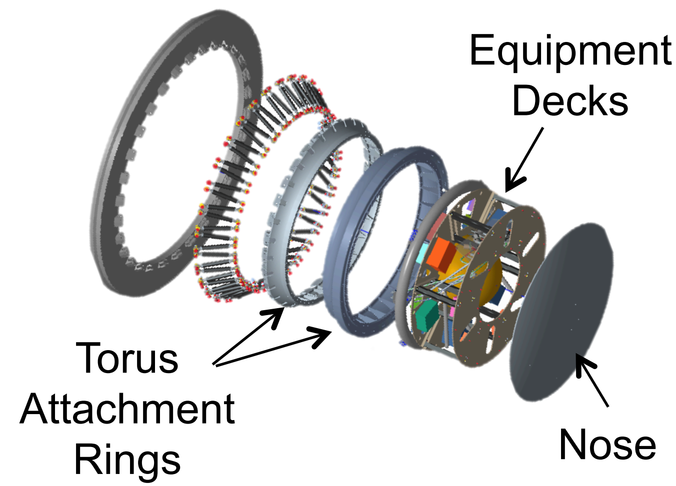
3 m EDU

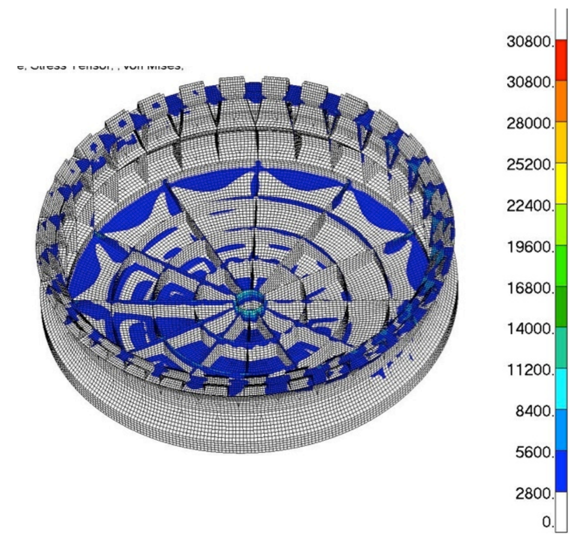


6 m EDU-Aero Load Testing at NFAC

Rigid Structure







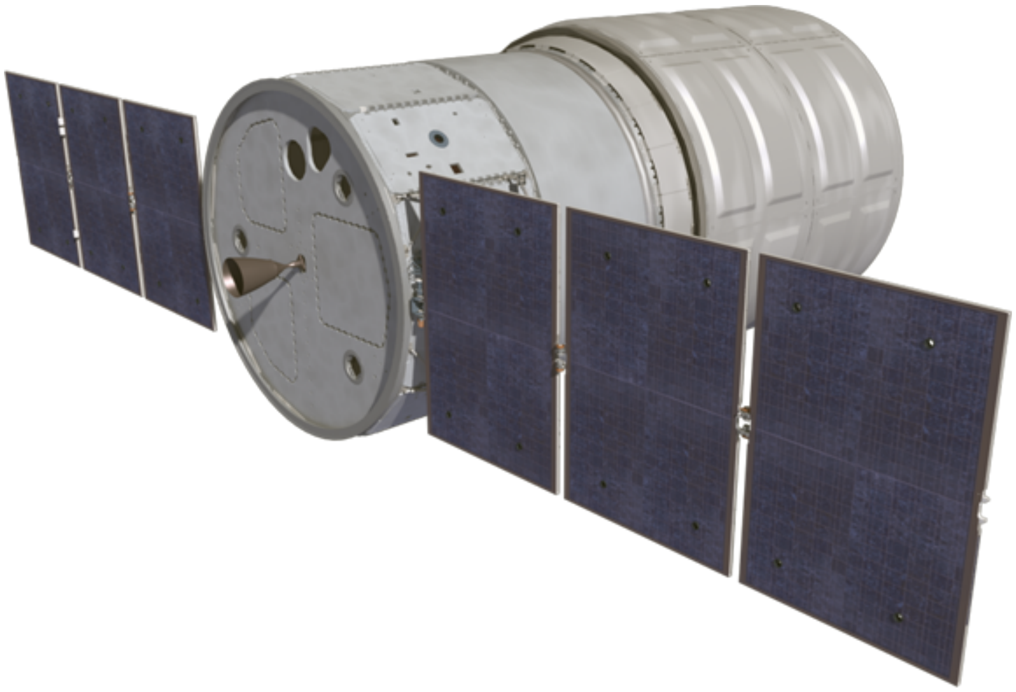
Baseline Rigid Structure

- Aluminum (Composite – future study)
- Supports subsystems
