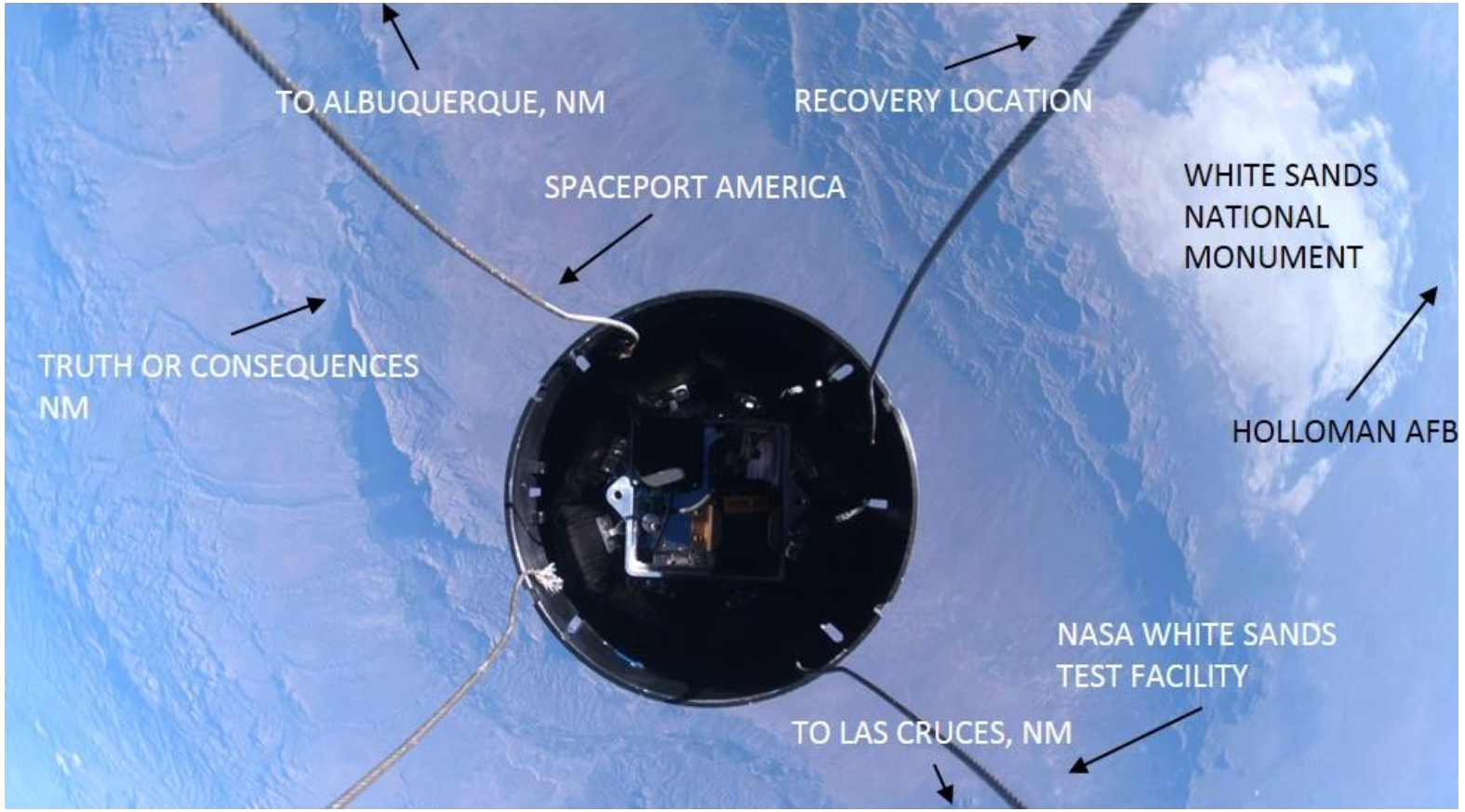
ADEPT For Interplanetary Small Satellite Missions

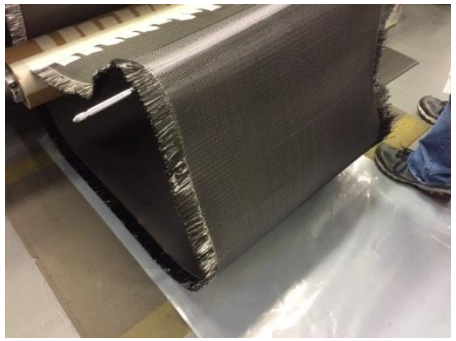


Alan Cassell, Paul Wercinski, Raj Venkatapathy
Entry Systems and Vehicle Development Branch
NASA Ames Research Center
Moffett Field, CA 94035

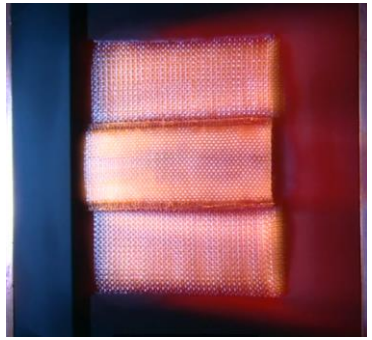
Outline

- **A**daptive **D**eployable **E**ntry **P**lacement **T**echnology Overview
- Interplanetary Mission Concepts
- Sounding Rocket Flight Test Overview
- Flight Test Results Summary
- Acknowledgements

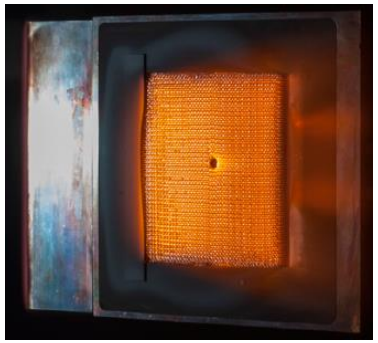
Manufacturing- 3d Weaving



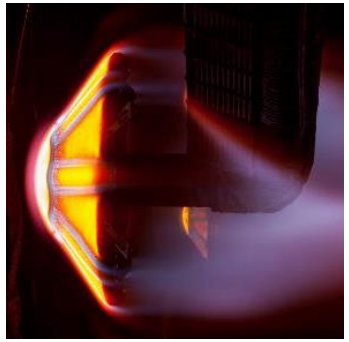
3d Carbon Fabric Structure & Thermal Protection Material



