

National Aeronautics and Space Administration

NASA's Entry, Descent and Landing (EDL) Background and Demonstration Needs

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Outline

- Background in entry/re-entry
- Goals and current investments
- Ground and flight test capabilities
- First inputs on demonstration needs
- First inputs on demonstrator projects

NASA's Planetary EDL Background

The U.S. EDL community (NASA, industry, and academia) has decades of experience with atmospheric flight missions, studies and technologies.

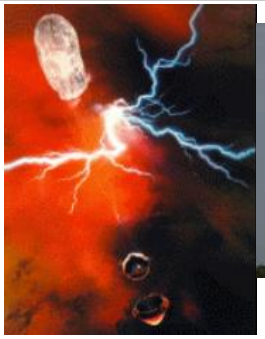
1960's 1970's 1980's 1990's



Apollo



Mars Viking



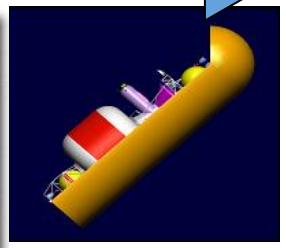
Pioneer Venus



Space Shuttle



Galileo Jupiter



Human Exploration Studies

2000's 2010's



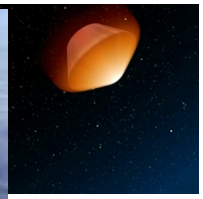
Mars Pathfinder



Mars Exploration Rovers



Genesis



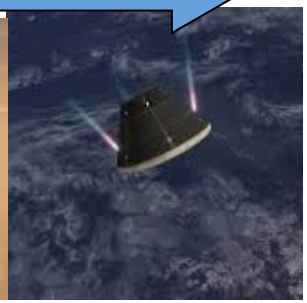
Stardust



Mars Phoenix



MSL



Orion EFT-1

In-Space Propulsion Space Technology

Aerocapture I Aeroshells I TPS I Instrumentation I Deployable Decelerators I Precision Landing



NASA's Current EDL Technology Investments

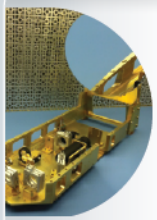
STMD's 8 Thrust Areas

Space Technology will focus investments in 8 key thrust areas that will enable or substantially enhance future NASA mission capabilities.



High Power Solar Electric Propulsion

Deep space human exploration, science missions and commercial applications with investments in advanced solar arrays and advanced electric propulsion systems, high-power Hall thrusters and power processing units.



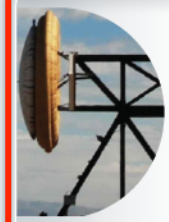
Space Optical Comm.

Substantially increase the available bandwidth for near Earth space communications currently limited by power and frequency allocation restrictions, and increase the communications throughput for a deep space mission.



Advanced Life Support & Resource Utilization

Technologies for human exploration mission including Mars atmospheric In-situ resource utilization, near closed loop air revitalization and water recovery, EVA gloves and radiation protection.



Mars Entry, Descent and Landing Systems

Permits more capable science missions, eventual human missions to Mars including hypersonic and supersonic aerodynamic decelerators, a new generation of compliant TPS materials, retro-propulsion technologies, instrumentation, and modeling capabilities.



Space Robotic Systems

Creates future humanoid robotics, autonomy and remote operations technologies to substantially augments the capability of future human space flight missions.



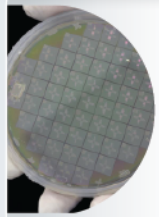
Lightweight Space Structures

Targets substantial increases in launch mass, and allow for large decreases in needed structural mass for spacecraft and in-space structures.



Deep Space Navigation

Allows for more capable science and human exploration missions using advanced atomic clocks, x-ray detectors and fast light optical gyroscopes.

