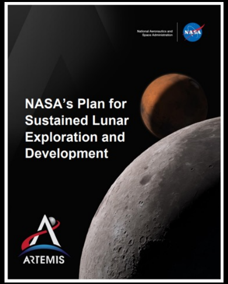
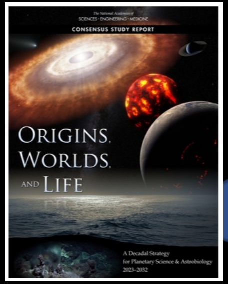
NASA’S Envisioned Futures (And Where We Fit)

Michael Wright
Acting Lead, NASA EDL Strategic Capability Leadership Team

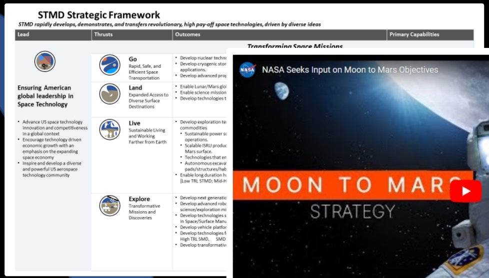
Strategic Technology Architecture Roundtable (STAR) Process





Draws directly on Artemis architecture and science decadal to identify technology gaps

Strategic Framework describes STMD's investment strategy. It aligns to the agency Moon to Mars Objectives and with science and industry partner needs, prioritized by NASA Strategic Capability Leads (SCLs) and Principal Technologists (PTs).



Community input to validate envisioned futures, the current state of the art, and gaps

STAR

STAR process inclusive of center chief technologists, ESDMD, and SMD inputs

Maps to OTPS Taxonomy

STARPORT

Internal STMD & ESDMD gap database

+

Envisioned Future Priorities

PPBE process

Envisioned Future priorities were developed by SCLs/PTs to show the pictured future state and suggested path forward to inform STMD's planning, programming, budgeting, and execution (PPBE) process.

STMD Strategic Framework Definitions

THRUSTS

Broad categories of strategic impact (Go; Land; Live; Explore)

Go: Rapid, safe, & efficient space transportation

STRATEGIC OUTCOMES

High-level goals under each thrust

Develop technologies to land payloads within 50 meters accuracy and avoid landing hazards.

CAPABILTY AREAS

Key technology focus areas aligned to NASA System Capability Leads and Principal Technologists

Advanced Propulsion; Entry, Descent and Landing; ISRU

ENVISIONED FUTURE PRIORITIES

Document that communicates an envisioned future for a capability area, the current state of the art, major gaps, and how to close gaps

TECHNOLOGY GAPS

Technical hurdles that need to be overcome to enable an envisioned future

TECHNOLOGY INVESTMENTS

Projects that aim to close technology gap(s) in one or more capability areas

STMD Strategic Framework

THRUSTS		OUTCOMES	CAPABILITIES
Lead **Ensuring American global leadership in space technology** • Advance US space technology innovation and competitiveness in a global context • Encourage technology driven economic growth with an emphasis on the expanding space economy • Inspire and develop a diverse and powerful US aerospace technology community	**Go** **Rapid, Safe, & Efficient Space Transportation**	• Develop nuclear technologies enabling fast in-space transits. • Develop cryogenic storage, transport, and fluid management technologies for surface and in-space applications. • Develop advanced propulsion technologies that enable future science/exploration missions.	• Nuclear Systems • Cryogenic Fluid Management • Advanced Propulsion
	Land **Expanded Access to Diverse Surface Destinations**	• Enable Lunar/Mars global access with ~20t payloads to support human missions. • Enable science missions entering/transiting planetary atmospheres and landing on planetary bodies. • Develop technologies to land payloads within 50 meters accuracy and avoid landing hazards.	• Entry, Descent, Landing, & Precision Landing

