ADEPT - A Mechanically Deployable Entry System Technology in Development at NASA

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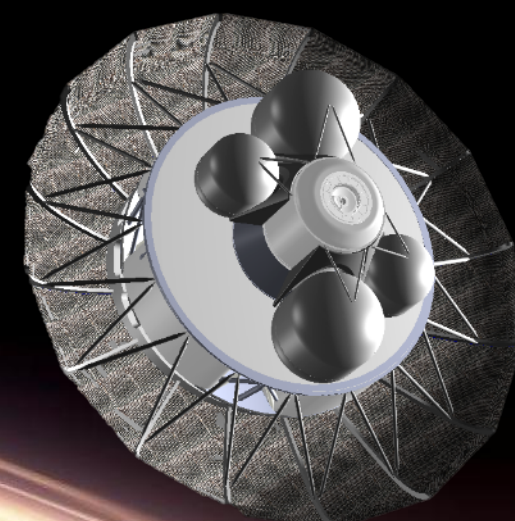

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TFAWS, NASA Ames Research Center

Acknowledgements

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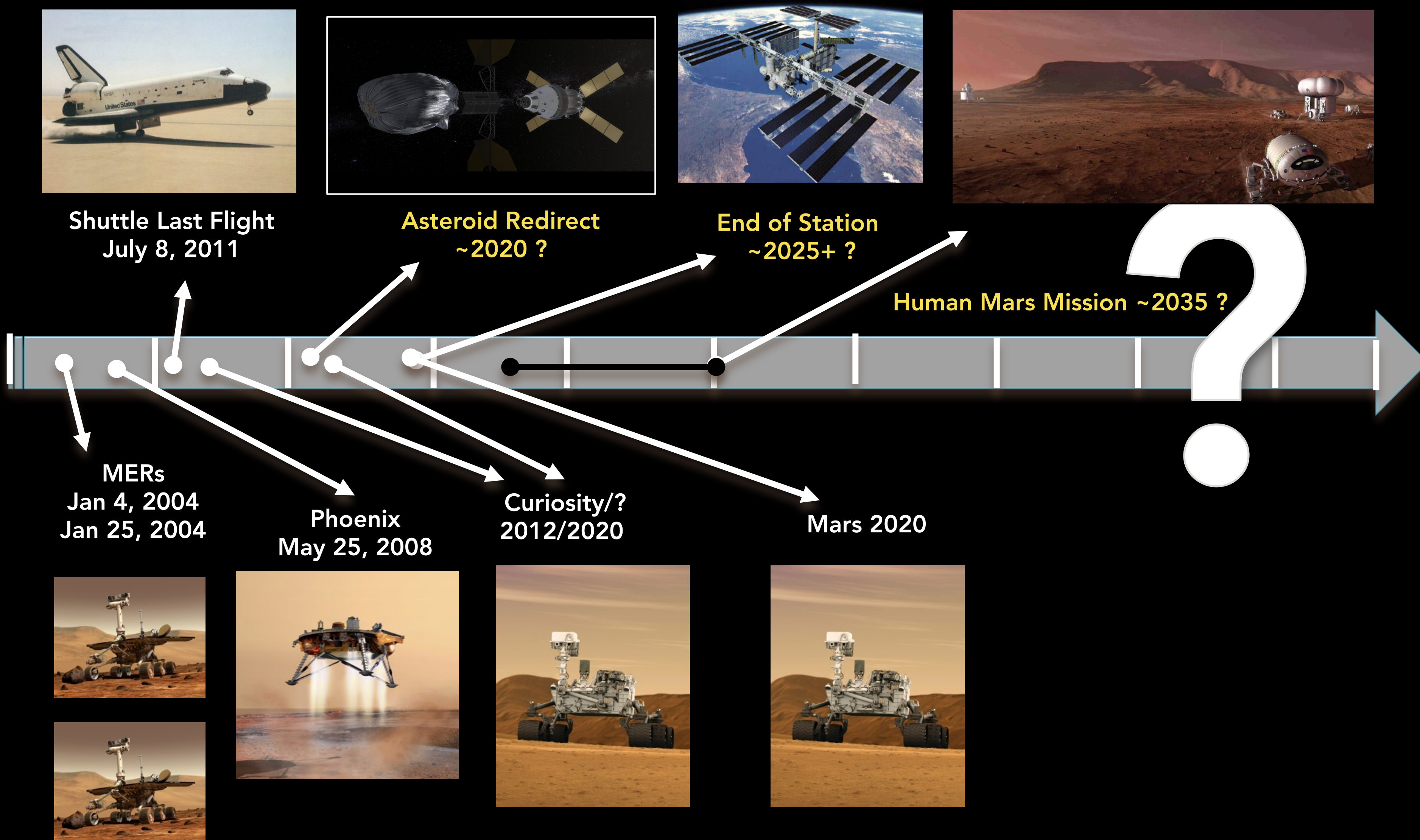
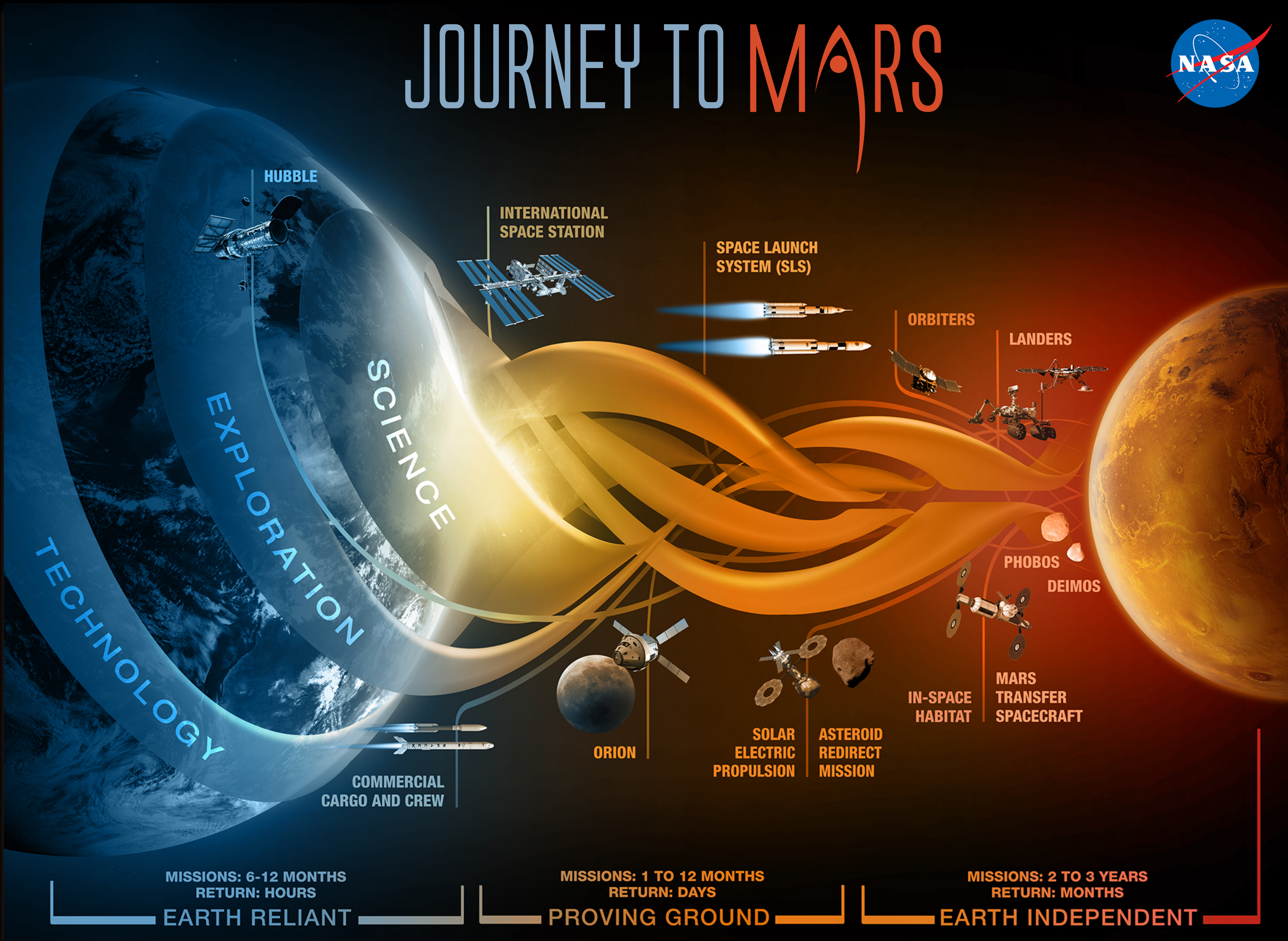
  - Project/Technical Leadership: Paul Wercinski, Alan Cassell, Brandon Smith and Bryan Yount
  - Experts at NASA Centers (Ames, Langley, Johnson, Goddard), JPL and APL
  - Funding support from NASA HQ and NASA Ames (Center Investment funds).
  - Facilities – Arc-jets and Wind-tunnels at Ames and JSC
  - Technology Partners – Bally Ribbon Mill and Thin Red Line