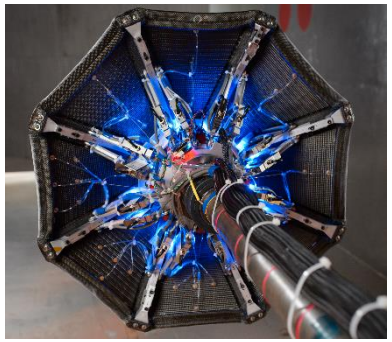
Fabric Seam Testing



Fabric Damage Testing



Flight-Like Systems Arc-Jet Testing



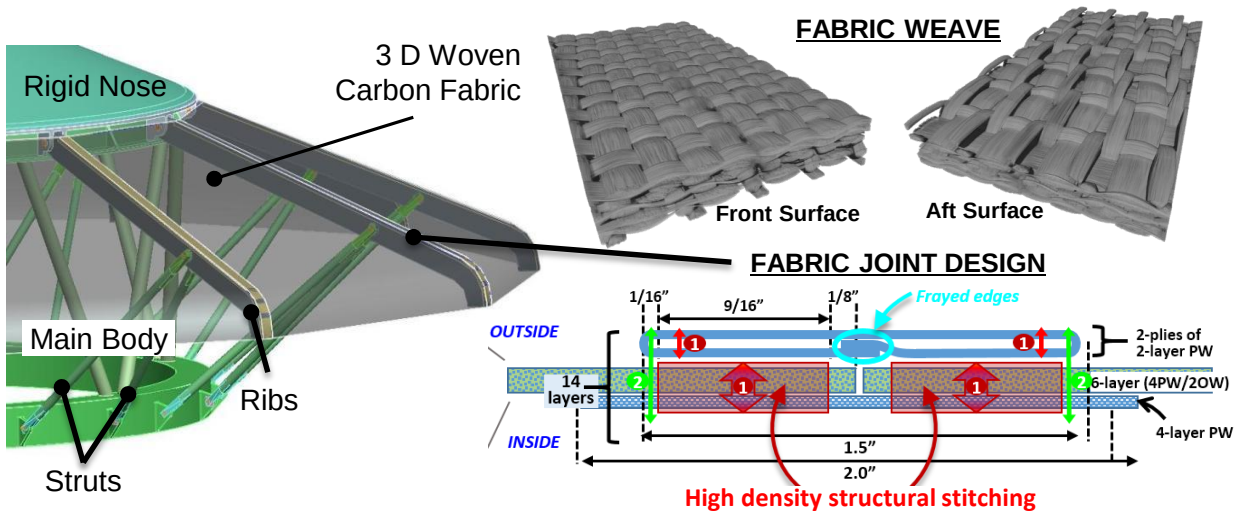
Aerodynamic Loads Testing

ADEPT Technology Overview

Technology Capability

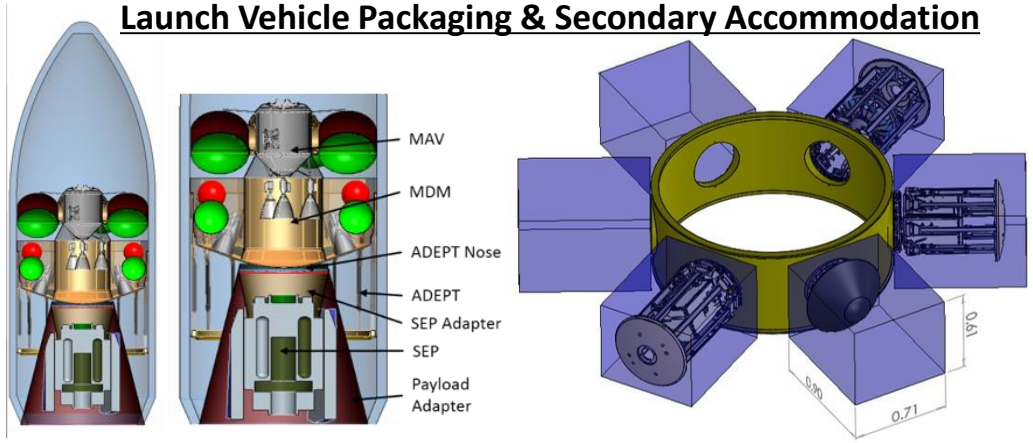
- **ADEPT is a mechanically deployable entry vehicle technology utilizing 3d woven carbon fabric.**
- **Compact stowage (3-4 x smaller than rigid aeroshell) during launch transforms into large drag area aeroshell for deceleration high in the atmosphere, lowering deceleration loads and aeroheating environments.**
- **The capability is particularly attractive for SmallSat class payloads.**

Key ADEPT Components



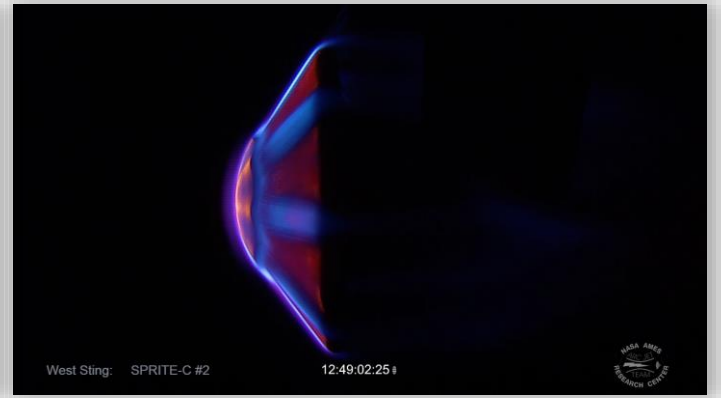
Carbon Fabric Ground tested to ~250 W/cm^2

