Red Dragon

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

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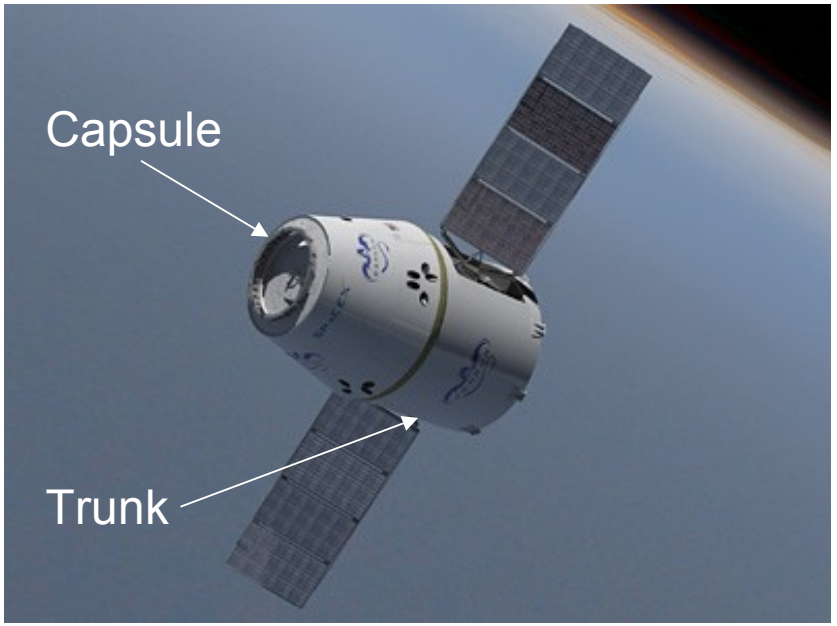
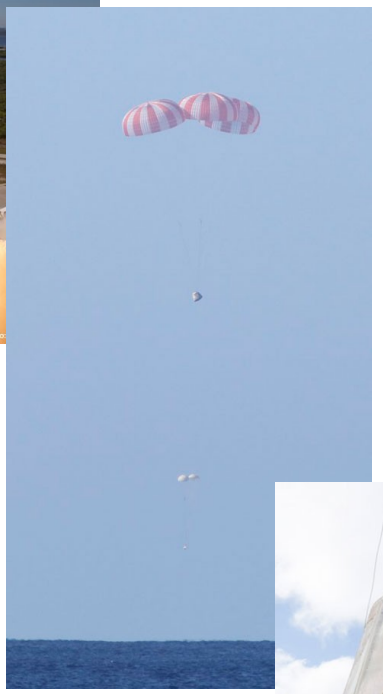
Introduction

- We are studying whether a substantially unmodified SpaceX Dragon capsule could be used as a lander for Mars robotic scientific and human-precursor payloads
- Currently evaluating Dragon as a platform for a low-cost (Discovery class) drilling mission concept
- The primary technical question is whether Dragon can perform all of the necessary EDL functions
  - Deceleration from hypersonic entry to supersonic speeds
  - Deceleration from supersonic speeds to terminal descent
  - Controlled soft landing
- SpaceX & NASA team are conducting a detailed EDL analysis
  - EDL trajectories close for a broad range of relevant entry conditions
  - The analysis indicates a capability to deliver ~ 1 tonne of payload to the surface

Dragon

- Crew and cargo for ISS
- Successfully orbited, reentered, and recovered during first test flight in December





Why a Dragon-derived Mars lander?

- Low cost. Preliminary estimate ~ $150–190 M 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

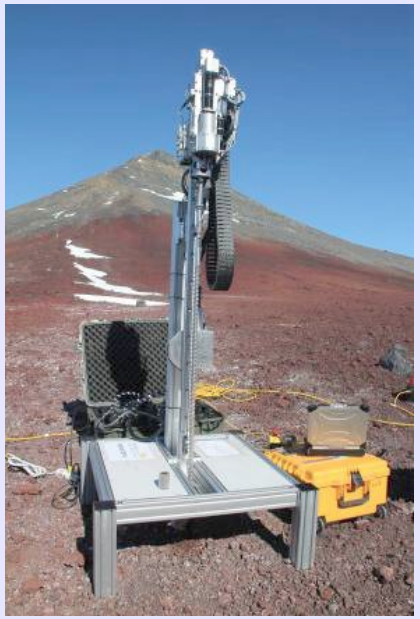
Mission concept

- 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
- Safe Dragon's systems
- Deploy surface systems & commence surface operations

