Mars Polar LAnder and ClimatE Record Network (Mars PLACER Net or MPN)

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Overview: We propose a mission using the MarsDrop architecture to investigate Mars' Polar Layered Deposits (PLD). Understanding Mars' recent climate history requires models that can accurately reproduce observations of the present-day atmosphere. To extrapolate backward in time, these models must also account for volatile exchange between the atmosphere and the PLDs[1] [2]. PLDs record climate variations spanning the last several million years, due to obliquity-driven insolation cycles[3]. However, to interpret this climate record, several key observations are lacking: 1) surface winds are largely unknown, especially in the polar regions[4] [5], 2) quantities and isotopic compositions of H_2O and CO_2 exchanged with the polar caps are poorly constrained[6], and 3) spatial scales of fine layers in the PLD may be unresolved from orbit[7]. This mission, Mars Polar LAnder and ClimatE Record Network (Mars PLACER Net or MPN), will provide new measurements to validate models and confidently extend them to past climate regimes.

The MarsDrop architecture is uniquely suited for making multiple pinpoint landings in the PLDs. This architecture could also be easily adapted and/or simplified (with different instruments) to investigate other regions of interest and/or science objectives. These include: 1) active dune fields (ADFs), 2) recurring slope lineae (RSLs), 3) hydrogeological cycle, 4) surface chemistry, 4) global seismology, 5) CH_4 temporal variations & the connection to possible life, 6) saltation-driven effects, 7) exploration of Valles Marineris (i.e., hazardous locations where one would not want to send a $B-mission), 8) unusual geological features (caves, pits, geysers, etc.), 9) characterization of future human landing sites, 10) network meteorology to understand climate as it relates to future human landings, etc.

Operations: MarsDrop is a new paradigm developed by The Aerospace Corporation (and later, JPL) for precision landing of small payloads on Mars enabling unprecedented surface access to achieve a wide range of science objectives[8]. MarsDrop combines reentry vehicle heritage from Aerospace's thrice-flown Reentry Breakup Recorder (REBR)[9], [10], [11], a 1940s-era Rogallo parawing[12], [13] (later matured by NASA for possible use by Gemini S/C), and JPL's Terrain Relative Navigation (TRN)[14] [15] system to enable pinpoint landings. Together, these technologies result in a low-cost, micro-lander capable of reaching a large portion of Mars' surface.

Several MarsDrops could be launched as a rideshare with another mission (requiring a propulsive cruise stage); a larger number could be launched on a dedicated launch vehicle (LV), enabling the delivery of multiple unique or identical payloads per launch (requiring a small, low-cost LV). MarsDrop could also be carried on an orbiter and, with a CubeSat-sized propulsion/GNC system, be deployed from orbit as desired or needed. After entering the Martian atmosphere (**Fig. 1**), MarsDrop decelerates to a subsonic speed, jettisons its backshell, deploys its parawing, and flies across Mars to land within a few tens of meters of a predetermined target. Just before landing, it jettisons its parawing and lands with an impact of ~25g. Once on the surface, it unfolds its solar arrays, rights itself if needed (à la Pathfinder and the Mars Exploration Rovers), and begins its science mission.

Instruments: MPN would deploy a series of micro-landers at even intervals along a line that transects a region of the PLD (**Fig. 2**). Each lander would be instrumented to measure wind velocity, temperature, pressure, and H_2O, CO_2, and radiative fluxes. Other possible instruments include: 1) a miniature ground-penetrating radar (GPR) to resolve thin layers in the PLD, 2) a tunable laser spectrometer (TLS) to determine isotopic abundances of H_2O and CO_2, 3) a saltation sensor, and 4) an electric field mill. The TLS can also measure temporal changes in CH_4.

