ADEPT, A Mechanically Deployable Re-Entry Vehicle System, Enabling Interplanetary CubeSat and Small Satellite Missions

32nd Annual Small Satellite Conference

7 August 2018

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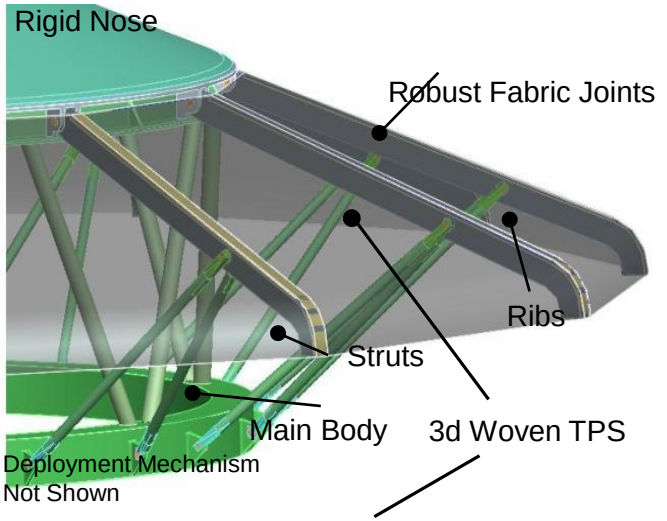
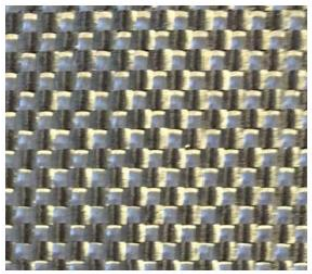
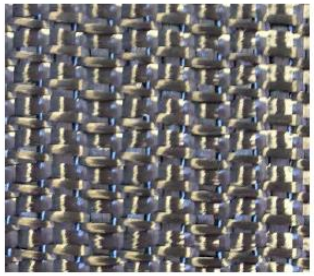
Adaptive Deployable Entry and Placement Technology

