



ADEPT Sounding Rocket One Flight Test Overview

Alan Cassell¹, Paul Wercinski¹, Bryan Yount¹, Owen Nishioka¹,
Joseph Williams¹, Soumyo Dutta², Ashley Korzun²

¹*NASA Silicon Valley Ames Research Center*

²*NASA Langley Research Center*

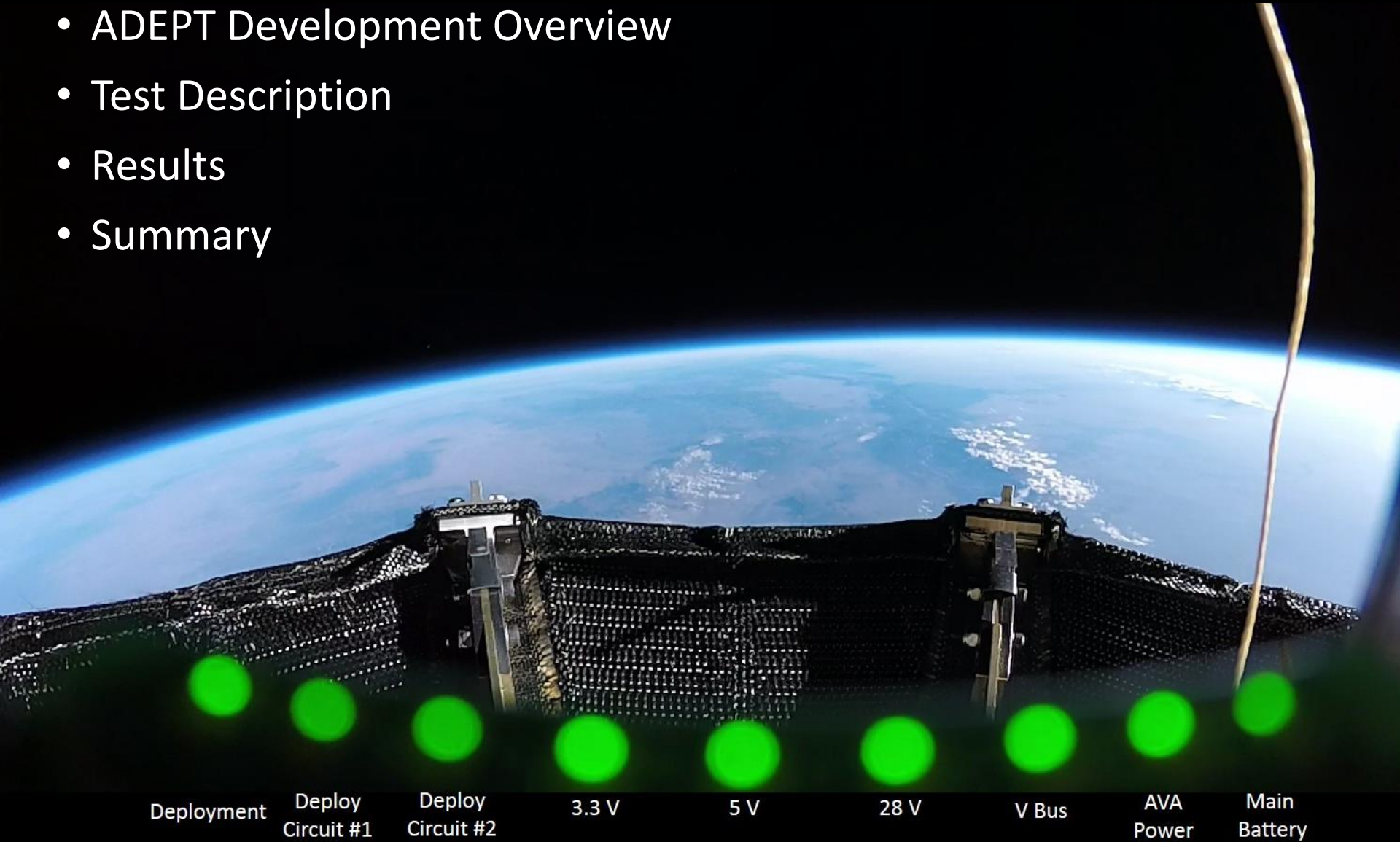
*16th International Planetary Probe Workshop
Oxford, United Kingdom
July 11, 2019*