Launch Vehicle Packaging & Secondary Accommodation

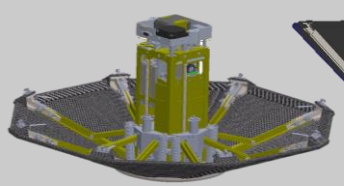
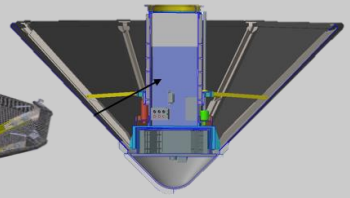
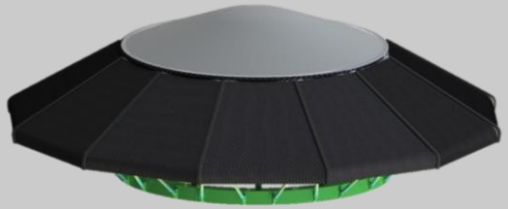
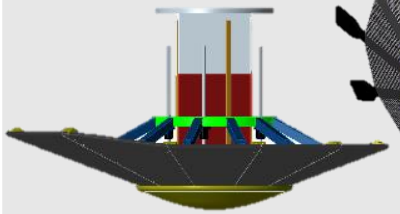
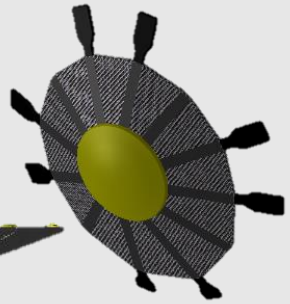
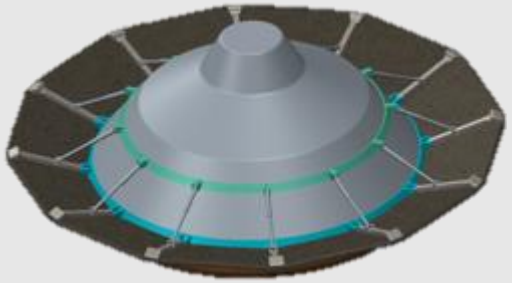
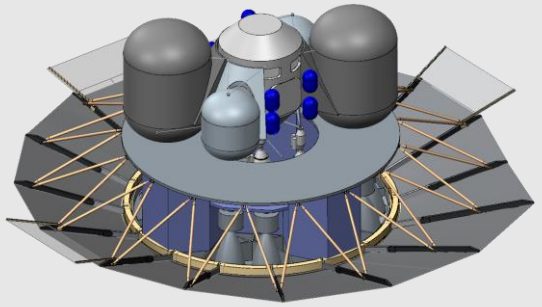


Deployment Time Lapse Video

Flight-Like Aerothermal Testing



ADEPT Vehicle Designs

	SmallSat Class (Tech Demo or Secondary Payload)	Robotic Class	Exploration Class (Human Mars)
BALLISTIC CONCEPT	 **ADEPT 3U**  **ADEPT DMAC**	 **ADEPT VITaL**	
LIFTING CONCEPT	 **ADEPT LNA**  **PTERODACTYL**	 **MARS SRL**	
DIAMETER RANGE	**< 2 m**	**2-10 m**	**>16 m**

