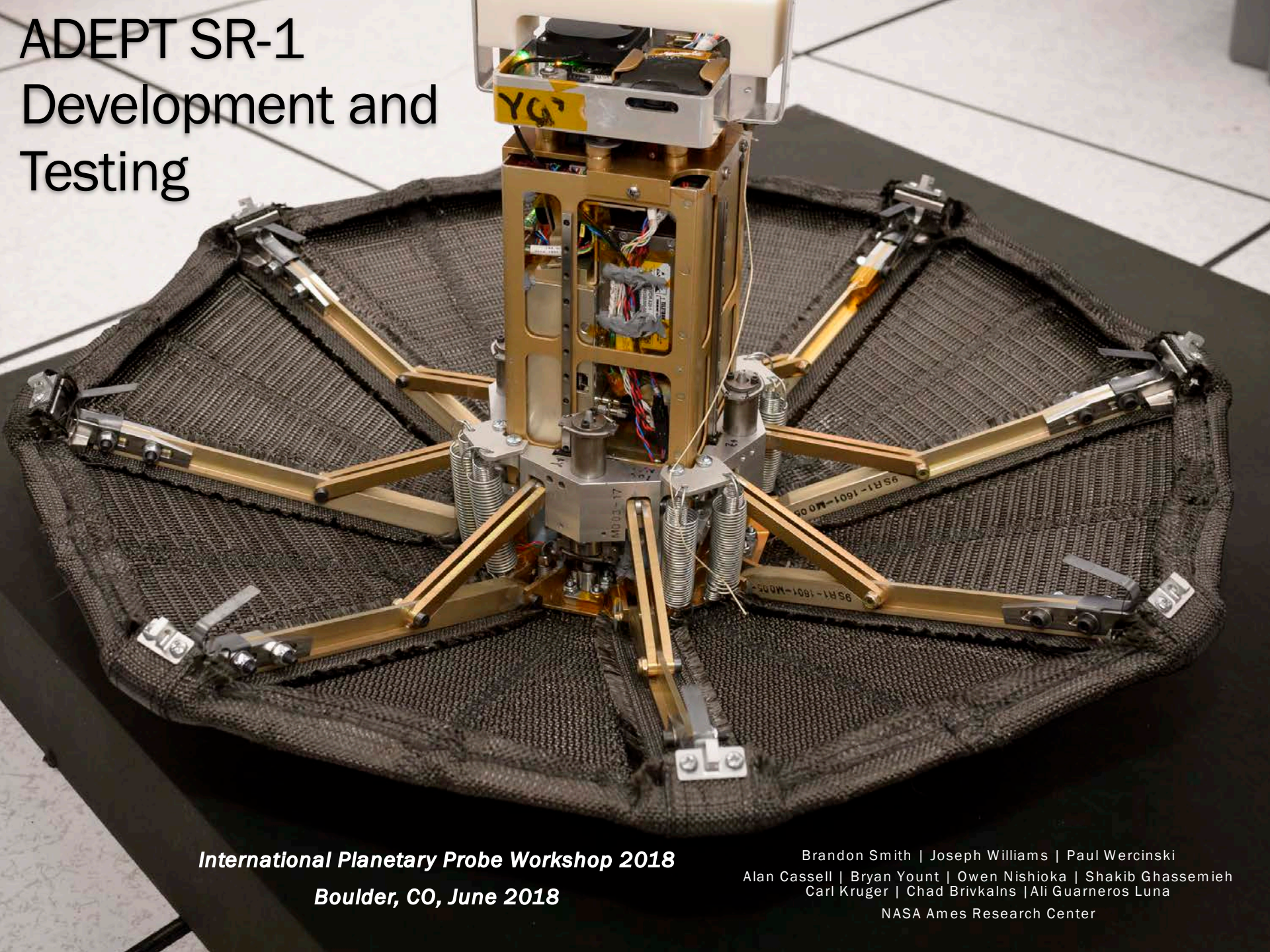
ADEPT SR-1 Development and Testing



International Planetary Probe Workshop 2018

Boulder, CO, June 2018

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