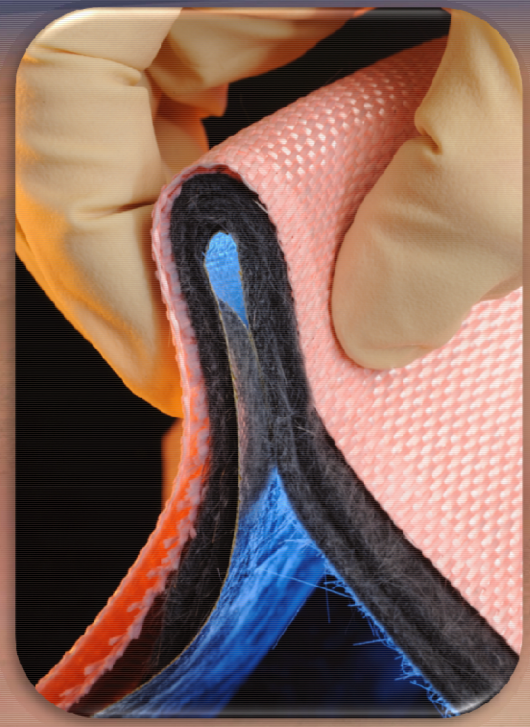
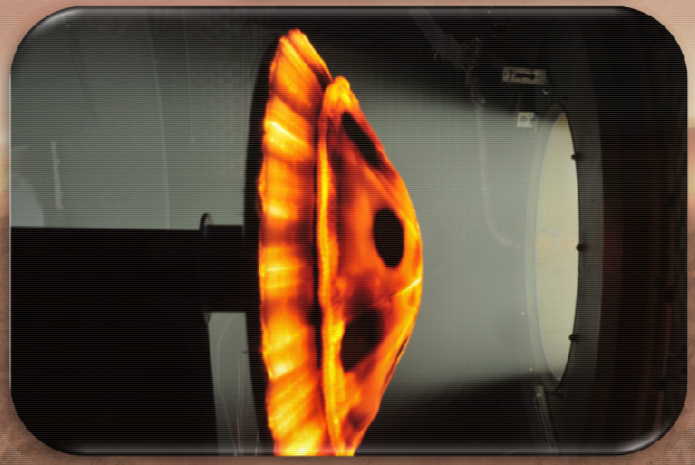
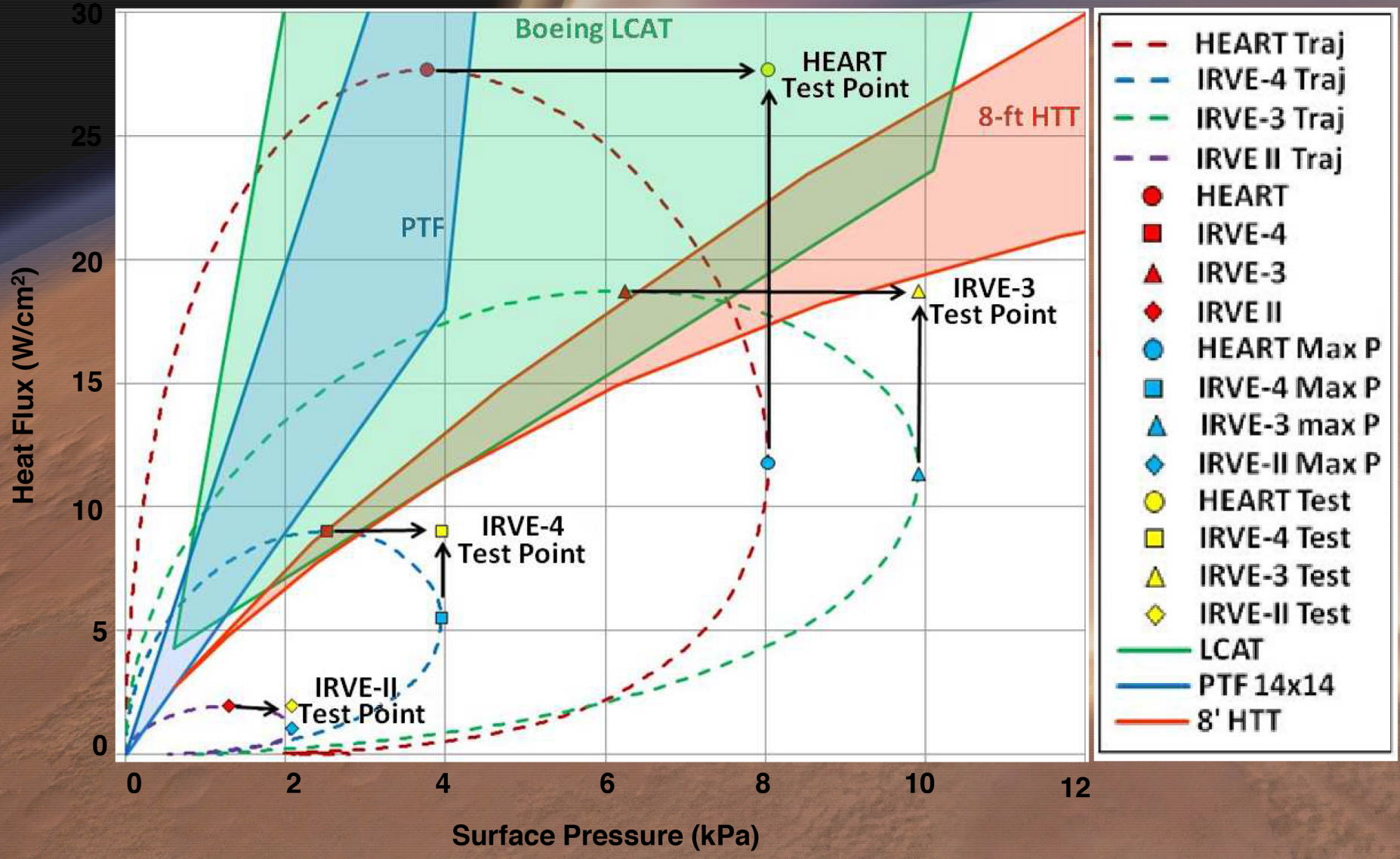
Flexible TPS Development