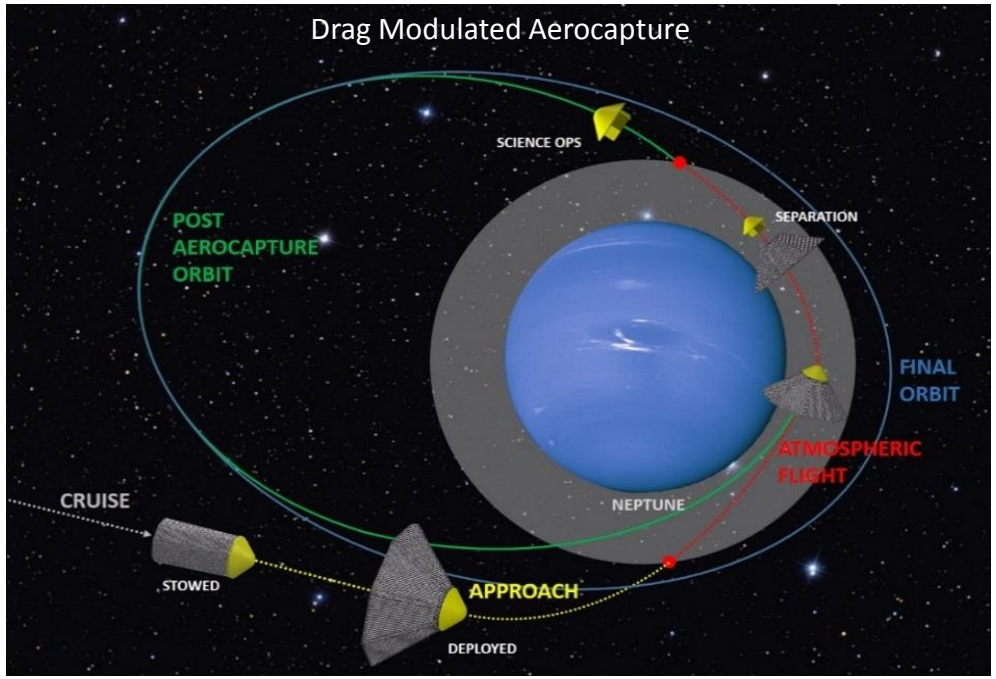
Applicability & Mission Concepts

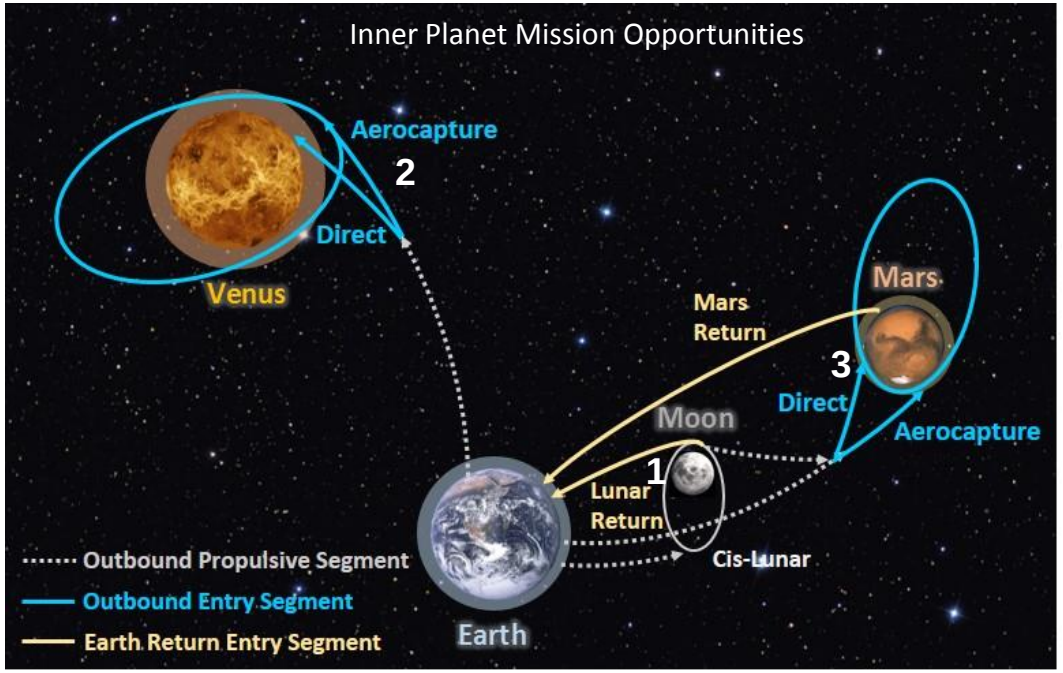
Exploration & Science Applicability

- Small Satellite mission designers can utilize ADEPT for direct entry and/or aerocapture.
- Guidance and control system integration with ADEPT enables precision targeting and landing.
- Human Mars exploration class missions require large drag area decelerators capable of precision targeting/landing.

Mission Infusion Opportunities

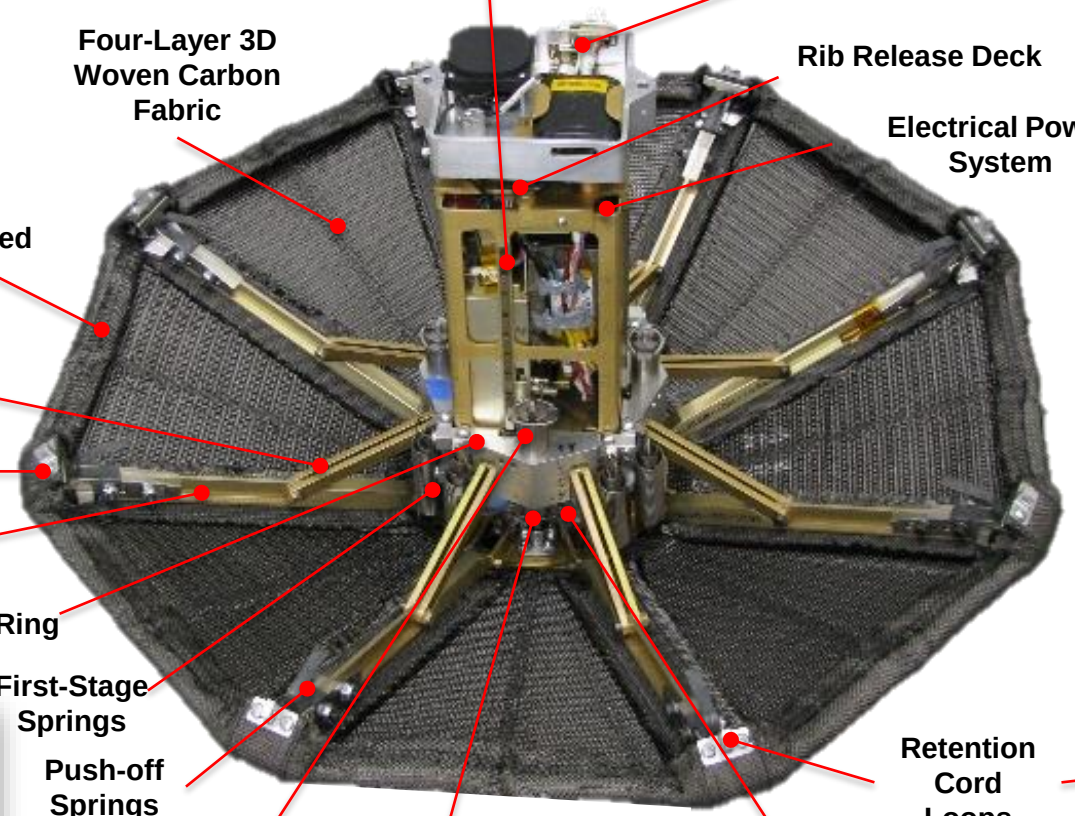
1. Investigating robotic sample return capability for cis-Lunar exploration applications (proposed as FY21 New Start)
2. Designing drag-modulated aerocapture at Venus, Mars & the Ice Giants in collaboration with JPL (IRAD)
3. Exploring the integration of ADEPT onto the Mars Sample Retrieval Lander Entry System.





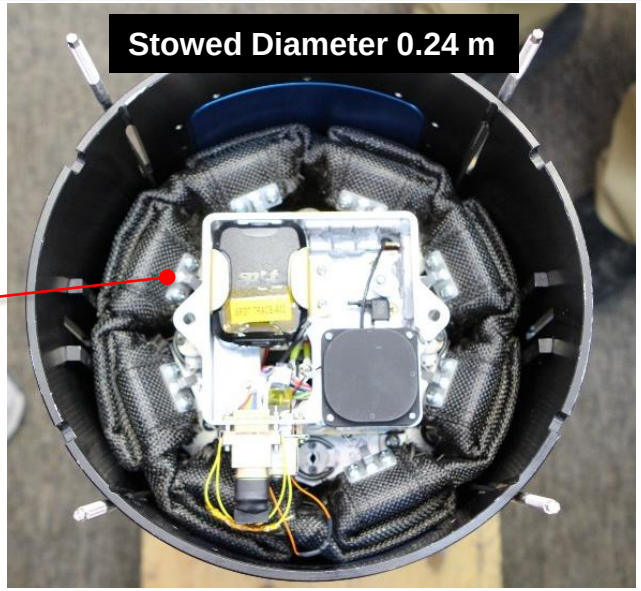
ADEPT SR-1
Vehicle Description

- **Rib tip to Rib tip diameter- 0.70 m**
- **Half cone angle (ribs)- 70 deg**
- **Mass- 11.0 kg (24.3 lb)**
- **β ~ 20 kg/m^2**
- **Xcg/D= 0.15**

