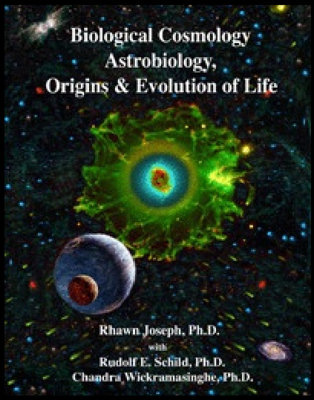

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Apollo on Mars:
Geologists Must Explore the Red Planet

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Abstract

Extension of human geological studies to the surface Mars requires the transfer of the principles of geology and the well-honed techniques of field exploration begun by astronauts on the Moon. The principles related to exploration planning and innovation, or to sample collection and documentation, do not change merely by leaving the Earth. Particularly unchanged is the need for human touch, experience, vision, and imagination in fully realizing the scientific and humanistic value inherent in exploration. Natural influences that affect Mars combine those affecting the Earth and Moon with Mars being a body intermediate in size between the two terrestrial planet extremes. In addition, the Martian atmosphere has filtered out all meteors and comets capable of forming craters less than about 30m in diameter. A field geologist's "x-ray" vision still will be required and must take into account the effect of wind or water-transported materials that may obscure or cover underlying rock contacts and structures. Beginning with precursor return missions to the Moon, professional field explorers should be part of every fourperson crew sent to the Moon so that this paradigm can be ingrained in planning for Mars' exploration as well as providing much enhanced returns from lunar exploration. Crew members and their operational support teams should commit to terrestrial, fieldbased training on real geological problems constrained by realistic operational planning, equipment, communications, and timelines. Mars exploration will not be easy. As with anything worthwhile, risks exist. But the alternative of postponing settlement of the Moon and the exploration of Mars beyond existing generations would leave the future to other explorers.

Key Words: Mars, Moon, Earth, exploration, Mars access, geology training

1. INTRODUCTION

Higher than the walls of the Grand Canyon of the Colorado, mountains over 2000 meters high confined the long, narrow valley of Taurus-Littrow. A brilliant sun, brighter than any sun ever experienced on Earth, illuminates the cratered valley floor and steep mountain slopes, starkly contrasted against a blacker than black sky. Exploration of the nearly four billion year-old valley, and the slightly younger volcanic lava rocks and ash partially filling it, culminated the Apollo Program and the first extension of hands-on geological studies from the Earth to the Moon (Schmitt, 1973, 2003). Now, we contemplate the extension of human geological studies to the surface Mars. What will be new and what will be familiar to the first geologist to step into a red Martian sunrise? With the Apollo missions to the Moon, astronauts began the transfer of the principles of geology and the well-honed techniques of field exploration to solid bodies away from Earth.

Historically, geology and exploration have been inexorably linked from the first known geological map, that of Saxony basalts by Johan Charpentier in 1778 (Charpentier, 1778); to William Smith's 1815 geological map of England (Smith, 1815); to Lewis and Clark's exploration of the Louisiana Purchase (Ambrose, 1996); to Eugene Shoemaker's 1958 preliminary photo and telescopic geological map of the area on the Moon that includes the crater Copernicus (Schmitt, et al, 1967); to the Apollo astronauts geological documentation of lunar samples (See Wolfe, et al, 1981); to the most recent tele-robotic observations on and around Mars (Christensen, 2005; NASA, 2010a); with thousands of other examples in between.

The actual placement of geological exploration in time and space does not change the fundamentals of documenting and graphically representing the relative age of natural features; the structure, internal evolution, and alteration of such features; their inferred origins; and their ultimate implications about potential resources useful to sustaining and advancing civilization. (See Hodges & Schmitt, 2011) Nor are the principles related to exploration planning and innovation, or to sample collection and documentation, changed merely by leaving the Earth – if anything, those principles become more important. Particularly unchanged is the need for human touch, experience, vision, and imagination in fully realizing the scientific and humanistic value inherent in exploration. For each new body to be explored in space, however, we must build on our experience in exploring the last place as geologists have done on Earth for centuries. We must continually ask what may be the same and what may be different as we approach a new challenge. In the future exploration of Mars, probably beginning within the first third of the 21st Century, how will Martian geology, human access, exploration approach, and crew characteristics compare with the experience of Apollo? (Schmitt, 1973).

2. GEOLOGY

"Geology," literally "Earth study," as a scientific discipline encompasses all interacting aspects of a planet whether or not they fall into sub-disciplines such as geophysics, geochemistry, geomorphology, geobiology, planetology, etc. This particularly holds true during geological field exploration when observations, mapping, and sampling must integrate all discernable past and present influences that have observations, mapping, and sampling must integrate all discernable past and present influences that have produced the features being examined. Extremely complex processes affect geological features on Earth due to interactions of the dynamics of the crust, water, atmosphere; impact of objects in and from space; and alterations by the biosphere, including humans.

On the Moon, the influences in the last 3.8 billion years largely have been external, confined to the effects of impacts of objects from space and of energetic particles that constitute the solar wind.