	Live
	Sustainable Living and Working Farther from Earth
		• Develop exploration technologies and enable a vibrant space economy with supporting utilities and commodities
		  • Sustainable power sources and other surface utilities to enable continuous lunar and Mars surface operations.
		  • Scalable ISRU production/utilization capabilities including sustainable commodities on the lunar & Mars surface.
		  • Technologies that enable surviving the extreme lunar and Mars environments.
		  • Autonomous excavation, construction & outfitting capabilities targeting landing pads/structures/habitable buildings utilizing in situ resources.
		• Enable long duration human exploration missions with Advanced Habitation System technologies.
			• Advanced Power
			• In-Situ Resource Utilization
			• Advanced Thermal
			• Advanced Materials, Structures, & Construction
			• Advanced Habitation Systems

	Explore **Transformative Missions and Discoveries**	• Develop next generation high performance computing, communications, and navigation. • Develop advanced robotics and spacecraft autonomy technologies to enable and augment science/exploration missions. • Develop technologies supporting emerging space industries including: Satellite Servicing & Assembly, In Space/Surface Manufacturing, and Small Spacecraft technologies. • Develop vehicle platform technologies supporting new discoveries. • Develop technologies for science instrumentation supporting new discoveries. • Develop transformative technologies that enable future NASA or commercial missions and discoveries	• Advanced Avionics Systems • Advanced Communications & Navigation • Advanced Robotics • Autonomous Systems • Satellite Servicing & Assembly • Advanced Manufacturing • Small Spacecraft • Rendezvous, Proximity Operations & Capture • Sensor & Instrumentation

Envisioned Future Priorities in “Land” Thrust

EXPLORESPACE TECH
TECHNOLOGY DRIVES EXPLORATION

Enable Lunar/Mars Global Access and ~20t Payloads

Precision Landing and Hazard Avoidance

Entry, Descent, and Landing to Enable Planetary Science Missions

EDL Gaps

- **A total of 66 technology gaps were identified within the EDL Discipline**
  - Gaps span hardware, software and infrastructure needs
- **Gaps were mapped to SMD & STMD desired outcomes and “Land” envisioned priorities**
  - A few EDL gaps were mapped to “Explore” due to their focus on commercial space
- **Prioritized by SCLT leadership in conjunction with Agency SMEs**

EXPLORESPACE TECH

TECHNOLOGY DRIVES EXPLORATION

LAND: Enable Lunar/Mars Global Access and ~20t Payloads

NASA Space Technology Mission Directorate

August 2022

STMD welcomes feedback on this presentation:

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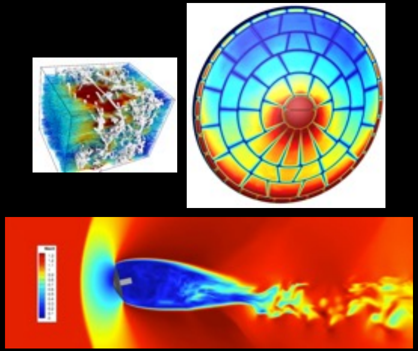
Current Investments to Achieve 20t Landings

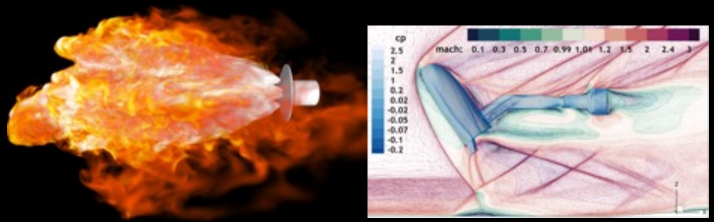
LOFTID
6m inflatable aeroshell test with United Launch Alliance (ULA) - 2022

***SPLICE**
Precision Landing/Hazard Detection sensor, computing, and algorithm development, flight testing, and commercialization
(see separate package for "50 m" outcome)

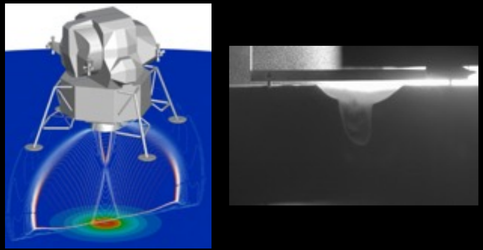


Entry Systems Modeling (ESM)
Advancing core capabilities and reducing mission risk through validation (Aerodynamics, Aerothermal, TPS, GN&C)