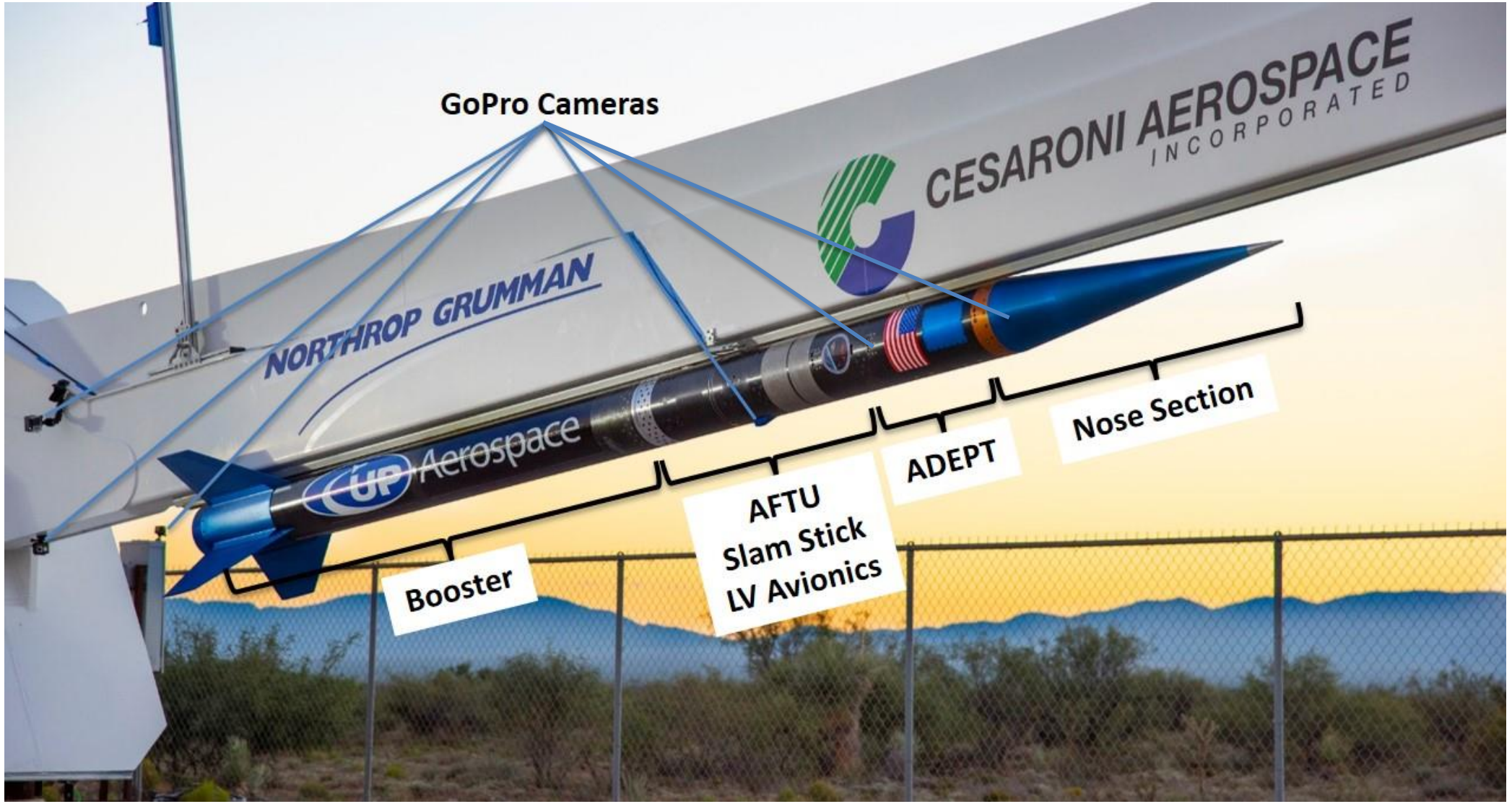


Instrumentation	Data/Function
AVA	Accelerometers, Rate Gyros, Magnetometer, GPS Tracking
NGIMU	Accelerometers, Rate Gyros, IMU Board Temp Sensors
LED Indicator Board	System Health Indicator Status
GoPro Video	1080p, 60 fps video
C-Band Transponder	WSMR Radar Tracking
SPOT Trace	GPS Recovery Tracker
Separation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