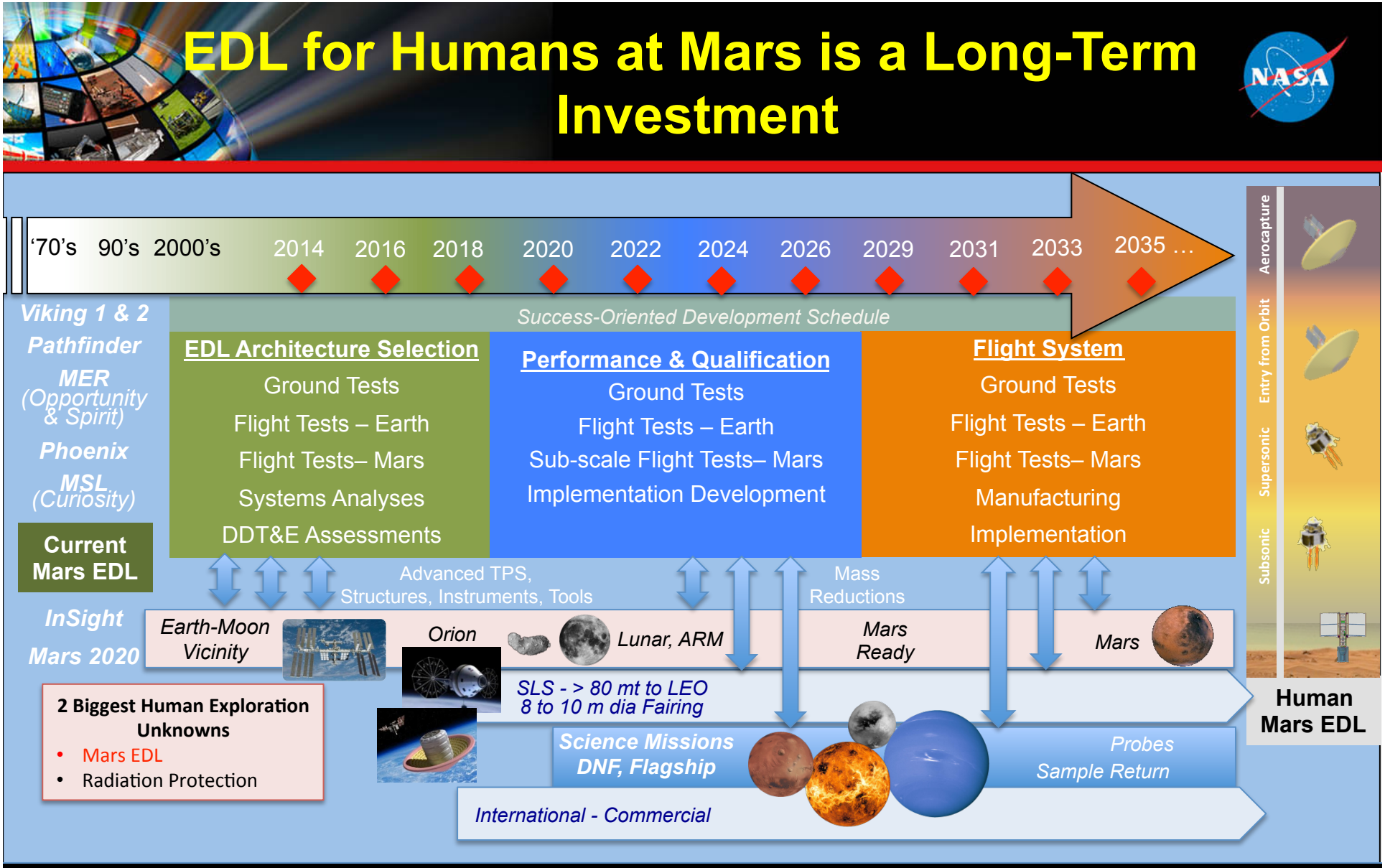


Space Observatory Systems

Allows for significant increases in future science capabilities including, AFTA/ WFIRST coronagraph technology to characterize exo-planets by direct observation and advances in the surface materials as well as control systems for large space optics.

