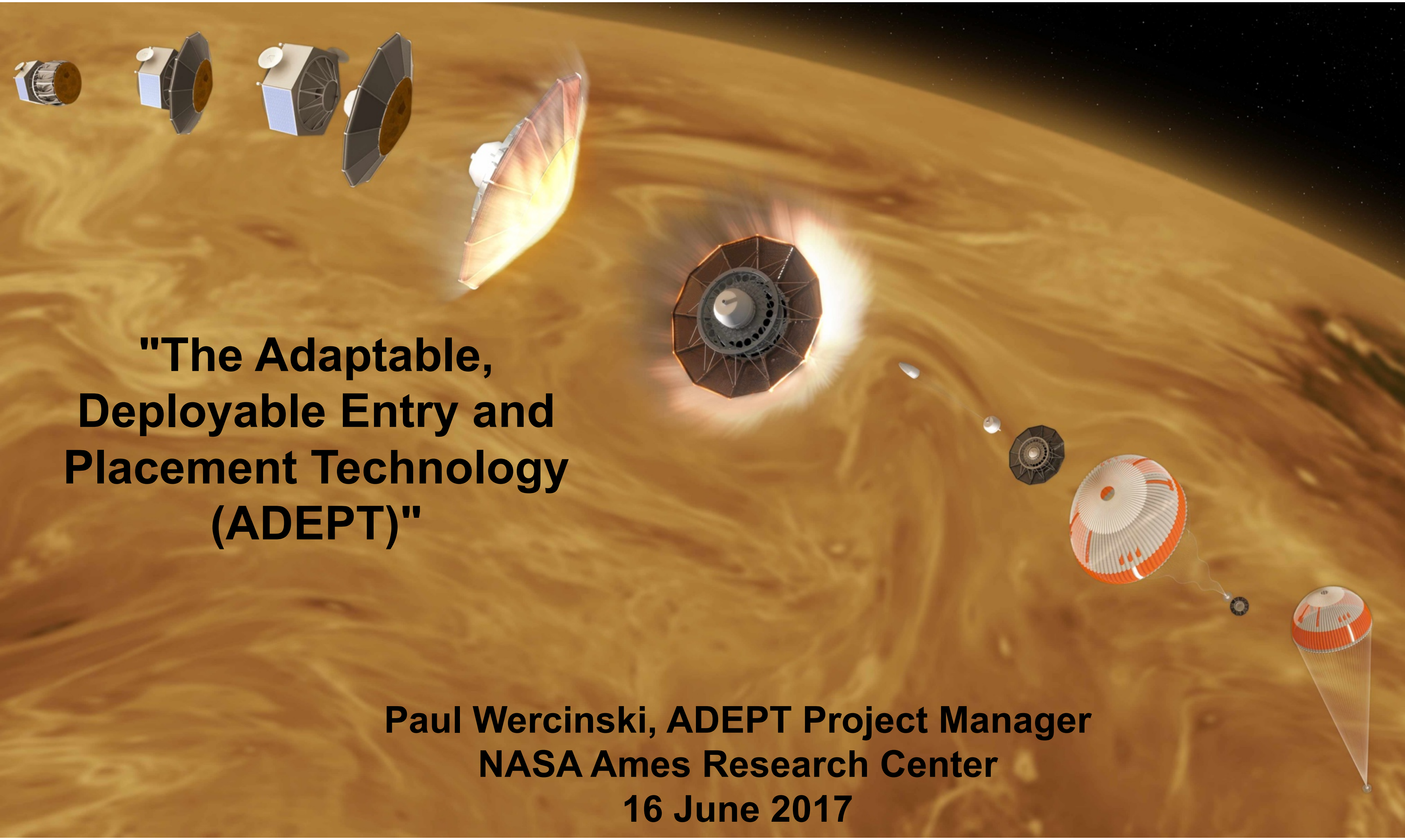


"The Adaptable, Deployable Entry and Placement Technology (ADEPT)"

Paul Wercinski, ADEPT Project Manager
NASA Ames Research Center
16 June 2017

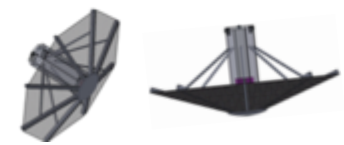
Outline

- ADEPT Technology Overview
- ADEPT SR-1 Flight Experiment
  - Overview and Test Objectives
  - Description and Status
- Summary

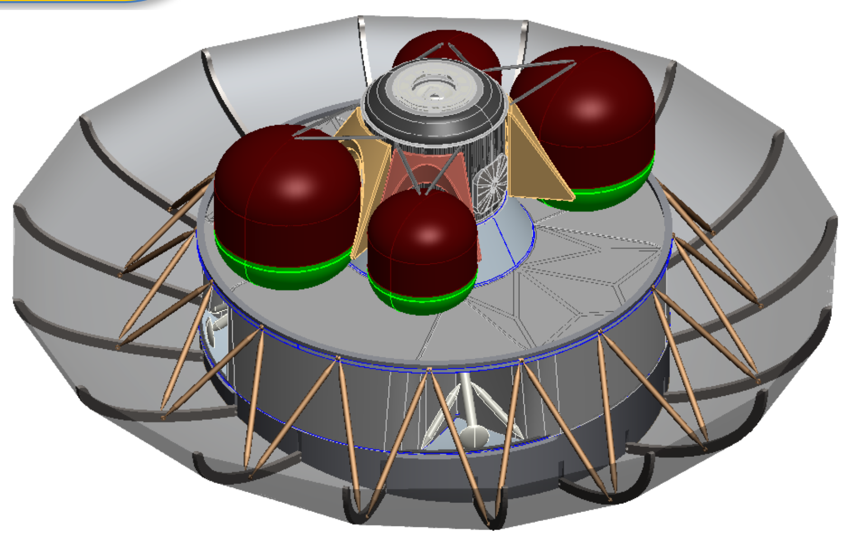
Adaptable, Deployable Entry and Placement Technology (ADEPT) Overview

- **ADEPT is an atmospheric entry *architecture* for missions to different planetary bodies with atmospheres.**
  - Enables missions where entry vehicle stowed volume on spacecraft is a constraint
  - 'Open back' (no backshell) expected to be dynamically stable in transonic flight, no supersonic chute @ Mars
  - Robust system can be deployed for long durations prior to entry
  - Low ballistic coefficient entry vehicle with low L/D enables large payload (20 mT) delivery to Mars surface

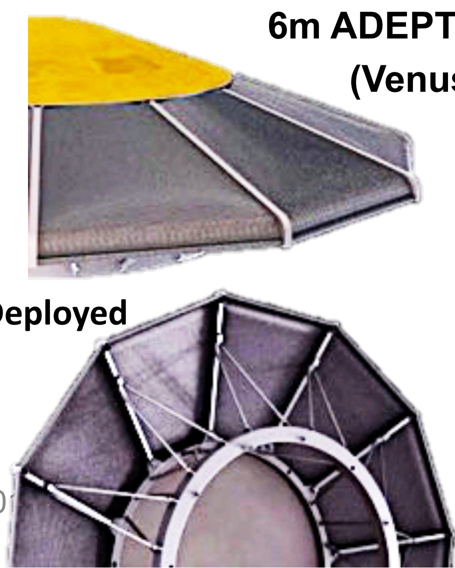
1m Nano-ADEPT (Mars)



