



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

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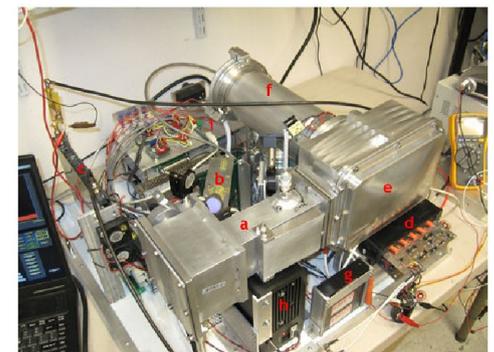
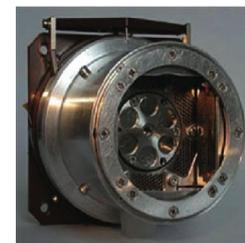
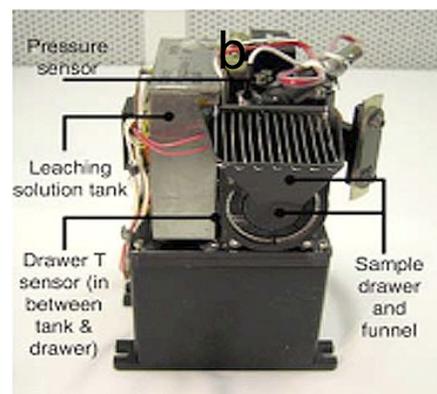
Overview



- 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

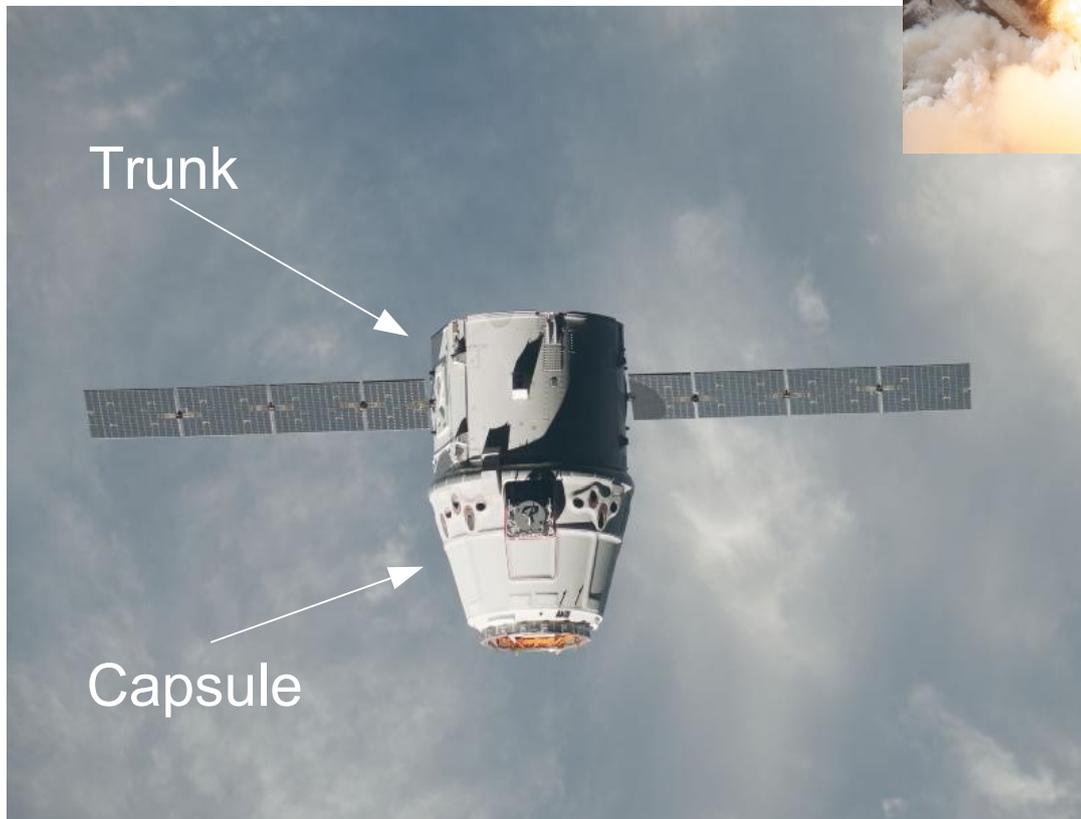
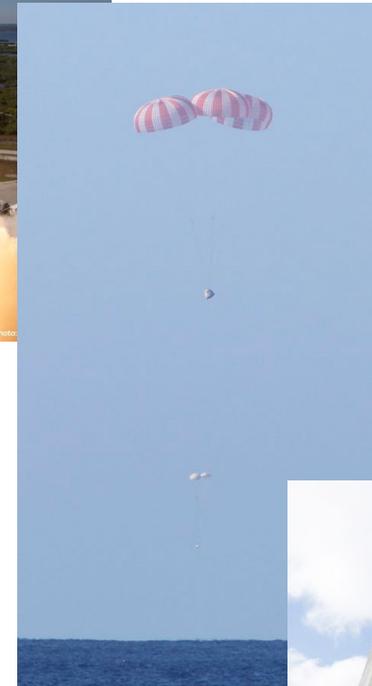
Icebreaker

