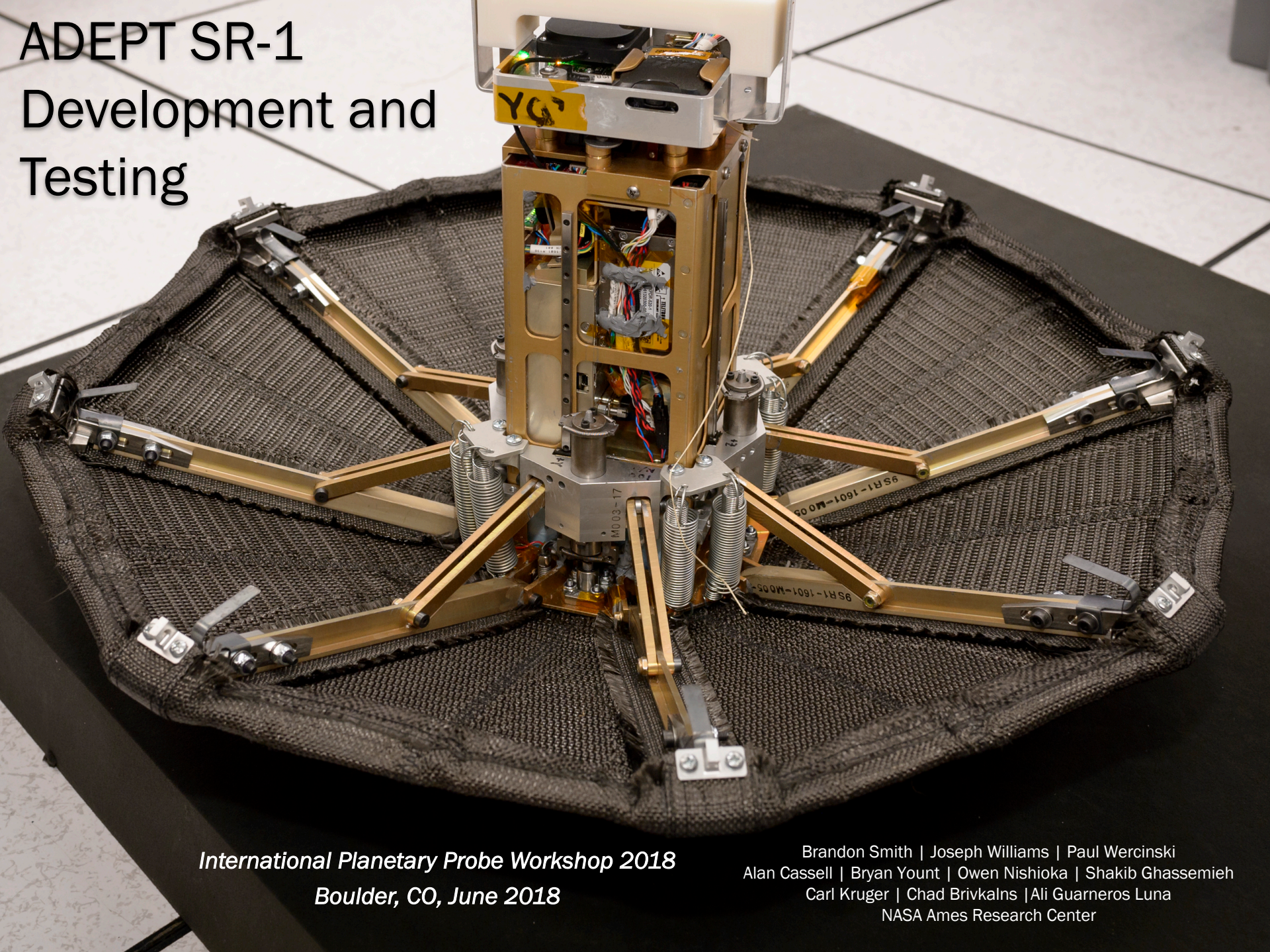
ADEPT SR-1 Development and Testing



International Planetary Probe Workshop 2018

Boulder, CO, June 2018

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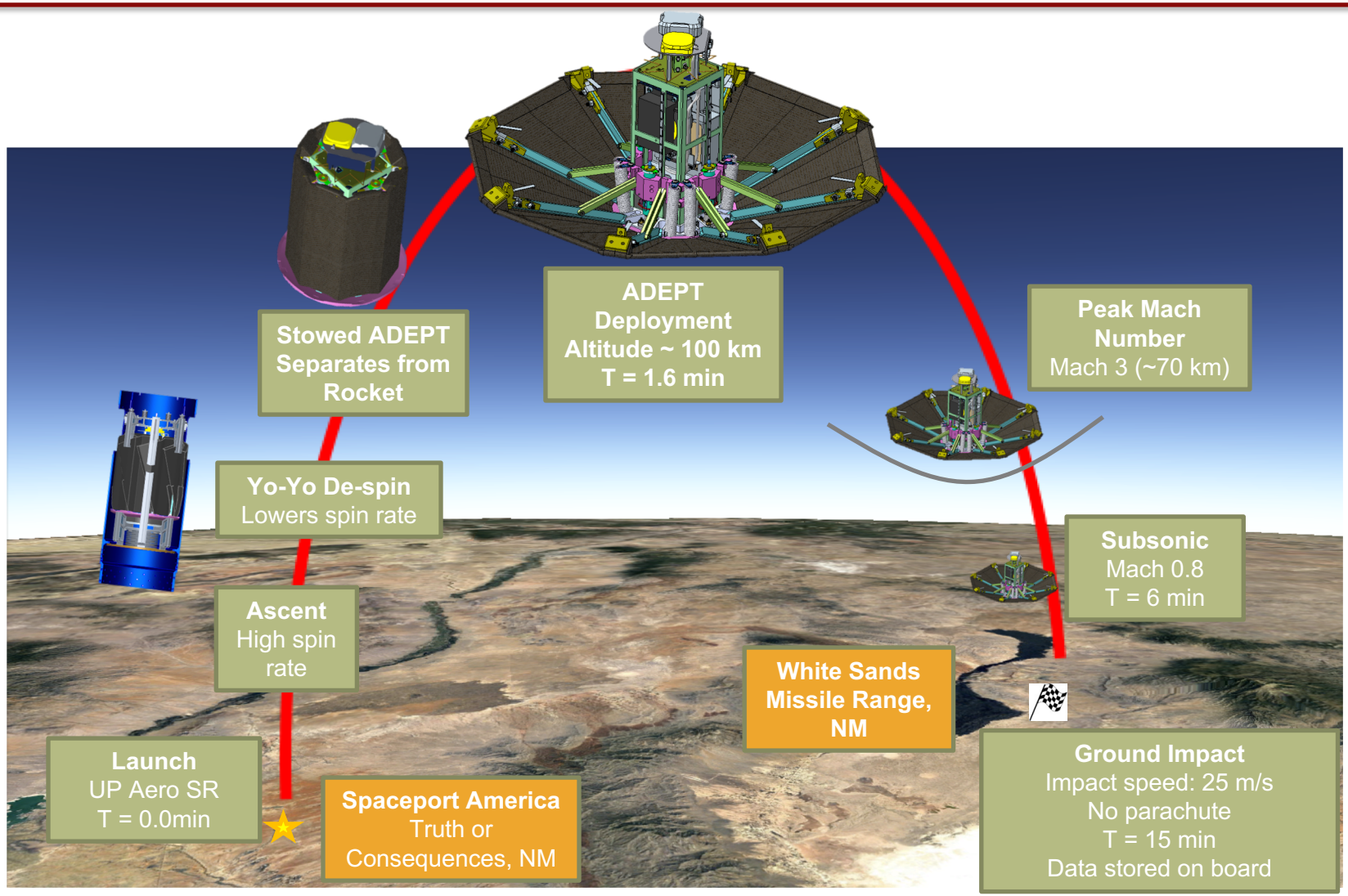
Carl Kruger | Chad Brivkalns |Ali Guarneros Luna