16m Lifting ADEPT Human Mars Exploration



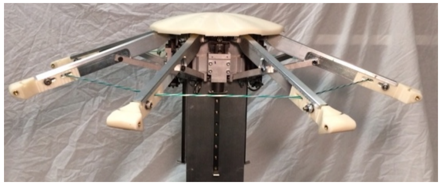
6m ADEPT-VITaL (Venus)



Deployed

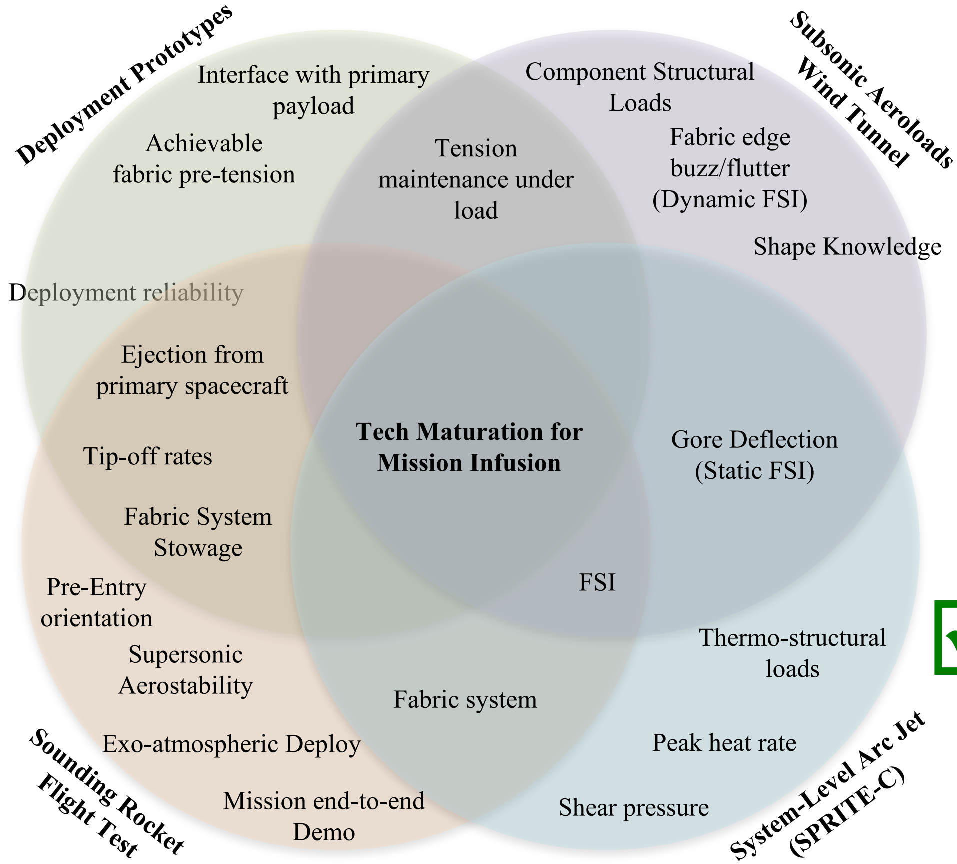
Stowed Atlas V Shroud

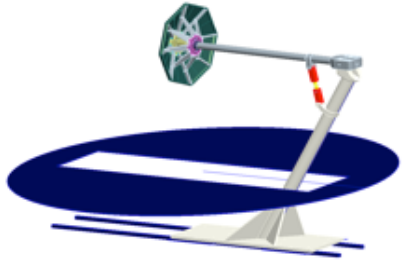
1m 'Nano' Technology Maturation Strategy



Deployment Prototype Demonstrator (FY15-16) ☑

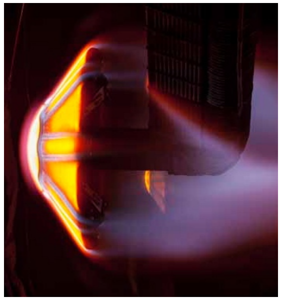
SR-1 Sounding Rocket Flight Test (FY17-18) ☐





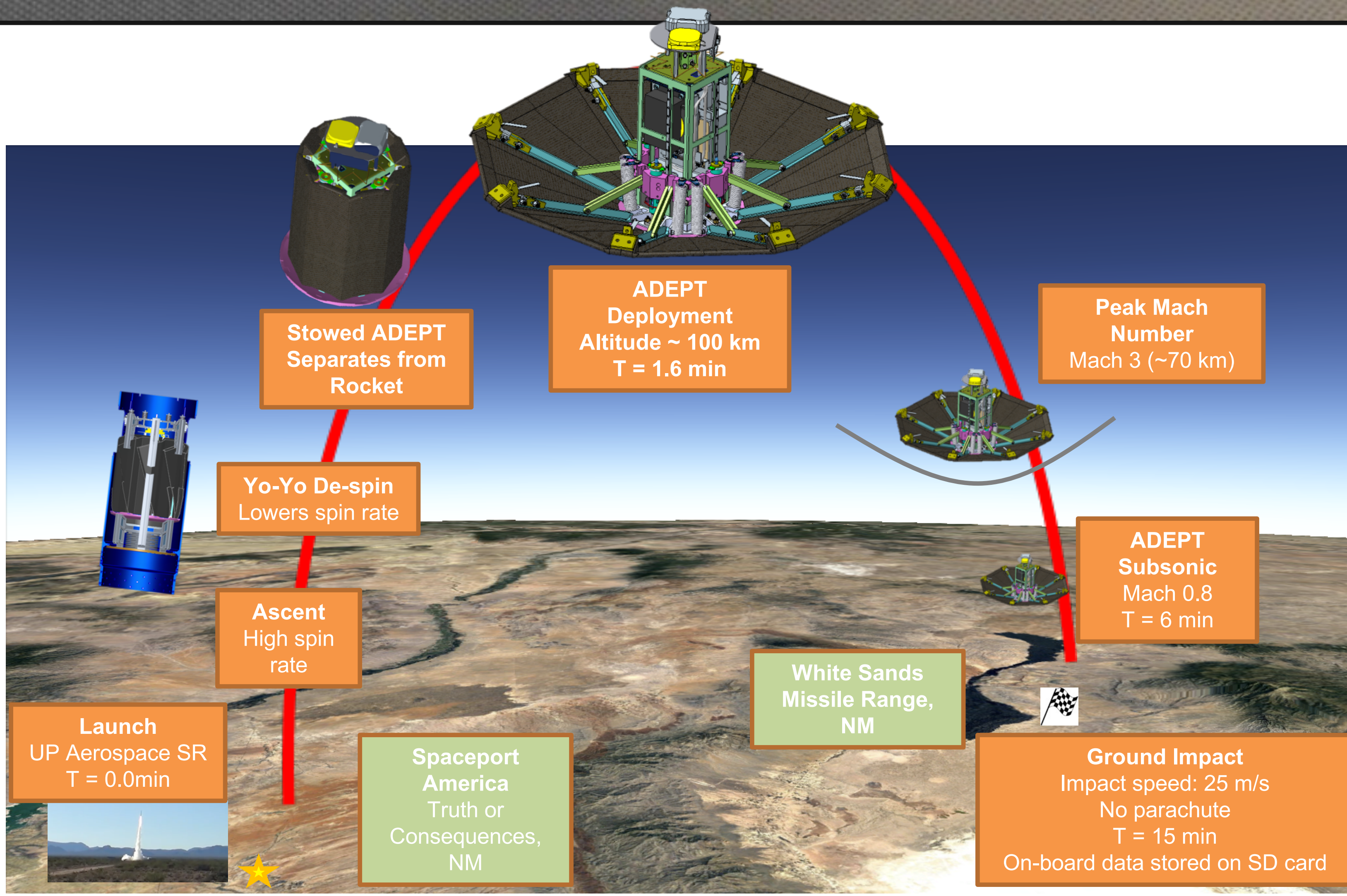
☑ **7x10 Wind-tunnel Aeroloads test (FY15)**