The Grand Challenge for the 21st Century
Human Mars Mission





Ref: Pioneering Space – the Evolvable Mars Campaign by Greg Williams and Jason Cruson

HUMAN MISSION TO MARS

The Grand Challenge:

Getting there and coming back, safely

- ❑ Humans are fragile – EDL has to be tailored for human survival

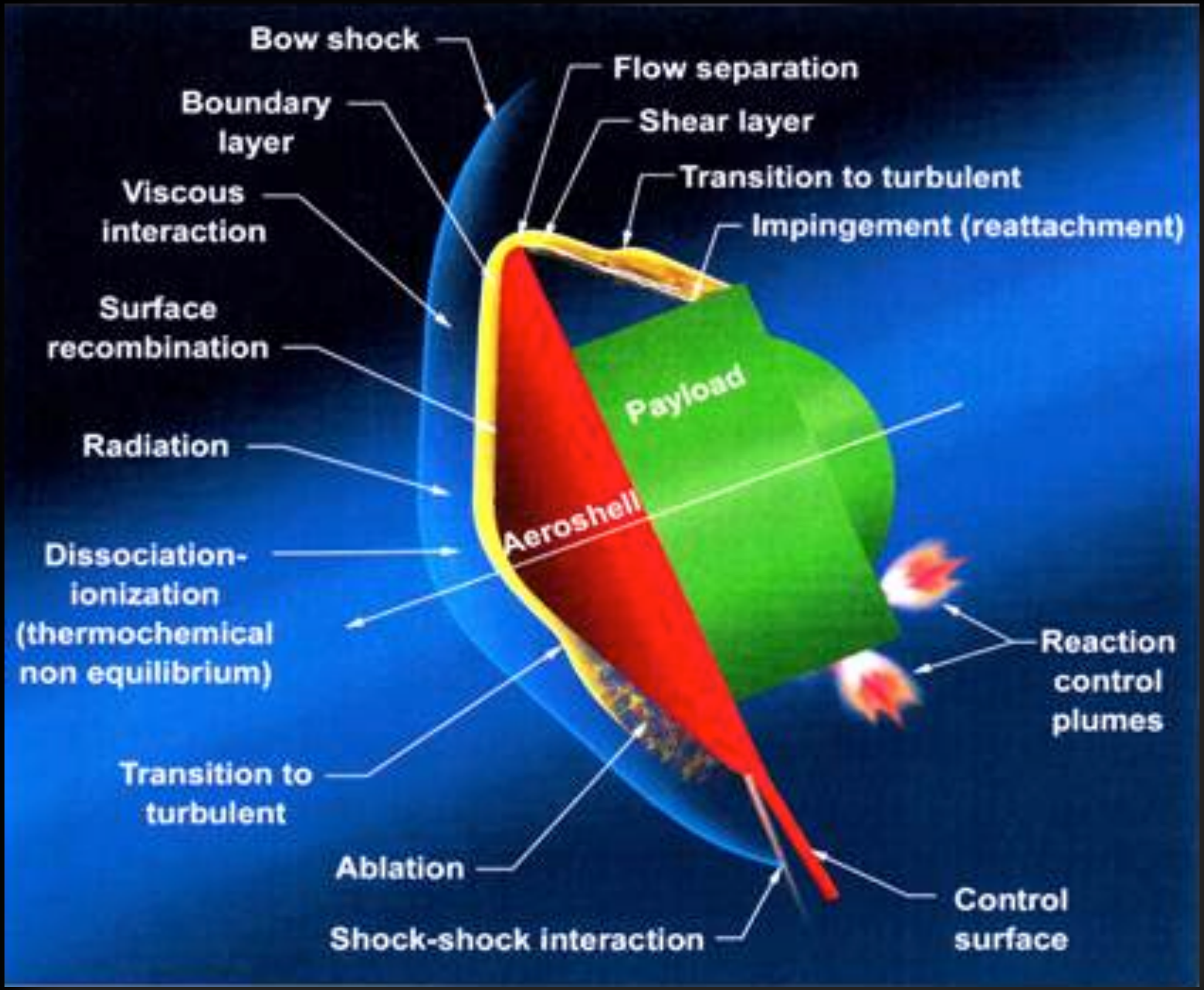
- ➢ Getting to the surface of Mars safely and with precision
  - ❑ Human missions require
    - ◆ ~(20mT - 40 mT) of landed mass per launch
    - ◆ MSL landed mass of 899 kg required a launch mass of 531,00 kg

- ➢ Getting back to Earth from Mars
  - ❑ Return velocity likely to be higher and entry G'load has to be low enough for returning astronauts to survive.