Outline

- ADEPT Development Overview
- Test Description
- Results
- Summary



Deployment

Deploy
Circuit #1

Deploy
Circuit #2

3.3 V

5 V

28 V

V Bus

AVA
Power

Main
Battery

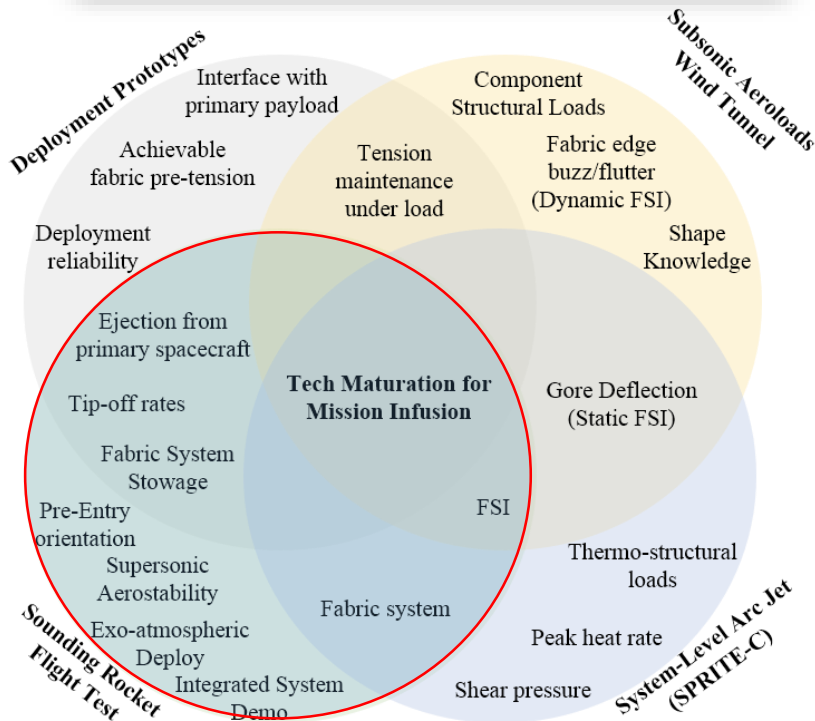
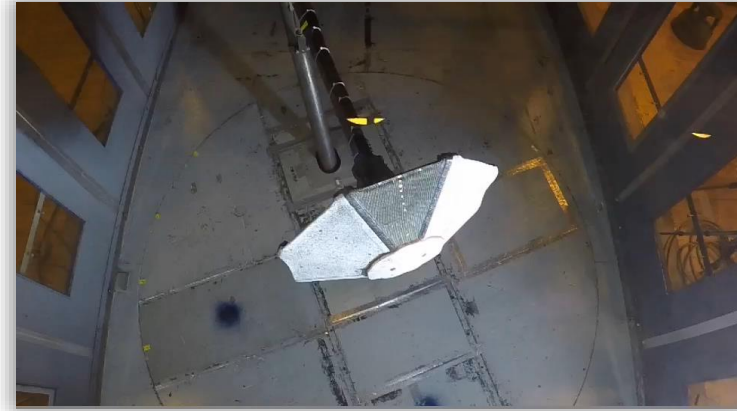


Adaptive Deployable Entry and Placement Technology 1 m Class Development Overview