On Mars, we could expect influences that combined those affecting the Earth and Moon as the Red Planet is a body intermediate in size between these two terrestrial planet extremes. Indeed, our growing geological knowledge confirms this as we analyze images and data collected from Mars orbit and from on the ground exploration by tele-robotic landers. Since the first photographs provided by the cameras on Viking landers and orbiters (NASA, 2010b), we have known that geological features formed on Mars resulted from combinations of internal and external processes. For example, remote sensing of Martian landforms earlyon indicated moving water had formed many features and that water-ice lay just below the surface across much of the planet and at the surface as polar caps (Carr, 1981).

Orbital sensors and robotic analyses of Martian minerals subsequently have identified a variety of water-containing clays, sulfate minerals precipitated from briny solutions, ice in the regolith, and subsurface hydrogen that is presumably water-ice (NASA, 2010c). Further, unlike the Moon where un-oxidized iron metal is stable in rocks and surface materials, extensive hematite (Fe_2O_3) deposits have been identified by the Mars Exploration Rover *Opportunity*. This means that the Martian geologist must be prepared to interpret the implications of a much larger spectrum of rock-forming and alteration minerals than we have encountered on the Moon (See Gornitz, 2008).

2.1. Effect of Atmosphere Mars has a thin atmosphere, now only about one percent the pressure of that around the Earth. The existence of this thin atmosphere around Mars results in major differences in the geological overprint that explorers evaluate and "look" through to identify, analyze, and understand the underlying rock units. On the Moon, the absence of an atmosphere exposes surface materials totally to the extraordinarily hard vacuum of space (~10-12 torr). Meteors and comets down to dust size, traveling at tens of kilometers per second, impact and modify the rocks and previously formed broken rock, glass, and dust at the lunar surface. This dominating impact process has produced a several meter deep covering of fragmental and partially glassy debris called the "lunar regolith" that covers most older volcanic flows and impact-generated formations. Only on steep slopes can the explorer find actual bedrock.

The impact-generated glass and glass coatings on other material in the lunar regolith contain extremely small (nano-phase) particles of iron, making the lunar dust strongly attracted to magnets. This property of the dust will be very important in keeping air, space suits, equipment, and dwellings clean. Of great potential economic importance in space and on Earth (See Schmitt, 2006), solar wind ions of hydrogen, helium-3 and -4, carbon and nitrogen, streaming from the fusion reactions in the sun, accumulate in the lunar regolith due to the absence of atmosphere.

Field exploration on the Moon requires that a geologist have "x-ray" vision, of a sort. To identify contacts between major rock units, the geologist must visualize how the gradual formation and spreading of regolith by impacts has broadened and subdued the contrasts in color and texture that existed when the contact was created. For example, in the valley of Taurus-Littrow explored on Apollo 17 (Schmitt, 1973), the surface expression of an originally sharp contact between dark, fine-grained basalt flows and older, gray fragmental rocks (impact breccias) had been spread over a few hundred meters in 3.8 billon years of lunar history. On the other hand, a similarly sharp contact between a dust avalanche deposit and that the dark regolith overlying that same basalt flow had spread only a few tens of meters in the 100 million years since the avalanche occurred. Still, the position of the contacts could be defined if one understood the processes actively modifying them.

Field identification of different rock types within exposed boulders on the lunar surface, however, required understanding of the effects of continuous and ubiquitous micrometeorite bombardment. Such bombardment by extremely high velocity particles creates a high temperature plasma as well as impact melt at the point of impact. This ejected plasma and glass re-deposits on nearby surfaces and produces a thin, brownish, glassy patina or coating over the entire boulder. Like looking through the desert varnish on exposed rocks in the Earth's dry regions, the lunar geologist must quickly scan and interpret what is underneath this patina until fresh rock can be chipped or broken with a hammer. Small impact pits interrupt the lunar patina and contain impact glass of varying colors in the pit, reflecting the variations in the chemical composition of underlying minerals. Where the pit has formed on a white mineral (plagioclase feldspar), a distinctive white spot interrupts the brown patina due to the very fine spider cracks in that mineral with translucent, milky glass at the point of impact. Where a magnesium and iron-rich mineral like olivine has been hit, the glass is green.

In contrast to the Moon, the Martian atmosphere has filtered out all meteors and comets capable of forming craters less than about 30m in diameter. On the other hand, the *Spirit* Exploration Rover discovered iron meteorites on the surface as a consequence of the braking effect of even that thin atmosphere. At latitudes greater than about 40 degrees, water derived from subsurface ice appears to have mixed with rock debris in the ejecta blankets from impact craters to form mudflows that leave lobate edges on these blankets.

Additionally, and unlike the continuous redistribution of impact-generated debris on the Moon, wind-blown dust has dominated migrating material on Mars, probably for most of the last 3.8 billion years. This dust forms by impacts, wind erosion, and reactivation of dust from earlier periods of active water erosion and mineral and glass alteration. Martian dust migrates on a global scale and accumulates non-uniformly as dunes, layers and coatings on older craters and crater ejecta, volcanic flows and deposits, and previous dust accumulations. Some dust dunes will be very soft and may need to be avoided by explorers much like deep, wind-formed snow drifts in the plains and mountain passes of Earth.

The "Martian regolith" thus generally consists of impact ejecta, hydrolyzed debris flows, and flood deposits interstratified with windblown dust deposits. In polarregions, water-ice and carbon dioxide ice and frosts also will be present in this regolith as recently confirmed by the Phoenix lander (LPL, 2010).