Deployment Video

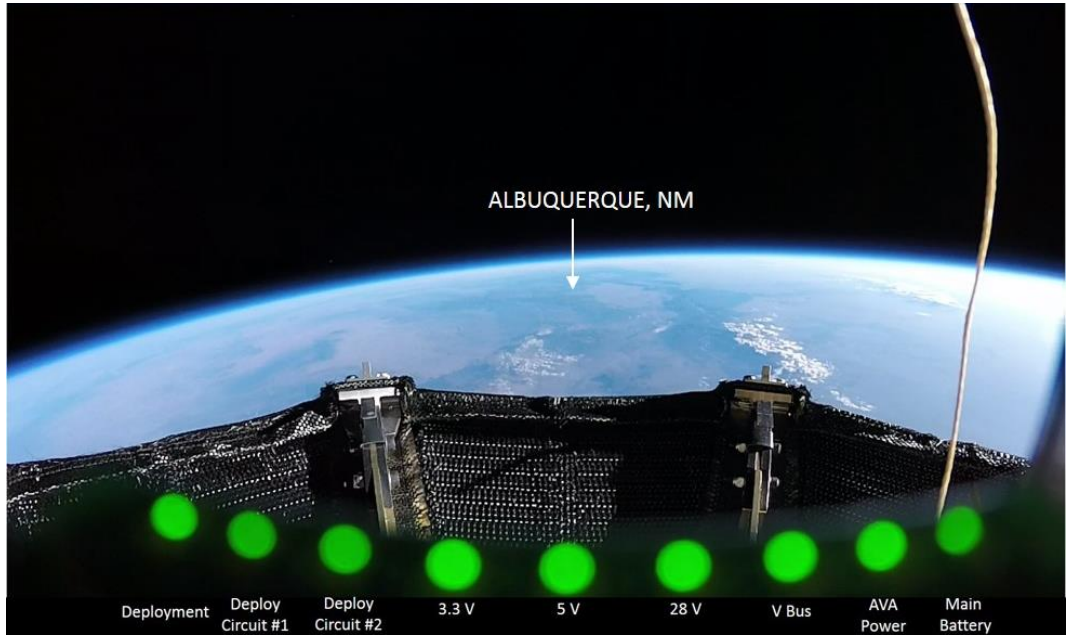


Launch Vehicle



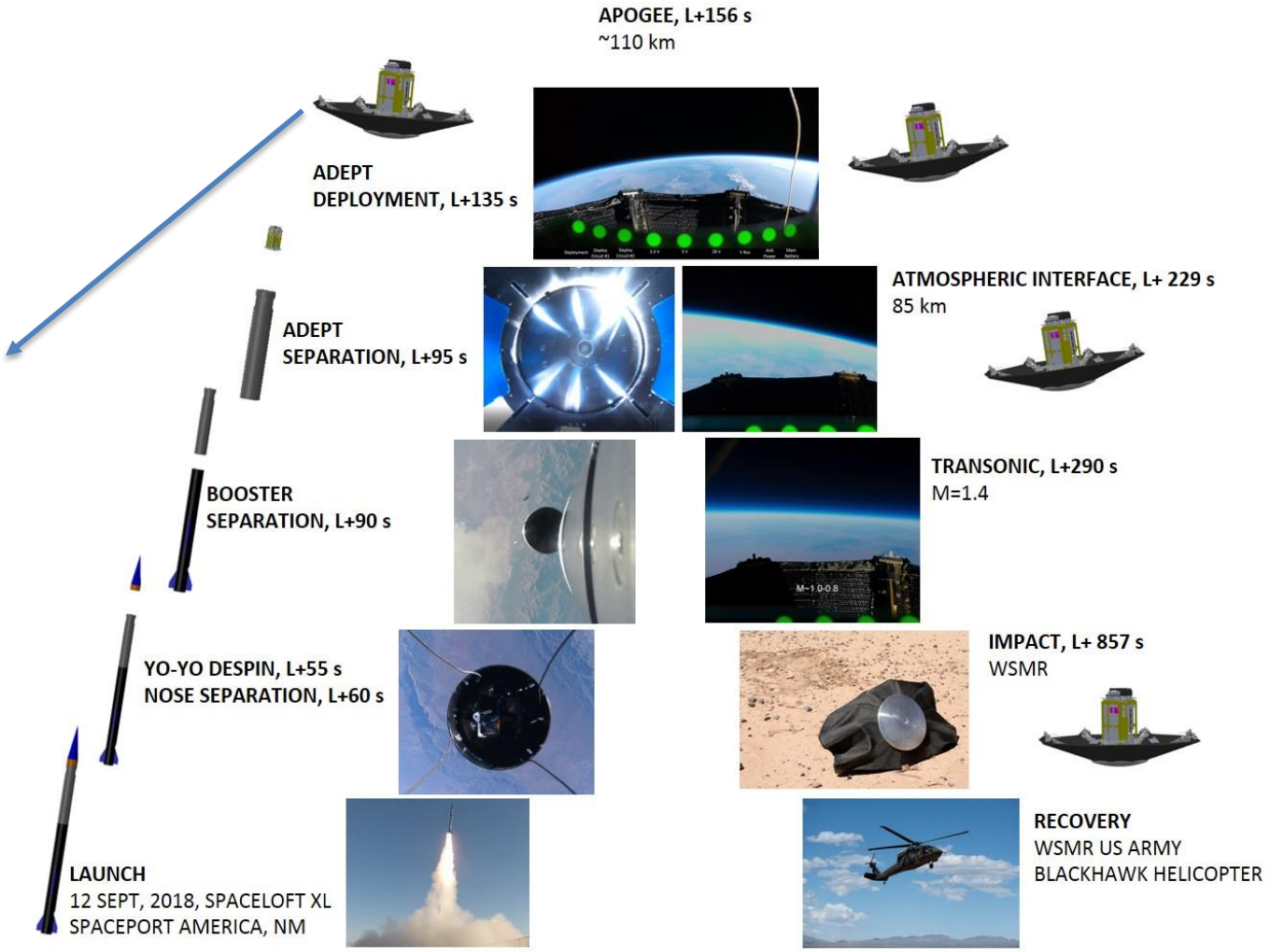
Flight Test Objectives & Timeline

Objective #1- Demonstrate exo-atmospheric deployment to entry configuration.
Objective #2- Demonstrate vehicle does not tumble prior to achieving Mach=0.8.