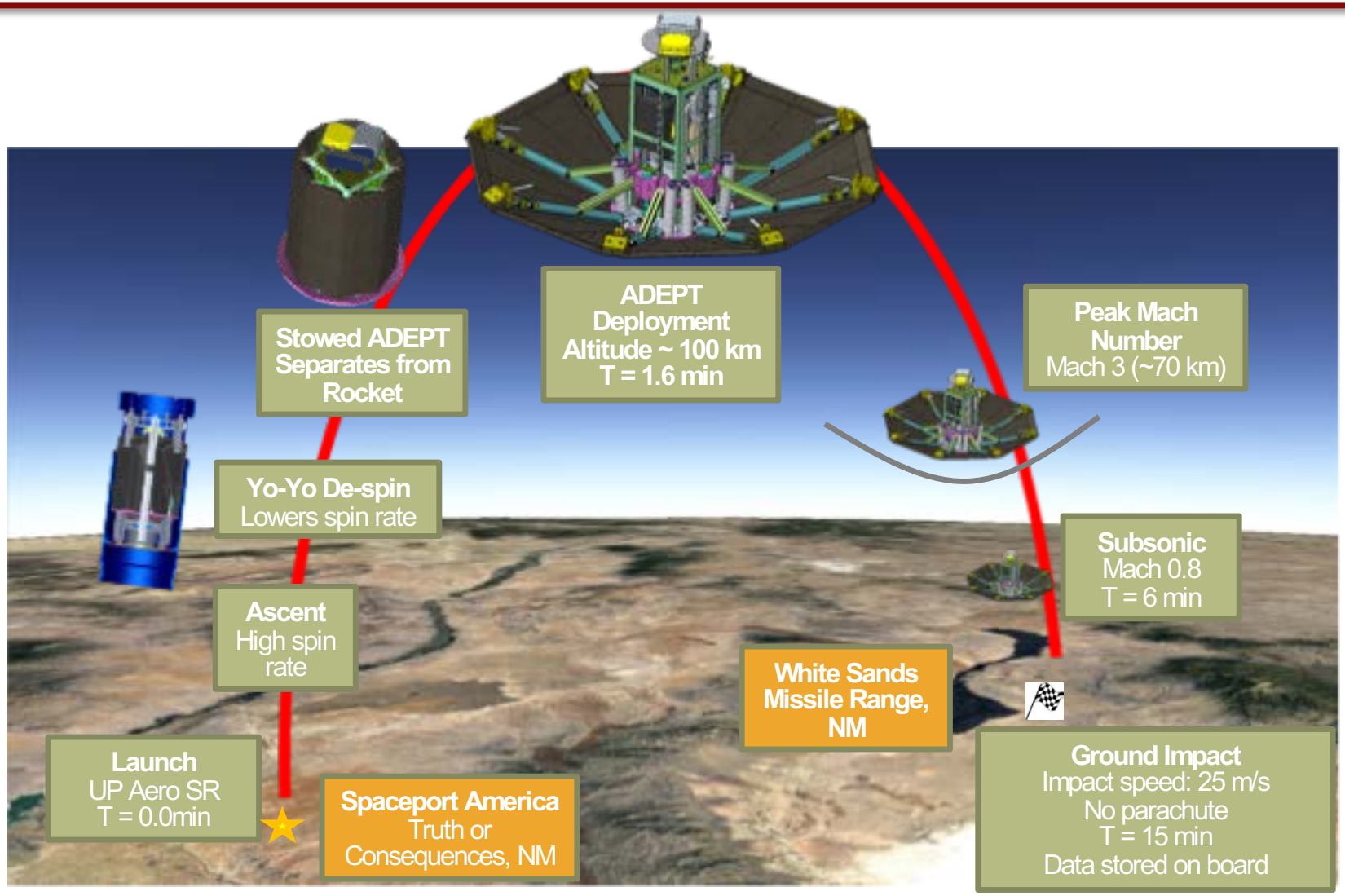
Alan Cassell | Bryan Yount | Owen Nishioka | Shakib Ghassemieh
Carl Kruger | Chad Brivkalns |Ali Guarneros Luna
NASA Ames Research Center