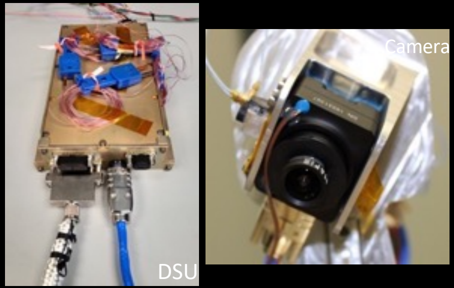
MEDLI2
Heating and pressure sensors on Mars 2020 aeroshell; provides aero/aerothermal model validation data (post-flight data analysis in progress)



Descent Systems Study
Mid L/D ground testing complete
HIAD and all SRP testing FY22-23



***Plume Surface Interaction (PSI)**
Model Advancement and Validation through Ground Testing, Flight instrument maturation



***SCALPSS**
Stereo Cameras to measure Plume Surface Interaction under CLPS landers; provides PSI model validation data

Early-Stage investments such as SBIR and academic efforts contribute to most projects shown
****Orange = Demonstration for Lunar missions in Near Term; Lunar-focused investments feed forward directly to Mars***

Highest-Priority Technology Gaps

There are 20 identified gaps mapped to the "Land 20t" outcome.

- **Aeroshell (Hypersonic Deceleration) System**
  - Flight Test Validation of Integrated High-Mass Mars Entry and Descent Architectures
  - Control Technologies for Exploration Class Inflatable Decelerator
  - Aeroshell/TPS Reliability Prediction
- **Ground Development and Scale-Up of Inflatable Decelerators and Large Structures**
- **Retropropulsion (Supersonic Deceleration) System**
  - Supersonic Retropropulsion (SRP) Modeling & Simulation
  - Supersonic Retropropulsion (SRP) Guidance, Navigation and Control
- **Validated Prediction of Plume-Surface Interaction (PSI) for Mars Landers**
- **Foundational Modeling and Testing, Instrumentation, and Computing**
  - High-End Computing Capability for EDL Modeling
  - Multi-disciplinary / coupled EDL Performance Models
  - Validated Aerothermodynamic Prediction for Human Mars EDL
  - Thermal Protection System Performance Modeling & Optimization for Human Mars Exploration
  - EDL Flight Vehicle (Aeroshell) Flight Performance Data for Human Mars Entry and Earth Return
  - Low Cost EDL Flight Instrumentation Data Acquisition System
  - Planetary Aerothermodynamics Test Facility

LAND: Entry, Descent, and Landing to Enable Planetary Science Missions

NASA Space Technology Mission Directorate

August 2022

STMD welcomes feedback on this presentation

See 80HQTR22ZOA2L_EXP_LND at nspires.nasaprs.com for how to provide feedback

If there are any questions, contact HQ-STMD-STAR-RFI@nasaprs.com

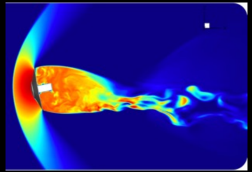
LAND: Enable science missions entering/transiting planetary atmospheres and landing on planetary bodies

Developing atmospheric entry technology to enhance and enable small spacecraft to Flagship-class missions across the solar system

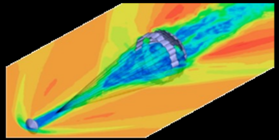
Entry Systems Modeling & Testing

Reducing entry system mass and risk by developing advanced, validated models

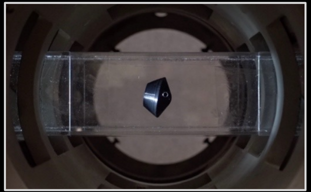
to enable



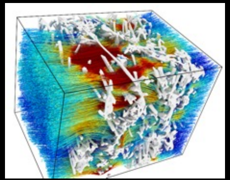
"DESKTOP WIND TUNNEL"