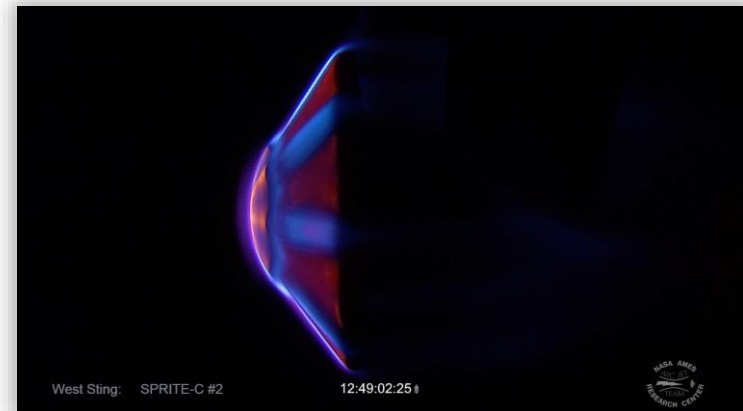
Deployment



Aeroloads Testing



Aerothermal Testing





Flight Test Objectives

SR-1 Key Performance Parameters		
Performance Parameter	Threshold Value	Project Goal
#1- Exo-atmospheric deployment to an entry configuration of the 1m-class ADEPT.	Less than fully locked condition resulting in shape with less than 70-degree fore body cone angle.	Full, locked deployment before reaching 80 km altitude on descent, to 70-degree fore body cone angle achieving 6x greater drag area.
#2- Aerodynamic stability without active control of the 1m- class ADEPT in a flight configuration.	Does not tumble prior to M=0.8 while decelerating from peak Mach # (when Mach number is decreasing after passing through peak Mach number).	ADEPT does not tumble* before ground impact; Sign of pitch damping coefficient (Cmq) is determined; FF-CFD simulation tool is validated