NASA Ames Research Center

ADEPT SR-1 Flight Test: September 12th, 2018



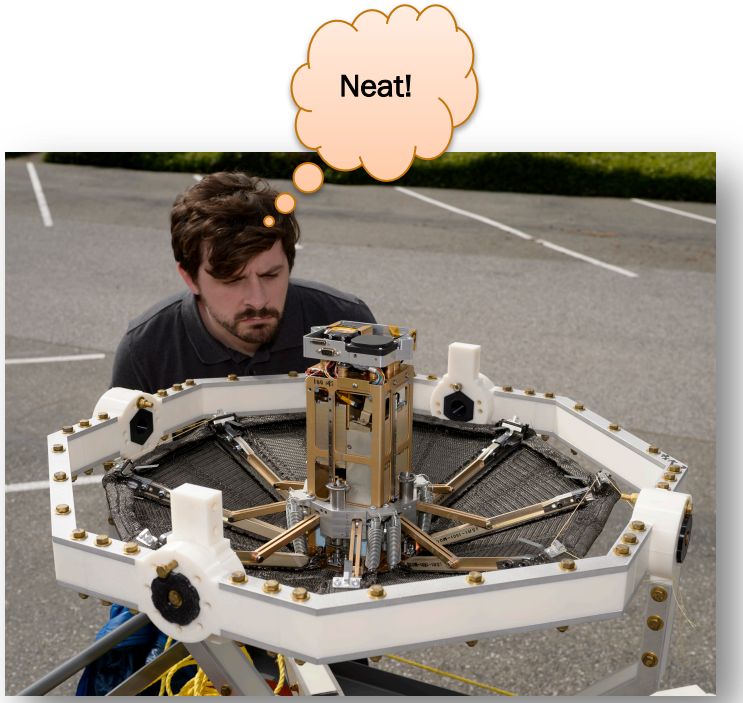
Key Performance Parameter 1: ***Exo-atmospheric deployment to an entry configuration***
Key Performance Parameter 2: ***Demonstrate aerodynamic stability without active control***

