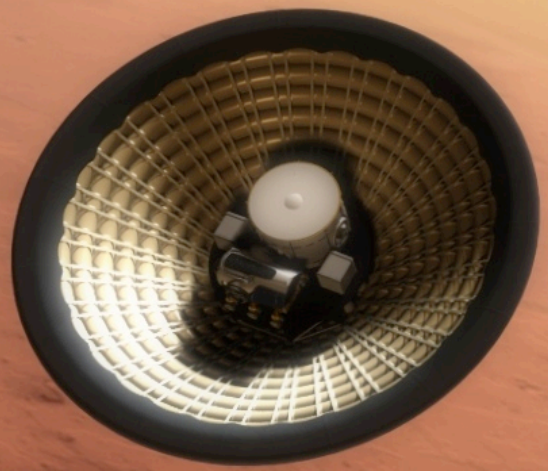
National Aeronautics and
Space Administration



# HIAD Mission Infusion: Technology Development & Potential Utilization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**IPPW-12 Presentation**
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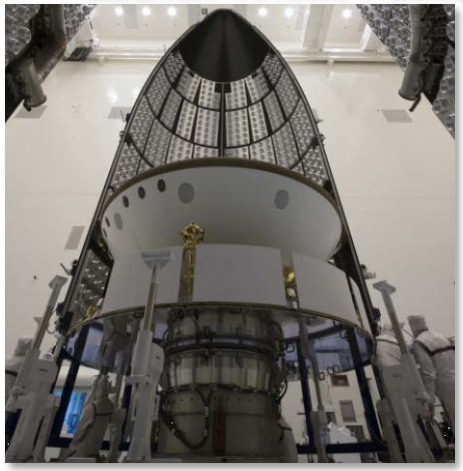
# What is a HIAD?

**A Hypersonic Inflatable Aerodynamic Decelerator (HIAD)** is a deployable aeroshell consisting of an Inflatable Structure (IS) that maintains shape during atmospheric flight, and a Flexible Thermal Protection System (F-TPS) employed to protect the entry vehicle through hypersonic atmospheric entry.

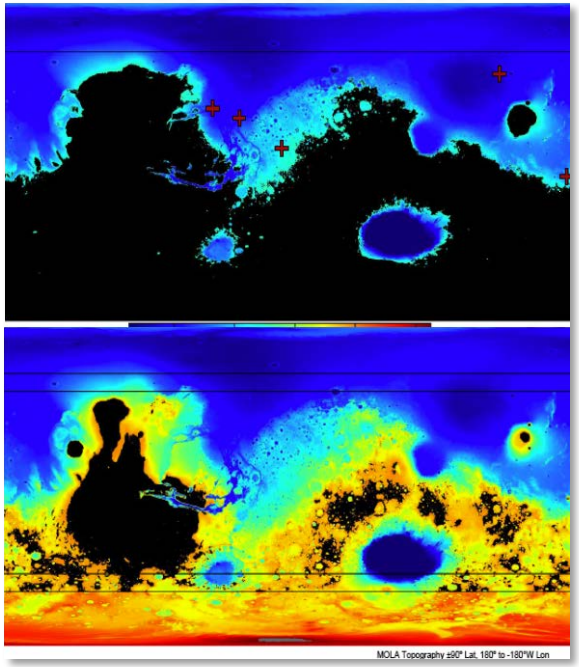
# Background: Why a HIAD?

- Entry mass at Mars (and other destinations with atmospheres) is limited by launch vehicle shroud size.
- At Mars, increased capability needed for higher mass and/or higher altitude, eventual human missions.
- Inflatable technologies allow larger aeroshell to be stowed inside launch shroud.
  - ✓ Inflation of Inflatable Structure (IS) occurs prior to atmospheric entry.
  - ✓ Flexible Thermal Protection System (F-TPS) protects IS and payload from entry environments.
- NASA LaRC has been developing Inflatable Aeroshell technology for over 10 years.

