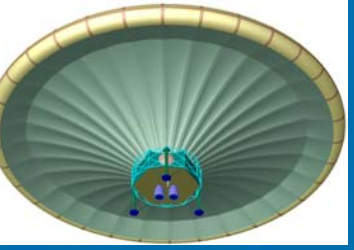

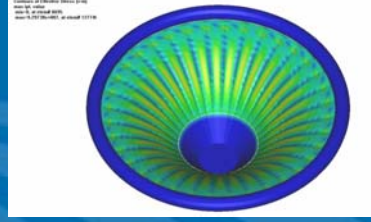

Parachute Seminar

3rd International Planetary Probe Workshop

Alternative Technologies

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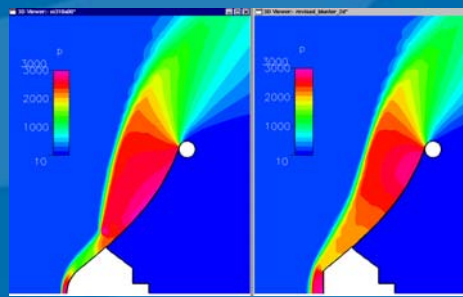

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Inflatables

- Inflatable entry systems
- Ballutes for aerocapture
- Hypercone

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Inflatable entry systems

- Overcomes launcher fairing limitation
- Reduced ballistic coefficient
  - Reduced flux
- Issues
  - Flexible TPS
  - Aeroelastic effects
  - Structural robustness
    - Impact damage
  - Active gassing system
  - Mass fraction

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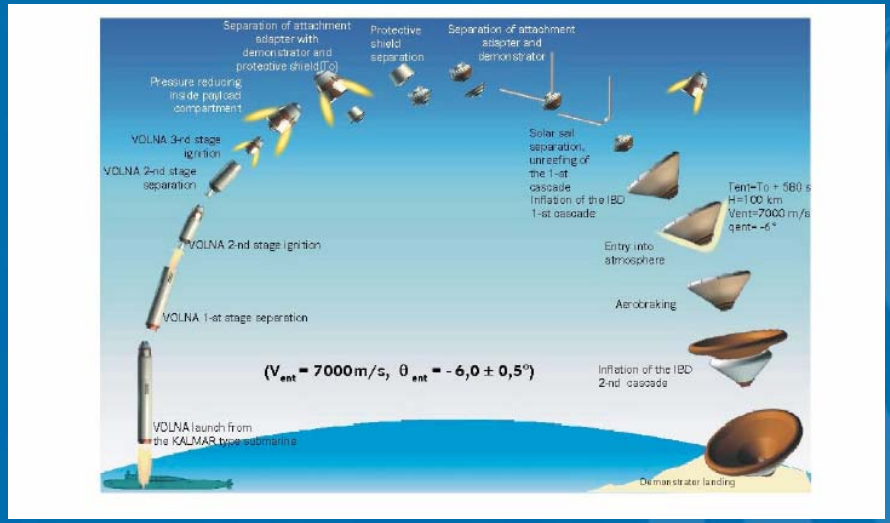
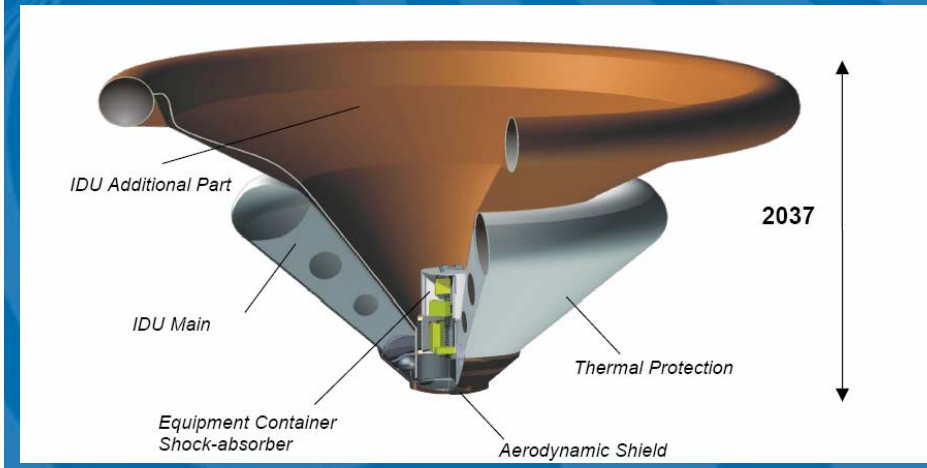
Inflatable re-entry systems





- IRDT-2 reflight early July
  - 7000 m/s -6°
- IRVE also flies this year

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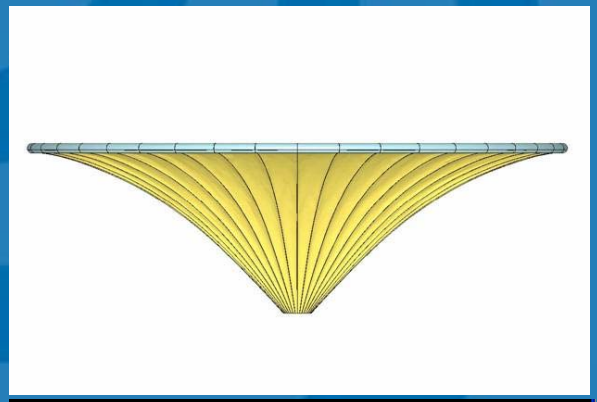
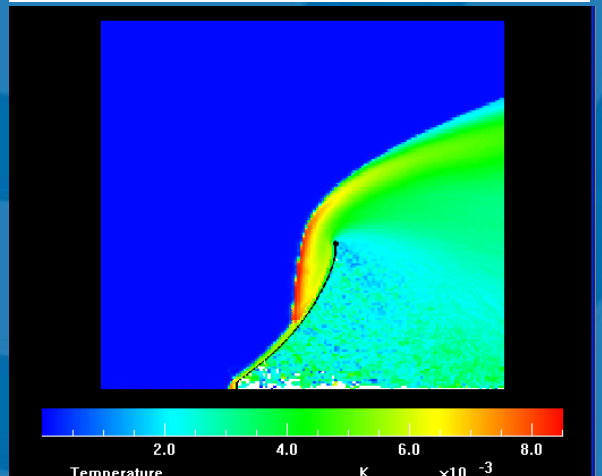
Ballutes for Aerocapture

- Low ballistic coefficient aerocapture
  - $\beta \approx 0.5$
  - Low heat flux
  - Material limited
  - Mass advantages over rigid technology seem feasible





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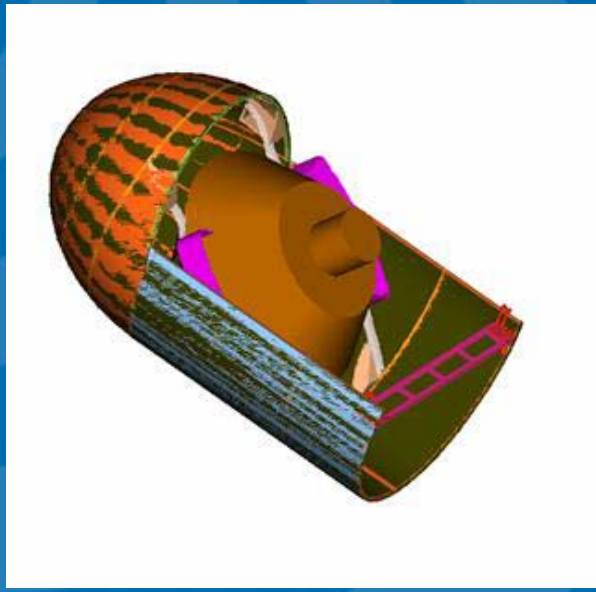
Hypercone - Background