A Fast-Paced, Moderate-Risk Development Approach

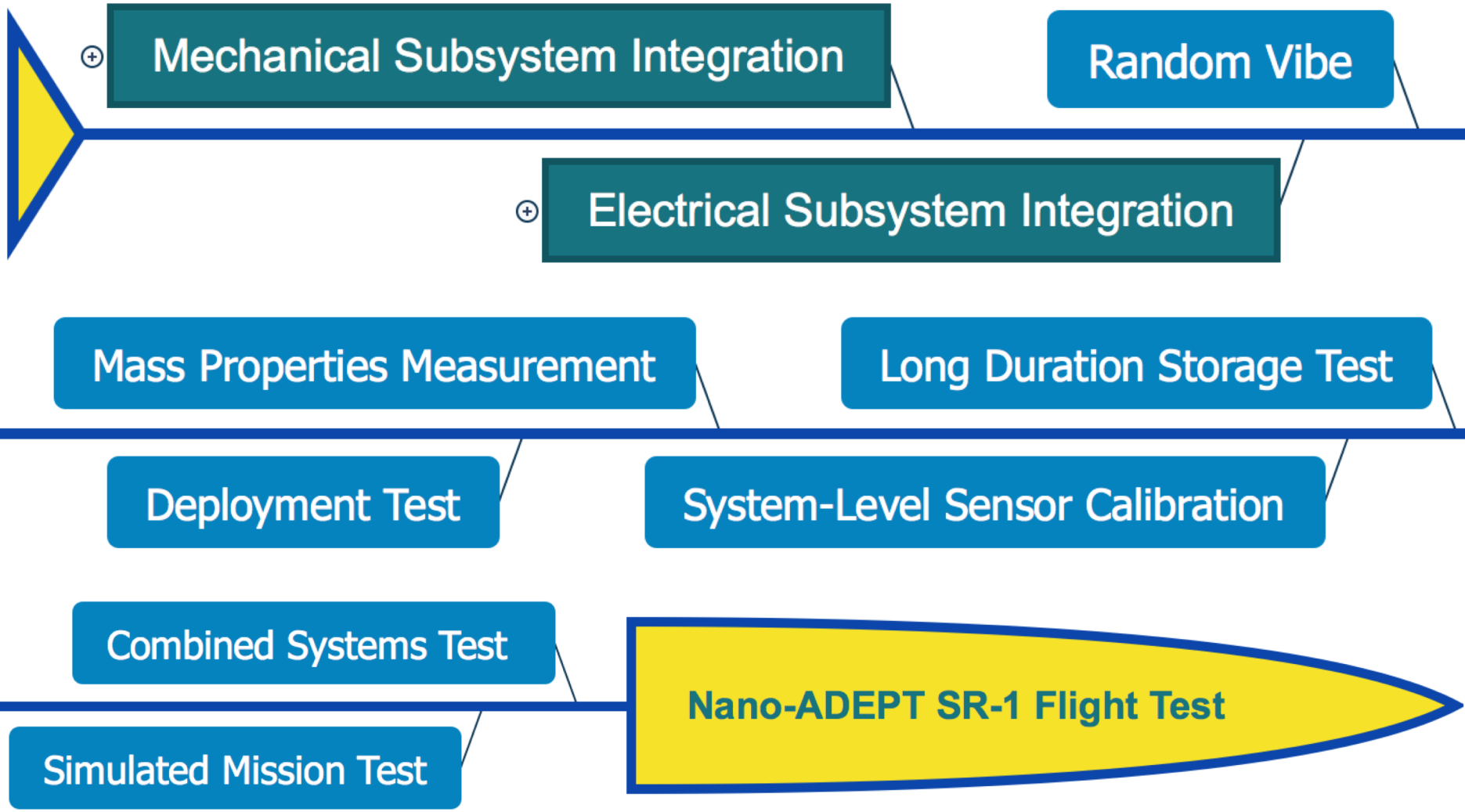
- **Original approved timeline was 12 months from project approval (Aug 2016) to launch (Aug 2017)**
  - Original approved life cycle cost : $3.15M (all in)
  - There have since been three launch slips due to launch vehicle technical problems
  - Current launch date is September 12th, 2018 (~1 year delay)

