Overview of Entry, Descent and Landing Issues

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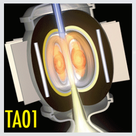
STMD EDL Principal Investigator

Presentation to the VEXAG

November 19, 2013

Space Technology Technical Areas

TA01

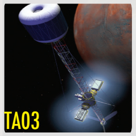


- LAUNCH PROPULSION SYSTEMS

TA02

- IN-SPACE PROPULSION TECHNOLOGIES

TA03

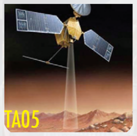


- SPACE POWER & ENERGY STORAGE

TA04

- ROBOTICS, TELE-ROBOTICS & AUTONOMOUS SYSTEMS

TA05



- COMMUNICATION & NAVIGATION

TA06

- HUMAN HEALTH, LIFE SUPPORT & HABITATION SYSTEMS

TA07

- HUMAN EXPLORATION DESTINATION SYSTEMS

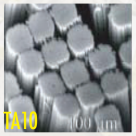
TA08

- SCIENCE INSTRUMENTS, OBSERVATORIES & SENSOR SYSTEMS

TA09

- ENTRY, DESCENT & LANDING SYSTEMS

TA10



- NANOTECHNOLOGY

TA11

- MODELING, SIMULATION, INFORMATION TECHNOLOGY & PROCESSING

TA12

- MATERIALS, STRUCTURES, MECHANICAL SYSTEMS & MANUFACTURING

TA13

- GROUND & LAUNCH SYSTEMS PROCESSING

TA14

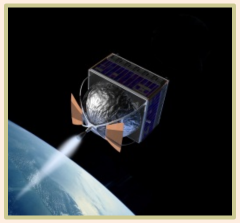
- THERMAL MANAGEMENT SYSTEMS

Space Technology Portfolio

Transformative & Crosscutting Technology Breakthroughs

Game Changing Development

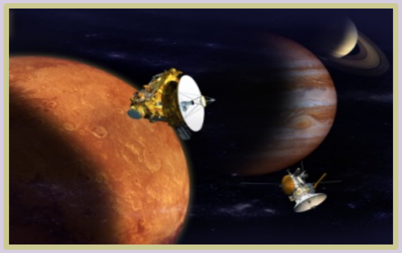
Technology Demonstration Missions



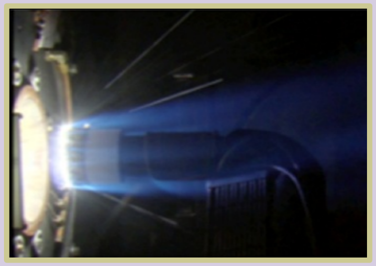
Small Spacecraft Technologies

Pioneering Concepts/ Developing Innovation Community

Space Technology Research Grant



NASA Innovative Advanced Concepts



Center Innovation Fund

Creating Markets & Growing Innovation Economy

Centennial Challenges Prize

Small Business Innovation Research & Small Business Technology Transfer (SBIR/STTR)