As a consequence of a very different geological history, new challenges will face the Martian field geologist. A field geologist’s "x-ray" vision will still be required; however, it will be more like that required on Earth where one must take into account the effect of wind or water-transported materials that may obscure or cover underlying rock contacts and structures. Rock surfaces will not have a glassy patina as on the Moon; however, fine, wind-blown dust appears to form a very thin, patina-like coating on many rocks. On the other hand, wind frequently cleans surfaces so that dust coatings do not appear to be a significant problem to rock and mineral identification.

Under-estimation of distances is one effect of the vacuum atmosphere of the Moon that will probably be the same on Mars. Estimating distances is difficult, even on Earth, in clear space in the absence of familiar objects such as houses, trees, bushes, power poles, and the like. From the Neil Armstrong’s first observations after landing Apollo 11 on the Moon, we knew that crews would underestimate the distance to lunar features, much like human experiences in the clear air of Earth’s deserts and high mountains. This problem can be solved for near and mid-field distances by comparing the known length of one’s shadow to what it seems to be and increasing the estimated distance by a factor of about 50 percent. This technique seemed to work quite well for the author.

Although daytime lighting will be a little more diffuse on Mars due to light scattering by atmospheric dust, down-sun back-scatter from dust probably will resemble the intense back-scatter we experienced on the Moon. This is the same phenomenon that seen looking toward one’s shadow on snow or when flying over a leafy forest or cropland. In contrast, looking up-sun will be looking into concentrations of shadows; however, back-scattered light will provide significant light into shadows, as can selfdirected reflections off the space suit. These lighting characteristics affect adjustments of camera apertures; but I would hope, that future exploration cameras and video systems would automatically adjust to lighting conditions, unlike the cameras we used during Apollo. Adjusting the f-stop relative to sun-line was necessary for nearly every photograph we took and added to other inefficiencies resulting from the mobility limitations of the space suit and gloves.

2.2. Near-Surface Geological Fabric In spite of the filtering effect of the Martian atmosphere, impact-related geology dominates the surface and near surface fabric of most exposed Martian formations except those exposed in the walls of rift valleys. In many of those valleys, as well as throughout other regions, layered rocks resembling sedimentary or volcanic strata dominate. Nonethe- less, ejecta, fractures, shock alteration, and remobilized volatiles related to impacts form the primary fabric of the rocks that must be deciphered by the first geologists. Absence of a continuous cover of impact-generated regolith, however, means that many outcrops of underlying Martian bedrock formations will be accessible for normal geological examination and sampling, as images from both Mars Exploration Rovers have documented. Ejecta blankets within a crater diameter of impact craters provide a broken and overturned version of the sequence of layers penetrated by the impact. To a significant level, inaccessible crater walls can be examined and sampled on traverses radial to such craters.

3. ACCESS

For the Apollo astronauts, the Moon was only three and a half days away. Mars, using conventional chemical rockets, is eight to nine months away at best. Even using an advanced Helium-3 fusion rocket that allows continuous acceleration and deceleration, Mars will be three or four months away. Fortunately, we have the Moon to provide critical aid in an inherently difficult task. The Moon represents the most efficient and lowest risk path to Mars. It provides the opportunity for systems verification, operational planning, crew training, settlement management, and gathering essential resources, whether hydrogen, oxygen, water, food, or helium-3. The development of helium-3 fusion power for consumption on Earth even can support much of the development costs of heavy lift launch and interplanetary fusion rockets. (Schmitt, 2006).

Once in orbit around Mars, there will be many challenges in entry, descent and landing of large crewed spacecraft (See Manning, 2007). It is currently estimated that to land a crew on Mars will require a mass of forty to sixty metric tonnes at entry into the atmosphere, or more than ten times the landed mass thought feasible today. Rockets can be used for the final phases of landing; however, like any crew's return to Earth from space, one would like to use friction with the Martian atmosphere to help slow down before gliding (like a Space Shuttle) or deploying parachutes (like Apollo's return to Earth) or using rocket engines (like Apollo lunar landings).

The thin Martian atmosphere, however, poses more problems than it yet solves for future explorers. Mars entry will require a shield to protect spacecraft from frictional heating. On the other hand, its atmosphere has too low a density to help much with atmospheric braking prior to deployment of any parachutes. Relative to parachutes, a forty metric tonne crewed spacecraft would require a parachute the size of the Pasadena Rose Bowl to further slow down before using rockets for an actual landing.

Development and test of such a huge parachute and other entry concepts, such as inflatable ballutes and heat shields, pose many problems.

No matter how it is done, entry and descent will require a detailed knowledge of the atmospheric parameters along the spacecraft's actual trajectory – altitude profiles for wind velocities and directions, pressures, and temperatures. Obtaining such critical information may require a precursor entry vehicle to proceed ahead of the actual landing spacecraft and provide these parameters for immediate use by guidance systems. Many high altitude regions of Mars actually may not be accessible except by post-landing use of rovers or flyers. Further, a direct entry, descent and landing sequence would need to be accomplished in about 90 seconds with nearly continuous high g loads, suggesting that some means of prolonged deceleration and flight through the atmosphere will need to be devised.

