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

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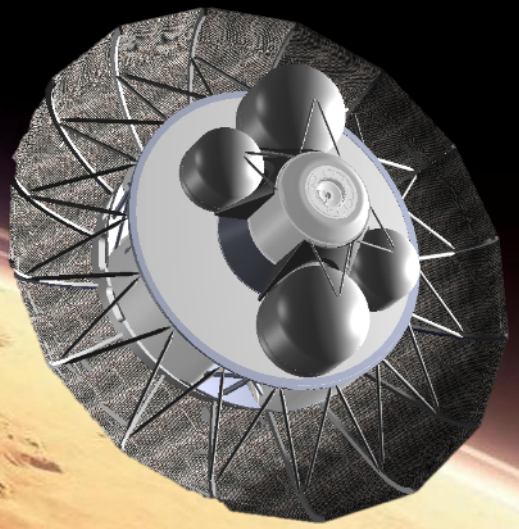


April 18, 2016
8th European Workshop on TPS and Hot-Structures
ESTEC, Noordwijk, Netherlands

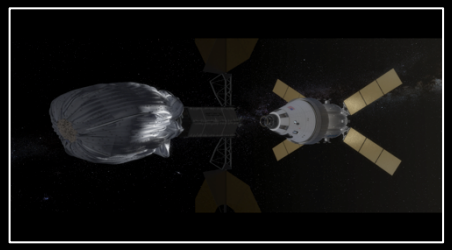
Acknowledgements

- Realizing the dream requires dedication by a large community of people and leadership along the way.
  - EDL 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

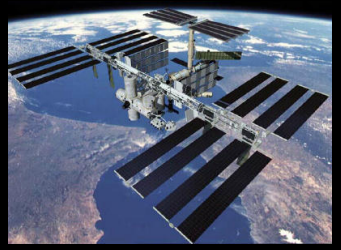
- ADEPT Project Leadership:
  - Peter Gage, James Arnold, Dinesh Prabhu, Keith Peterson, Ken Hamm and numerous others at Ames and other NASA Centers.

The 21st Century – Will It be as Great as the 20th Century for Human Exploration?

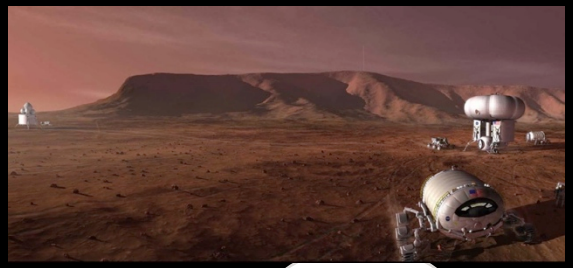
Shuttle Last Flight
July 8, 2011



Asteroid Redirect
~2020 ?



End of Station
~2025+ ?



Human Mars Mission ~2035 ?

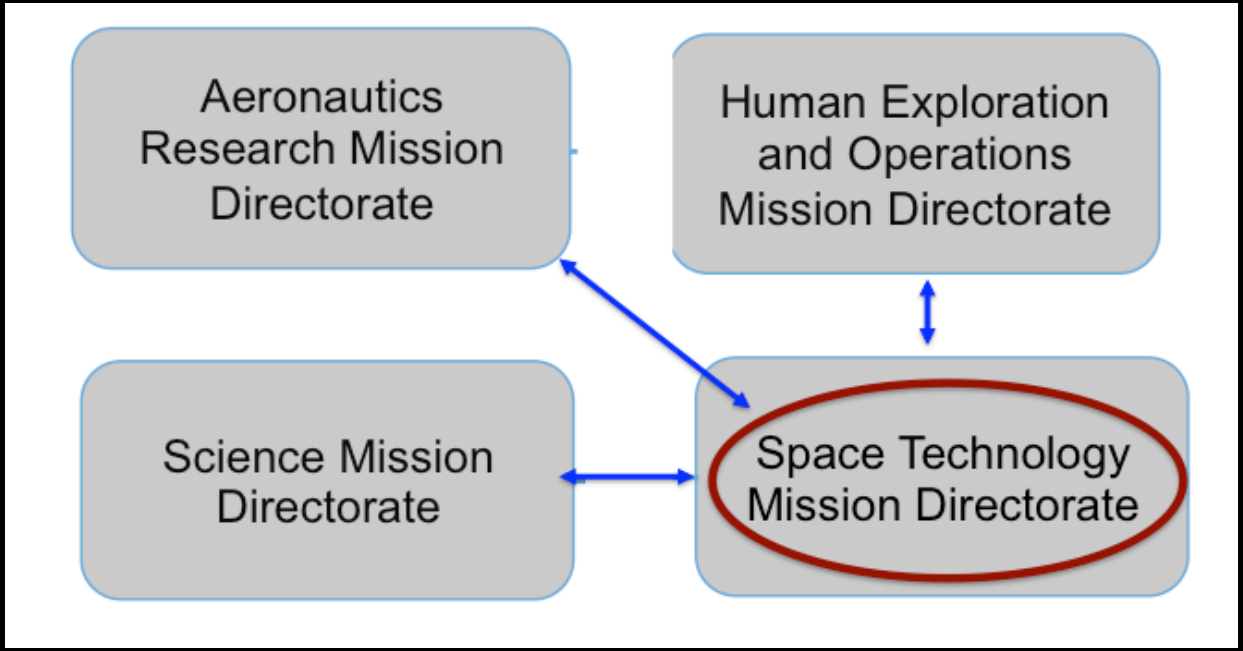
MERs
Jan 4, 2004
Jan 25, 2004

Phoenix
May 25, 2008

Curiosity/?
2012/2020

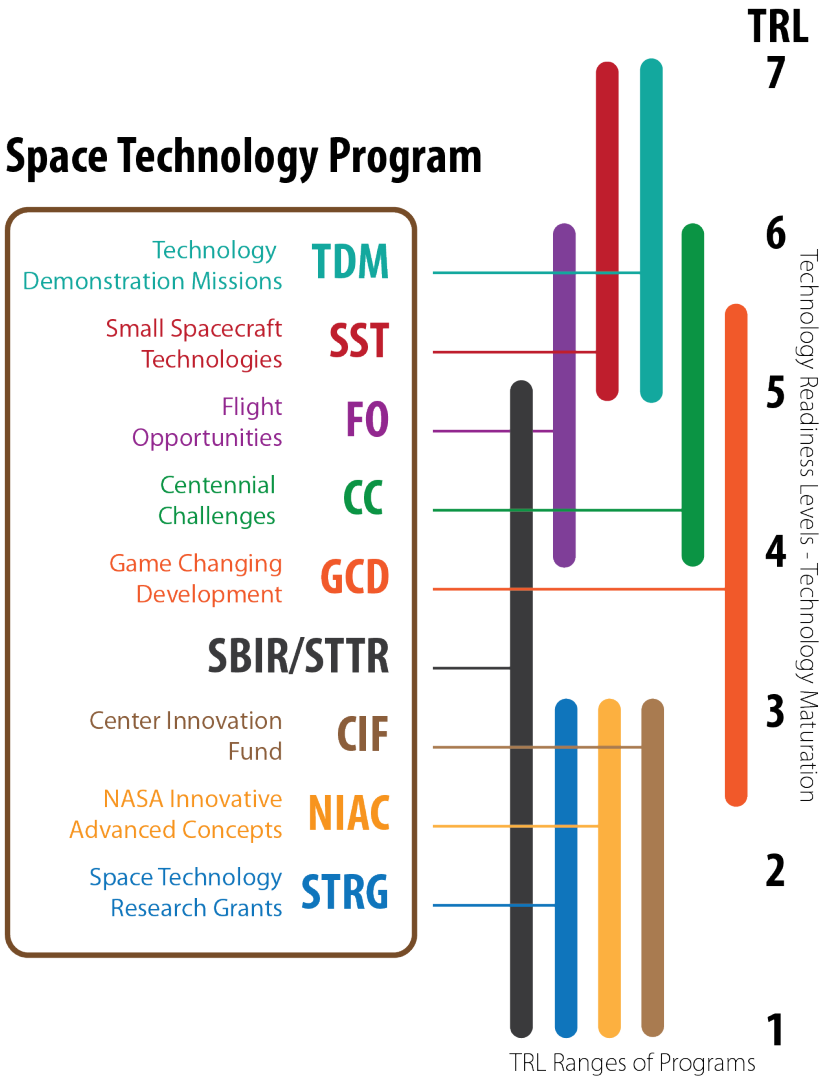
MSR? Precursor to Human?