Flight Opportunities

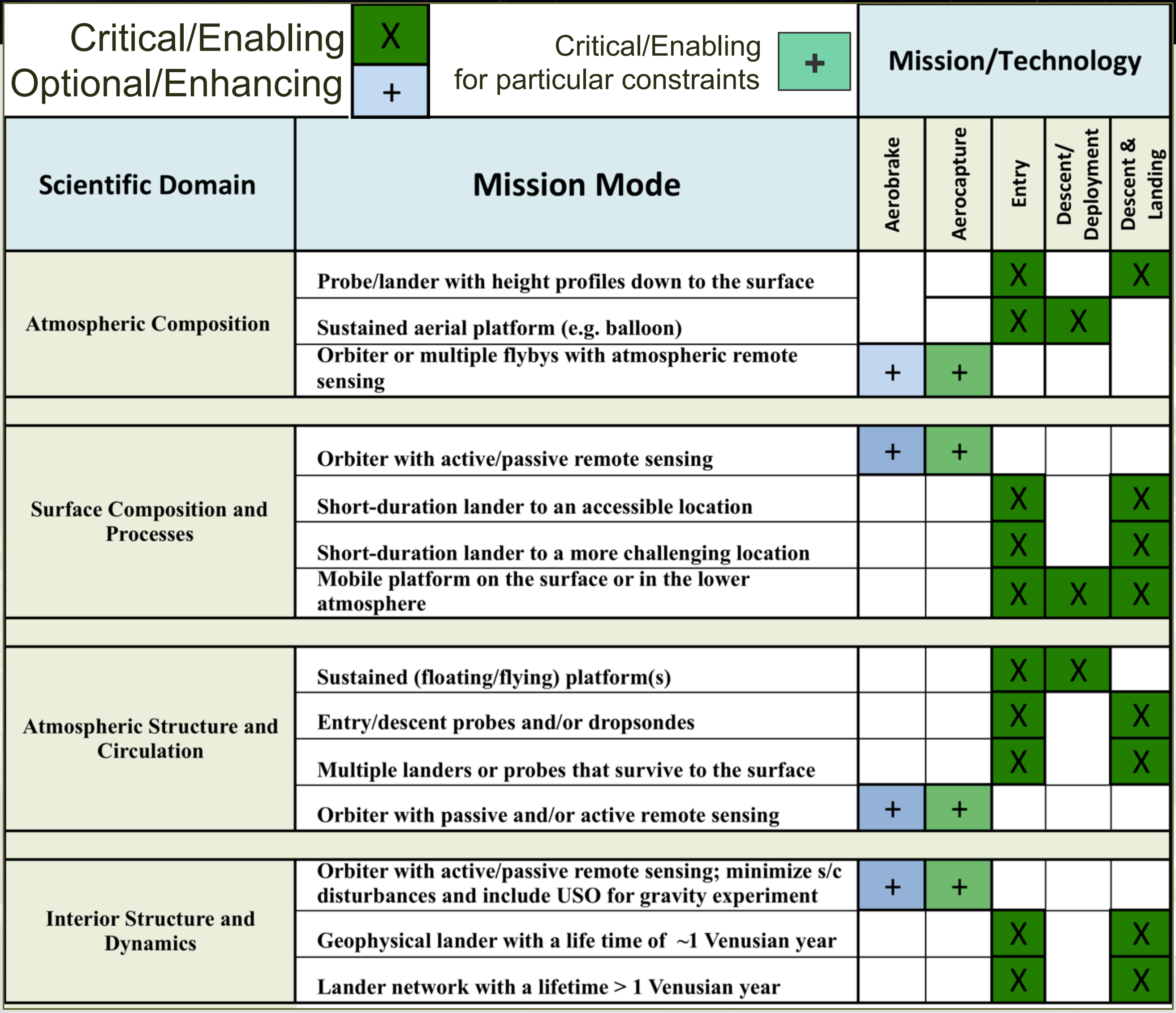
Entry Technology
VEXAG Findings, Nov. 2012

- Continued development of entry technologies is critical to ensuring availability for New Frontiers-4 and Discovery 13 Venus mission proposals.

- VEXAG encourages NASA's Planetary Science Division to continue the advocacy for and monitor the progress of entry technologies that Space Technology Mission Directorate is currently investing in, and entry technologies available from industry, and then to coordinate the release of the most current technical information prior to issuance of the Announcements of Opportunity.

- VEXAG also encourages NASA to incentivize the adoption of entry technologies needed for these missions including instrumentation to monitor the performance of the thermal protection systems.

Scientific Focus, Mission Modes and Technologies



Critical/Enabling X
Optional/Enhancing +
Critical/Enabling for particular constraints +

Scientific Domain	Mission Mode	Mission/Technology				
		Aerobrake	Aerocapture	Entry	Descent/ Deployment	Descent & Landing
Atmospheric Composition	Probe/lander with height profiles down to the surface			X		X
	Sustained aerial platform (e.g. balloon)			X	X	
	Orbiter or multiple flybys with atmospheric remote sensing	+	+			
Surface Composition and Processes	Orbiter with active/passive remote sensing	+	+			
	Short-duration lander to an accessible location			X		X
	Short-duration lander to a more challenging location			X		X
	Mobile platform on the surface or in the lower atmosphere			X	X	X
Atmospheric Structure and Circulation	Sustained (floating/flying) platform(s)			X	X	
	Entry/descent probes and/or dropsondes			X		X
	Multiple landers or probes that survive to the surface			X		X
	Orbiter with passive and/or active remote sensing	+	+			
Interior Structure and Dynamics	Orbiter with active/passive remote sensing; minimize s/c disturbances and include USO for gravity experiment	+	+			
	Geophysical lander with a life time of ~1 Venusian year			X		X
	Lander network with a lifetime > 1 Venusian year			X		X