- Provides load path for IAD to ballast (PCM)

Cruise and Deployment Configurations

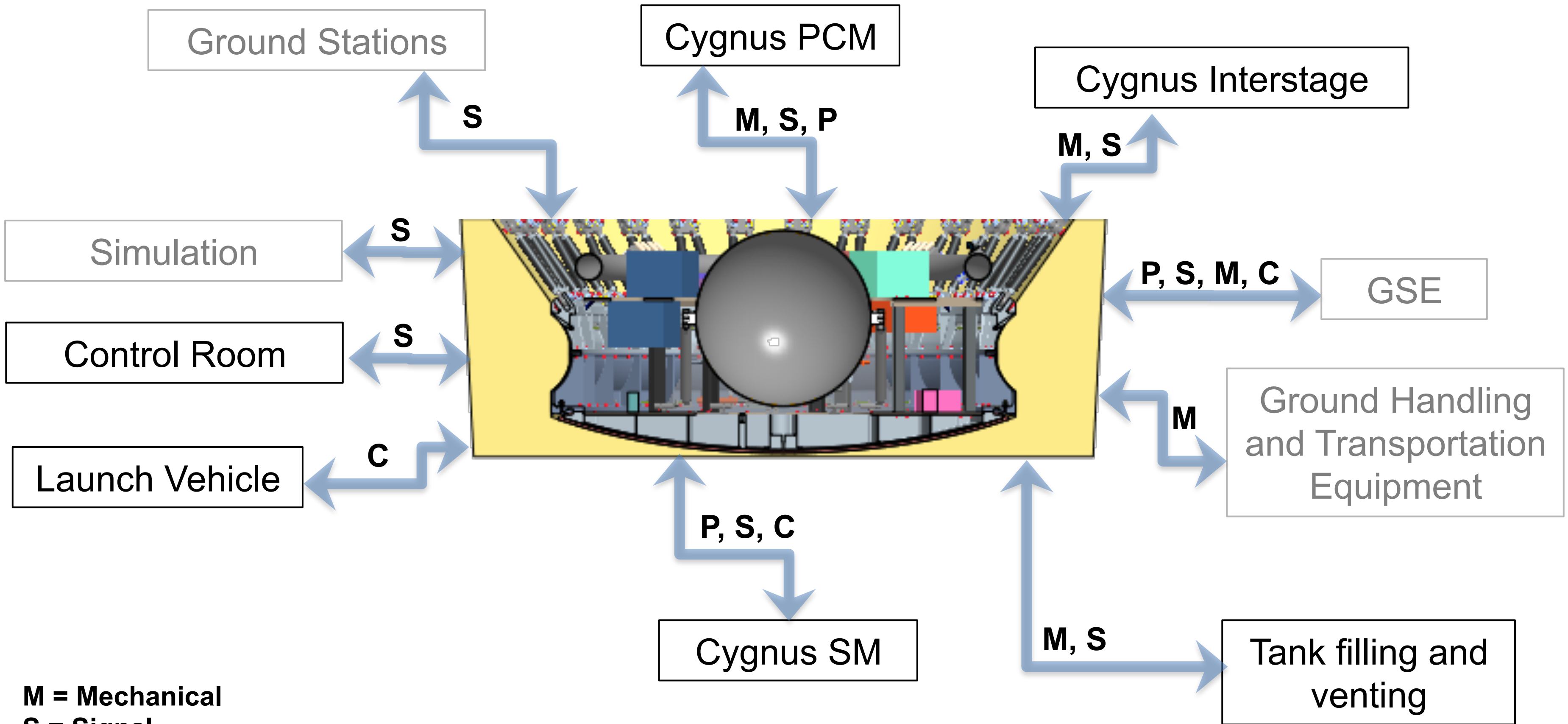
Cruise Configuration: HEART and Cygnus

- Cygnus SM + Interstage + Stowed HIAD Module + Flight restraint with cover + PCM + Upmass Cargo (or Downmass Cargo)