THRUST AREAS

EDL for Humans at Mars is a Long-Term Investment



Mars			
Landed Mass:	1 mt	10 mt	20-40 mt
Precision:	10-25 km	5-10 km	<0.1 km
Planet Access:	~40%	~75%	Near global

Shared chart credit: Jeff Herath, LaRC

STMD EDL Investments Infuse to Both Science and Human Missions

Entry

- Woven TPS (HEEET) – sustainable, efficient materials for Venus, Mars & Outer Planets
- Hypersonic Inflatable Aerodynamic Decelerator (HIAD) and THOR – increased payload mass and surface access at Mars
- Adaptable Deployable Entry and Placement Technology (ADEPT) – deployable heat shield for Venus provides benign entry loads

Descent

- Low Density Supersonic Decelerator – can provide increased mass to Mars surface
- Propulsive Descent Technologies – leveraging commercial experience in Supersonic Retropropulsion

Cross-Cutting

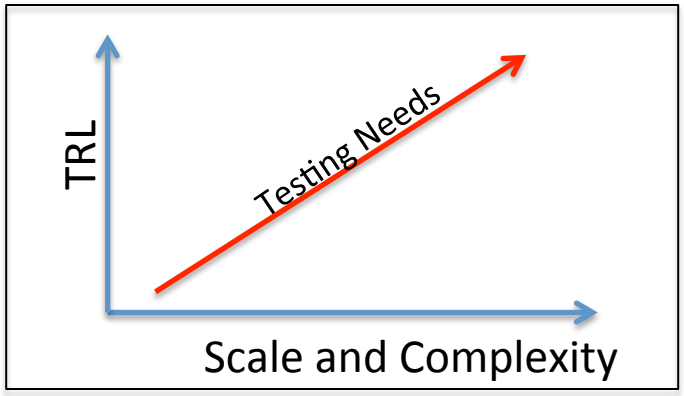
- MEDLI and MEDLI2 – provide flight data for aero/ aerothermal model improvement and validation
- Entry Systems Modeling – improves materials, models and tools used across all entry missions



Blue = Game Changing Development, Green = Tech Demo Missions

EDL Demonstration Needs

- EDL technology development is driven by: Science Missions, and Human Exploration of Mars
- NASA is interested in maturing multiple technology candidates for EDL systems. The technologies are currently at various maturity levels.



- Low-L/D (deployable) and Mid-L/D (rigid) concepts for human Mars
- Guidance and Control Strategies for large (10+ m) Deployables
- Backshell TPS Materials and sensors
- Forebody TPS materials and sensors
- Improved aerothermal, materials, and vehicle system modeling

Ground and flight tests/demonstrations and datasets will be required, to get these systems ready for mission infusion.

NASA's EDL-Relevant Testing Venues

- International Space Station (ISS)
  - Not very high entry speed (7.8 km/s), but can get Mars-relevant
  - Can be expensive
  - EDL usually has limited need for human intervention
- Space Launch System (SLS) secondary payloads (new)
- Flight Opportunities Program
  - Sounding Rockets
  - Balloons
- Supersonic Flight Test Capability (LDSD) and rocket sled
- LANDIR, Morpheus and others
- Arcjets, wind tunnels, ballistic ranges

