Mars 2050: Air Vehicles and Extreme Environments. W. M. Calvin[1], [1]Department of Geological Sciences and Engineering, University of Nevada–Reno, wcalvin@unr.edu.

Synopsis: Mars Sample Return is the highest priority in the Planetary Sciences Decadal Survey and Humans to Mars continues to energize the public and underlies the long-range plans for the Journey to Mars NASA vision. Development of air vehicles for Mars and deep drilling or rover access to the Martian poles will enable pioneering exploration and science of the planet while also benefitting outer planet and ocean world missions.

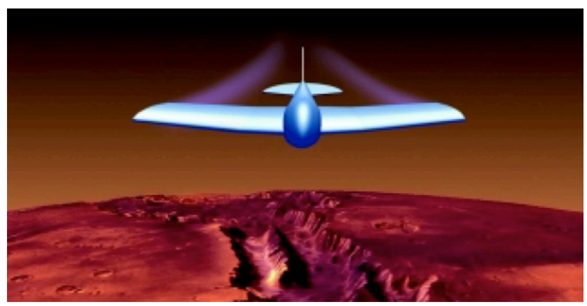
First, a look back: In 1986 I had just begun my graduate career at the University of Colorado in Boulder. I was working with Bruce Jakosky on a model of radar scattering from Mars, which ultimately became my first peer-reviewed paper (published in Icarus in 1988). Students in LASP were eagerly anticipating the launch of Galileo to Jupiter, until the Challenger Shuttle explosion grounded the shuttle fleet and delayed the planned launch. We were in the planning stages for Magellan's orbit of Venus, Mars was on hold following Viking, and my former boss at Ball Aersopace was planning participation in ESA's Giotto mission to encounter Halley's comet.

In the three decades since we have completed orbital or fly-by reconnaissance of every type of object in the solar system, including the major planets and their moons, asteroids, comets and dwarf planets. We (or our international space partners) have returned samples of the solar wind, comet dust, and asteroids. We have landed on Titan and roved on Mars, and sent projectiles hurtling into the Moon and comet Tempel 1. We have also had our share of failures.

Fast Forward to 2009: As the Vice-Chair of the Mars panel and a member of the Steering Group for the most recent decadal survey "Visions and Voyages" [1], the Mars panel Chair, Phil Christensen, and I worked to create a panel that encompassed the science of Mars from the core to the atmosphere, and I think we were successful at that. While Mars sample return emerged as the highest priority, both for the Mars community and the decadal report overall, there is obviously much to be done at Mars beyond sample return and understanding resources to support the eventual work of astronauts on the surface.

The Future: While numerous scenarios can be imagined there are two technologies that could enable break-through discoveries in Mars science. This includes development of air vehicles that operate in the extremely thin martian atmosphere, and electronics that can survive the extreme temperatures at the polar regions. These take advantage of the emerging field of autonomous air vehicles on Earth and a vast legacy of polar exploration that continues to inspire the public's imagination.

Air Vehicles. Although our landed vehicles have been tremendously successful at Mars, Opportunity has traveled only 40km over the span of nearly 13 years. While that may set a distance record for autonomous driving, it is paltry compared to what could be and has been imagined for unpowered and powered flight on Mars. The KittyHawk Discovery class mission concept [2] dropped gliders from orbit that were deployed in the atmosphere to traverse ~ 140km over rugged terrain that is inaccessible to landed and roving vehicles. The ARES powered aircraft [3] would have also deployed in the atmosphere and executed a pre-defined trajectory covering 500km within an hour. I have recently consulted with an engineering firm that has credible and exciting designs for vertical take-off and landing (VTOL) small aircraft that could be used as reconnaissance for up to 10km from a base station in hours rather than years.



All these advanced concepts would allow reconnaissance over larger distances in shorter periods of time than land-based vehicles. Science instruments on board could collect critical data on atmospheric winds and composition, surface and sub-surface resources and the planet's deep interior. Such technologies could also be envisioned to allow break-through science discoveries on Titan or Venus as well.

Extreme Environments. For the decadal I was also "science champion" for a rapid mission architecture study to consider mission concepts for crucial Mars climate observations [4]. Surface access at the poles via sampling or drilling has been widely proposed as the only way to constrain recent Martian climate history [5,6], understand the stratigraphic record preserved in the polar layered deposits [7], and search for potential biomarkers in buried ground ice - one of the most habitable places on Mars [8]. The success of the Phoenix lander notwithstanding, significant hurdles exist for long-lived missions that seek to access the ice-rich terrains at latitudes above 70º. Both landed and roving mission scenarios would benefit from using ASRGs as a power system instead of solar, and such systems might even survive a full martian year. This would enable direct observation of the polar environment throughout the spring, summer, and fall seasons during which the majority of the atmospheric interaction takes place. Technology development supporting deep drilling would allow unprecedented access to the subsurface of Mars. This technology could also enable innovative or pioneering explorations of icy satellites and ocean worlds.

The World's View: Planetary exploration is already encountering private sector influence (Google's Lunar X Prize) and increased international participation (India's MOM, China's Jade Rabbit lunar rover, UAE's planned Mars orbiter "Hope"). In the coming years, these developments are expected to continue to build, and will create a crowded playing field vying for the public's attention and continued Federal support. NASA's role and legacy should always be one of "firsts" lest we lose the 21st century space race. I propose "fly Mars" and being the first to touch the poles of Mars (celebrating and honoring the many terrestrial Arctic and Antarctic expeditions), are compelling ways to continue our long and storied history of exploration.

References: [1] National Research Council. 2011. *Vision and Voyages for Planetary Science in the Decade 2013-2022*. Washington, DC: The National Academies Press. doi: 10.17226/13117. [2] W. M. Calvin, et al., *Concepts and Approaches for Mars Exploration (2000), Abstract #6155.* [3] R. D. Braun, et al., J. Spacecraft & Rockets, 43 (5) (2006), pp. 1026-1034. http://dx.doi.org/10.2514/1.17956. [4] Mission Concept Study, Planetary Science Decadal Survey, Mars Polar Climate Concepts, available at http://sites.nationalacademies.org/cs/groups/ssbsite/documents/webpage/ssb_059312.pdf [5] M. H. Hecht, et al. *Concepts and Approaches for Mars Exploration (2012), Abstract #4330*. [6] W. M. Calvin, C. L. Kahn *Concepts and Approaches for Mars Exploration (2012), Abstract #4298.* [7] M. H. Hecht, Chronos Team *Fourth International Conference on Mars Polar Science and Exploration (2006), Abstract #8096.* [8] C. P. McKay, et al. *Concepts and Approaches for Mars Exploration (2012), Abstract #4091.*