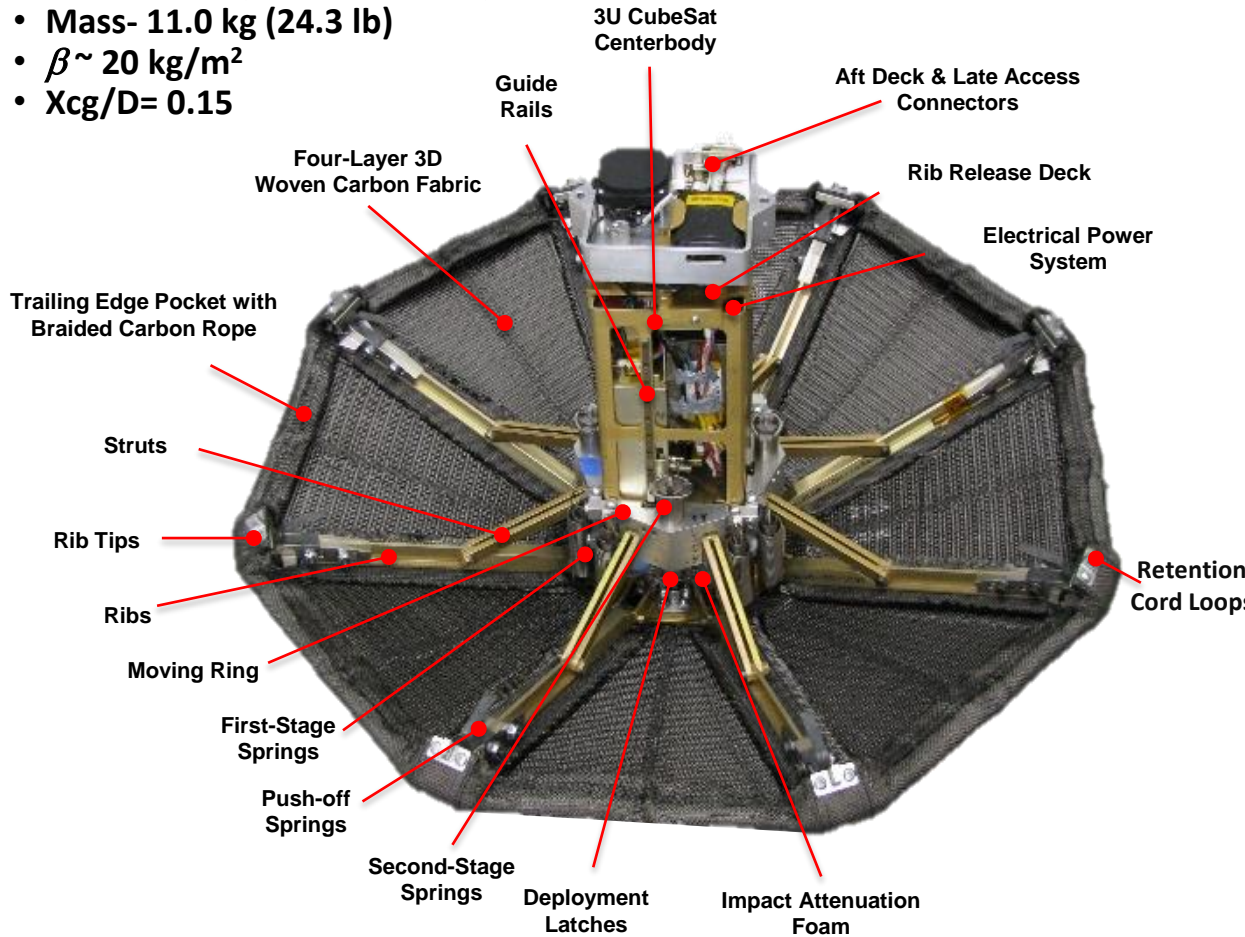
Mission Success Criteria

- A. ADEPT separates from the sounding rocket prior to apogee- **SUCCESSFUL**
- B. ADEPT does not re-contact any part of the launch vehicle after separation- **SUCCESSFUL**
- C. ADEPT reaches an apogee greater than 100 km- **SUCCESSFUL**
- D. ADEPT achieves fully deployed configuration prior to reaching 80 km altitude on descent- **SUCCESSFUL**
- E. Obtain on-board video of deployed ADEPT to observe fabric response during entry- **SUCCESSFUL**
- F. Obtain data necessary to reconstruct ADEPT 6-DOF descent trajectory- **SUCCESSFUL**

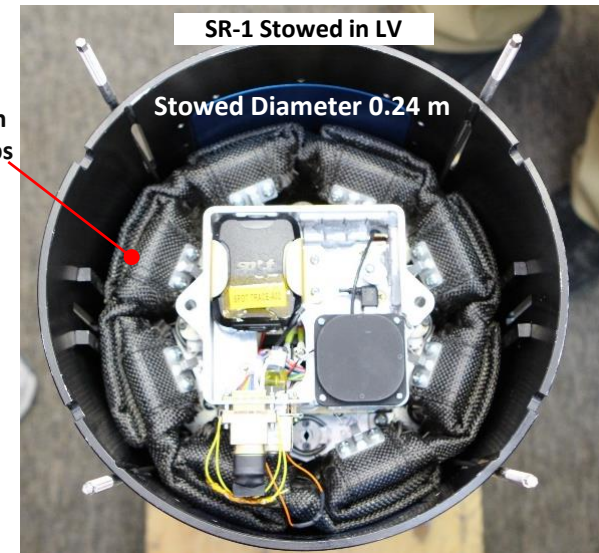


SR-1 Flight Article Description

- Rib tip to Rib tip diameter- 0.70 m
- Half cone angle (ribs)- 70 deg
- Mass- 11.0 kg (24.3 lb)
- $\beta \sim 20 \text{ kg/m}^2$
- $X_{cg}/D = 0.15$

