Red Dragon

Feasibility of a Dragon-derived Mars lander for scientific and human-precursor missions

May 7, 2013

John S. Karcz (john.s.karcz@nasa.gov)

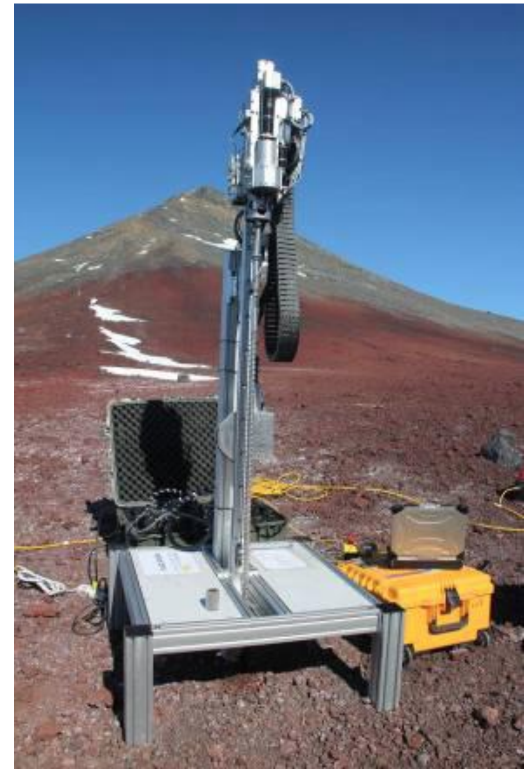
NASA Ames Research Center

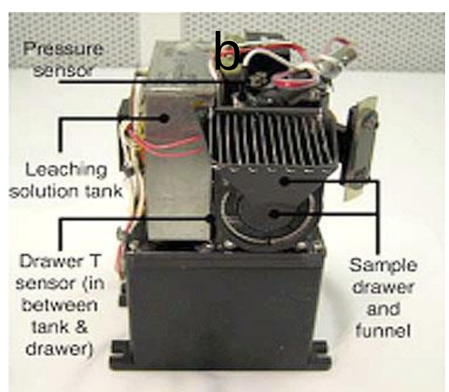
Overview

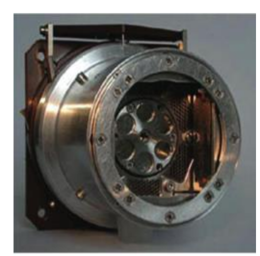
- We are studying whether a substantially unmodified SpaceX Dragon capsule—a Red Dragon—could be used as a lander for the Icebreaker Discovery mission concept
- The primary technical question is whether Dragon can perform all of the necessary EDL functions at Mars
  - Our analysis indicates EDL trajectories close for a broad range of relevant entry conditions
  - Capability to deliver ~ 1 tonne of payload to the surface
- Red Dragon appears so far to be a feasible option for Icebreaker and would allow expanded mission objectives
- Ames is interested in any capabilities relevant to future Mars scientific and human-precursor opportunities: “Sources Sought” NNA1312345L

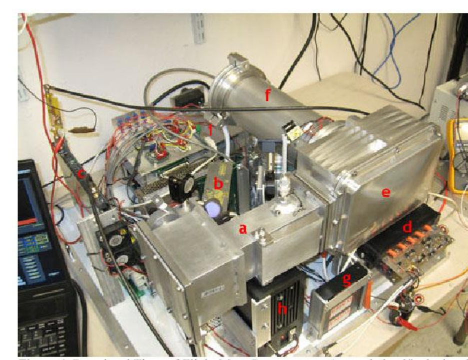
Icebreaker

- Search for biomolecular indicators of life in polar sub-surface ice
- Perform a general search for organic molecules in the ice
- Determine the nature of the ground ice formation and the role of liquid water
- Assess recent habitability
- Understand the mechanical properties of the ice





