MARS IS THE EARTH'S ONLY NEARBY EARLY LIFE ANALOG, BUT THE MOON IS ON THE PATH TO GET THERE. H.H. Schmitt[1], [1]University of Wisconsin-Madison, P.O. Box 90730, Albuquerque, NM 87199

Introduction. Mars provides a geological integration of the early solar system impacts recorded by the Moon and the contemporaneous water-rich pre-biotic period on Earth. Consideration of human missions to Mars logically would include an evaluation of the successful implementation of a comparable space effort, namely Apollo. The keys to the success of the Apollo Program included the existence of:

- A sufficient base of technology,
- A reservoir of young engineers and skilled workers,
- A pervasive environment of national unease,
- The catalytic event of Yuri Gagarin's orbital flight,
- An articulate, persuasive and patriotic president and congress,
- A commitment of a ~100% management reserve of funding, [1]
- Tough, competent, disciplined and courageous managers, [2]
- The a goal that could be accomplished in a decade, and
- A working environment of liberty.

All these keys to success must accompany a Mars Program with the following additions:

- Improved education in STEM, engineering skills, and critical thinking,
- Given the advance of technology, a ~30% management reserve through systems' CDRs may be adequate, and
- China's rapid progress substitutes for the Cold War I stimulus,
- An indefinite national commitment to deep space exploration,
- Maintenance of an average workforce age of <30 years, and
- Elimination of the political aversion to taking necessary risks.

Major Mars Program Requirements. The catalysts for initiating a Mars Program include all of the following: geopolitical reality with respect to China, economic need to stimulate future technologies, and addressing the crisis in engineering and science education facing the United States. Also, deep space operational experience must be regained by continuous generations of young implementers. Finally, there must be a permanent public and political commitment to deep space exploration and development on a par with, and related to a commitment to National Security.

A focused Apollo-style management system will be needed, possibly involving a new national space exploration agency. This system must "stay young-stay lean-stay risk takers." Once the decision to go to Mars is made, the sole focus should be to just that. With such a decision, early tradeoff studies will be needed on interplanetary propulsion development, consumables requirements and sources, specialized technology development, and human spaceflight planning and operations. Additionally, first landing mission decisions will drive development and operations, specifically, crew size and capabilities (one or two crews with one or two landers), desired exploration science returns, and space resources delineation and use.

Management Requirements. The success of Apollo depended on the evolution of a management system that, with hindsight, includes many common sense attributes. NASA and its contracting corporation had access to the best engineers and engineering managers available. Because of the short duration of the program, the average age of the workforce remained below 30 years, a characteristic that has been maintained by an equally complex nuclear Navy with similar success. (Youth provided the motivation, stamina, patriotism and courage to see projects to successful conclusions.) The bureaucratic newness of NASA meant that management was minimally layered so that decisions could be made quickly and good ideas could move rapidly to implementation. NASA also supported an internal, independent engineering design capability that gave managers alternative viewpoints to those of contractors on major issues. Finally, Administrator James Webb persuaded the White House and Congress to provide a management reserve sufficiently great to maintain schedule in the face of unexpected engineering issues and accidents.

These management lessons and requirements should be embedded in the enabling legislation for a Mars Program, along with providing the Mars implementation agency with the hire, fire and re-assignment personnel authority necessary to maintain the vigor of the program.

Moon in the Context of Mars. Consideration of missions to Mars should include the value of returning to the Moon. The Moon lies only three days away in regard to Mars mission development, simulation and training versus the many months required to reach Mars. Flying to the Moon and working there require similar deep space operational discipline that new generations of space managers, engineers and flight controllers will need to assimilate. Also, many of the same deep space technological capabilities will be needed.

The Moon remains geopolitically critical in its own right. The existence of space consumable resources and potential energy sources [3] of importance to Earth have not been lost on other international players. Accessing these resources presents the possibility of cost reduction through private-government partnerships. Further, evaluation of the effects of 1/6 earth's gravity on physiological re-adaptation will answer the question, for better or worse, concerning the consequences of re-adaptation requirements in the 3/8 earth's gravity of Mars.