PARACHUTE MODELING



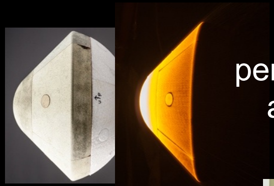
MAGNETIC SUSPENSION WIND TUNNEL



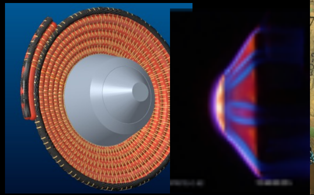
IN-DEPTH MATERIAL RESPONSE

Hardware Development

Maturing new materials and systems to fill performance gaps and enable new missions

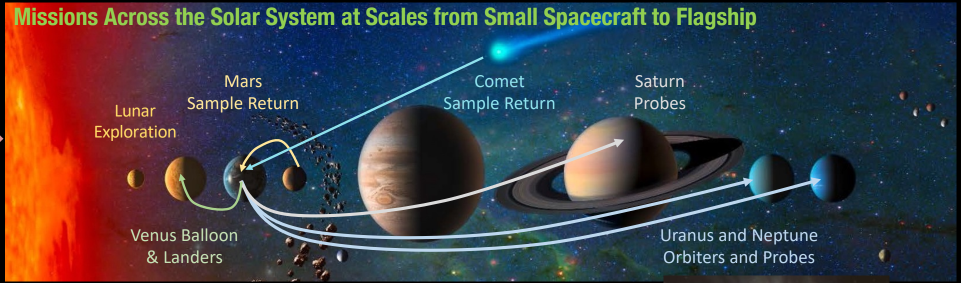


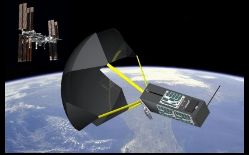
CONFORMAL MATERIALS



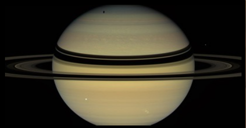
DEPLOYABLE DECELERATORS

3D WOVEN HEATSHIELDS



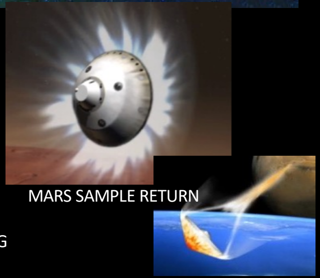


PRECISION DEORBIT



SATURN PROBE

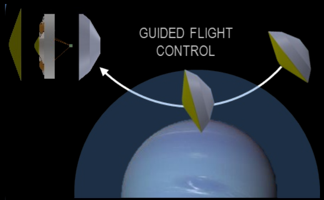
TITAN PINPOINT LANDING



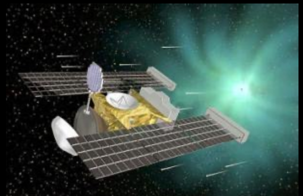
MARS SAMPLE RETURN

Increasing Science Return, Decreasing Risk, Cost, and Schedule

ICY MOON PRECISE LANDING



ICE GIANT AEROCAPTURE



HIGH-SPEED SAMPLE RETURN

<u>Not all activities depicted are currently funded or approved. Depicts "notional future" to guide technology vision.</u>

Context: Mission Priorities from the 2022 Planetary Decadal Survey
List of Missions that Include Entry, Descent and/or Landing (EDL)

	2022 Decadal Survey Priority	Enabling/Enhancing EDL Capability Advancement
Flagship	Uranus Orbiter and Probe*	Potential Aerocapture for orbiter; atmospheric modeling, aero/aerothermal modeling, mass-efficient entry system
	Enceladus Orbilander*	*Precision landing/hazard avoidance?*
	Europa Lander*	*Hazard detection and avoidance*
	Mercury Lander*	*Precision landing/hazard avoidance?*
	Neptune-Triton Odyssey	Aerocapture for orbiter(?); atmospheric modeling, aero/aerothermal modeling, mass-efficient entry system
	Venus Flagship*	Atmospheric modeling, aero/aerothermal modeling, mass-efficient entry system, precision landing?