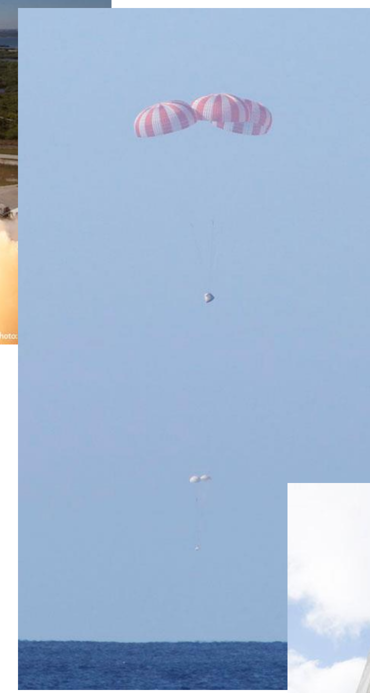


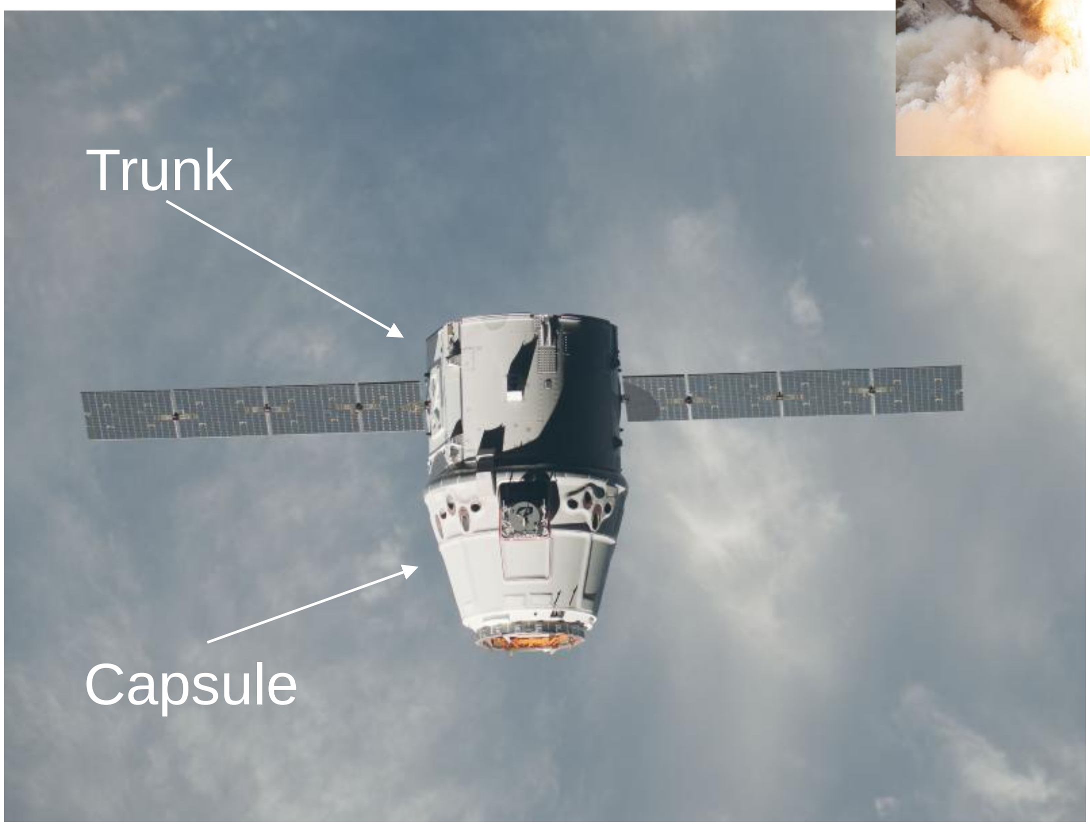


McKay et al. 2013, Astrobiology, 13, 334–353

Dragon

- Crew and cargo for International Space Station
- Four flights so far—three to ISS—all successful.





Why a Dragon-derived Mars lander?

- Low cost for *launch vehicle and lander*
- Dragon systems *already* have most necessary capabilities
  - Sufficient lifetime & resources for Mars transfer trajectory
  - Atmospheric entry systems capable of guided lifting entry
  - Highly capable, throttleable retropropulsion thrusters
- Falcon Heavy can throw Dragon to Mars
  - Throw mass > 10 t to Mars (C_3 ~ 10 km^2/s^2)
  - Red Dragon injected mass ~ 6.5 t plus payload
- High payload mass & large interior volume
- EDL technology scalable to large cargo & human landers

Powered descent & soft landing

- LEO crew version will have integrated high-thrust storable bi-prop propulsion
  - Initially for launch abort
  - Eventually will be used for precision landing on legs
- Mars version will use same propulsion systems
  - Capacity to decelerate from supersonic speeds
  - Throttle range sufficient for landing