- The Ellipsled mid L/D aeroshell shape originated with studies on human missions to Mars
  - Good volume and packaging efficiency
  - Efficient aerodynamic deceleration appropriate for human crews
  - Good aerodynamic manoeuvrability for precision trajectory control
  - Good aerodynamic stability characteristics



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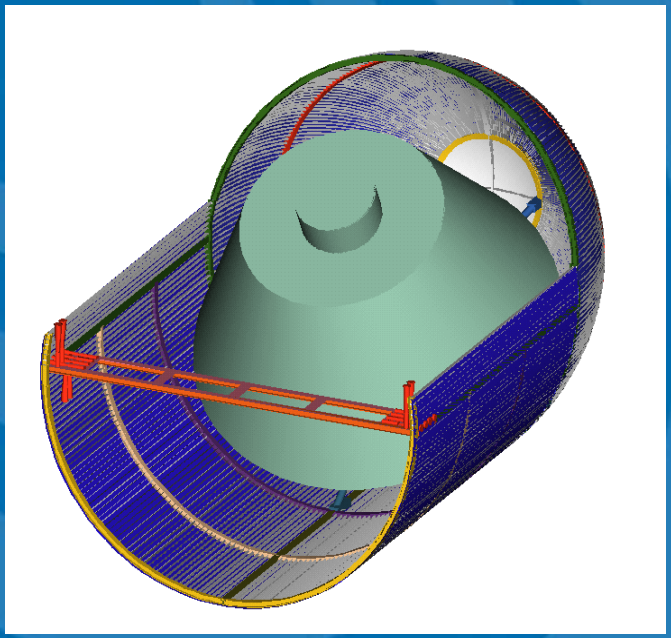
Background

- Ellipsled capable of delivering more mass to the surface of Mars than the sphere cone shape but requires larger launch masses
- Expansion of high Mach parachute technology increases landed mass capability of both the ellipsled and sphere cone systems by about 75%
- No new technologies required except for expansion of the parachute envelope: M=1.4 to 3; q = 400 to 1600 Pa to make robotic and human missions viable with the ellipsled



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Descent System Requirements

- Define descent system able to:
  - Achieve terminal descent velocity of <50m/s 4km above MOLA
  - Landing at Challenge site 2.5km above MOLA
  - Initial conditions
    - Mach: 3.0
    - Dynamic Pressure: 1600 Pa
    - Altitude wrt geoid: 6.65 km
    - Relative Velocity: 675.9 m/s
    - Relative Flight Path Angle: -20.47°
- Masses
  - Launch: 7492kg
  - Entry interface:6689kg
  - Separated ellipsled 1846kg
  - Descent mass: 4843kg

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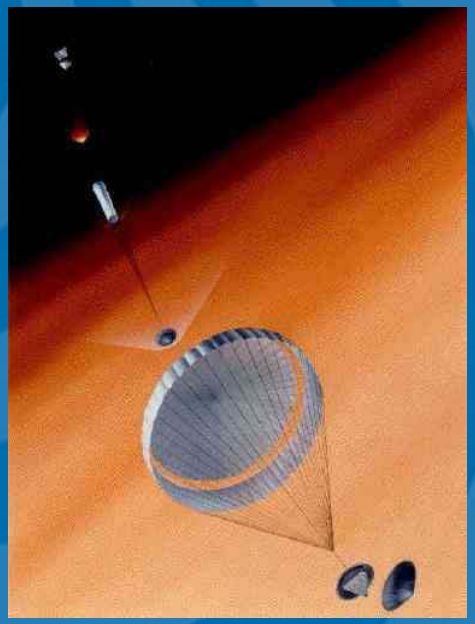
Background

- 2 stage parachute system was reviewed (DGB for supersonic phase, ringsail for subsonic phase)
  - Could not meet Challenge site requirements
  - Potential problems with separation from the ellipsled at Mach 3.0
- Viking Disk-Gap-Band parachute
  - tested to Mach 2.8
  - show increasing inflation instability and severe reduction in drag above Mach 1.5.
  - poor deceleration performance
- Without a radical improvement in parachute technology or an alternative decelerator technology better suited to supersonic Mach numbers the potential benefits of the ellipsled may not be realised.



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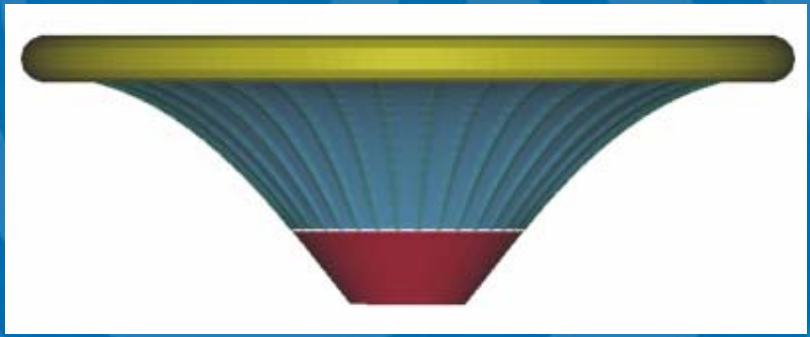
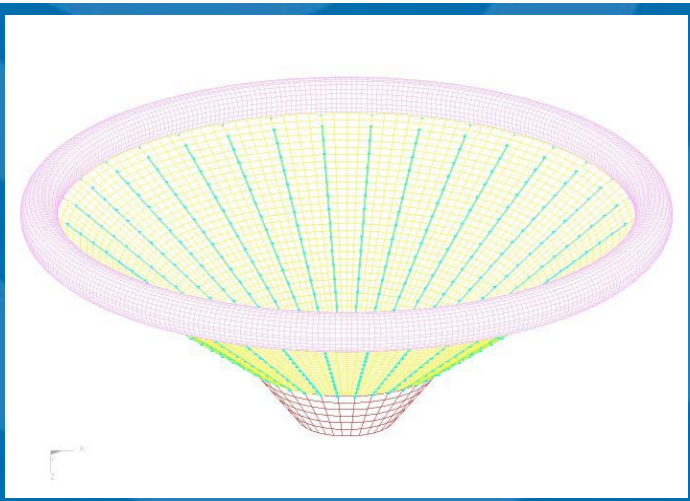
Hypercone Concept

- Inflatable aerodynamic decelerator
  - proposed to NASA by Vertigo Inc.
  - provides deceleration and stabilization
  - Mach 4.0 to subsonic conditions
  - comprises an inflated torus supporting a conical fabric forward section
  - fully flexible can be packed like a parachute
  - deployed directly attached to the lander
  - previous trajectory / mass studies conducted for 60MT and MT payloads