Note: Science objectives and mission modes from the Venus Exploration Roadmap document

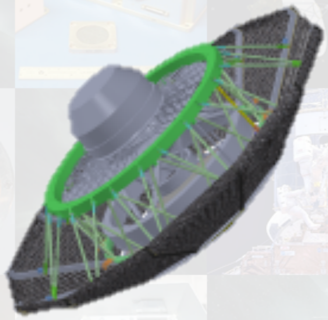
System Technologies

Entry Technology - Status

- The thermal protection systems that were used for the Pioneer Venus direct entry probes can no longer be manufactured or qualified
- Venus Entry needs:
  - Ablative TPS for conventional aeroshell heatshield and backshell
  - Low ballistic coefficient (deployable entry system):
    - Enables large landers and balloon missions that require low (30'g – 50'g) for enabling sensitive science instruments or ASRG power system.
- Space Technology Mission Directorate is making investments in entry technologies such as Woven TPS, deployable and inflatable entry systems.

3-D Woven

Multi-mission capable
3-D Tailorable TPS



Deployable Entry System

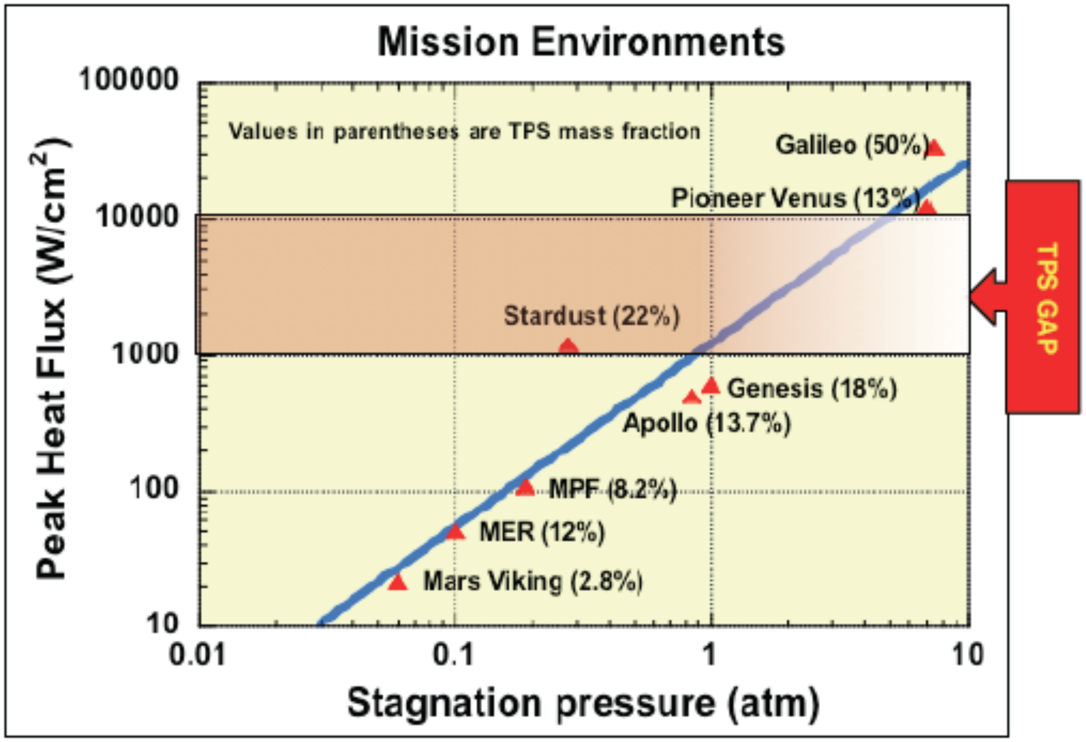
Emerging entry technologies can enable other technologies such as ASRG