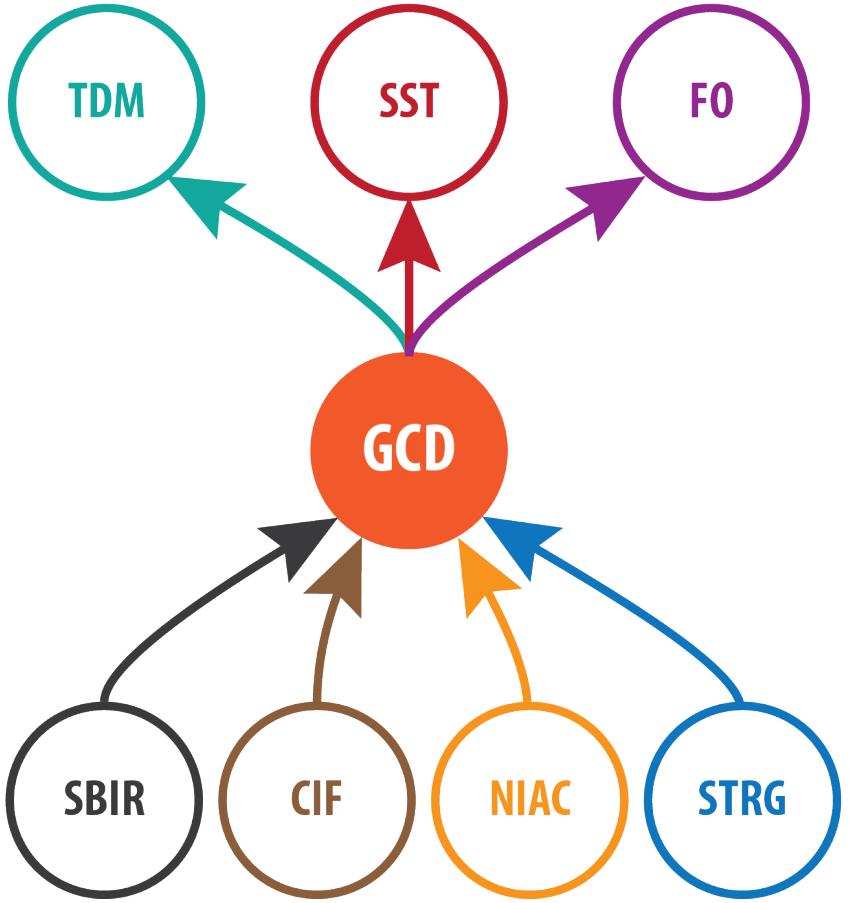
NASA TODAY
TECHNOLOGY INVESTMENTS FOR THE FUTURE



- Interaction and Collaboration between Mission Directorate
  - Technology Roadmap and Investment Prioritization
  - NRC Decadal Committee Recommended Missions

NASA TODAY: STMD
TECHNOLOGY INVESTMENT OPPORTUNITIES





HUMAN MISSION TO MARS

Technical challenges - Getting there and coming back, safely.

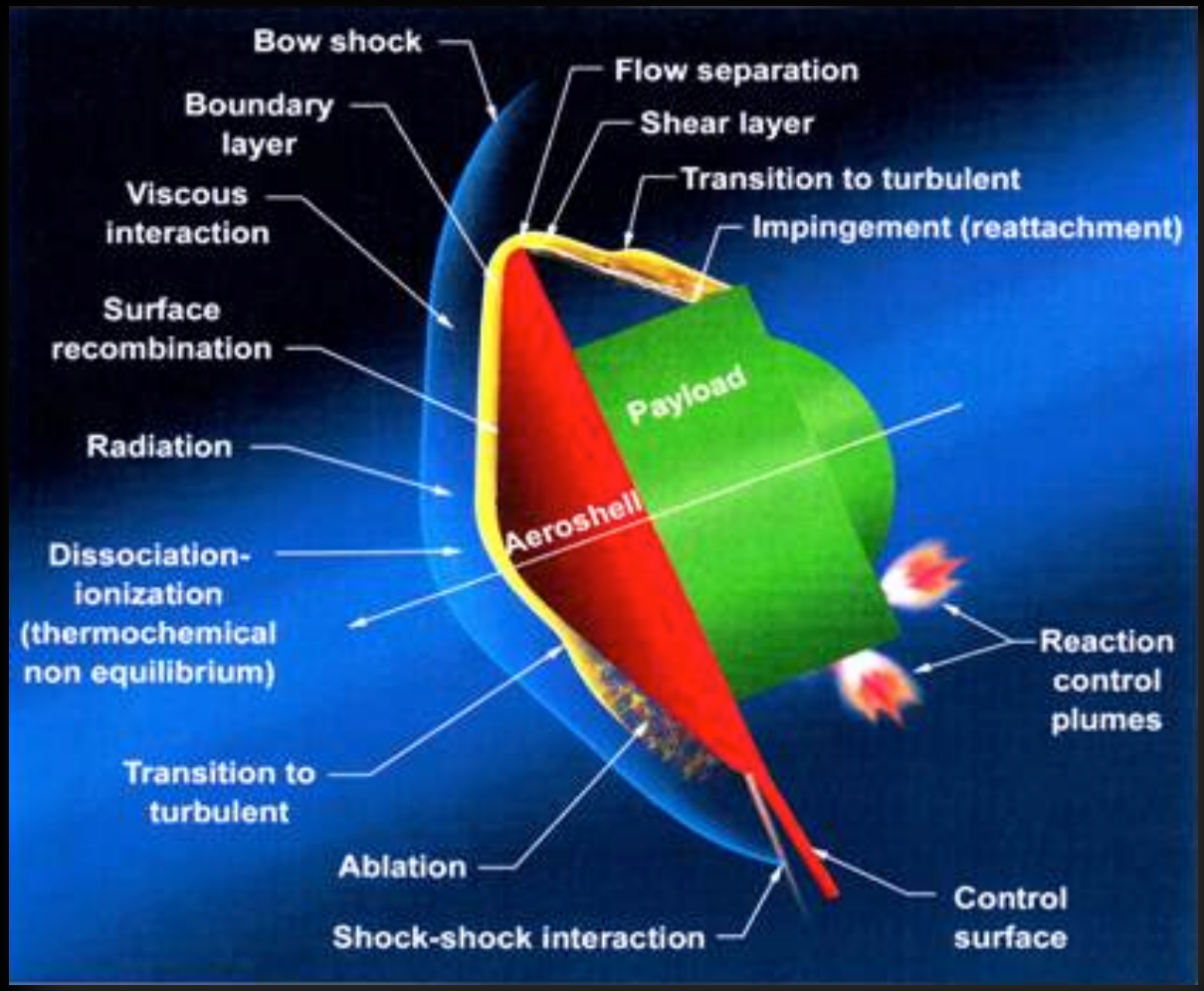
- Getting to the surface of Mars safely and with precision
  - Humans are fragile – EDL has to be tailored for human survival
  - Human missions require
    - ~(20mT - 40 mT) of landed mass per launch
    - MSL landed mass of 899 kg required a launch mass of 531,00 kg
- Getting back to Earth from Mars
  - Orion derived capsule may need upgrade
    - Return velocity likely to be higher