- **Mission Simulation Testing**
  - LaRC 8-Foot High Temperature Tunnel (HTT)
  - Laser Hardened Materials Exposure Lab (LHMEL)
  - ARC Panel Test Facility (PTF)
  - JSC Test Position 2 (TP2)
  - Boeing Large Core Arc Tunnel (LCAT)
- **Materials Testing and Characterization**
  - Materials Development/Characterization for All Layers (heatshield, insulator, gas barrier, structure)
  - Age Testing
  - Surface Catalycity
- **Physics-Based Modeling**
  - Inter-layer Heat Transfer (convective and radiative) Characterization
  - Analytical Model Development



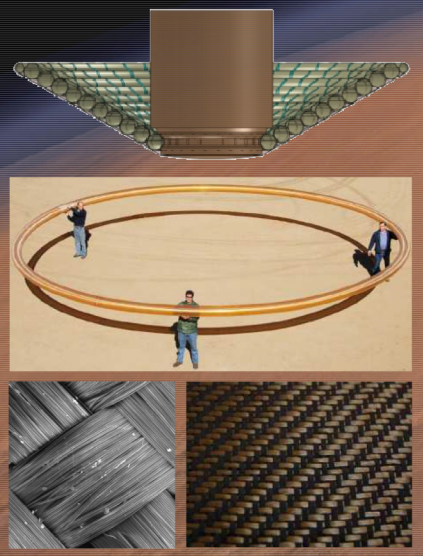