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



Key Performance Parameter 1: ***Exo-atmospheric deployment to an entry configuration***

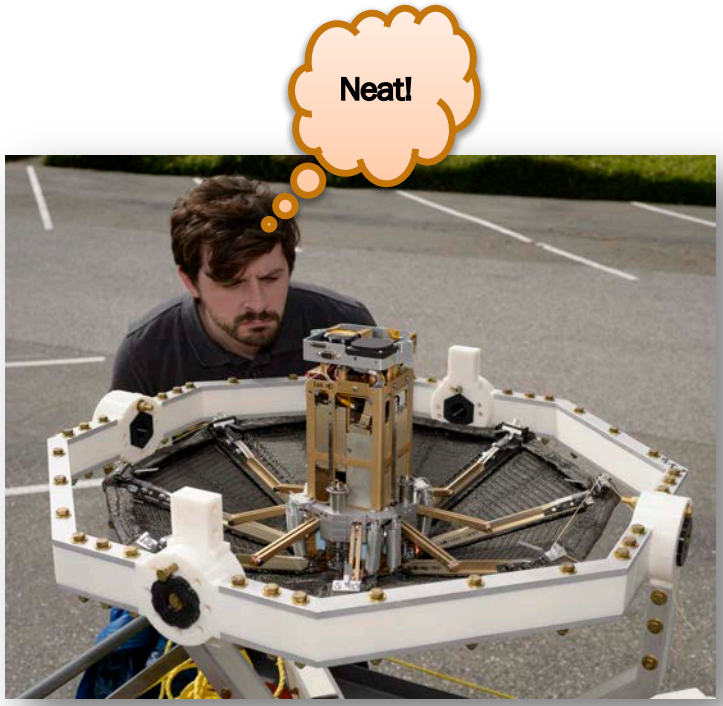
Key Performance Parameter 2: ***Demonstrate aerodynamic stability without active control***