NASA, specifically NASA Ames, is working on both the challenges

- Mars Entry, Descent and Landing concept development
- Ablative Thermal Protection System For Earth Return

ENTRY PHYSICS

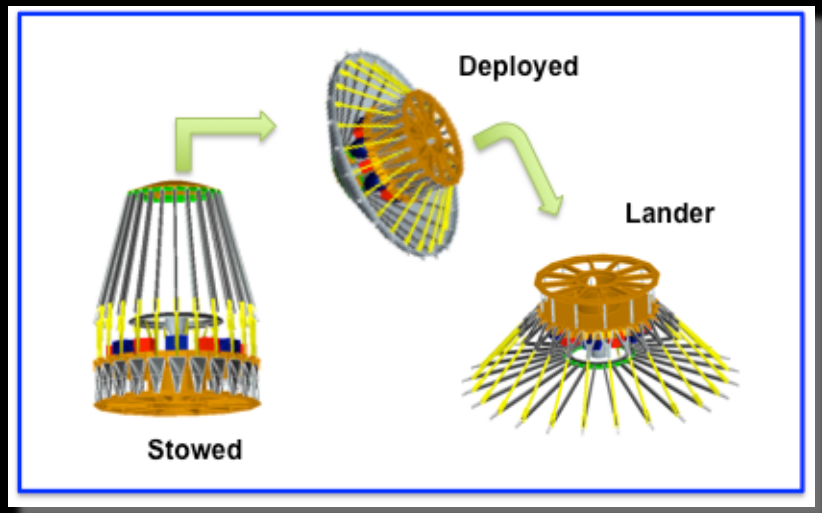
- Complex and our ability to predict has improved considerably
  - Computational simulations, ground test facilities, and flight data

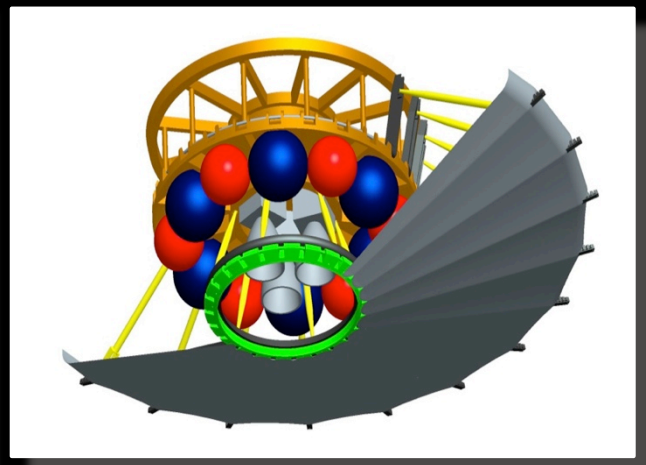


ADAPTIVE DEPLOYABLE ENTRY AND PLACEMENT TECHNOLOGY (ADEPT- 2011)

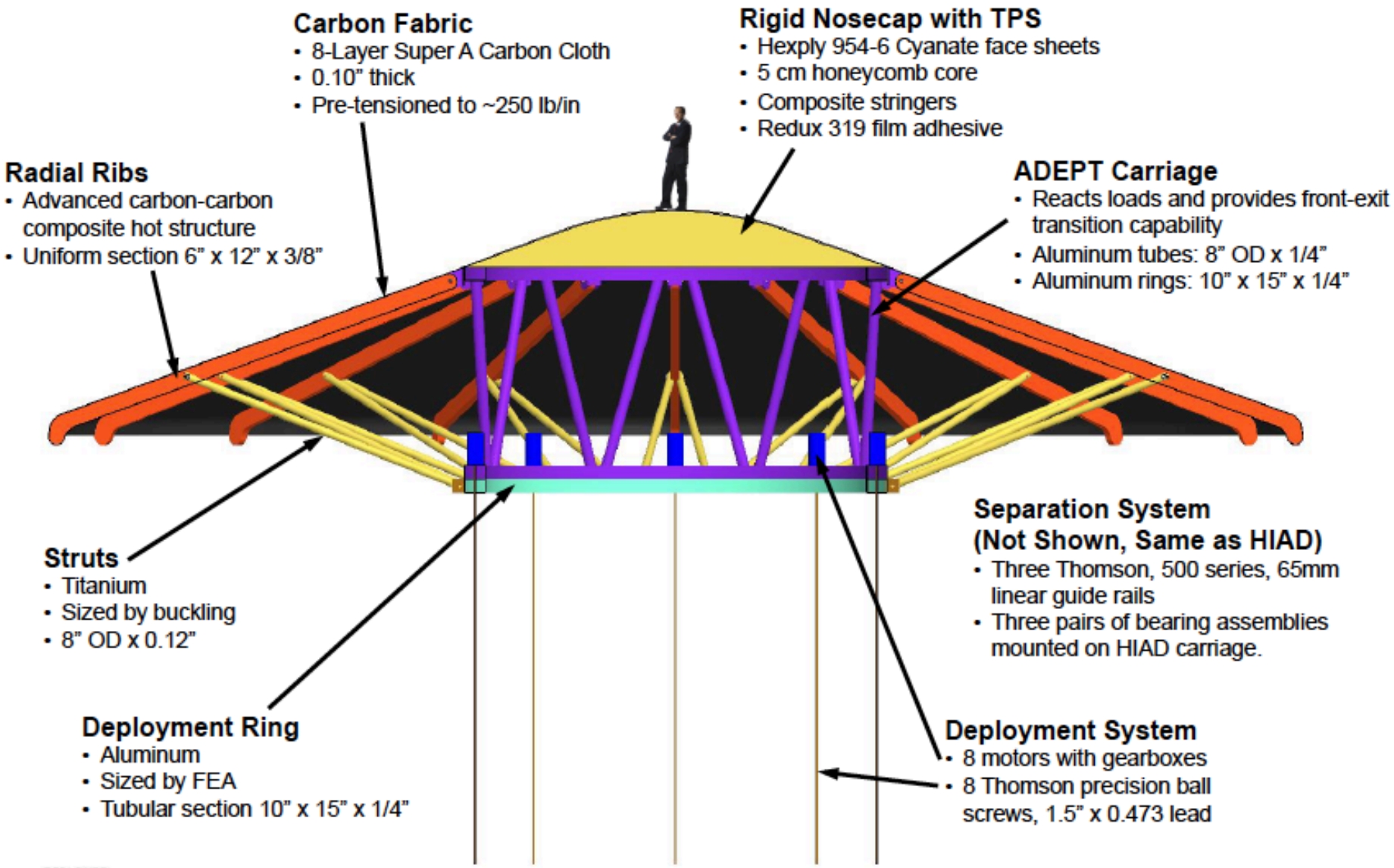
The mechanically deployable and transformable concept is similar to an umbrella but more complex functionally.