Launch Vehicle Fairing Constraints

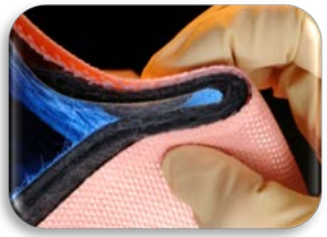


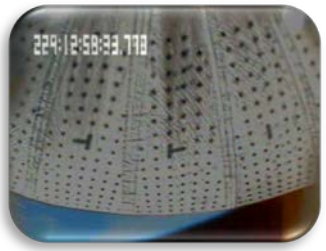
Mars Surface Access

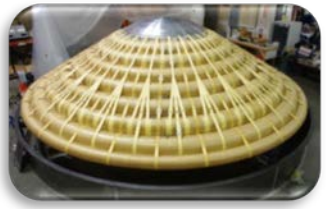


# HIAD Technology Development Cadence

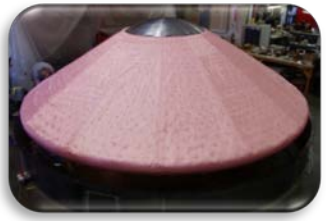
- **Systematic and stepwise technology advancement**
  - ✓ **Ground Test**: Project to Advance Inflatable Decelerators for Atmospheric Entry (PAI-DAE)—Softgoods technology breakthrough
  - ✓ **Flight Test**: Inflatable Reentry Vehicle Experiment (IRVE), 2007: LV anomaly—no experiment
  - ✓ **Flight Test**: IRVE-II, 2009—IRVE "build-to-print" re-flight; first successful HIAD flight
  - ✓ **Ground Test**: HIAD Project improving structural and thermal system performance (Gen-1 & Gen-2)—Extensive work on entire aeroshell assembly
  - ✓ **Flight Test**: IRVE-3, 2012—Improved (Gen-1) 3m IS & F-TPS, higher energy reentry; first controlled lift entry







- **Next Steps**
  - ⇨ **Ground Effort**: *Gen-3 F-TPS, advanced structures, packing, manufacturability at scale >10m, controllability, and demonstrated staging to secondary decelerator.* **Prepares for large-scale flight test and readiness for Mars mission**.
  - ⇨ **Flight Test Possibilities**: *United Launch Alliance (ULA) flight test and/or booster recovery at scale and environments relevant to Mars Human EDL Pathfinder*.



# HIAD Ground-Based Development To Date

## Inflatable Structure

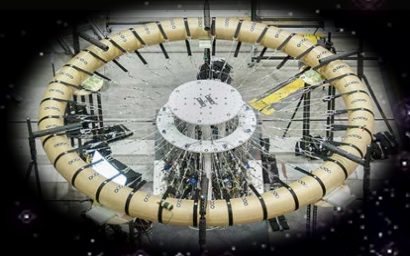
### Manufacturing

- Define large-scale fabrication methods
- Optimize packed volume and density requirements
- Establish manufacturing processes and quality control standards

Torus Stacking and Alignment

### Testing

- Quantify aerodynamic structural response
- Verify load reaction and structural integrity
- Establish structural performance limits



Torus Compression/ Torsion Tests

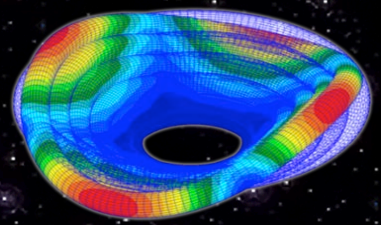
### Performance

- Qualify structural materials performance capability
- Establish handling and stowage requirement
- Define design methods and safety margins

Static Loading

### Modeling

- Validate non-linear structural modeling capability
- Establish structural design procedures and standards
- Define system weight, stiffness, and strength options



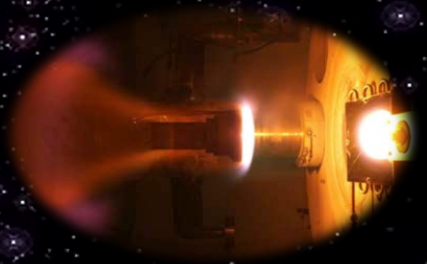
Dynamic Response

## Flexible TPS

- Establish large-scale fabrication methods
- Define manufacturing processes and quality control standards
- Determine handling and stowage requirements

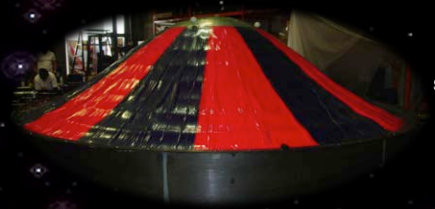
Fabrication

- Characterize mechanical and thermal physical properties
- Define mission-cycle performance capability
- Establish F-TPS material performance limits