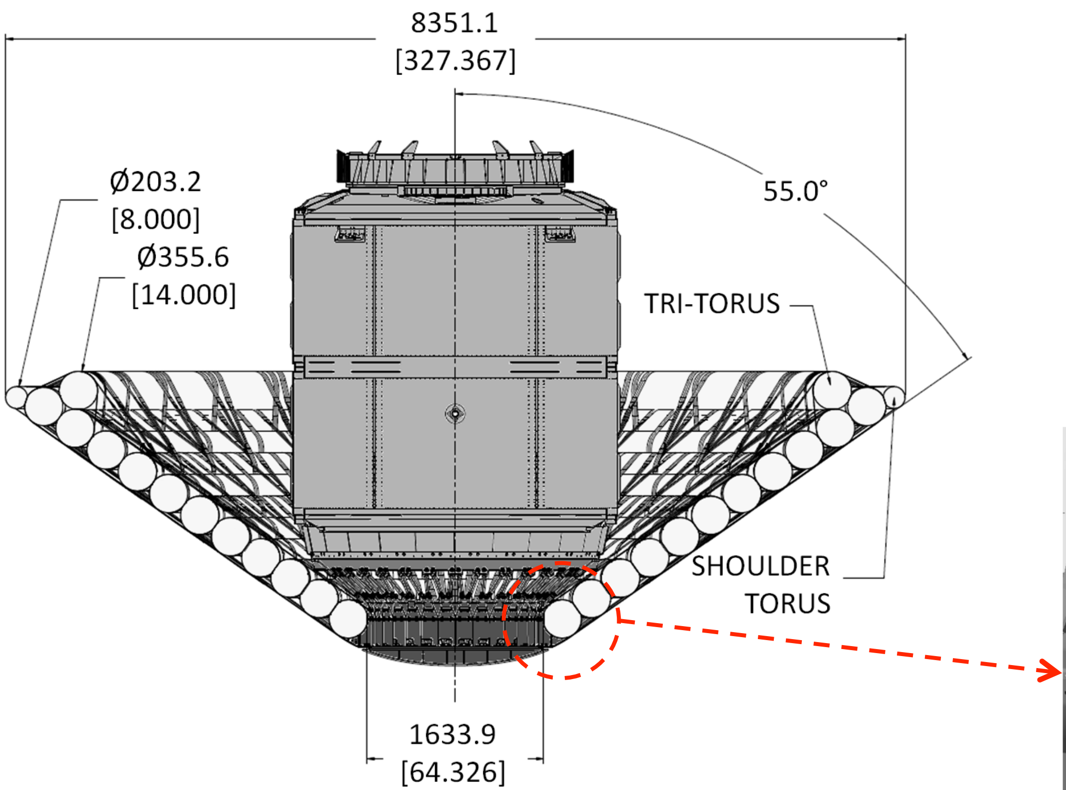
HEART Interfaces With Cygnus & Antares

- HIAD External Interfaces (depicted in stowed HIAD configuration)

