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A Maturing Earth Entry Vehicle Concept for Potential Mars Sample Return

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Executive Summary

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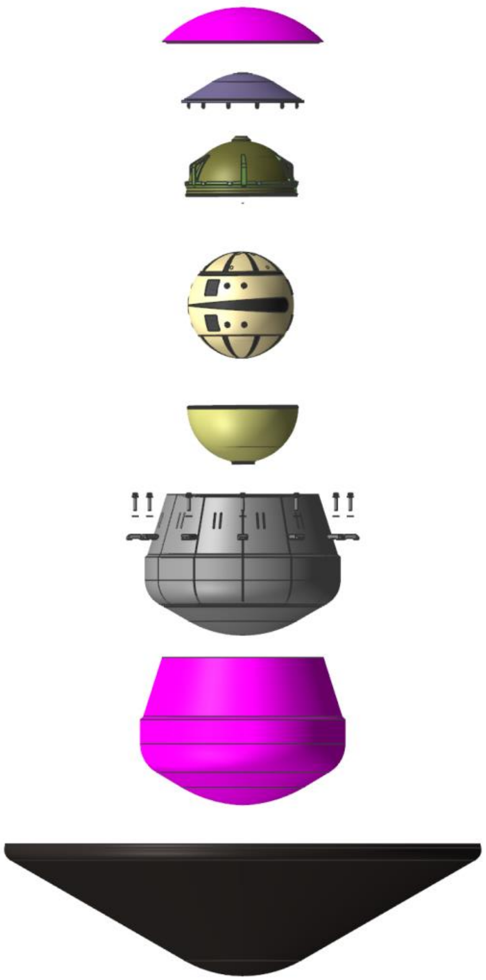
This presentation details NASA's previous and ongoing efforts to develop an Earth Entry Vehicle for Potential Mars Sample Return.

Exploded View of Current Reference EEV Concept



- Introduction & Background
- New Hardware Considerations for EEV
- Nominal EEV ConOps
- Risk Areas and Design Drivers
- A Hot Structure EEV Concept
- Sub Element Descriptions
  - Aeroshell
  - Containment Assurance Module
  - Contained-OS

What is an Earth Entry Vehicle?

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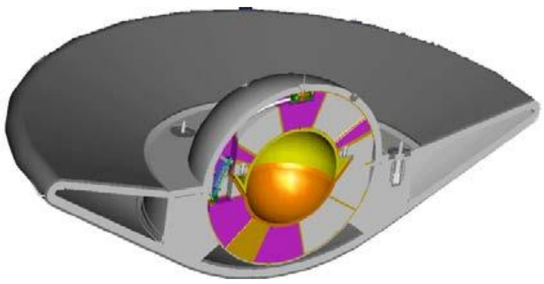
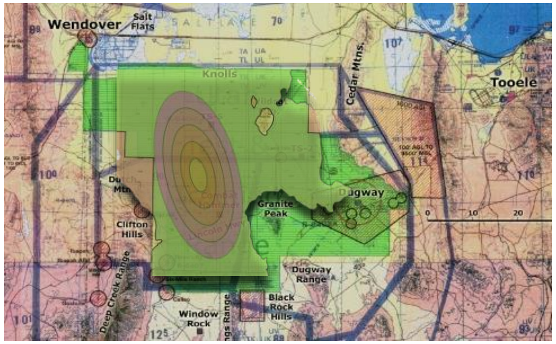
The EEV is a simple & reliable ballistic reentry vehicle concept for planetary sample return missions

1. Originally developed for a 03’-05’ MSR mission
2. Minimal/no complex active mechanisms or electronics: Passive designs are emphasized
3. Passively stable aerodynamics from hypersonic thru terminal velocity
4. No parachute or retrorockets
5. Possibly redundant thermal protection systems
6. Samples protected by multiple layers of energy absorbers
7. Redundant sealed containers around OS/samples for planetary protection assurance aka ‘robust containment’
8. 5σ landing ellipse within a controlled landing site, (notionally UTTR)

Early NASA MSR-EEV Concept



A Predicted Landing Ellipse (Notionally UTTR)



