Development of Inflatable Entry Systems Technologies

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Overview

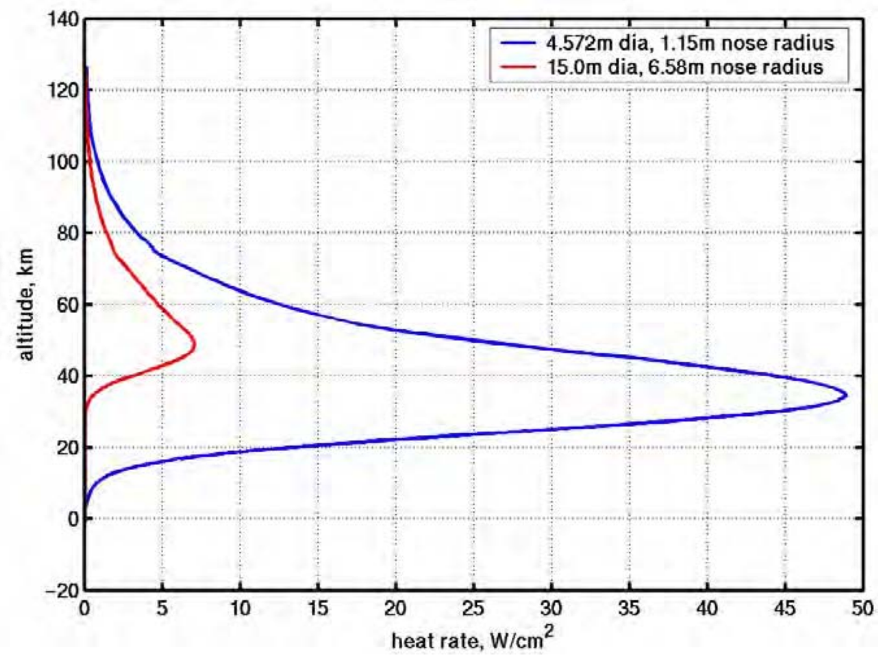
- Why an Inflatable Aeroshell?
- Current LaRC Inflatable Aeroshell Projects
  - IRVE
  - IATD
- Proposed Inflatable Aeroshell Projects
- Analysis & Capabilities Development
- Overall Technology Development Plan

Why an Inflatable Aeroshell?

- Advantages over rigid aeroshell
  - Deflated/Stowed, the aeroshell is a small, modular component thereby allowing:
    - Increased payload volume fraction in the launch vehicle shroud
    - Access to the payload after the launch vehicle integration
    - System duplication between the cruise stage and entry vehicle
    - Delivery of more payload mass to the surface
  - Inflated, the aeroshell can achieve sizes much larger than those attainable by rigid aeroshells allowing:
    - Rapid high-altitude deceleration for access to high altitude landing sites
    - A less hazardous thermal environment for the total entry system
- Technical Challenges
  - Flexible Structure
    - Unpredictable drag performance
    - Aero-structural dynamic instability
  - Durability / Reliability
  - Aerothermal heating

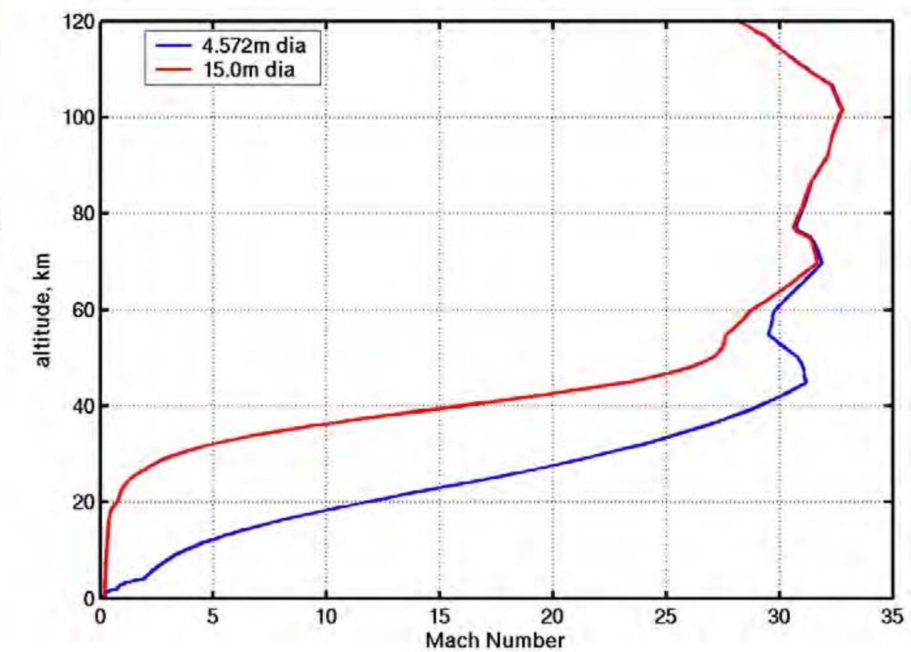
Rigid vs. Inflatable Representative MSL Mission

