Entry, Descent, and Landing System for a 3U Landed Payload

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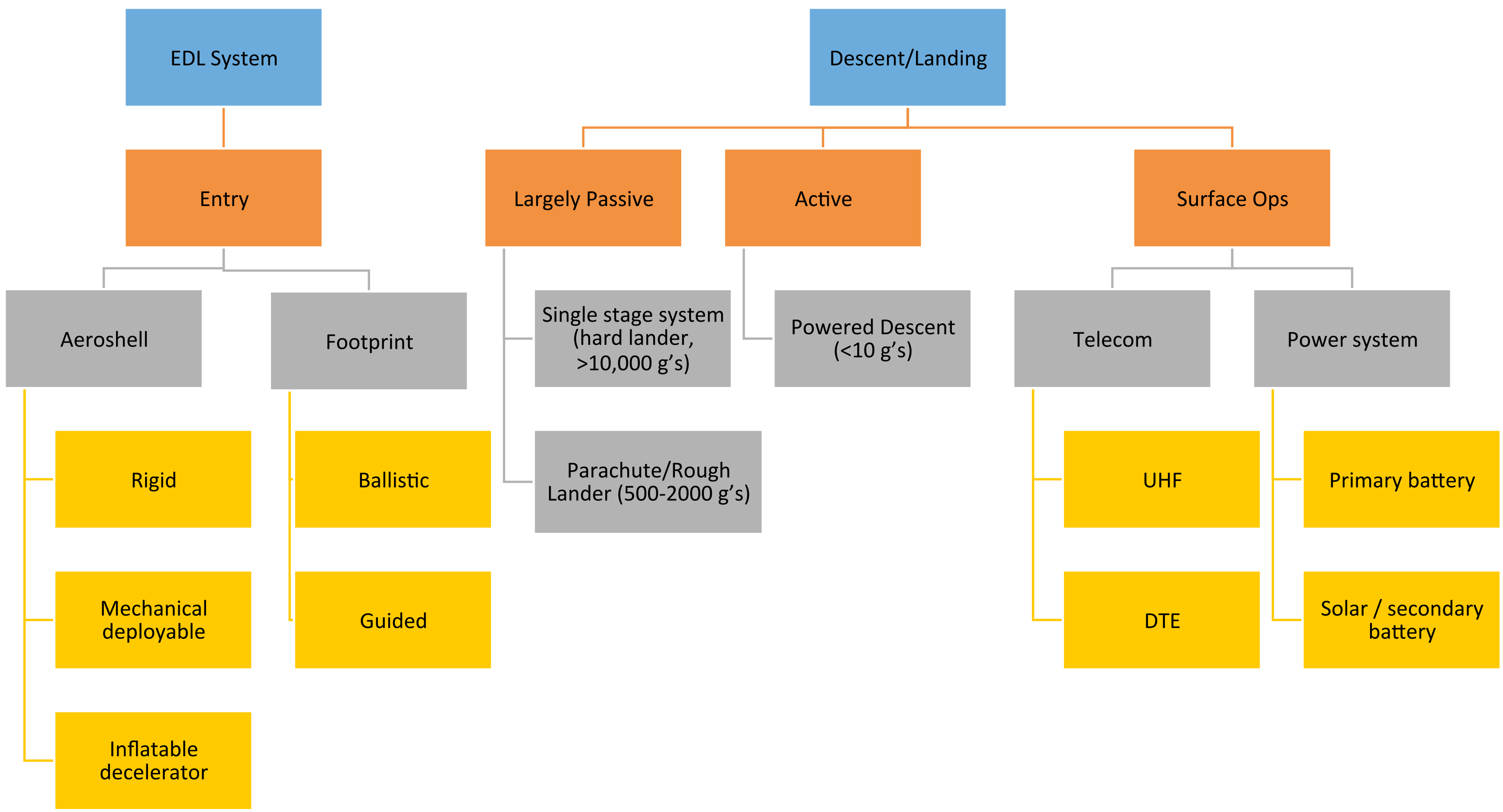
Motivation