Key ADEPT Components





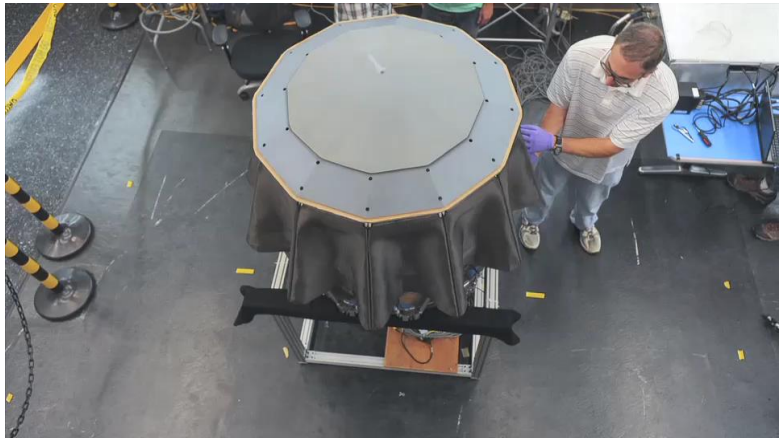
Front Surface- Plain Weave



Aft Surface- Ortho Weave

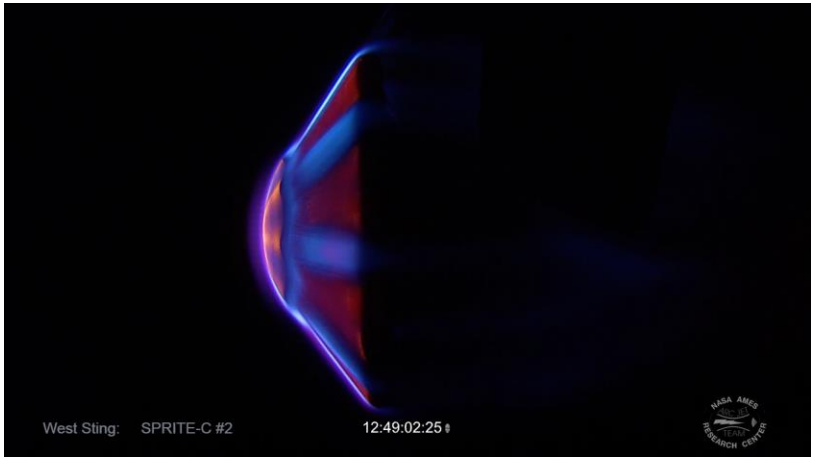
- Dual use **3d woven carbon fabric** TPS/structural membrane. 12-layer fabric demonstrated for high heat load entries
- Proven ground test capability to **~ 250 W/cm² (~2100 °C).**

2 m Deployment Prototype Time Lapse Video



-Electrically driven actuators to achieve high fabric pre-tension

System Level Aerothermal Testing



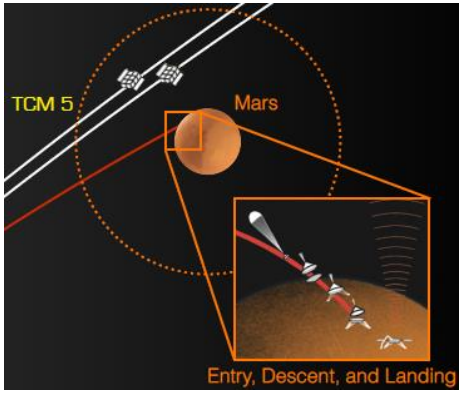
-System level test to understand key interfaces and transitions
-Fabric Tested to heating rates of 250 W/cm² (2100 °C)

Motivation- ADEPT for CubeSat and SmallSat Missions

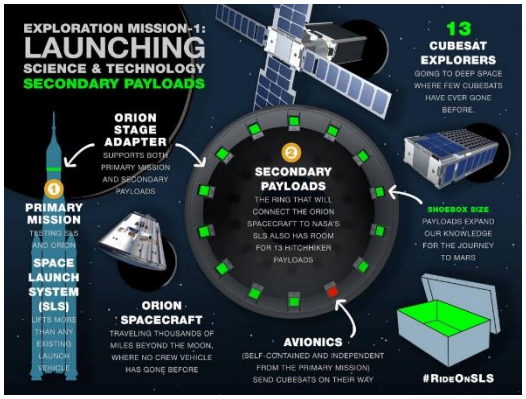
Deep Space CubeSats

- CubeSats are rapidly gaining traction as cost-effective secondary payloads to enhance primary missions or as stand-alone scientific investigations in deep space.
- Continued investments are expected through various programs to utilize excess launch capacity. NASA PSDS3 & SALMON AOs.

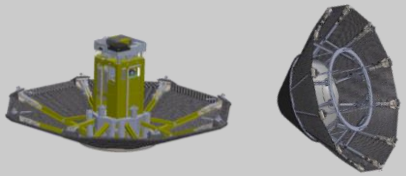
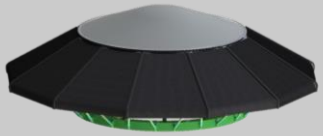
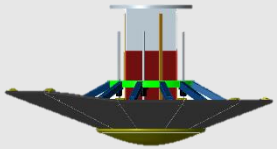
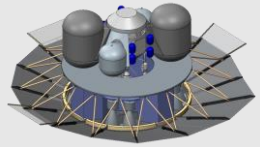
The **Mars Insight Mission** has ***two 6U*** CubeSats (**MarCO**) that will relay Entry, Descent and Landing data.