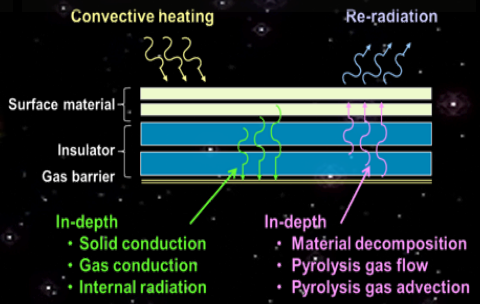
Stagnation

- Extend F-TPS materials performance capability
- Qualify thermal and aero-elastic response
- Define system integration metrics and requirements



Structural Contribution

- Validate a multi-physics thermal response model
- Establish design requirements and safety margins
- Verify integrated system load response




Multi-Physics Model

# IRVE-3: A Fully Successful Flight Test

Check out the video at:
http://youtu.be/7JGaOvC1sV4

Apogee
366s, 474km

Coast…

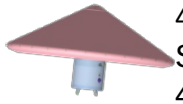
Eject Nose Cone
102s, 177km

NIACS damps rates
91s, 152km (10s duration)

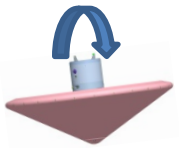
Separate RV & Nose Cone
From Brant & Transition
90s, 152km

Yo-Yo De-Spin, 80.0s
Brant Burnout, 56.9s
Brant Ignition, 23.0s
Taurus Separation 21.0s
Taurus Burnout, 18.5s
Taurus Ignition, 15.0s
Talos Burnout, 6.4s
Spin Motor Ignition, 0.9s
Leaves Rail, 0.5s
Talos Ignition, 0s

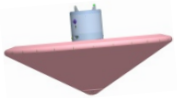
Launch on Black Brant-XI from WFF
940lb payload, El 84deg, Az 155deg



Aeroshell Release
429s, 457km
Start Aeroshell Inflation
433s, 455km

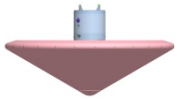


ACS Reorientation
587s, 266km (40s duration)



Actuate CG offset system
628s, 181km (1s duration)

**Atmospheric Interface, 25Pa** (666s, ~86km)

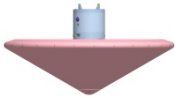


RV Peak Heat Rate 14-17W/cm2
680s, 50km, Mach 7 (peak Mach 10.2)

RV Peak Dynamic Pressure
685s, 41km, 20.8g's

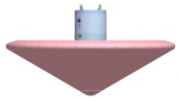
**Reentry Experiment Complete at Mach < 0.7**
(709s, 27km)