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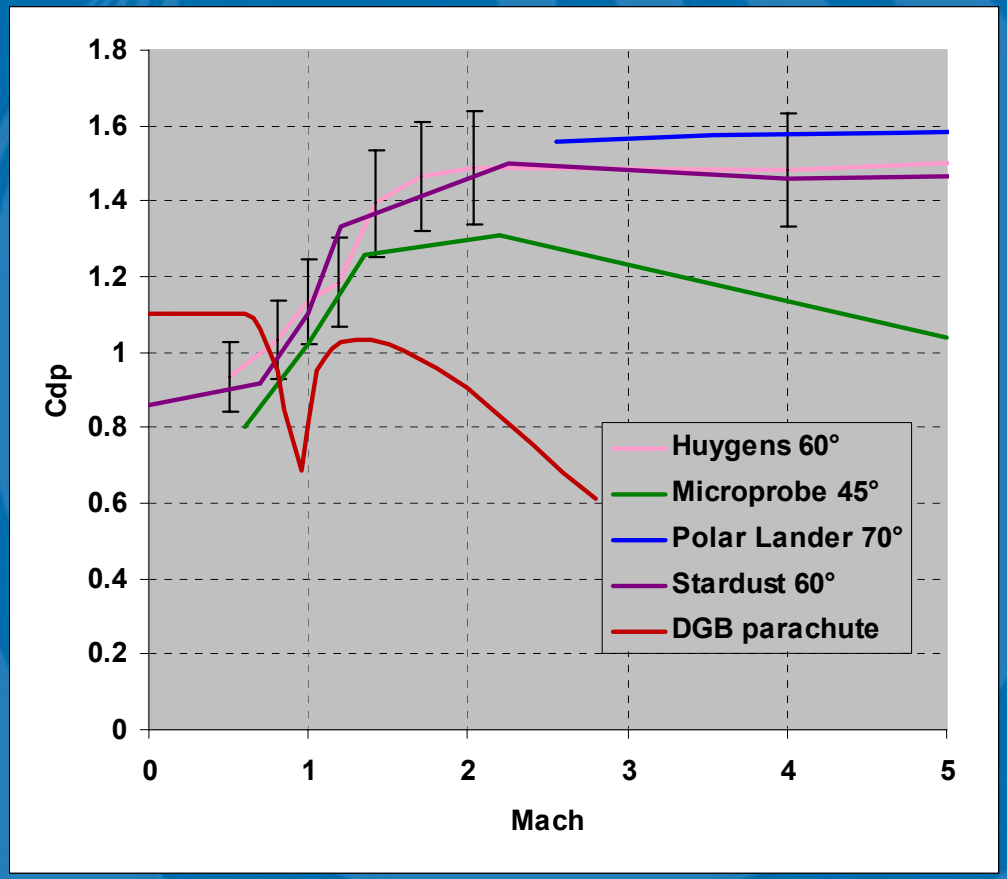
Why Hypercone?

- Sphere cone provides:
  - Good drag performance
  - Good static stability
  - Dynamically stable to Mach 1.5



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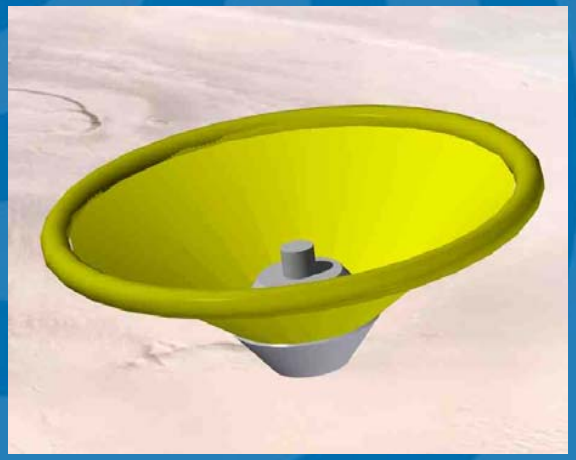
Hypercone System Studies

- Vorticity contracted by Vertigo under NASA JSC prime contract to conduct analysis, trade studies and decelerator system design
  - Requirements Analysis
  - System sizing / nominal performance for Mars missions
  - Off nominal sensitivity analysis
  - System sequence definition
  - System inflation dynamics
  - System dynamic stability
  - Stress analysis
  - System mass optimization
  - Inertia estimates
  - Interface load estimates / general load cases
- Wind Tunnel Test Design and Planning



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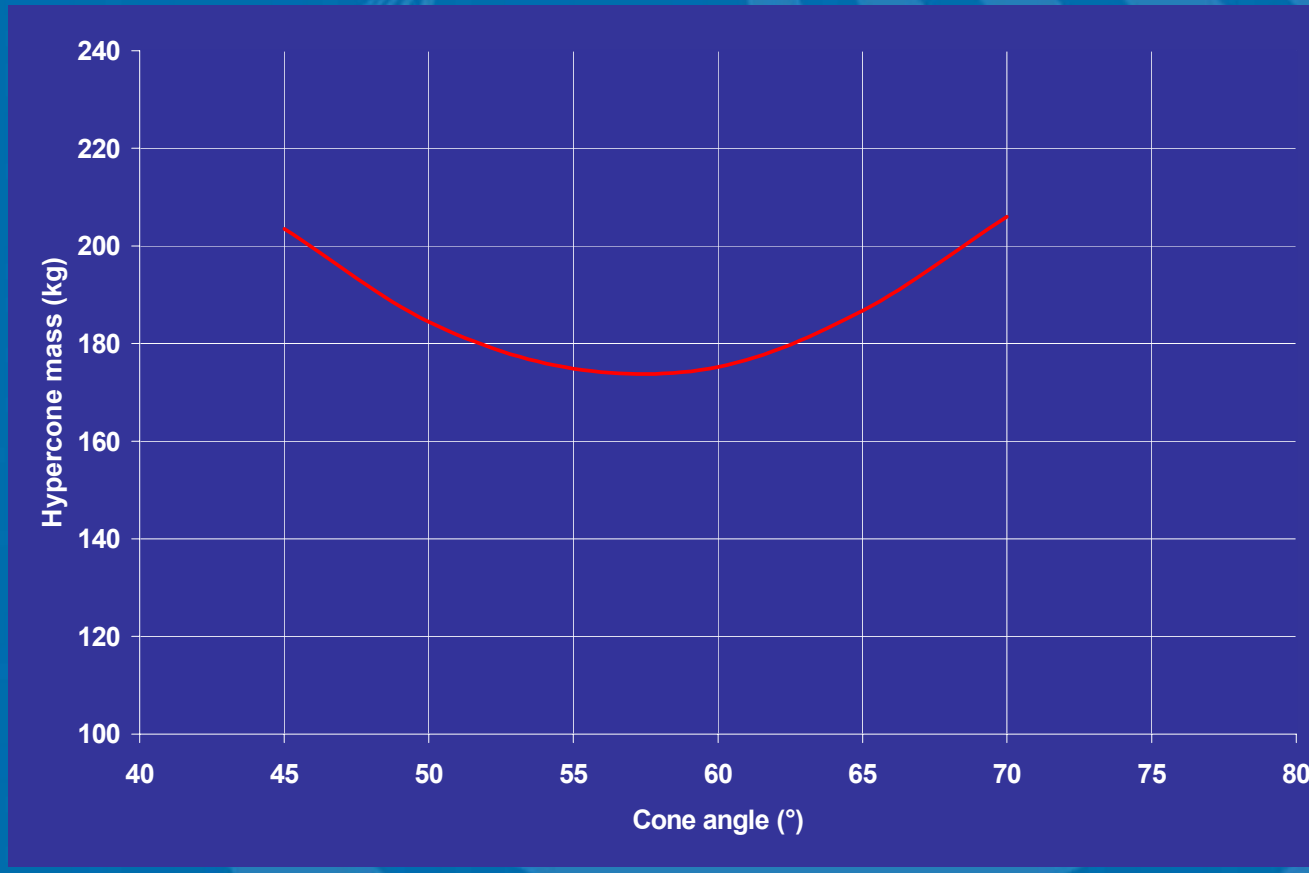
Hypercone Optimization