A Fast-Paced, Moderate-Risk Development Approach

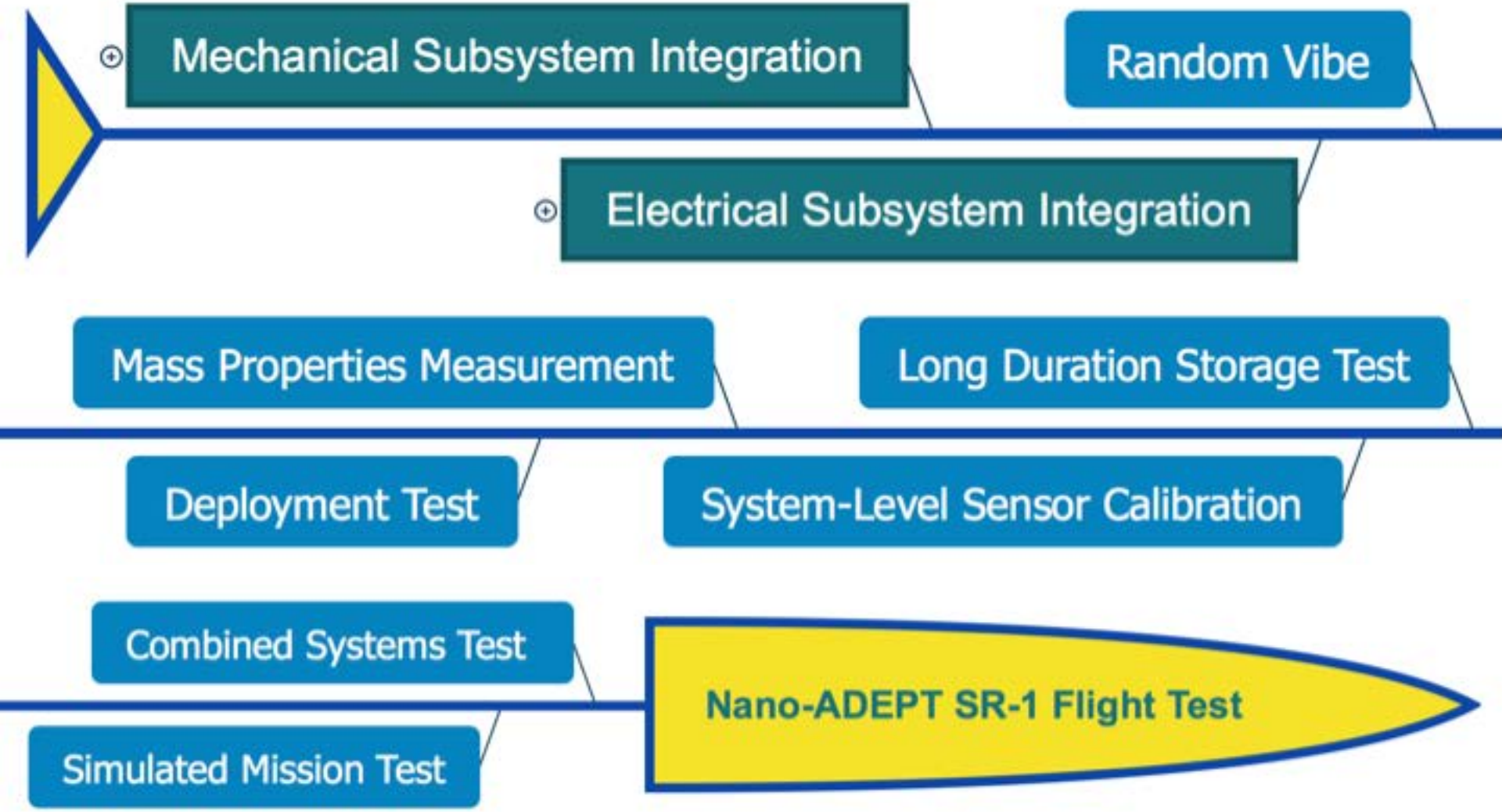
- **Original approved timeline was 12 months from project approval (Aug 2016) to launch (Aug 2017)**
  - Original approved life cycle cost : $3.15M (all in)
  - There have since been three launch slips due to launch vehicle technical problems
  - Current launch date is September 12th, 2018 (~1 year delay)

