Presentation to

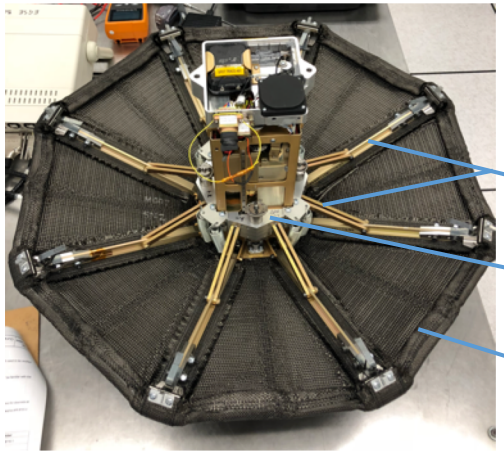
Technology, Innovation & Engineering Committee
NASA Advisory Council

David Hash,	Division Chief (Acting)
Raj Venkatapathy,	Senior Technologist for Entry Systems
Paul Wercinski,	ADEPT Project Manager
Don Ellerby,	HEEET Project Manager
Mike Wright,	EDL SCLT Deputy Lead and ESM Project Manager
Alan Cassell	ADEPT Lead Systems Engineer

August 27th, 2018

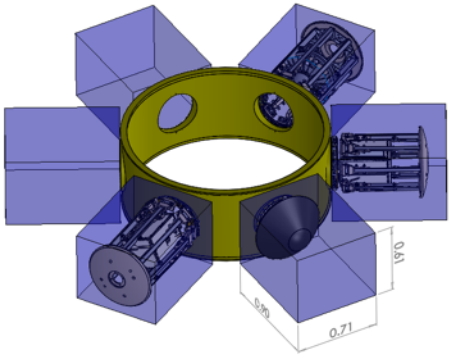
Entry Systems and Technology Division,
NASA Ames Research Center

ADEPT
Development Status and Opportunities

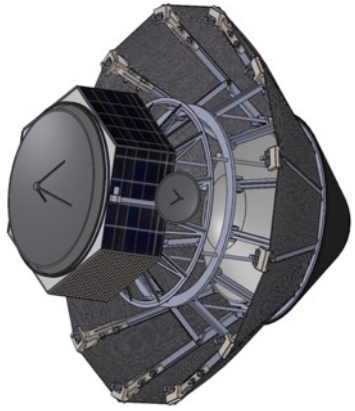


ADEPT SR-1
Sounding rocket launch
Sept 12, 2018 @ WSMR

SmallSat ESPA-CLASS PACKAGING COMPARISON
- ADEPT more efficiently packages in the ESPA dynamic volume than conventional rigid aeroshells
- ADEPT enables diameters up to 2m (only ~0.6 m for rigid)

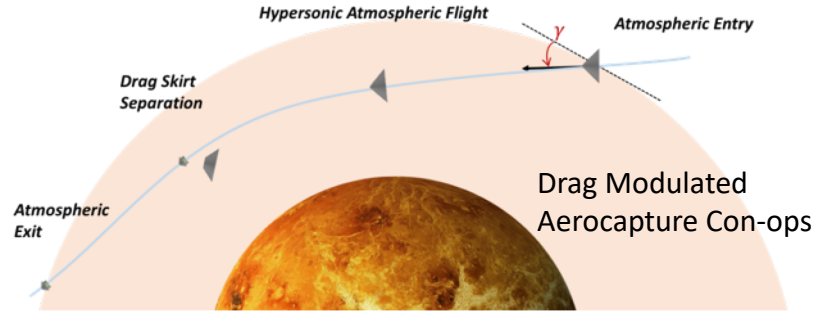


ADEPT offers 2x-4x greater payload volume



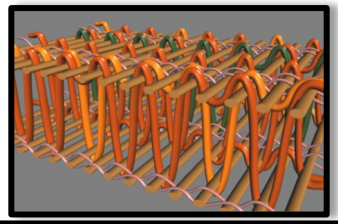
ADEPT Venus Direct entry concept

Recent ADEPT SmallSat Mission Interest
- STMD STP Solicitation: Proposal by Prof. Putnam (UIUC) "Maturation of an Aerocapture Orbit Insertion System to Enable Future Deep Space Small Spacecraft Missions"
  - Ames/ADEPT partner on Proposal
- SMD PSD sponsored Venus Aerial Platform study
  - ADEPT is the only deployable system capable of surviving Venus direct entry
- JPL IRAD (w/ Ames CIF) FY18-19 "Small Satellite Aerocapture for Increased Mass Delivered to Venus" PI: Adam Nelessen (JPL)



ADEPT Future and Opportunities
- Project Pterodactyl FY18 start - Lifting ADEPT GN&C (ECI funded)
- SmallSat mission interest responding to SIMPLEx and other solicitations
- ADEPT seeking SMD sponsorship for FY19 resources for ADEPT Venus SmallSat focus

