MER CACHING ROVER FOR 2018 EXPLORATION OF ANCIENT MARS.
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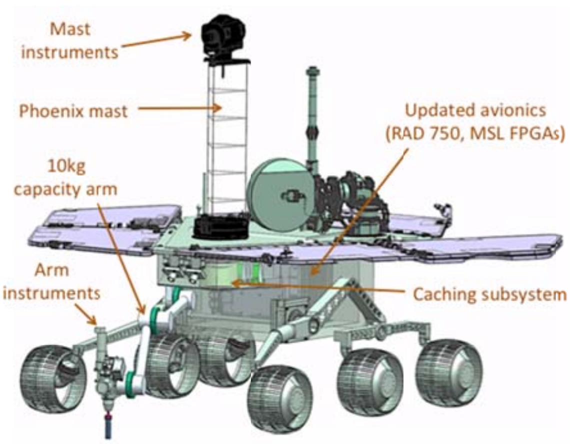

Figure 1. Minimal updated MER could cache dozens of samples from Noachian-Hesperian terrain in 2018.

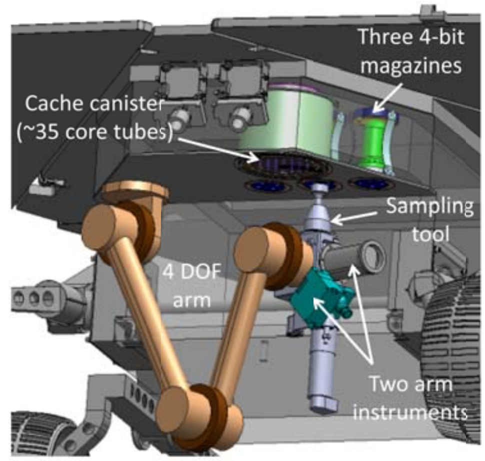

Figure 2. MER-compatible instruments and caching subsystem could meet Decadal sample-return objectives.

The past decade of Mars exploration has revealed diverse aqueous minerals preserved in the ancient rock record [1-4]. An ideal 2018 mission would build upon this discovery using in-situ exploration to traverse a stratigraphic record of environmental change, determine past aqueous environments, and cache samples for age-dating and astrobiological investigation in Earth laboratories. Such a mission would be a successful cornerstone for Mars Next Decade if it could:

- land at sites of high scientific interest with capabilities for in situ exploration and sample selection
- collect and preserve multiple samples with context
- collect surface data relevant to human exploration
- fit within a reasonable 2018 budget forecast.

MER scale, architecture, and capabilities are aptly suited for these criteria; their heritage provides an affordable, feasible way to meet Decadal Survey objectives [5] by pressing forward on an MSR pathway.

Major elements of the MER architecture would remain the same: landing system, rover structure and mobility, telecom, thermal and power subsystems with avionics updates only for obsolete electronic parts. MER payload mass and volume constraints can accommodate a caching system, arm with capacity for a drill/corer, and instruments to characterize sites and collect scientifically useful samples (Fig. 1).

Updated MER Payload: Stowed volume – not mass – is the limiting resource on MER. The MER mast, front mezzanine, and arm areas provide available volume for science and caching hardware (Figs. 2, 3). An updated imaging mast would be based on the Phoenix (PHX) design that reduces stowed volume and mass. The mezzanine would host the caching system and stronger arm holding a drill/corer and three science instruments. The instrument payload follows MEPAG guidance [6] (Table 1), enabling field observations essential to sampling and to interpretation of the samples back on Earth, as well as robust in-situ science, e.g., discrimination of past environments. This mast, arm, caching, and instrument suite (total 40 kg) would be twice the MER payload.

Caching Subsystem: This is based on JPL's Mini-SAC (Miniature Sample Acquisition and Caching Subsystem) architecture [7], compatible with a MER-class rover (Fig. 3). It can store 28-40 10-15 g samples. In accordance with [6], it collects intact rock core samples up to several cm long directly into individual sample tubes. The arm positions and exchanges sample tubes and drill bits. A sample is acquired, then its tube is sealed and placed in the mezzanine storage canister. This developmental caching design, based on currently available actuator and robotics capabilities, has undergone initial testing and is at ~TRL 4. It incorporates

Table 1. 2018 caching rover instrument suite.