CG Offset Maneuvers



LOS by land radar & TM
12-29km altitude

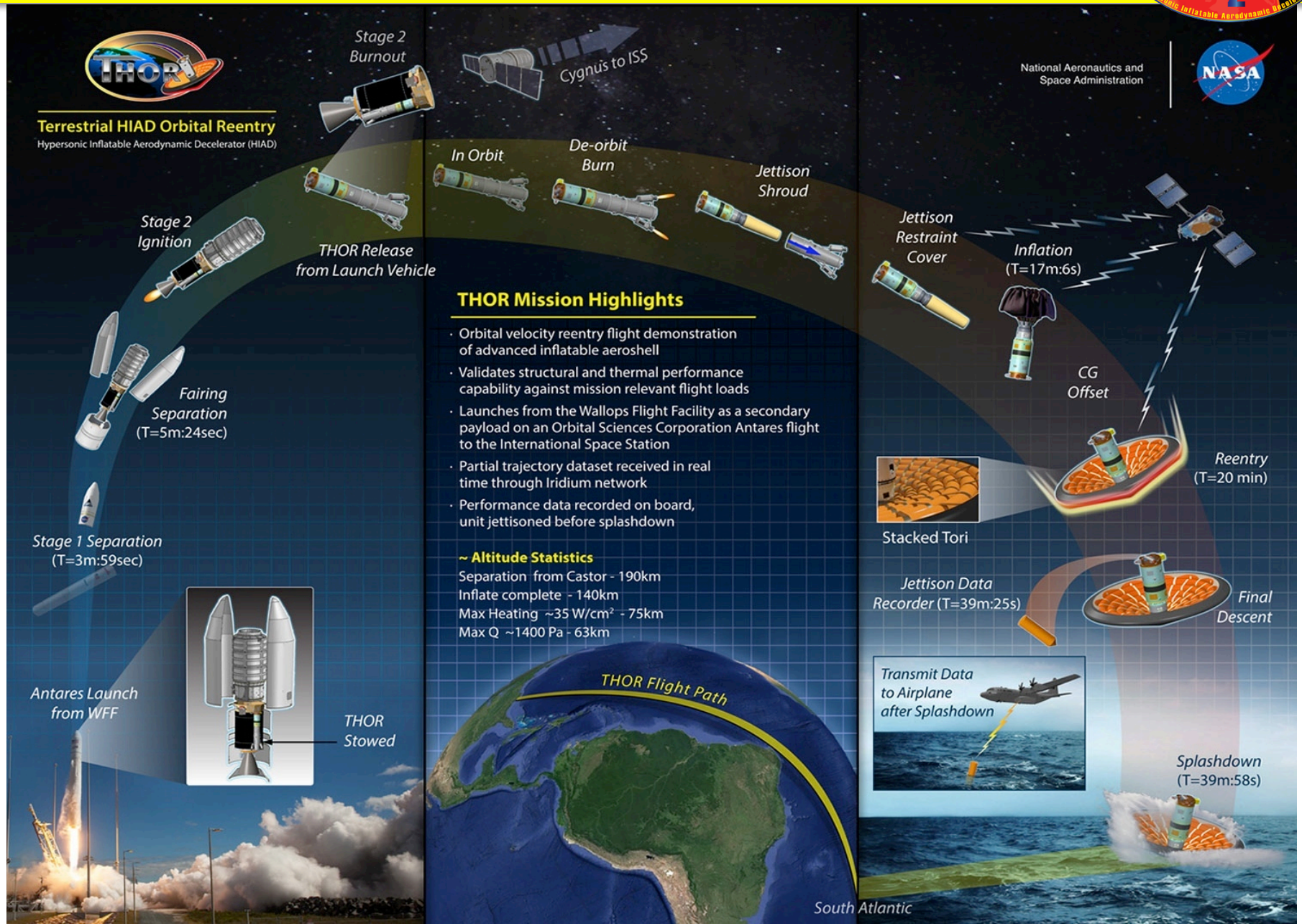
Vent NIACS and Inflation System Gas



RV splashdown at 30m/s
383km downrange (1193s)

Recovery Attempt

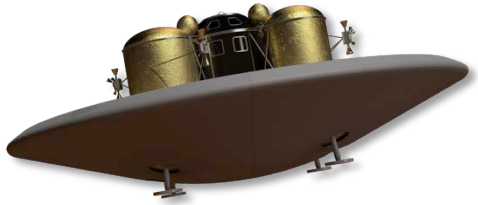
# THOR: The One That Got Away…



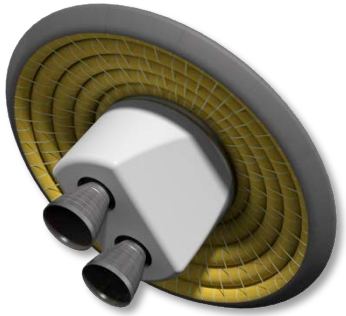
# Potential HIAD Mission Infusion

- Robotic missions to any destination with an atmosphere (including sample return to Earth)

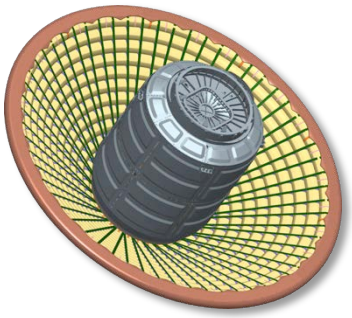
- High mass delivery to high altitudes at Mars (including humans to Mars)