Science Objectives: The major science questions to be addressed to extract and interpret the climate record stored in Mars' PLD are:

1. What are the present/past fluxes of volatiles, dust, and energy in/out of the polar regions?

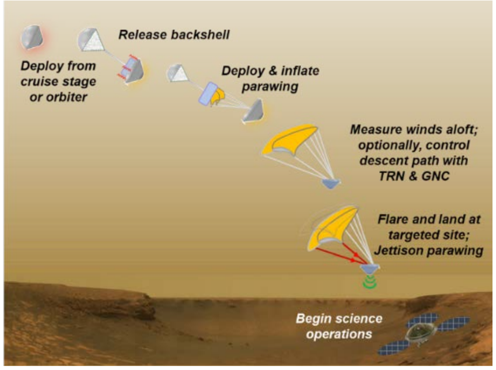

Fig. 1. MarsDrop EDL Sequence. With TRN, MarsDrop is capable of (10s of meters) landings.

2. What chemical and physical processes form and modify layers?
3. What is the timespan, completeness, & temporal resolution of the PLD climate record?

These Science Objectives are addressed:

1. Quantify mesoscale polar atmospheric circulation models, boundary layer turbulence, & volatile exchange to constrain/validate process models
2. Resolve the thinnest layers in the PLD to constrain rates of accumulation/ablation and link to orbital observations
3. Determine isotopic fractionation recording volatile exchange in the PLD

Needed Technologies/Current TRLs: While some elements of MarsDrop have high TRLs and the basic concept of deploying a parawing from an entry system has been tested via high-altitude balloon drops (**Fig. 3**), the system-level TRL is still low (TRL 2). Since MarsDrop's inception, we have identified a number of key areas needing more work. These include (with associated TRLs):

- Probe entry stability studies involving trades between the vehicle's CG, ballistic coefficient, entry system shape, and packaging (3)
- Modeling and testing of post landing orientations on different terrains given various initial entry conditions to understand solar array deployment, uprighting, and potential interference with the parawing lines (2)
- Design/prototyping of a miniature altimeter to measure height above ground to determine timing of landing flare/parawing jettisoning (4)
- Design/prototyping of parawing attachment mechanisms, actuators for steering using suspension lines, & a jettisoning system (3)
- Monte Carlo analyses of the entire EDL sequence to show that MarsDrop can handle entry dispersions, as well as atmospheric uncertainties based on location and season (2)

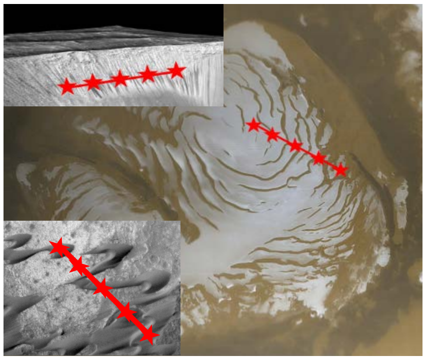

Fig. 3. Notional depiction of a series of MarsDrop landers transecting the PLD. Such landing patterns would require the use of TRN. This architecture could also be used to investigate RSLs or ADFs (see insets).

- Use of miniaturized subsystems to allow increase in payload mass (e.g., ~5 kg) (3)
- For rideshare scenarios, trade studies between cruise stage type, e.g., propulsive ESPA rings or COTS small S/C buses (2)
- For dedicated LV scenarios, mission design studies to determine ΔV for TCMs, and trades between new, low-cost LVs (3)
- Planetary Protection technologies for landing in habitats for extant life (4)

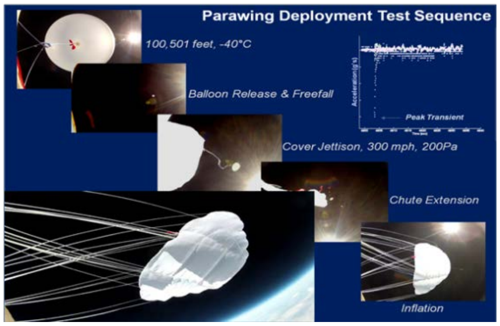

Fig. 2. MarsDrop Parawing Tests. Initial tests showed that a parawing could be deployed in Mars-like atmospheric conditions.

References:

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