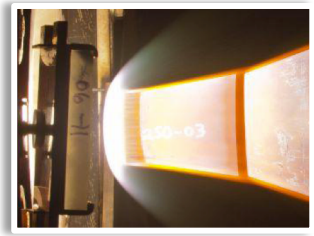
Woven TPS Technology
Enabling Human and Robotic Science Missions



Woven TPS

- Ames Center Investment Fund
- Partnered with Bally Ribbon Mills
- Exploratory

April 2011



Woven TPS

- Competitively selected under 1st BAA by NASA OCT
- Scoping the capability

January 2012

June 2012

3-D Woven Multifunctional Ablative TPS (3D-MAT)
3 years and ~$3M

- Enabling Orion with Lunar Capable Compression Pad
- Challenge: Weaving/Resin Infusion
- Tech Transferred: BRM and SDC
- In use at ~18 different locations

Orion EM1 (2019)

October 2013

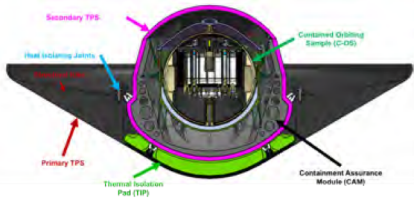
Incentivized for Discovery & New Frontiers

Heatshield for Extreme Entry Environment Technology (HEEET)

- Enable missions to Venus, Saturn and Ice-Giants (~ 5000 W/cm^2, 5 atm)
- Challenge: Weaving & System Integ.
- Tech Transfer to: BRM and FMI
- DoD Pursuing 3-D C-C Leveraging NASA Investments

March 2019 HEEET at TRL 6

MSR EEV (2026)



- High reliability required
- Direct impact – chuteless
- MMOD impact damage tolerance
- Entry Velocity highest for Earth entry
- Currently PICA, C-C and 3-D Woven are under consideration
- HEEET or 3-D Woven variant could meet the requirements

2026 MSR EEV

Entry Systems Modeling

- **Modeling & Simulation is critical path for EDL, in every mission phase, with a reach extending beyond NASA**
- **The Entry Systems Modeling Project (ESM) is focused on delivering real advancements to the current SoA that impact NASA missions**
  - Mid-TRL R&D, with topic areas driven by mission needs
  - Establish a "pipeline" to fundamental research via creative partnerships within NASA, OGAs, and academia to leverage the best new and innovative ideas
    - Over 100 academics (students & faculty) involved each year via multiple funding mechanisms
    - Multiple international partnerships supported (DLR, JAXA, UQ, VKI, Ecole-Supalec)
  - Mature new capabilities and prepare them for mission infusion; products handed to missions and line organizations for application and stewardship
    - Long-term maintenance and support is out of scope; remains a significant challenge for the Agency

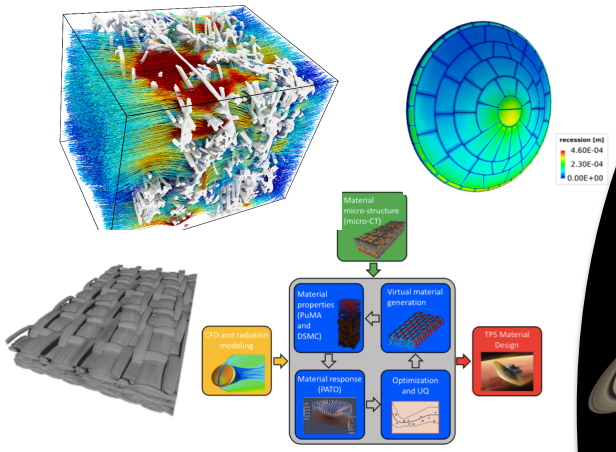
"For complex missions that cannot be fully tested on Earth, we rely on computer models to convince ourselves that the integrated system will work in its intended environment. We have no other way to do this. Detailed subsystem hardware and software testing help us validate that each of these models do a good job of representing reality."