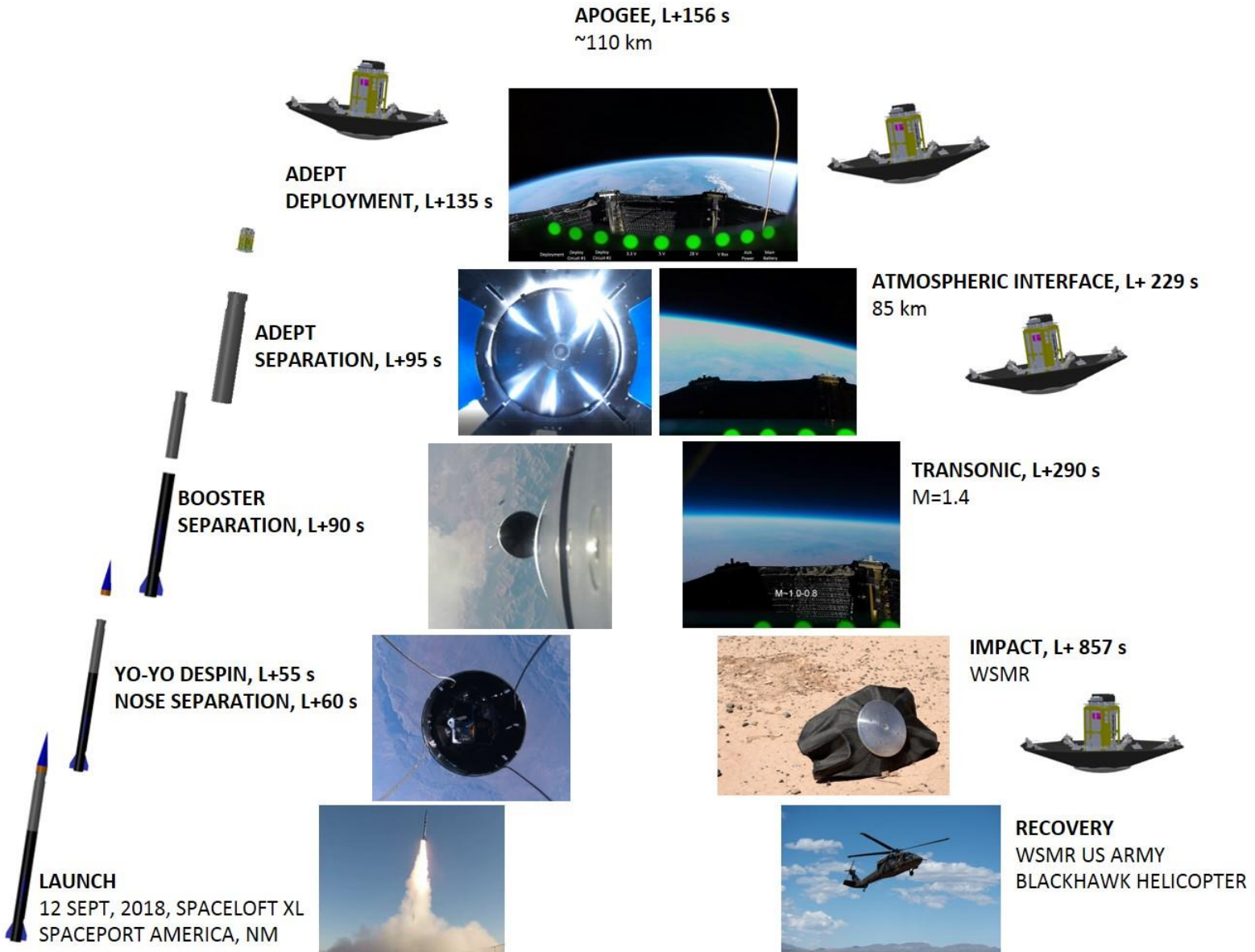


Instrumentation	Data/Function
AVA	Accelerometers, Rate Gyros, Magnetometer, GPS Tracking
NGIMU	Accelerometers, Rate Gyros, IMU Board Temp Sensors
LED Indicator Board	System Health Indicator Status
GoPro Video	1080p, 60 fps video
C-Band Transponder	WSMR Radar Tracking
SPOT Trace	GPS Recovery Tracker
Separation Sensors	Power-on signal for deployment timer, C-Band & GoPro
Deployment Switch	Indicates full deployment





Operations Timeline





Flight Test Video

UP Aerospace

September 12th, 2018

SL-12 Mission: Successfully deploy
NASA Adept SR-1 Payload approx
100km. Testing new heat shield
technology.

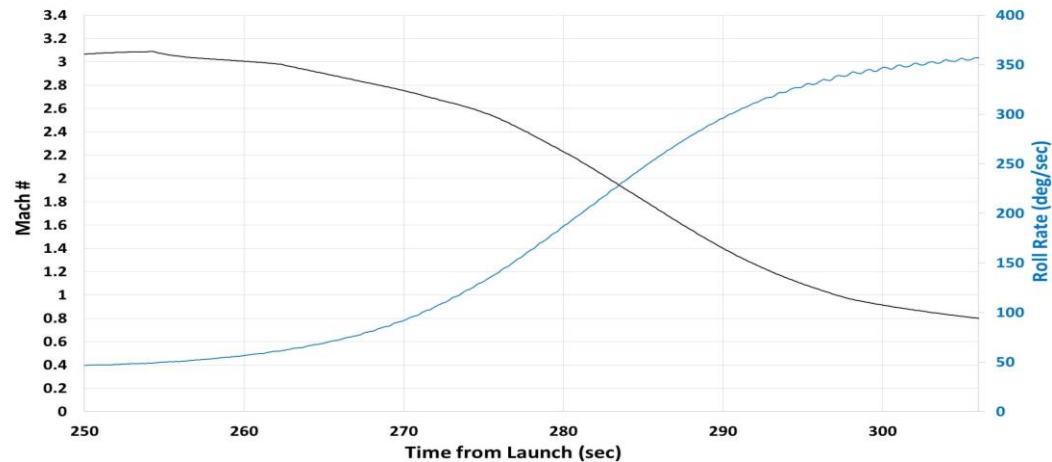
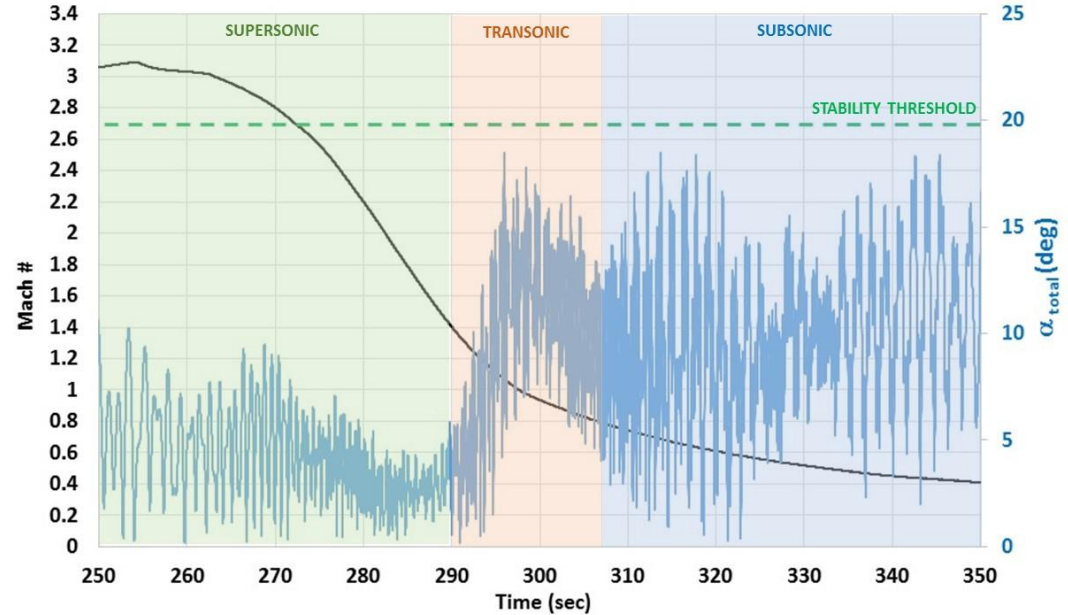
Required Re-Entry Speed: Mach 2.5