- 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

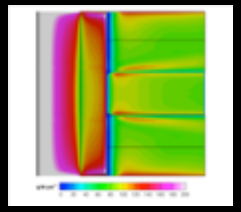


Project Background

- ADEPT FY12-FY13
  - STMD Game Changing Development Program
  - 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
  - Project re-plan to 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

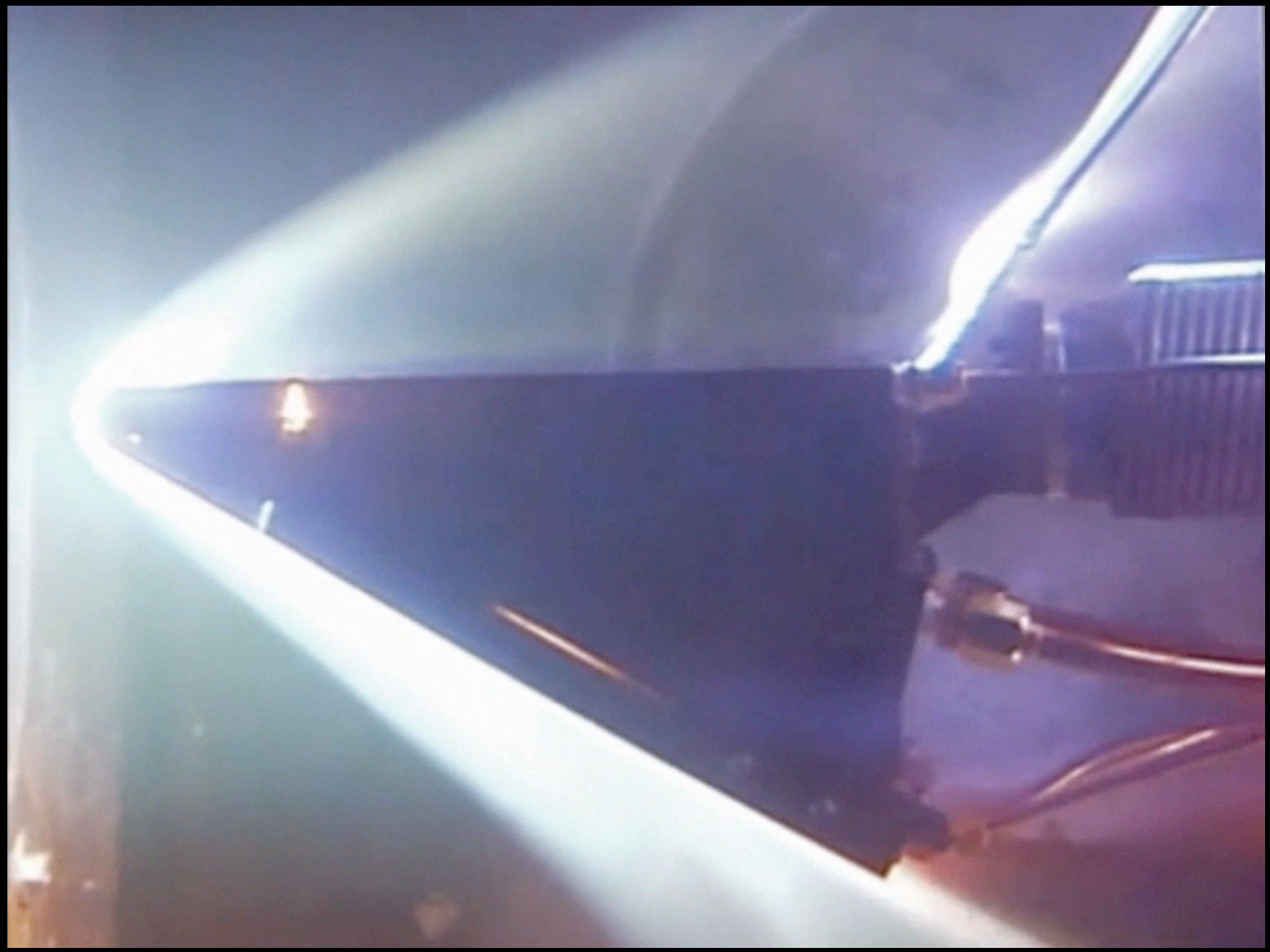
Carbon fabric arcjet testing (2012)

2 m Ground Test Article (2013)