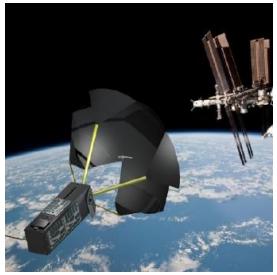
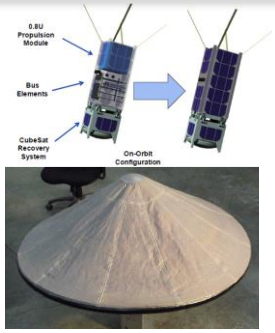
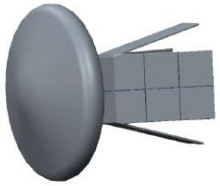
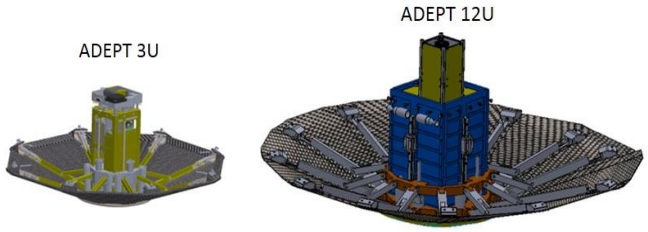
The Orion **Exploration Mission-1** will have ***thirteen 6U*** CubeSats conducting stand-alone science investigations in cis-Lunar Space.



ADEPT Entry Vehicle Designs

	SmallSat Class (Tech Demo or Secondary Payload)	Robotic Class (Discovery or Secondary)	Flagship or New Frontiers Class	Exploration Class (Human Mars)
Ballistic Concept(s)		**Trades Underway**		
Lifting Concept		**Trades Underway**	**Trades Underway**	
Diameter Range	**< 2 m**	**2-6 m**	**6-10 m**	**>16 m**

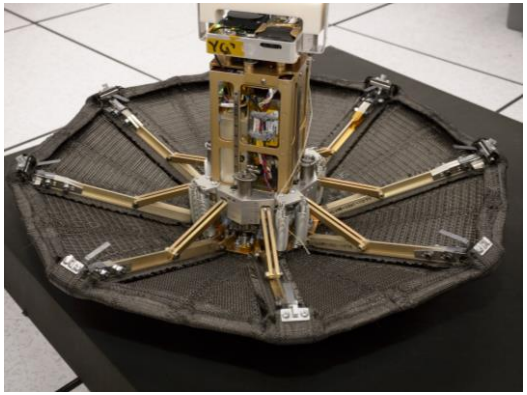
Deployable Entry Systems for CubeSats

	TechEdSat	Deorbit and Recovery System	HIAD w/in 6U	ADEPT CubeSat Class
	 M. Murbach, SmallSat 2016	 J. Andrews, SmallSat 2011	 S. Hughes, et al, IPPW 2016	
CubeSat Configuration	3.5U	3U	6U	3U-16U (could include dispensers)
Entry System Volume	1.5U ExoBrake de-orbit system	1U	3U	Integrates around CubeSat or CubeSat Dispenser
TPS Material	N/A	Ablative Coating on Flexible Fabric (Ceramic?)	Woven SiC on C-Felt	High Temperature Capable 3D Woven Carbon Fabric
Flex TPS Temp Limit	N/A	?	~1600 °C	Test Capability Demonstrated to **2100 °C**
Flight Heritage	TechEdSat 1-6	N/A	N/A	ADEPT 3U Sub-Orbital Demo September 2018
Comments	• Does not survive entry • SPQR concept in development	• Designed for LEO entries • 3 U EDU Developed	• Concept Design • Based on HIAD & IRVE heritage	• Capable of high speed entries (~11 km/s) • Technology also useful for Aerocapture

- Entry/De-orbit designs integrated within CubeSat consume valuable science volume.
- Integrating the entry system around the CubeSat alleviates these challenges.
- Deployable concepts thus far are limited in their aerothermal capability for high speed entries encountered with some missions.
- ADEPT offers a highly capable entry system that can package around the CubeSat/SmallSat form factor (1U-16U) or dispensers.

