THE USE OF TERRESTRIAL ANALOGS AS HIGH FIDELITY TEST BEDS FOR THE DEVELOPMENT AND REFINEMENT OF MARS SURFACE SYSTEM CAPABILITIES. D. S. S. Lim[1,2], C. P. McKay[1], J. L. Heldmann[1], M. M. Marinova[1,3], G. Osinski[4], A. L. Brady[5], A. F. Davila[1,2], T. Cohen[1], D. Lees[1], T. Smith[1], T. Fong[1], and M.L. Gernhardt[5]. [1]NASA Ames Research Center, Moffett Field CA 94035, [2]SETI Institute, [3]Bay Area Environmental Research Institute, [4]University of Western Ontario, [5]University of Calgary, [6]NASA Johnson Space Center.

Introduction: As the next generation planning for future Mars exploration begins, we put forth that strategically selected terrestrial analogs will provide an innovative and cost-effective environment in which to test both near- and mid- to longer-term technological and operational development requirements. Terrestrial analogs can play a key role in our preparations for these complex voyages, since in addition to their scientific value, analogs afford the exploration community a means to safely prepare and test exploration strategies for future robotic and human planetary missions [1].

Analogs relevant to informing Mars surface system capabilities will be most effective if selected to meet a combination of science, engineering and operational objectives associated with the robotic and human exploration of Mars. Furthermore, analog research that merges these three research areas will enable and support an applied collaboration between NASA Science Mission Directorate, Human Exploration and Operations Mission Directorate and Office of the Chief Technologist funded research activities that will Strategic Knowledge Gaps (SKGs) in the pursuit of sending humans to Mars.

Terrestrial Analogs: Analog sites are typically chosen to allow for research focused on one or a combination of the following three topics: 1) Science, 2) Engineering, and 3) Operations. When strategically chosen, these analogs offer high fidelity environments in which to test and refine hypotheses, hardware, and exploration concepts, respectively. Science analogs provide an approximation of geological, environmental and/or putative biological conditions on a particular planetary body either at present or in the past [2]. Fieldwork, remote sensing campaigns, comparison of terrestrial and planetary datasets, and numerical and computer modeling of geological processes, amongst other research endeavors, are facilitated by science activities at science analogs. Much of the astrobiology and geobiology field-based research around the world is used as a scientific analog for early Earth and for the past and present-day conditions on other planetary bodies. Engineering focused analogs typically capitalize on similarities between the physical properties associated with a terrestrial site and that of a planetary body of interest. These analogs are valuable in proof of concept studies. One such engineering or technology focused analog is the NASA Desert Research and Technology Studies (DRATs). The research objectives aim at evaluating technology, human-robotic systems and extravehicular equipment in the high desert near Flagstaff, Arizona [3]. Field testing provides a knowledge base that helps scientists and engineers design, build and operate better equipment, and establish requirements for operations and procedures associated with that hardware.

Operational analogs are chosen to approximate conditions and complexities related to the human exploration of space and other planets. These analogs can cover a broad spectrum of topics such as human health and psycology, communications, ground data systems, telemedicine, human-robotic interactions, mission control support tools, planning, and astronaut training, among many other exploration considerations. Ops analogs can range from controlled environments such as the Neutral Buoyancy Lab to field-based experiments such as those conducted by the NASA Extreme Environment Mission Operations (NEEMO) program in Key Largo, Florida.

Analogs Concepts for Mars Exploration: Ongoing analogs that are focused on either science, engineering or operations objectives continue to fill strategic knowledge gaps pertaining to our understanding of how best to explore Mars and other planetary systems. Going forward, the support of analog programs that offer an integrated opportunity to investigate all three research topics in tandem in a real, non-simulated manner, are predicted to produce high fidelity insights that will inform the strategic development of Destination Road Map (DRM) concepts. While mock up use case scenarios tend to miss out on the real drivers and unexpected demands of science, real field science and exploration activities demand and enable the development of cost-effective and innovative science, engineering and operational solutions to meet real end-user needs.

Current examples of integrated analog activities include a broad range of terrestrial environments, science and engineering objectives, and operational complexities that have varying levels of fidelity to human Mars exploration. As an example, the Antarctic Dry Valleys has been the focus of the ASTEP funded Mars Icebreaker Drill project [4]. This project leverages the arid and cold climate properties of this region of the Antarctic in which to test and refine drilling capabilities for future subsurface exploration of Mars, while answering key questions related to the preservation of organics in ground ice on Earth and on Mars. The Haughton Mars Project (HMP) and the Arctic Mars

Svalbard Expedition (AMASE) are further examples of multi-disciplinary research programs aimed at studying extreme Mars-like environments using instruments and techniques that may be used for future planetary missions. In both cases, operational learnings were also acquired given the relevance of the real science and exploration program to exploration concept development for human Mars mission.

The Pavilion Lake Research Project's (PLRP) DeepWorker (Submersible) Science and Exploration (DSE) activities present a unique opportunity to integrate real science and real exploration field activities in a hostile environment that is a universally recognized space flight analog - underwater. Underwater, humans must, as they do in space, contend with limited connection to colleagues, protection/isolation from the environment, and life support systems (LSS), all while exploring and conducting science in variable and unfamiliar terrains. These working constraints are not simulated, but real and inextricable from any human underwater science activities. The PLRP activities required the seamless integration of both hypothesis and exploration driven field science with the physical, mental and operational rigors and challenges associated the SCUBA diving and DeepWorker submersible operations at Pavilion Lake. Science support needs of the field research team operating in this complex, high-stakes environment drove the development and refinement of geospatial software tools and communications infrastructure that are immediately relevant to other analog programs (e.g. NEEMO, ISRU) and ultimatley highly relevant to future human Mars exploration support needs [1]. Furthermore, operational scenarios that enable the highest degree of science productivity and data return could be accessed through these real science and exploration activities [5], and astronauts [6], mission operators and planners have been afforded a chance to develop new skills, and redesign existing support tools to meet the rigors of human science exploration in hostile environments.

Conclusions: The support and use of integrated science, engineering and operations based analog programs will lead to the development of relevant, innovative and insightful exploration concepts for future human missions to Mars.

References: [1] Lim et al. (2011), A historical overview of the Pavilion Lake Research Project—Analog science and exploration in an underwater environment, The Geological Society of America, Special Paper 483: 85-116. [2] Osinski et al. (2006), Terrestrial Analogues to Mars and the Moon: Canada's Role, Geoscience Canada 33:175-188. [3] http://www.nasa.gov/exploration/analogs/desertrats/index.html. [4] Paulsen, G. et al. (2011) Field testing of the IceBreaker Mars Drill in the Antarctic. LPSC Abstract 1608, p.1901 [5] Forrest et al. (2010), Underwater vehicles as analogues for space exploration. PSS 58: 706–716. [6] Lim et al. (2010), Scientific field training for human planetary exploration. PSS 58:920-930.