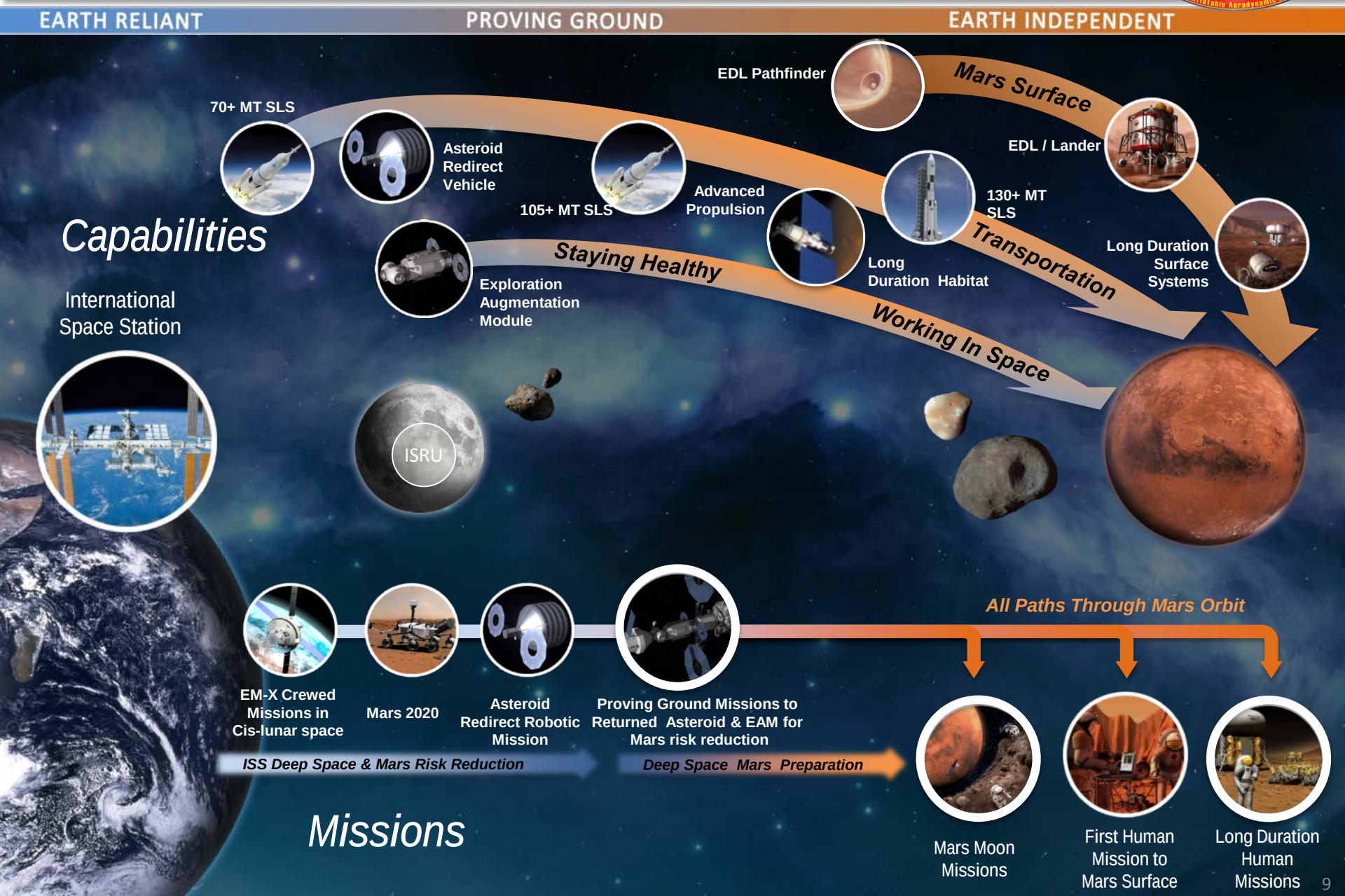
- Lower cost access to space through launch vehicle asset recovery (for example, ULA's booster module)