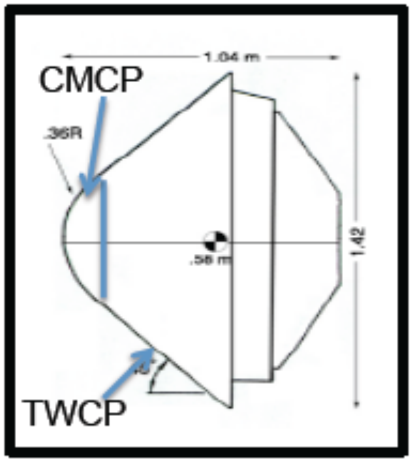
Entry Technology Options and Status

Readiness

- The heritage carbon phenolic TPS used in previous Venus missions no longer available but an attempt could be made to recreate it
  - An ablative carbon phenolic replacement needs to be requalified for the Venus entry conditions. **Unfunded** 🟥
- STMD is investing in ablative TPS for both heatshield and backshell for sustainable manufacturability, better payload fraction and reduced entry loads
  - 3-D Woven TPS is more robust, sustainable and mass efficient (40% lighter) compared to heritage carbon phenolic for heatshields. **Currently funded** 🟩
  - Conformal TPS (CA250) is easier to integrate and more mass efficient (factor of 2 compared to PICA) on the backshell. **Currently funded** 🟨
  - Low ballistic coefficient technologies (mechanical deployable and inflatable) with a potential mission application for Venus direct and aerocapture entries. **Currently funded** 🟨

Thermal Protection System Needs





Carbon-Phenolic heatshield requires Chop Molded and Tape-Wrapped manufacturing capability

- The only flight proven TPS that can meet the extreme entry environment (heat-flux, pressure, entry g'load) is **heritage, entry-grade carbon phenolic**
- **Decadal survey missions, Venus, Saturn and Uranus, baseline heritage carbon-phenolic**

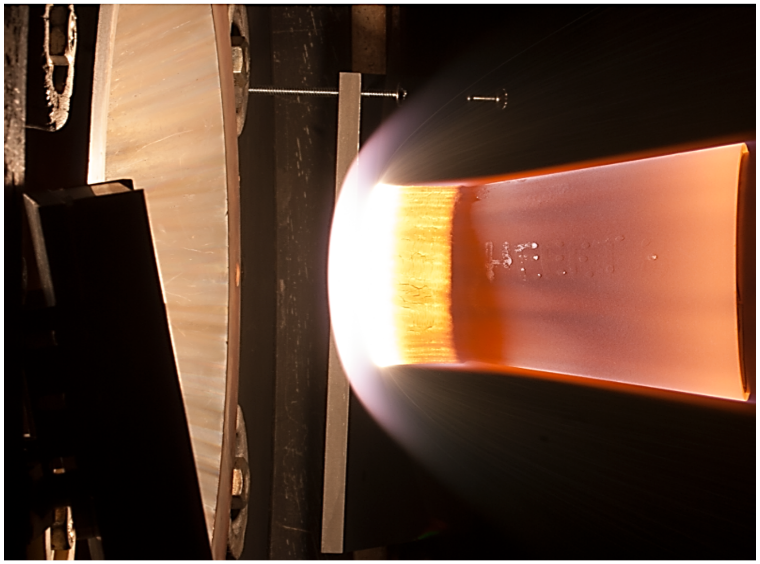
Progress in Testing Relevant Environments