KPP #1- Achieved Fully Locked & Deployed Entry Configuration

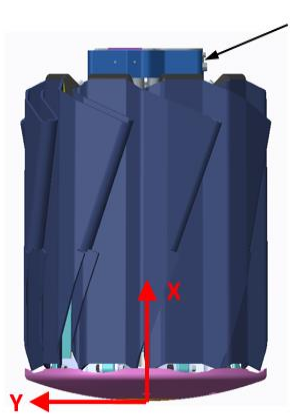
Operations Timeline



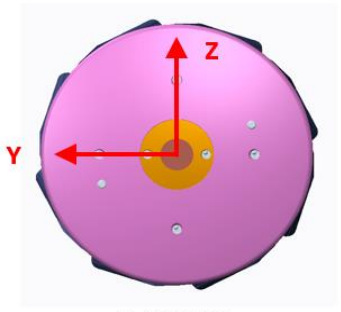
Flight Test Video

Results Summary- Ascent & Deployment

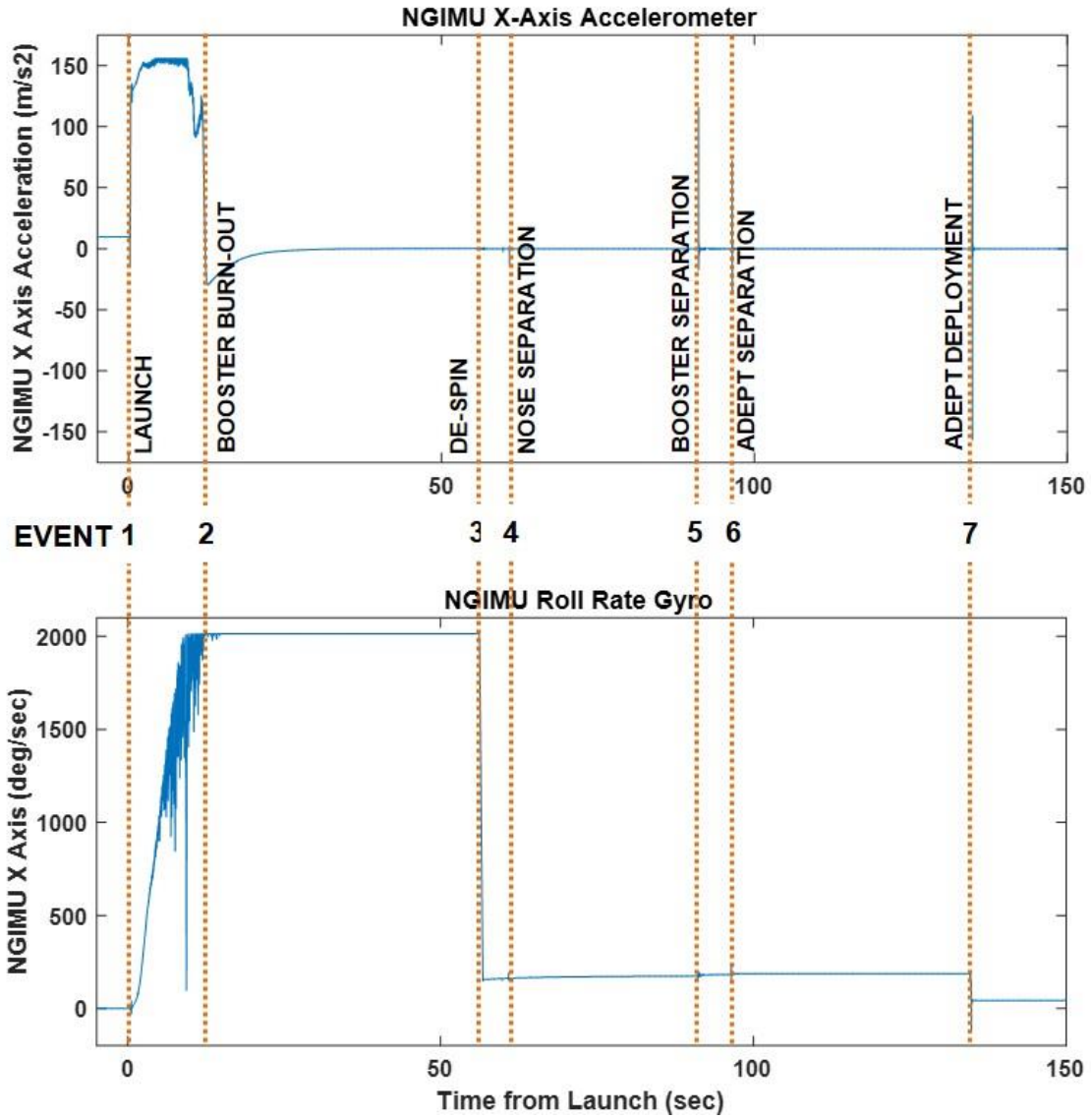
EVENT #	DESCRIPTION	PLANNED TIME (SEC)	ACTUAL TIME (SEC)
1	LIFTOFF	N/A	N/A
2	BOOSTER BURN-OUT*	12	12
3	DE-SPIN DEPLOY*	55	55
4	NOSE FAIRING SEPARATION*	60	60
5	BOOSTER SEPARATION*	90	90
6	ADEPT SEPARATION*	95	95
7	ADEPT DEPLOY*	100-135	135