The atmosphere, thin as it is, also makes it difficult to use rockets as an alternative to parachutes for descent as the rockets would need to thrust into a hypersonic airflow. Significant development and testing in the equivalent upper Earth atmosphere will be necessary. Also, such rockets and their propellants would add significantly more mass to the spacecraft launched from Earth. A good guess, with our current state of knowledge, would be that Martian landings will be accomplished by a combination of aerodynamic deceleration for initial entry, rocket and aerodynamically controlled skipping, combined rocket and aerodynamic decent, and a controlled rocket landing. Spacecraft concepts and mission operations both will require designs that assume an "abort to land" if any major system's problems occur during descent. Once on the surface, the problem can be addressed and resolved in contrast to aborting a landing after the cost, time, and risk to get to Mars.

Based on our lunar experience as well as the special circumstances at Mars, the landing spacecraft will probably be a two-stage vehicle, that is, a descent stage and a crewed cabin-ascent stage. For entry, this lander will be protected by an aero-shell that would be jettisoned before the decent rocket is fired. One major departure from Apollo 13 lunar landing operations will be the necessary design requirement that all landing aborts be to the surface, rather than back to orbit, with trouble-shooting and repairs of the ascent vehicle done after landing.

During Earth to Mars transit, the upper stage will serve first as an entry, descent and landing simulator for crew proficiency training during the long Earth to Mars transit period and then as an ascent and rendezvous trainer during the stay on the Martian surface. Because of atmospheric friction during ascent, the upper stage will need to be aerodynamically shaped, unlike the Apollo lunar module's Ascent Stage that operated only in vacuum.

With respect to landing humans on Mars, therefore, the bad news is we do not know how…yet. Bright young men and women, on the other hand, will meet these challenges once we decide to go to Mars. Already ideas are developing on how to do accomplish a Mars landing, how to test those ideas, and how to prepare for the missions. Returning to the Moon with these engineering, operational, and training challenges in mind would help lay the foundations for missions to Mars, and, indeed, may be essential for success.

The time required to reach Mars may create some differences in the psychological environment of Martian exploration versus that of the Moon. A minimum of several months to return home versus a few days might affect some individuals in adverse ways. For example, psychologically, I personally felt very at ease while on the Moon. I attribute this to being both highly motivated and highly trained as well as having very great confidence in the support team on Earth. Although a Mars crew will have to be much more self-reliant than a lunar crew due to physical isolation from Earth and communication limitations, nonetheless, motivation, training, team confidence, and survival instincts will be much the same as working on the Moon. Historically, human explorers have been subjected to much longer separations from home than will early Mars crews.

Psychological issues may not be much of a problem, though there are differing opinions on this (Bishop, 2010; Fiedler & Harrison 2010; Harrison & Fiedler 2010, Suedfeld, 2010). Everyone will be extraordinarily busy with normal spacecraft operation and maintenance activities, scientific tasks, physical conditioning, simulation training for future tasks, continuous updating of the plans for exploration, and many other duties. In fact, if the history of long term Earth-orbit space flight to date is any indication, finding personal time to relax may be the main psychological challenge facing the crew.

Access to Mars, therefore, will require addressing a myriad of complex technological and operational issues. If Americans and their partners are serious about such an effort, as they should be, the most important step is to establish clear and focused objectives and milestones to meet those objectives. Throughout history, Americans and their partners have successfully responded to challenges of this nature and magnitude when given clear goals and competent, courageous leadership. Obvious examples are the Transcontinental Railroad (Ambrose, 2000), the Panama Canal (McCullough, 1977), the Manhattan Project (Kelly, 2007), and Apollo (Cortwright, 1975) as well as victory in two World Wars. In this challenge of taking freedom into deep space, time and dithering are not our friends.

4. EXPLORATION APPROACH

Martian exploration probably will begin with what is referred to as "surface rendezvous," that is, a three or four person crew landing in the vicinity of a previously landed, un-crewed habitat and back-up ascent vehicle. This approach also permits the use of a guidance beacon on the habitat to guide the crewed vehicle to a nearby, safe location. A tele-operated rover would provide the opportunity to refine exploration planning prior to crew arrival. It then could be driven from the habitat to the lander for the crew's use in transferring themselves and additional equipment to the habitat. With completion of exploration in the area accessible from the habitat, the rover or rovers can be tele-operated to follow-up on the crewed exploration and then to explore the region between one exploration site and the next. The next crew at another location samples could be collected for examination and sorting for return to Earth on Mars.

The primary constraint on exploration efficiency on Mars, like on the Moon, probably will remain those imposed by having to wear a pressurized space suit as protection against the near vacuum. It remains conceivable that space suit technology will evolve so that the suit glove or its equivalent will approach the dexterity of the human hand and that the suit itself will become as mobile as cross-country ski clothing. Conceivably, robotic field assistants may provide a net increase in exploration efficiency.

Until effective future space suit and robotic technology appears, however, many procedural, equipment, and planning enhancements to exploration efficiency will be required. The Apollo 7LB suit used during the exploration of the valley of Taurus- Littrow in December 1972 was a very good suit, and it allowed us to do a remarkable amount of fieldwork in a very hostile environment. Running at ~6km per hour was easy in this 3.7psi suit. Using a cross-country skiing gait, this speed probably could be maintained at a steady pace for several kilometers if need be. With the tools available, astronauts could take samples, document them photographically, and bag them at a reasonable rate. In about 18 hours of exploration, Apollo 17 collected 250 pounds of mostly well-documented rocks and soils.