At Mars: We don't know how to do EDL for any landed mass greater than 1mT today and in addition, we need precision landing of 100m radius

ENTRY PHYSICS

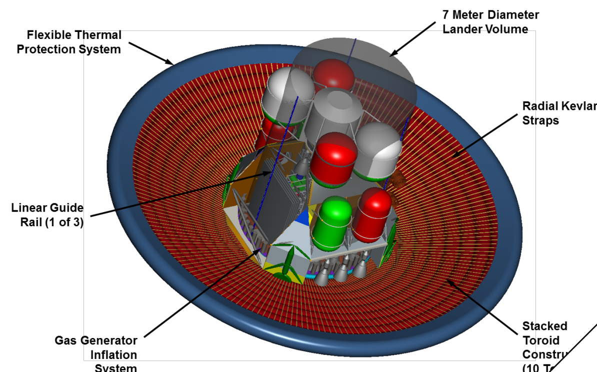
- Complex .
  - Computational simulations, ground test facilities, and flight data



TECHNOLOGIES CONSIDERED FOR HUMAN MARS MISSIONS

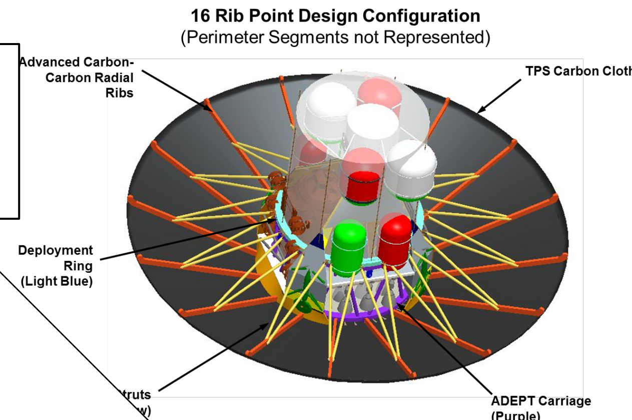
Inflatable

HIAD – Hypersonic Inflatable Aerodynamic Decelerator

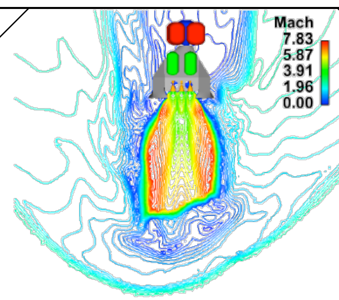


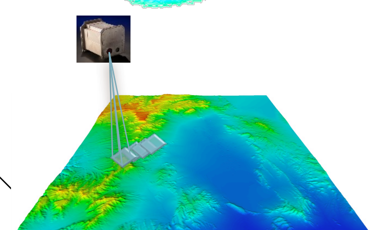
Deployable

ADEPT – Adaptable Deployable Entry and Placement Technology



Supersonic Retro-Propulsion



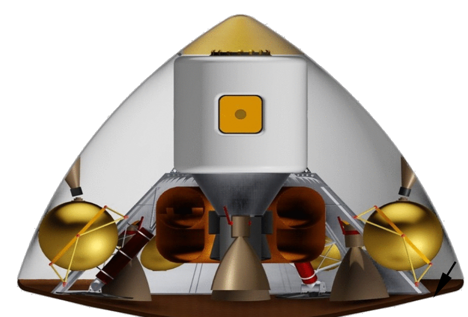


Precision Landing

Mid L/D

Rigid Structure

Capsule Concept



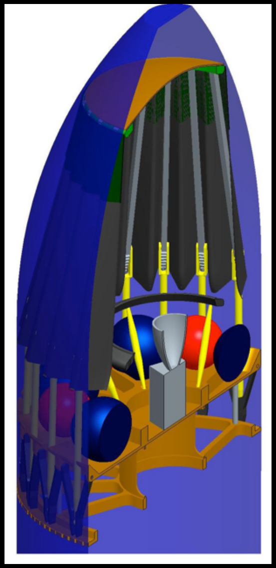
All configurations are conceptual

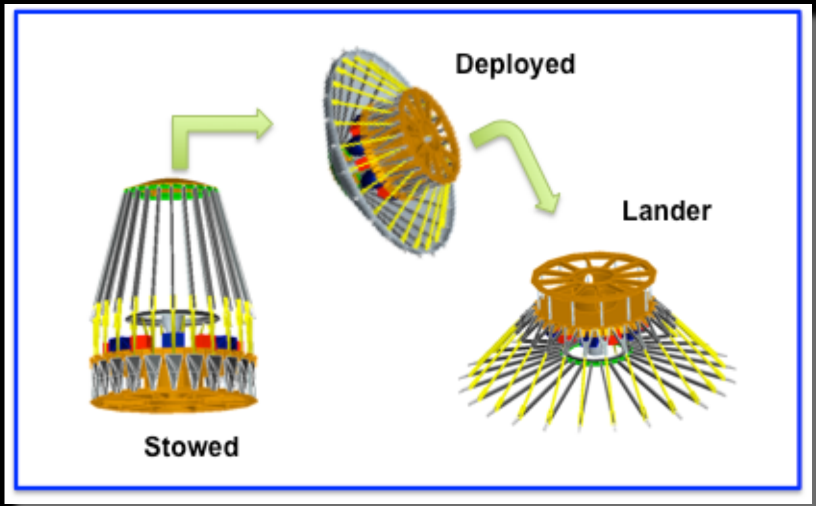
From the presentation by Munk, IPPW 2016

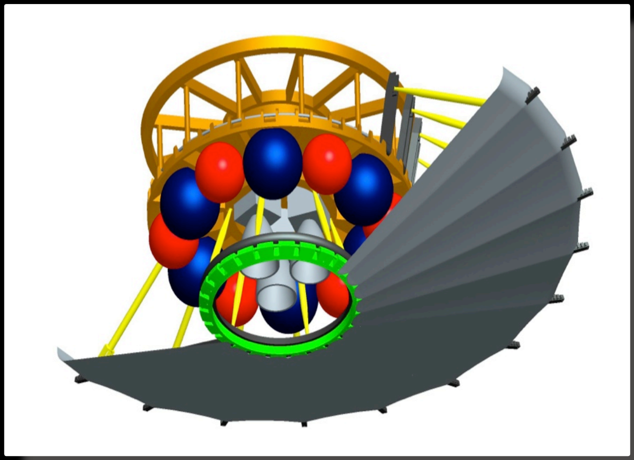
TRANSFORMABLE ENTRY SYSTEM TECHNOLOGY (CONCEPT DEVELOPMENT - 2011)

The mechanically deployable and transformable concept is similar to an umbrella but more complex functionally.