History of NASA MSR-EEVs

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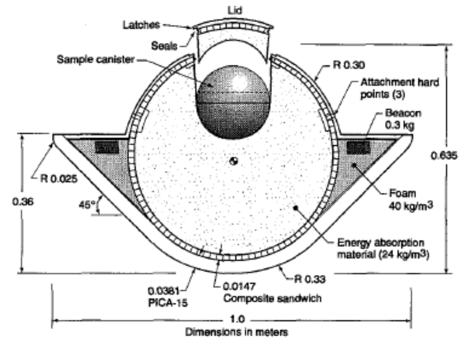
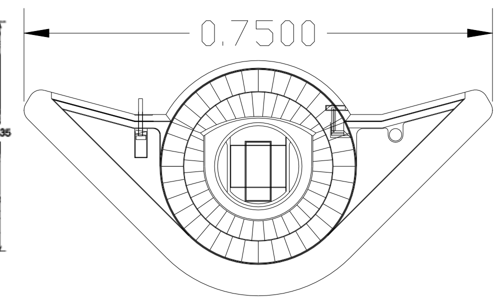
Earlier Concepts

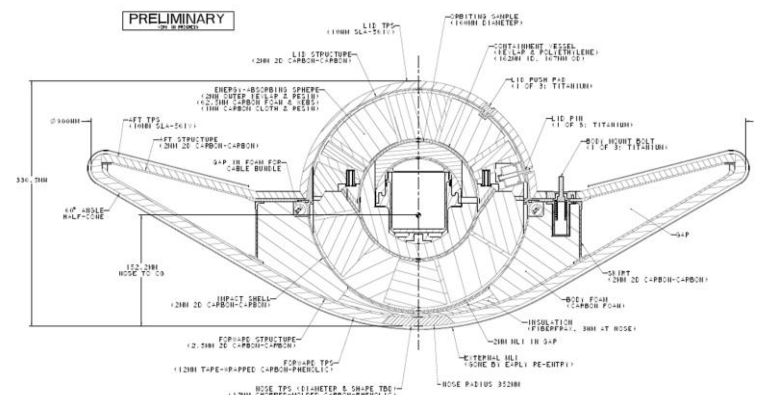
- Early proposal concepts, small, light, notional
- Limited analysis, never built
- TPS: Phenolic Impregnated Carbon Ablator (PICA)
- Sphere-cone 45˚ w/ 33 cm tip radius





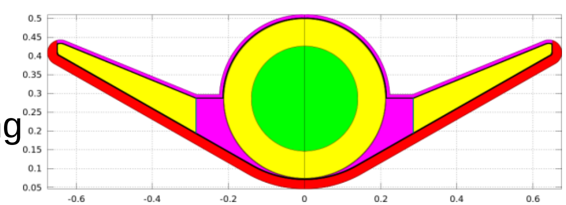
03’-05’ MSR Campaign Design

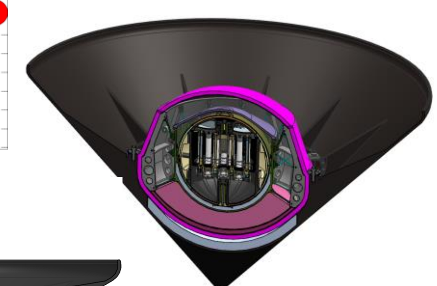
- Significant structural, aero, impact analysis & vehicle testing
- Primary TPS: Carbon-Phenolic (CP)
- Sphere-cone 60˚ w/ 30 cm tip radius
- 44 kg Total mass, 5 kg/16 cm Orbiting Sample (OS) payload
- Entry Velocity = 11.56 km/s at -15˚

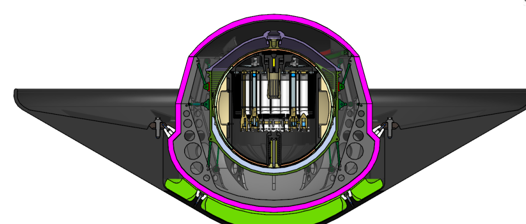


Recent Concepts

- Some brand new concepts and some derived from 05’ design
- Some structural, aero, impact analysis & testing
- Primary TPS: PICA, CP, or Carbon/Carbon (C/C)
- Sphere-cone 45˚/60˚ w/ 2-30 cm tip radii
- ~80-150 kg Total mass w/ 12 kg/28 cm OS
- Designed for entry velocity = 11.5-14.5 km/s @ -10 to -20˚







