MARS MISSION CONCEPT - RESOURCE AND SCIENCE-RICH TARGETS FOR HUMAN LANDING SITES.

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Introduction: The first human missions to land on Mars will have surpassed the significant collective risks of launch from Earth, interplanetary transit, atmospheric entry, and landing on the surface. After that, one major risk could be avoided by the astute selection of landing sites based on both safety and science. Once on the surface, the main risks to people involve accidents or the loss or depletion of O_2 and H_2O supplies. But loss of these supplies is preventable.

Added Risk of Hybrid Missions: It is important to distinguish between missions dependent on carried supplies vs. those that adapt to use rich native resources. Missions that carry all needed resources will have to trade food and science instruments for oxygen and water payload. Also, the larger the landed payload the greater the difficulty and risk to achieve a safe landing. This has led to hybrid mission concepts where automated landers would be sent ahead of human missions to cache supplies, or to chemically extract and accumulate H_2O, O_2, H_2, and N_2. Cracking CO_2 to obtain and store O_2 is possible but still poses difficulties due to catalyst fouling. Surface water sources are rare or hard to scavenge at mid to low latitudes. Then comes the added and *very* substantial risk of having to land near the supply station. Failing to do so would immediately risk lives and the mission.

Power of Unlimited Resources: Water exists on Mars in vast quantities, virtually unlimited in surface sheets near the poles were the volatile has been cold-trapped over 10^6 to 10^8 years. Some areas are rough but others present the smoothest surfaces on Mars, relatively safe for landing. Once there the science team would literally be walking on millions of tons of critical resource. In the 6-month long late-spring to summer season the team would enjoy long days and short nights. However, winters are long, dark, and frigid. CO_2 thickly plates out on polar surfaces, meters thick in the higher elevation south. Mars is closest to Earth during the southern summer but there is little temperature advantage because the south polar region has much higher elevations than the north. To solve the need for water resources, do ice sheets exist far enough from the poles to provide safe targets?

Polar Wander to the Rescue: The distribution of ice sheets in Mars' southern hemisphere gives strong evidence that geographic poles have shifted. Various theories have been advanced to explain this, the most logical one being a response to the effusion of vast volcanic fields and volcanos and their redistribution of planetary mass. Tharsis is a prime suspect. Regardless of their origin, off-center ice masses preserve huge repositories of water far from the pole. The spectacular ice deposits of Ultima Lingula suggest a former pole displaced from the present one, along longitude 140E (220W). If polar wander occurred, then the age of the sequestered ice could be estimated within broad limits. For example, a polar shift due to Tharsis volcanism would suggest ages $>10^8$ yrs for older ice deposits.

Technology Advantage: Extraction of O_2 from water is a mature and reliable engineering process (i.e., submarine technology). Atmospheric extraction can still be relied on to obtain N_2 for air-mix ratios, using zeolite-enhanced pressure sequestration. Obtaining water from soil ice would be unduly labor intensive. Extraction from soil also has the difficulty that dissolved salts must be removed from the H_2O. At low latitudes, failure of water recycling equipment would compel astronauts to spend precious time mining soil to scavenge small amounts of ground ice.

Shelter from Surface Hazards: The cold of higher latitudes poses risk and operational difficulties (Fig. 1), but not nearly the risk of equipment failure and total loss of water and oxygen supplies at low latitudes.

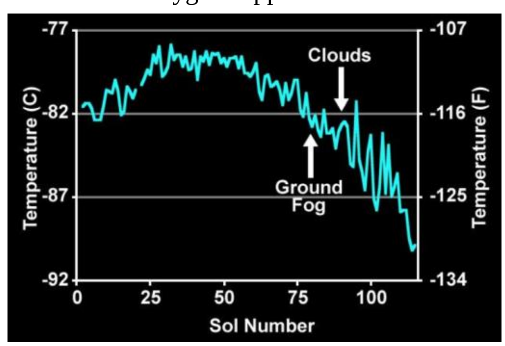

Fig. 1. Temperatures measured at Phoenix lander, May-Sep 2008. Credit: NASA/JPL-Caltech/Univ. of Arizona/Canadian Space Agency [68.22°N 125.7°W Vastitas Borealis].

A bonus for science teams is that thick ice can be selectively mined to create underground spaces to enclose habitats, giving protection from extreme cold and also cosmic radiation. Ice coring and analysis of samples can be accomplished from within these protected spaces. Although the ice mass itself could not be depended on for a pressure seal, it might be possible to spray the inside of ice "caves" with a thick aerogel-like substance that would both insulate and seal the internal space, preventing melt of the peripheral ice and creating large, free-form living quarters.

Engineering Criteria for Landing Sites: NASA has identified an upper elevation limit of +2 km and a desired latitude range of ±50° for human landing zones [1]. The latitude criterion was not imposed for landing safety. It relates to length and warmth of working day, booster power to reach orbit, where proximity to the equator is a plus, and also relates to orbit rendezvous trajectories. Low altitudes are favored as parachutes can be used longer for deceleration in denser air.