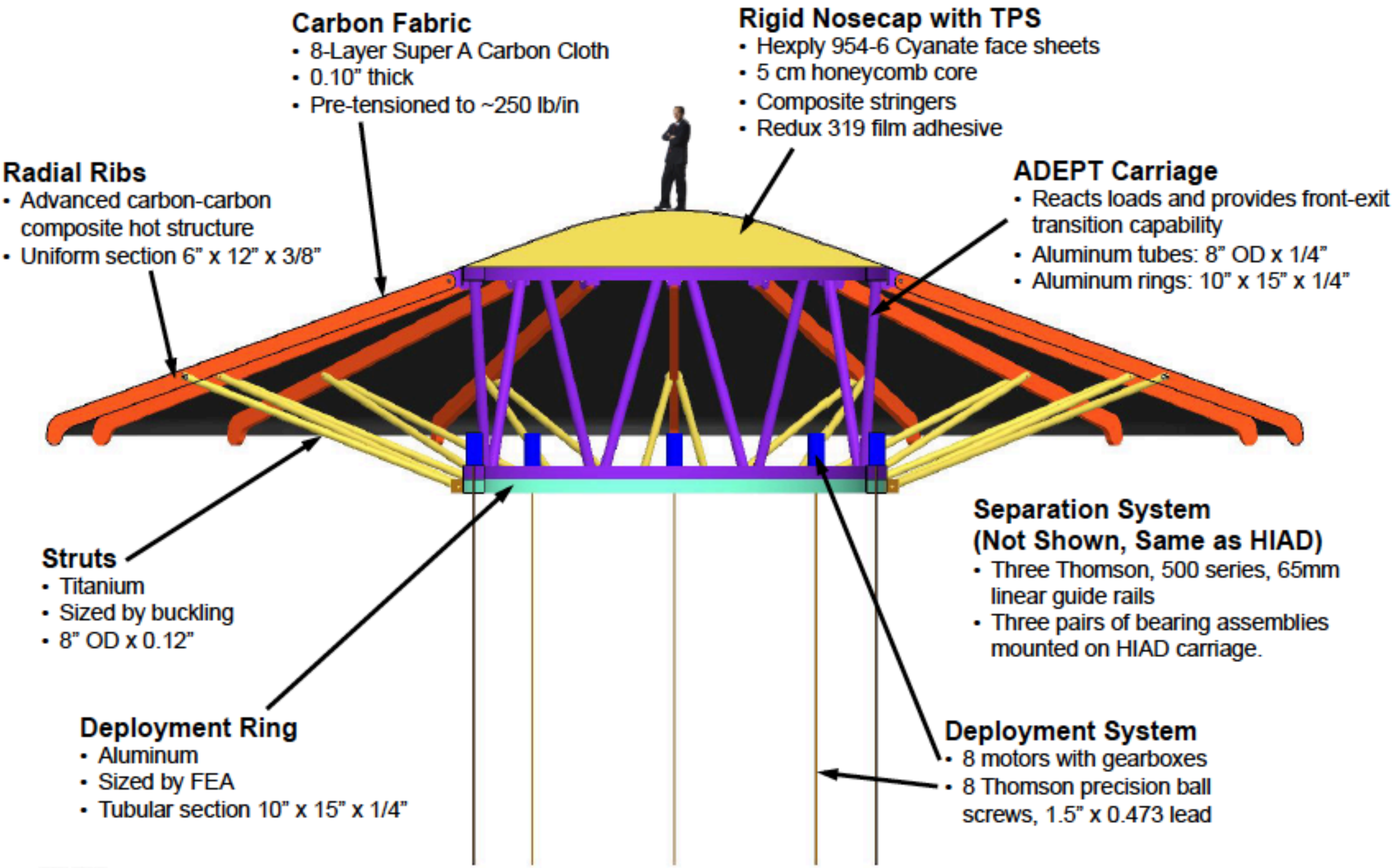
- Deployable thermal protection and aerodynamic load bearing fabric system;
- A deployable structure behind the that reacts to the primary aerodynamic load and provides a simple interface to the delivered payload;
- A self-contained deployment system;
- A primary gimbal design for pivoting of the aeroshell and thereby providing GN&C.
- An ejectable nose heat shield for the retro-propulsion system function;
- A design that transforms the aeroshell into a lander configuration







ADEPT FOR HUMAN MARS MISSIONS



Project Background

Transformable Entry System Technology FY11:

- ❑ Conceptual Studies at 23m scale
- ❑ Evaluation of 2-D and 3-D fabrics

ADEPT FY12-FY13

- ❑ Focus on 6m Venus DRM (Delivery of 1000kg lander with peak decel < 30 g's)
- ❑ Carbon fabric arc-jet tested 100-240 W/cm^2.
- ❑ Successful demonstration of 2m Ground Test Article

ADEPT FY14

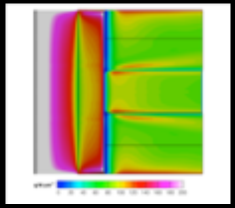
- ❑ Demonstration carbon-fabric stitched joint
- ❑ Nano-ADEPT Concept Development 1m scale
  - ◆ Potential for 'cubesat class' secondary payload mission infusion
  - ◆ Cost effective approach for key system-level demonstrations

ADEPT FY15/FY16

- ❑ Focus on 0.7m aero-loads wind tunnel test & 0.35m SPRITE pathfinder arcjet test
- ❑ Development efforts - 0.7m sounding rocket flight

Carbon fabric arcjet testing (2012)

2 m Ground Test Article (2013)