Much better leg, waist and arm mobility definitely would be desirable; but the A7LB, worked well. What almost didn't work, or at least created significant fatigue and hand trauma, were the suit gloves. Something must be done about the technology of the gloves when we return to the Moon and go on to Mars. The estimated hand efficiency using the glove was reduced due to forearm fatigue to about ten percent of normal within the first 30 minutes of pressurized activity.

Three, 8-9hr pressurized excursions could be performed using the A7LB suit, including preparation time; but it is not clear how many more would be possible with the hand abrasions and nail damage that the glove caused. One advantage of more efficient cardiovascular circulation in one-sixth gravity, however, is that after an eight-hour rest period, there was no residual muscle soreness. In addition, based on the experience of astronauts constructing the International Space Station, we now know that physical training techniques exist for much superior conditioning of arm muscles for continuous hand exertion.

5. CREW CHARACTERISTICS

Intelligent and detailed planning and knowledgeable management, along with spacecraft and equipment designs that reflect the best available experience and technology, comprise the foundation up on which successful Martian exploration will take place. The crew, on the other hand, ultimately will be the guarantor of success (Bishop, 2010; Fiedler & Harrison 2010; Harrison & Fiedler 2010, Suedfeld, 2010). In addition to being fully prepared to contribute specially skills to an integrated team, each member of a Martian crew must be fully and unequivocally comfortable and compatible with a hierarchical command structure and have absolute confidence in their leader. Successes and failures in human history clearly show that such a command structure is required during long-term isolation of small teams of explorers.

The optimum selection of crews for the field exploration of Mars can benefit from the experience of Apollo and from the new experiences that will be inherent in the planned return to the Moon early in the 21st Century. Specifically, initial crews of Martian explorers should be a mix of professional pilots, field geologists and biologists, physicians and engineers, all cross-trained in each other’s skill areas. The optimum crew size for early exploration appears to be four – two professional pilots cross-trained as field explorers and systems engineers as was done for Apollo lunar crews; one professional field geologist cross-trained both as a pilot and a field biologist; and one professional field biologist cross-trained as a physician and field geologist. If permitted by mass and other operational constraints, two such crews should be on each early Mars mission so that one crew can act as an orbiting "mission control center" for the surface crew with the roles reversed when the second crew lands at a different site. The extra lander necessary to implement such a strategy also provides important redundancy that helps to insure overall mission success.

The political urgency and test flight nature of early Apollo planning and development left few options for selecting experienced field geologists as regular members of lunar mission crews (Hodges and Schmitt, in press). On a more or less theoretical basis, one could argue that more field geologists could have been selected in the mid-1960s, trained as jet and helicopter pilots as was the author, and assigned to Apollo 15 and 16 in addition to the author’s Apollo 17 mission. Pragmatically, however, the vast developmental uncertainties in how Apollo would be accomplished led to a crew population consisting mostly of professional test and military pilots with only one pilottrained field geologist. In addition, the necessary design and operational characteristics of the two Apollo spacecraft required that all members of a three person crew needed to be accomplished, experienced, and confident in the use of the machines and methods necessary for flight. Field geologist "passengers" would not be compatible with these requirements. Unfortunately, the selection process for Apollo "scientist astronauts" was not designed by the National Academy of Sciences or NASA to maximize the number of field geologists sent to pilot training and then fully integrated into the mission crew selection pool.

Beginning with precursor return missions to the Moon, professional field explorers should be part of every four-person crew sent to the Moon so that this paradigm can be ingrained in planning for Mars’ exploration as well as providing much enhanced returns from lunar exploration. Also ingrained in all crew members and their operational support teams should be a commitment to as much possible terrestrial, field-based training on real geological problems constrained by realistic operational planning, equipment, communications, and timelines. This commitment governed the exploration training for most Apollo missions to great benefit and should be modernized for future lunar and Martian missions. (Schmitt, et al, in press).

The author highly recommends that all lunar and Martian crew personnel be trained jet and helicopter pilots. No substitute exists for the psychological preparation for solving real problems in complex spacecraft that comes with all members of an astronaut crew being professional pilots whether originally a test pilot or scientist or engineer.

test pilot or scientist or engineer..

6. CONCLUSIONS

As the lunar exploration experience matures during the 21st Century, thought must be given to the major ways that lunar and Martian exploration will differ. For example:

> 1. The trip to Mars will be measured in months rather than days and during that time crew training, mission planning, and physiological countermeasures must be aggressively pursued. For example, the spacecraft for landing and return to Earth must incorporate the capability to be simulators for proficiency training as well as being functional spacecraft. For Apollo missions, the last computerized training simulation for landing on the Moon took place less than a week before we actually began powered descent to a landing site. Without an in-flight simulation capability, that gap could be on the order of nine months for Mars trips; clearly too long and thus the need for using the spacecraft for regular training activity. Similarly, regular training for ascent from Mars, Mars orbit rendezvous and departure, and Earth entry on return all would be necessary.
>
> 2. The basic approach to landing will be to rendezvous with a previously landed, uncrewed vehicle that has most of what will be needed for the exploration mission, including habitat, rovers, field and analysis equipment, and a backup ascent vehicle.
>
> 3. The Earth will not perform the traditional "mission control" functions due to the long delays in communications. The Earth will become "that great data processor in the sky," participating in exploration data analysis and synthesis, weekly planning, systems and consumables monitoring and analysis, maintenance requirements, ascent simulations scenario development and critique, and other activities where live, that is, "real time" interaction with the crew is not required.
>
> The actual live mission control functions will need to be carried out by an orbiting crew and/or by half the landed crew during alternating non-excursion days. Although we planned the Apollo lunar exploration activities to the degree possible using available photographs, we left significant latitude to the crews to pursue unanticipated targets of opportunity. We pursued that latitude probably to the limit after discovery of the orange volcanic glass in the rim of Shorty Crater with only 30 minutes of time available for observation and sampling. No time was available to discuss this plan with Mission Control, but we knew immediately what needed to be done. Exactly this approach will be required of the crews on Mars, but implemented continuously, with Mission Control on Earth finding out everything tens of minutes after the fact.
>
> 4. In light of the expense and historical importance of each Mars' exploration mission, mission philosophy must be totally success oriented. For example, ideally, two landers should be available in case one cannot be used. Two landers also would allow two separate sites to be explored if both are deemed functional. Further, systems or software anomalies observed during the entry, descent and landing sequence should be resolved by having designed to an "" rule rather than an abort-to-orbit rule as existed during Apollo landing sequences. Solutions to such problems can be resolved over time and in consultation with the Earth once the crew lands safely. This abort-to-land concept, however, will impact the design and level of redundancy of the landing craft.
>
> 5. Crews should be comprised of exceptionally expert and broadly experienced professionals, cross-trained in each other's specialty so that mission success depends not on any one individual but on enhanced mutual capabilities. Professional and training experience in geological field exploration will constitute an essential component of each crew as a whole.

Young people now alive could have the privilege and adventure of settling the Moon, using its resources, studying its contribution to the history of the Earth and solar system, then exploring and settling Mar - if their parents and grandparents provide the opportunity for them to do so. Parents also must make possible that their children have the education and character necessary to do great things.

Mars exploration will not be easy. As with anything worthwhile, risks exist. But the alternative of postponing settlement of the Moon and the exploration of Mars beyond existing generations would leave the future to other explorers. Further, without the capability to go back to the Moon and on to Mars and the capability to work in deep space leaves all of humankind vulnerable to the impact on Earth of asteroidal and cometary travelers of the solar system. We have little choice but to continue what Americans began on July 20, 1969, and paused after placing the last men on the moon in December 14, 1972.

References

Ambrose,, S. E. (1996). Undaunted Courage. Simon and Schuster, NewYork, US.

Ambrose, S. E. (2000). Nothing Like It In The World. Simon & Schuster, New York, US.

Bishop, S. L. (2010). Moving to Mars: There and back again, Journal of Cosmology, 12, 3711-3722.

Carr, M. H. (1981). The Surface of Mars. Yale University Press, New Haven, US.

Charpentier, J. (1778). Mineralogische Geographie der Chursachsischen Lande. Crusiius, Leipzig, Germany.

Cortwright, E. M. (1975). (Ed.) Apollo Expeditions to the Moon. NASA Special Publication 350, U. S. Government Printing Office, Washington DC, US.

Christensen, P. (2005). The many faces of Mars. Scientific American, April.

Fiedler, E. R., & Harrison, A. A. (2010). Psychosocial Adaptation to a Mars Mission, Journal of Cosmology, 12, 3685-3693.

Gornitz, V. (2008). Decoding the mineral history of Mars. Mineral News, pp.12-13.

Harrison, A. A., Fiedler, E. R. (2010). Mars, Human Factors and Behavioral Health, Journal of Cosmology, 12, 3694-3710.

Hodges, K. V., Schmitt, H. H. (2011). A New Paradigm for Advanced Planetary Field Geology Developed Through Analog Exploration Exercises on Earth. In: G. Bryant, editor, Analogs for Planetary Exploration, Special Paper, Geological Society of America, Denver, US, in press.

Kelly, C. C., Editor, (2007). The Manhattan Project. Black Dog & Leventhal, New York, US.

LPL (2010) Uncovering the mysteries of the Martian arctic, http://phoenix.lpl.arizona.edu/mission.php

Manning, R. (2007). Interview by N. Atkinson. http://www.universetoday.com/2007/07/17/the-mars-landin-approach-getting-largepayloads- to-the-surface-of-the-red-planet/.

McCullough, D. (1977). Path Between the Seas. Simon & Schuster, New York, US. NASA (2010a). NASA's Mars exploration program. http://marsprogram.jpl.nasa.gov/science/geology/

NASA (2010b). NASA marks 35th Anniversary of Mars Viking Mission. http://www.nasa.gov/mission_pages/viking/.

NASA (2010c) Found it! Ice on Mars. http://science.nasa.gov/science-news/science-atnasa/ 2002/28may_marsice/

Schmitt, H. H., Trask, N. J., Shoemaker, E. M. (1967). Geological Map of the Copernicus Quadrangle of the Moon. USGS Geological Atlas of the Moon, 1-515, LAC 58, Geological Survey, Washington, D.C, US.

Schmitt, H. H. (1973). Apollo 17 Report on the valley of Taurus-Littrow. Science, 182, 681-690.

Schmitt, H. H. (1973). Exploring Taurus-Littrow. National Geographic Magazine, 144, September 1973, pp. 290-307.

