Mars Science Laboratory
Entry, Descent and Landing Overview
Nominal Mars Entry Timeline: (Reference Only)

Entry Interface
- $r = 3522.2$ km
- $L/D = 0.18$
- Hypersonic Aeromaneuver Guidance

Deploy Supersonic Chute

Jettison Heatshield, Activate Radar, and Deploy Mobility

Mach | Velocity | Flight Path Angle | Altitude AGL
--- | --- | --- | ---
2.0 | 447 m/s | $\gamma = -18.8$ deg | 6.5 km
0.7 | 160 m/s | $\gamma = -35.3$ deg | 4.3 km
0.6 | 133 m/s | $\gamma = -41.0$ deg | 3.9 km

Sense Velocity with Radar

Jettison Chute and Backshell, Begin Powered Descent

Timeline:
- $E + 0$ s
- 272.5 s
- 293.6 s
- 298.6 s
- 331.8 s
- 358.7 s

Velocity Altitude AGL
- $V = 84$ m/s, $V_H = 24$ m/s, $\gamma = -74.1$ deg, $h = 1.0$ km
- $V = 3$ m/s, $V_H = 0$ m/s
- $V_v < 1$ m/s, $V_H < 0.5$ m/s

Rover Touchdown

Flyaway

Touchdown Dynamics Testbed Used to Simulate Only This Portion of the Landing Profile

2500 m above MOLA areoid
Updated Sky Crane Maneuver Description
(Reference Only)

One Body Phase - Vertical Descent -
1. 35 m. way-point alt reached
2. 2 center thrusters turned off
3. Vertical velocity = 4 m/s. Lateral velocity nulled to ~zero
4. System Z axis aligned with G vector
5. Attitude rates zeroed out
6. 27.3 m way-point alt. reached
7. Commands sent to pyro devices to release the rover (transition event)

Two Body Phase - DRL/Bridle Deployment -
1. Pyro devices release the rover.
2. DRL controls the separation rate while bridle and umbilical are deployed
3. Umbilical maintains data & RF interfaces between rover and DS
4. Bridle comes to full extension and all load is transferred to triple bridle.
5. DS nulls dynamic transients induced by deployment & continues deceleration to .75 m/s

Two Body Phase - Constant Velocity -
1. 15 m way-point alt. reached
2. Touchdown Logic initiated
3. Target velocity reached: .75 m/s
4. Constant velocity descent starts
5. Rover makes initial contact with surface

Two Body Phase - Touchdown Event -
1. .75 m/s downward velocity continues while rover is offloaded to the ground.
2. System throttles down to maintain .75 m/s descent rate, TD logic monitors commanded Z force.
3. Z force threshold & persistence criteria met (rover offloaded). TD confirmed
4. Control handed-off to DS
5. Umbilical lines dead-faced & cut.
6. Commands sent to pyro devices to cut bridles (transition event)

Fly-Away Phase
1. DS under control of the DS micro controller.
2. DS ascends to 15 m, pitches over to a 45 degree trajectory angle and flies away.

Touchdown Dynamics Testbed Used to Simulate This Portion of the Landing Profile
First Order Analog:
Descent Stage can be thought of as a rocket powered helicopter delivering a slung payload to the surface.

Motion Simulator Use:
Simulate the motion of the Descent Stage during a typical rover landing.
**Flight System:**
Translations and rotations are effectively decoupled because the Bridle confluence point is located at the Center of Gravity of the Descent Stage structure.

**Test System:**
The resultant translational compliance of the Descent Stage system is reproduced using electric motor actuators operated in closed-loop mode.

**Motion Simulation**
- Use motion simulator to simulate the translations of the Descent Stage
- Bridle (Cable) confluence point anchored to a 3 axis load cell
- Closed loop control system actuates the 3 degrees of freedom to replicate Descent Stage motion and compliance
- Motion Simulator mimics the closed-loop response of the Descent Stage during the Touchdown event

**6-DOF response bandwidth**
- Vertical bandwidth: 2 Hz
- Lateral bandwidth: .08 Hz

**3-DOF actuator bandwidth**
- Vertical bandwidth: [20] Hz
- Horizontal bandwidth: [.8] Hz

**Force Sensing for feedback control**