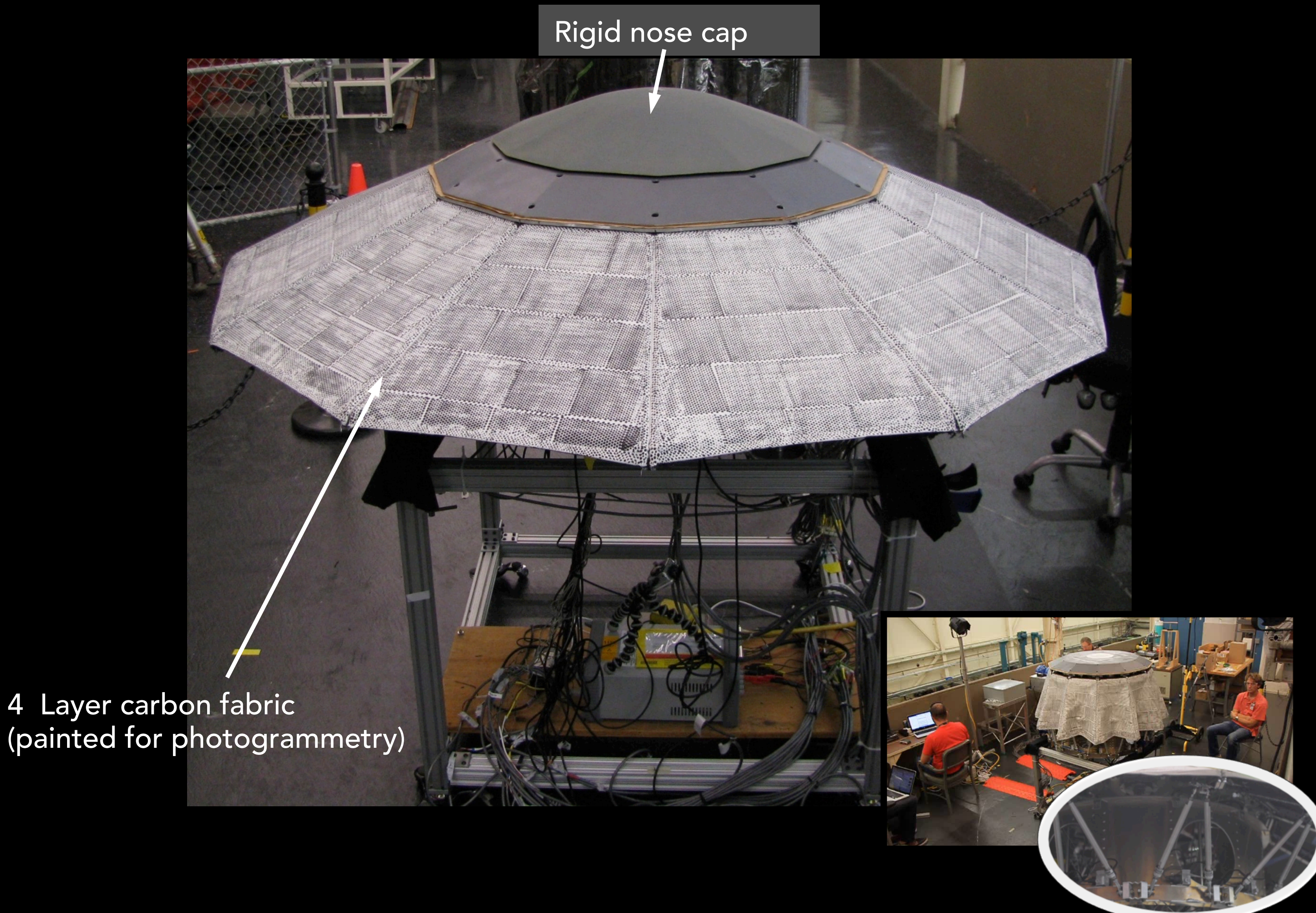
Fabric Joint Design Testing (2014)

CARBON FABRIC TESTING AT VENUS RELEVANT CONDITIONS

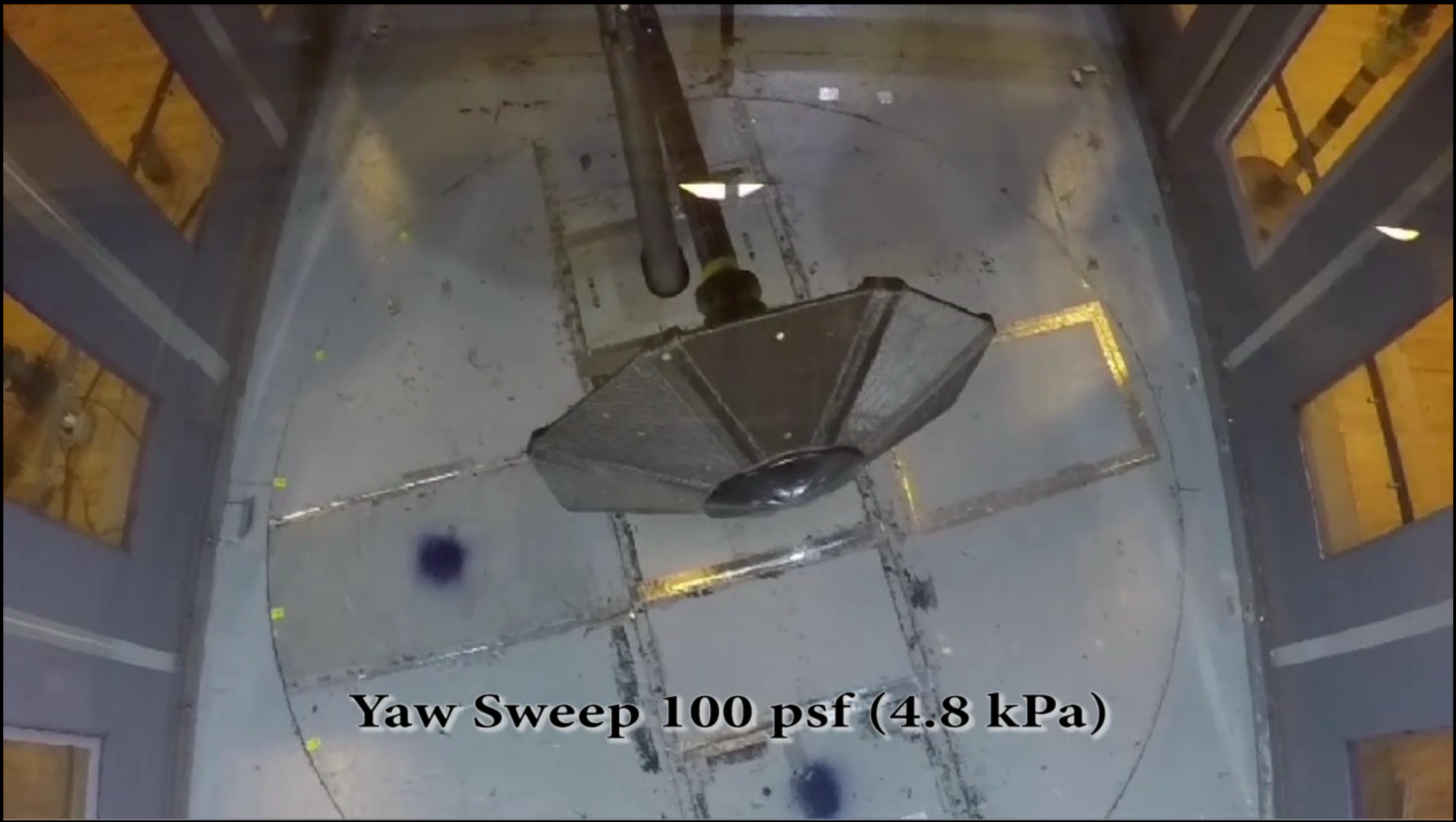
Bi-axially Loaded Aerothermal and Mechanical (BLAM) Model