Direct Ballistic Entry, 6km/s, 2200kg Entry Mass,
1.3N, 27.0 longitude landing site

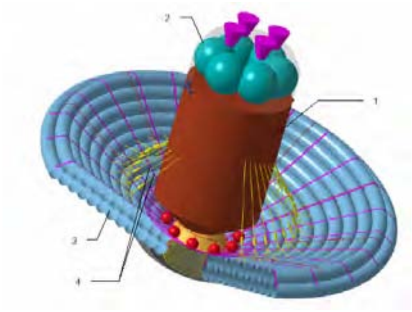


15m Inflatable 70deg Sphere-Cone

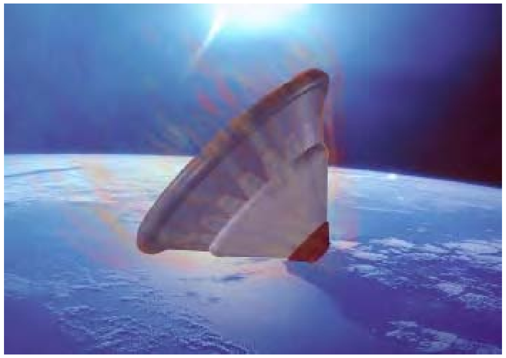
4.572m Rigid 70deg Sphere-Cone



Other Inflatable Entry Systems Work



MIAS



IRDT

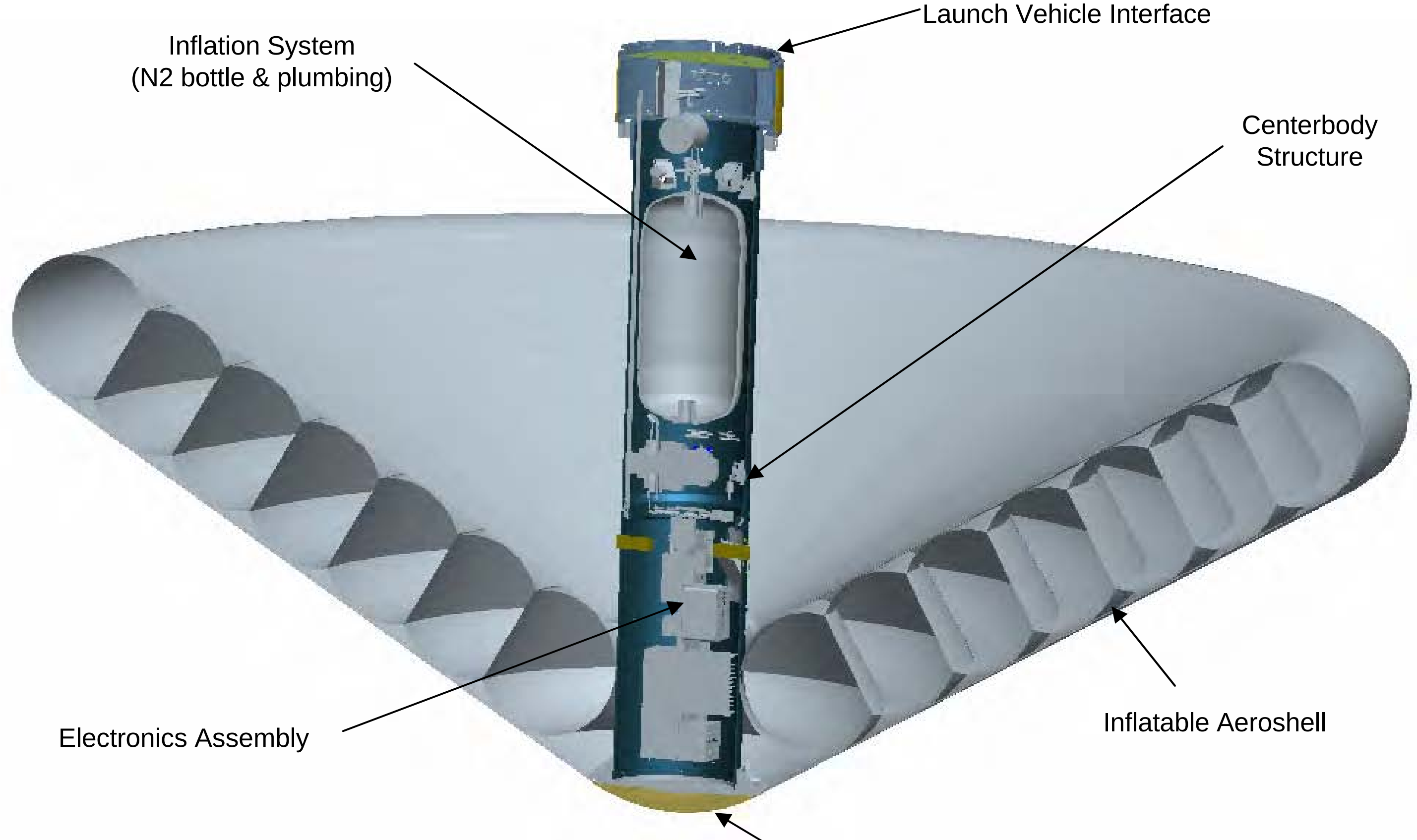
Hypercone

- Mars Inflatable Aeroshell System (MIAS)
  - JSC funded activity with several international partners
  - Requirements & concept development for Mars aero-assist entry vehicles
- Inflatable Re-entry and Descent Technology (IRDT)
  - Flight Test program of aeroshell developed by Lavochkin for Mars-96
- Vertigo Inc., Hypercone
  - Supersonic decelerator technology feasibility analysis

