Contemporary Gully Processes on Mars

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Introduction: Since their discovery [1], martian gullies have been the focus of much Mars community attention. Discovery of gully deposits emplaced between 1999 and 2006 [2], additional examples added since 2006 [3], and more recently, recurring slope lineations (lineae) in 2011 [4], enhance the view that gullies are the sites of contemporary processes, with the predominant view that these processes involve the action of a fluid composed mostly of liquid water. Alternative interpretations are still possible, as the only substantive observations are orbiter images of deposits of material mobilized by the active process, and not of the actual fluid itself or the actual active process.

The presence of liquid water at the surface of Mars today, in quantities capable of geomorphic action, is of considerable interest not only to searches for potential habitats for extant life, but also to future human exploration of the planet (water could be used in *in-situ* resource utilization for astronaut sustenance and propellant manufacturing).

Approach to Mission: Our approach to this mission is to a) start with the science objectives, b) determine where on Mars the objectives could be addressed, c) establish how the objectives could be addressed (what payload was needed), and d) examine mission hardware and mission design approaches.

Mission Objective: The proposed mission objectives would address the nature, composition and source of the fluid (including the minority view that the deposits seen from orbit are emplaced by dry flow). Stated as a hypothesis: liquid water exists at or near the surface of Mars in these gully locations. Additional objectives include examining the recent and longer term history of the processes in the crater.

Where on Mars?: Orbiter observations show more than 6000 locations where gullies are found, with many sites displaying multiple gullies (number of gullies > 30,000). The majority of gullies occur on crater walls. Only about 0.33% of these locations show gully deposits formed since 1999. A somewhat larger number of features (light-toned gully deposits that resemble recent gully deposits but were formed before 1999) are also found, more than doubling the possible candidates. Recurring slope lineations are equally rare. Clustering of gully sites (Figure 1) guided the search for mission targets with gullies, recurring slope lineations, and rarely, both landforms. Combined with mission design constraints (room for a landing ellipse, trafficability of the surface, and accessibility to the recent features) a few sites were found with both recent gully deposits and recurring slope lineations. Figure 2 shows one of these sites.

How are the Objectives to be Addressed: An important aspect of this question is whether or not the same types of observations should be made of a recent gully deposit and recurring slope lineations? This

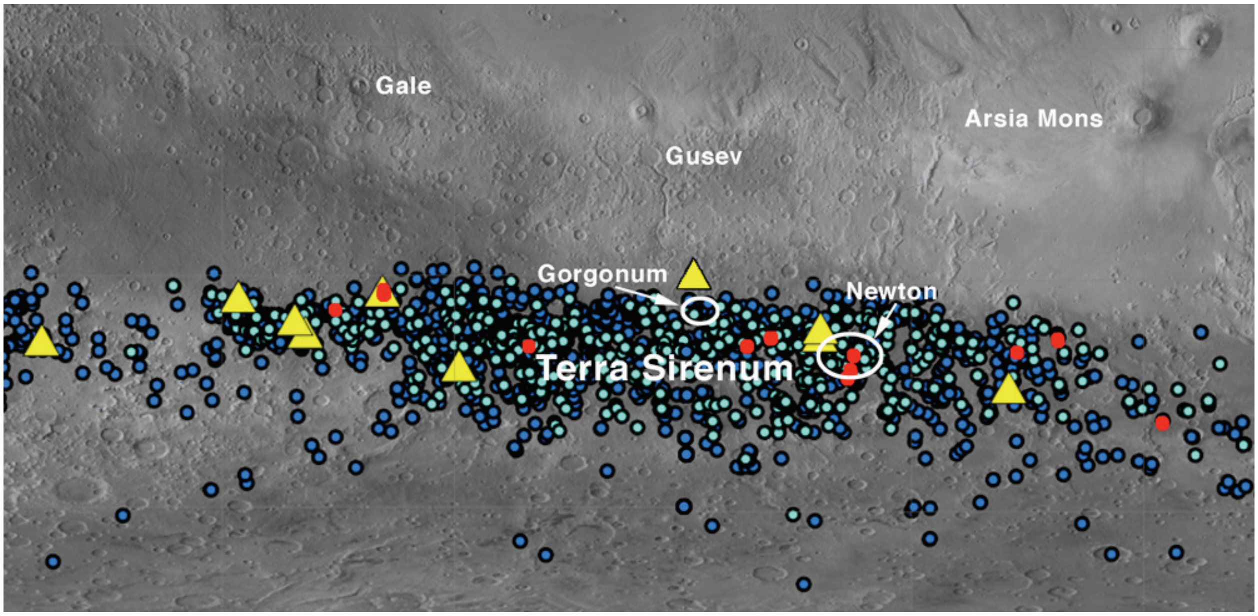

Figure 1: Gully locations (dark blue dots), gully monitoring sites (light blue dots), recent gully deposits (yellow triangles), and recurring slope lineations (red dots). Map covers ~165° of longitude and ~78° of latitude in rectangular projection.

