IMPACTOR SCIENCE AT MARS. A. A. Wolf[1], A. Freeman[1], S. Kedar[1], F. H. Webb[1], S. Matousek[1], [1]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA.

Introduction: Impactors have yielded breakthrough science on a comet (Deep Impact) and the Moon (LCROSS). A Mars impactor mission could accomplish multiple scientific objectives: 1) reveal and characterize subsurface composition at depths below 1 meter; 2) explore areas where liquid flows have been observed such as deep gullies or where liquid flow is likely at the base of existing glaciers; 3) conduct an active seismic investigation of the Martian interior. Excavation by impactors could also facilitate return of a sample from Mars or from Phobos.

Possible targets with liquid water:

Gullies. Recent MRO observations show flows that appear in spring and summer on a slope inside Mars' Newton crater (Figure 1). Sequences of observations recording the seasonal changes at this site and a few others with similar flows are the best evidence of liquid water on the planet's surface today. Fresh-looking gullies suggest slope movements in geologically recent times, perhaps aided by water.

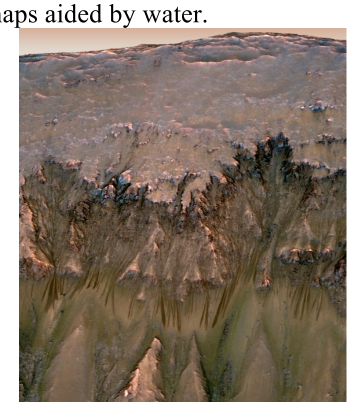

Figure 1: An image combining orbital imagery with 3-D modeling shows flows that appear in spring and summer on a slope inside Mars' Newton crater. **Image Credit:** NASA/JPL-Caltech/Univ. of Arizona. [1].

Glaciers. A likely yet unexplored location for year-round liquid water on Mars is at the base of the mid-latitude glaciers revealed by the Sharad radar on MRO [1] (Figure 2). Here, as on Earth, friction would cause water that has been frozen for millenia to turn to its liquid state, lubricating the glacier's slow descent downhill. An impactor with sufficient momentum (or added explosive capability) could target the base of these glaciers and expose the basal conditions.

Subsurface composition: Just as meteor impacts on Mars reveal hidden mineral deposits, an impactor with sufficient momentum could expose buried strata at depths significantly greater than one meter (which is about the limit for drills). Targeting an impactor to a ~90° entry flight path angle significantly improves landing accuracy compared to the tens of km associated with landers which must fly shallow entry trajectories. A steep entry flight path angle minimizes the effects of uncertainties in atmospheric density and vehicle aerocoefficients on position errors at landing. Landing accuracy of a few km could enable impacting a gully or glacier base.

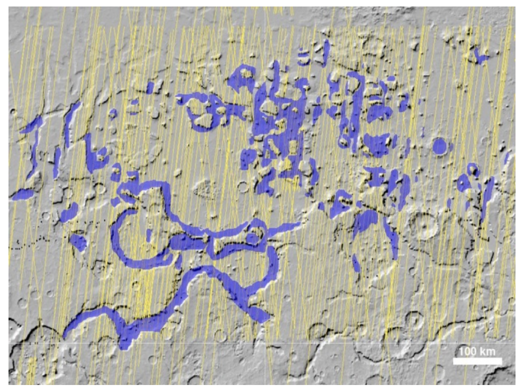

Figure 2: Map of Deuteronilus Mensae in the N. hemisphere shows detected ice deposits in blue. Yellow lines indicate ground tracks of radar observations from multiple orbits. **Image Credit:** NASA/JPL-Caltech/ASI/University of Rome/SWRI. [2-3]

The chemical composition of the materials exposed at the surface by an impactor could be examined using either a Raman spectrometer or a Fourier Transform Spectrometer (FTS). Both techniques require a strong illumination source. For the Raman spectrometer this could be a laser, similar to the Raman spectrometer proposed for ExoMars [2]) carried by a follow-up rover. If microbial life were present in the exposed sample, Raman spectroscopy is a well-proven technique to detect its presence [3]. If a larger plume were thrown up into the atmosphere, its chemical (or even biochemical) composition would best be examined using a solar occultation FTS [4] (similar to MATMOS [5]), in which case the strong light source is the Sun. Timing of the impact and the flyover of the orbiter carrying the FTS are critical but similar to that of Deep Impact, where the cometary impact's plume was successfully observed by a spectrometer on the spacecraft that carried the impactor to its destination.