☑ **SPRITE C System level Arc-jet testing (FY15)**



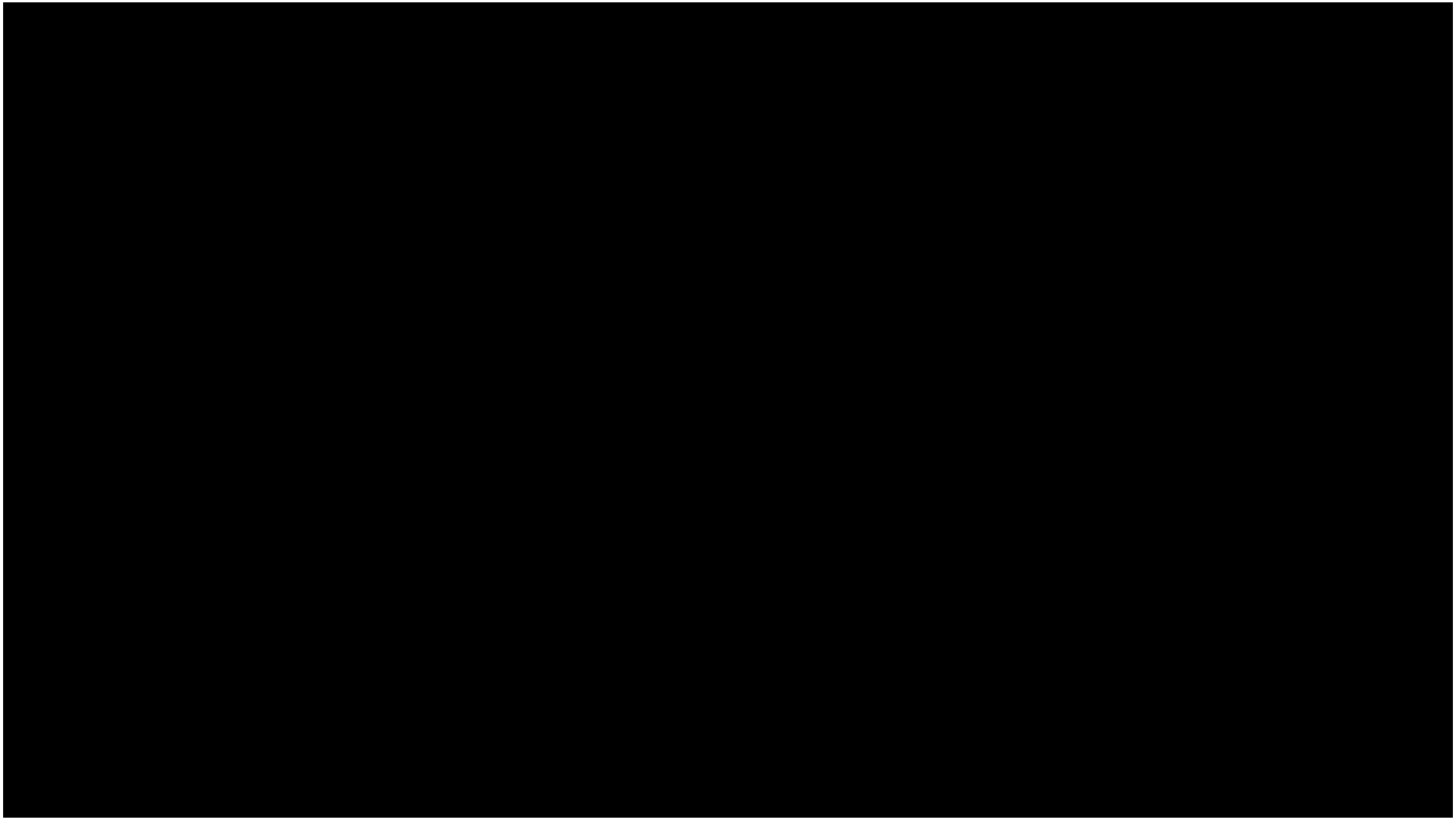
- **System Level testing in relevant environments: TAYF -> FAYT**