- **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

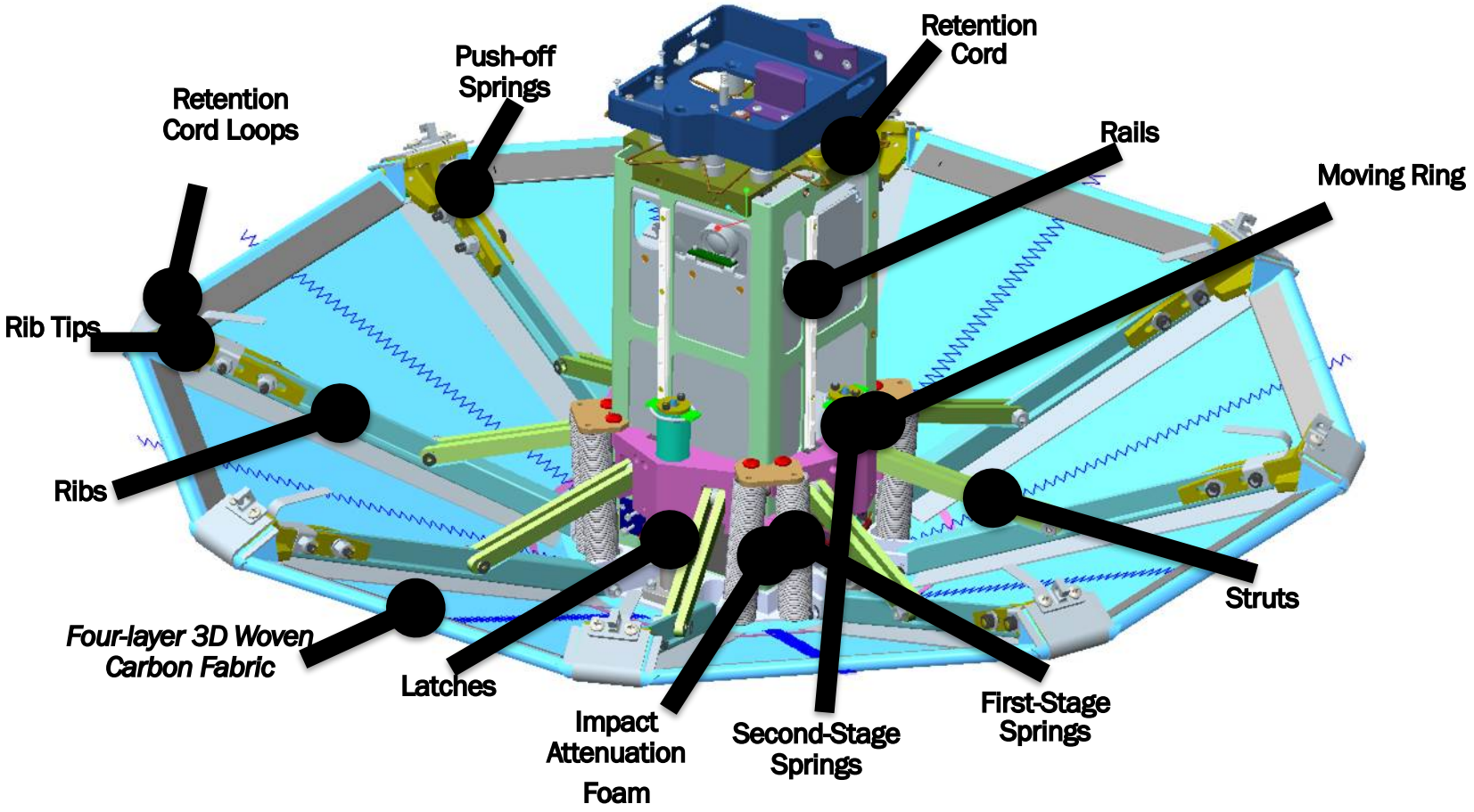
- **Extra time due to launch delays has been used to reduce technical risk**
  - Increased margin on deployment force
  - System-level rate gyro and accelerometer calibrations
  - Additional mission simulation testing to keep fresh on procedures