Mission Profiles/Facility Envelopes



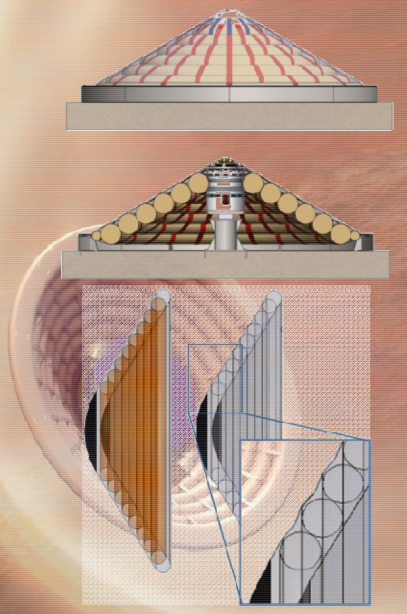
Advancement of Inflatable Structures

Large-Scale Manufacturability & Material Development



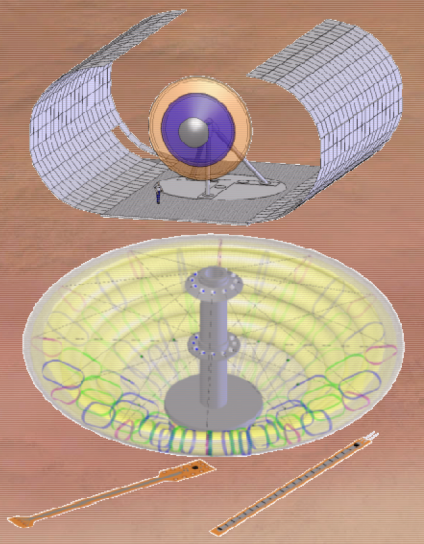
Development of large-scale manufacturing capabilities and advanced, high-temperature capable inflatable structure materials

Large-Scale Static Load Testing, Component Testing & Model Development



Ground test to demonstrate HIAD scalability and initial structural model development

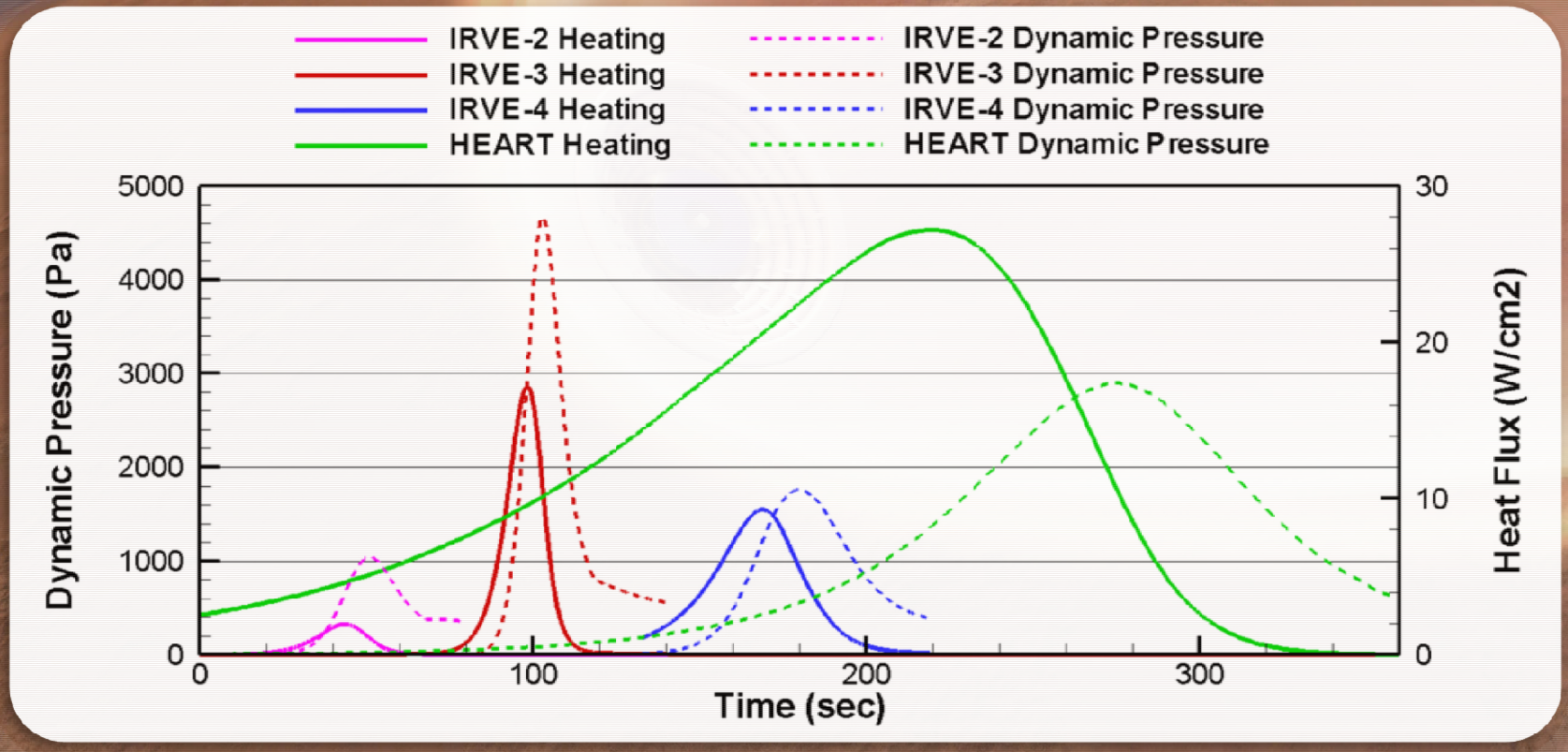
Large-Scale Wind Tunnel Testing & Instrumentation Development