SR-1 Flight Experiment Overview

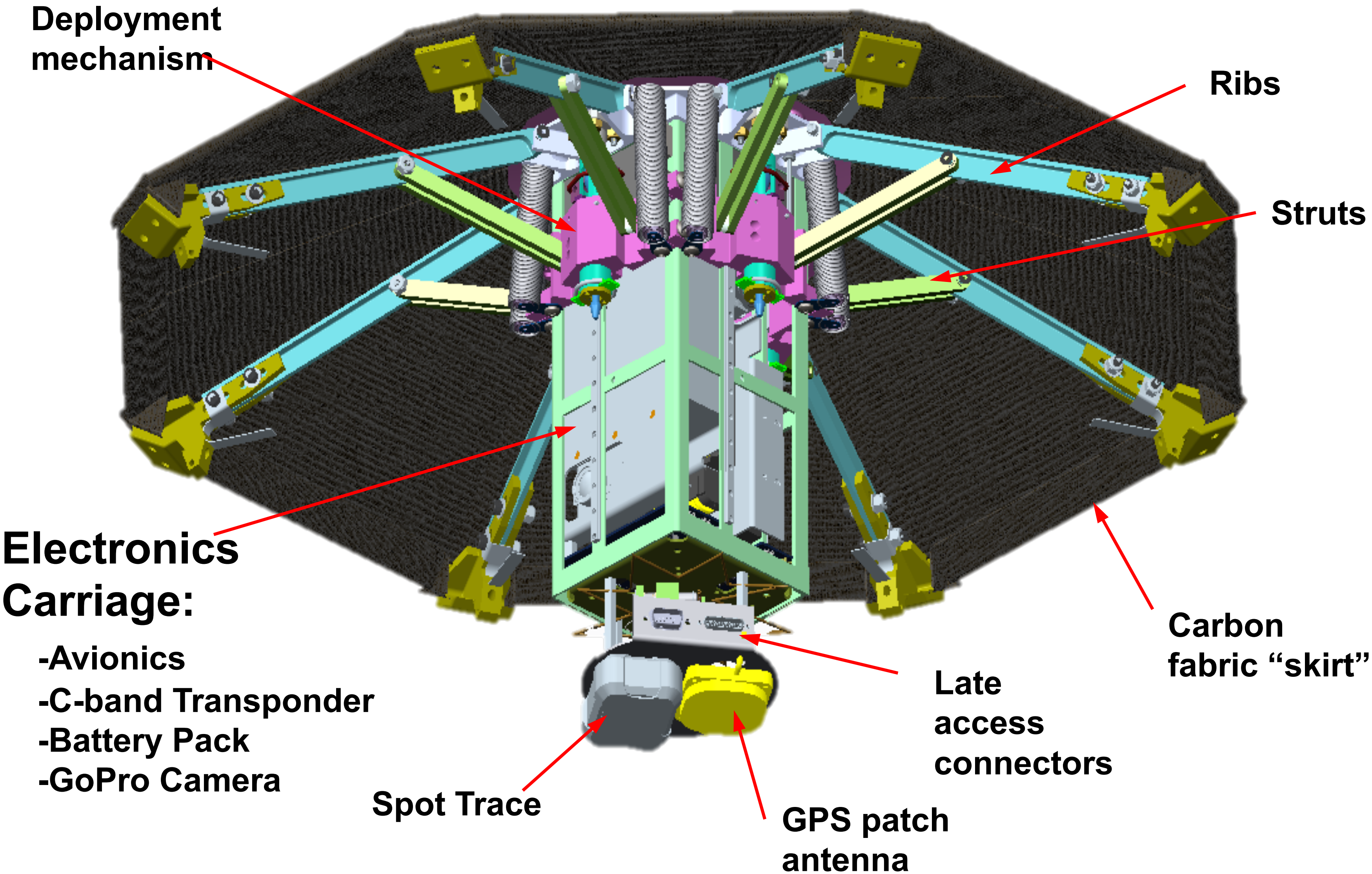


Key Performance Parameter 1: ***Exo-atmospheric deployment to an entry configuration***
Key Performance Parameter 2: ***Demonstrate Aerodynamic stability without active control***