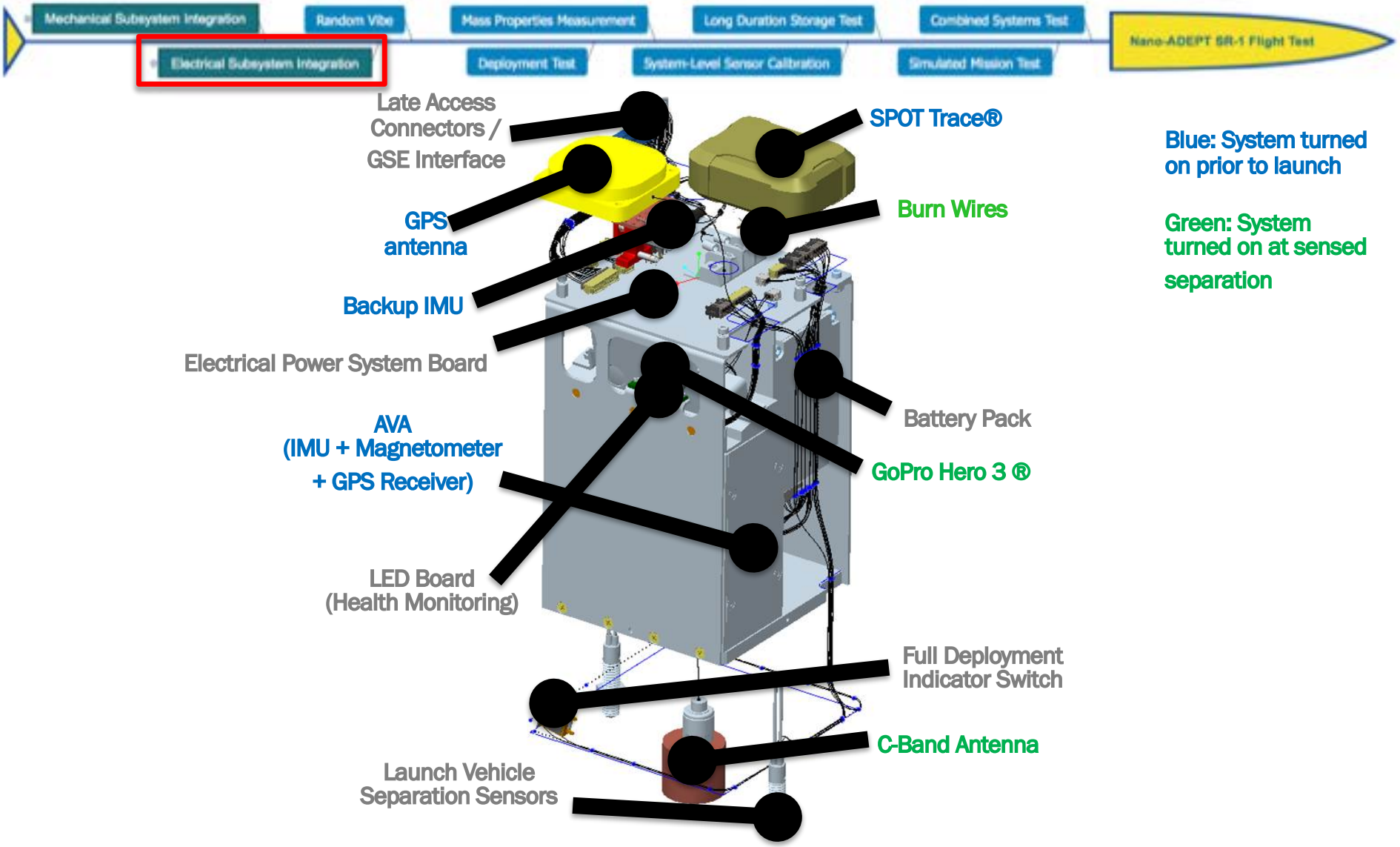
System Integration and Testing Timeline



Mechanical Subsystem



Electrical Subsystem and Operations



Blue: System turned on prior to launch

Green: System turned on at sensed separation

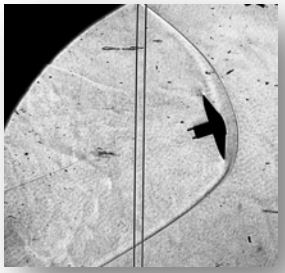
Subsystem Developmental Tests

Impact Tests

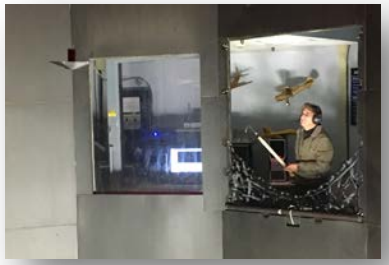
"Flat Sat" Tests

- 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
- Vertical Spin Tunnel Test
- Ballistic Range Test
- CoM / Ballast Mass Decision
- Launch Vehicle Separation Test
- Long Duration Storage Test
- Rib Release Mechanism Test
- Mechanical Subsystem Integration