Schmitt, H. H., (2003). Apollo 17 and the Moon. In: Mark, H. (Ed.), Encylopedia of Space and Space Technology. Wiley, New York, US.

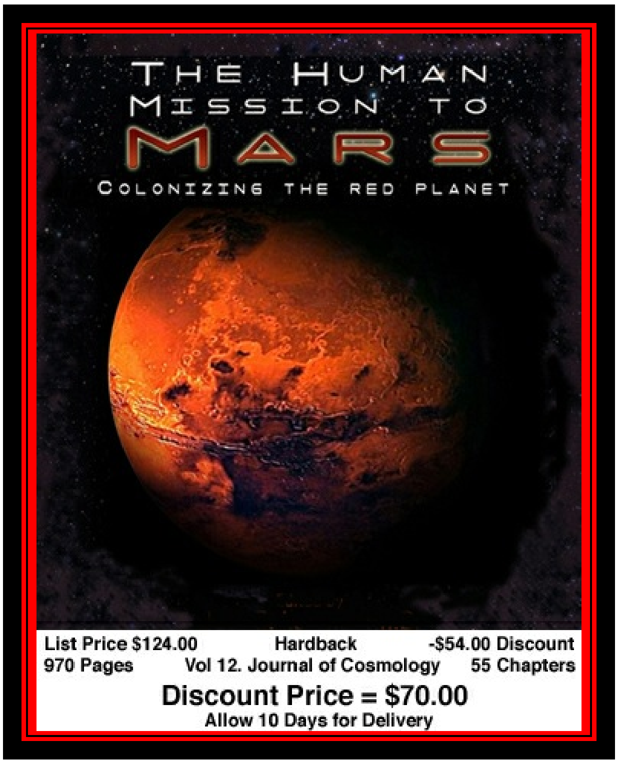
Schmitt, H. H. (2006). Return to the Moon. Copernicus-Praxis, New York, US.

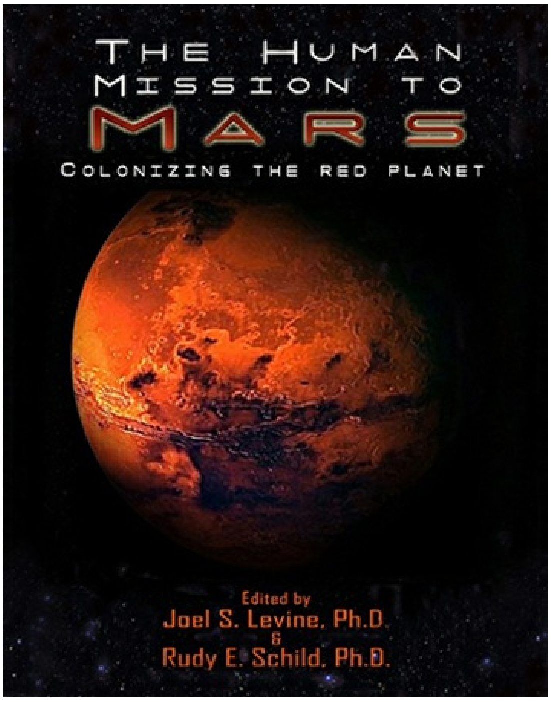
Schmitt, H. H., Snoke, A. W., Helper, M. A., Hurtado, J. M., Hodges, K. V., Rice, J. W., Jr. (2011). Motives, Methods, and Essential Preparation for Planetary Field Geology on the Moon and Mars. In: G. Bryant, editor, Analogs for Planetary Exploration, Special Paper, Geological Society of America, Denver, US, in press.

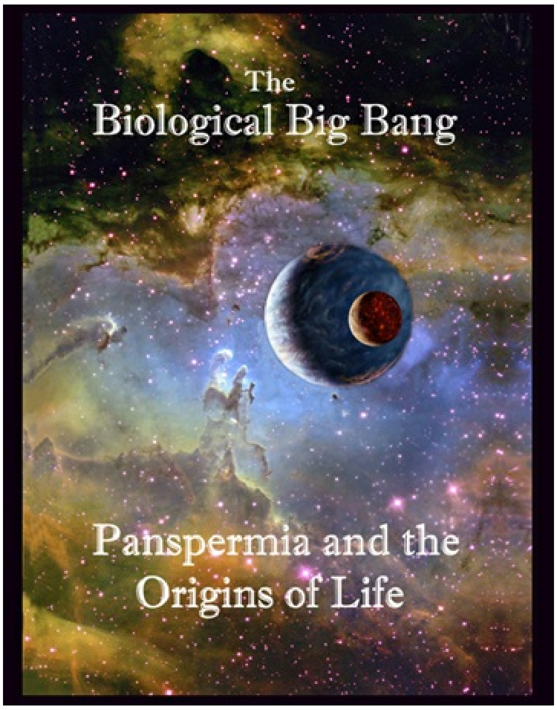
Smith, W. (1815). A delineation of the strata of England and Wales, with part of Scotland. Cary, London, UK.