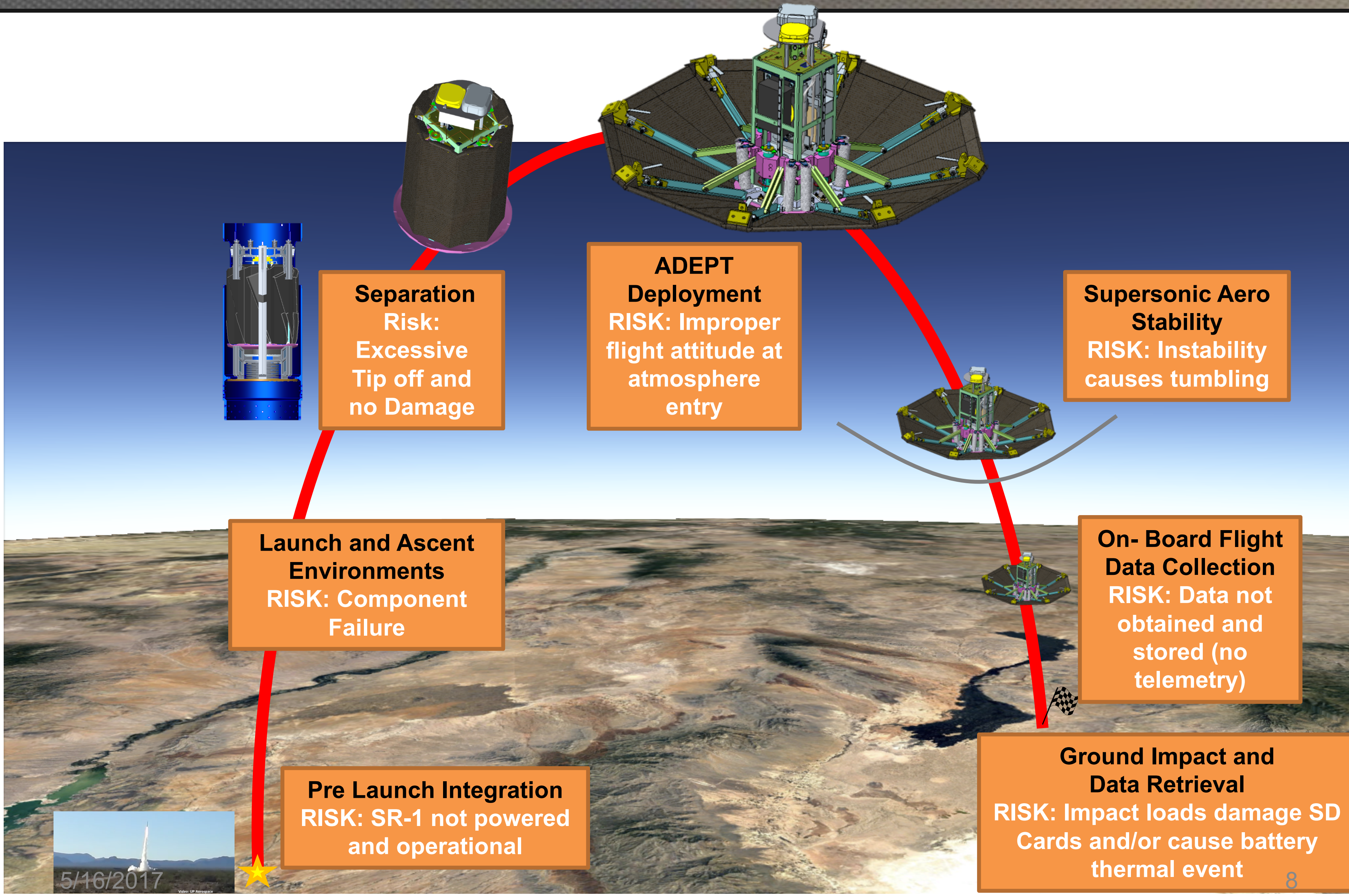
SR-1 Animation movie



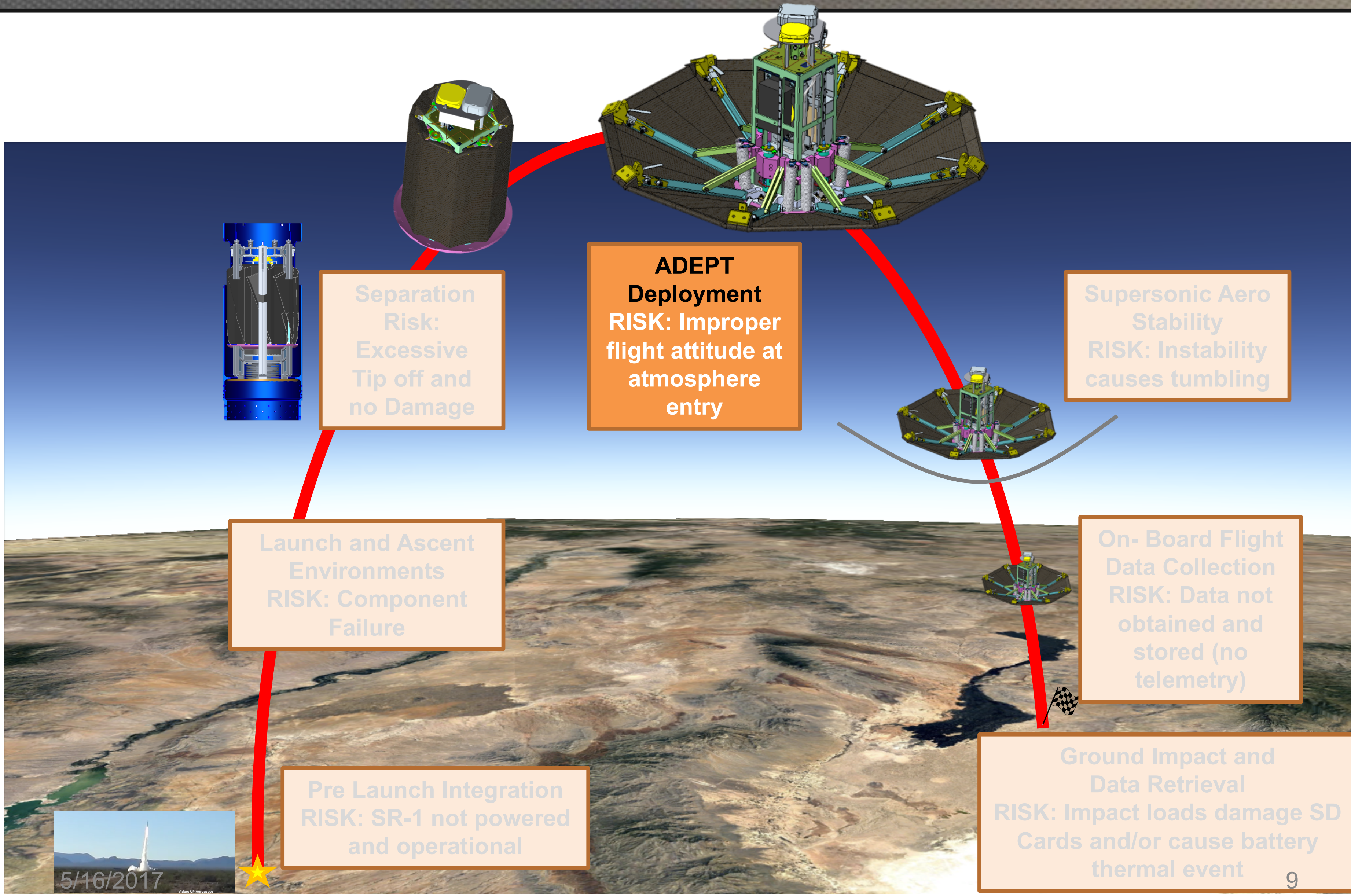
SR-1 Layout and Subsystems



SR-1 Flight Experiment
Development Tests driven by Risks



SR-1 Flight Experiment Development Tests driven by Risks

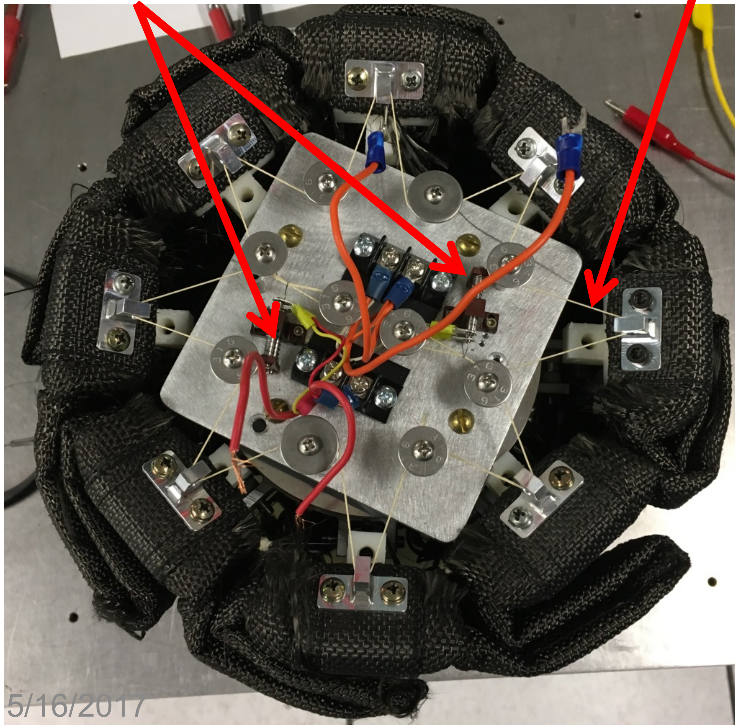


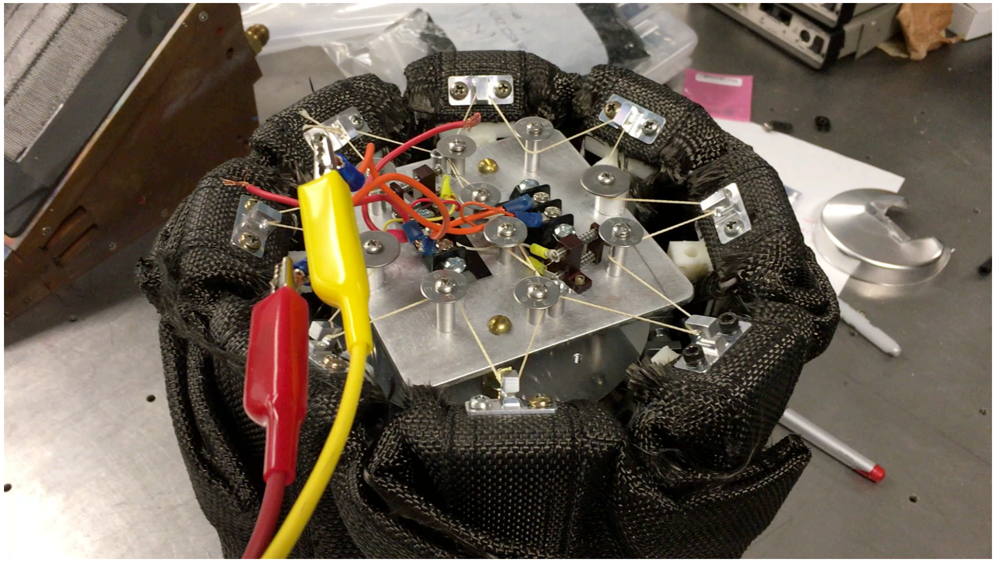
Deployment System (Rib release) Test results