An Inside Look

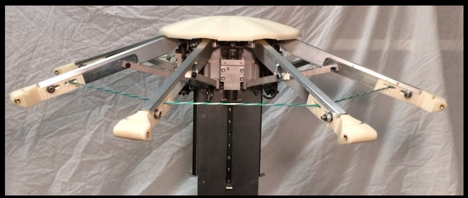
2m GROUND TEST ARTICLE DESIGN, BUILD AND TESTING



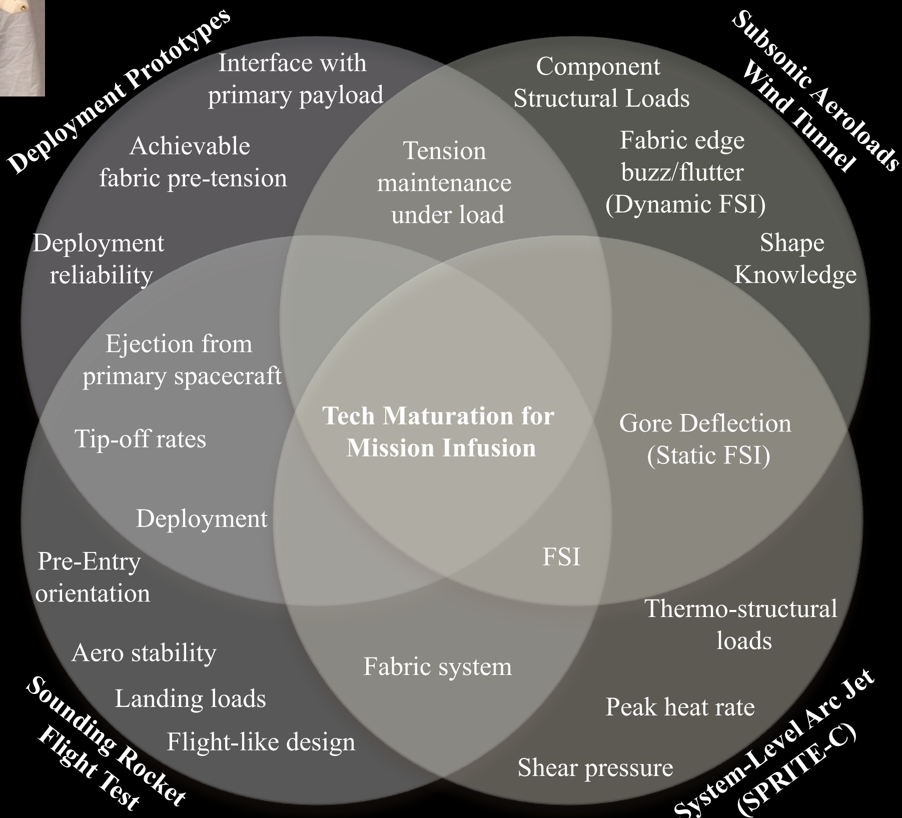
VIDEO HIGHLIGHTS FROM 7X10 TEST

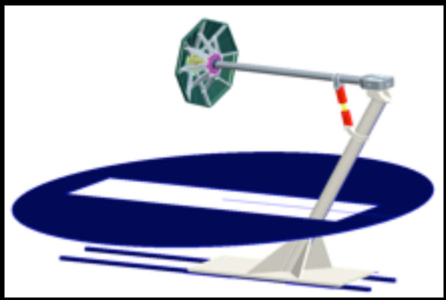


1m ADEPT Technology Maturation Approach FY15-16



Deployment Prototype Demonstration (FY15)

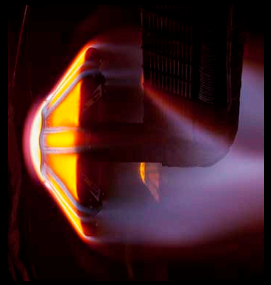




7x10 Wind-tunnel Aeroloads test (FY15)

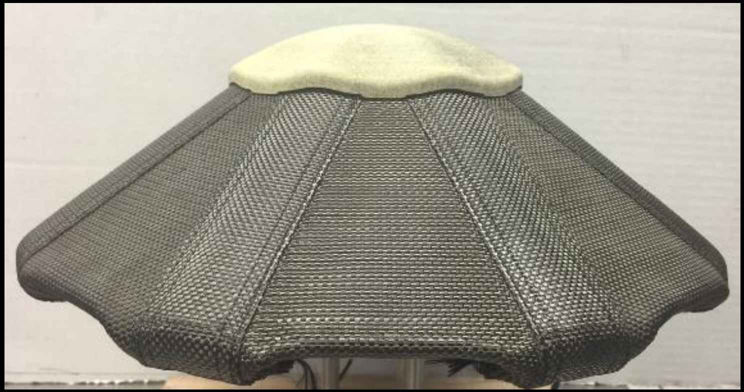
Sounding Rocket Flight Test

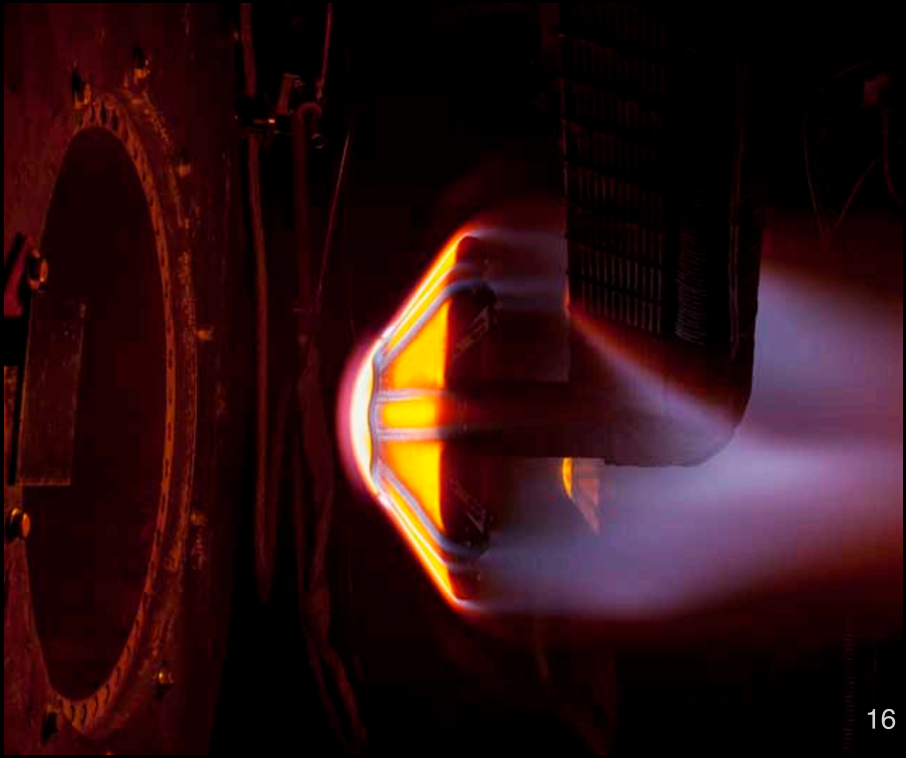
SPRITE C System level Arc-jet testing



Each test campaign provides system knowledge in more than one system attribute, and many system attributes are explored by more than one test.