STMD Flight Opportunities

SpaceLoft™ XL
36 kg to ~115 km



SpaceShipTwo
~500 kg to 110 km



Xaero/Xombie



Tycho 20/285
MAX ALT: Up to 32/43 km
PAYLOAD: 20 kg / 285 kg



High Altitude Shuttle System
10 kg to 30 km

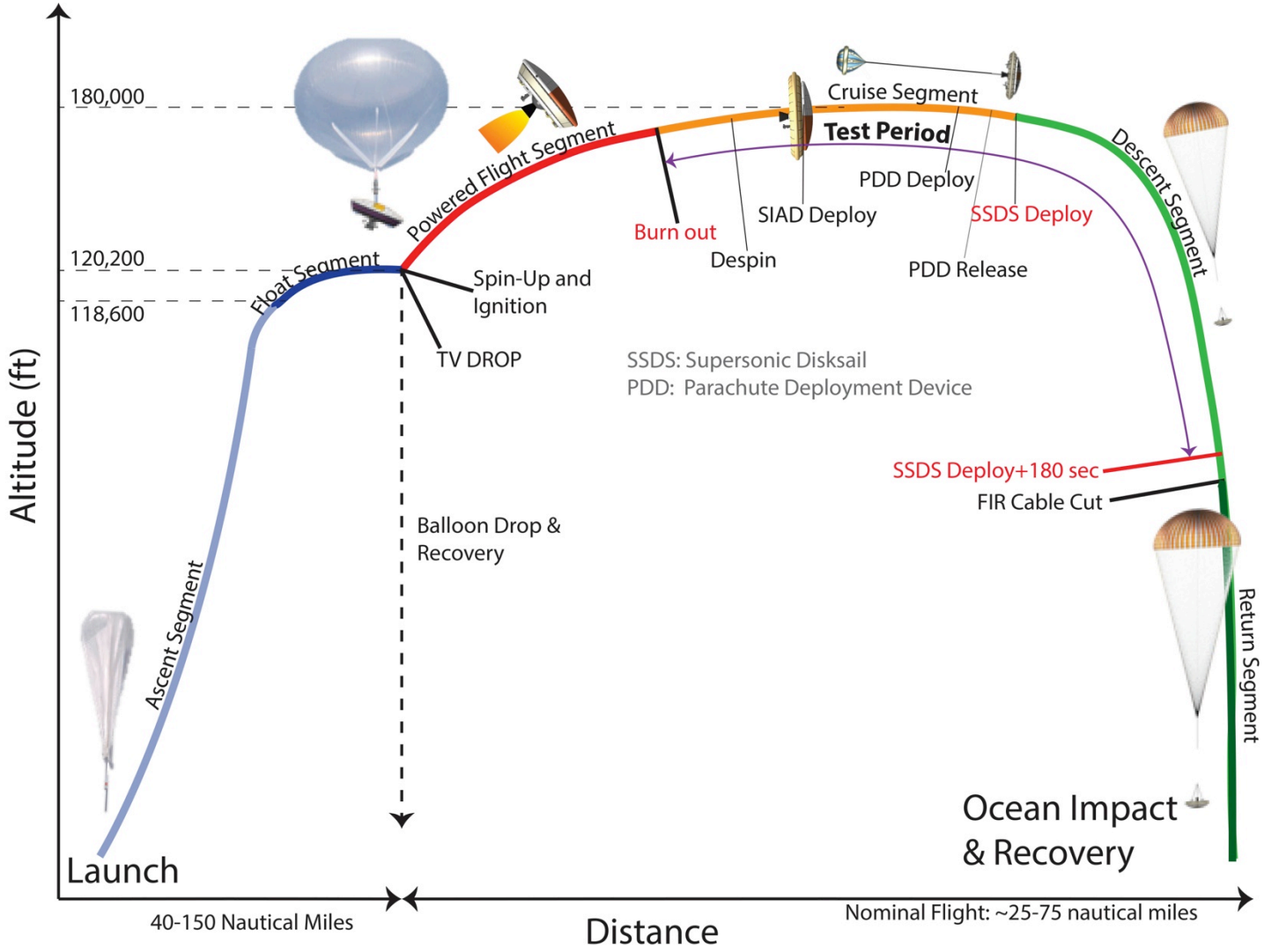


Small/Nano Balloon System
10 kg to 35 km



See: https://flightopportunities.nasa.gov/platforms/

Supersonic Flight Dynamics Test (SFDT)