Current LaRC Inflatable Aeroshell Projects

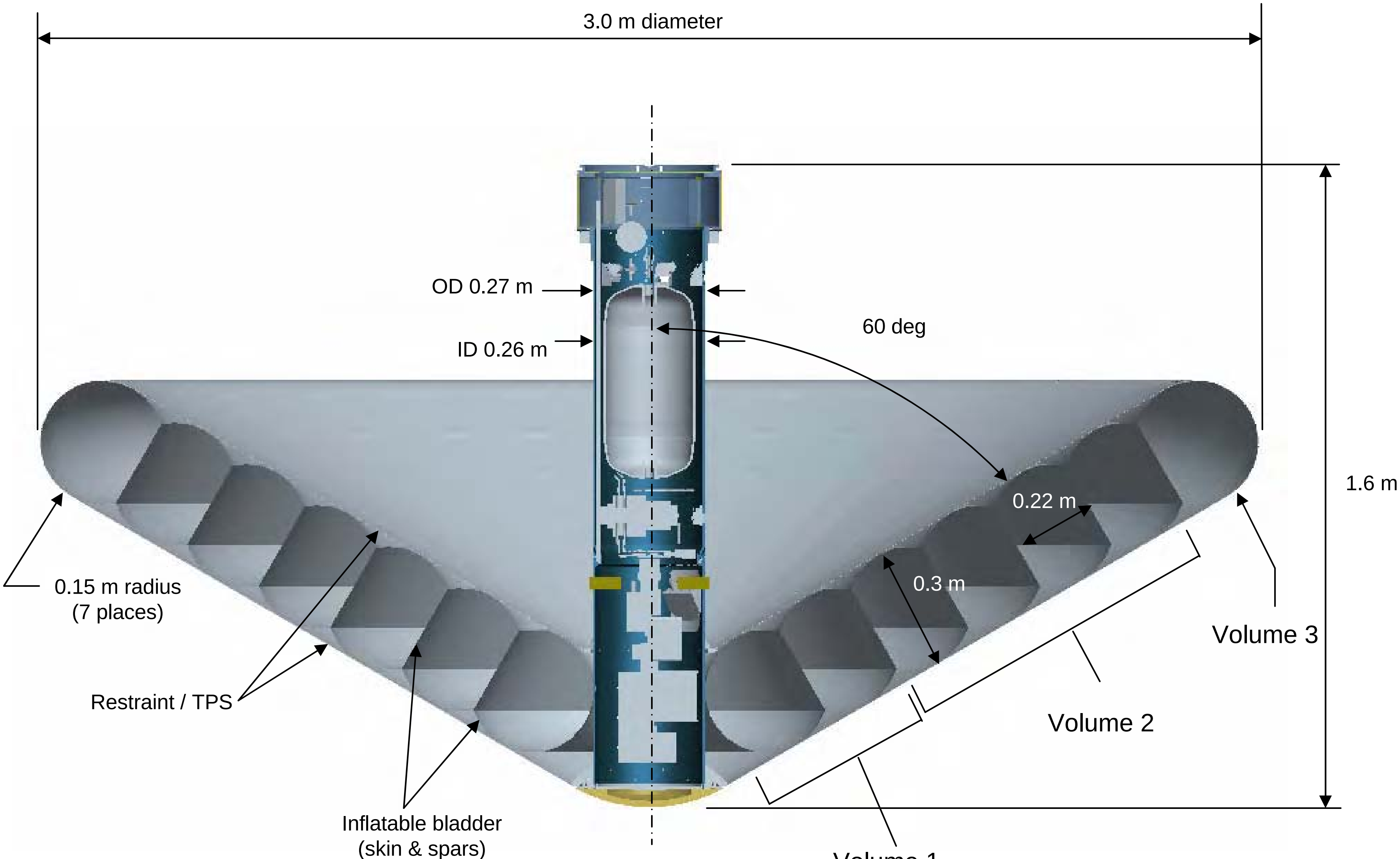
- Inflatable Reentry Vehicle Experiment (IRVE)
  - Collaboration between LaRC and WFF
  - Started in 2003
  - Flight Demonstration in December 2005
    - Packaging efficiency
    - Exo-atmospheric Deployment and Inflation
    - Structural integrity and aerodynamic stability throughout the flight
- Inflatable Aeroshell and Thermal Protection System Development (IATD)
  - JSC led ESR&T Project
  - Started January 2005
  - Demonstrate inflatable aeroshell technology specifically for VSE applications
  - Application Trade Study phase
  - Three Flight Demonstrations