SPRITE-C Pathfinder Test Article #2
C-PICA Nose, 6 Layer, Phenolic Resin joint





SPRITE-C Pathfinder Test Article #2
Test Video (1st Pulse 40s duration)

IHF 301
21" Nozzle

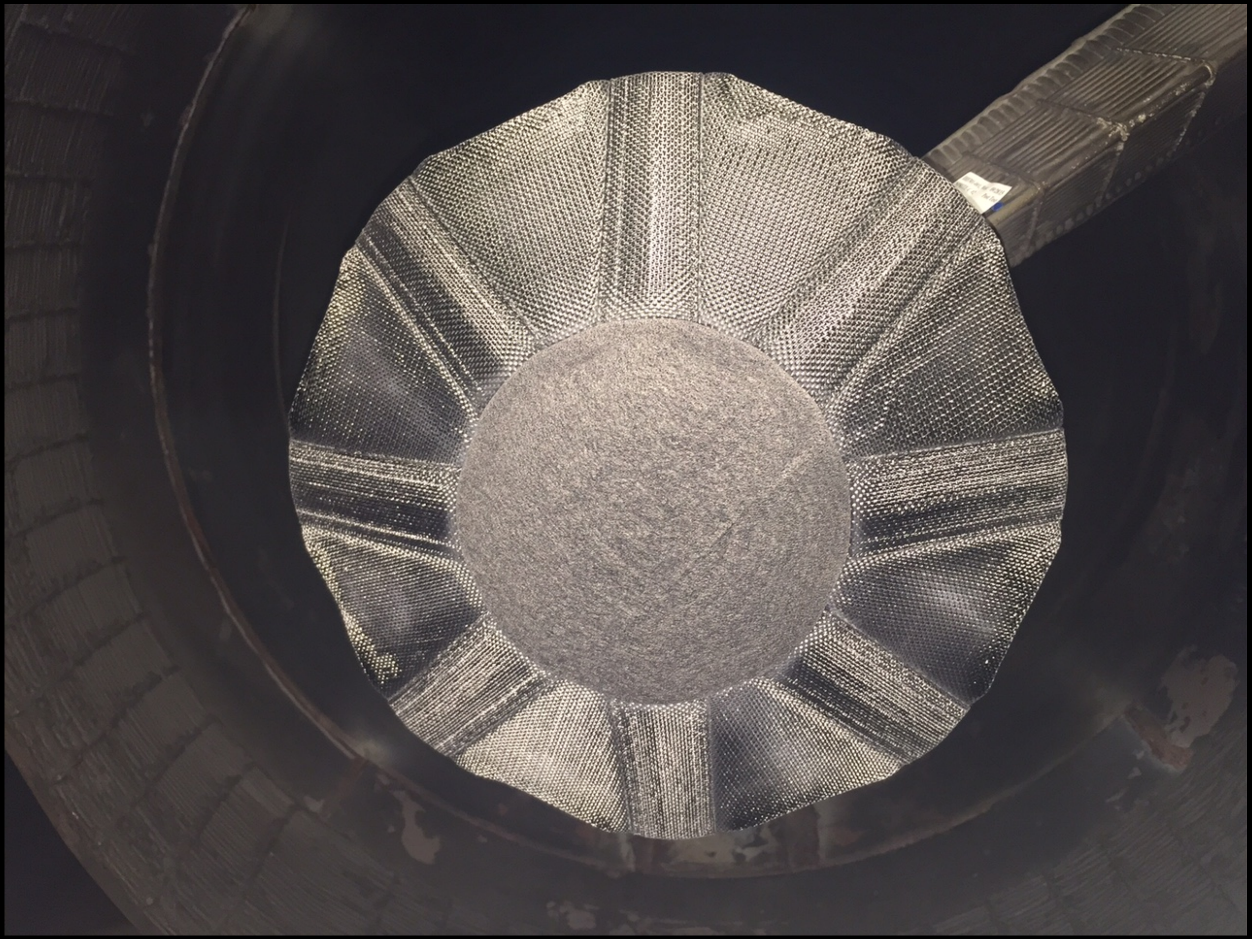
East Sting: SPRITE-C #1

Overhead Sting: Slug_Cal_102mm_Hemi_OH

West Sting: SPRITE-C #2

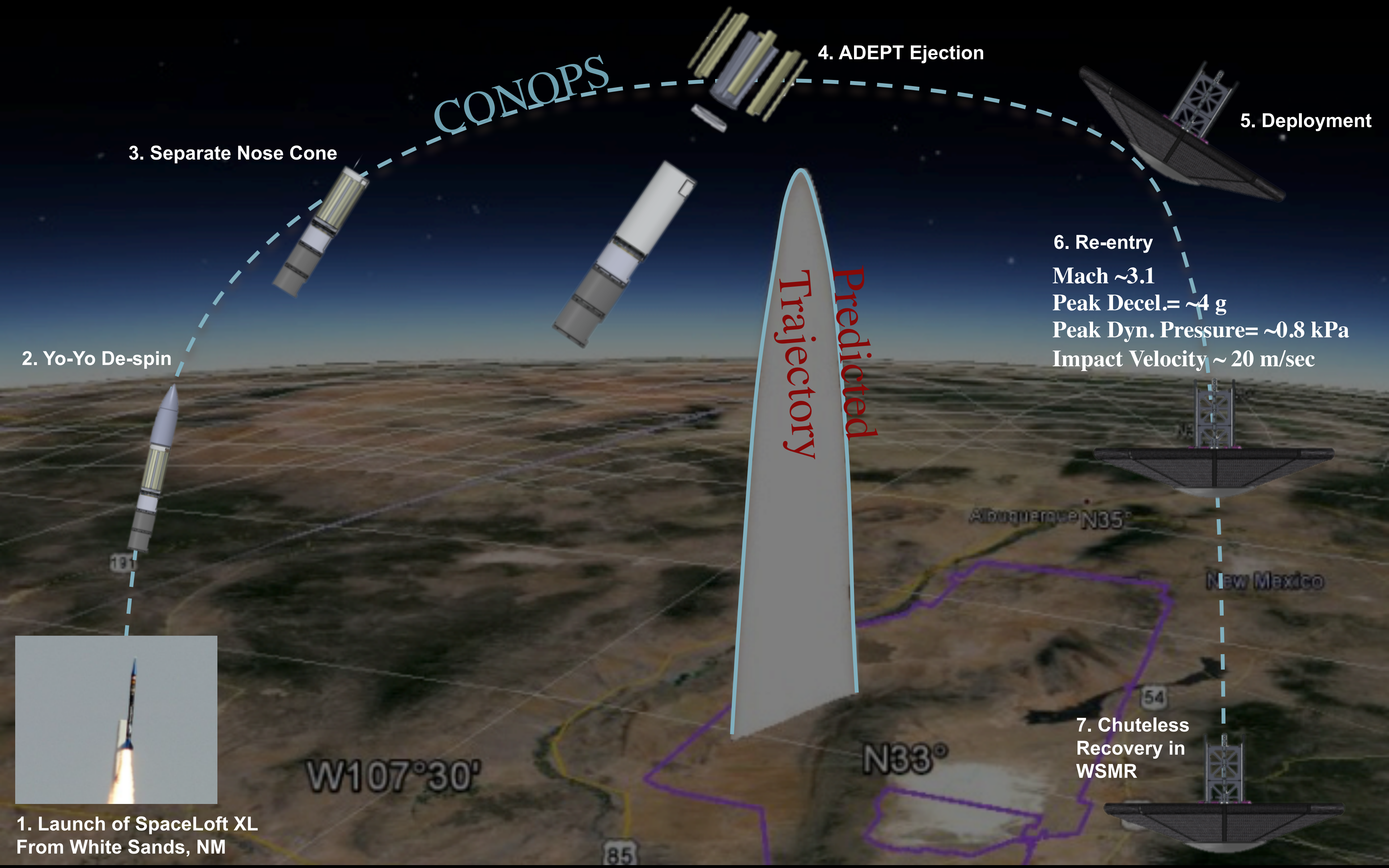
Run: 001
Date: 09/28/2015

SPRITE-C Pathfinder Post-Test Image

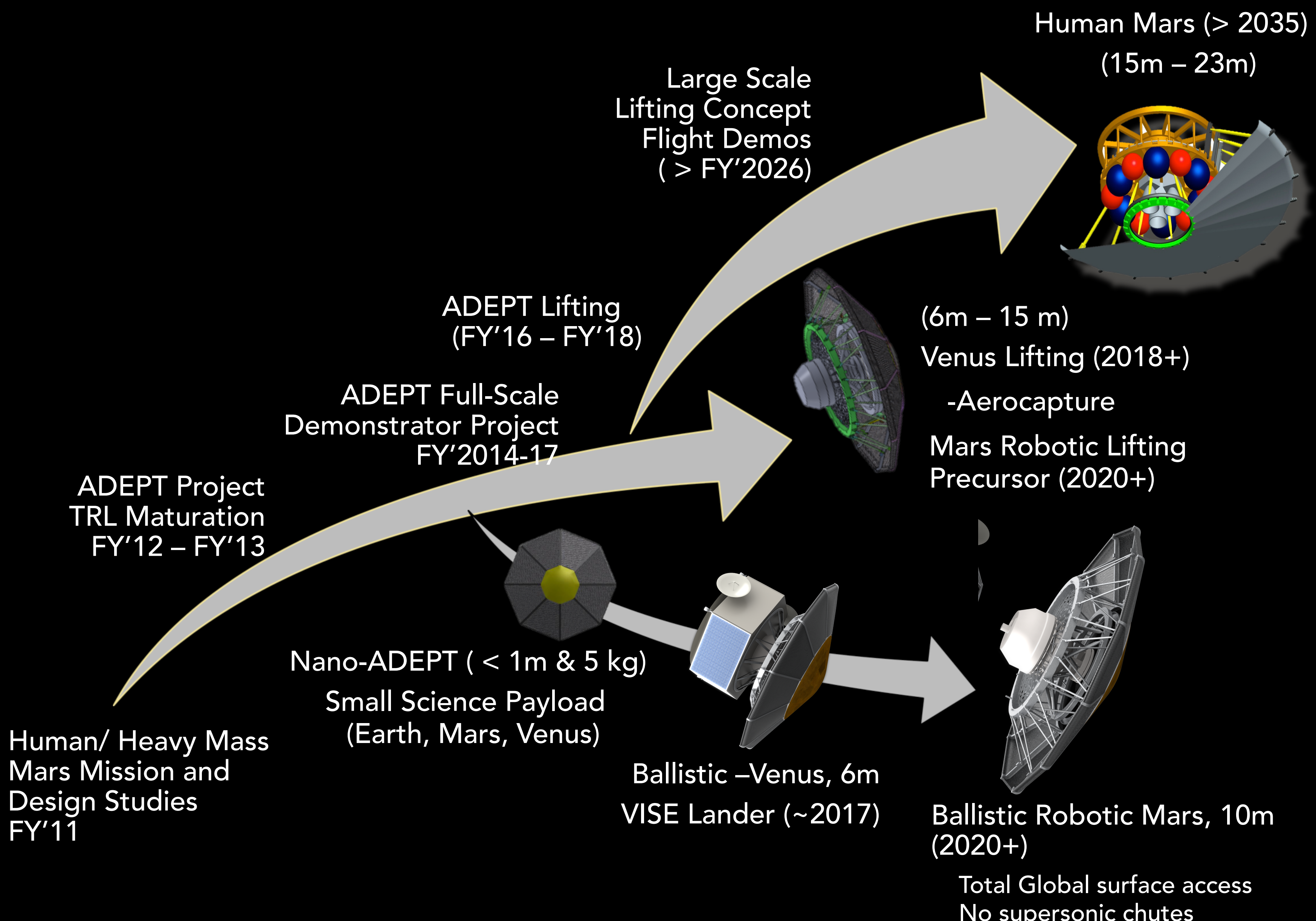


Dual heat pulse – 7.5 kJ/cm^2 total stagnation point heat load

SOUNDING ROCKET FLIGHT TEST (CY'15)



A SCALABLE ADEPT EDL ARCHITECTURE MISSION INFUSION OPPORTUNITIES



SUMMARY REMARKS

- Mars has been and continues to be both an exciting and a challenging place to explore
  - We have reached the limit of EDL technology with MSL
  - Landing large payloads and human at Mars is a grand challenge
    - Combination of innovation and new technologies needed

- The EDL grand challenge requires innovation at many levels
  - Entry System and integration
  - Multi-disciplinary by nature
  - Need multi-functional materials and sub-systems

- Fluid, thermal and structural aspects require innovative approaches to design, development, testing and verification

Thank you

Questions?