-- Rob Manning, Mars Program Chief Engineer

Entry Systems Modeling
Key Investment Areas – FY18-FY20

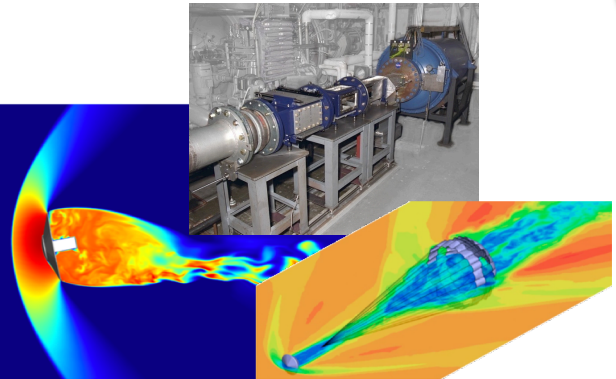
Predictive Materials Modeling

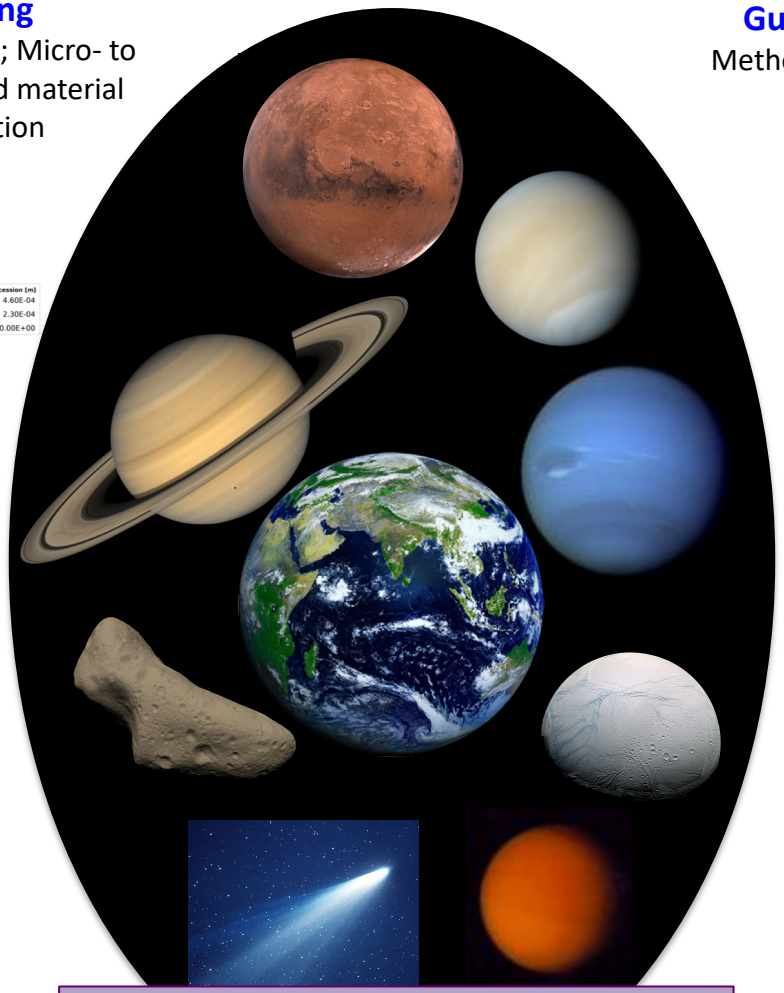
Advanced models of PICA and woven TPS; Micro- to engineering-scale analysis tools; Detailed material characterization and model validation



Aerosciences

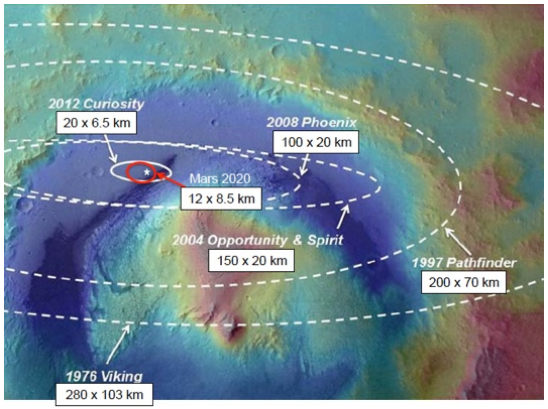
Parachute dynamics; Free-flight CFD; Magnetic suspension wind tunnels; Experimental validation; Roughness, Advanced computational methods





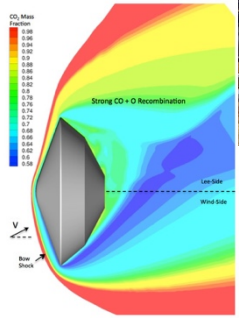
Guidance, Navigation, and Control

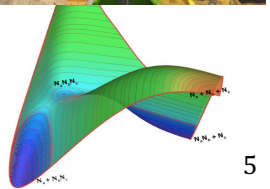
Methods for precision landing of large robotic and human Mars missions



Shock Layer Kinetics and Radiation

Shock layer radiation databases and models for all destinations of interest; High-fidelity analysis tools