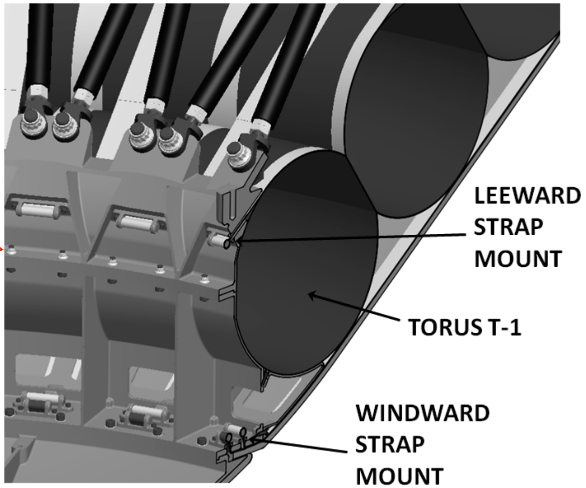


M = Mechanical
S = Signal
P = Power
C = Thermal Conditioning

Inflatable Structure

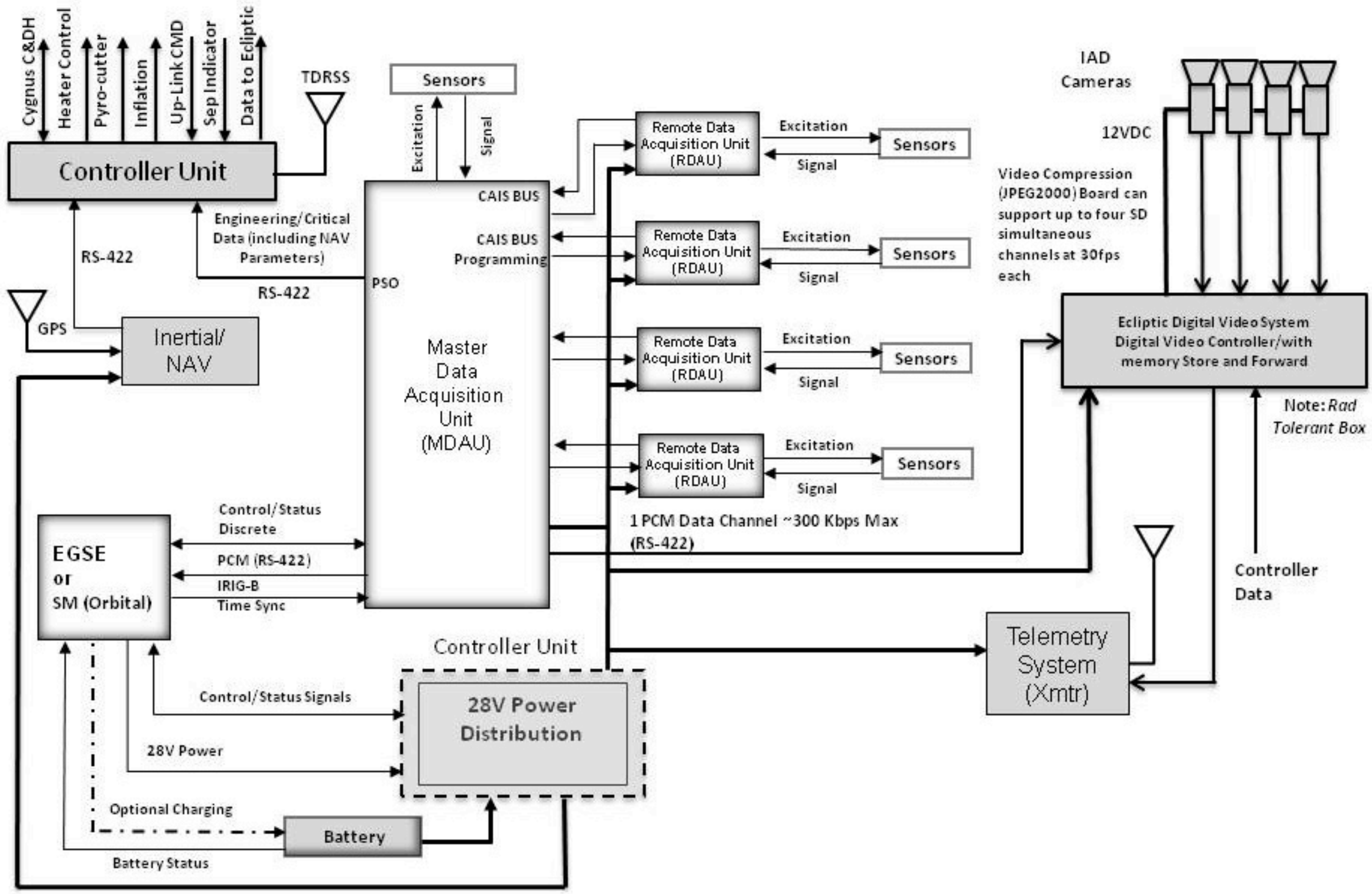


Torus – Braided Kevlar™ for structure; Silicone bladder for gas retention; RTV film for adhesion and sealing