IRVE Reentry Vehicle

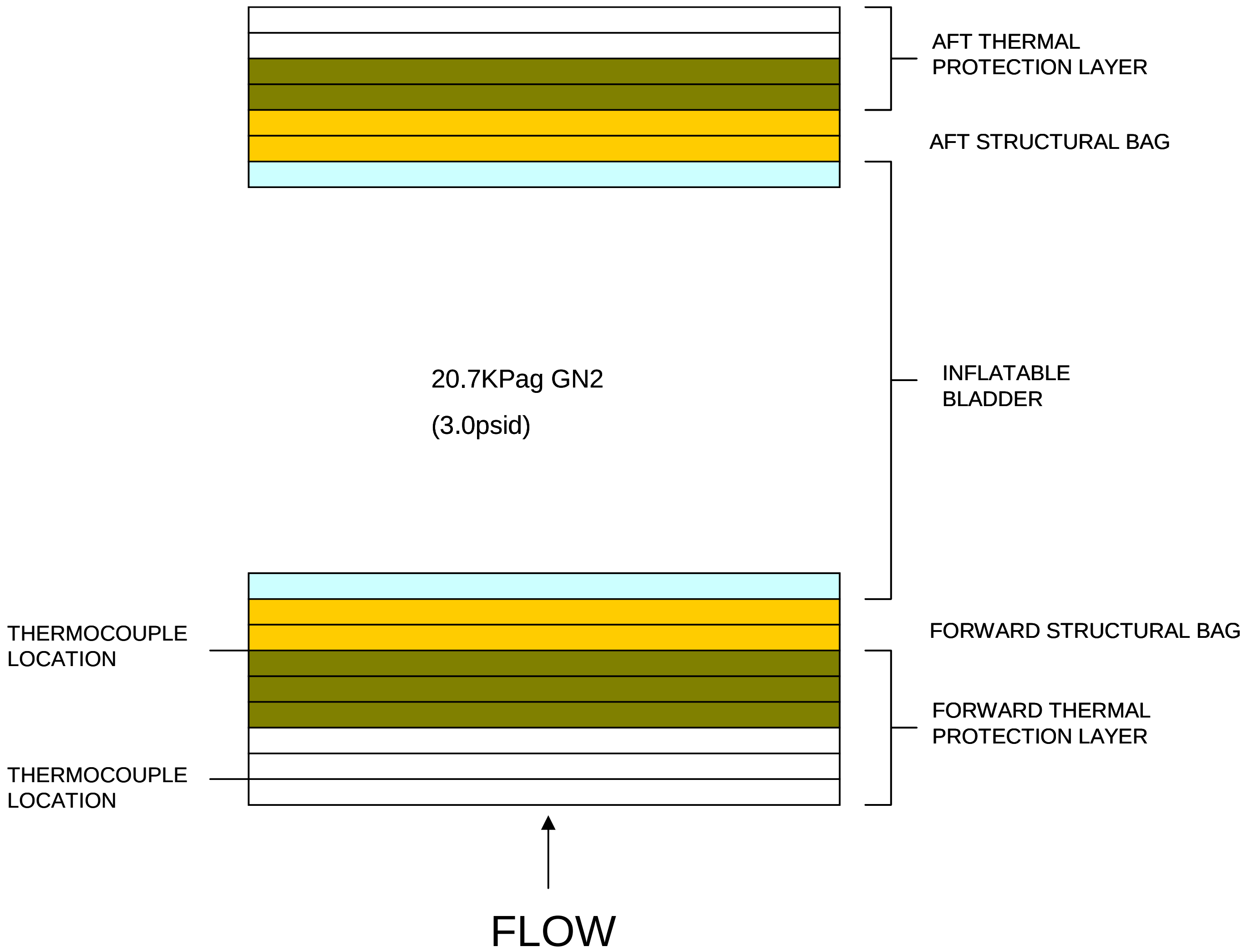


Mass = 101.6kg

IRVE Aeroshell Construction



Inflatable Ply Lay-Up



IRVE Flight Test Timeline

RV separation from TM
64s (78 km)

Inflation begins at 250s

Separate Booster and
Fairing From RV and
T/M 60s

RV completes inflation
prior to Reentry

RV begins broadcast
of data after separation

T=302s **125 kilometers**

Atmospheric Interface

Coast to 72 km, (60s),

RV passes through pressure
pulse at ~46 kilometers.

2nd stage burnout, 40 seconds
2nd stage ignition, 15 seconds

Flight Experiment concluded
just after vehicle has passed
Max dynamic pressure

T=370s or
Alt < 46 km

Launch on Terrier-Orion
From Wallops Island

T=0s

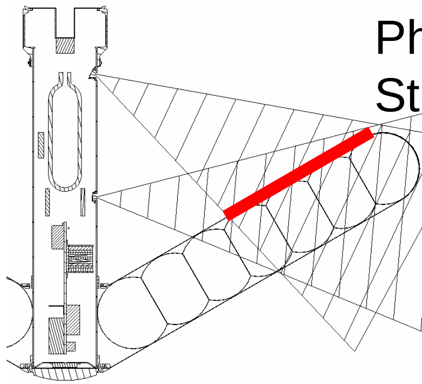
WFF provides launch
operations, telemetry
acquisition, and radar
track of flight

RV impacts water at 16.5 m/s.