Updated Hardware Considerations

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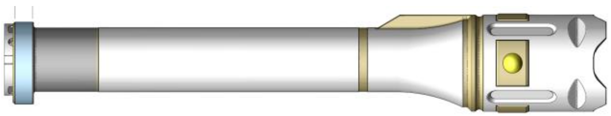
Mature Tubes

- Mars 2020 sample tube design finalized.
- Seal load limits require OS orientation for landing
- Major dimensions: Length: 144 mm, Diameter: 23 mm,
- Mass ~100 g depending on enclosed sample.

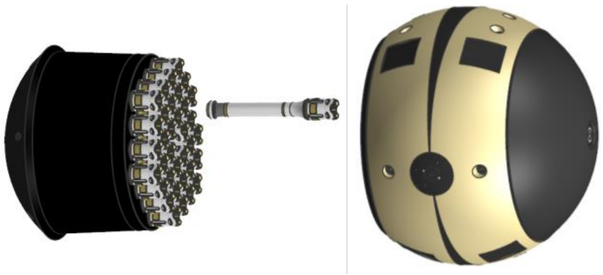
Post-CDR Mars 2020 Tube Design



Detailed OS

- Reference OS concept: NTE 12.0 kg & 28 cm diameter
- Other OS concepts in consideration and trade

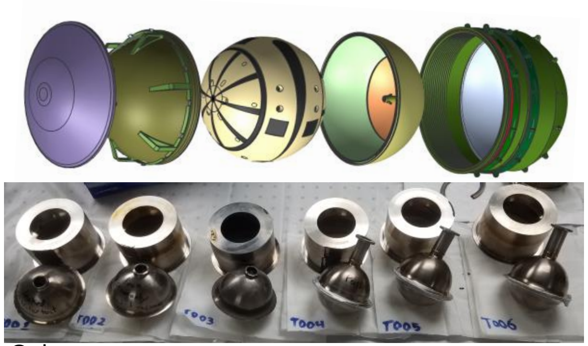
Reference OS Concept



BTC & Containment Vessels

- New concepts and testing of BTC & brazing are underway.
- Leading BTC technology utilizes brazing of titanium shells
- Current thinking is to have Secondary Containment Vessel (SCV) partially integrated within EEV
- Margined Contained-OS mass = 33 kg.