- 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



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 ($C_3 \sim 10 \text{ km}^2/\text{s}^2$)
 - 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



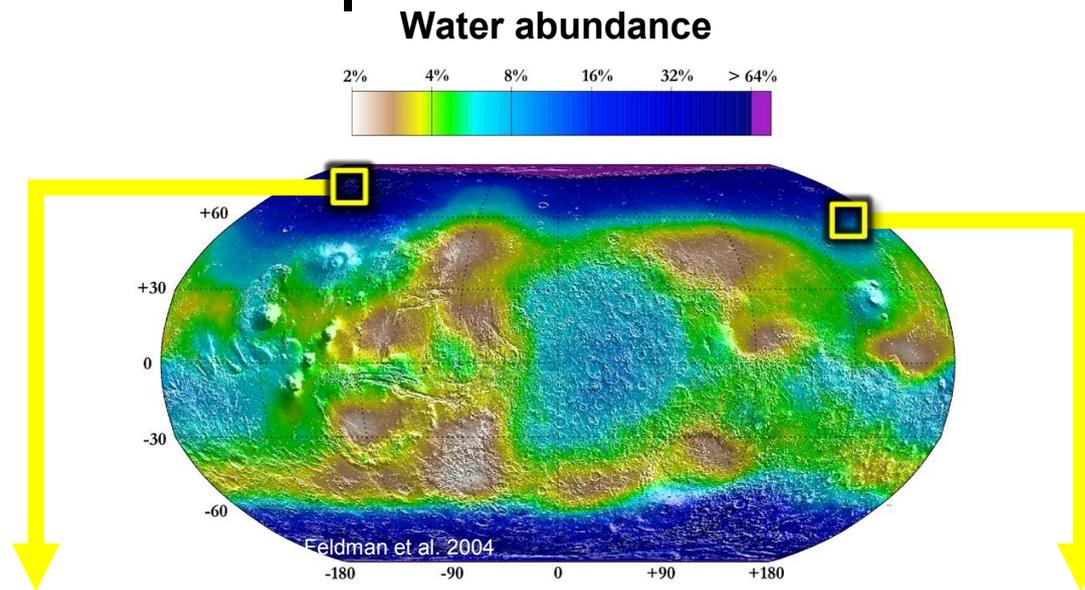
- Use Dragon with the minimum necessary modifications
 - Remove systems unique to LEO missions (e.g. berthing hardware)
 - Add systems unique to Mars missions (e.g. deep space communications)
- Launch on a Falcon Heavy
- Separate Dragon's trunk—perhaps including secondary payloads—prior to entry (same 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

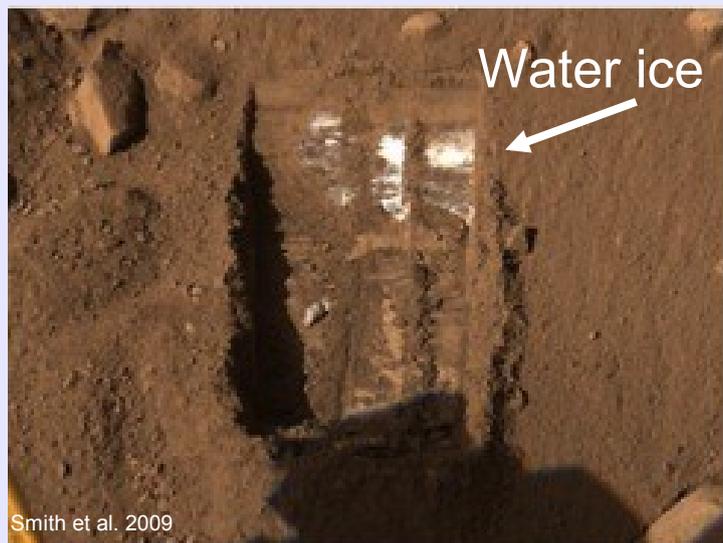


- Entry, descent, and landing
- Interplanetary cruise
 - Communications and navigation
 - Thermal environment
 - Radiation tolerance
- Planetary protection
- Payload accommodation
- Surface power, communications, thermal, etc.