- Current EDL technology efforts tend toward landing larger payloads
- Smallsat surface payloads can accomplish a variety of innovative Mars exploration and science objectives while providing an opportunity for low-cost flight testing
  - For example, science objectives for this landed payload could include atmospheric, geophysics (e.g., high resolution measurement of Mars remnant magnetic fields) and/or surface imagery. Weather station network, seismology network, impactors, navigation beacons are also possible
- Low mass payloads can access high terrain elevations; previously unattainable science objectives
- In this study, a self-contained lander payload with a volume of 3U (30x10x10 cm) and mass of 10 kg is assumed.

Braun, R.D.; and Manning, R.M.: “Mars Entry, Descent and Landing Challenges.” *Journal of Spacecraft and Rockets*, Vol. 44, No. 2, pp. 310-323, Mar-Apr, 2007.

Christian, J.A.; Manyapu, K.; Wells, G.W.; Lafleur, J.M.; Verges, A.M.; and Braun, R.D.: “Sizing of an Entry, Descent, and Landing System for Human Mars Exploration.” *Journal of Spacecraft and Rockets*, Vol. 45, No. 1, pp.130-141, Jan-Feb, 2008.

SmallSat EDL Architecture Design Space



SmallSat mass/volume requirements allow for significant reduction in g's associated with landing event.

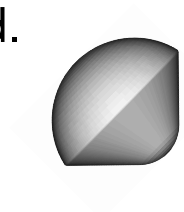
Technical Concept

- A self-contained 3U smallsat payload is flown within a 45 deg sphere cone configuration. Entry conditions of 5.8 km/s and -15^{o} FPA are assumed. An unguided ballistic trajectory removes need for RCS, gyros and sophisticated avionics. Landed ellipse is on the order of 200km.
- A combination of accelerometer and timer measurements are used to initiate deployment of the parachute (MPF architecture).
- The payload is designed to withstand tens of Earth g's (< 50) of deceleration on landing.
- Considering omni-directional science operations and telecommunications approach when the landed payload is on the surface.

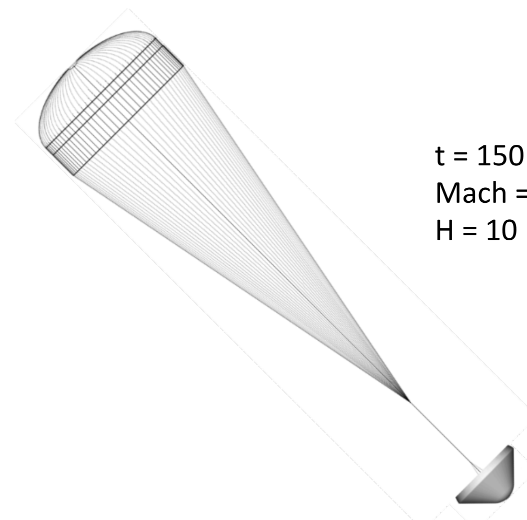
Key systems:

- Rigid 1m diameter aeroshell
- 2 rpm roll rate (pre-entry spin up)
- Ablative TPS (SLA or PICA)
- Large (~15m dia) supersonic parachute
- Crushable impact attenuator at landing