- q = 1600 Pa
- Mach 3.0
- CdS = 236.8 m^2



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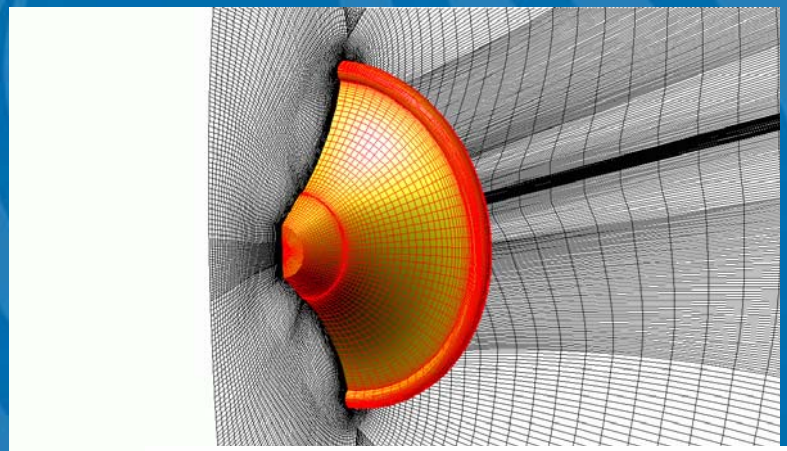
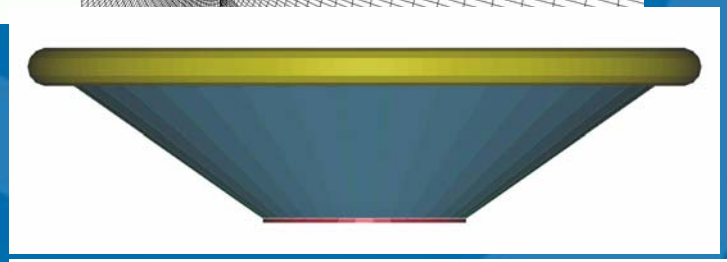
Hypercone Aerodynamics

- Modelled 14m hypercone in LS-DYNA with estimated surface pressures for Mach 2.3 and associated deceleration of 6g to obtain shape
- Flow modelled in CFD Fastran
  - Non-reacting Martian atmosphere 97% CO_2, 3%N_2
  - Mach 0.85 – Mach 4.0
  - Incidences up to 20°
- Derived pressures reapplied to hypercone to check errors in shape





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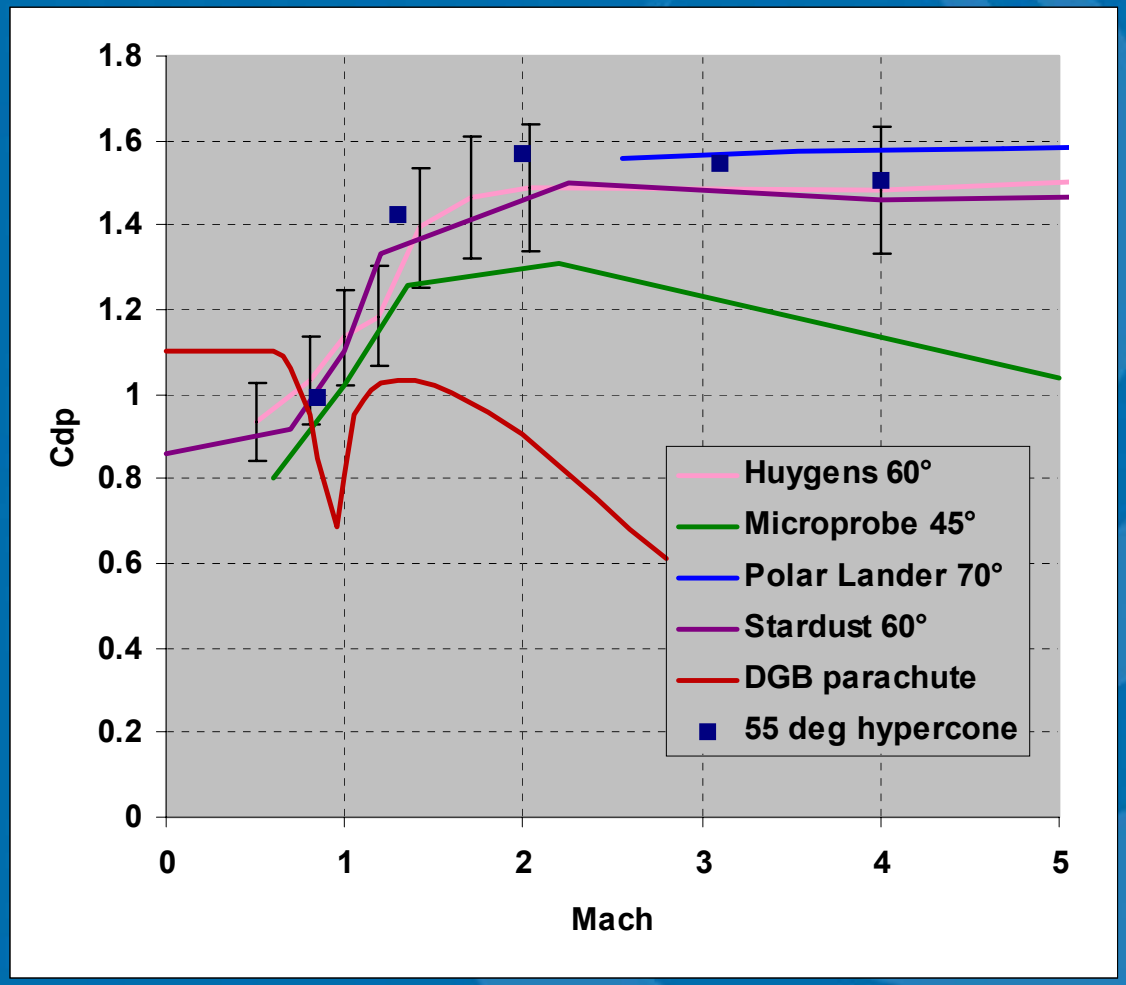
Hypercone Aerodynamics