- **Two nearly identical Nano-ADEPT SR-1 units have been assembled**
  - FLIGHT unit and SPARE unit
  - SPARE unit was used to flesh out procedures prior to running them on FLIGHT unit
  - SPARE unit provides a backup re-fly option in case something unexpected happens to FLIGHT unit during launch

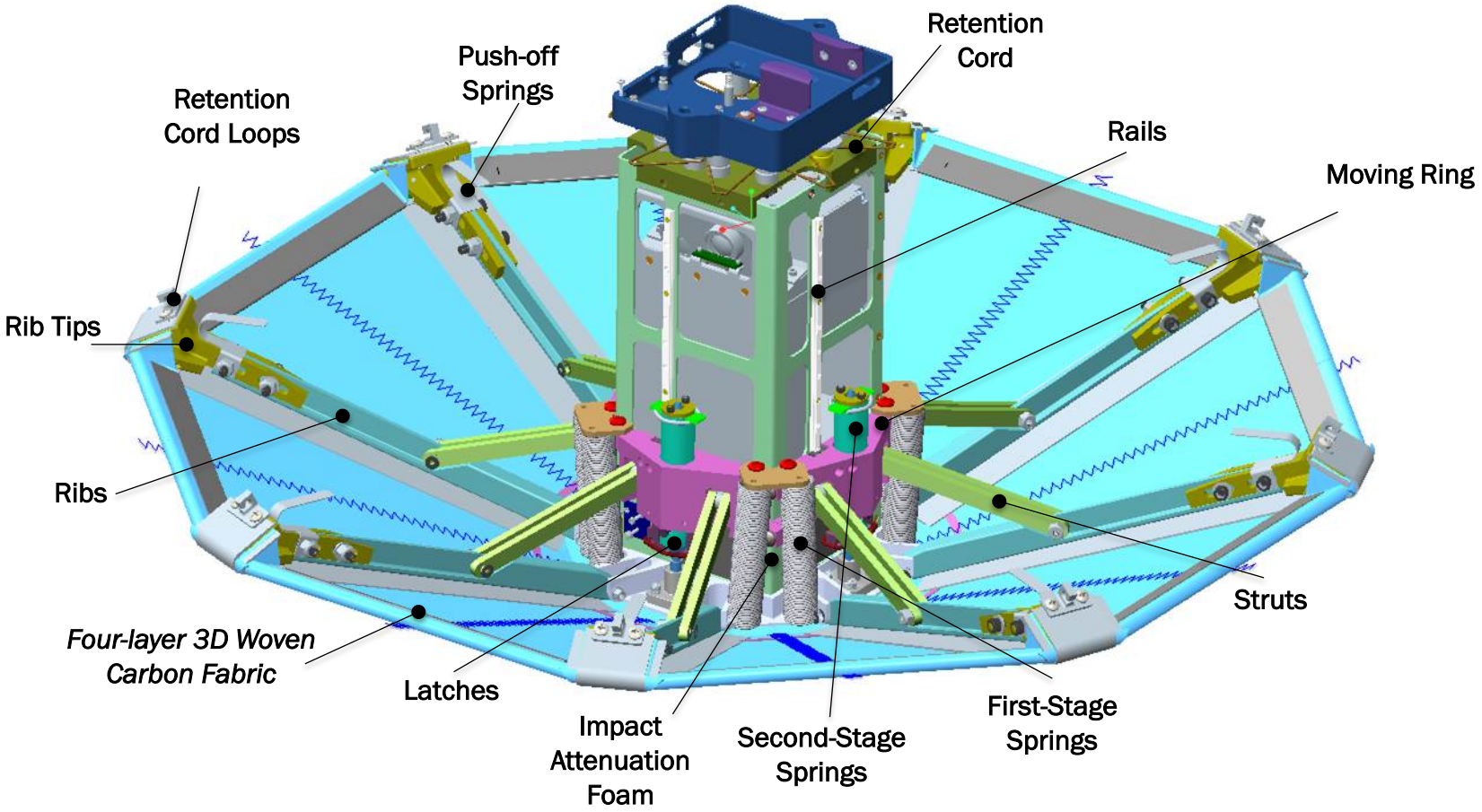
- **Extra time due to launch delays has been used to reduce technical risk**
  - Increased margin on deployment force
  - System-level rate gyro and accelerometer calibrations
  - Additional mission simulation testing to keep fresh on procedures