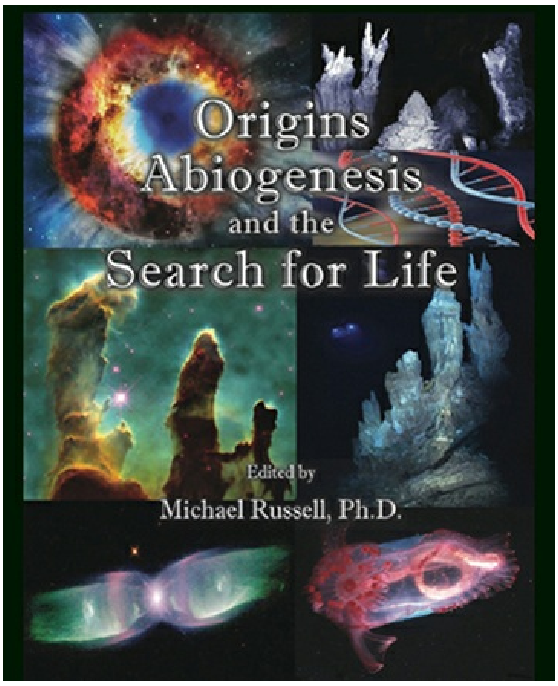
Suedfeld, P. (2010). Mars: anticipating the next great exploration, Journal of Cosmology, 12, 3723-3740.

Wolfe, E., and 10 colleagues (1981). The Geologic Investigation of the Taurus-Littrow Valley: Apollo 17 Landing Site. Professional Paper 1080, Geological Survey, Washington, DC, US.









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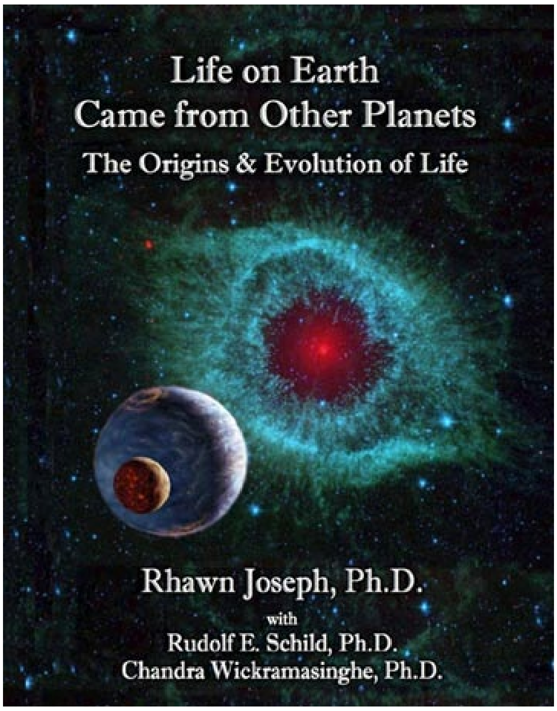

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A robotic geologist and two miniature satellites launch from California on a six-month mission to study the temperature and geological stability of Mars.Â A robotic geologist armed with a hammer and quake monitor rocketed toward Mars on Saturday, aiming to land on the red planet and explore its mysterious insides. Key points: The first Mars lander launched by NASA since Curiosity in 2012. Will drill further into Martian surface than any other mission. Will be accompanied on entire journey by two miniature satellites named WALL-E and EVE. 5. Apollo on Mars: Geologists Must Explore the Red Planet Harrison H. Schmitt 36. 6. Humans on Mars: Why Mars? Why Humans?Â 15. The Integration of Planetary Protection Requirements and Medical Support on a Mission to Mars John D. Rummel, Margaret S. Race, Catharine A. Conley and David R. Liskowsky 152. 16. Infection Risk of a Human Mission to Mars Mihai G. Netea, Frank L. van de Veerdonk, Marc Strous, and Jos W.M. van der Meer 160. 17. Location, Location, Location! Lava Caves on Mars for Habitat, Resources, and the Search for Life Penelope J. Boston 169. 18. The Mars Homestead For An Early Mars Scientific Settlement Bruce Mackenzie1, Georgi Petrov, Bart Leahy, and Anthony Blair 189. Mars is the planet closest to Earth, in terms of distance and physical make-up. Since it's our neighbor, we want to know more about it. Could we one day live there?Â A big robot-vehicle that is set to explore Mars later this year was built at NASAâ€™s Jet Propulsion Laboratory at the California Institute of Technology. The whole point was to make something durable enough to land, explore, and figure out the Red Planet.Â This infographic highlights NASAâ€™s twin robot geologists, the Mars Exploration Rovers (MER) Spirit and Opportunity. The rovers landed on the Red Planet in 2004, in search of answers about the history of water on Mars. Spirit concluded its mission in 2010. Apollo 17 moon walker and geologist Jack Schmitt champions the possible economics of mining helium 3 on the moon. Credit: Barbara David. For example, he said, helium 3 mining would produce by-products including water, hydrogen, carbon and nitrogen.Â And according to SpaceX engineer Paul Wooster, Red Planet planning by Muskâ€™s private company is steadily progressing. â€œThe vision for SpaceX, long-term, is making it possible for large numbers of people to go to Mars,â€ he says.Â SpaceX Red Dragon nears autopilot touchdown on Mars. The private firm has the Red Planet in its sights to establish an outpost, and eventually a city, on that distant world. Credit: SpaceX. SpaceX Marks the Spot. â€œFirst and foremost is to learn how to land large payloads on Mars,â€ Wooster says.