T=1256s

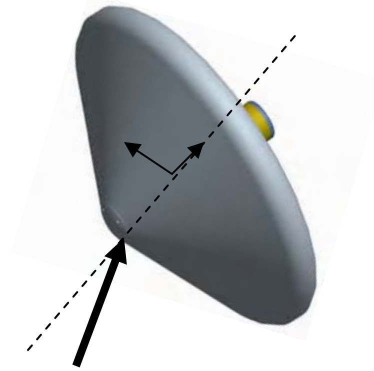
IRVE Data Products

- In-Flight Measurements
  - Attitude
  - Deceleration
  - Video of inflation
  - Aeroshell dynamics
  - In-depth and surface temperature measurements
  - Inflation system performance measurements
- Data Products
  - AoA History
  - Drag History
  - Inflation History
  - RV Trajectory
  - Thru-depth Temperature History
  - Surface Temperature History
  - System Health & Status History

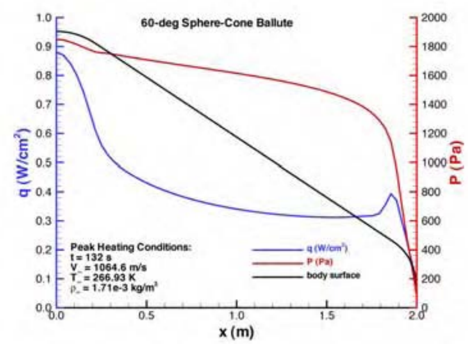


Photogrammetric Structural Analysis

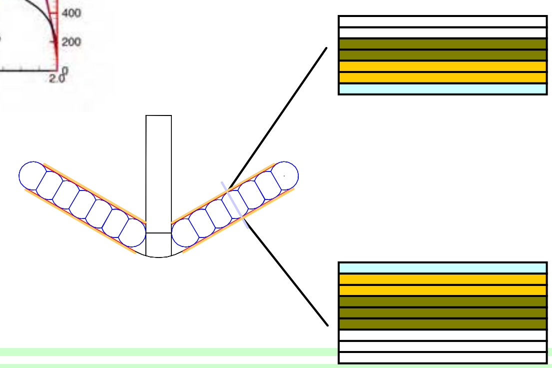
Angle of Attack, Trajectory, Drag History