Landing and Impact Research Facility
LANDIR, NASA-Langley

- 80-m tall steel tower
- Used in Apollo Lunar landing tests (can simulate various g-loads)
- Recently refurbished (2007-10) for Orion capsule testing
  - Bridge holds 64,000 lbs
  - 16-ton winch
  - Various landing surfaces
  - Water pool (35 x 90 x 6.1 m)







Morpheus Flight Test Platform

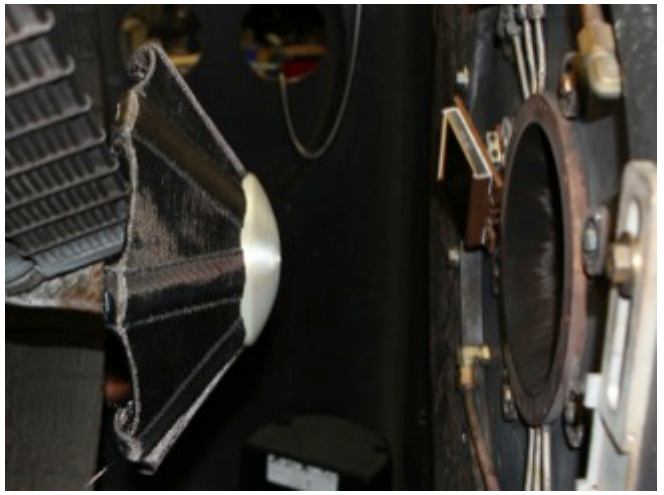


While technologies offer promise, capabilities offer potential solutions with application for future human exploration beyond LEO. Morpheus provides a bridge for evolving these technologies into capable systems that can be demonstrated and tested – in a relevant flight environment.

- Morpheus is a Full Scale Robotic Lander (500kg payload) built as a risk reduction test article
  - Morpheus system includes the vehicle, ground systems, operations
  - Developed, tested and operated in-house at Johnson Space Center and KSC
- Technologies:
  - Liquid oxygen/methane propulsion (cryogenic, green, safe for ground handling and crew)
  - Precision landing and hazard detection Sensors
  - Leverages GSFC's modular, reusable Core Flight Software
  - Technology incubator for advanced development efforts
- Tests complete: 12 hot fire, 34 tethered, and 14 free flights to date
- Lean Development Approach
- Forward Leaning towards Human Spaceflight

Establishing Ground-to-Flight Traceability

- NASA-Ames has “large article” capability in the Interaction Heating Facility (IHF) using a 22” nozzle
- Articles up to 13” (~35 cm) in diameter can be tested



SPRITE-C Prototype Test Article Fit check in the Ames Interaction Heating Facility

- This same size article will fit on a sounding rocket and can perform a reentry test
- Can validate material response models, correlate ground and test environments, calibrate instruments, etc.



