SAMPLE RETURN MISSIONS TO MARS, VENUS, AND THE ICES ON MERCURY AND THE MOON.

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Introduction: Venus and Mars likely had liquid water bodies on their surface early in the Solar System history. The surfaces of Venus and Mars are presently not a suitable habitat for life, but reservoirs of liquid water remain in the atmosphere of Venus and the subsurface of Mars, and with it also the possibility of microbial life. Microbial organisms may have adapted to live in these ecological niches by the evolutionary force of directional selection. The search for life on the inner terrestrial planets should follow the presence of water (both liquid and solid). Missions to our neighboring planets should therefore be planned to explore these potentially life-containing refuges and return samples for analysis. Sample return missions should also include ice samples from Mercury and the Moon, which may contain information about the biogenic material that catalyzed the early evolution of life on Earth (or elsewhere) [1].

Mission Goals: Prior robotic missions to planetary bodies such as Mars have focused either on exploration of a single site with a single lander (immobile agent) or rover (mobile agent) or a global mapping orbiter. The lander/rover missions tend to analyze a rather confined, readily accessible site in more detail, but often at the expense of a regional understanding, while orbiter missions return immense data sets that tend to overlook the local and regional significance [2].

Atmospheric and surface conditions of the inner planets Mercury, Venus, Earth, and Mars challenge spacecraft landing operations and exploration. Current surface exploration scenarios favor single lander/rover missions at the expense of mission redundancy, mission safety, and mission science return. Single landers/rovers are also restricted to small areas of exploration and are not likely to explore potentially hazardous, but scientifically interesting, terrains, which include: (1) canyons (e.g. Valles Marineris on Mars), (2) mountain ranges (e.g. Thaumasia highlands on Mars, Isthar Terra on Venus), (3) sites of suspected magmatic-driven uplift and associated tectonism and possible hydrothermal activity (e.g. plume-related activity such as hypothesized for the central part of Valles Marineris and the Warrego Valles rise on Mars, and Maxwell Montes on Venus), (4) polar ice caps (e.g. Mars), (5) ice deposits within impact basins (e.g. Mars, Mercury and Moon), (6) volcanoes of diverse sizes and shapes (e.g. Venus and Mars), (7) putative ancient accreted terrains and associated volcanism (e.g. Mars), (8) regions indicating potential recent hydrologic activity such as spring-fed seeps (e.g. Mars), and (9) chaotic terrain (e.g. source areas of the circum-Chryse outflow channel system on Mars) [1,2]. Ironically, all of the terrains listed above are particularly crucial for astrobiologically oriented exploration. As such, a change in how we approach future planetary exploration is overdue and required: in place of single orbiter, lander, or rover missions, a multi-tier (e.g. orbit-atmosphere-ground/subsurface), multi-agent (e.g., orbiters, blimps, and rovers/landers/sensors) hierarchical mission architecture with varying degrees of mission operation automation/autonomy is called for [2]. This novel mission architecture will not only introduce, for the first time, redundancy and safety into missions, but also enable distributed scientific exploration, spanning larger surface areas than previously possible.

Sample Return Mission to Mars: In our view, the highest priority for a sample return mission should be a potential hydrothermal site on Mars [3,4]. The NSV region, for example, is a prime candidate site for such future science-driven Mars exploration because it records Noachian to Amazonian Tharsis development in a region that encapsulates (1) a diverse and temporally extensive stratigraphic record, (2) at least three distinct paleohydrologic regimes, (3) gargantuan structurally-controlled flood valleys that generally correspond with gravity and magnetic anomalies, possibly marking ancient magnetized rock materials exposed by fluvial activity, (4) water enrichment, as indicated by Mars Odyssey and impact crater analyses, (5) long-lived magma and ground water/ice interactions that could be favorable for the development and sustenance of life, and (6) potential paleosol development [3]. As such, there is a high probability that this region could yield significant geologic, climatic, and astrobiological information that would revolutionize our understanding of Mars. Interestingly, this region also indicates elevated chlorine [5] and methane [6] abundances. Among several possible explanations, the GRS-based elevated chlorine signature could indicate aqueous processes in the past or present, which includes magma-water interactions [3,7]. Another region where water may be present at or near the surface is within Valles Marineris due to its geomorphic expression [8], which includes dendritic valleys [9] and relatively low topography. At a site difficult to access, such as inside Valles Marineris, sample return missions are feasible using a novel mission architecture [2].

Sample Return Mission to the Moon and Mercury: For all three terrestrial planets with an atmosphere (Venus, Earth, and Mars), it is crucially important to know how the atmospheres of the planets changed over time. Did all three planets start out with the same type of atmosphere? Was liquid water stable on the surface of all three planets early after the Solar System formed? Did Mars have sufficient atmosphere for life to thrive at its surface, such as during the transient magmatic-driven hydrologic/climatologic events?

Thus, it is important to understand the amount and composition of the pristine volatiles with which the terrestrial planets were seeded [10] and sample some of the cometary material accumulated on the Moon and Mercury that has been preserved through time. The water-enriched material could provide critical clues with regard to the nature of the molecules that protected and catalyzed the synthesis of the first biological structures on Earth, and possibly on Mars and Venus. It could even contain organic molecules from the evolution of life on the terrestrial planets. Understanding the evolution of atmospheres through time will provide us with answers as to why Venus turned into a "hot house", Mars into a "cold-house", and Earth into a planet just right to allow for stable oceans on its surface throughout much of the history of the Solar System.

Sample Return Mission to Venus: Evidence has been presented that the atmosphere of a planet may also serve as a primary habitat for microbial life [11,12]. These findings and the more benign conditions in the venusian atmosphere, compared to Earth's atmosphere, has led several authors to speculate on the possibility of microbial life in the venusian atmosphere [13-16]. Earth's atmosphere serves as a transient habitat for microbes and even macroscopic life, and experiments should be conducted to test whether it also serves as a permanent habitat for microbial life in spite of harsh conditions. Compared to Earth's atmosphere, the atmospheric conditions on Venus are much more benign with respect to temperature, pressure, and particle residence times, and thus microbial life in the venusian atmosphere is a distinct possibility. Therefore, a sample return mission to the venusian lower cloud layer, where microbes may reside, should be considered. Schulze-Makuch et al. [17] contemplated various mission options and concluded that a sample return mission involving a Parachute Drop – Balloon Floatation Mission, designed to return astrobiologically relevant material for analysis to the International Space Station, would be the most preferable option. Even if the promising mode 3 particles in the venusian atmosphere were not of biological nature, a sample return mission would significantly increase our knowledge about the composition and dynamics of the atmosphere.

The relative ease of reaching Venus and returning to Earth, and the availability of appropriate existing technology, makes such a mission feasible in the short term. A blimp/balloon would have the capability of hovering at the altitude of 51 km or descending to lower altitudes, where it could collect samples of cloud particles with aerogels similar to STARDUST and GENESIS [1]. These cloud particles, once obtained by the blimp/balloon, could be transported into orbit, and from there to the International Space Station or Earth for analysis. Thus, technology for a sample return mission to Venus exists and the mission could be done in short order.

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