Ground test to demonstrate HIAD performance under flight-like aerodynamic loading

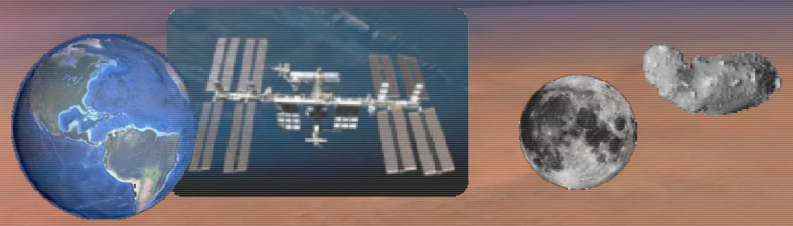
Progression of HIAD Development Flights

	IRVE-II	IRVE-3	IRVE-4	HEART
Peak Heating (W/cm²)	2	15	7	27
Dynamic Pressure (kPa)	1.2	4.7	2	3
Angle of Attack (deg)	0	7	10	0
Diameter (meters)	3	3	3	8.3

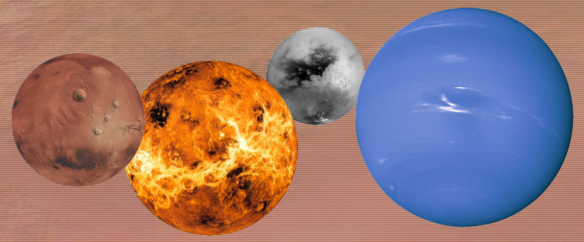


Mission Applications: Plans Forward

- **Objectives**
  - Identify the improvements associated with HIAD integration within the concept of operations of high priority missions
    - Reduced launch costs?
    - Increased performance margins?
    - Expanded mission potential and science return?
  - Provide full systems view of HIAD integration
  - Conduct what-if scenarios to guide future investments.



ISS downmass, LV booster recovery, Earth return (LEO, GEO, lunar, NEO)



Sample return, robotic entry at Mars, Venus, Titan, and gas giants, human-scale entry at Mars

- **Approach**
  - On-going trade studies
    - Release trade study results over multiple analysis cycles
    - Expand scope and fidelity with each cycle
    - Special projects
    - Perform analysis in response to ad-hoc requests

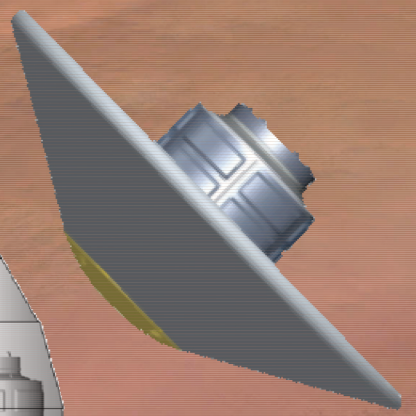
Near Term Milestones

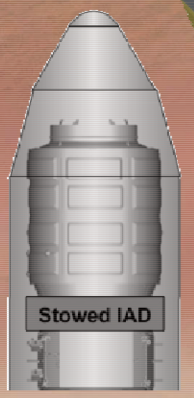
Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday

- **November, 2011**: LV Booster Recovery Quick Look
- **January, 2012:** Cycle 1 Trade Study (Benchmark)