Temperature Distribution



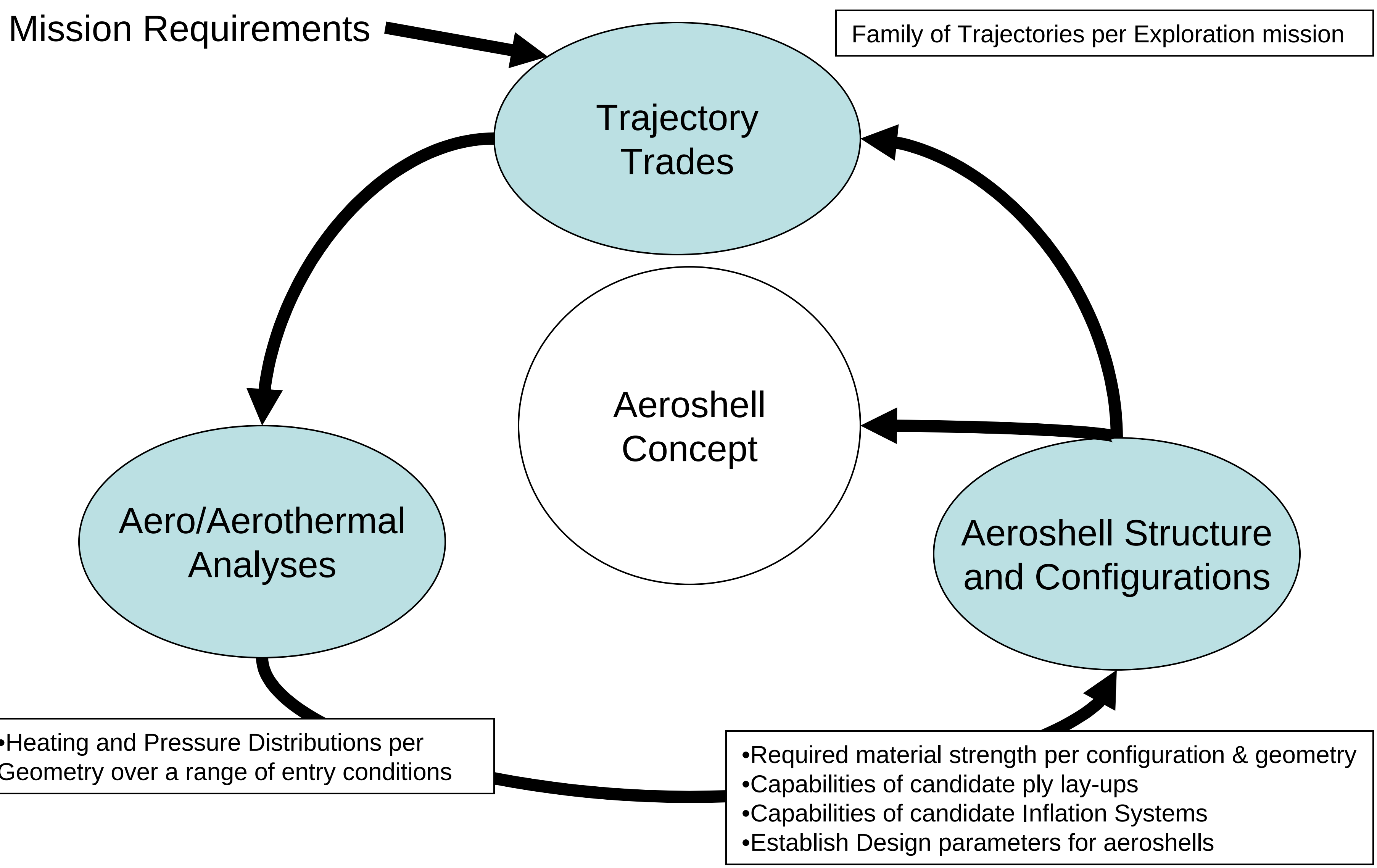
Thermal Gradient



IATD Application Trade Studies

- Mission Specific Applications
  - ISS Downmass
  - Trans-Lunar Injection Stage Return Aerocapture
  - Lunar Return Aerocapture
  - Crew Exploration Vehicle Abort
  - Mars Entry (Robotic and Human Precursor Missions)
  - Trans-Martian Injection Stage Return Aerocapture
  - Mars Return
- Trajectory Trades
  - Output a family of trajectories that meet mission requirements parameterized by L/D & C_B
- Aero/Aerothermal Analyses
  - Output Normalized heating and pressure distribution over a trade space of multiple aeroshell geometries, and C_DA combinations
- Aeroshell Structure and Configurations
  - Characterize inflatable aeroshell subsystems (i.e. inflation system, ply lay-up, bladder material properties, etc.) per aeroshell geometry and mission environment

IATD Application Trade Studies



IATD Flight Tests

- Flight Test 1 Objectives
  - Demonstrate Lift Generation
  - Demonstrate survivability at a more challenging re-entry environment
- Flight Test 2 & 3 Objectives
  - Demonstrate scalability to an 8-12 meter aeroshell
  - Demonstrate Controllability
  - Demonstrate survivability at a more challenging re-entry environment
- Mission Supporting Technologies
  - Gas Generator inflation systems
  - Angle-of-Attack Control and/or Roll Modulation Techniques
- Development Supporting Technologies
  - Talus-Oriole sounding rocket