Summary

- Exoatmospheric deployment to entry configuration was confirmed through sensor and video data. **Meets KPP#1 Project Value.**
- Total angle of attack remains below stability threshold of 20 degrees through $M=0.4$. **Meets Threshold Value for KPP#2-** vehicle tumbled at $\sim M=0.2$.
- The spin rate increase through supersonic deceleration was unexpected. Post flight analysis is ongoing to determine cause.
- For details on the flight mechanics modeling, see: Soumyo Dutta's presentation Friday.
- For further details on the ADEPT SR-1 Flight Test, see series of papers in a special session at AIAA Aviation, 2019. See list of publications on the last chart for details.





Acknowledgements



- Soumyo Dutta (LaRC, Flight Mechanics Lead)
- Shakib Ghassemieh (Ames, Lead Avionics Systems Engineer)
- Chris Karlgaard (LaRC-TEAMS2, Traj. Reconstruction)
- Ashley Korzun (LaRC, Aerosciences Lead)
- Carl Kruger (Ames, Mechanical Design)
- Ali Guarneros-Luna (Ames, SS & MA)
- Owen Nishioka (Ames, Mechanical Design)
- Brandon Smith (Ames, SR-1 Principal Investigator)
- Paul Wercinski (Ames, Project Manager)
- Joseph Williams (Ames-AMA, Instrumentation and Test)
- Shang Wu (Ames, Electrical Systems Lead)
- Bryan Yount (Ames, Structures and Mechanics Lead)
- Steve Battazzo (Ames, AVA Integration)
- Chad Brivkalns (Ames, Mechanical Design)
- Juan Cruz (LaRC, Aerodynamic Testing)
- Neil Davies (Ames, Electrical Technician)
- Dzung Hoang (Ames, Test support)
- Nghia Mai (Ames, Electrical Testing Support)
- Alberto Makino (Ames, Structural Testing and Analysis)
- Mark Mallinson (Ames, Risk and CM Manager)
- Ryan McDaniel (Ames, Aero CFD)
- Matt Padilla (Ames, Electrical Technician)
- Justin Green (LaRC, Traj Reconstruction)
- Jake Tynis (LaRC-TEAMS3, Traj Reconstruction)

Space Technology Mission Directorate:

- Game Changing Development Program
- Flight Opportunities Program

Spaceport America

White Sands Missile Range

Bally Ribbon Mills

Thin Red Line Aerospace





Bibliography



1. Venkatapathy, E., et al, "Adaptive Deployable Entry and Placement Technology (ADEPT): A Feasibility Study for Human Missions to Mars" AIAA Aerodynamic Decelerator Systems Technology Conference, May 23-26, 2011, Dublin, Ireland. AIAA 2011-2608
2. Arnold, J., et al., "Thermal and Structural Performance of Woven Carbon Cloth for Adaptive Deployable Entry and Placement Technology," AIAA Aerodynamic Decelerator Systems Technology Conference, March 25-28, 2013, Daytona Beach, FL.
3. Arnold, J., et al. "Arcjet Testing of Woven Carbon Cloth for Use on Adaptive Deployable Entry Placement Technology." IEEE Aerospace Conference, March, 2013, Big Sky, MT.
4. Yount, Bryan, C., et al. "Structures and Mechanisms Design Concepts for Adaptive Deployable Entry Placement Technology" AIAA Aerodynamic Decelerator Systems Technology Conference, March 25-28, 2013, Daytona Beach, FL.
5. Kazemba, C., et al, "A Versatile 3D-Woven Carbon Fabric for Broad Mission Application of ADEPT" International Planetary Probe Workshop, June 16-20, 2014, Pasadena, CA.
6. Smith, B., et al, "ADEPT for Secondary Payloads" International Planetary Probe Workshop, June 16-20, 2014, Pasadena, CA.
7. Yount, Bryan, C., Kruger, Carl, E., Cassell, Alan, M., Kazemba, Cole, D. "Deployment Testing of the ADEPT Ground Test Article. International Planetary Probe Workshop, June 16-20, 2014, Pasadena, CA.
8. Smith, B. P., Cassell, A. M., Kruger, C. E., Venkatapathy, E., Kazemba, C. D., Simonis, K. R., "Nano-ADEPT: An Entry System for Secondary Payloads," *IEEE Aerospace Conference*, Big Sky, MT, March 2015.
9. Smith, B., et al "Nano-ADEPT Aeroloads Wind Tunnel Test" IEEE Aerospace Conference, 2016.
10. Cassell, Alan, M., et al. "System Level Aerothermal Ground Testing for the Adaptive Deployable Entry and Placement Technology." International Planetary Probe Workshop, June 13-17, 2016, Laurel, MD.
11. Cassell, A. M., et al "Human Mars Mission Design Study Utilizing the Adaptive Deployable Entry and Placement Technology" *IEEE Aerospace Conference*, Big Sky, MT, March 2017.
12. Wercinski, P. F. et al., "ADEPT Sounding Rocket One (SR-1) Flight Experiment Overview," *IEEE Aerospace Conference*, Big Sky, MT, March 2017.
13. Cassell, A. M., et al "ADEPT, a Mechanically Deployable Re-Entry Vehicle System, Enabling Interplanetary CubeSat and Small Satellite Missions" *SmallSat 2018*, Logan, UT, August 2018.
14. Cassell, A., et al "ADEPT for Interplanetary Small Satellite Missions" Interplanetary Small Satellite Conference, 29-30 April, 2019, San Luis Obispo, CA.
15. Cassell, A. M., et al "ADEPT Sounding Rocket One Test Overview" *AIAA Aviation Conference*, Dallas, TX, 17-21 June 2019.
16. Korzun, A. M., Dutta, S., McDaniel, R. D., Karlgaard, C., Tynis, J. A., "Aerodynamics for the ADEPT SR-1 Flight Experiment," *AIAA Aviation Conference*, Dallas, TX, 17-21 June 2019.
17. Cruz, J. R., Green, J. S., "Subsonic Dynamic Testing of a Subscale ADEPT Entry Vehicle," *AIAA Aviation Conference*, Dallas, TX, 17-21 June 2019.
18. Tynis, J. A., Karlgaard, C., "Reconstruction of the Adaptable Deployable Entry and Placement Technology Sounding Rocket One Flight Test," *AIAA Aviation Conference*, Dallas, TX, 17-21 June 2019.
19. Dutta, S., Green, J. S., "Flight Mechanics Modeling and Post Flight Analysis of ADEPT SR-1," *AIAA Aviation Conference*, Dallas, TX, 17-21 June 2019.
20. D'Souza, S. D., Johnson, B. J., Okolo, W. A., Nikaido, B. E., Smith, B. P., "Pterodactyl: Developing a Design, Build and Test Capability for Non-propulsive Control Systems for Lifting Nano-ADEPT," *AIAA Aviation Conference*, Dallas, TX, 17-21 June 2019.