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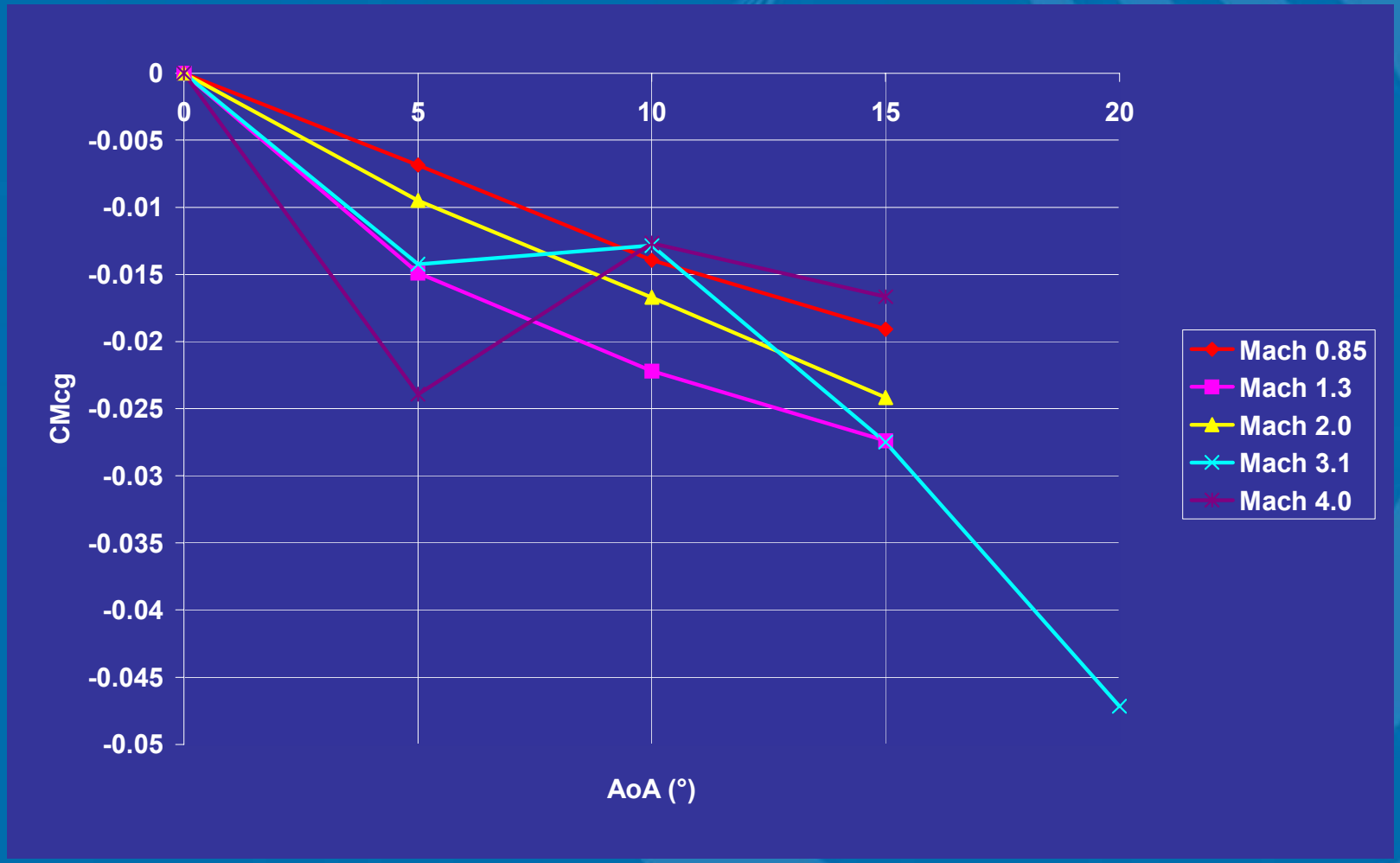
Hypercone Aerodynamics



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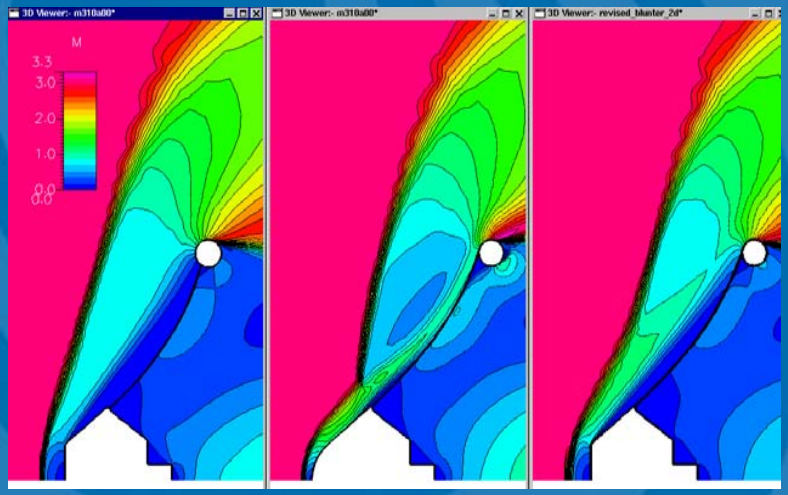
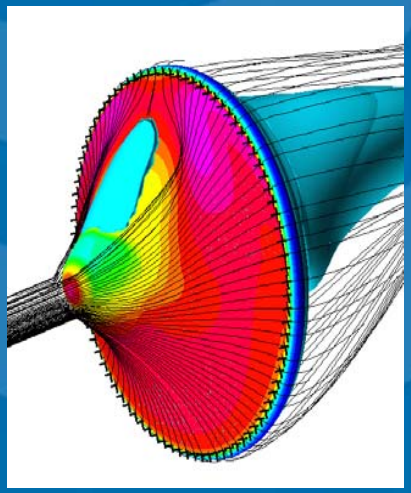
Hypercone Aerodynamics

- Nose shape and cone to torus junction investigated
- Optimum stability and drag achieved with
  - Blunt nose
  - Mid torus junction
- Adverse stability from rounded nose attributed to high total pressure stream moving around a separation bubble toward the surface of the fabric, slowing, and compressing





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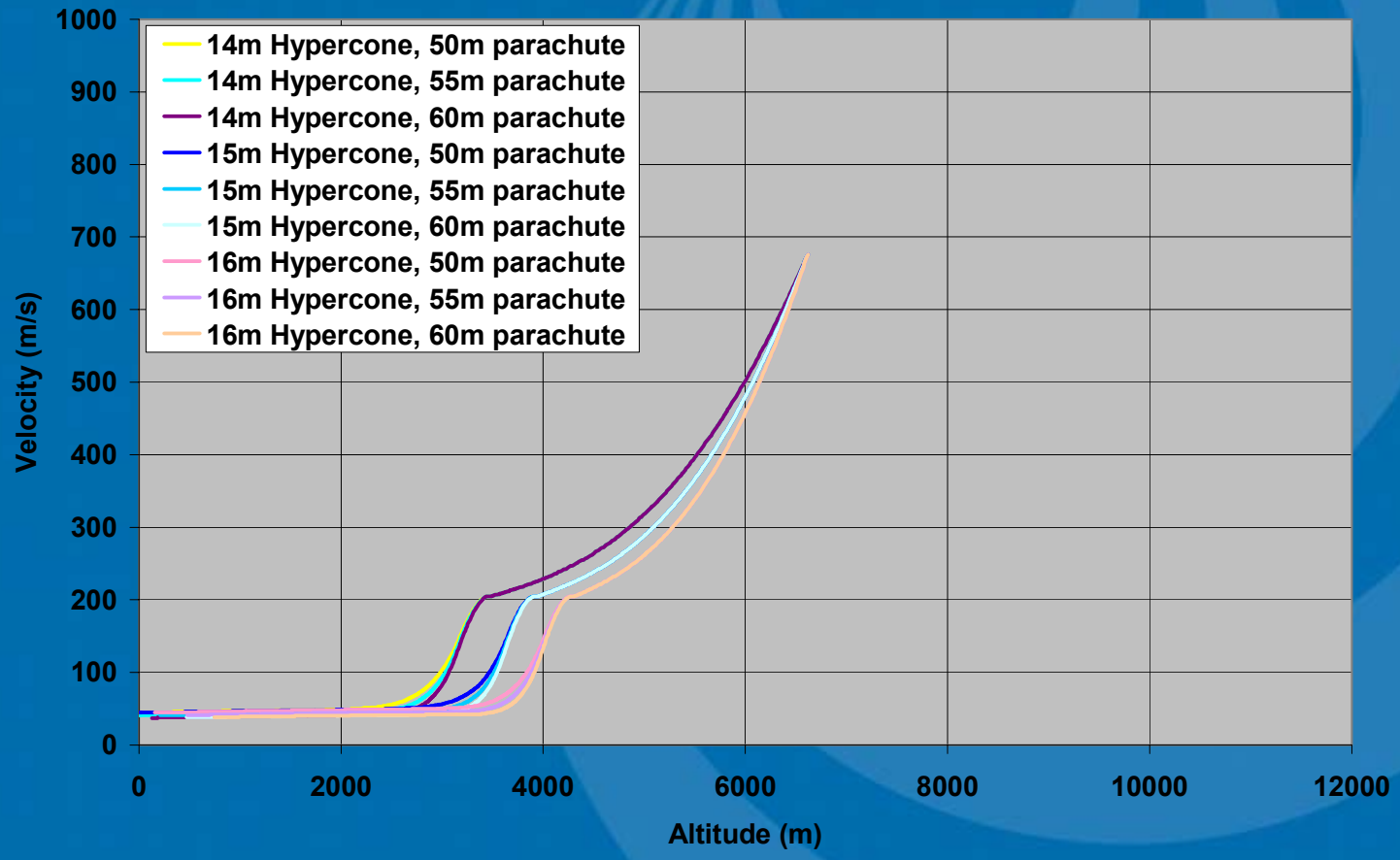
Hypercone System Performance
Mach 3.0 deployment