HEART Reference Concept Description

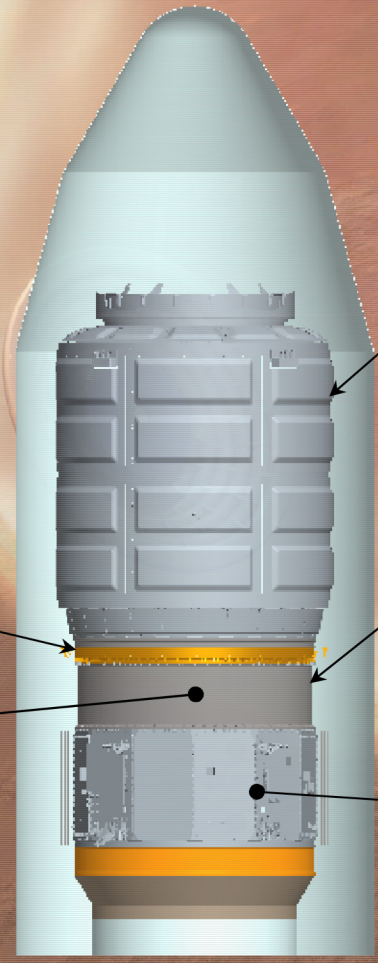
- **HEART integrates all aspects of the HIAD Development Project to demonstrate the performance and survivability of an integrated low ballistic coefficient entry vehicle in a relevant environment**
- **HIAD Vehicle**
  - Single 7 - 9 m diameter HIAD (8.5 m nominal)
  - 55 to 65 degree sphere cone-stacked torus (55 degree nominal)
  - Entry: mass ~3300-3500 kg; Ballistic Coefficient ~45 kg/m^2
  - Ballistic entry: 0 degree AoA
- **Entry Environments — Initial Limits**
  - Peak heat rate: 25 to 35 W/cm^2
  - Peak dynamic pressure: 4800 Pa
- **Launch, Orbit, De-orbit**
  - Integrated with the Orbital Sciences Corp Cygnus module as part of the ISS Cargo Resupply Service
  - NASA-OSC Data Exchange SAA in Signature Loop
  - Launch on Enhanced Taurus II
  - Cygnus berths with ISS: up to 90 days
  - Cygnus performs all maneuvering
  - Entry from LEO: 7.6 km/s
  - HIAD returns Pressurized Cargo Module