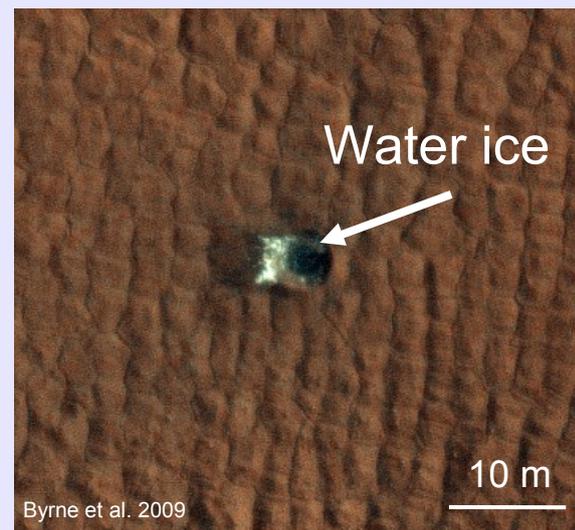
Potential landing sites: Polar or mid-latitude sites with proven near-surface ice



Phoenix site

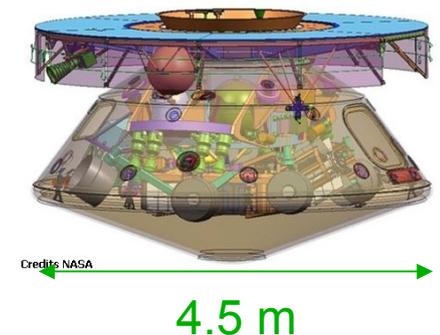
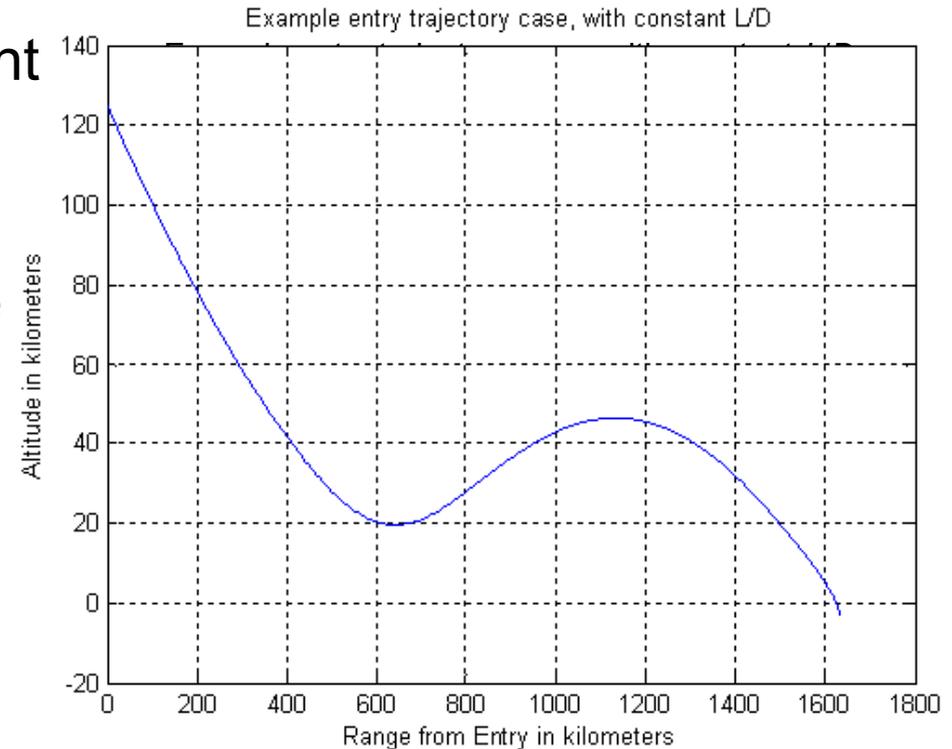


Mid-latitude ice



Entry, descent, and landing

- Dragon has a high ballistic coefficient ($\beta = M / C_D A > 300 \text{ kg/m}^2$) 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) $\sim 0^\circ$
 - Variations around nominal cases in vehicle parameters and entry conditions
- Comparing retropropulsive Δv 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**
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 - Jennifer Heldmann
 - Lawrence Lemke
 - Christopher McKay
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 - Kerry Trumble
- **ERC, Inc.**
 - Gary Allen
- **SETI Institute**
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- **SpaceX**
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 - 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