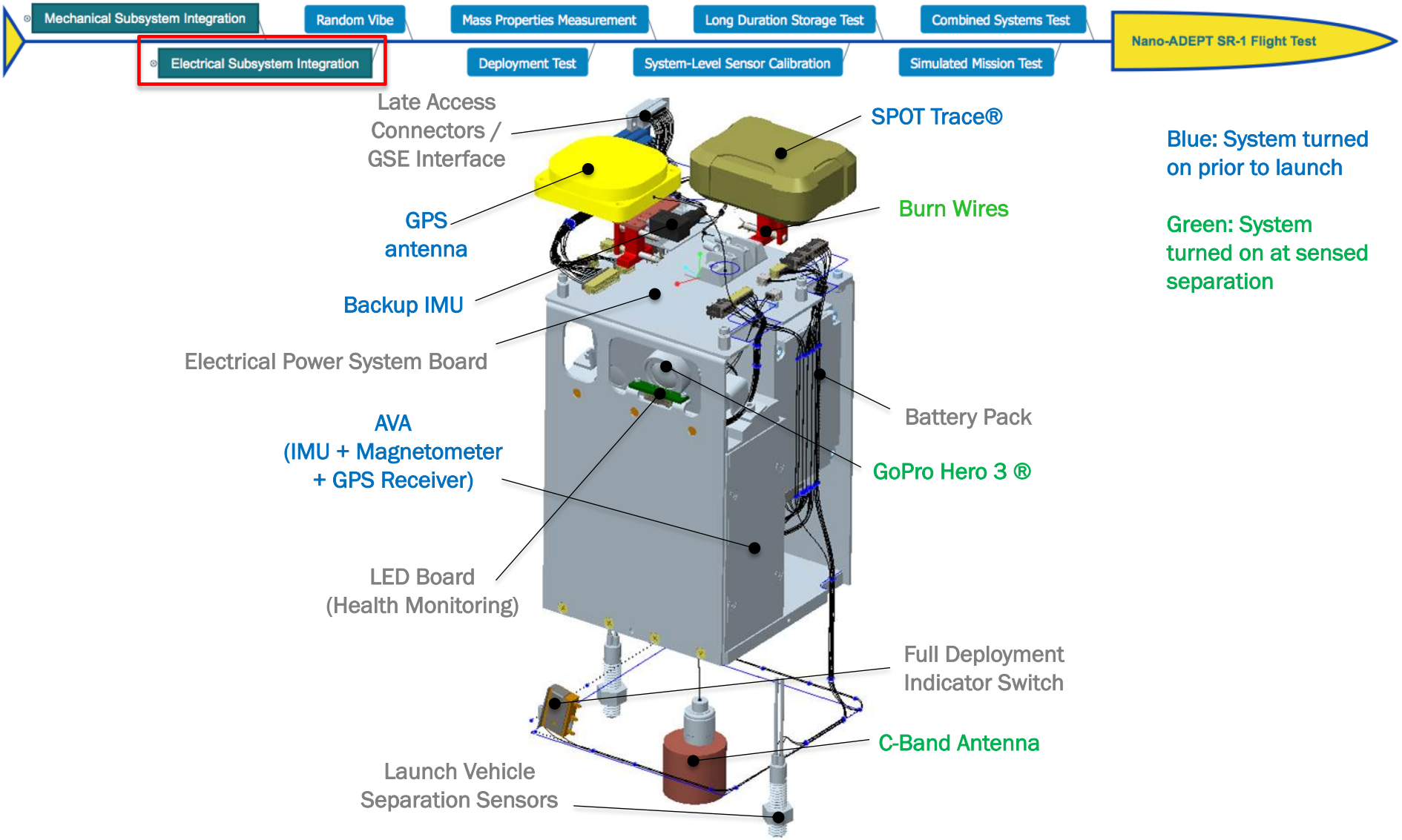
System Integration and Testing Timeline



Mechanical Subsystem



Electrical Subsystem and Operations

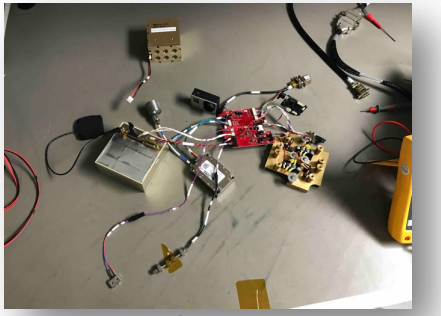


Blue: System turned on prior to launch

Green: System turned on at sensed separation

Subsystem Developmental Tests

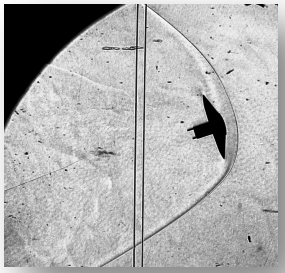
Impact Tests



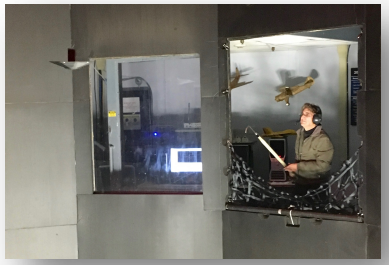
"Flat Sat" Tests

- Impact Tests
  - Battery safety risk
  - Data survivability risk
- Component Environmental Tests
- Sensor Subsystem Calibration
- Subsystem Functional Tests
  - GoPro
  - AVA (Primary IMU + Magnetometer + GPS)
  - NGIMU (Backup IMU)
  - Battery
  - Electrical Power System
- Electrical Subsystem "Flat Sat" Tests
- Electrical Subsystem Integration
- Mechanical Subsystem Integration