Redundant Containment Concept and Test Articles



Pre-Decisional Information – For Planning and Discussion Purposes Only

Nominal EEV OpsCon

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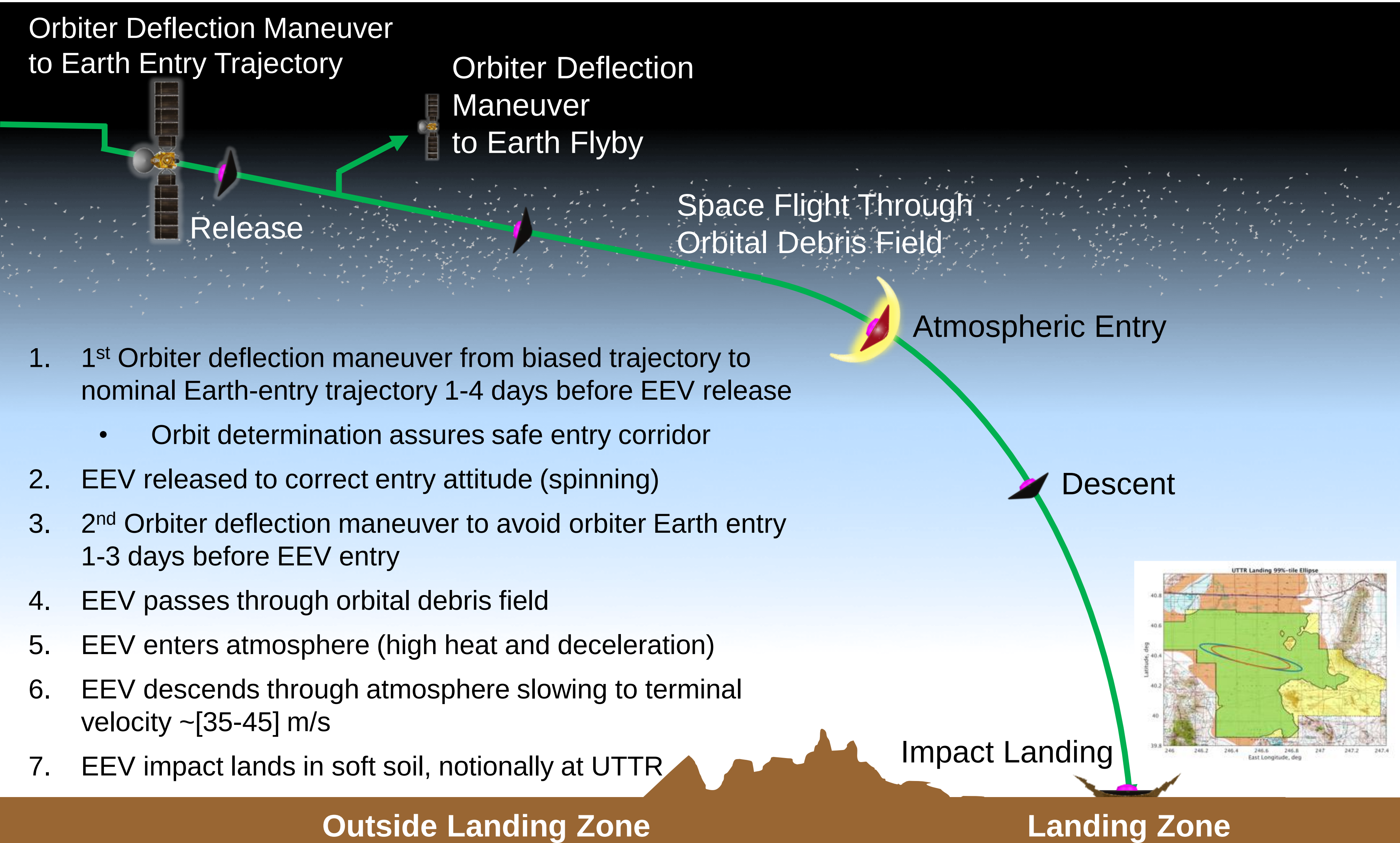

1. 1st Orbiter deflection maneuver from biased trajectory to nominal Earth-entry trajectory 1-4 days before EEV release
    - Orbit determination assures safe entry corridor
2. EEV released to correct entry attitude (spinning)
3. 2nd Orbiter deflection maneuver to avoid orbiter Earth entry 1-3 days before EEV entry
4. EEV passes through orbital debris field
5. EEV enters atmosphere (high heat and deceleration)
6. EEV descends through atmosphere slowing to terminal velocity ~[35-45] m/s
7. EEV impact lands in soft soil, notionally at UTTR

The following pages describe just one of many EEV concepts in evaluation for use on MSR

Hot Structure EEV Concept Intro

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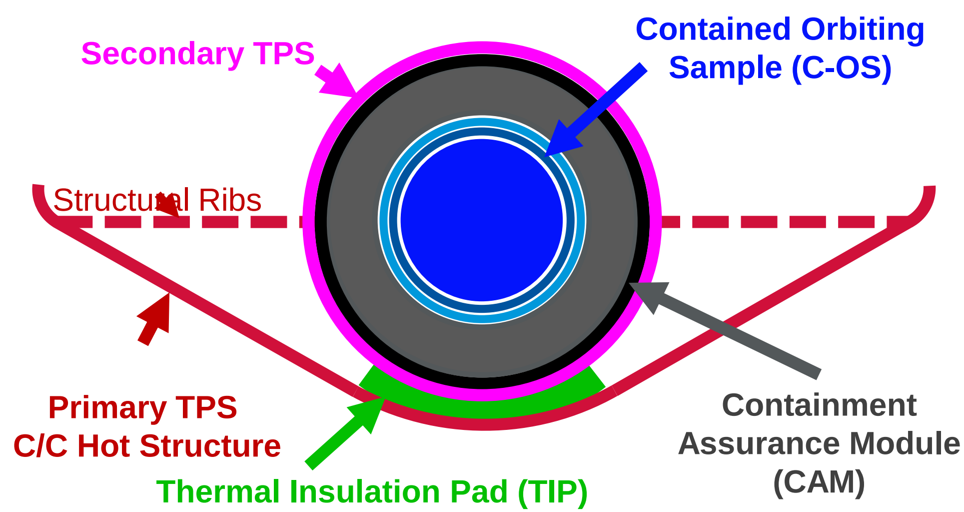
Concept utilizes a Carbon-Carbon (C/C) aeroshell. C/C is used extensively by the US military & on several NASA entry vehicles including Shuttle.