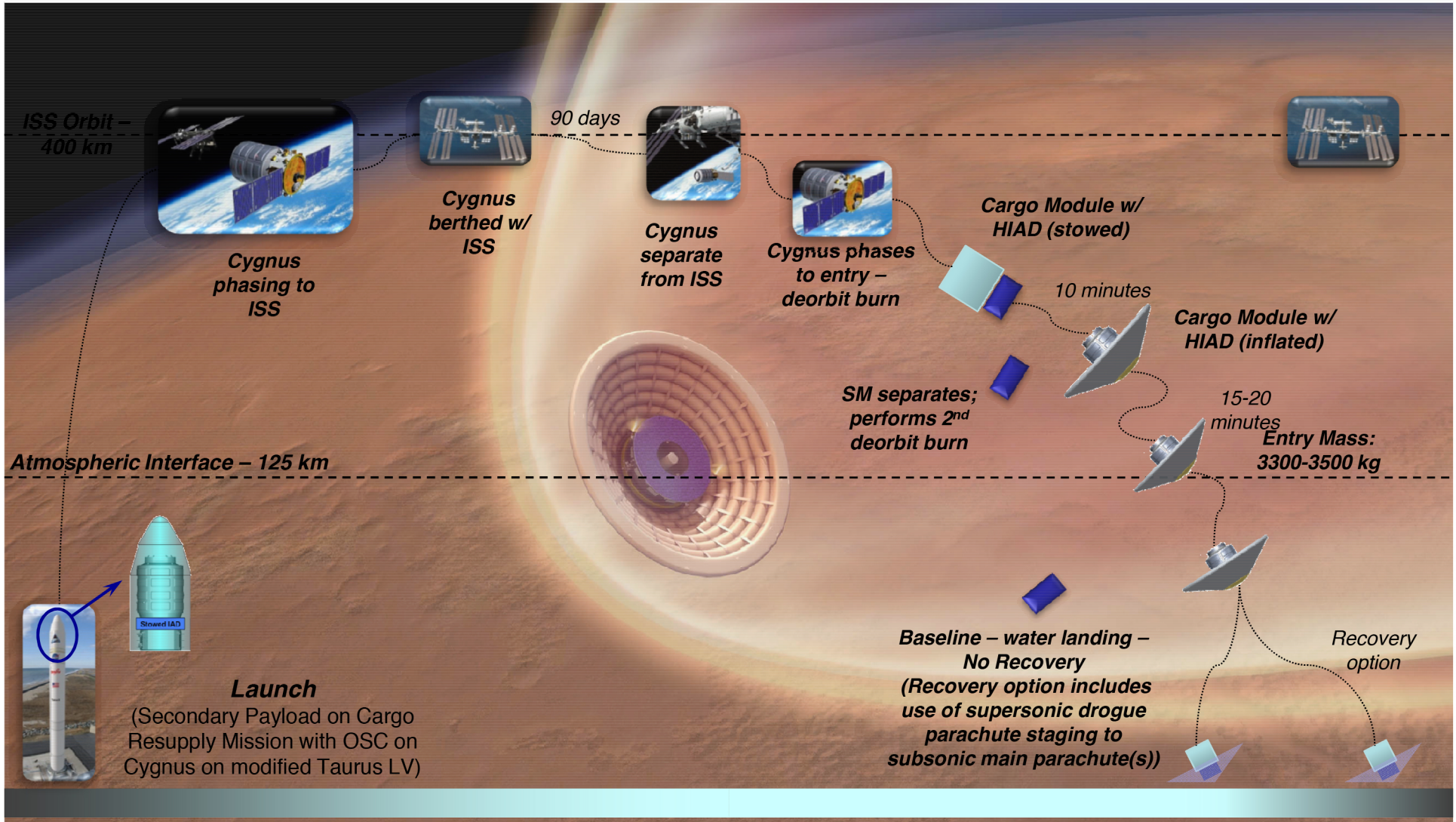


HEART Project Configurations

- **Launch Configuration: HEART and Cygnus**
  - Cygnus SM + Interstage + Stowed HIAD Module + PCM + Upmass Cargo + Flight restraint with cover