Mast	***Color stereo camera***: Navigation, outcrop-scale texture/structure; correlation with mineralogical/chemical instruments
Mast	***Spectrometer for mineralogy/chemistry***: Discrimination of outcrop-scale compositional units, relation to orbital- and arm-based data
Arm	***Color microscopic imager***: μm- to mm-scale examination of petrographic/textural relationships among minerals
Arm	***Precision elemental chemistry/mineralogy***: μm- to mm-scale examination of compositional variation
Arm	***Surface preparation tool:*** *brushing/abrasion for* removal of dust and weathering layers prior to imaging/measurement

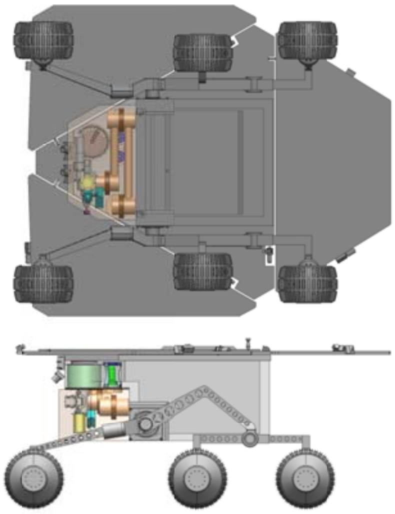

Figure 3. MER-class accommodation is sufficient.

rock-interrogation and sampling lessons learned from MER and PHX operations and MSL development.

Landing Sites and Traverse Distances: Landing site selection flexibility need not drive new engineering requirements. From MRO data, multiple specific sites of high science interest are precisely known [4], enabling site selection and certification. With guided entry, the landing ellipse (Fig. 4) enables us to "land on science" in target-rich ellipses where roving distances less than 1-2 km can reach outcrops of interest. MER demonstrated significant range capability (Spirit at 7.7 km and Opportunity at 34.4 km so far). Among multiple sites of high astrobiological interest, three 2018 reference sites [6] are compatible with this EDL (Entry, Descent, and Landing) system (lower than -2 km elevation, ±25° latitude), and the rover power system would allow full operation during summer and optional hibernation during winter.

EDL System: Operational experience indicates that the MER-heritage descent imaging and radar would support landing a vehicle mass of ~750 kg,

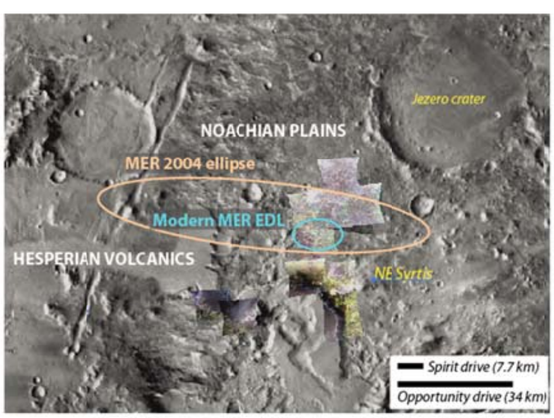

Figure 4. Guided entry lands MER within a CRISM footprint.

~40% more than MER. To land within one of the target-rich ellipses, guided entry (used on Viking and MSL) would be needed. For 2018, a reaction control system would be integrated into the heat shield (Viking implementation). This larger entry vehicle could be accommodated in any 3.5-m or larger launch fairing. Because our landing sites are lower than the MER sites, the heavier entry vehicle would still be within the performance envelope of the MER parachute. The airbag landing system could be used as flown before; the 40-kg payload mass is well within this heritage.

Low Implementation Risk: While the concept maximizes MER heritage, recent NASA investments (particularly robust FPGA electronic-chip designs done for MSL core avionics) would replace obsolete MER parts. Higher efficiency solar cells, higher energy-density batteries, and updated telecom components – all with flight heritage – are also available.

The instrument suite listed provides the capabilities needed for in-situ exploration and sample selection. Were an SMD/OCT partnership to focus quickly on Mars instrument development, even more advanced instruments could be accommodated up until PDR. Extensive post-MSL technology investments are already rapidly maturing coring and caching approaches.

Summary: A "modern minimal MER" could land in 2018 at sites already known to capture Noachian-Hesperian transitions. MER roving could reach the diversity of outcrops that allow in-situ exploration of these key places, now known from orbit. MER could carry the instrumentation and equipment needed to acquire and cache dozens of scientifically selected samples during this exploration. Workable configurations are demonstrated and manipulation and caching machinery is in development. This investigation concept is right-sized for the 2018 opportunity budget.

Our concept implements a programmatic strategy for missions to cache as they explore. With caching onboard, it could accomplish the first element of the MSR architecture as it discovers rocks so compelling they must be returned. Because caching can be undertaken with a MER-class machine, Mars Next Decade could consider caching at two or more of the several locations known to contain astrobiologically interesting environments, taking the first step of MSR in 2018.

References: [1] Bibring, J-P., et al. (2006) *Science*, 313, 1899 [2] Squyres, S.W., et al. (2004) *Science*, 306, 1709 [3] Squyres, S.W., et al. (2008) *Science* 320, 1063 [4] Murchie, S.L., et al. (2009) *JGR*, 114, E00D06, [5] SSB (2011) *Vision and Voyages for Planetary Science in the Decade 2013-2022* [6] MEPAG E2E-iSAG (2011) *Planning for Mars Returned Sample Science* [7] Backes, P., Younse, P., Ganino, A., "A Sample Acquisition and Caching Architecture Applicable to a MER-class Rover for Mars Sample Return," this workshop.