  - Vertical Spin Tunnel Test
  - Ballistic Range Test
  - CoM / Ballast Mass Decision
  - Launch Vehicle Separation Test
  - Long Duration Storage Test
  - Rib Release Mechanism Test

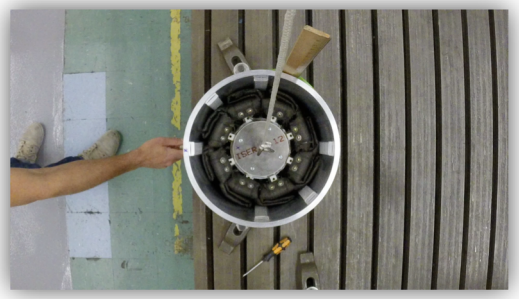
Target $x_{COM}/D = 0.150$
FLIGHT unit as-built $x_{COM}/D = 0.147$
Supersonic β ~20 kg/m^2
Entry mass = 11.1 kg
Ballast mass = 0.6 kg
Ballast adds ~1 kg/m^2 to β and < 1 m/s to impact velocity



Ballistic Range Test



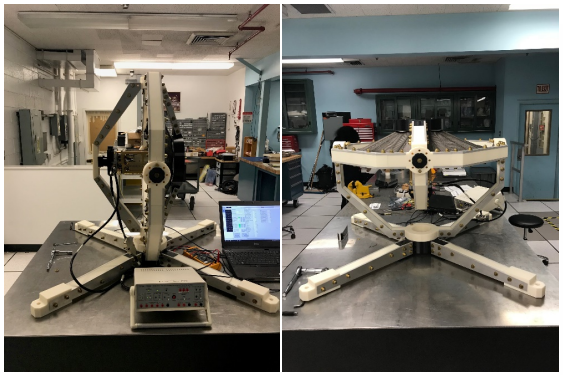
Vertical Spin Tunnel Test



Separation Test

Integrated System Tests

Magnetometer Calibration



Accelerometer Calibration

Rate Gyro Calibration

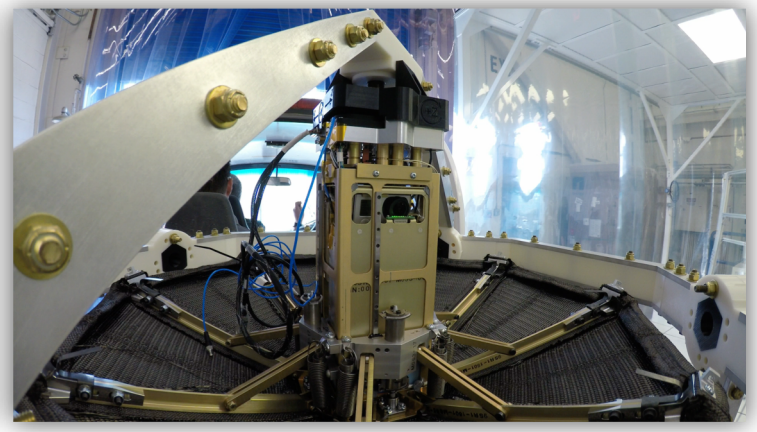
August 9th, 2018

Random Vibe | Mass Properties Measurement | Long Duration Storage Test | Combined Systems Test | Nano-ADEPT SR-1 Flight Test