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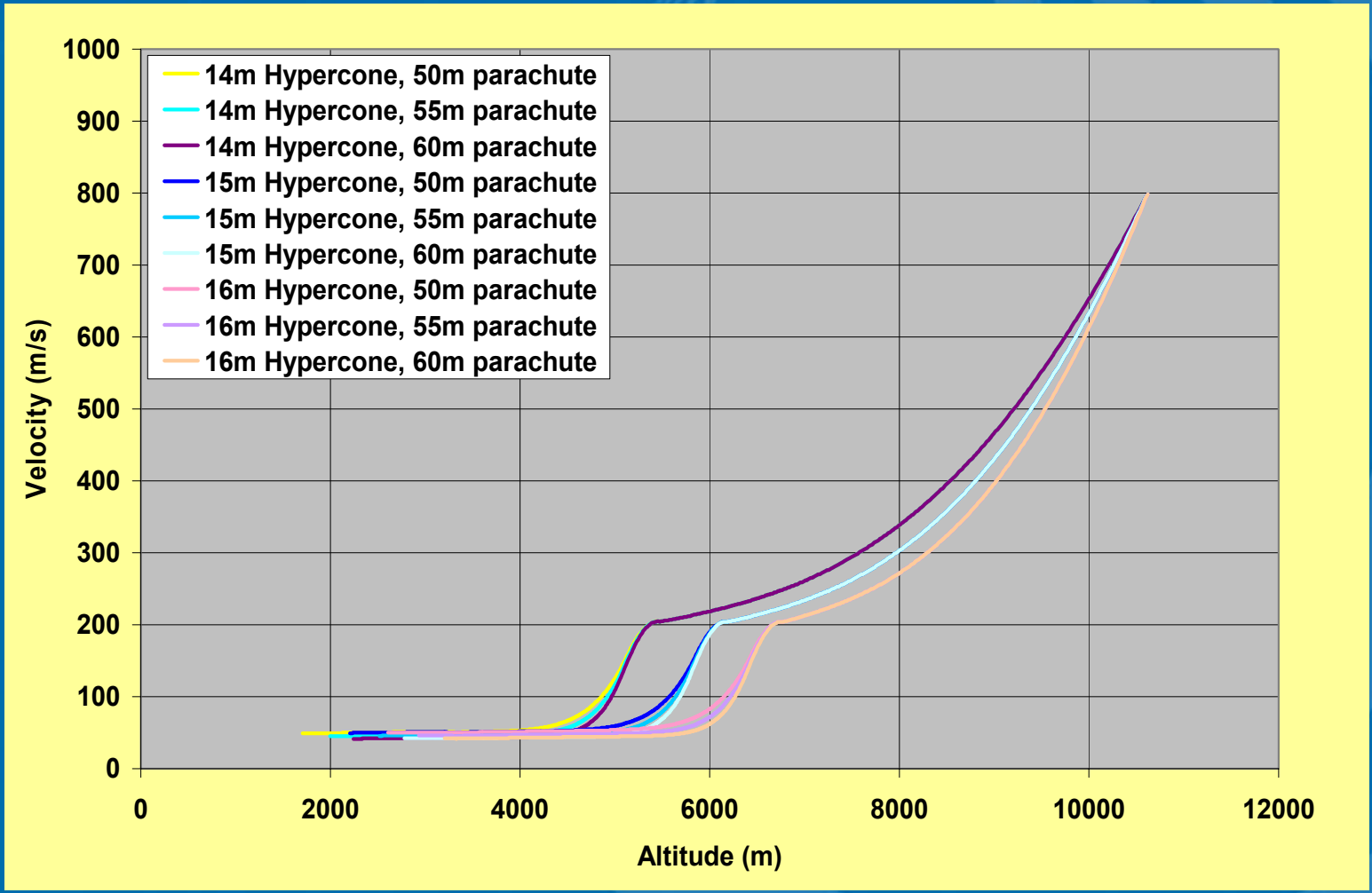
Hypercone System Performance
Mach 3.5 deployment



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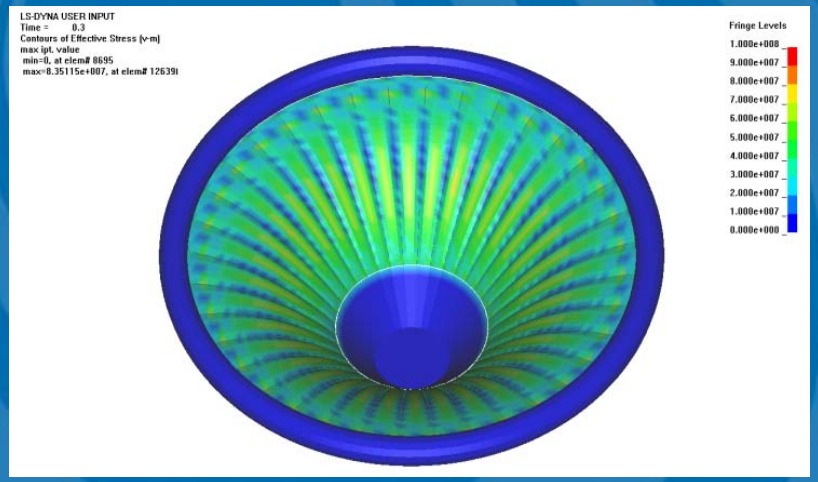
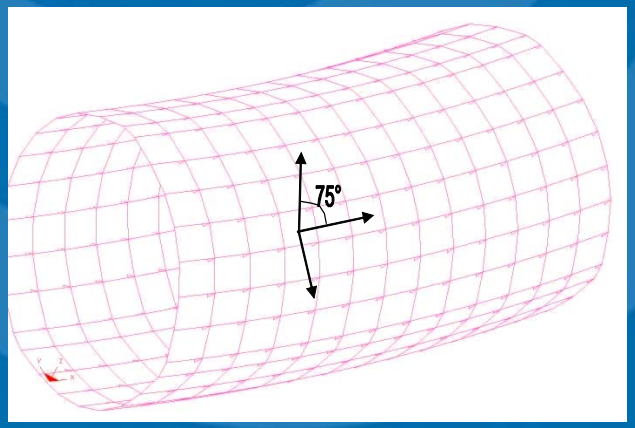
Hypercone Structural Analysis