Primary TPS: C/C

- Originally developed for the nose-tips of ICBMs & was also used on Space Shuttle
- Very capable material: Handles very high temp and heat flux without structural knockdown & minimal regression
- No need for additional traditional insulative or ablative TPS on a C/C aeroshell
- Open-back aeroshell design enables heat to escape off the aft side of the aeroshell
- Attaches to CAM via hot-structure joints that minimize heat transfer while still assuring a strong structural connection.
- Mature material, in development since the 60's with several flight test examples
- Multiple manufactures available today (2D layup, 2D tape-wrapping, & 3D)

Secondary TPS: [PICA, HEEET, CP, or FRCI (i.e shuttle tile)]

- A secondary heatshield fully wraps the cold-structure CAM & C-OS
- Secondary TPS heat load is primarily re-radiation from the C/C and aft-shell recirculation
- In event of primary TPS damage or puncture, the secondary TPS can handle a significantly higher heat loads

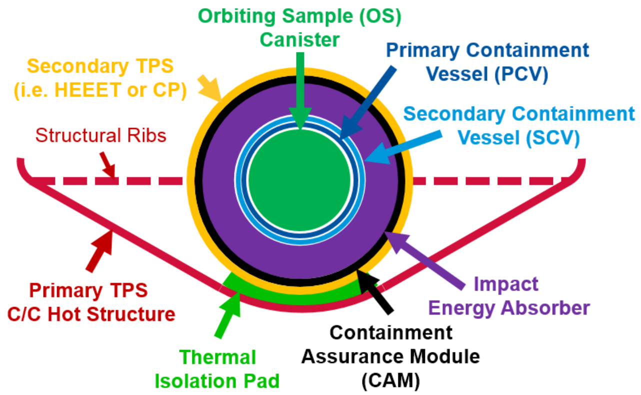


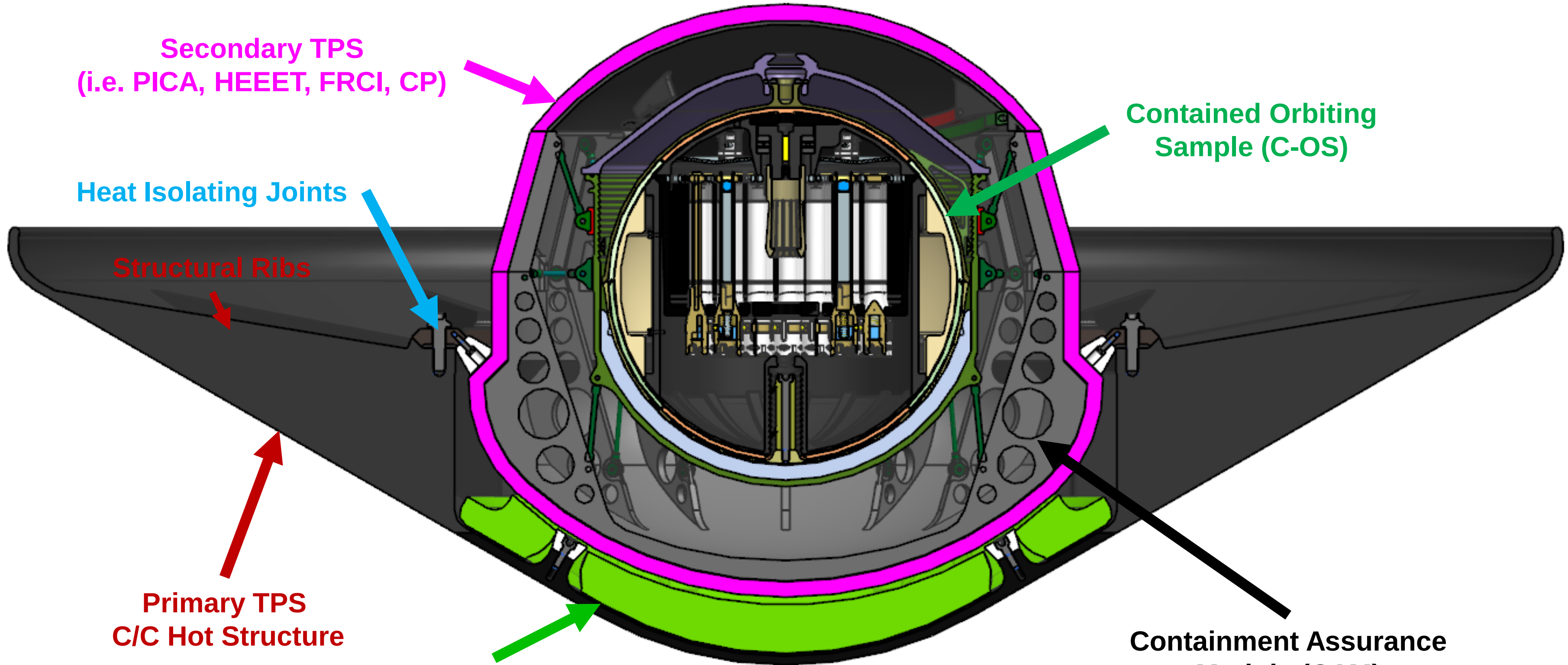
C/C aeroshell puncture due to in-space debris will not lead to Columbia-like failure modes

Reference C/C EEV Concept

This concept is designed to address containment assurance issues identified in previous PRAs

1) MMOD Risks, 2) Aerostability Risks, & 3) Landing Risks





Key Benefit: *All components outside of the CAM can withstand high heat, therefore 'TPS failure' i.e puncture of the C/C heat shield is unlikely to result in subsequent runaway failure modes.*

C/C Aeroshell Concept Description

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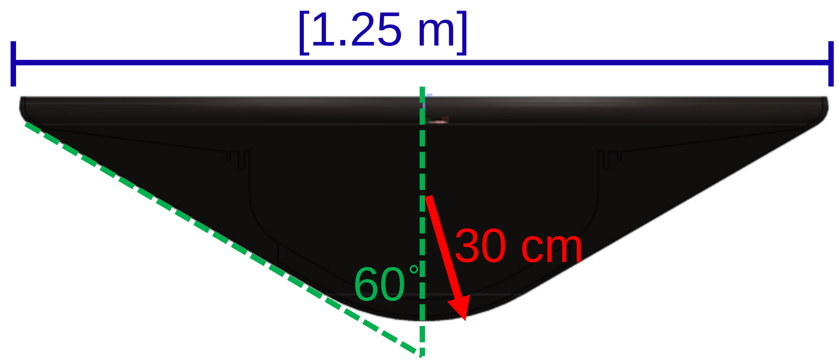
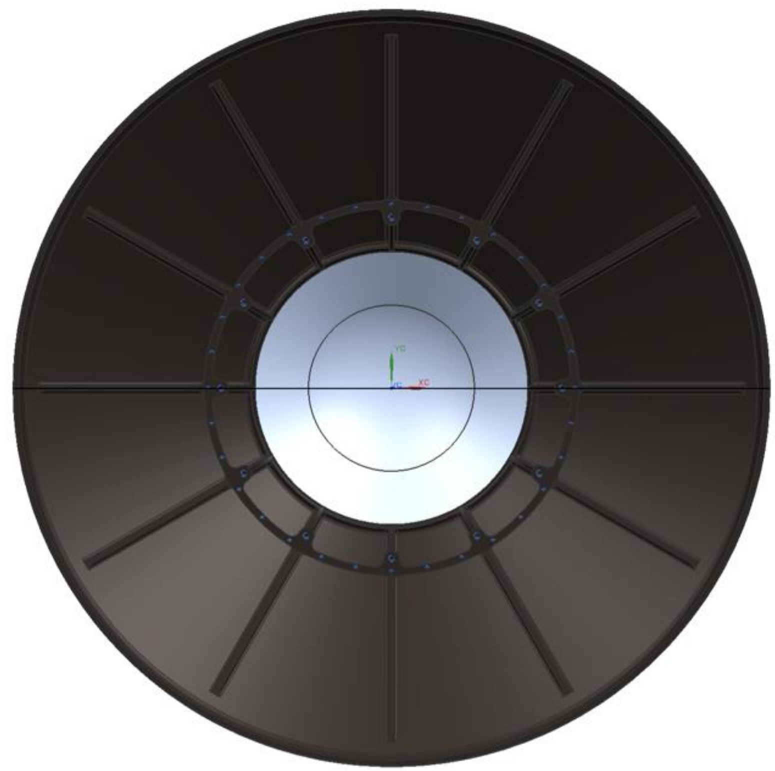
A C/C aeroshell provides an opportunity vehicle for mass reduction and potentially reduced entry mishap risk