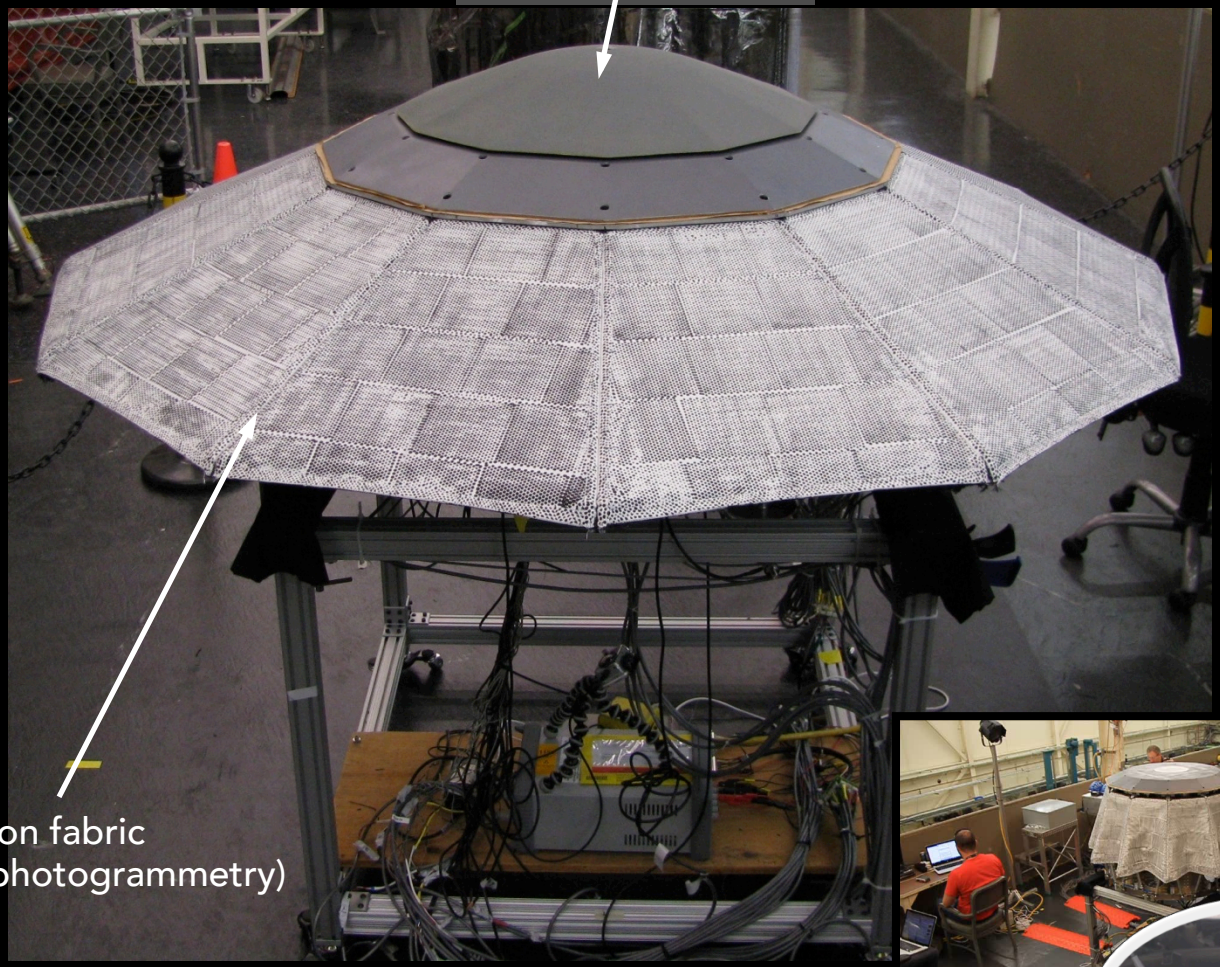


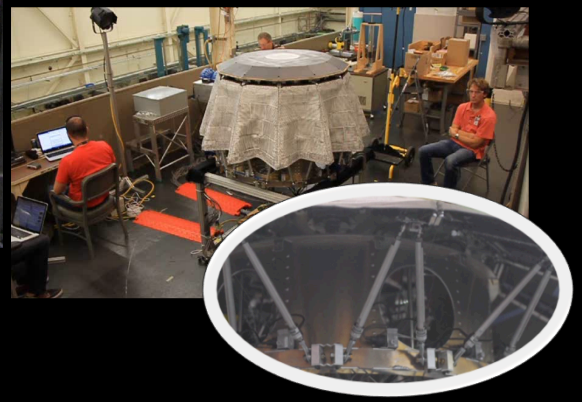
Fabric Joint Design Testing (2014)

CARBON FABRIC TESTING AT VENUS RELEVANT CONDITIONS

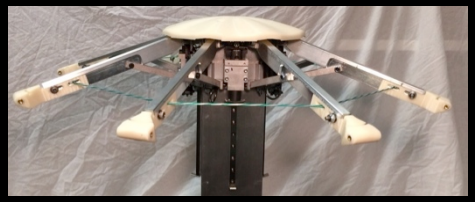


2m GROUND TEST ARTICLE DESIGN, BUILD AND TESTING

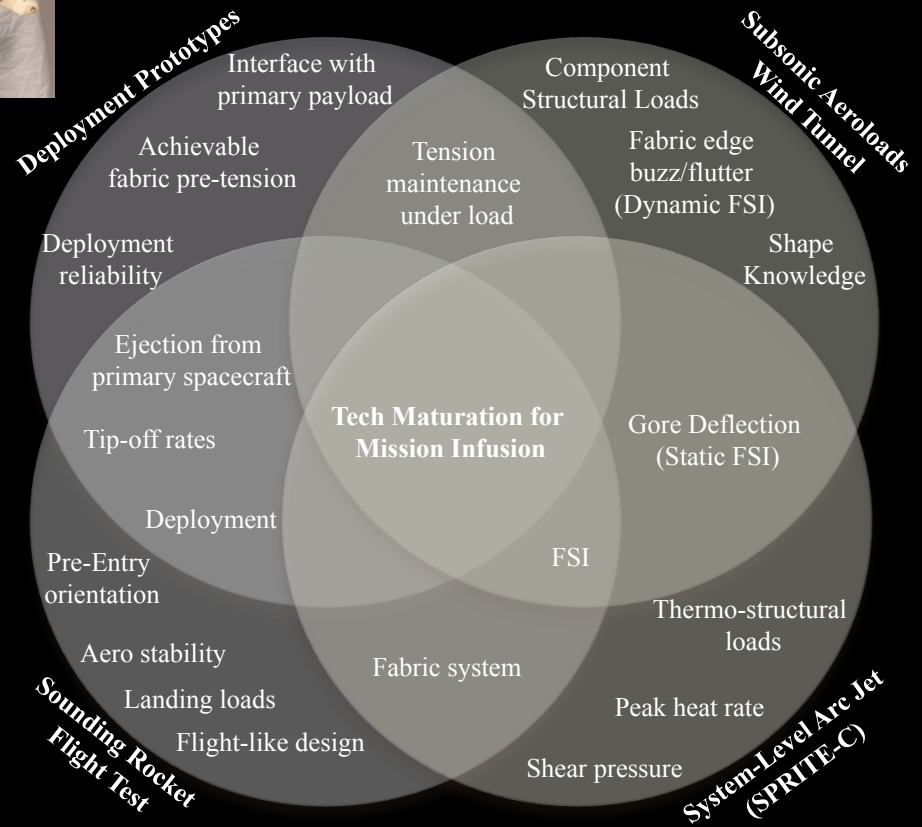


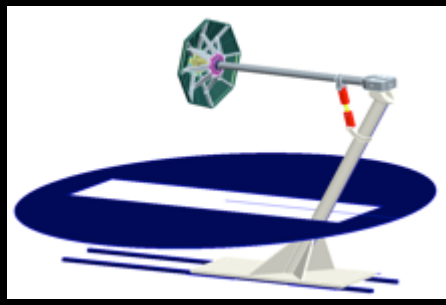


1m ADEPT Technology Maturation Approach FY15-16



Deployment Prototype Demonstration (FY15)

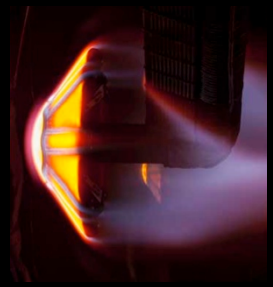




7x10 Wind-tunnel Aeroloads test (FY15)