<u>Entry Budget</u>
Mass: 38 kg
Power: 10W
β = 48 kg/m^2

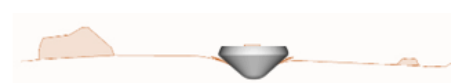


t = 80 s
V = 3.3 km/s
Peak heating



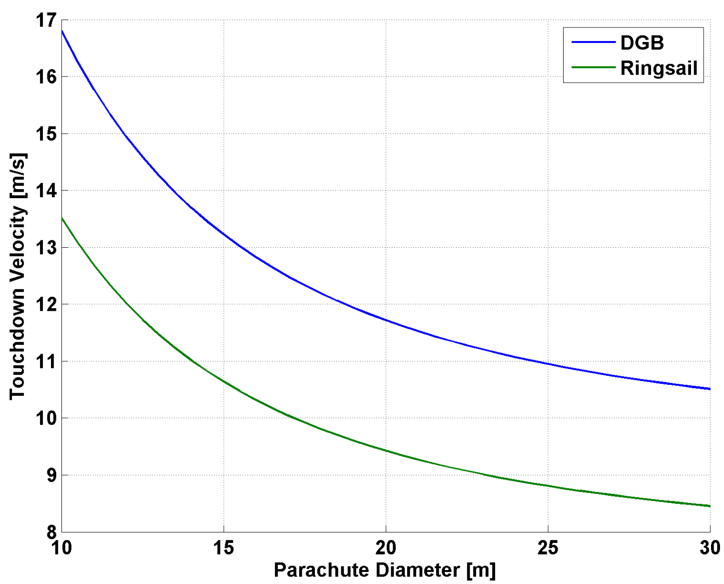
t = 150 s
Mach = 1.4
H = 10 km

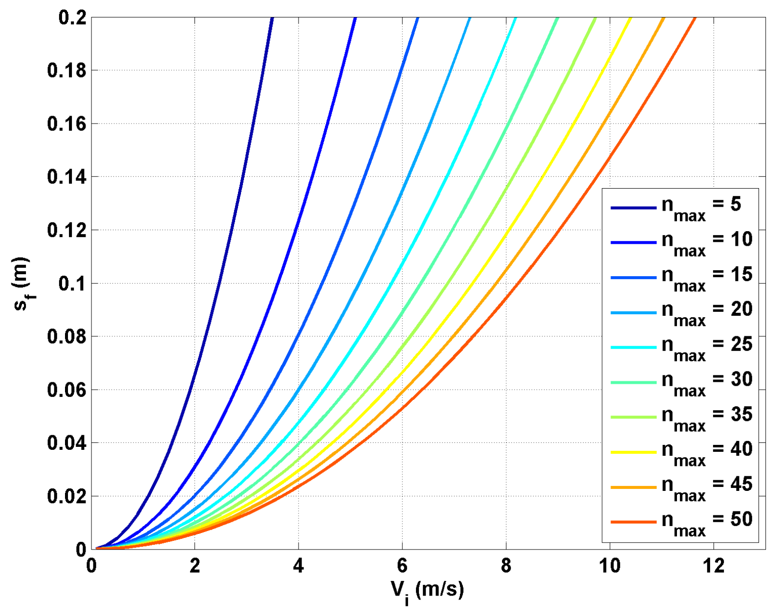
t = 400s
V = 0 m/s
Impact < 50 g's



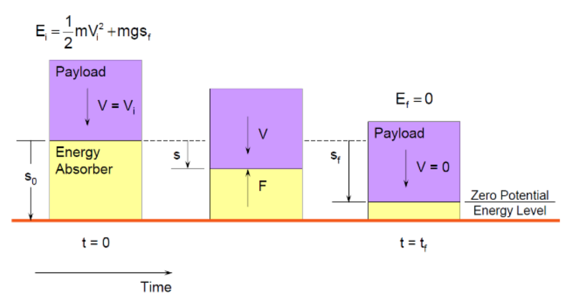
Current Parachute Technology and Crushable Foam Align Well for SmallSat Landed Payloads

- Surface impact loads of approximately 50 Earth g's can be achieved with use of a parachute with diameter on the order of 15 m.
- ~20 cm of crushable honeycomb impact attenuator is required to limit touchdown to 50 g