- Torus and cone modelled in detail in LS-DYNA
  - Torus is 75° Vectran biased braid with straps
  - Anisotropic braid correctly modelled
  - Cone is Vectran gores modelled as as orthotropic membrane with cable elements for seams
  - Pressures from CFD studies
  - Determine stresses and size materials
  - Examine requirements for inflation pressure / buckling
    - 235kPa inflation pressure for Mach 3.5 case q =1600





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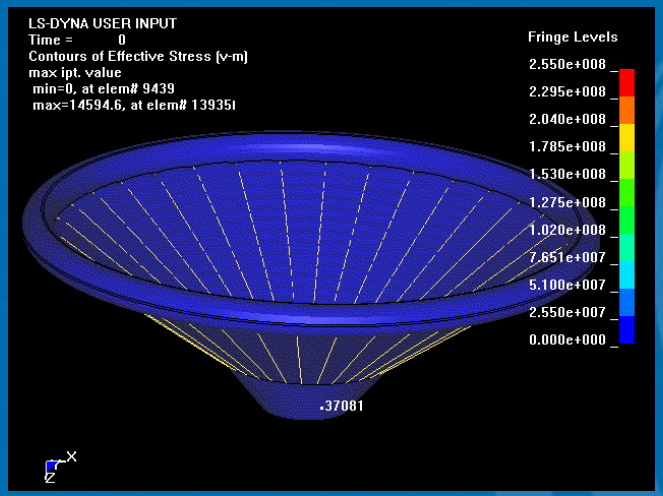
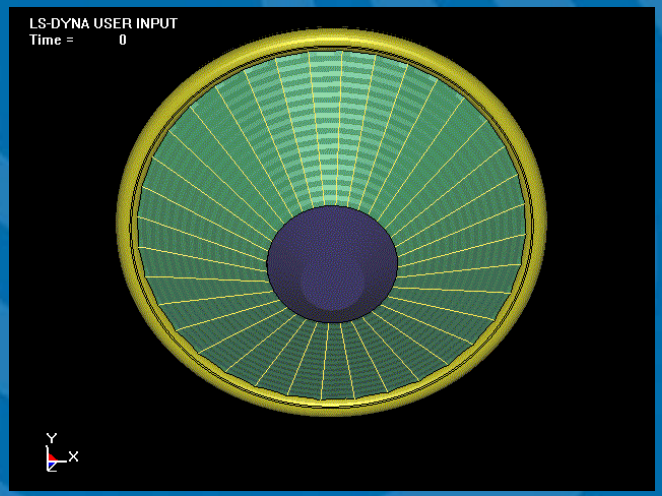
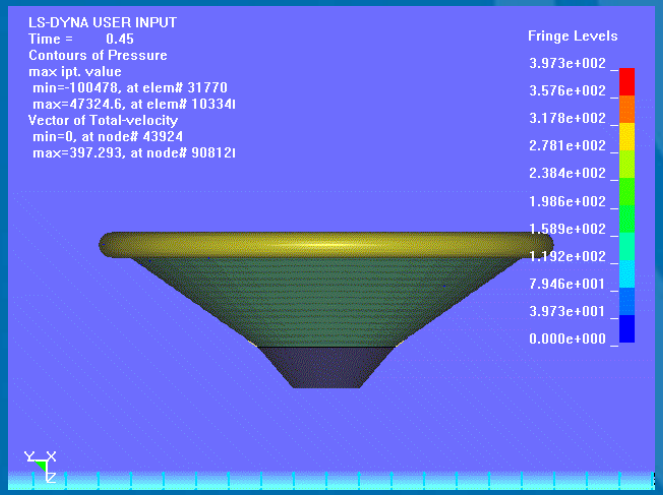
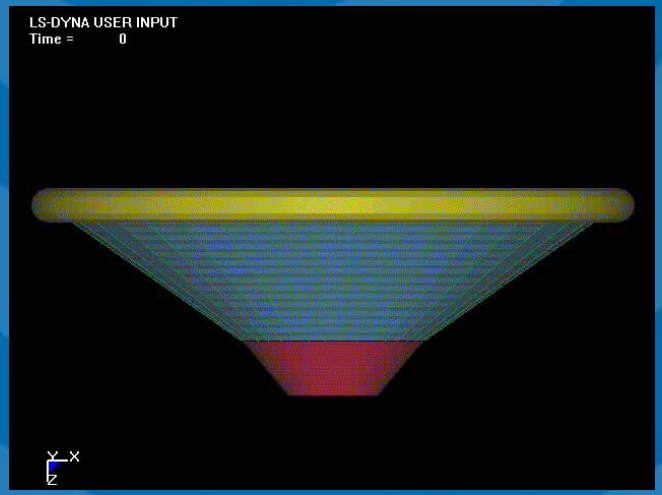
Performance Prediction









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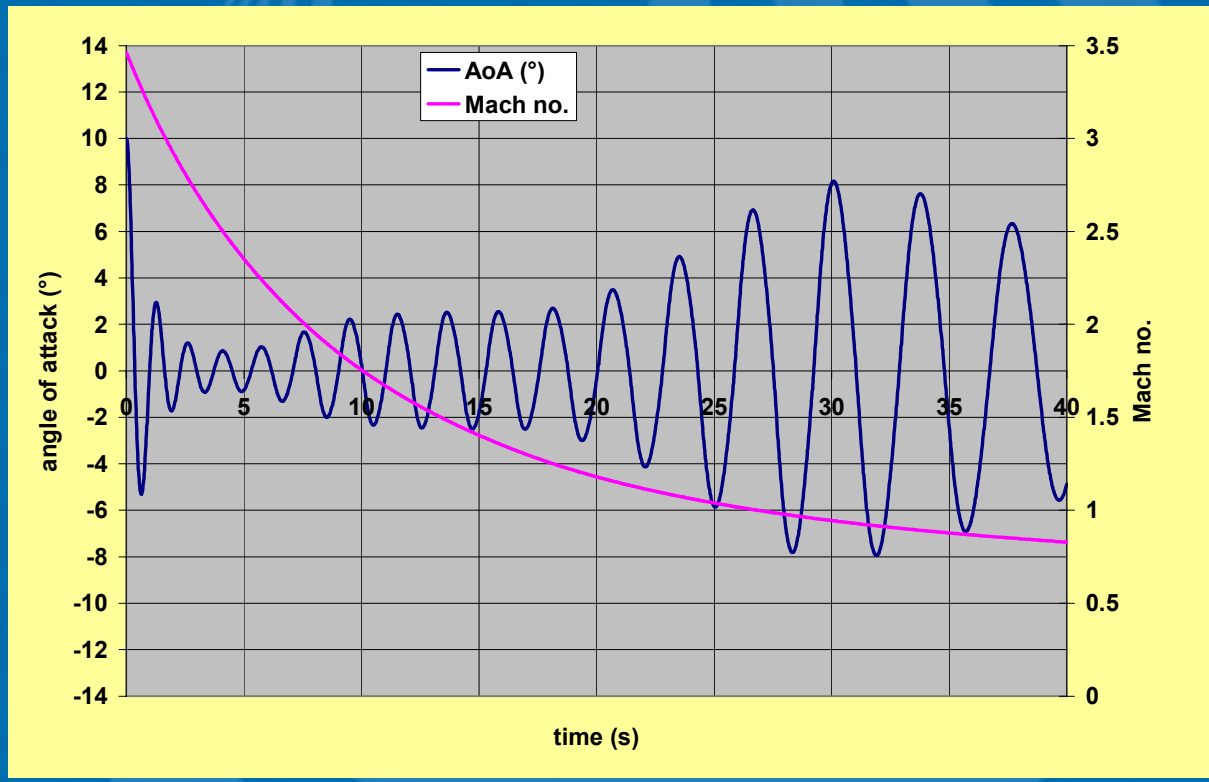
Hypercone Stability