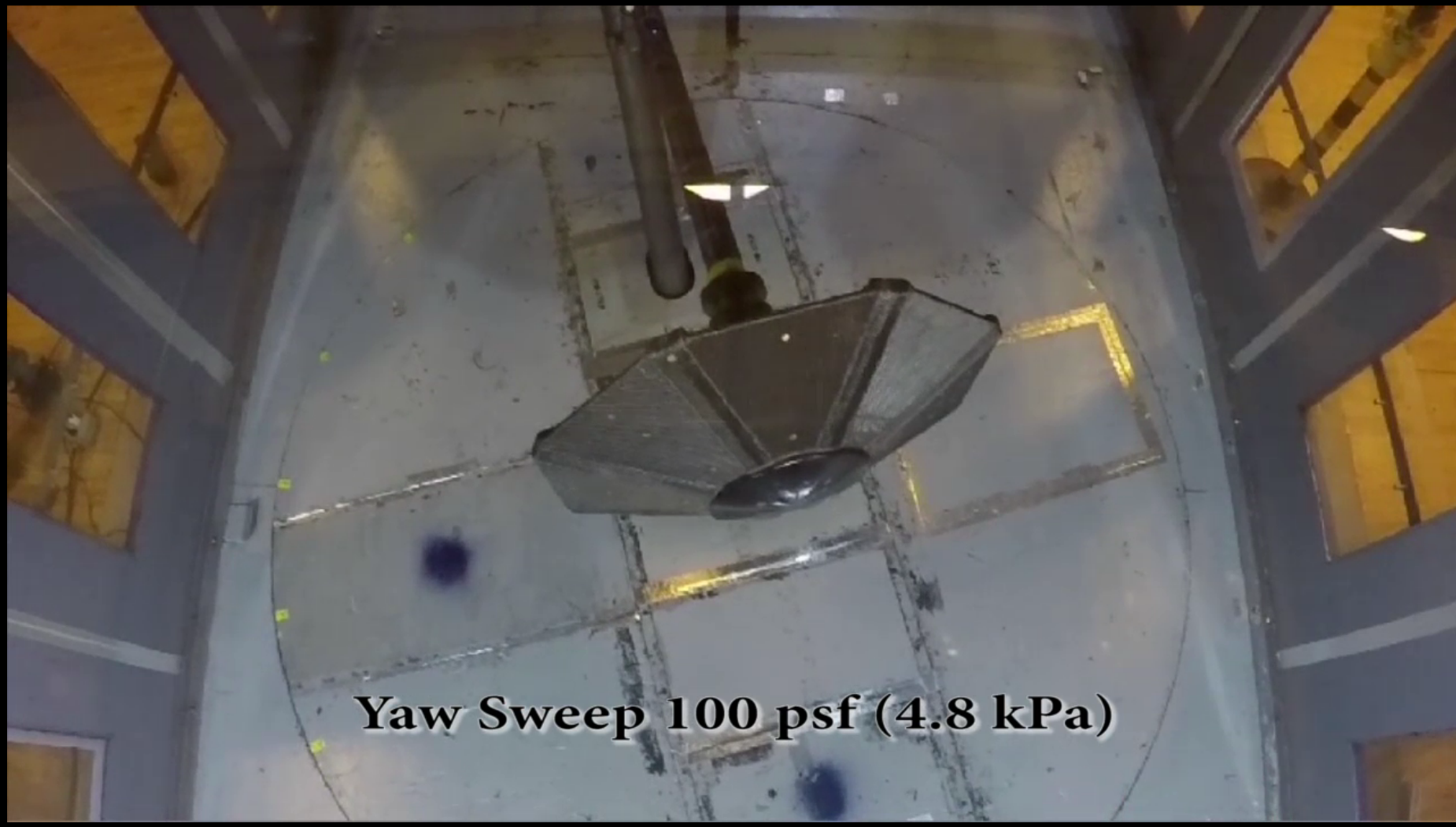
Sounding Rocket Flight Test

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.