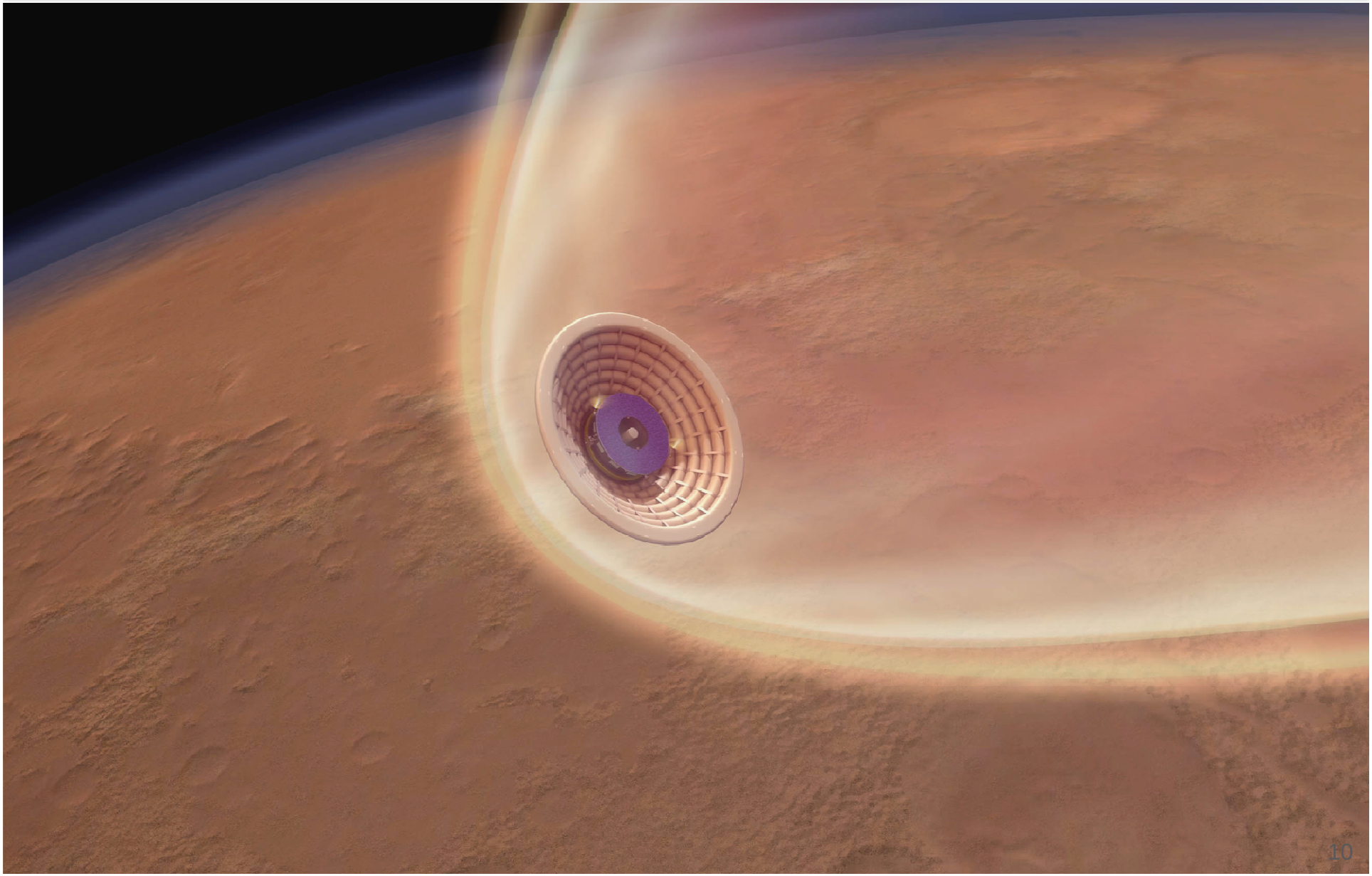
HEART Concept of Operations



NextGen Subsystems: Plans Forward

- **Alternate lift effectors**
  - ✓Two-axis movable CG
  - ✓Deployable tabs
  - ✓Fixed deployable mass
  - ✓Articulating mass boom
- **NextGen geometries**
  - ✓Pre-stressed shapes (flex under load to desired shape)
  - ✓Sharper shoulders, ellipsoidal noses, hyperboloids
  - ✓Asymmetic shapes
  - ✓Unconventional configurations
- **Test methods for large articles**
  - ✓Balloon drop of >8m at subsonic
  - ✓Balloon drop rocket-assist of >8m
  - ✓Advanced lab testing
- **G&C**
  Two lift knobs (direction & magnitude)
- **Aeroshell structural concepts**
  - ✓Rib and stringer
  - ✓Rigidizable
  - ✓Radial boom behind stacked torroids
- **Inflation systems**
- **Staged aeroshells**
  - ✓Dual use bladders with two single-use TPS
  - ✓Drop TPS after q-pulse for supersonic
  - ✓Deploy additional area after q-pulse
  - ✓Drop outer torroids (bladder and TPS) after aerocapture before 2nd entry

Education and Public Outreach



Summary/Next Steps

- **TPS and Flexible Structures development demonstrating robotic scale mission relevant capabilities with development path to larger scales**
- **IRVE-3 flight test to demonstrate HIAD Technology in a relevant environment**
- **HEART flight test to demonstrate HIAD Technology at a relevant environment AND scale (mass and size)**
- **Team focused on achieving 2011/2012 milestones:**
  - IRVE-3: CDR (Jun), Complete System Test (Nov), Launch (Apr 2012)
  - HEART: Peer Review (May), MCR (Jul), SRR (Nov), PDR (Sep 2012)
  - Transition to Turbulence Wind Tunnel Test: LaRC M6 (Jun)
  - Flexible TPS Testing: HTT (May-Aug), Boeing LCAT (Jun)
  - Large-scale Inflatable Articles: 6-m (Sep 2011), 8.3-m (Nov 2011), NFAC Test (Jan/Feb 2012)