MPF design descent velocity: 65 m/s
MER design descent velocity: 85 m/s

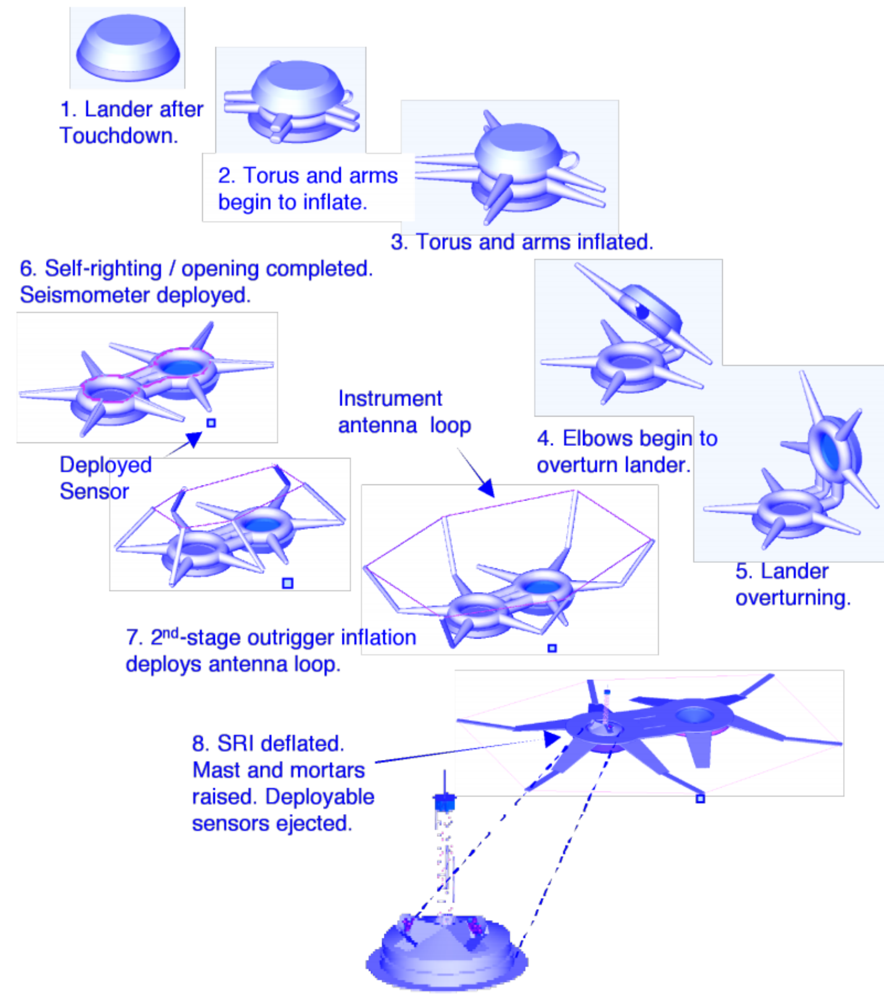


s_f = stroke distance
V_i = impact velocity
n_{max} = max load factor

Key Trades and Challenges

- Interface and deployment from host spacecraft
- Scalability of flight proven EDL technology
- Packaging/volume constraints
- Passive approach to parachute release

Surface reorientation capability or omni-directional surface operations capability



Thurman, S. W., and Rivellini, T. P., "Rough Lander Concept for Mars Exploration," *Core Technologies for Space Systems Conference*, Colorado Springs, CO, November 2002.

Summary

- Cubesat surface missions have significant scientific and exploration potential. Significant reduction in landed mass enables new EDL opportunities
  - Higher MOLA surface elevation altitudes
  - Potential for network science
- Hosted EDL payload likely carried on cruise-stage and released prior to final targeting maneuver.
- As a secondary payload, Smallsat EDL design minimizes complexity, both in manufacturing and in operation, with a minimum number of staging events and use of well-established subsystems.
- Because the landed payload mass is relatively small, use of existing systems provides ample control over deceleration and heating environments.
- Preliminary observations indicate that low mass Mars payloads may be landed safely and efficiently.