VIDEO HIGHLIGHTS FROM 7X10 TEST



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

IHF 301
21" Nozzle

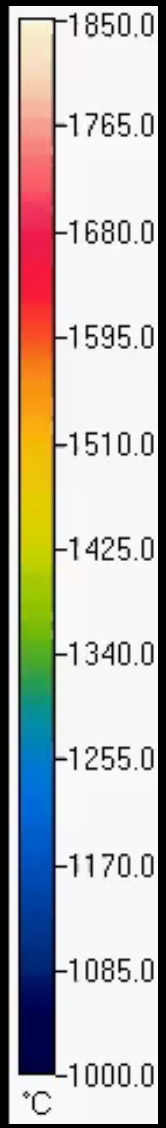
East Sting: SPRITE-C #1

Overhead Sting: Slug_Cal_102mm_Hemi_OH

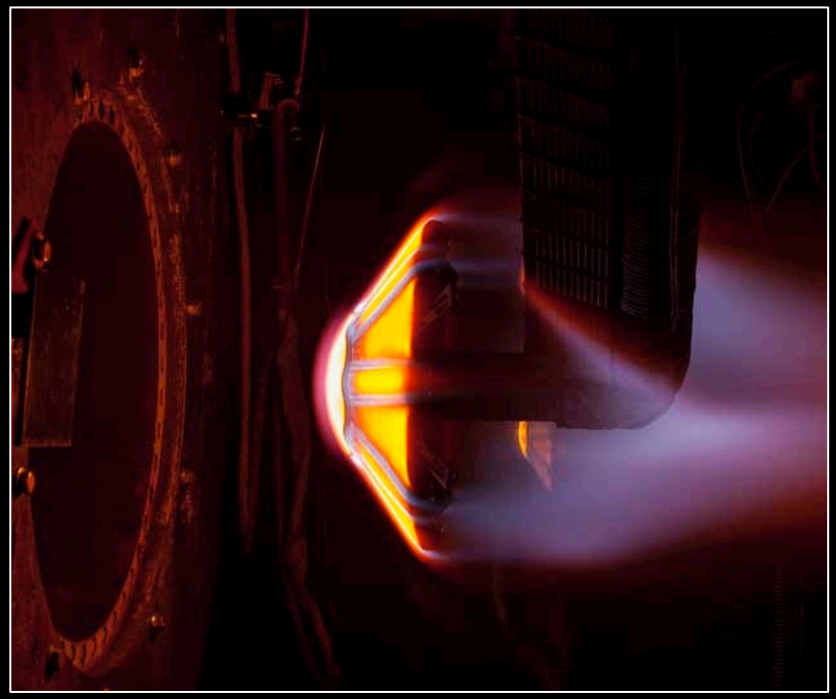
West Sting: SPRITE-C #2

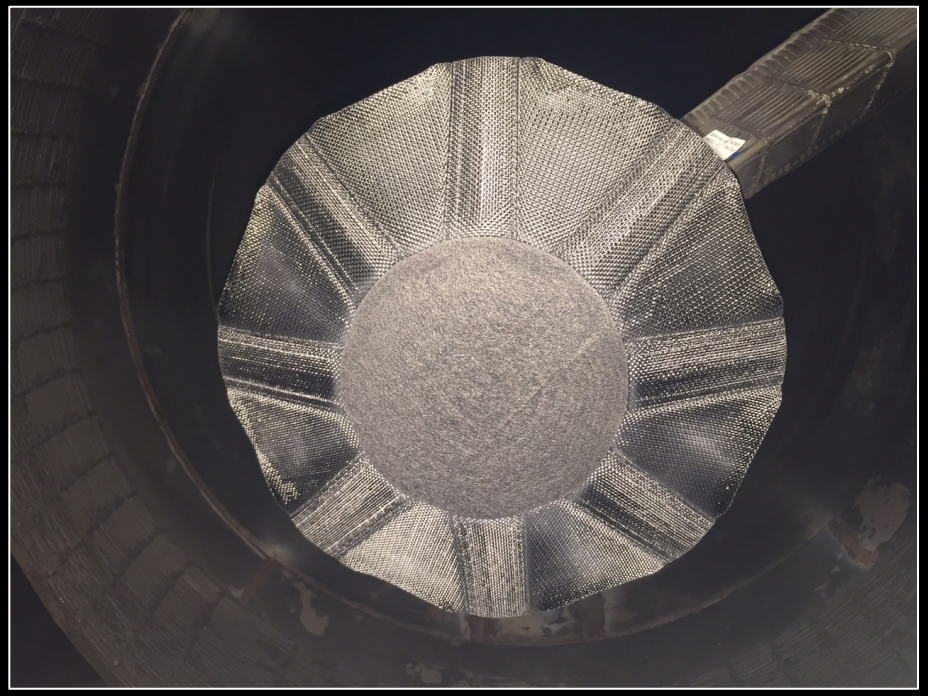
Run: 001
Date: 09/28/2015

Test Article C1 IR Video



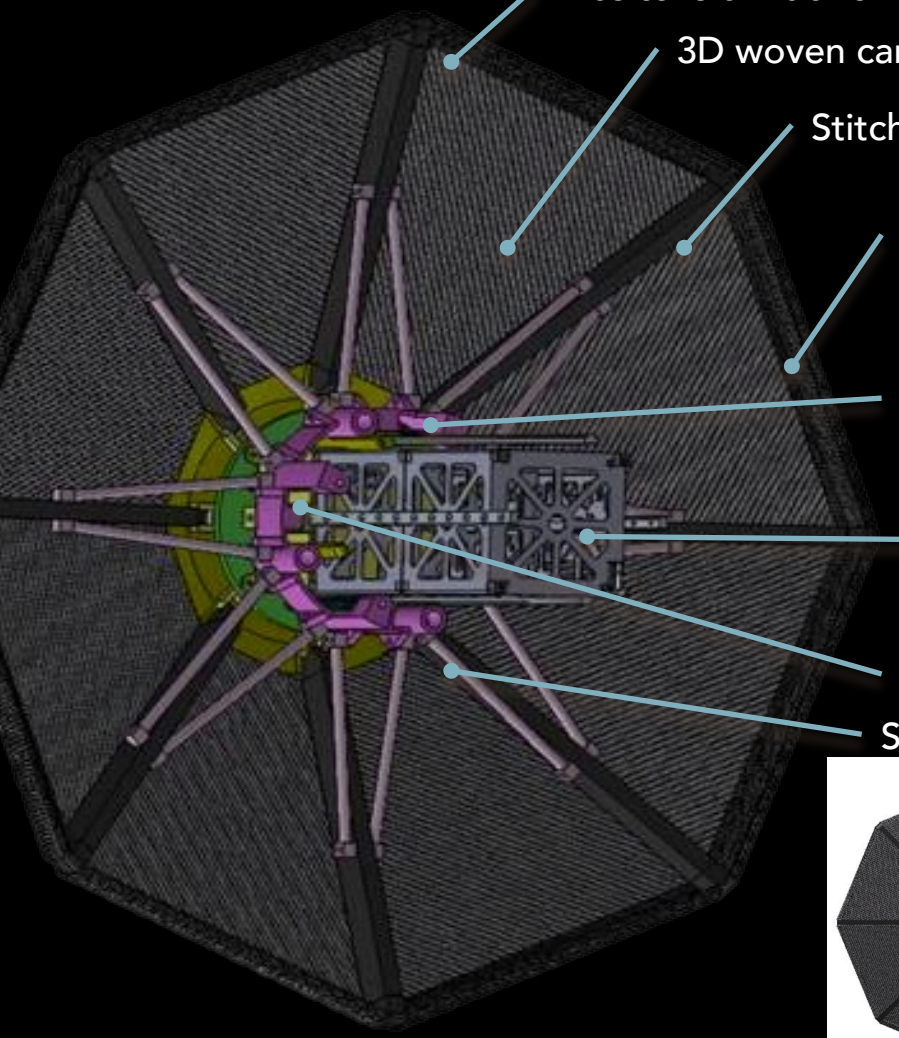
SPRITE-C Pathfinder Post-Test Image





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

SUB 1m NANO-ADEPT



Ribs tension fabric with pockets at tips (like an umbrella)

3D woven carbon fabric sized for mission

Stitched and resin-infused seams

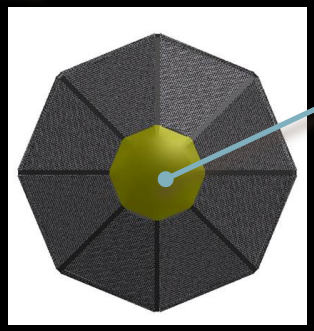
Shoulder stitching treatments

Two phase spring-deployment system
(1- high displacement, 2- high tension)

Payload area (2U shown for example)

Avionics unit (IMU, GPS, solid memory, power)