Attachment of Inflatable Structure to Rigid Structure

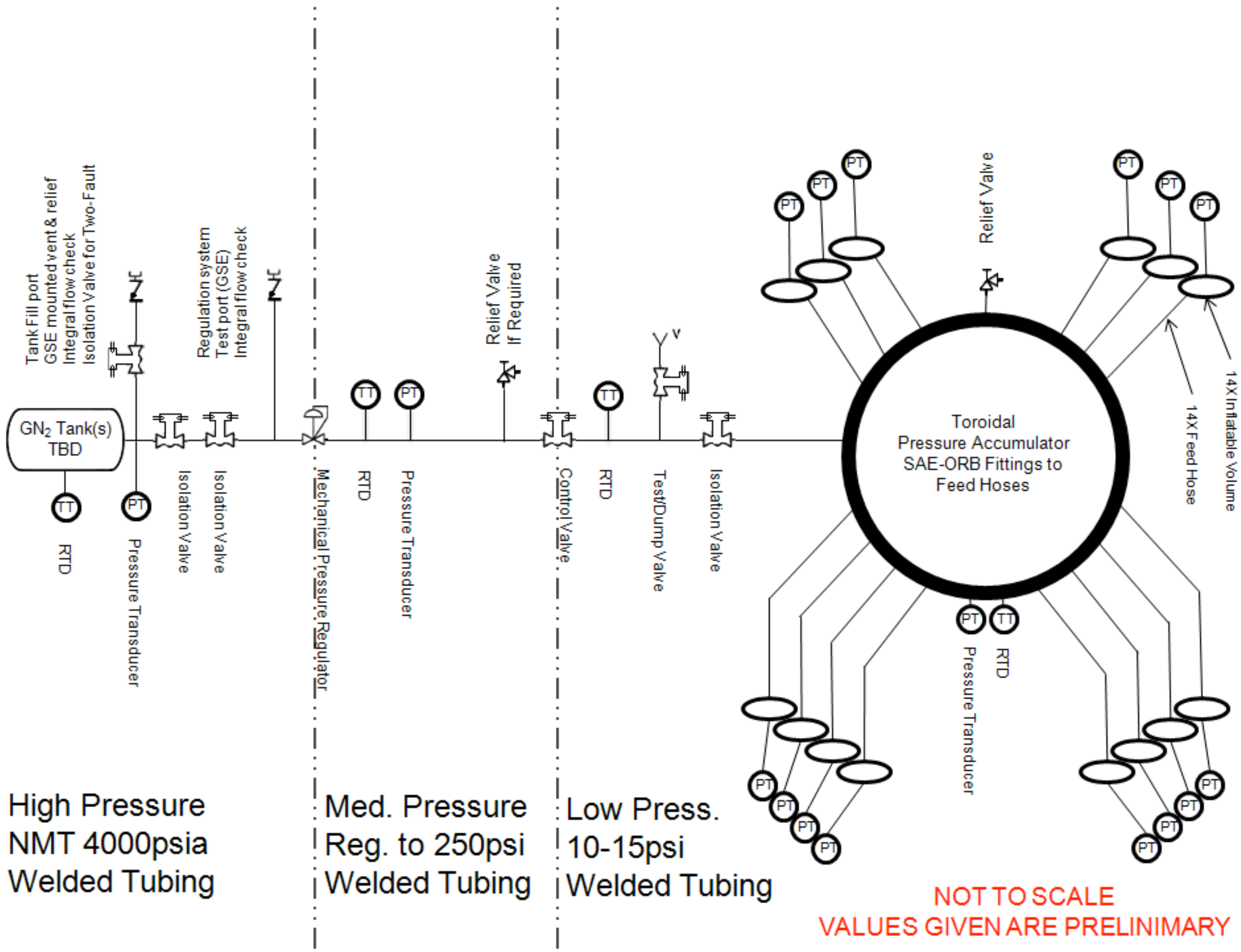
Avionics Subsystem – 1 of 2



Avionics Subsystem – 2 of 2

Element	Description
Controller	FPGA based sequencing controller. Inflatable structure pressure is primary controlled item
Telecom	S-band to TDRSS – critical events; continuous; omni patch antennas mounted on PCM X-band to ground station(s) – all data (including resend of critical events); after blackout; patch antenna(s) on the nose
Navigation	Space Integrated GPS Instrument (SIGI) – includes IMU and GPS; GPS antennas mounted on PCM; pressure switch for altitude – only return navigation sensor data, no navigated solution determined in-flight