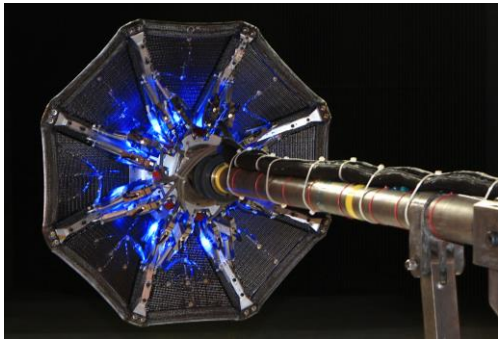
ADEPT 3U Development Overview

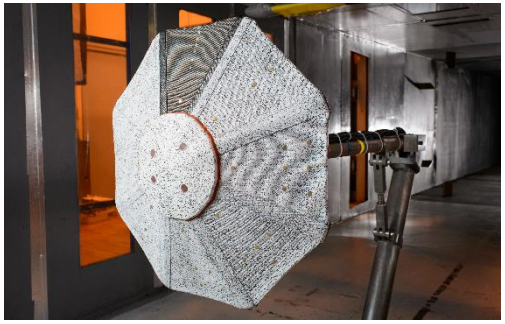
Deployment Prototyping



- Develop spring-based deployment system
- Utilizes retention cord, 2-stage spring mechanism
- Deployment initiated by proximity relay sensors that turn on RC delay circuit for timing.

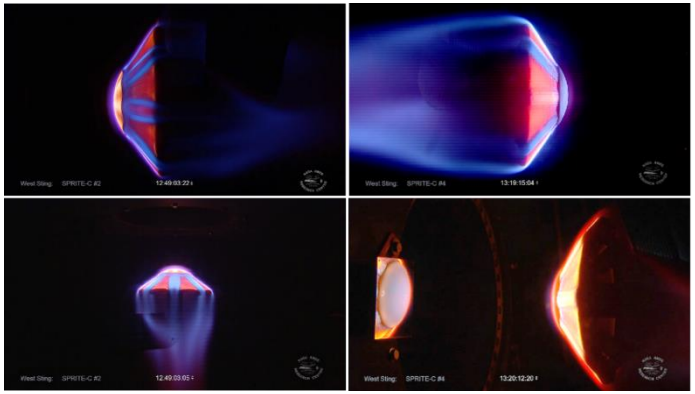
Subsonic Aeroloads Test

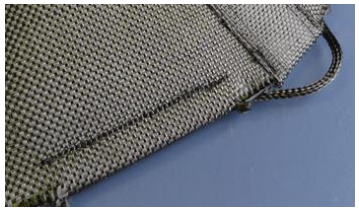




- Understand fabric pre-tension vs deflected shape (photogrammetry)
- Measure load transfer into struts
- Determine if detrimental aeroelastic behavior is observed while varying dynamic pressure and pre-tension