- Different design challenges: C/C is much more conductive than traditional TPS
- Unlike traditional TPS and structural materials C/C no bond-line or temperature restrictions
- Ribbed design driven by launch loads, Preliminary 12x rib concept shown.
- Skin thickness driven by reentry aerothermal recession rates and peak dynamic pressure
- Material capability provides flexibility for mission architecture & entry conditions changes
- Thermal Isolation Pad (TIP) minimizes radiation heat transfer to CAM off backside of skin.
- Unlike traditional TPS, C/C should be more robust for MMOD impacts and/or extra tolerance to orbital debris impact damage.



CAM Concept Description

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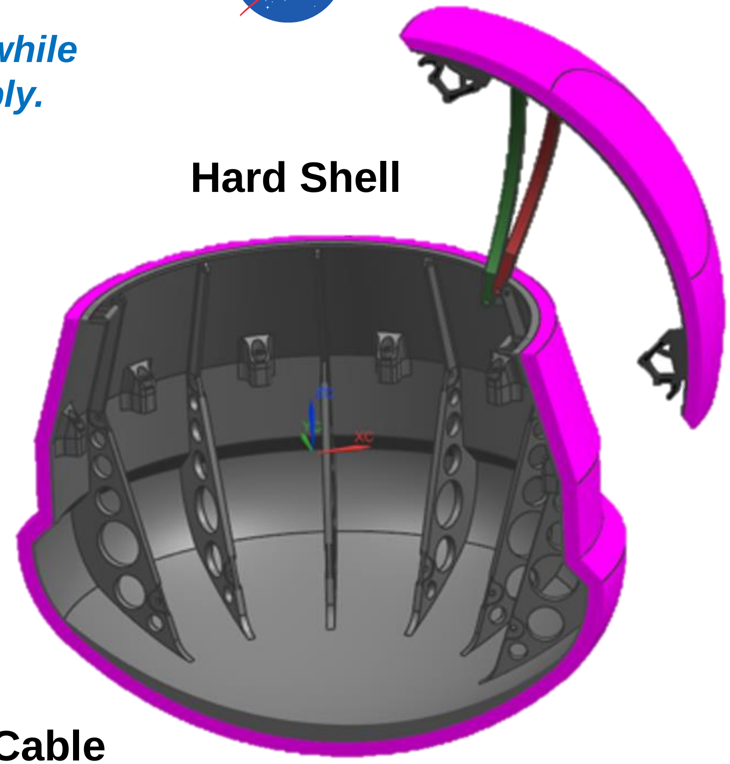
CAM is designed to be robust against containment threats while providing a simple and reliable method for in-space assembly.