Data Acquisition	Multiple data acquisition units – include signal conditioners and communications interfaces
Electrical Power	Primary batteries, switching/isolation, grounding
Sensors	Thermocouples in TPS layers, Heat Flux sensors on nose, pressure transducers at nose (FADS), pressure transducers on back side, accelerometers on inflatable structure, load cells at strap mounts

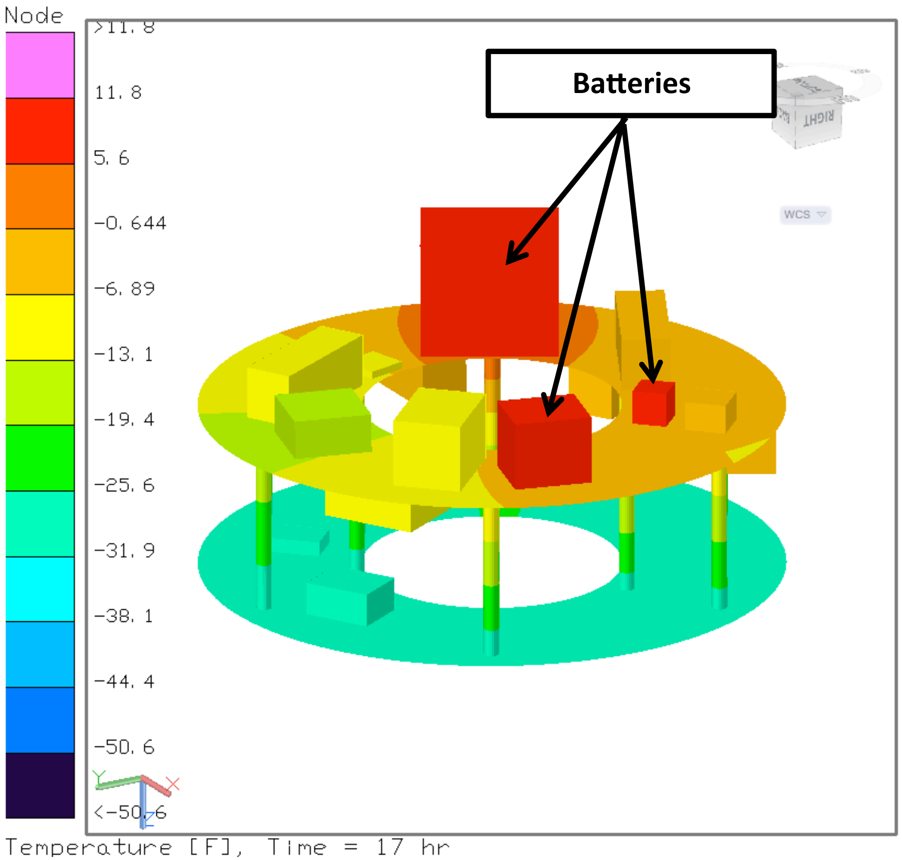
Inflation Subsystem



HEART Inflation Subsystem is comprised of components rated for the launch and entry environments while meeting the torus inflation and pressure control requirements.