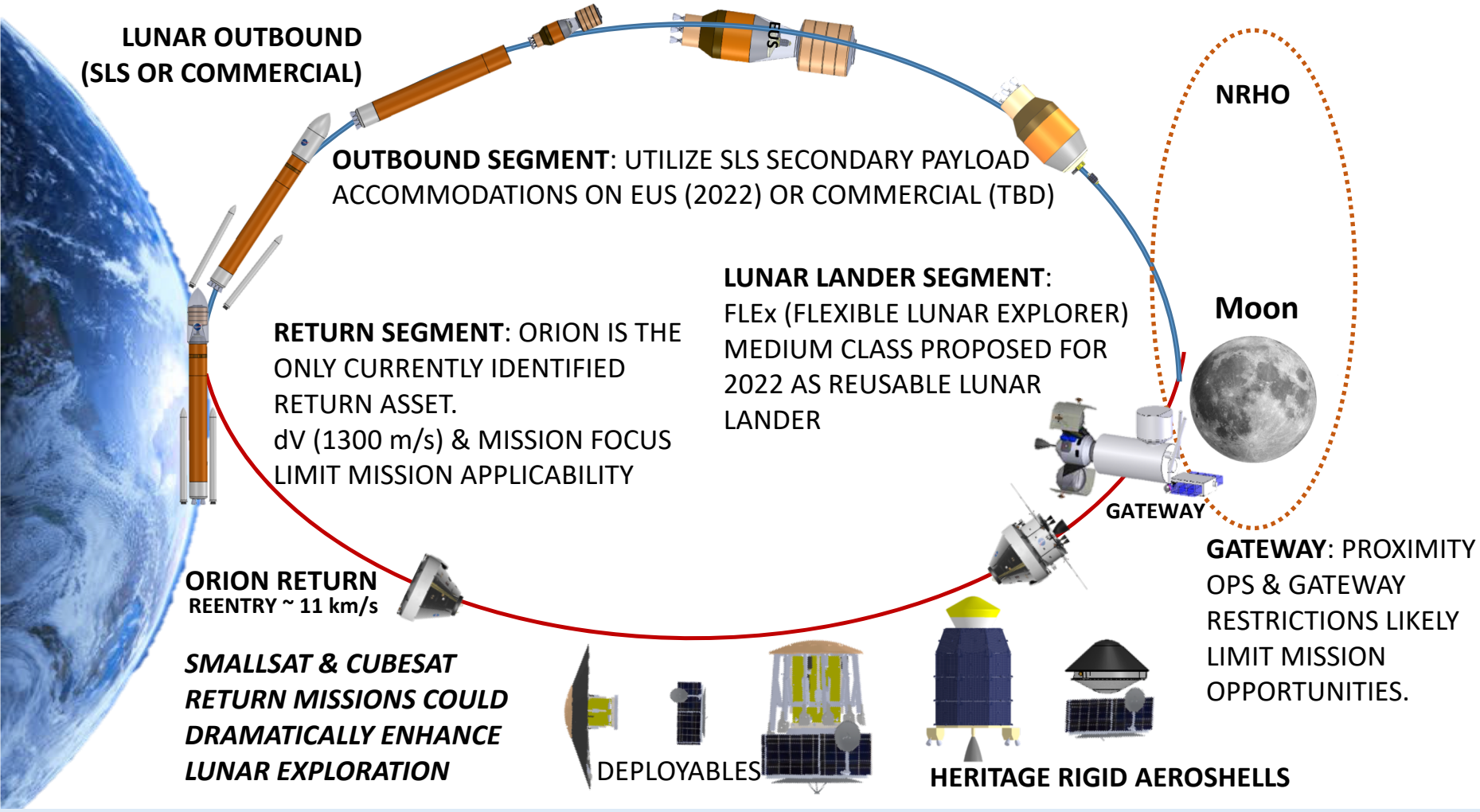




ESM is the <u>only</u> dedicated research effort for EDL modeling at NASA, impacting all mission directorates and exploration programs with EDL.

Cis-Lunar Sample Return Mission Development

PROBLEM STATEMENT: GIVEN ORION FREQUENCY (~18 MONTHS) AND PRIMARY HUMAN OPS FOCUS, HOW DOES ADDITIONAL CIS-LUNAR SAMPLE RETURN CAPABILITY ADVANCE LUNAR EXPLORATION AND COMMERCE?



ACCELERATE CIS-LUNAR EXPLORATION VIA SMALL SAT PAYLOAD RETURN CAPABILITIES

- **2013 NRC DECADAL SURVEY RECOMMENDED DEVELOPING LUNAR SAMPLE RETURN CAPABILITY TO ENHANCE LUNAR EXPLORATION**
- **LIFE SCIENCES BEYOND LEO WOULD DRAMATICALLY BENEFIT FROM SAMPLE RETURN CAPABILITY (RADIATION AND COMBINED EFFECTS)**
- **EXPLORE MISSION CONCEPTS THAT MAKE USE OF SECONDARY PAYLOAD ACCOMODATIONS FOR EARTH RETURN, INCLUDING CAPABILITIES THAT REQUIRE CRYOPRESERVED AND DECELERATION SENSITIVE PAYLOADS**