- Vectran cable **<u>retains</u>** rib tips in stowed state
- A separation sensor in the nose cap detects when ADEPT is ejected from the payload module.
- Sensor activates Ni-Chrome burn wire, which cuts through Vectran cable.
- SR-1 spring-actuated deployment occurs immediately after Vectran cable has been cut.
- Burn wire tested in vacuum chamber equivalent to 100K ft altitude.
- Cut time was repeatable 4.5 seconds at 1.6 amps. (Temperature was 66°F)

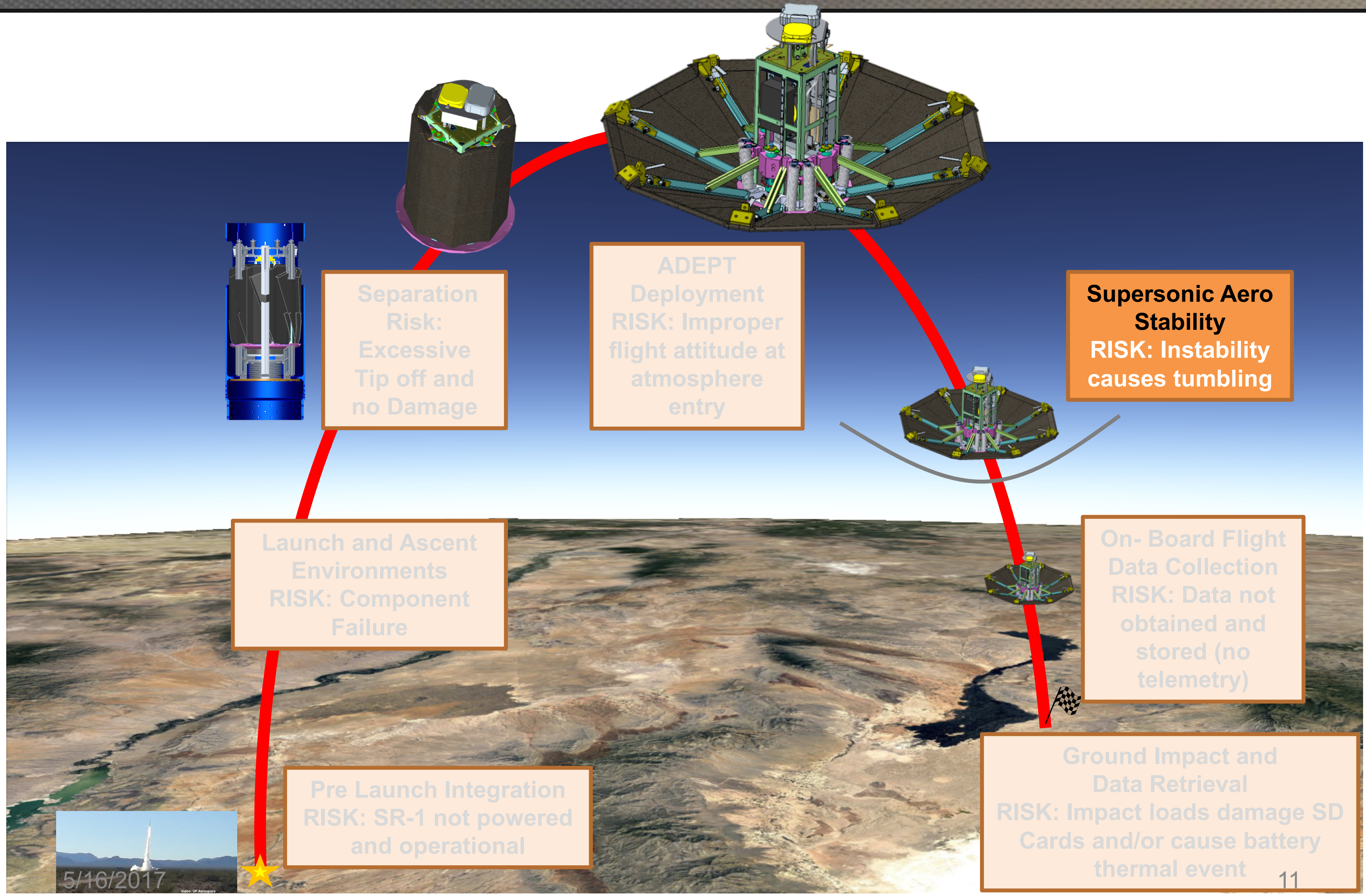
Ni-Chrome burn wire
(2X for redundancy)