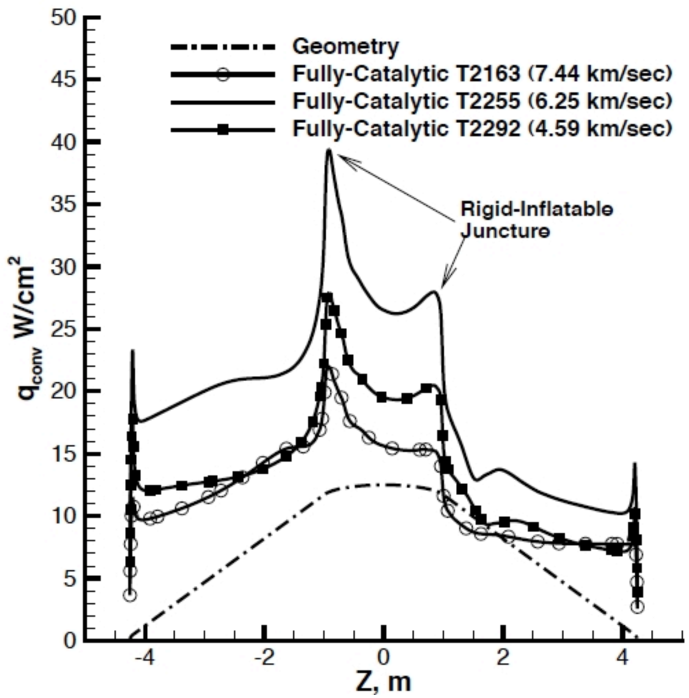
Thermal Subsystem

- Thermal subsystem consists of
  - Passive components – coatings, thermal straps, MLI
  - Active components – thermostatically controlled heaters
- Component sizing considers cruise to/from ISS while deenergized; berthed at ISS – nadir and zenith – while deenergized; and Entry while energized
- Influence of packed IAD considered including sensitivity to varying packing density (minimal)
- Straightforward approach to maintain components within limits

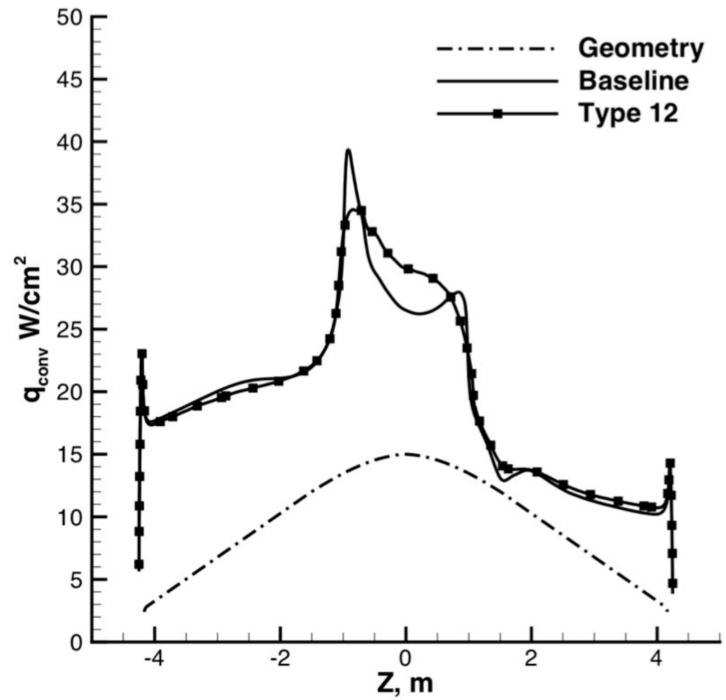


With Heaters
Min about. -38ºF
Max about 12ºF

Environments – 1 of 2



Peak Heat Rate point (2255)
Original configuration
Elliptic nose with low curvature; includes discontinuity at nose to conic interface



Peak Heat Rate point (2255)
Modified configuration
Nose curvature increased; tangent point moved aft; reduced discontinuity at nose to conic interface