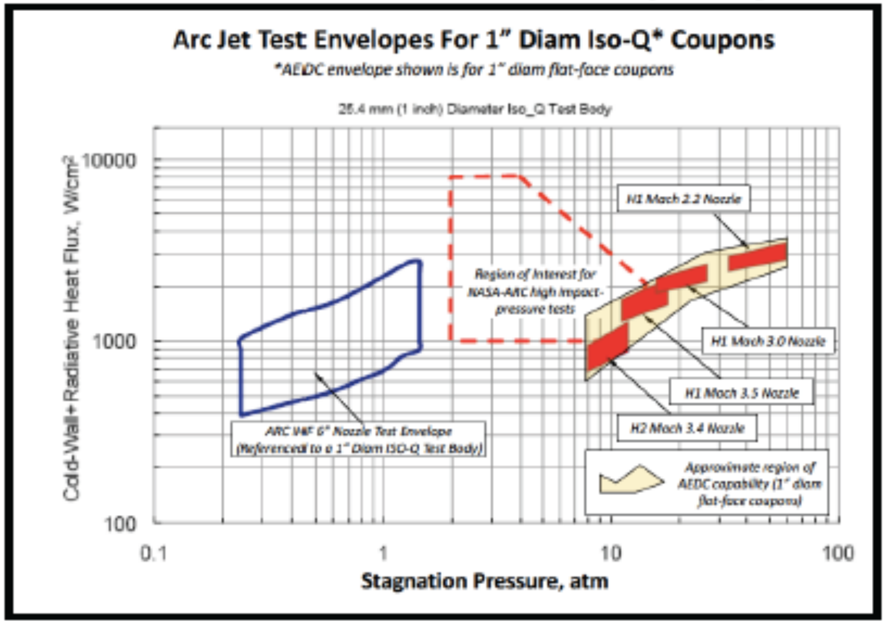
Decadal Sponsored Mission Studies

	Saturn Probe	Venus Lander (VITAL)	Venus Balloon (VCM)	Uranus Probe
Size - Entry System, m	1.0	3.5	2.0	0.76
Mass – Entry System, kg	216	2700	330	127
Mass – Heat shield, kg	92	932	208	33
Entry - Peak Heat-Flux, W/cm^2	~5000	~4500	4250	5500
Entry - total HeatLoad, J/cm^2	~200,000	~ 13,000	~18,000	38,000
Entry – Peak Pressure, atm	4 - 6	~ 5	~4.0	N/A

Mission Thermal Requirements

Arc Jet Test Capability



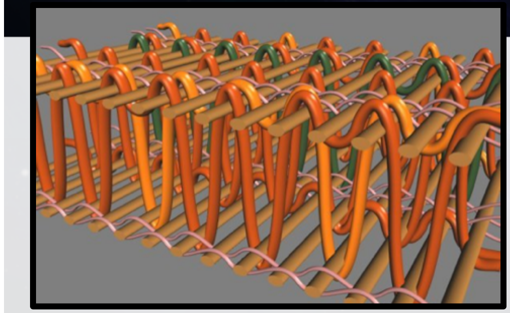


Summary/Current Status

- Future Venus missions are enabled or enhanced by entry systems technologies including TPS and deployable aeroshells
- NASA’s Space Technology Mission Directorate is investing in technologies to enable and enhance Venus missions:
  - Woven TPS
  - Conformal TPS
  - Deployable aeroshells
  - Foundational modeling—CFD and materials
- Funding levels are not ideal; progress and customer needs are constantly being reviewed, but there has been, and will be, significant progress before AO release
- An agreement between STMD and SMD to facilitate technology delivery and detail any incentivization is being drafted

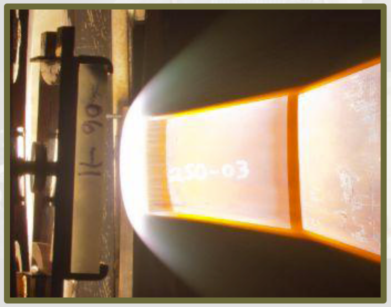
Additional Information

Heatshield for Extreme Entry Environment Technology (HEEET)



Designing the Weave

Weaving the TPS



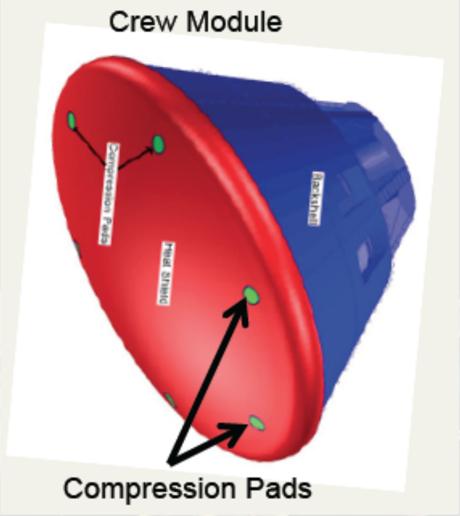
Testing the TPS

Fills a critical gap in TPS technology for high-heating missions

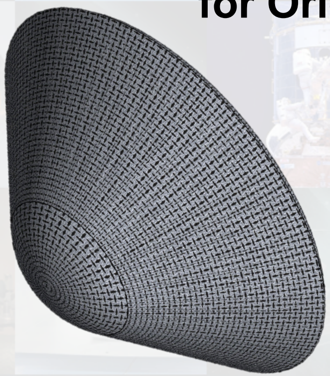
Alternative to nearly-obsolete Carbon Phenolic