- CFD derived static aerodynamics
- Cmq from Viking data
- Assumes rigid body motion



Deployment at Mach 3.54

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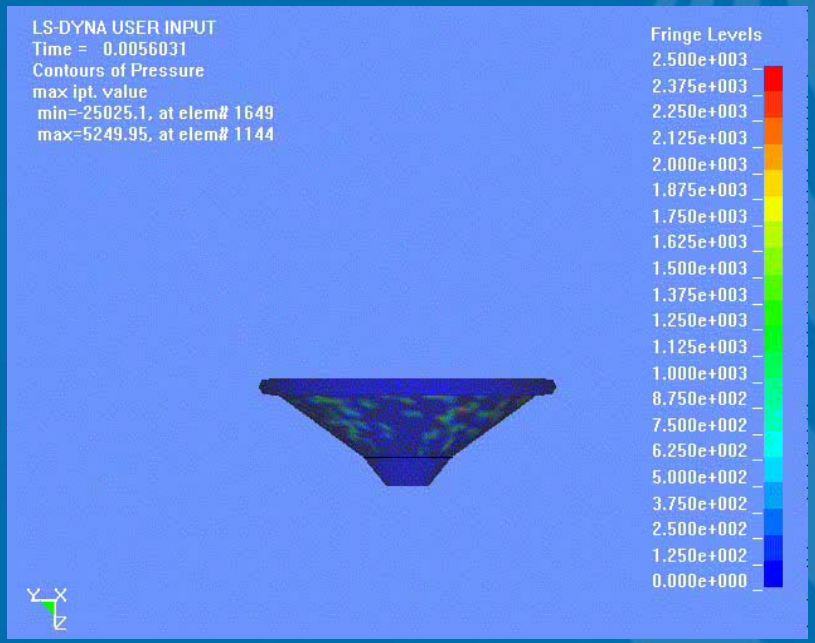
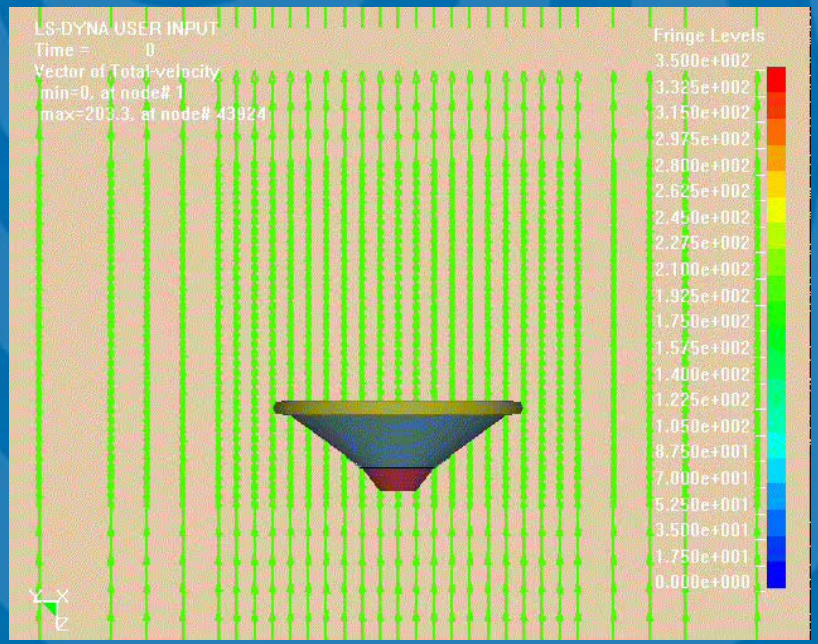
Hypercone Stability

Mach 3.0 10 rad/s



Mach 0.9 1 rad/s



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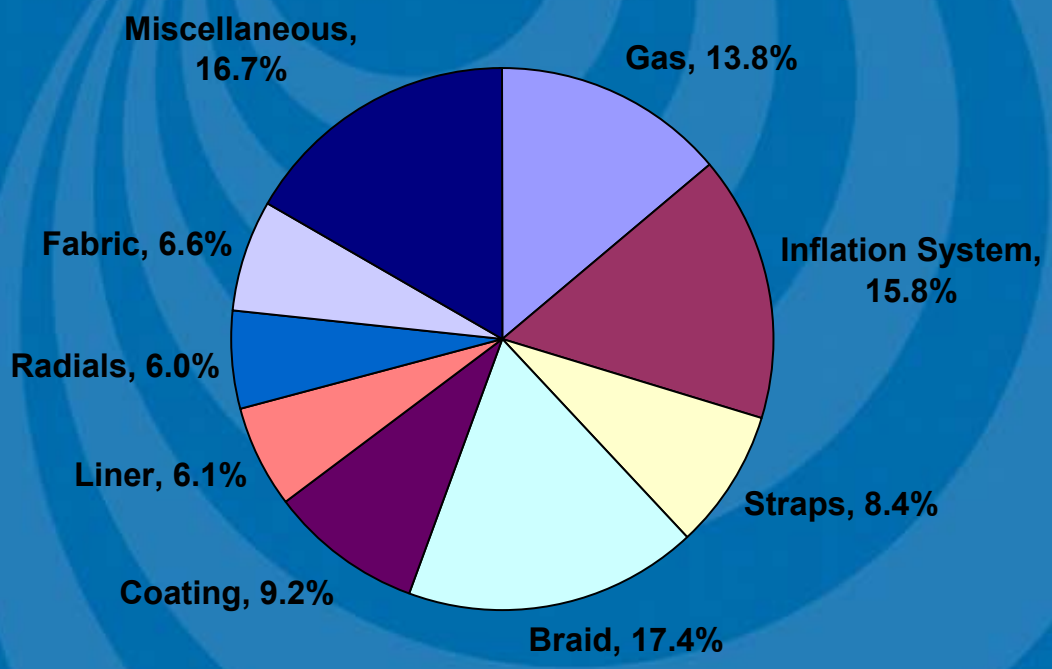
System Mass

- Assume a ammonia hybrid inflator
- Challenge site deployment conditions
- Hypercone mass is 182.9 kg



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System Optimization

- Configurations
  - Hypercone alone: 45m diameter - mass inefficient
  - 14m hypercone + 50m ring sail parachute approximately 400kg
    - Hypercone 183 kg
    - Ring sail 192 kg
  - Single reefed parachute: 600kg
    - No guarantee of successful performance at Mach 3.5
- To achieve high landing sites on Mars optimum configuration is inflatable + parachute

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Conclusions

- The Hypercone concept analyzed for trajectory, aerodynamic, structural, stability performance and interfaces
- shown to be viable for improving landed mass capability on Mars
- 14 m diameter Hypercone + 50 m diameter Ringsail parachute can deliver a landed mass of 4059 kg to the Challenge Site
- good aerodynamic drag characteristics with a typical CA of 1.55
- aerodynamically statically stable throughout its operational Mach number range.
- mass advantage of 200kg over a parachute system
- stable flight in the supersonic regime with limit cycle of ±2.5° and a maximum incidence excursion of 8° in the transonic regime
- can separate the lander positively from the ellipsled entry body at Mach 3.5
- produces lower interface loads on the lander vehicle than an equivalent parachute system.
- simpler to test than equivalent parachute system - supersonic aerodynamics and behavior could be qualified using subscale tests.

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