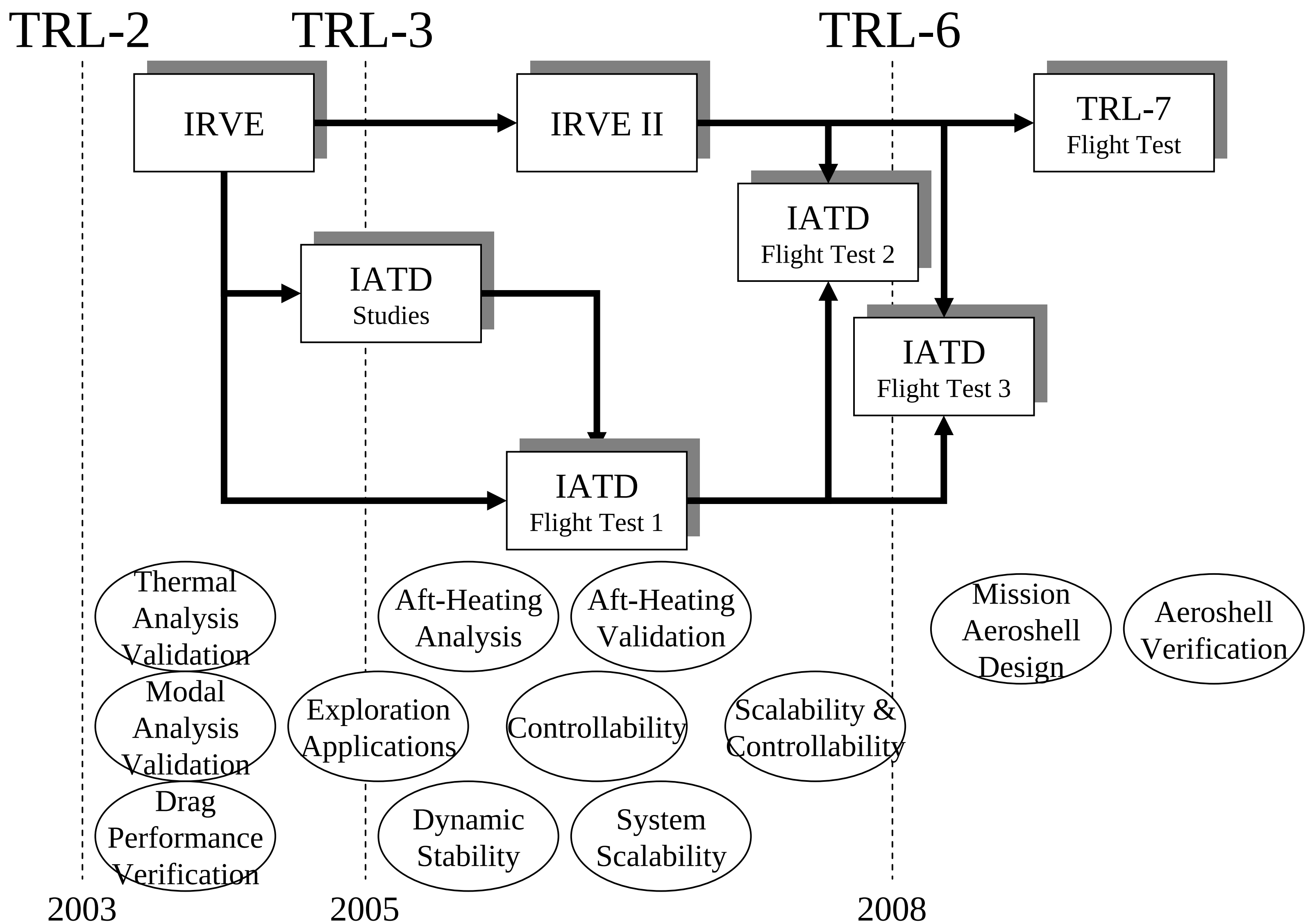
Proposed Inflatable Aeroshell Projects

- IRVE II
  - LaRC and WFF are currently in discussions over a follow-on flight to IRVE
  - Flight on a Talus-Oriole Sounding Rocket
  - Demonstrate an 8-10 meter aeroshell on a ballistic trajectory
  - Provide an independent path for technology development
- TRL-7 Flight Test
  - Secondary payload on geo-satellite launch
  - Reentry Vehicle deployed into a GTO orbit
  - Entry velocity approximately 10 km/s.
  - 4-meter aeroshell
  - Entry conditions are mission relevant for ISS Downmass and Lunar Return missions

Development of Analysis & Prediction Capabilities

- Flight tests serve as demonstrations of the technology's capabilities
- Flight tests serve as a test bed to validate the tools and methodologies used to design each flight test article
- Modeling and Analysis Capabilities Required
  - Aero- and Radiative heating prediction
  - Structural response prediction
  - Aft-body heating
  - Dynamic stability prediction
  - Controllability
  - Scalability

Overall Technology Development Process



Summary

- Key to Technology Development is Risk Reduction
  - Sufficient technical risk reduction for mission implementation
    - Demonstrated Technology Performance
    - Demonstrated Design Techniques
    - Demonstrated Fabrication Techniques
  - Technology development process risk reduction
    - Continued promotion of the technology
    - Technical risk mitigation plan for technologies that support the technology development process
    - Multiple technology development paths / options

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Questions