System Level Arc Jet Testing



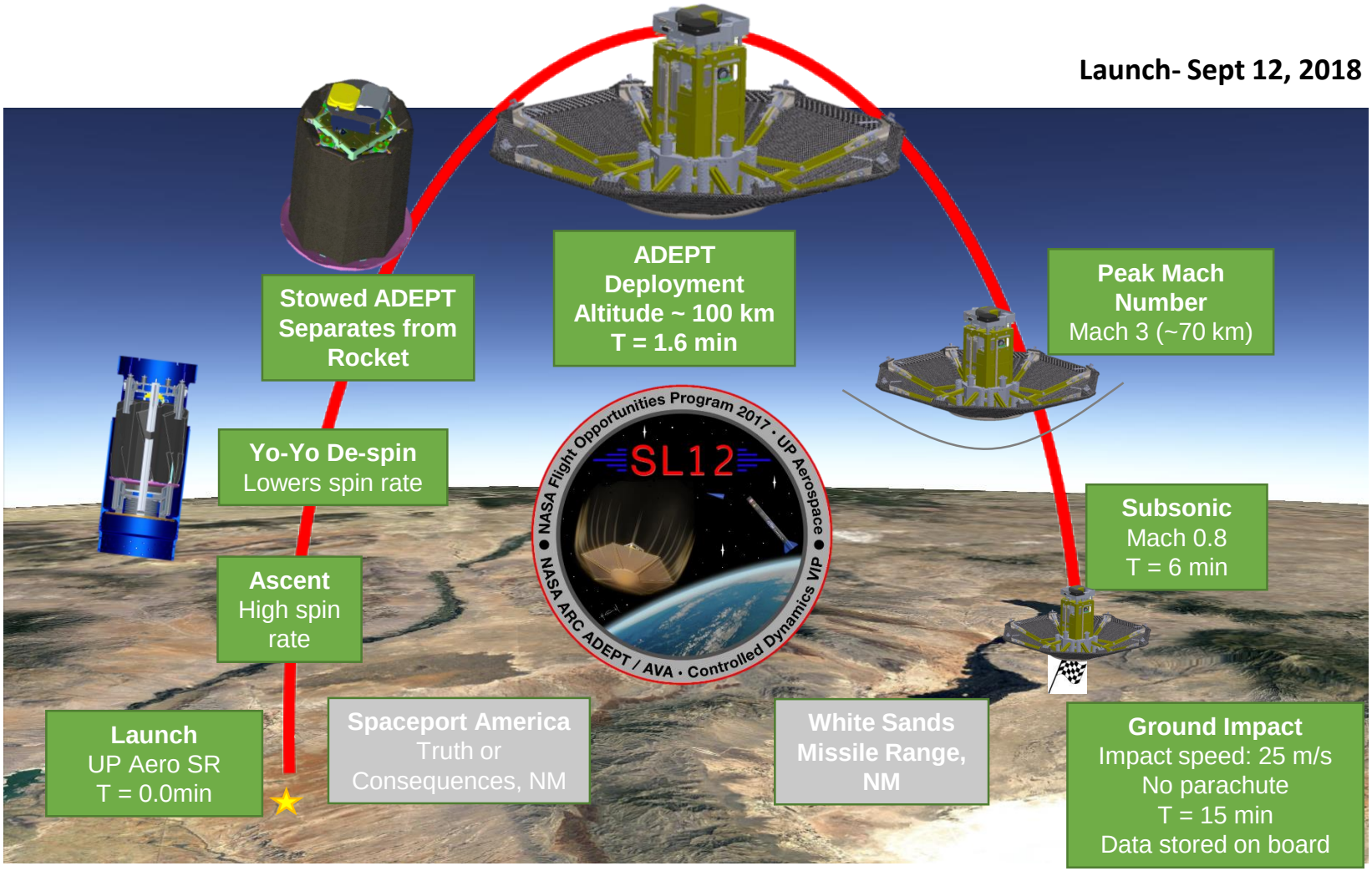


TRAILING EDGE TENSION CORD POCKET

JOINT STITCHING & INSULATING LAYERS

- Develop ADEPT 3U system level ground test methodology to evaluate various designs
- Utilizes high strength stitched joints and trailing edge tension cord
- Integrates with various nose ablator materials included heritage PICA (Mars Science Lab) and HEEET (high density ablator).