Rooted in sustainable textile industry

Enables science missions to the far corners of the Solar System, and human missions



Near-Term Infusion: Lunar Capable Compression Pad for Orion

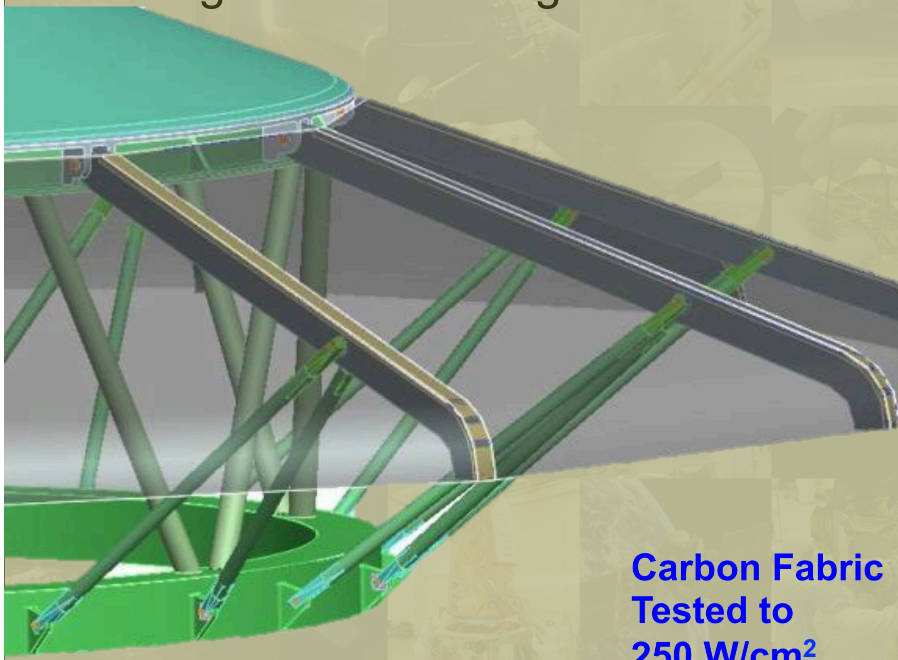


SMD Mission Infusion: Venus, Saturn, High-Speed Sample Return

Adaptable, Deployable Entry and Placement Technology (ADEPT)

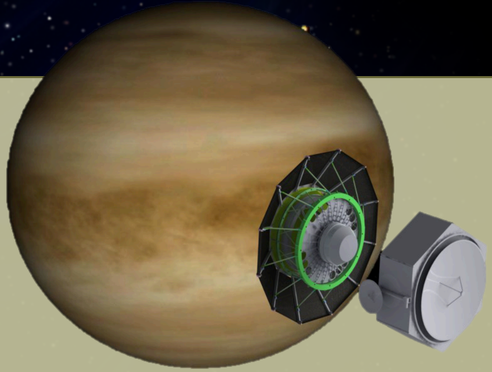
Mechanically Deployable, Low Ballistic Coefficient Entry Architecture Enabling:

- Venus science missions with very low G-load (< 30 g's)
- Venus upper atmosphere balloon missions with ASRG
- Mars robotic landers with mass greater than MSL
- Mars exploration with pole-to-pole surface access
- Long term: Enabling Human Mars Exploration