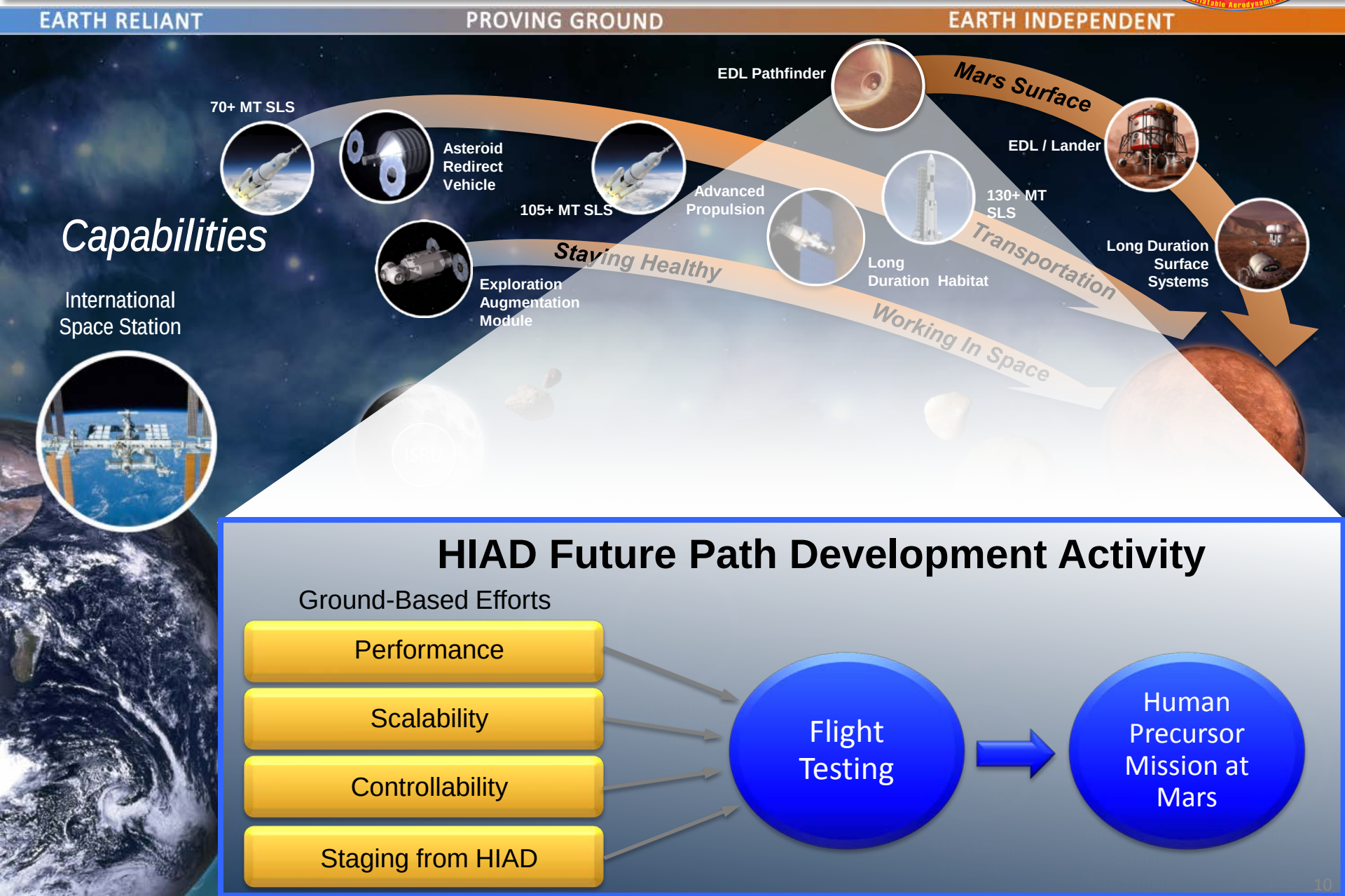
- ISS down mass (without Shuttle, the U.S. has no large-scale down mass capability)