Where to go? Epithermal neutron mapping by Mars Odyssey shows the regions of interest. Rich surface/near-surface ice extends broadly from the South Pole, with a large region that extends north from -60° latitude in longitudes between 90 and 120°E (Fig. 2).

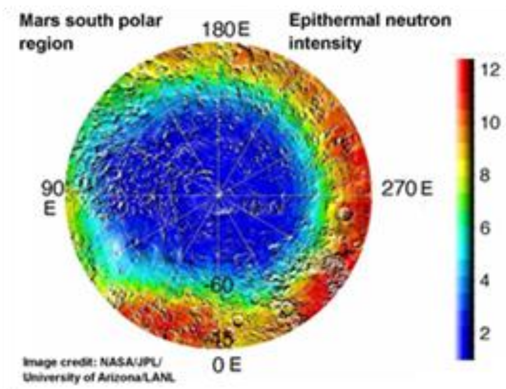

Fig. 2. Epithermal neutron intensity detected from orbit. Hydrogen atoms "thermalize" neutrons spawned by cosmic ray influx to epithermal range. Small numbers (blue) indicate richest ice at or near the surface.

Rich ice deposits occur within and northwest of 230-km-wide Secchi Crater, at the relatively low latitude of -57.2° (99.0° long.) (Fig. 3). The floor of Secchi has elevations from +300 to 500 m, considerably lower than most surroundings at +2500 m. The NW crater rim is degraded and low, giving surface access to ice rich terrain at elevations of 1000 m or less.

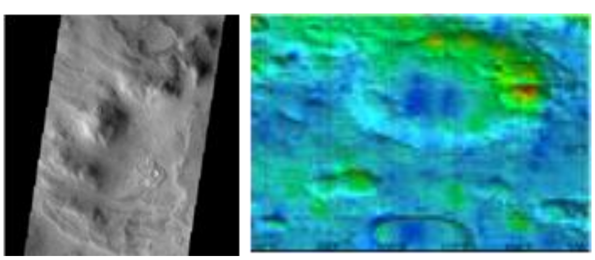

Fig. 3. NW Secchi Crater (vis. THEMIS, left) & TES TI.

Elsewhere, a steep terminus of the layered terrain half fills an unnamed crater at 71.88°S 143.52°E, with a crater floor elevation of +200 to 400 m and a definite ice thickness of >1600 m (Fig. 4). Ice deposits are also common on the shadowed northern ends of south polar craters (e.g., Charlier Crater and others nearby).

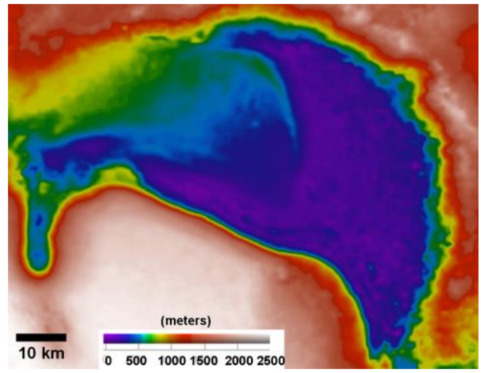

Fig. 4. Margin of south polar layered deposits in crater at 71.88°S 143.52°E. [HRSC 2198_0000].

What About the Science? Contrary to some strategic plans for Mars missions, there can be no better or richer science targets than the permanent ice caps and layered deposits. Like the ice sheets of Earth, the climatic and volcanic history of Amazonian Mars is preserved there. Ash and isotopic variations in the ice will preserve evidence of all major volcanic eruptions on the planet during the period of ice deposition. And if microscopic life ever existed on Mars, its spores or other residue would have been carried by the winds and deposited in the ice, preserved there, protected from most cosmic radiation, possibly still viable. As Earth experiments have revealed, spores 250 million years old [in a salt crystal] have been isolated and grown [2].

Timing of Launch Windows: There is a future window that would allow astronauts to arrive at Mars near late southern spring. For a southern landing, a launch window opens late Feb. 2031. Arrival ~11/7/31 would benefit from a summer solstice on 12/16/31.

Essential Precaution: It is crucial to precede a human landing on Mars with a "scout" mission to land a medium-sized rover outfitted with a panoramic camera, a neutron probe, and GPR, equipment that will confirm the presence and minimum thickness of ice. A rover will also "ground-truth" smooth landing areas.

Summary: I recommend that planners consider landing sites on Mars that are somewhat closer to the poles than latitudes ±50°. That would ensure astronaut access to vast native supplies of ice, yielding "endless" resources of H_2O and O_2. The scientific data and results from the study of deep ice cores would reveal the rich climatic and volcanic history of Mars during the period of ice deposition. The ice may also preserve evidence of past and perhaps present life on the planet. Access to rich ice deposits at landing sites is essential for astronaut safety and science on Mars, and would be mandatory to support long-lived research stations.

References: [1] Bussey, B. & Hoffman, S. (2017) https://ntrs.nasa.gov/search.jsp?print=yes&R=20150019636.
[2] Vreeland, R. et al. (2000). *Nature* **407**, 897-900.