Johnson Space Center Engineering Directorate

L-8: Entry, Descent, and Landing at Mars

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Public Release Notice
This document has been reviewed for technical accuracy, business/management sensitivity, and export control compliance. It is suitable for public release without restrictions per NF1676 #_____.
We are sharpening our focus on Human Space Flight (HSF) Exploration Beyond Low Earth Orbit.

We want to ensure that HSF technologies are ready to take Humans to Mars in the 2030s.

- Various Roadmaps define the needed technologies
- We are attempting to define our activities and dependencies

Our Goal: Get within 8 years of launching humans to Mars (L-8) by 2025

- Develop and Mature the technologies and systems needed
- Develop and Mature the personnel needed

We need collaborators to make it happen, and we think they can benefit by working with us.
- Life Support
- Active Thermal Control
- EVA
- Habitation Systems

- Human System Interfaces
- Wireless & Communication Systems
- Command & Data Handling
- Radiation & EEE Parts

- Lightweight Habitable Spacecraft
- Entry, Descent, & Landing
- Autonomous Rendezvous & Docking
- Vehicle Environments

Entry, Descent, & Landing
- Autonomous Rendezvous & Docking
- Deep Space GN&C

Reliable Pyrotechnics
- Integrated Propulsion, Power, & ISRU
- Energy Storage & Distribution
- Breakthrough Power & Propulsion

Crew Exercise
- Simulation
- Autonomy
- Software
- Robotics
The Problem

- Desire to land increasingly large cargo on Mars, and humans in the 2030’s
- State of the art Mars landed mass is ~1 metric ton (Curiosity rover)
- Need to land significantly larger mass payloads to support human missions
- Need to land on Mars safely, accurately, and repeatedly for human campaigns

Entry, Descent, and Landing at Mars

- Develop a set of technologies to support human planetary landing:
  - Slowly
    - Entry decelerators
  - Accurately
    - Terrain Relative Navigation
  - Softly
    - Altimetry and velocimetry
  - Safely
    - Hazard Detection and Avoidance
ATMOSPHERE
[characteristics and approximate composition]

OVER 100 TIMES DENSER THAN MARS’ ATMOSPHERE

78% NITROGEN
21% OXYGEN
1% OTHER

96% CARBON DIOXIDE
<2% ARGON
<2% NITROGEN
<1% OTHER
Mach 0.15
“touchdown”
(about 120 mph)

Mach 1.5
7 U.S. Mars Entry, Descent, and Landing Successes
Historical Entry Configurations for Mars Robotic Landings

Viking MPF MER Phoenix MSL

Supersonic Disk-Gap-Band Parachute

Human Mission Payload Requirement (20 * Curiosity)
Landing Accuracy
Curiosity
12 x 4 mi ellipse

100 m (or better) accuracy is needed
Mars Entry, Descent, and Landing (EDL) Technologies

Entry Decelerators

Precision Landing and Hazard Avoidance
Mars Entry, Descent, and Landing (EDL) Technologies

Entry Decelerators

Mid L/D

Precision Landing and Hazard Avoidance

PL & HA
Mid L/D Technology Roadmap and Major Risk Reduction Activities

- **2016**
  - Design and Analysis

- **2017**
  - Wind Tunnel Testing

- **2018**
  - Ground Testing (systems)

- **2019**
  - Subscale Earth Demo (full-scale relevant) with integrated supersonic retropropulsion (SRP)

- **2020**
  - Potential robotic precursor tech demo (not required for V&V)

- **2021**
  - Small scale EDL from orbit

- **2022**
  - Integrated V&V test for human Mars system for GN&C, aero, aerothermal, SRP, and thermal protection

- **2028**
  - Human Mars EDL

- **2030’s**
  - Additional applications:
    - Lunar sample return
    - Mars sample return
    - Neptune aerocapture
    - Missions to other bodies of interest, as applicable
Progression of GN&C Landing System Capabilities
Controlled – Precise – Safe

**GN&C Subsystem**

- **Controlled Landing**
  - IMU, Altimeter, Velocimeter, Touch down sensor

- **Precise Landing**
  - Add: Terrain Relative Navigation (TRN)

- **Safe Landing**
  - Add: Hazard Detection & Avoidance (HDA)

**Controlled Landing**
- Minimize vertical descent rate and lateral velocity to ensure a soft (or controlled) touchdown
- No knowledge of global position – “blind” landing

**Precise landing – Terrain Relative Navigation (TRN)**
- Global navigation through onboard matching of real-time terrain sensing data with *a priori* reconnaissance data
- Enables efficient maneuvering to minimize landing error and avoid large hazards identified in *a priori* analyses

**Safe Landing – Hazard Detection & Avoidance (HDA)**
- Real-time terrain sensing to identify sites safe from lander-sized hazards that are undetectable in *a priori* data
- Enables a hazard avoidance maneuver to the identified safe site
- Can be leveraged for subsequent Hazard Relative Navigation (HRN) – similar to TRN
Portfolio of **PL&HA** Technologies

**Controlled Landing (Soft Landing)**

Velocity & Altitude Sensing

- **Navigation Doppler Lidar (NDL)**
  Measures velocity and range

- **Long-range Laser Altimeter (LAlt)**
  Measures range

- **Optical Velocimeter**
  (code)
  Estimates velocity with camera images & algorithms

**Precise Landing**

Terrain Relative Navigation (TRN)

- **Passive-Optical/Camera-Based**
  (requires lighted terrain: applicable to most missions)

- **Active/Lidar-based**
  Can utilize Laser Altimeter or other 3D Lidar. Operates in dark/shadowed or lighted terrain.

**Safe Landing**

Hazard Detection (HD) and Hazard Relative Nav (HRN)

- **Hazard Detection System (HDS)**
  Lidar used to create hazard map of landing area from multiple images

- **Compact HDS** - Takes single image and finds safe sites

**GN&C Subsystem**

Software

- Navigation techniques for ALHAT
- Guidance logic
- Autonomous Flight Manager
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• Pointer to Co-Dev Announcements
• Pointer to intake site