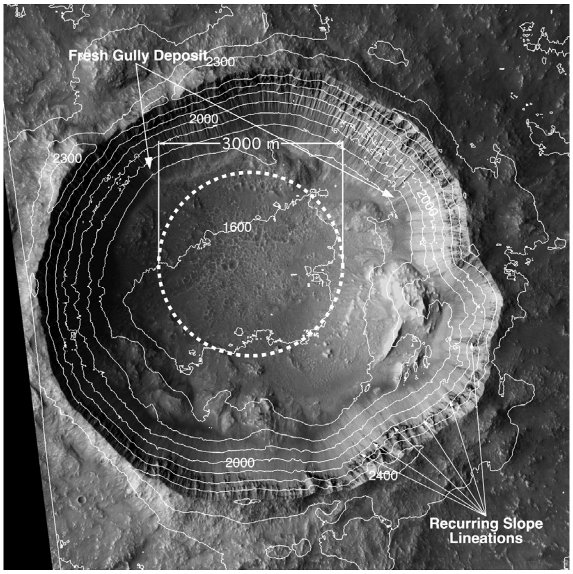

Figure 2: Candidate crater with both recent gully deposits and recurring slope lineartions. Crater wall slopes are composite and concave upward, with upper rim slopes averaging 40-55° and the lower slope averaging about 20-30°. CTX DEM contours 100 m.

depends on whether the locations of the materials are accessible, and if so, what measurements can be made, and if not, what observations might still provide a test of the hypothesis. Access is related to mission hardware and design issues, so these are iterated. We assessed what could be observed remotely, then examined contact science, and concluded with an assessment of the role and need for sample analyses.

Remote Sensing: would include telescopic visible and thermal IR imaging (day and night monitoring observations of activity), NearIR spectrophotometry (remote composition), passive and active microwave measurements (search for high dielectric constants associated with liquid water, brines, and water ice), and a spectrometer (mass or tunable diode laser) to sense atmospheric water vapor.

Contact Science: includes a microscopic imager (for particle size analyses), a composition spectrometer (Alpha Particle X-ray Fluorescence or Raman), and a backhoe for exposing surface and subsurface materials.

Analytic Science: X-ray diffraction (definitive mineralogy) and mass spectrometry (for volatile chemistry) are candidate investigations, although sample collection and preparation for these greatly increase the complexity and cost of the mission.

How are these used: Recent gully deposit materials often flow down the crater wall and reach the floor of the crater (where slopes are typically less than 20°). Here, both remote sensing and contact science can be applied directly. Among the tests are the size frequency of the materials in the debris aprons. Dry granular flows are generally well sorted and consist of fine material; they rarely entrain or carry larger materials, and these are not segregated as they are in liquid-fluidized flows. The spatial relationships (both longitudinally and transverse to the flow) of particle patterns (size, composition, shape) can also be characteristic of the mode of emplacement.

For recurring slope lineations, that occur on much steeper slopes—30° below the base of the steeper (~20-55° or higher) rim head scarp, contact science is unlikely to be possible. However, these features are expected to occur during the mission, so remote observations of their timing, speed, extent, topography, and morphology, especially while in motion, would be particularly diagnostic. Increases in atmospheric volatiles spectroscopically could be diagnostic.

Mission Hardware and Design: Our efforts focused on several critical technical challenges, and approaches to increasing technical readiness levels of these mission areas, while reducing their costs. Among the challenges are landing altitude (2+ km relative to MOLA) and accuracy, dry heat microbial reduction (DHMR), mobility, and paylod mass fraction. Building on JPL's experience with landing approaches, we concluded that pin-point landing (uncertainty ~100's m) was not required; rather, precision landing with an uncertainty of 3 km was achievable with guided hypersonic entry augmented with range triggering of parachute deployment. Additional safety and accuracy can be achieved with terrain relative navigation during powered descent (though this is a slight cost increase and has not been demonstrated in space flight). The 2+ km altitude and the altitude cost of range trigger can be attained with a lower ballistic coefficient entry vehicle. DHMR, a huge cost impact on Viking, is likely to be much smaller for this mission given the present state of the art for electronic and other materials, and the access to rentable ovens (composite curing technology). Mobility based or scaled on previous systems is likely to be able to reach the target features within the slope constraints noted above. Payload mass of ~20 kg out of 175 kg (MER) (twice MER's payload mass) is possible with mass savings in electronics and mechanical systems (including cabling).

The basic mission plan lands within a 3 km uncertainty within a high altitude crater, provides mobility significantly greater than the landing uncertainty, power for a 20 kg science payload and at least 1 Earth year of operations.

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