New Frontiers 5 (2024 AO)
- Comet Surface Sample Return (CSSR)*
- Lunar South Pole-Aitken Basin Sample Return*
- Ocean Worlds (only Enceladus)
- Saturn Probe*
- Venus In Situ Explorer*
- Io Observer
- Lunar Geophysical Network (LGN)*

New Frontiers 6
- Centaur Orbiter and Lander (CORAL)*
- Ceres Sample Return*
- Comet Surface Sample Return (CSSR)*
- Enceladus Multiple Flyby (EMF)
- Lunar Geophysical Network (LGN)*
- Saturn probe*
- Titan orbiter
- Venus In Situ Explorer (VISE)*

New Frontiers 7

New Frontiers 6 list, plus
- Triton Ocean World Surveyor

**Missions potentially involving EDL*

Reference: https://www.nationalacademies.org/our-work/planetary-science-and-astrobiology-decadal-survey-2023-2032

High-Priority Gaps and Current STMD/SMD Investments

There are 26 identified gaps mapped to the “Planetary EDL” outcome. Highest-priority gaps, as ranked by the EDL System Capability Leadership:

Current/Recent STMD Investments	
▪ Entry Systems Modeling (ESM) Project* ▪ ACCESS STRI (5 yrs, $15M) ▪ ECF and ESI Awards: Modeling, Chutes ▪ Plume Surface Interaction (PSI) Project ▪ Global Reference Atmospheric Models*	**Modeling & Simulation (includes UQ across the breadth of models)** ▪ Validated Aerothermodynamic Prediction for Robotic Mission EDL ▪ Thermal Protection System Performance Modeling & Optimization for Robotic Missions ▪ Validated Static/Dynamic Aerodynamics Prediction from Supersonic to low Subsonic Speed ▪ Validated Wake Models, Including Reaction Control Thruster Effects ▪ Atmospheric Model Development
▪ SPLICE† ▪ MEDLI and MEDLI2 Flight Instruments* ▪ DrEAM Flight Instrumentation* ▪ Parachute Sensors (ECI, SBIR) ▪ SCALPSS*, SCALPSS 1.1 (for PSI)	**Performance Validation** ▪ Integrated, Multi-Function Precision Landing Sensors for Robotic Missions† ▪ EDL Flight Vehicle (Aeroshell) Flight Performance Data for Robotic Missions ▪ Flight Instrumentation to Acquire Parachute Performance Data ▪ Planetary Aerothermodynamics Test Facility
▪ Entry Systems Modeling (ESM) Project* ▪ ACCESS STRI ▪ 3-D Woven TPS (HEEET, 3MDCP) ▪ Multiple SBIR awards	**EDL Hardware Technologies** ▪ High-Reliability Earth Entry Vehicles for Robotic Missions ▪ Supersonic Parachute Systems and Modeling
▪ Exo-Brake ▪ Additively-Manufactured TPS (ECI) ▪ Deployable Decelerators (HIAD, ADEPT)	**Enabling Small Spacecraft Missions** ▪ Small Spacecraft EDL ▪ Small Spacecraft Aerocapture with feed forward to Ice Giant missions

†NOTE: Precision Landing Technologies apply to several missions and are found in the “Land within 50 m” Outcome package.

*Funded/Co-funded by Science Mission Directorate

Moving Forward

- **A primary function of the SCLT leads is to help formulate, and advocate for, new activities within Space Technology to address high priority gaps**
- **A critical part of the process is community feedback**
  - A public RFI for the ”Land” thrust was issued in August and closed last month. Feedback is being integrated into an EFP revision
  - Additional feedback is always welcome; see QR code at the end
- **Gap closure is possible at all levels within STMD**
  - Academic grants, institutes
  - Graduate fellowships
  - In-house efforts at all scales
  - Hardware flight demonstrations

View Envisioned Futures presentations for each capability area and submit written feedback

techport.nasa.gov/framework

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