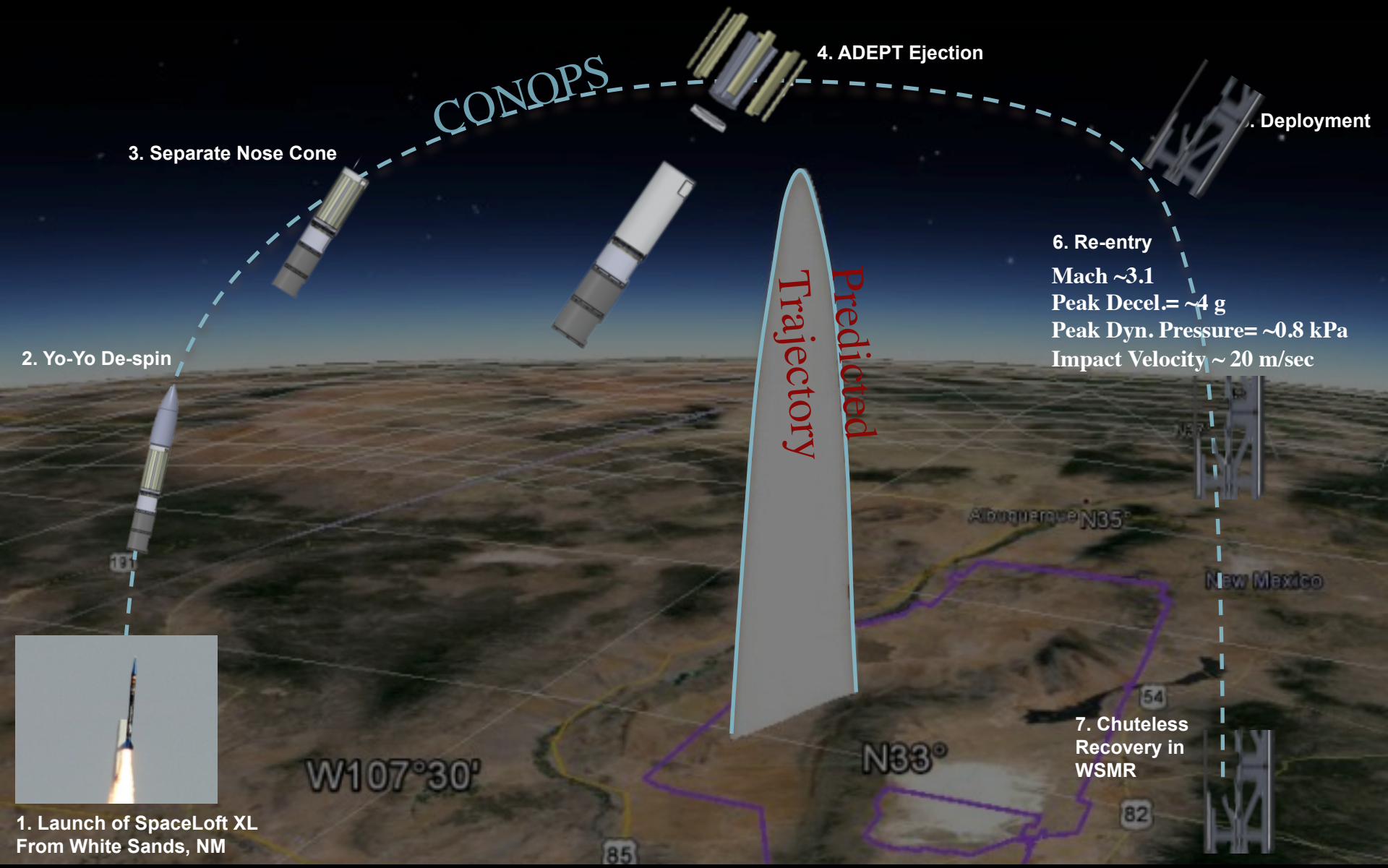
Struts



Conformal TPS Nosecap

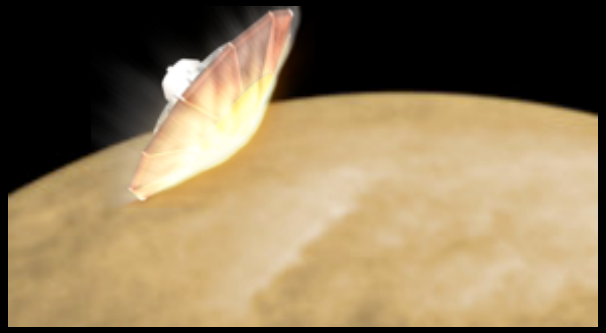
Other mission-specific hardware not shown: antennae, parachute

SOUNDING ROCKET FLIGHT TEST (CY'15)



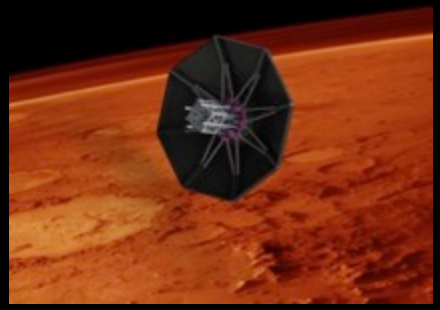
1m ADEPT Mission Pull (Discovery class)

Venus



Science Pull:
- Delivery of In-situ atmosphere science instruments.
- Achieve low deceleration loads for sensitive instruments

Mars

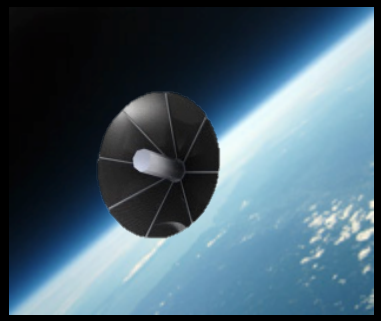


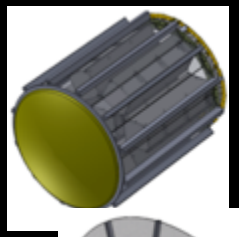
Science Pull:
- Global distribution, low cost
- Numerous landers

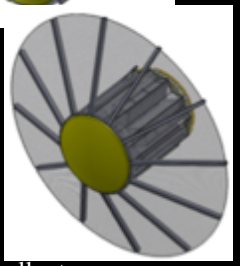
Dandelander (Malin SSS):
Cubesat distributed surface network concept

Earth

LEO Return: Secondary on Upper Stage, ISS Downmass or free-flyer on Super Strypi class LV







-De-orbit Capability
-22 N thruster incorporated with green propellant
-6 ea, 3U slots for subsystems or payloads

Titan

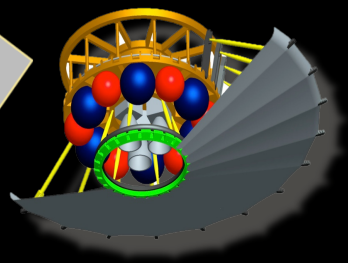
- Lifting ADEPT configuration allows aerocapture at Titan, effective thermal control with open-back configuration

A SCALABLE ADEPT EDL ARCHITECTURE
MISSION INFUSION OPPORTUNITIES

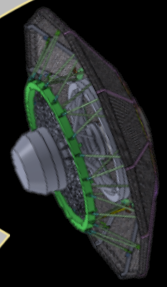
Human Mars (> 2035)

(15m – 23m)

Large Scale
Lifting Concept
Flight Demos
(> FY'2026)



ADEPT Lifting
(FY'16 – FY'18)



(6m – 15 m)

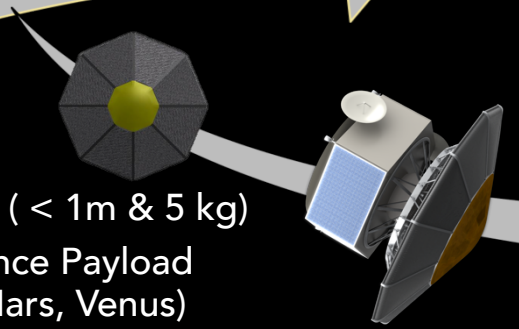
Venus Lifting (2018+)

-Aerocapture

Mars Robotic Lifting
Precursor (2020+)

ADEPT Full-Scale
Demonstrator Project
FY'2014-17

ADEPT Project
TRL Maturation
FY'12 – FY'13



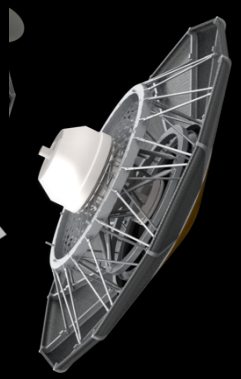
Nano-ADEPT (< 1m & 5 kg)

Small Science Payload
(Earth, Mars, Venus)

Human/ Heavy Mass
Mars Mission and
Design Studies
FY'11

Ballistic –Venus, 6m

VISE Lander (~2017)



Ballistic Robotic Mars, 10m
(2020+)

Total Global surface access
No supersonic chutes

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

- Mechanically deployable entry system, ADEPT, is a game changing concept that has the potential
  - Within 5 years, retrieving small-satellites from around earth orbit and send small payload to Mars and Venus.
  - Within a decade, enable cost effective, in-situ missions to robotic science exploration
  - In the longer term, the concept and the robotic experiences at earth, Venus and Mars can enable Human Mars missions

Thank you

Questions?