Drilling mission concept goals

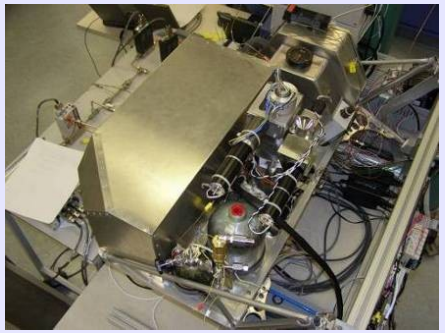
- Scientific goals
  - Search for evidence of life
  - Assess subsurface habitability
  - Establish the origin, distribution, and composition of ground ice
  - Reconstruct climate using ground ice record
- Human precursor goals
  - Conduct human-relevant EDL demonstrations
  - Assess potential hazards in dust, regolith, and ground ice
  - Characterize resources
  - Demonstrate access to subsurface resources
  - Conduct ISRU demonstration

Drilling mission payload concept

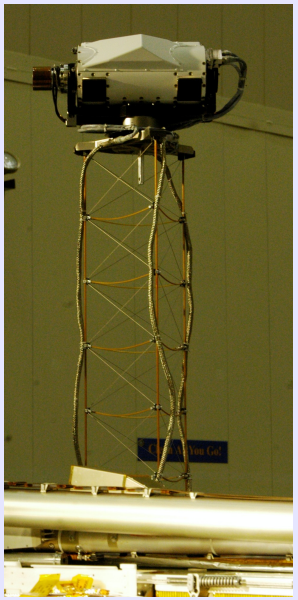


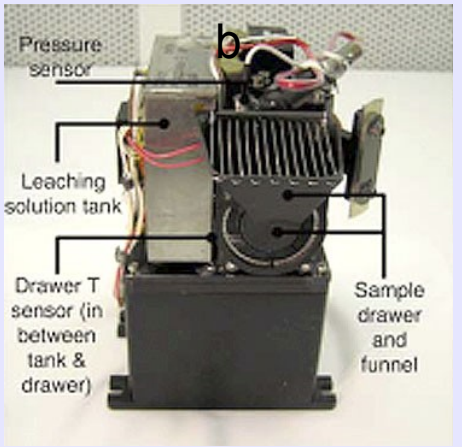
TRL 5 drilling system. Has been tested in field and Mars environment with HEOMD & SMD support.

Instrument to detect extant life (SOLID, from Spain) at TRL 5.

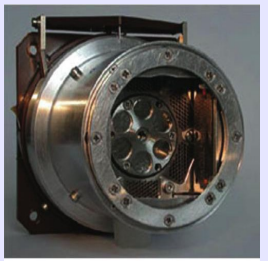


Water extraction system & propellant production system. HEOMD funded KSC & JSC ISRU activity at TRL 5.