Deployment Test | System-Level Sensor Calibration | Simulated Mission Test

September 12, 2018

Deployment Testing



Simulated Mission "Drive Around" Test

Conclusions & Future Work

- **Building two nearly identical units added value by reducing risk**
  - A small increment of time was spent building and testing SPARE unit
    - SPARE unit was used to flesh out procedures prior to running them on FLIGHT unit
    - SPARE unit has degraded robustness compared to FLIGHT unit, but it could be prepared to fly relatively quickly
  - Approach worked well at this small scale where the components are relatively inexpensive and assembly quickly

- **Mark your calendars: Launch is September 12th 2018**

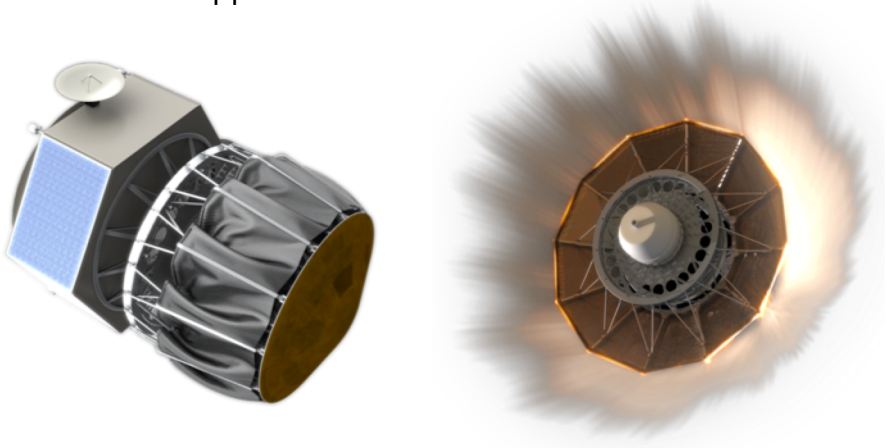
- **What's next for Nano-ADEPT?**
  - FY18-19 Study: Mission design for Venus aerocapture (single-event drag modulation). See related talks:
    - Robin Beck et al., "Studies in Support of Venus Aerocapture Utilizing Drag Modulation"
    - Adam Nelessen et al., "Drag Modulation Aerocapture for Smallsat Science Missions to Venus"
  - FY18-19 Study: Guidance and control architecture and prototype development. See talk:
    - Sarah D'Souza et al., "Pterodactyl: Integrated Control Design for Precision Targeting of Deployable Entry Vehicles"
  - FY18-19 Study: Mission design for lunar sample return applications

Backup

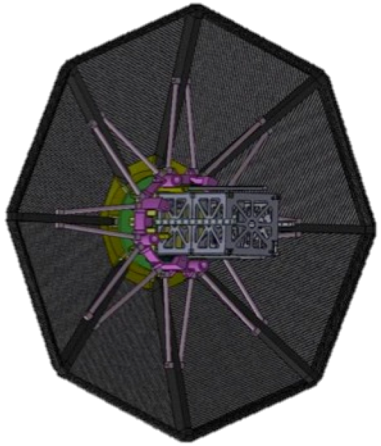
ADEPT:
Adaptable Deployable Entry and Placement Technology

- ADEPT is a mechanically deployed entry system
  - Stows during launch and cruise (like an umbrella)
  - Serves as both heat shield and primary structure during EDL
  - Enabling technology: 3D-woven carbon fabric (tows in all three dimensions)
- Nano-ADEPT is the application of ADEPT for small spacecraft where volume is a limiting constraint
  - NanoSats, CubeSats, other secondary payloads, etc.
- Why Nano-ADEPT?
  - Give rise to novel applications for small spacecraft by offering an entry system less constrained by volume
  - Achieve rapid technology development extensible to large ADEPT applications

Former NASA Administrator Charlie Bolden observing 3D-weaving processes at Bally Ribbon Mills