Mission concept

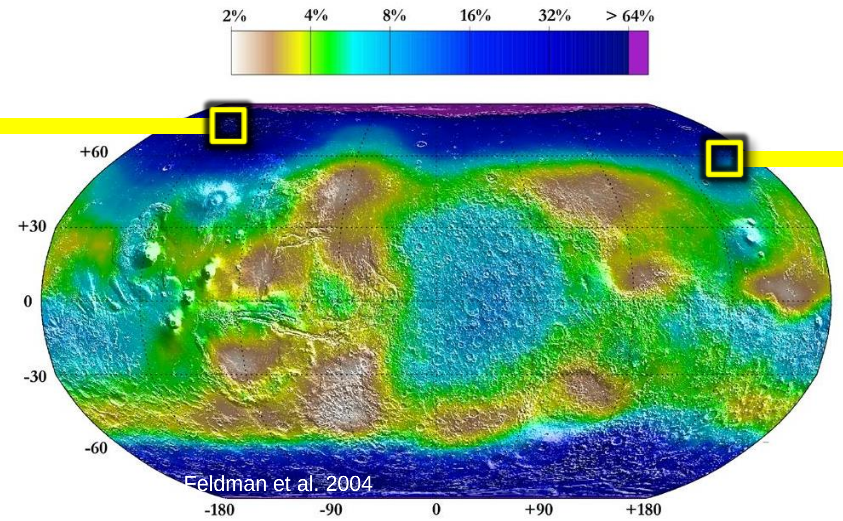
- Use Dragon with the minimum necessary modifications
  - Remove systems unique to LEO missions (e.g. berthing hardware)
  - Add systems unique to Mars missions (e.g. deep space communications)
- Launch on a Falcon Heavy
- Separate Dragon's trunk—perhaps including secondary payloads—prior to entry (same as standard LEO missions)
- Enter and decelerate through guided, lifting, hypersonic trajectory
- Fire launch abort motors supersonically and use them for remainder of descent
- Land on legs
- Deploy surface systems & commence surface operations

Establishing feasibility

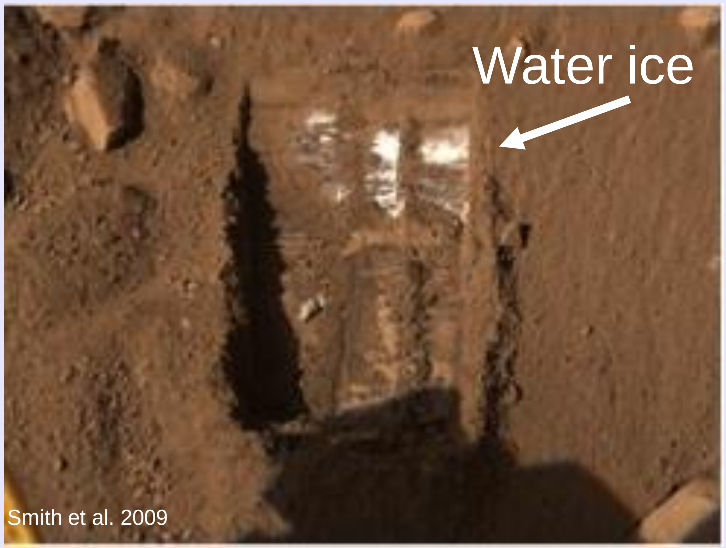
- Entry, descent, and landing
- Interplanetary cruise
  - Communications and navigation
  - Thermal environment
  - Radiation tolerance
- Planetary protection
- Payload accommodation
- Surface power, communications, thermal, etc.

Potential landing sites: Polar or mid-latitude sites with proven near-surface ice