Target xCOM/D = 0.150
FLIGHT unit as-built xCOM/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

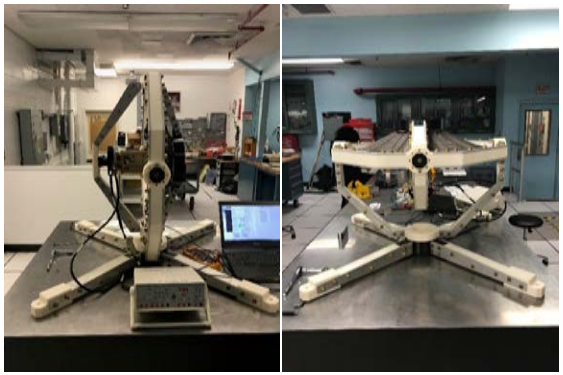


Vertical Spin Tunnel Test

Separation Test

Integrated System Tests

Magnetometer Calibration



Accelerometer Calibration

Rate Gyro Calibration

August 9th, 2018

Random Vibe

Mass Properties Measurement

Deployment Test

Long Duration Storage Test

System-Level Sensor Calibration

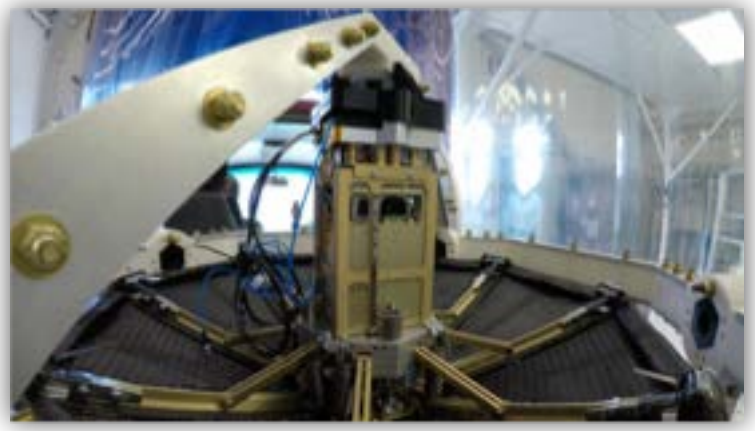
Combined Systems Test

Simulated Mission Test

Nano-ADEPT SR-1 Flight Test

September 12, 2018

Deployment Testing



Simulated Mission "Drive Around" Test

Conclusions & Future Work