# Evolvable Mars Campaign – *Capability & Mission Extensibility*



# Evolvable Mars Campaign – *Capability & Mission Extensibility*




## HIAD Future Path Development Activity

Ground-Based Efforts

- Performance
- Scalability
- Controllability
- Staging from HIAD

→ Flight Testing → Human Precursor Mission at Mars

# ULA's Planned Utilization of a HIAD

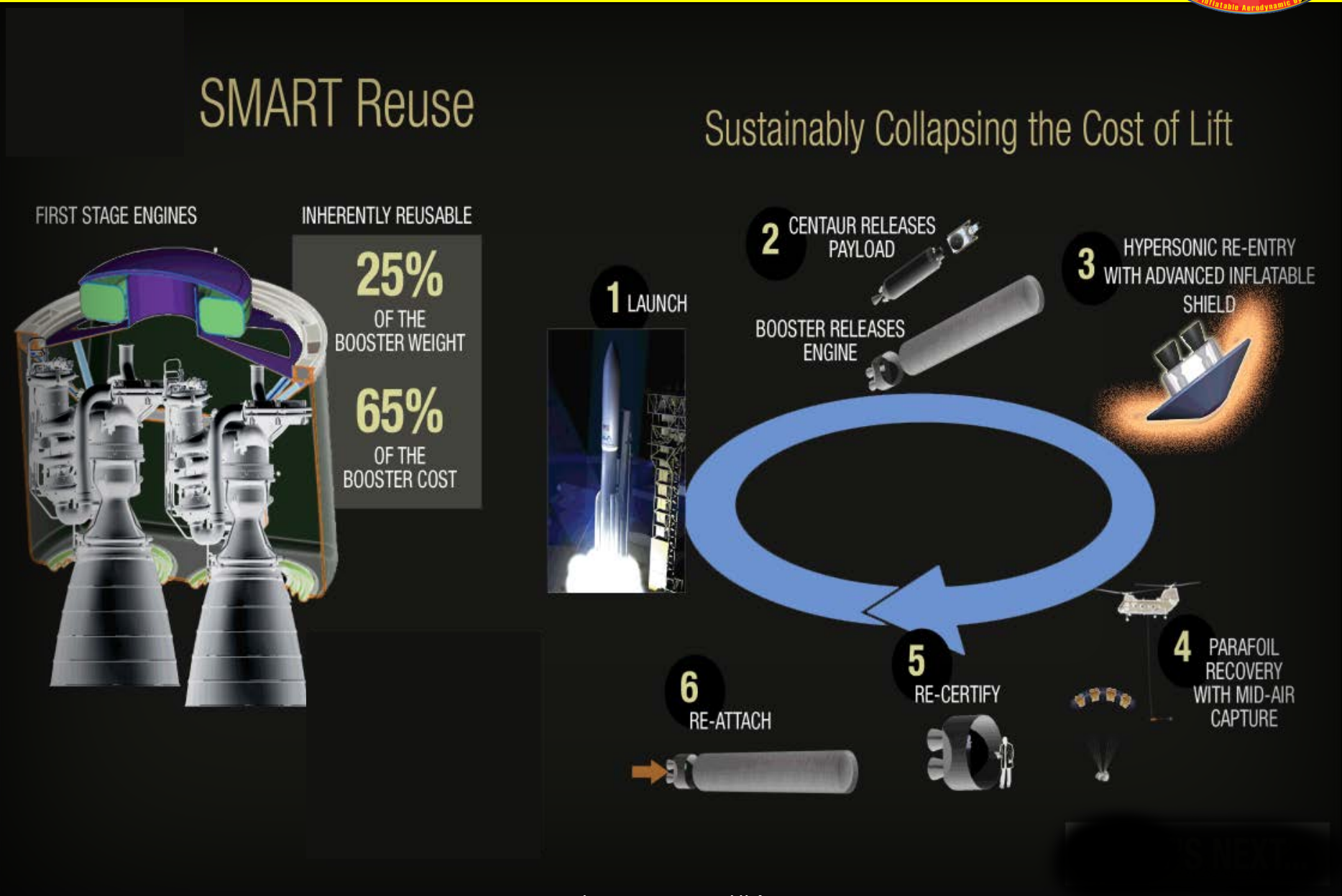
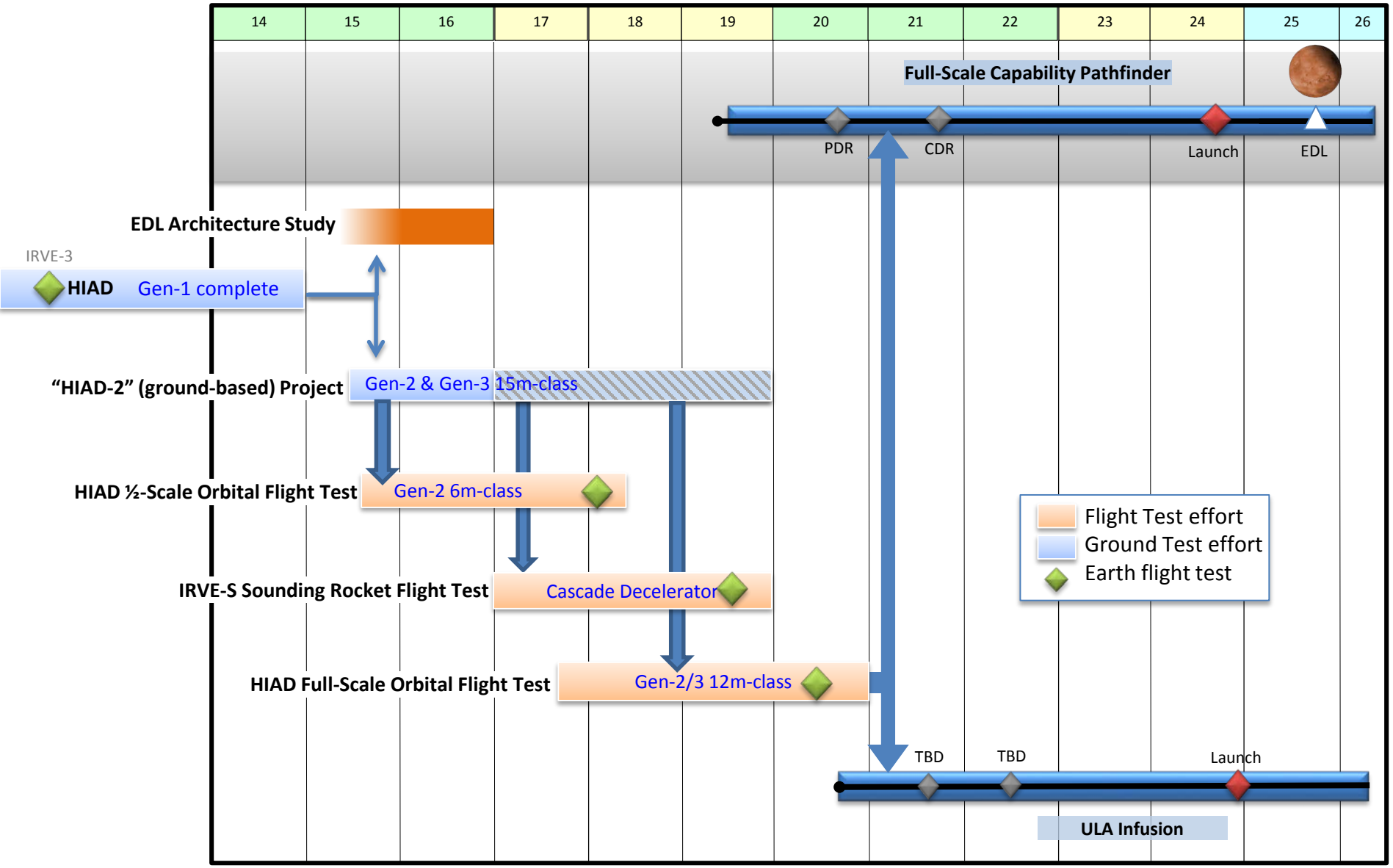
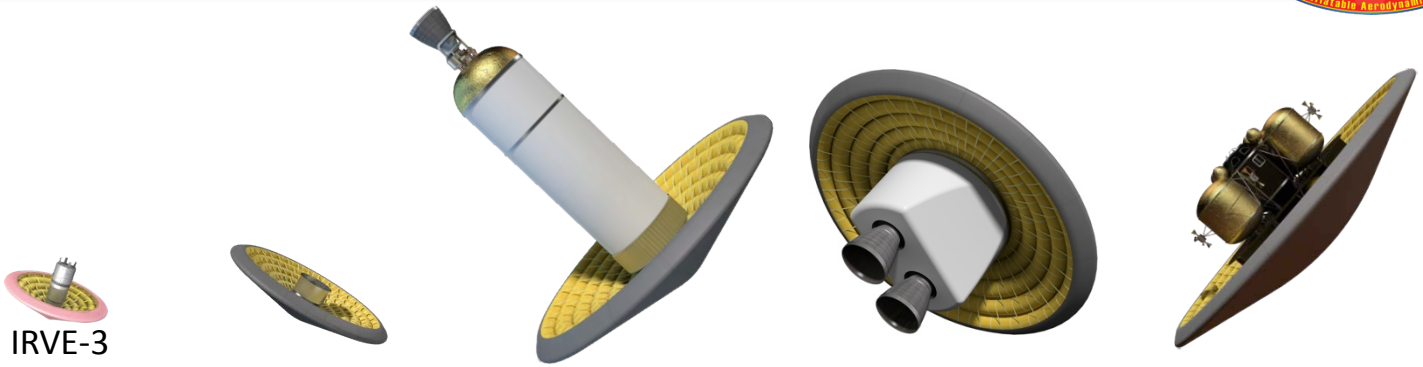



Image courtesy ULA

# Development Path for 2024 Mars Demo, Utilizing ULA



# HIAD Similitude




| | ½-Scale Demo | Full-Scale Centaur Recovery | ULA Booster Recovery | Mars 2024 EDL Pathfinder |
|---|---|---|---|---|
| Scale | 5-6m | 10-12m | 10-12m | 10-12m |
| TPS | SiC<br>5X carbon felt<br>Pyrogel | SiC<br>3X carbon felt<br>Pyrogel | SiC<br>3X carbon felt<br>Pyrogel | SiC<br>5X carbon felt<br>Pyrogel |
| Parafoil & Recover of Device(s) | X | | X | |
| Cascade Decelerator | X | | | X |
| Similar ConOps | X | X | X | X |