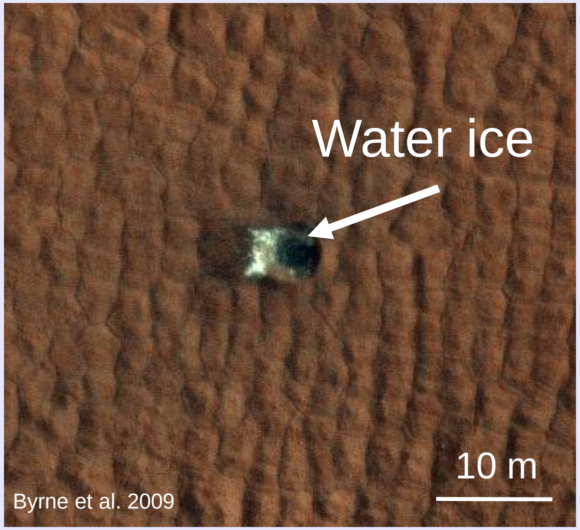
Water abundance



Phoenix site

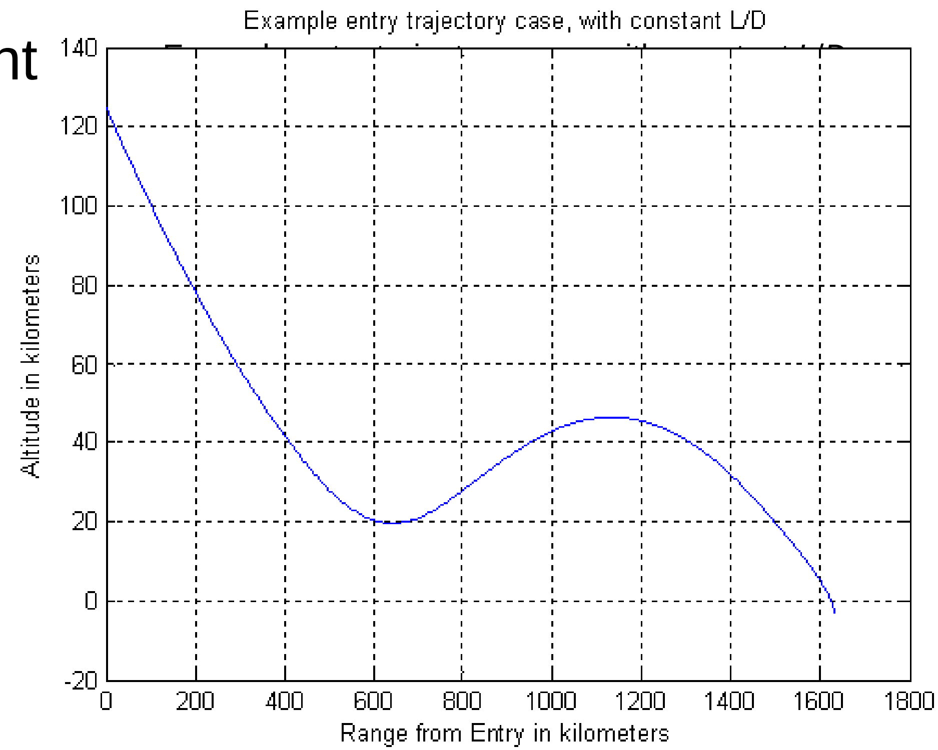


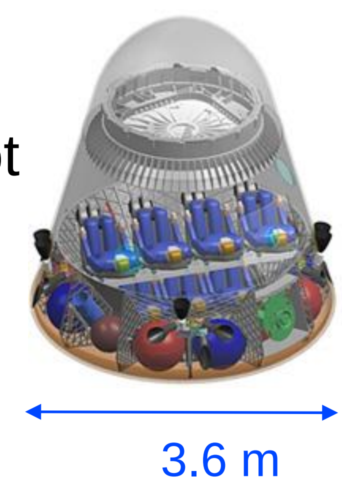
Mid-latitude ice

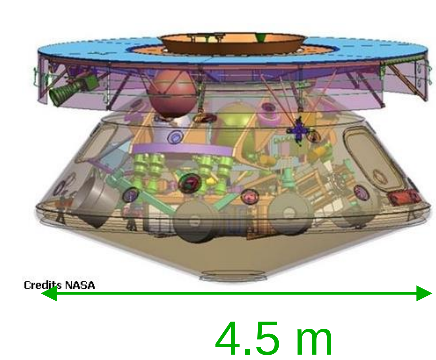


Entry, descent, and landing

- Dragon has a high ballistic coefficient ($\beta = M / C_D A > 300$ kg/m^2) and modest lift ($L/D < 0.3$)
- Feasibility determined by propulsive capacity of the launch abort motors
- Parachutes not preferred—on edge of feasible and would require significant development program
- Approach common for large-scale lander concepts
- Preliminary CFD analysis to date indicates propulsive performance not sensitive to aerodynamic flowfield







Performance for the mission concept

- Target sites and conditions
  - Elevation ~ 3 km below the MOLA reference (i.e., most of the northern hemisphere)
  - Arrival solar longitude (L_s) ~ 0°
  - Variations around nominal cases in vehicle parameters and entry conditions
- Comparing retropropulsive Δ*v* requirements with vehicle capability
- Analysis so far indicates an ability to deliver **more than one tonne** to our candidate landing sites

Summary

- The Dragon capsule design contains most of the features necessary for a Mars lander
- Analysis indicates Dragon would be capable of performing all EDL functions
- Landing approach scales to future human landers
- The analysis indicates that Dragon would be able to deliver more than one tonne to our candidate landing sites, with margin

Collaborators

- **Ames Research Center**
- Brian Glass
- Andy Gonzales
- Jennifer Heldmann
- Lawrence Lemke
- Christopher McKay
- Carol Stoker
- Kerry Trumble
- **ERC, Inc.**
- Gary Allen
- **SETI Institute**
- Alfonso Davila
- **SpaceX**
- Steve Davis
- Lars Blackmore
- Margarita Marinova
- Justin Richeson
- Paul Wooster
- **Kennedy Space Center**
- Phil Metzger
- Tony Muscatello
- **Johnson Space Center**
- Jerry Sanders
- **Langley Research Center**
- Artem Dyakonov
- Karl Edquist