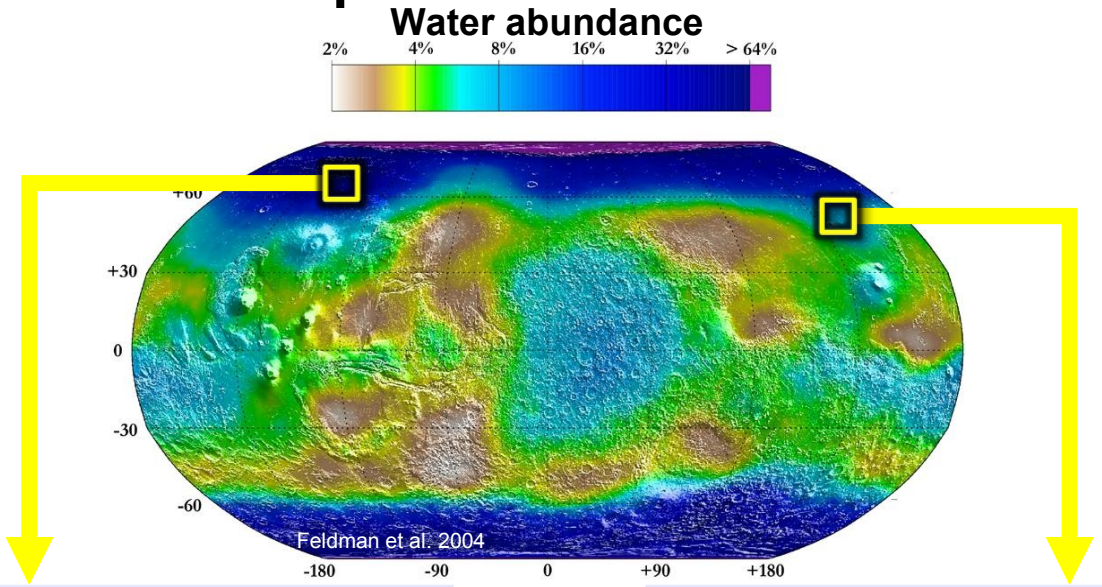


SSI and Wet Chemistry Lab from Phoenix (TRL 9).

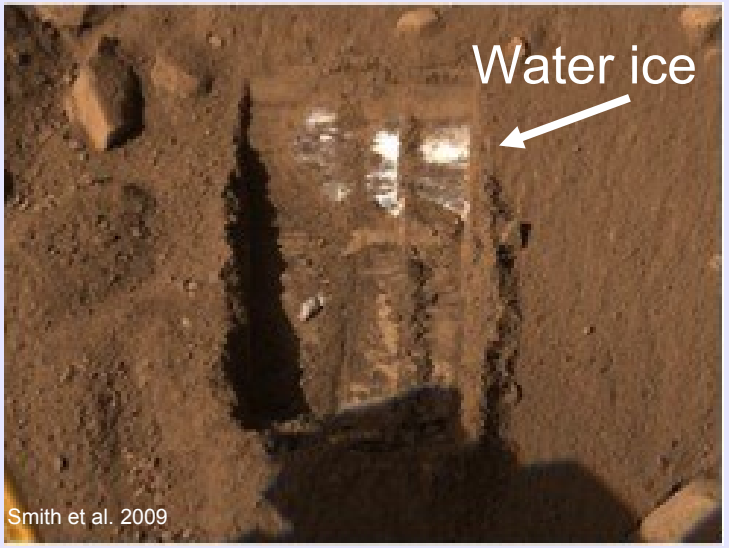


Alpha-Particle X-ray Spectrometer (TRL 9).

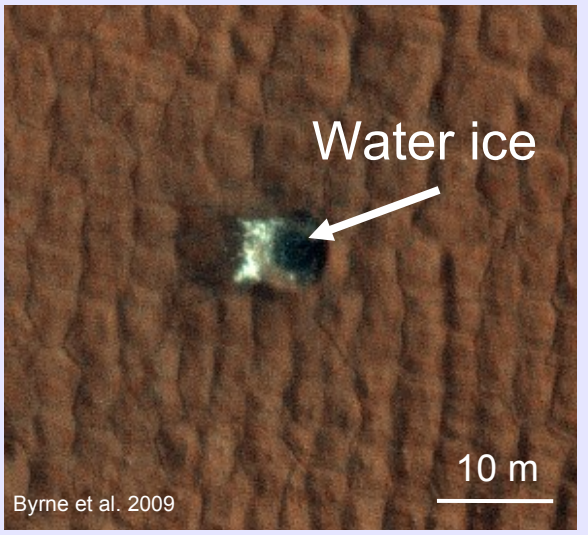
Potential landing sites: Polar or mid-latitude sites with proven near-surface ice