Hard Shell

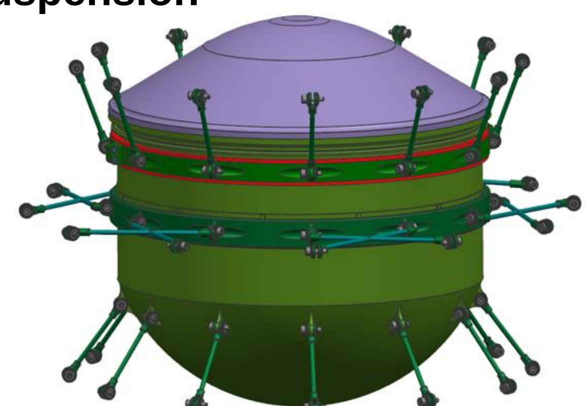
- Designed to isolate C-OS from damaging loads for science and sample containment
- 2 piece titanium skin-rib construction.
- Plate at base resists penetration from rocks and other sharp threats
- Option for additional energy absorbers such as foam for additional protection.



Cable Suspension

- Pretensioned cables provide stiff positioning of C-OS in center of CAM. (Like a bicycle wheel hub)
- Many materials possible: Titanium, Spectra, Kevlar, etc.
- Distributed cables spread load evenly around C-OS and minimize load transfer to C-OS seals

Cable Suspension



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Contained-OS Concept Description

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C-OS provides full containment of Martian material and minimizes thermal and mechanical load transfer to samples

OS

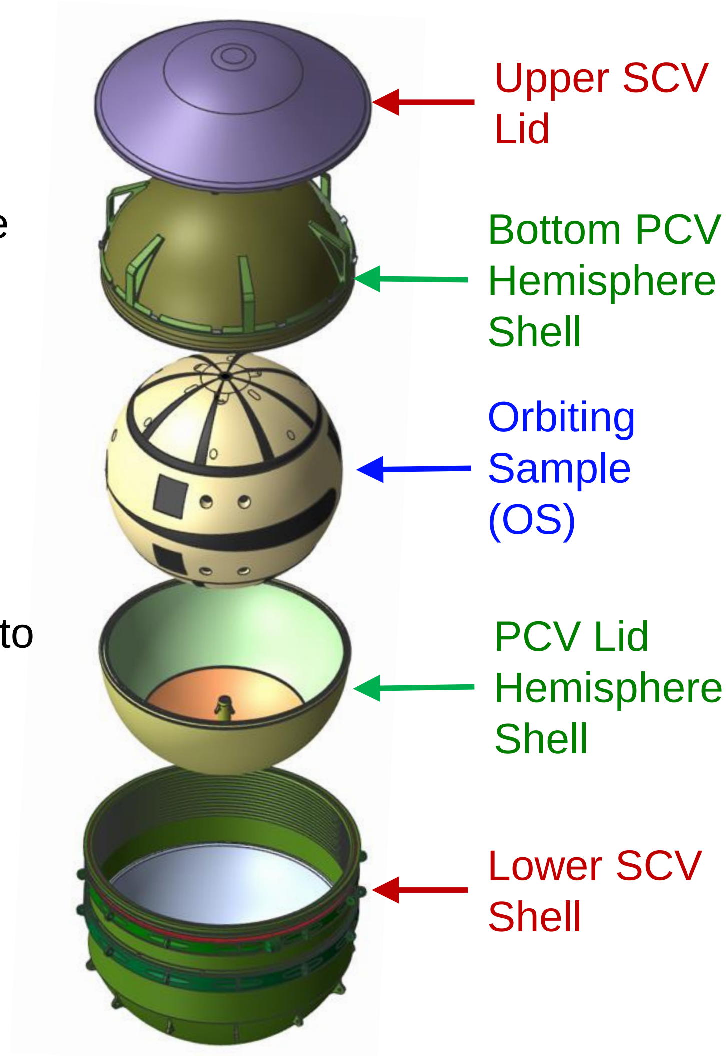
- Assembled on Mars surface, launched to orbit, and captured by ERO-ROCS
- Requires orientation in EEV to minimize loads on tube seals
- Connects to PCV via recessed ribbed hole.

PCV

- Provides 'Break the chain' containment functionality
- Brazing simultaneously seals and sterilizes
- Pin with flexure barbs on interior of lid ensures irreversible lid connection when inserted into OS.
- Bottom shell has external flexure barbs that interface to SCV

SCV

- Provides extra tough and redundant containment.
- Inner wall of lower SCV shell has ribs that interface to PCV
- External features for connection to cable suspension system



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Thank you for your attention!

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