Important new and unique science will come from a return to the Moon. Whereas Mars will give new insights into pre-biotic and, potentially, early biotic history, the Moon provides insights into the extraordinarily violent impact history in which life's precursors formed. [4]

Mars Transit Hurdles. Missions to Mars will not be easy for many years to come. Transit alone presents the issues of radiation protection, micro-gravity countermeasures, consumables supplies, spacecraft redundancy and maintenance, crew proficiency for landing and return, crew composition and crew compatibility, and challenging in-flight work. Solutions to some of these issues may relate to solutions to others; however, many potential solutions require consideration of a return to the Moon to stay.

Water, oxygen, nitrogen, hydrogen, methane and other possible consumables provided by lunar resources can significantly reduce the required Earth launch mass of Mars-bound spacecraft. Among those other possible consumables is helium-3, a potential fuel for fusion-powered propulsion that could shorten transit time.

Mars Landing Hurdles [5]. Mars has enough atmosphere (~1/100th of Earth's) to cause entry, descent and landing (EDL) problems, but not enough to help much in kinetic energy dissipation. It is generally calculated that a Mars Lander will have a mass of at least 40 metric tonnes, so this is not a trivial issue. Further, EDL must be accomplished without real-time assistance from Mission Control. Landing, whether automated or not, likely will utilize a beacon operating from a previously landed, un-crewed habitat-supply precursor, necessitating a rover-assisted, surface rendezvous after landing.

Whatever approaches to EDL ultimately are developed for operational testing, such tests probably will take place at appropriate altitudes in the Earth's atmosphere. Also, operational technologies and procedures will need to be developed to support consideration of aborts to a landing in contrast to aborts to orbit. Future lunar landings offer the best means of testing abort-to-land concepts along with doing so with simulated Mars communications constraints.

Related to abort-to-land considerations will be evaluation of whether each early Mars mission should consist of two landers and two full crews. The cost, time and risk inherent in Mars missions argue for steps to maximize landing and exploration success. In the likely event that both landers reach the surface successfully, the science return from two separate landing sites will be an added benefit to adopting this approach. An additional potential benefit of having two crews is that the orbiting crew can provide real-time mission support during landing and ascent and during other nominal or off nominal events. This latter activity compensates, in part, for the absence of real-time Mission Control input.

Major Mars Exploration Hurdles. Exploration of the surface of Mars will have many similarities to future lunar exploration. Lunar preparatory missions provide the means of testing, operating and maintaining Mars-consistent equipment such as mixed-mode rovers, sampling and analytical tools, analytical equipment for return sample selection, bio-containment systems for drills and sample packaging, dust mitigation concepts, food production concepts, and nuclear power systems.

Of particular importance will be the evaluation of Mars extravehicular mobility units (EMU). Whereas, Apollo EMUs were designed for use over a few days, Mars EMUs will need to be designed for long duration use and maintenance. Lunar exploration provides an unique opportunity for testing such systems over extended cycles of use.

Simulation of a variety of operational issues that will arise during Mars exploration can be conducted on the Moon. These include variable communication delays that can be integrated into lunar exploration, providing real-world operational experience with this form of crew-earth interaction.

Although consumables production (water, oxygen, nitrogen, helium, fuels and food) on the Moon begins with processing regolith rather than the more chemically variable Mars surface materials, the operational experience with such processing, as well as volatiles refining, will provide invaluable experience in the design of consumables production systems for Mars.

Conclusion. A return to the Moon appears to be essential to significantly increasing the probability of success of a Mars program and to maximizing the scientific return from such a program. Such a return to deep space exploration, however, requires the unequivocal and sustained commitment of the Nation, even more so that was required for the Apollo Program.

References: [1] Lambright W. H. and Webb J. E. (1995) *Powering Apollo*, Johns Hopkins, 101.[2] Kranz E. *Failure is Not an Option*, Berkley Trade, 119-384. [3] Schmitt H. H. (2006) *Return to the Moon,* Springer, 335p. [4] Schmitt H. H. (2015) *GSA Spl. Paper 518*, 1-16. [5] Braun R. D. and Manning R. M. (2007) *Spacecraft & Rockets,* 310-323.