Phoenix site

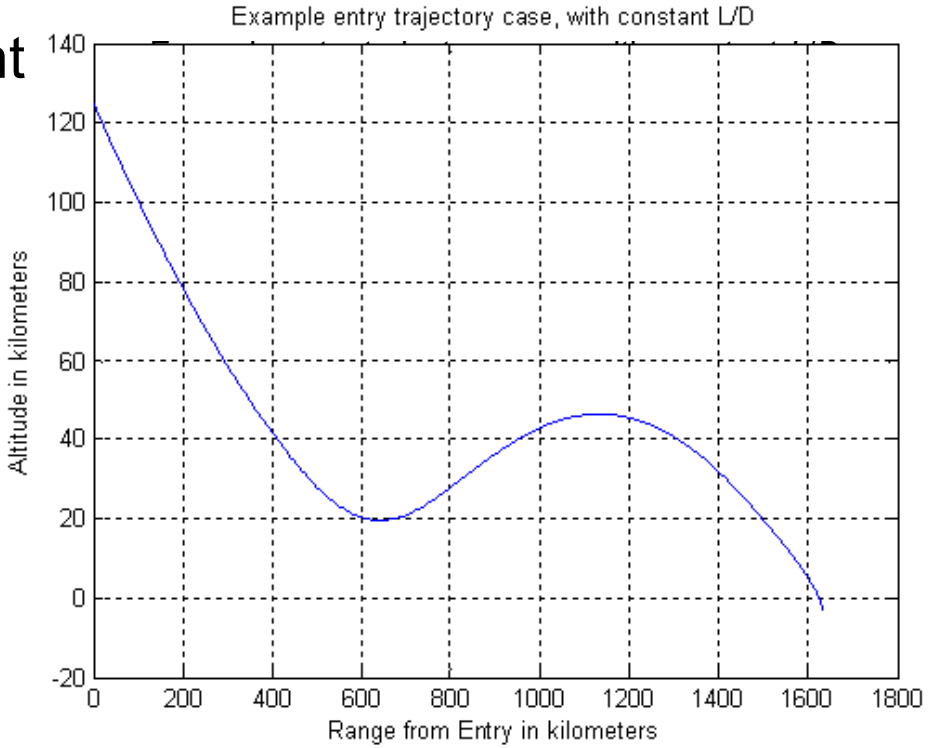


Mid-latitude ice



Hypersonic entry and deceleration

- Dragon has a high ballistic coefficient ($\beta = M / C_D A > 300$ kg/m^2) and modest lift ($L/D < 0.3$)
- Drag must slow capsule sufficiently for remainder of descent & landing to be within propulsion system capabilities
- SpaceX performed a 3-degree of freedom analysis
  - Varied entry conditions (speed, entry mass, flight path angle, & atmospheric density) and vehicle parameters (L/D, entry mass)
- Mission analysts at NASA Ames reproduced the results; results consistent with Braun & Manning (2006)



3.6 m

4.5 m

Supersonic deceleration

- Red Dragon will use retropropulsion from supersonic speed to touchdown
  - Takes advantage of existing capabilities
  - Suitable for large, dense human mission landers
- Parachutes not feasible without vehicle modifications (e.g. increasing *L*/*D*) and would require significant development program
- Deceleration performance depends on propulsive capability and aerodynamic effects
  - Currently assessing aero-propulsive interactions
  - Preliminary CFD analysis to date indicates propulsive performance not sensitive to aerodynamic flowfield

Current results

- Currently assessing payload capacity for point cases
  - Elevation ~ 3 km below the MOLA reference
  - Arrival solar longitude (L_s) ~ 0°
  - 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

- Falcon Heavy can send Dragon to Mars
- 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, with margin
- The analysis indicates that Dragon would be able to deliver more than one tonne to our landing sites
- Dragon launched on Falcon Heavy would be a cost effective option for future missions

Next steps

- Continue studying feasibility and performance
  - Independent review of EDL analysis
    - Hypersonic trajectories/aerodynamic deceleration
    - Propulsive decent
  - Optimize trajectories
    - Determine maximum payload capacity
    - Assess feasibility of high-elevation landings
  - Continue developing options for payload integration with Dragon
  - Continue developing planetary protection strategy
  - Determine what other modifications to Dragon are necessary
- Continue refining concept scientific & human precursor investigations