Vectran cable



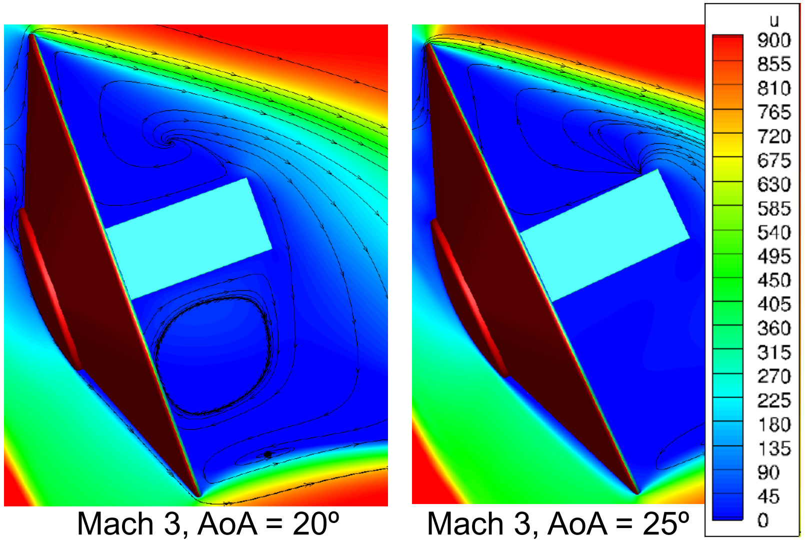


SR-1 Flight Experiment
Development Tests driven by Risks

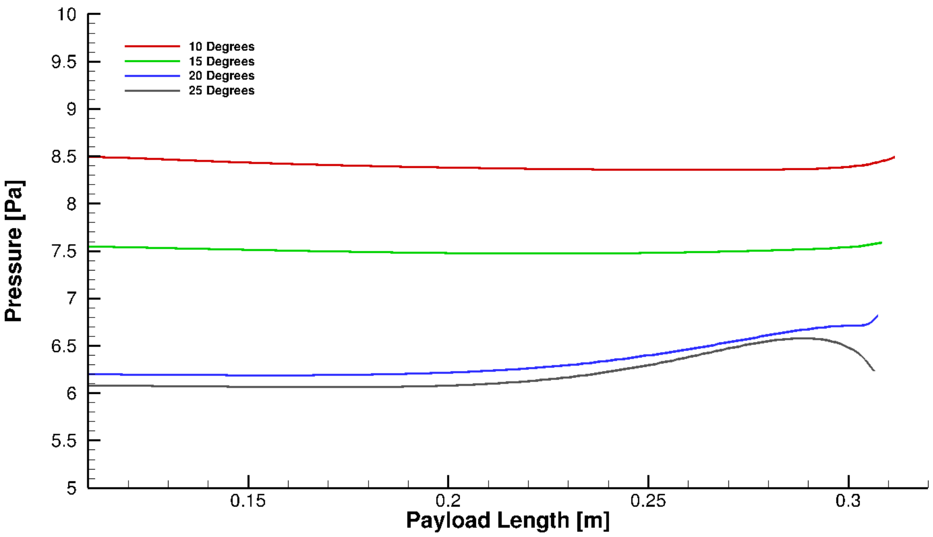


Vehicle Length Limitation

- **The maximum vehicle length is constrained by the need to avoid impingement with the high-speed flow as it expands in the wake**
  - Aerodynamic interaction with shear layer could cause unpredictable flight dynamics
  - No “payload heating” concerns with SR-1, but need to avoid any impingement for DRM traceability
- **This need puts severe limitations on the volume available for instrumentation**
  - Most volume is already consumed by crushable mass, C-Band transponder, and AVA
- **Current vehicle length: 0.32 m (nose tip to aft end)**
  - Payload configuration is getting close to the shear layer at this angle of attack and is feeling some effects from the higher velocity flow
  - Magnitude of induced forces are an order of magnitude lower than forebody
  - <u>Recommendation to limit vehicle length to 0.32 m</u>

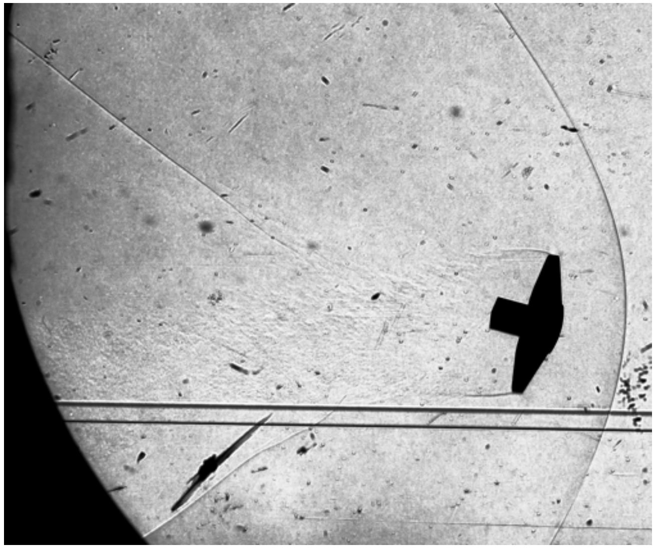


Mach 3, AoA = 20º   Mach 3, AoA = 25º



Preliminary Ballistic Range Test Results

- 15 total shots were performed
  - 11 calibration shots
  - 4 "for credit" shots
- Mach at mid-range of "for credit" shots: 1.225, 1.208, 1.493, 2.245
- *Preliminary* results:
  - The vehicle is dynamically unstable at low angle of attack (typical of blunt body entry vehicles)
  - Limit cycle oscillation amplitude is ~25º at Mach 2.2
  - SR-1 Flight Design CG set to x/D=0.15 based on test observations



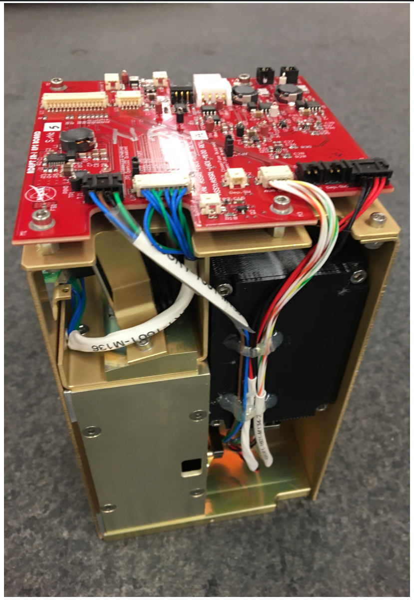
Mach 1.50, -13.7º angle of attack

Mach 2.58, 19.2º angle of attack

Preliminary VST Test Results

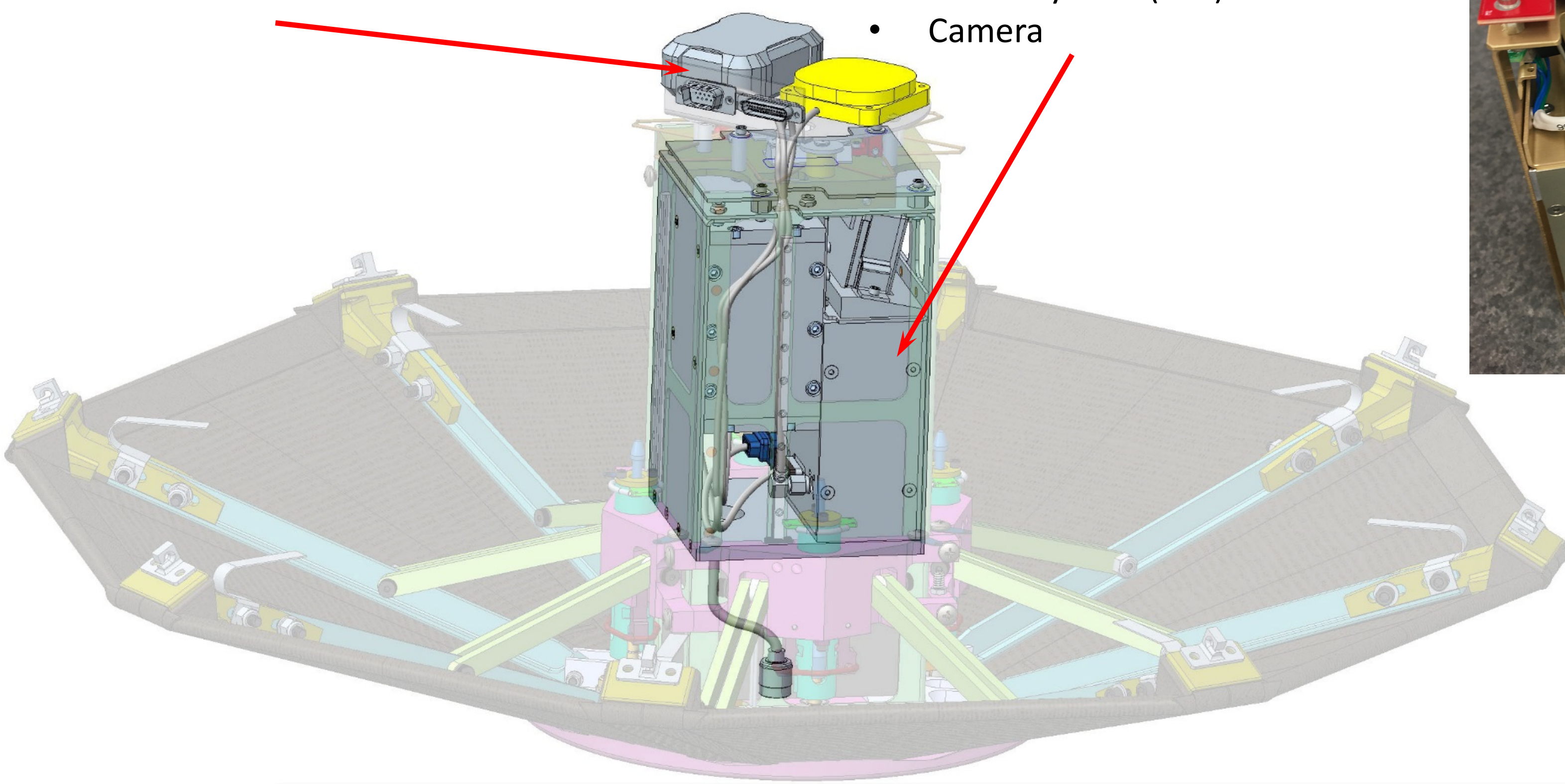
- The models flew near the expected airspeed.
- The 50% model was statically and dynamically stable at a wide range of CoM locations.
- Unperturbed pitch/yaw oscillations were relatively small in amplitude.
- Inverted, the model is statically stable and dynamically unstable: it eventually tumbles
- For the 15% model (high altitude), with the CoM in a near nominal location, the model was statically and dynamically stable *for the most part*.
- Once either model tumbles, they tend to glide (move laterally). The models give no indication that they will recover from a tumble if it occurs.