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

- **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

- **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

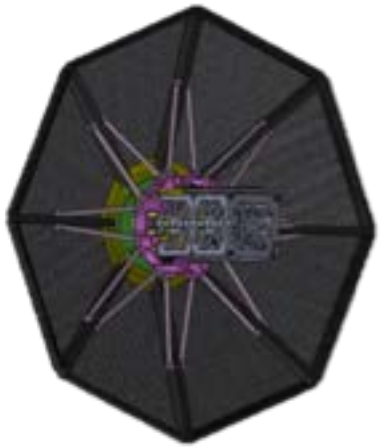
Backup

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

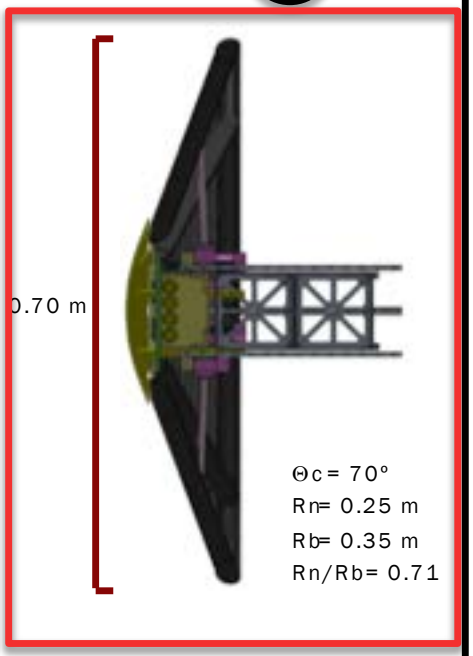


0.7 m diameter Nano-ADEPT shown with notional 2U chassis payload

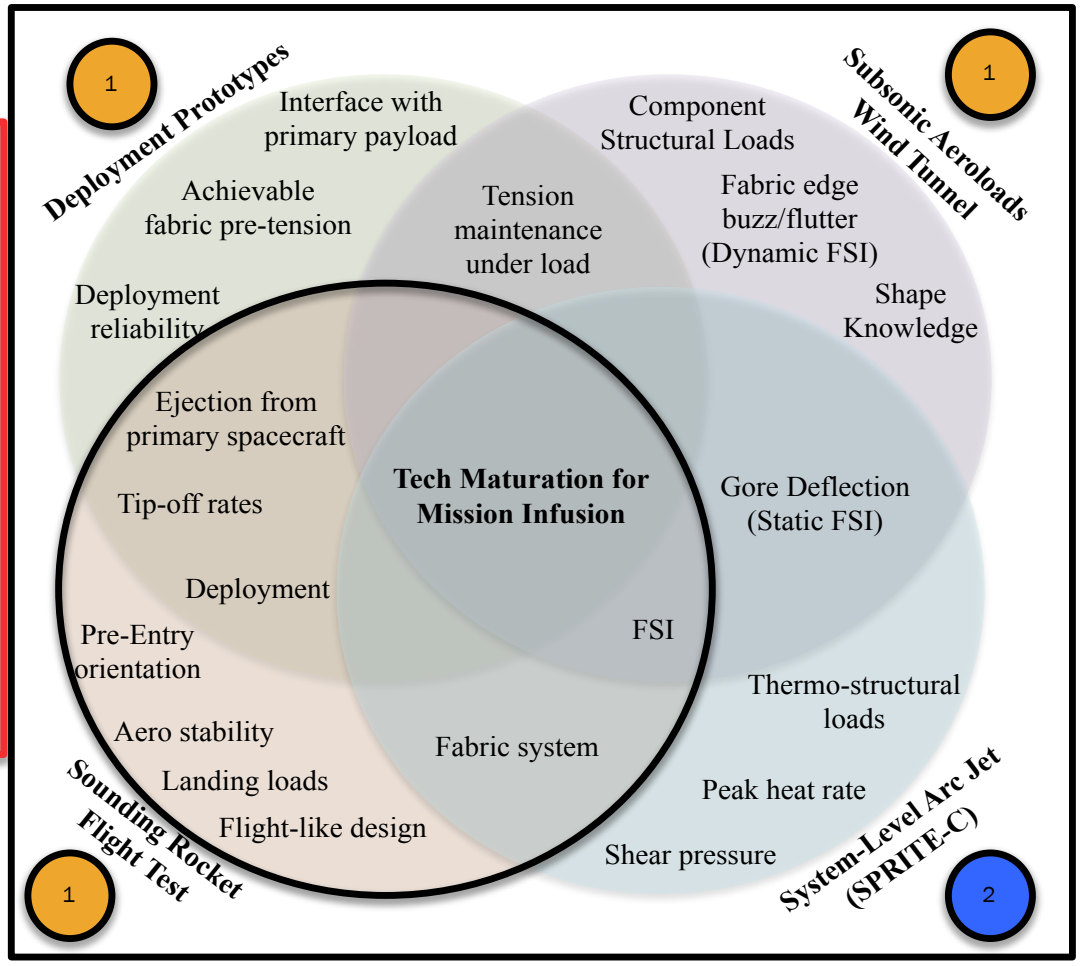
Nano-ADEPT Development Roadmap to TRL 5

- 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

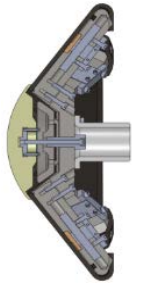
Config. 1



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)