ADEPT 3U Suborbital Flight Experiment Overview

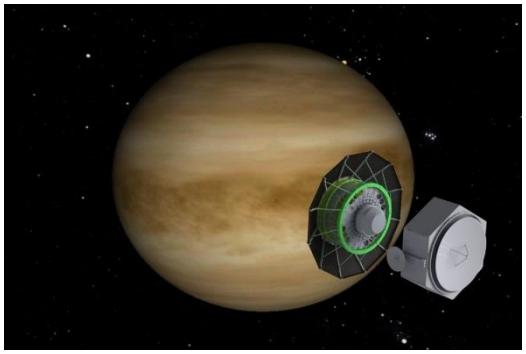


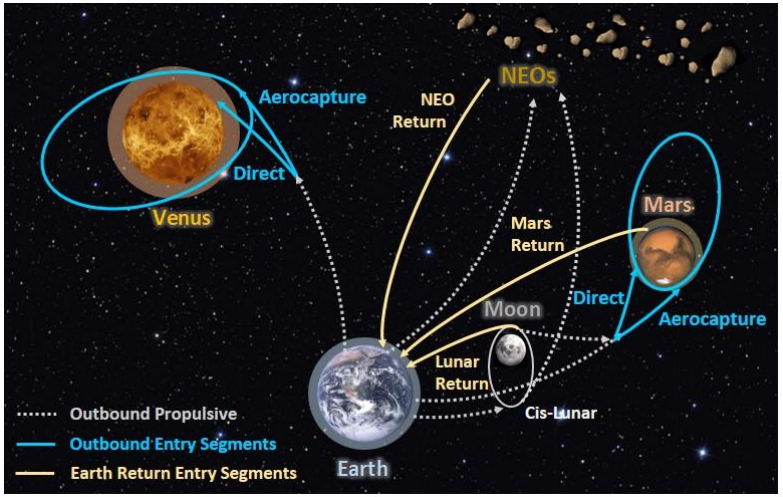
Key Performance Parameter 1: *Exo-atmospheric deployment to entry configuration*
Key Performance Parameter 2: *Demonstrate Aerodynamic stability without active control*

Interplanetary Mission Concepts with Entry Segments

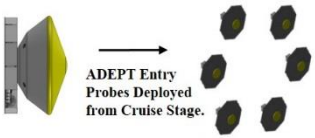
ADEPT has applicability to multiple entry mission concepts