6 m diameter ADEPT-Venus
in cruise (left) and entry (right) configurations

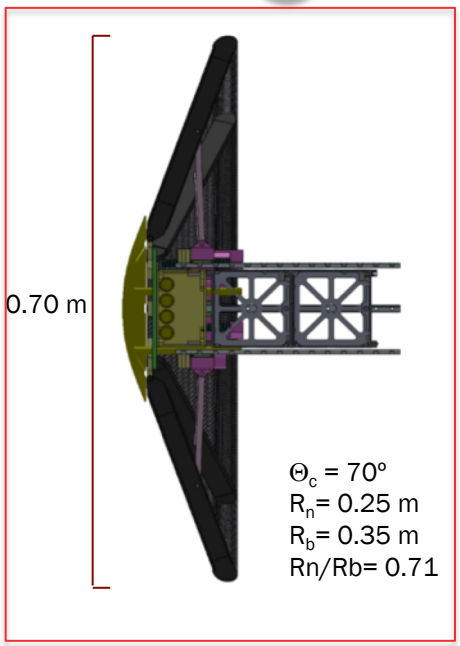


0.7 m diameter Nano-ADEPT
shown with notional 2U chassis payload

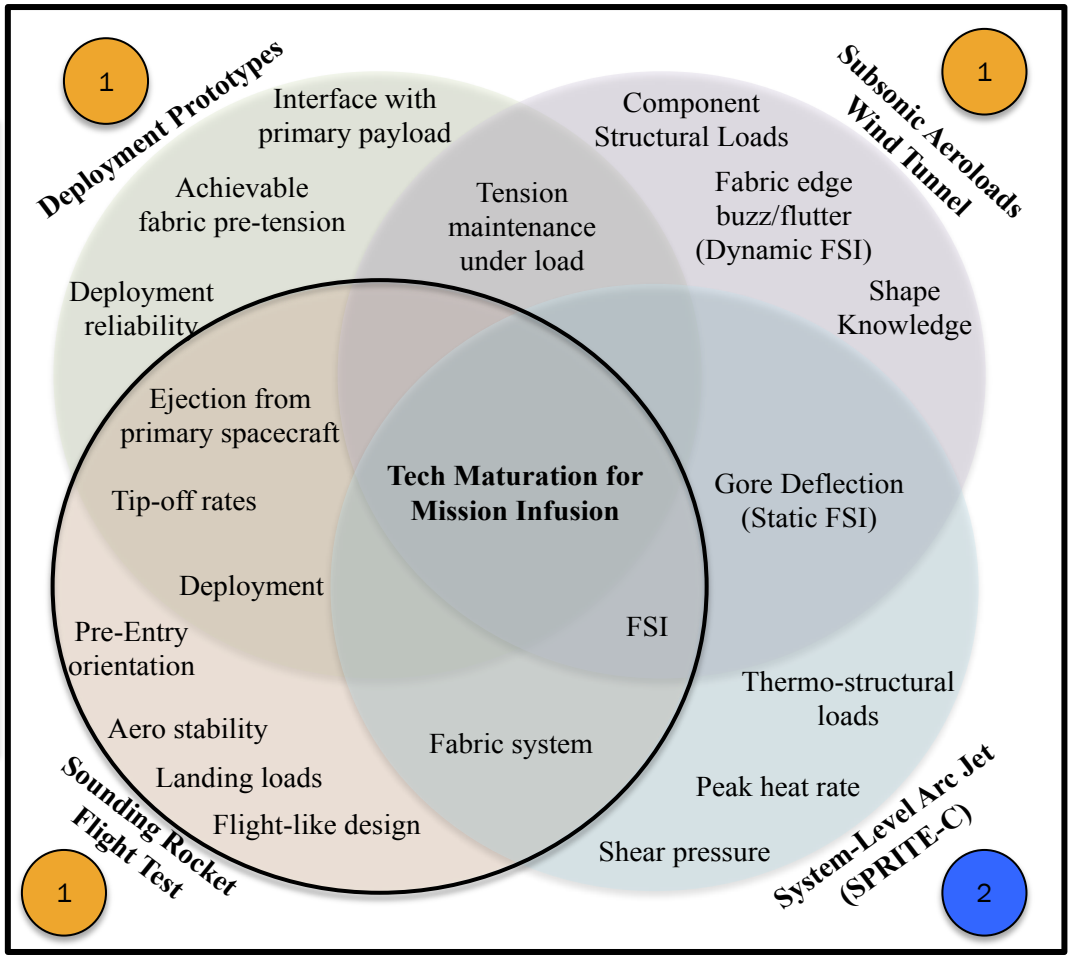
Nano-ADEPT Development Roadmap to TRL 5

- Strategy addresses technical challenges with four system-level tests
- Common geometric features between design reference missions (DRMs), ground tests, and flight test help provide ground-to-flight traceability

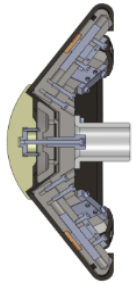
Config. 1



Primary geometric features of deployment prototypes, subsonic aeroloads wind tunnel test articles, sounding rocket flight test, and some DRMs



Config. 2



Primary geometric features of system-level arc jet tests (SPRITE-C)