To expose the base of glaciers at depth >> 1m, a penetrating explosive charge could be carried by the impactor, using the technology developed for 'bunker buster' bombs to throw up a plume much higher in the atmosphere, making its analysis from orbit using an FTS much easier.

Active seismic investigation: While aiming the impactors at the targets described above, they could at the same time be targeted to provide information about the planet's interior by generating seismic waves penetrating deep into the Martian subsurface (Figure 3).

Low estimates of seismicity rates on Mars motivated a feasibility study in 2009-2010 of a mission to determine Mars' interior structure with an active seismic experiment, in which a single lander with a seismometer is placed on Mars and then one or more impactors strike the planet in different locations.

This study showed that an Atlas V 541 launch vehicle could deliver a seismometer-equiped Phoenix-class lander, 3-4 500kg projectiles, and sufficient fuel to separate the lander and impactors in space and time to guarantee science return. The lander would arrive at Mars in advance of the impactors with sufficient lead-time to allow the seismometer to set up. Then, the impactors would arrive in a sequence spaced by enough time to allow the seismic signals from each event to dampen out below detectability across the frequency band of the seismometer. Impacts would be spatially distributed to optimize the imaging of the interior structure of Mars. The seismic waveforms recorded at the lander would be returned to Earth and analyzed for the interior structure. After the impact phase of the mission, the seismic station could continue to operate to detect and make use of naturally occurring seismic events, such as Mars-quakes and meteorite impacts.

Selection of the INSIGHT mission would place a seismometer-equipped lander on the surface of Mars, simplifying the above concept. Multiple impactors could be delivered as a follow-on to INSIGHT instead of delivering the lander and impactors on one mission.

Mars or Phobos impactor and sample return. A Mars impactor large enough to create a plume carrying particles a few tens of km high allows the capture and return of samples using the technique pioneered by Stardust at Comet Wild 2 and previously proposed for the SCIM mission ([6], [7]). This approach could return a Martian sample quicker and at much less cost than the traditional Mars Sample Return architecture.

A Phobos sample return could be accomplished during a flyby, without the need for orbit insertion or any pass through the Martian atmosphere. During the flyby, an impactor arrives at Phobos followed by a Stardust-like carrier with an aerogel collector which, having been launched on an Earth-return trajectory, returns the sample to Earth using a Stardust-like sample return capsule.

Conclusions. Impactors, employed successfully in the past on Deep Impact and LCROSS, can be used on a wide range of mission types to achieve a variety of objectives of interest to both scientific and human exploration.

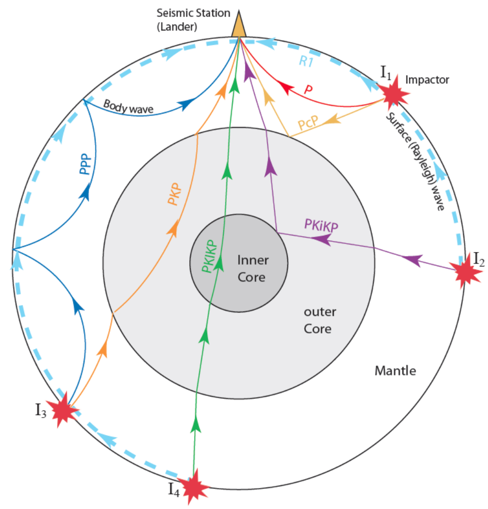

Figure 3: A planet's internal material interfaces and structure would reflect and refract the seismic waves generated by impacts on the planet's surface as they travel through the planet's body, forming a unique seismic fingerprint that would be used to reconstruct the planet's internal structure and elastic properties. [8]

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