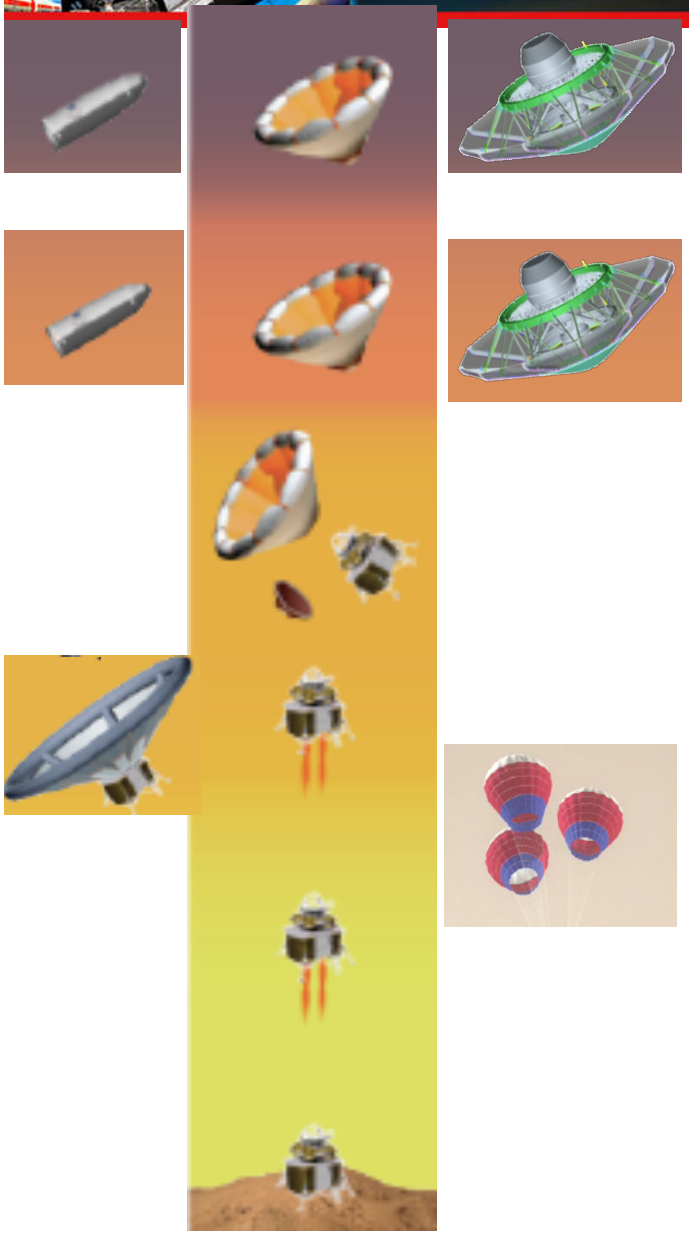
Summary

- NASA has much experience and interest in EDL systems and technologies
- Future EDL challenges focus on science missions and the ultimate goal, humans to Mars
- Potential collaborations span the spectrum of cost and integration
  - Utilizing a NASA test venue
  - Partners instrumenting or putting samples on some simple “core” vehicle according to their needs
  - Securing a flight opportunity with >1 payload, and data sharing across
  - Joint test of a new EDL concept, maybe with partners supplying EDL systems for different flight regimes (hypersonic, supersonic, subsonic/landing)



Additional Information

EDL for Human Mars Missions



Aerocapture: enables Mars orbit insertion with very little propellant

Entry: The hypersonic portion of EDL requires thermal protection, and a system capable of autonomous guidance as well as predictable aerodynamics. Options include HIAD, ADEPT, and Mid-L/D aeroshells.

Transition: Extracting the vehicle from the hypersonic decelerator and orienting correctly for supersonic decelerator use

Descent: The supersonic portion of EDL requires slowing from ~Mach 5 to <Mach 1. Options include SRP, SIAD, and parachutes.

Landing: The human-scale payloads must avoid hazards (natural and predeployed assets) as well as land in a precise location close to other mission elements.



Acronyms

- ADEPT – Adaptable Deployable Entry and Placement Technology
- CA-TPS – Conformal Ablative Thermal Protection System
- ESM – Entry Systems Modeling
- HEEET – Heatshield for Extreme Entry Environment Technology
- HIAD - Hypersonic Inflatable Aerodynamic Decelerator
- LDSD - Low Density Supersonic Decelerator
- MEDLI – MSL Entry, Descent and Landing Instrumentation
- MEDLI2 – MEDLI for Mars 2020 mission
- PDT – Propulsive Descent Technologies
- SBIR – Small Business and Innovative Research
- SIAD – Supersonic Inflatable Aerodynamic Decelerator
- STRG – Space Technology Research Grants
- THOR – Terrestrial HIAD Orbital Reentry
- TPS – Thermal Protection System