Bringing the Data Home
Avionics and Power Subsystems



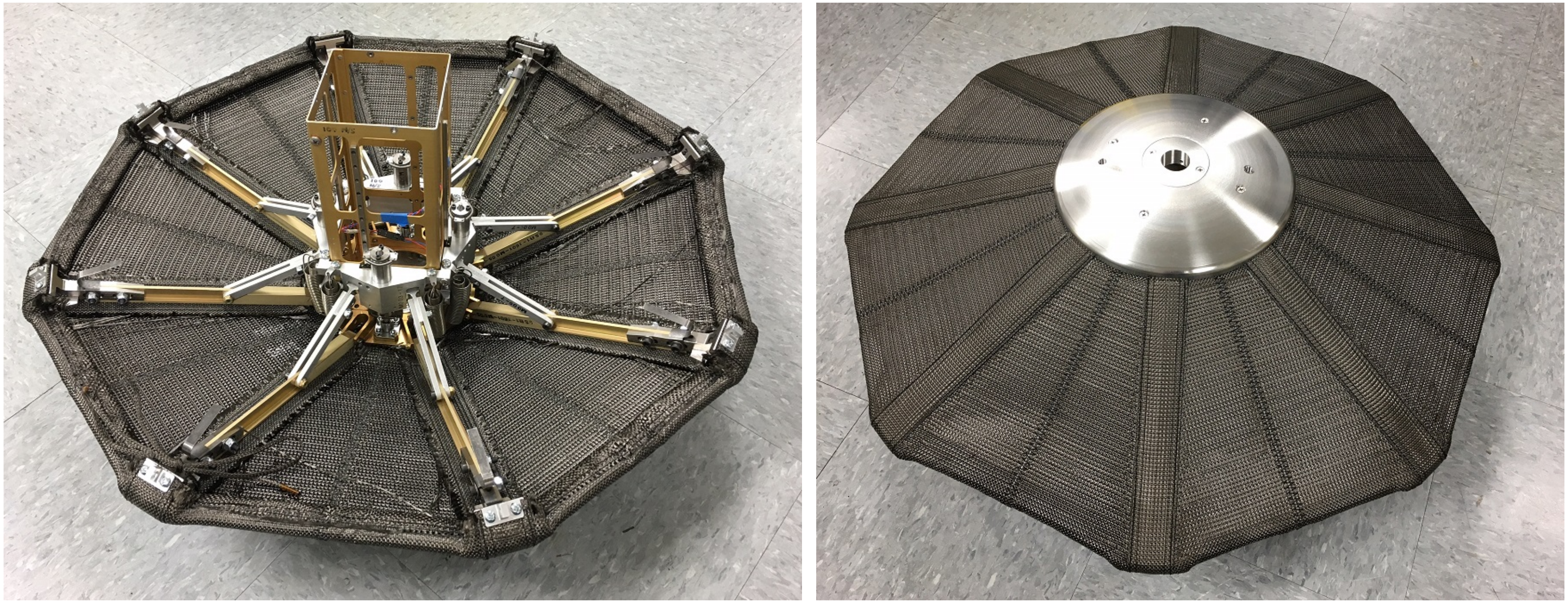
Aft Deck:
- GPS Antenna
- Spot Trace
- Late Access Connectors

Electronics Carriage:
- Avionics
- C-Band Transponder
- Power System (EPS)
- Camera



ADEPT SR-1 Data Sources (On-board and Ground Tracking)
- Confirm full and locked deployment
- Trajectory reconstruction for dynamic stability assessment
- Locate SR-1 after ground impact

ADEPT SR-1 Flight Hardware Integration Underway!



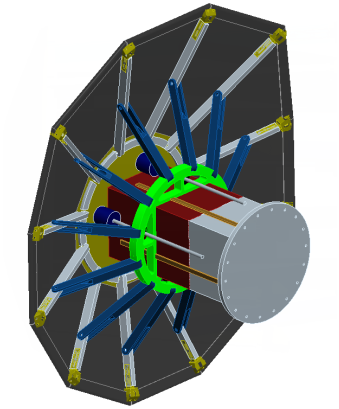
Carbon Fabric Skirt – Integration Fit Checks

Hardware Assembly, Integration and Test Progressing Well!
SL-12 Launch scheduled for Sept 18, 2017

Summary

- **ADEPT SR-1**
  - "First step" flight experiment demonstrating ADEPT flight and operations
- **Looking beyond SR-1…**
  - Small spacecraft mission using an ADEPT EDL to overcome volume limits
  - Secondary payloads to Venus, Mars, and LEO return are feasible near-term applications. Potential Discovery and New Frontiers pathways.
  - Nano-ADEPT provides technology development extensible to large ADEPT applications

1m ADEPT Mars Lander Malin SSS Concept (2014)



2m-3m Lifting ADEPT LEO Flight Test Concept NASA Ames & JHU-APL Study (2016)

8m Lifting ADEPT Mars Precursor Human Exploration