SR-1 SIDE VIEW



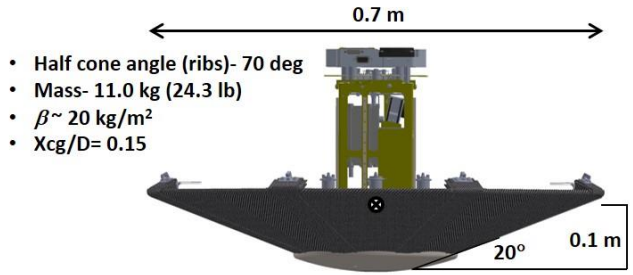
SR-1 NOSE CAP

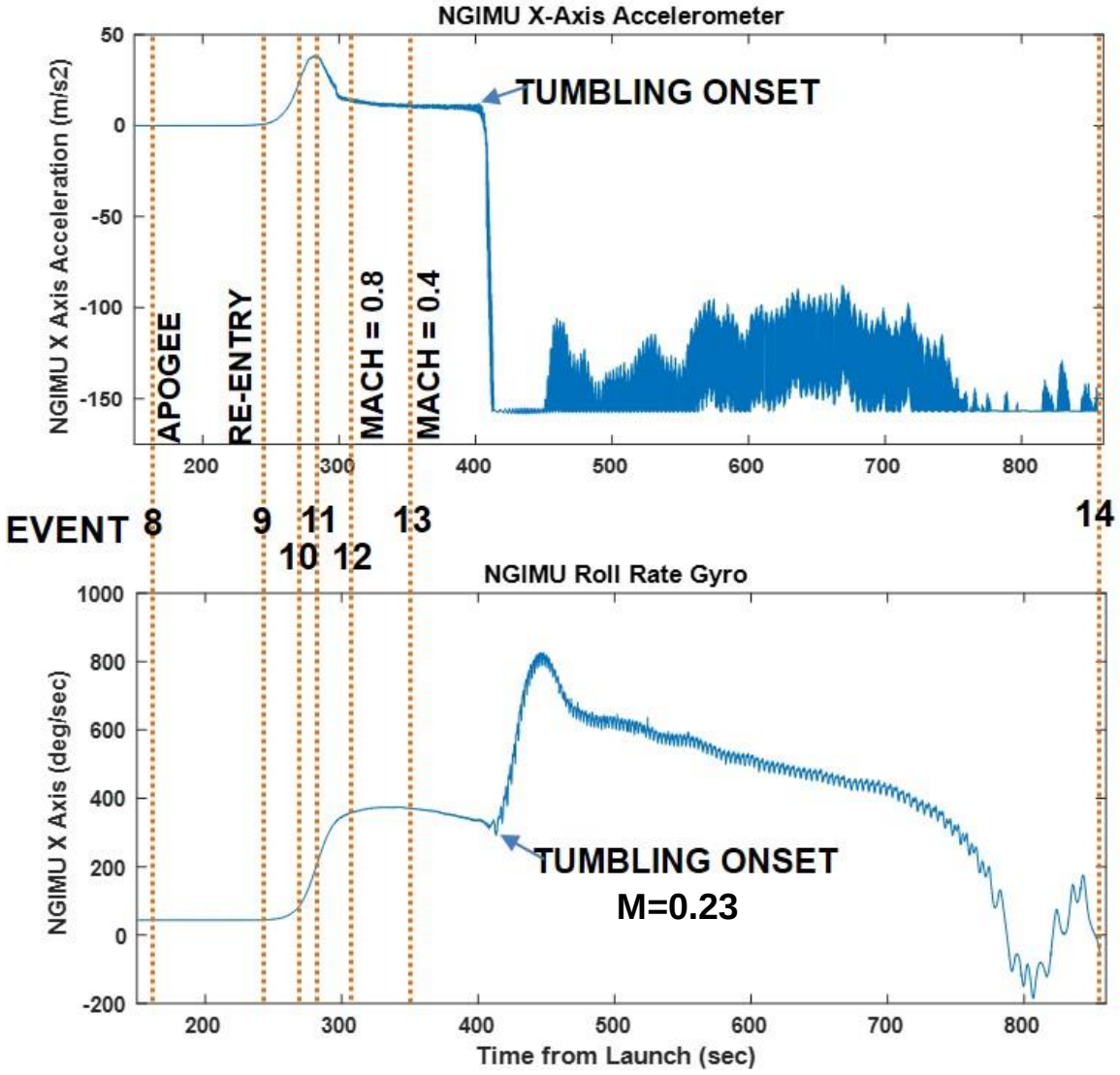


Results- Reentry, Descent & Impact

KPP #2- Project threshold of no tumbling prior to M=0.8 achieved

EVENT #	DESCRIPTION	PREDICTED TIME (SEC)	ACTUAL TIME (SEC)
8	APOGEE	161	156
9	ADEPT RE-ENTRY (85 km)	244	229
10	PEAK MACH # (3.2, PREDICTED)	270	254
11	PEAK DYNAMIC PRESSURE (~822 Pa,)	294	282
12	ADEPT MACH 0.8	318	307
13	MACH 0.4	363	352
14	IMPACT (~25 m/sec, NOMINAL)	879	856





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

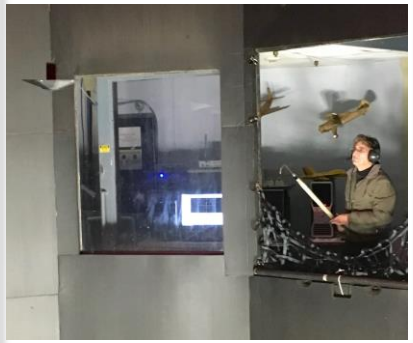
Thank You!
Questions?

AIAA Aviation 2019 Aerodynamic Decelerator Systems Technology Conference Special Session

Interplanetary Small Satellite Conference
beyond LEO

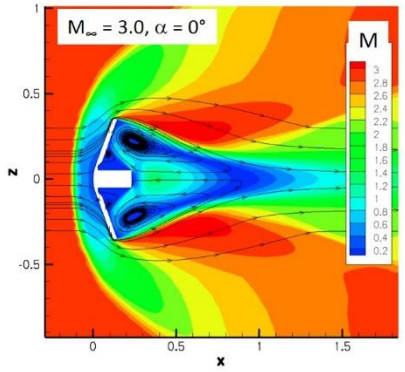
ADEPT Sounding Rocket One Flight Test Overview

Alan Cassell, et al
NASA ARC



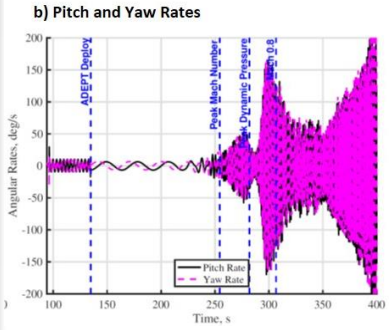
Subsonic Dynamic Testing of a Subscale ADEPT Entry Vehicle

Juan Cruz, et al
NASA LaRC



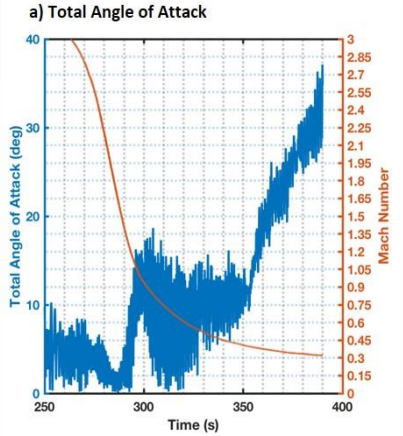
Aerodynamics for the ADEPT SR-1 Flight Experiment

Ashley Korzun, et al
NASA LaRC



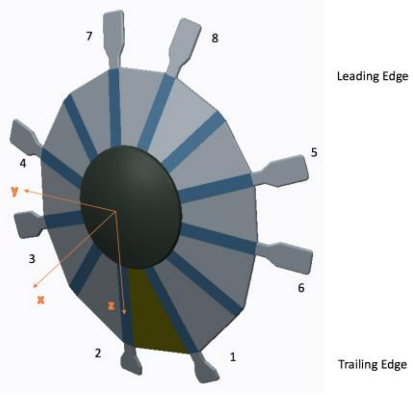
Reconstruction of the Adaptable Deployable Entry and Placement Technology Sounding Rocket One Flight Test

Chris Karlgard, et al
NASA LaRC



Flight Mechanics Modeling and Post-Flight Analysis of ADEPT SR-1

Soumyo Dutta, et al
NASA LaRC



Developing an Entry Guidance and Control Design Capability using Flaps for the Lifting Nano-ADEPT

Sarah D'Souza, et al
NASA ARC