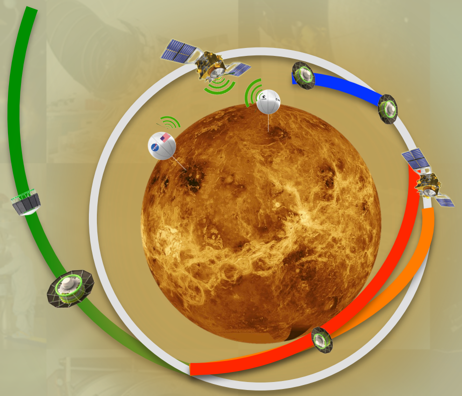


6m ADEPT Deployed

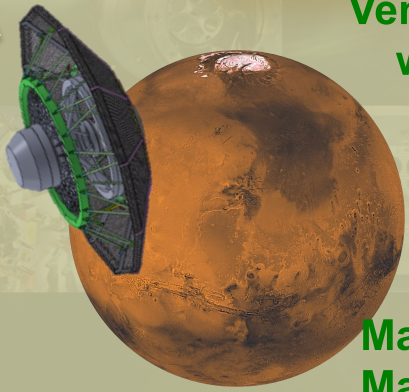
Carbon Fabric Tested to 250 W/cm^2



Venus Lander



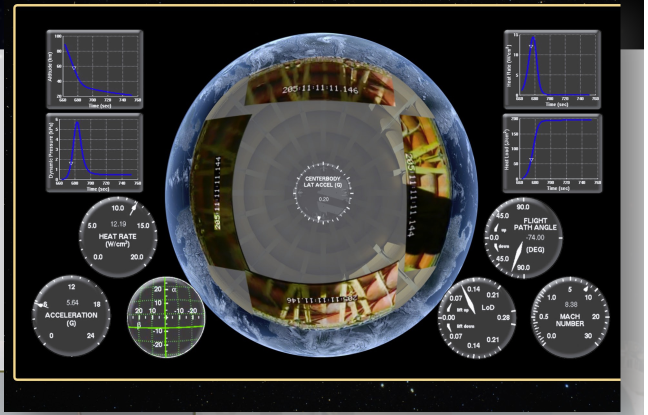
Venus Balloon with ASRG

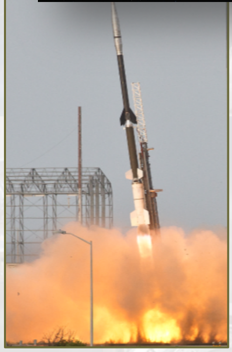


Mars Heavy Mass Landers

Hypersonic Inflatable Aerodynamic Decelerator (HIAD)

- Enabling at Mars; applications at Earth, Titan, Venus
- Inflated exo-atmospherically, allowing larger entry drag areas not limited by launch vehicle fairing
- Lower ballistic coefficient allows higher altitude deceleration, providing access to higher surface elevations, greater landed mass, lower g's, and longer EDL timelines.
- Feasibility at 3-6 m scale established through ground and flight test

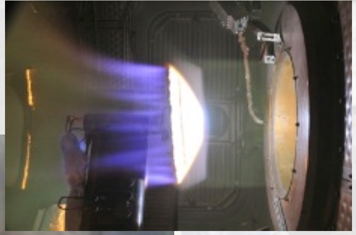




Sub-scale HIAD Flight Test – IRVE-3 (2012)

NFAC Aerodynamic Test

Flexible TPS



Inflatable Structure

Hypersonic Entry, Descent and Landing (HEDL)

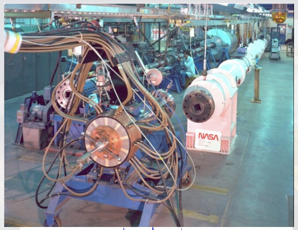
HEDL is a foundational EDL research PORTFOLIO project within GCD

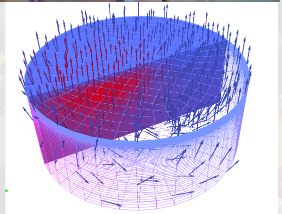
Goals:

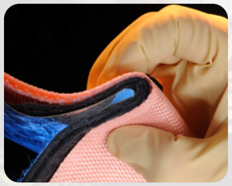
- Deliver advanced physics based models to enable informed decision-making
- Explore new component-level EDL technologies with feed forward to existing projects or programs

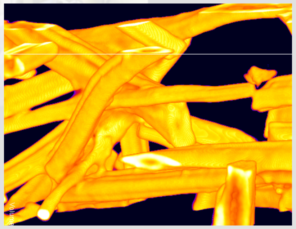
Aerosciences

- Completion and delivery of two new aerothermal CFD codes (US3D and FUN3D)
- A first-ever validated shock layer radiation model
- An experimental validation database, at flight-relevant enthalpy, for current and future generations.









EDL Materials

- Development and delivery of two new flexible TPS systems to enable HIAD missions
- Vastly improved ablator modeling capability
- Improved polymer resins for future woven, flexible and conformal TPS.