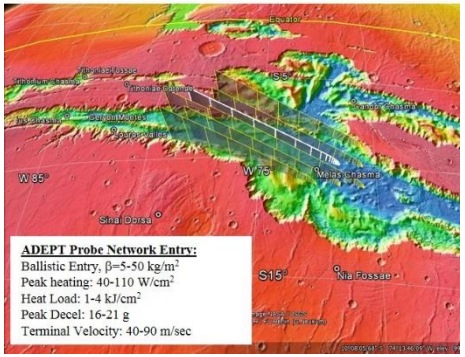
Venus Entry



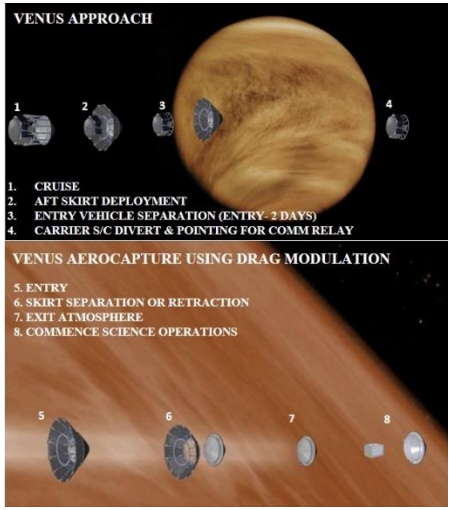


Mars network probe mission

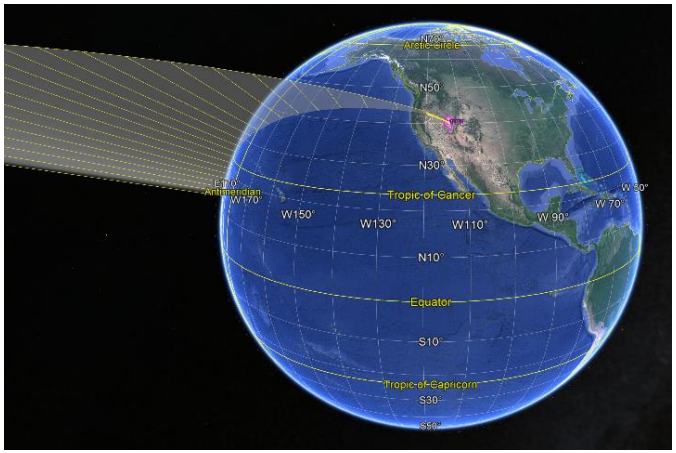




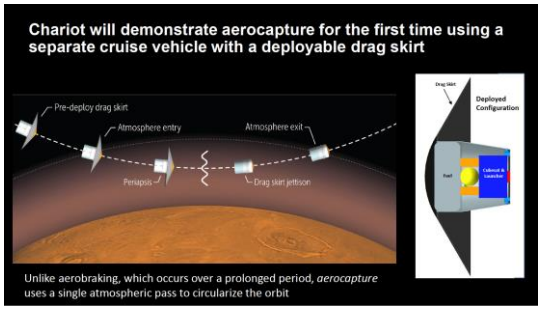
Venus Aerocapture



Sample Return Missions

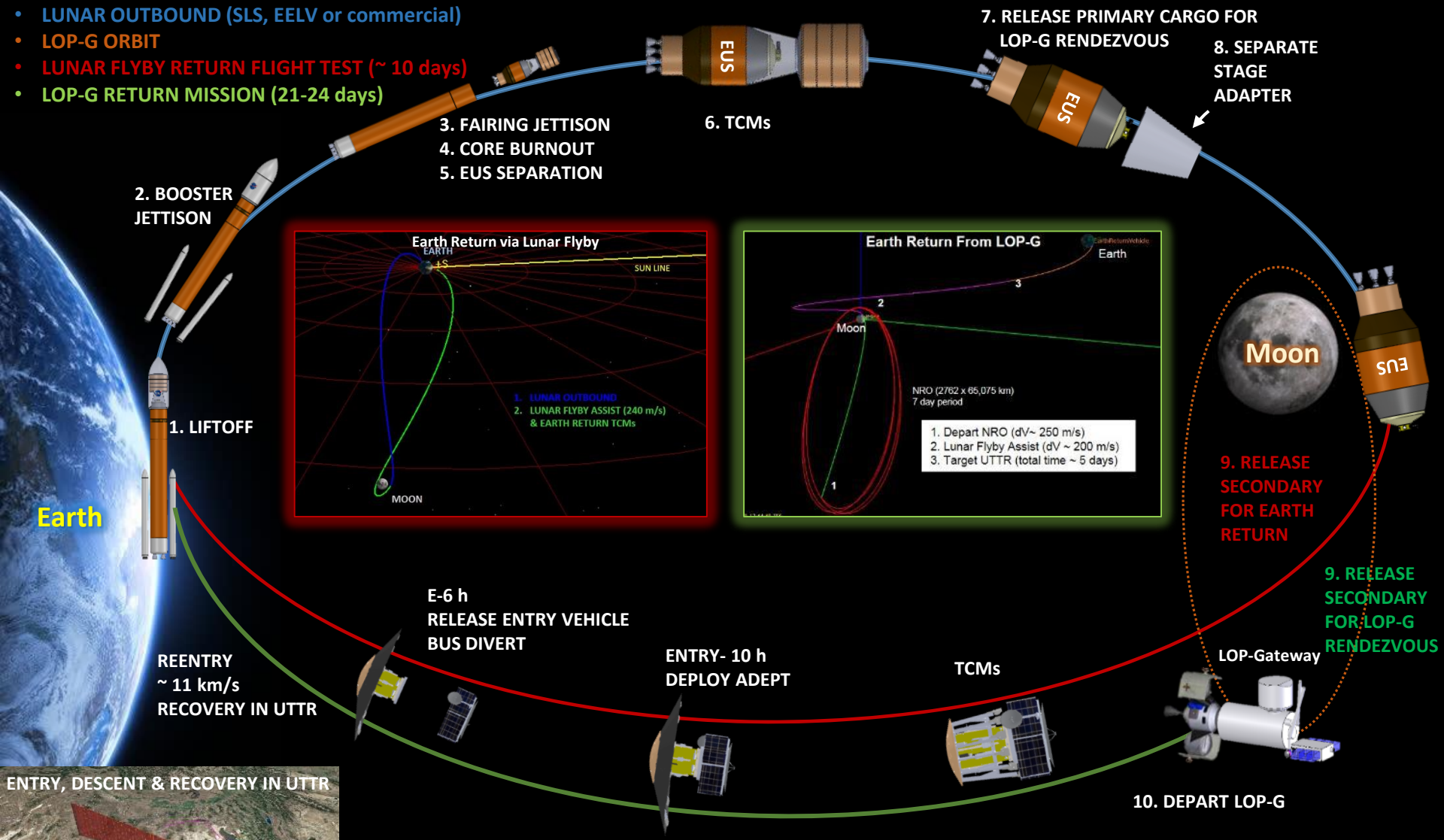


Mars Aerocapture



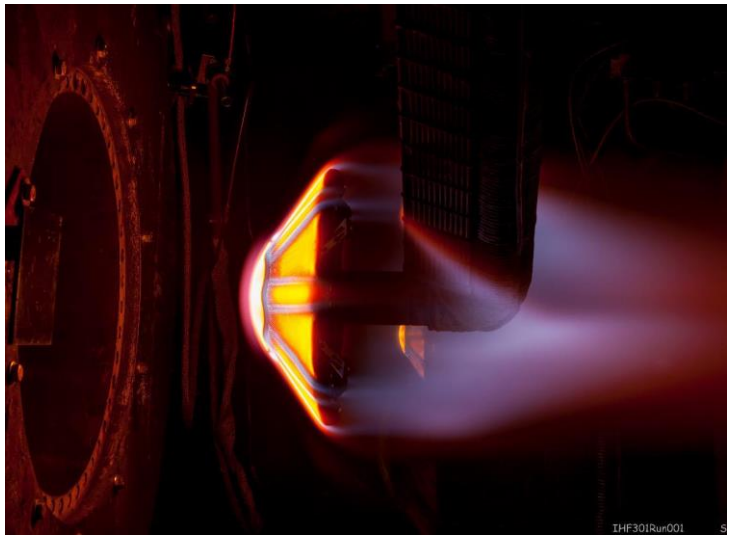
Cis-Lunar Return Mission Concepts

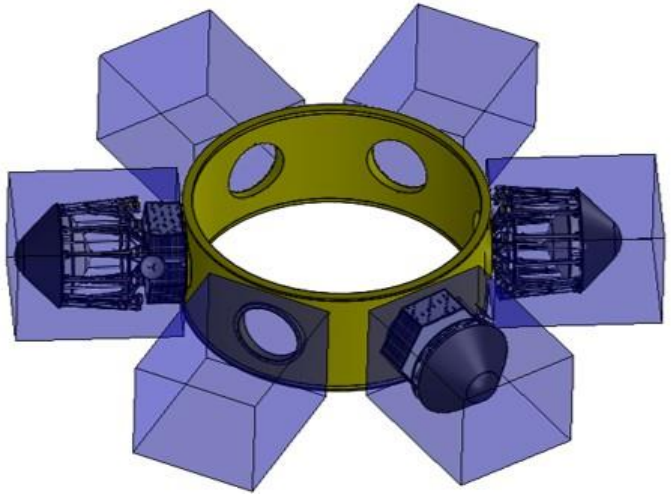
- LUNAR OUTBOUND (SLS, EELV or commercial)
- LOP-G ORBIT
- LUNAR FLYBY RETURN FLIGHT TEST (~ 10 days)
- LOP-G RETURN MISSION (21-24 days)



Summary

- **CubeSats beyond low Earth orbit are becoming more mainstream for Solar System Exploration.**
- **ADEPT offers a highly capable entry system technology for the SmallSat community to consider for Deep Space Mission Design incorporating an entry segment.**
- **ADEPT CubeSat class technology development is continuing through a sub-orbital flight demonstration scheduled for September, 2018.**
- **SmallSat missions incorporating an atmospheric entry segment are being considered for missions to Venus, Mars and Earth return that fly as secondary payloads. ADEPT packs more efficiently than rigid aeroshells is ESPA and similar accommodation volumes.**
- **Organizations interested in considering ADEPT mission concepts are encouraged to contact ADEPT team.**





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