THE NEED FOR ANALOGUE MISSIONS IN SCIENTIFIC HUMAN AND ROBOTIC PLANETARY EXPLORATION. K. J. Snook[1] and W. W. Mendell[1], [1]Office of Human Exploration Science / SX, NASA Johnson Space Center, 2101 NASA Parkway, Houston, TX 77058, (281) 483-0928, kelly.j.snook@nasa.gov, wendell.w.mendell@nasa.gov.

Introduction: With the increasing challenges of planetary missions, and especially with the prospect of human exploration of the moon and Mars, the need for earth-based mission simulations has never been greater. The current focus on science as a major driver for planetary exploration introduces new constraints in mission design, planning, operations, and technology development. Analogue missions can be designed to address critical new integration issues arising from the new science-driven exploration paradigm. This next step builds on existing field studies and technology development at analogue sites, providing engineering, programmatic, and scientific lessons-learned in relatively low-cost and low-risk environments.

One of the most important outstanding questions in planetary exploration is how to optimize the human and robotic interaction to achieve maximum science return with minimum cost and risk. To answer this question, researchers are faced with the task of defining scientific return and devising ways of measuring the benefit of scientific planetary exploration to humanity. Earth-based and space-based analogue missions are uniquely suited to answer this question. Moreover, they represent the only means for integrating science operations, mission operations, crew training, technology development, psychology and human factors, and all other mission elements prior to final mission design and launch.

Eventually, success in future planetary exploration will depend on our ability to prepare adequately for missions, requiring improved quality and quantity of analogue activities. This effort demands more than simply developing new technologies needed for future missions and increasing our scientific understanding of our destinations. It requires a systematic approach to the identification and evaluation of the categories of analogue activities. This paper presents one possible approach to the classification and design of analogue missions based on their degree of fidelity in ten key areas. Various case studies are discussed to illustrate the approach.

Analogue Mission Design and Evaluation: *Identifying mission to be simulated.* Analogue missions can be most broadly characterized by the type of space mission they are designed to simulate. We propose five classes of analogue missions, simulating:

- I. Robotic orbital platforms (e.g. Mars Odyssey)
- II. Long duration joint human and robotic transit or orbital missions (e.g. Mir)
- III. Autonomous robotic surface missions
- IV. Semi-autonomous or teleoperated robotic surface missions (e.g. Spirit)
- V. Joint human and robotic surface missions (e.g. Apollo)

Once an analogue class has been identified, it is then possible to specify which aspects of the mission will be simulated (and sometimes more importantly, which will not) in the analogue activity. Fidelity of the analogue will be impossible to assess until at least this basic set of properties is established *for the mission being simulated*:

- i. Mission destination, purpose, and timeline
- ii. Overall mission architecture
- iii. Mission segment
- iv. Mission command, control, communication and data flow scenarios
- v. Daily mission schedules and anticipated task management
- vi. Anticipated mission technology level
- vii. Anticipated support architecture on Earth
- viii. Anticipated mission public outreach and education
- ix. Other relevant anticipated mission elements

Analogue fidelity. In any analogue activity, the key element to consider is fidelity. For a scientific analogue, fidelity hinges on the degree of physical similarity of the chosen analogue site to its counterpart on another planet. Similarity might be morphological, chemical, biological, geological, or otherwise based on analogous physical processes. For an analogue experiment focused on technology development, such as rovers and drills, fidelity might depend more on topography and physical parameters such as temperature, precipitation, rock abundance, and engineering properties of soils and rocks. Fidelity in operational, human factors, and training analogues requires situational and logistical similarities, such as remoteness, isolation, confinement, and limited data rates or pathways of communications. The extent to which an analogue activity is useful is directly related to its fidelity in the category or categories of its intended investigations. Experiments have shown that activities with high degrees of fidelity in more than one analogue category raise new issues and provide unexpected lessons learned, making them more useful to space mission planners than those focusing only on one category. It is therefore highly desirable in the design of analogue missions to explore opportunities for maximizing fidelity in as many categories as possible, without losing the focus necessary to generate useful qualitative and quantitative results.

Ten key categories of analogue fidelity are defined and discussed in this paper:

A. Science and science return
B. Science Operations
    1. *Types of science tasks, investigations, and traverses.*
    2. *Scheduling and planning of science tasks and traverses*
    3. *Functions of technologies used for scientific tasks and traverses.*
    4. *Science support, remote science, and the "Science Backroom"*
    5. *Degree of Human Influence*
C. Technology Development
D. Technology Integration
E. Mission Operations
F. Crew/Ground Team Training
G. Human Factors
H. Human physiology/biology
I. Outreach and Education
J. Overall Integration

Metrics for cost-effectiveness of analogue activities can then be developed within this systematic framework.

Case Studies: A brief survey of ten existing or planned analogues is provided here for the purpose of illustrating how the classes of missions and categories of analogues may be useful. The analogues selected are not intended to represent a comprehensive survey of all analogue activities, but instead are limited to those with which the authors or their institutions have been directly involved. A figure indicating the fidelity of the case study analogues in the ten fidelity categories is presented.

1. The NASA Haughton Mars Project (HMP) [1]
2. The NASA Science Backroom Experiment at the NASA HMP [2]
3. The NASA Oceanographic Analogue Mission Activity (NOAMA)
4. The Mars Society's Mars Desert Research Station (MDRS) Crew 6 Rotation
5. The NASA Desert Research and Technology Study (Desert RATS)
6. NASA's Mobile Agents project [3]
7. The NASA Advanced Integration Matrix (AIM) [4]
8. The NASA Extreme Environment Mission Operations (NEEMO) project [5]
9. The NASA Mars Analog Research and Technology Experiment (MARTE) [6]
10. The International Space Station (ISS)

References: [1] Lee P. C. (2004) www.marsonearth.org. [2] Glass B., et al. (2003) *Proceedings – 7th International Symposium on Artificial Intelligence, Robotics, and Automation in Space (iSAIRS)*, Nara, Japan, May. [3] Clancey W. A. (2004) *Submitted - Proceedings Florida AI Res. Symp. (FLAIRS), Miami.* [4] NASA http://advlifesupport.jsc.nasa.gov/
[5] Todd, W. (2004) Proceedings – *Habitation (in press) 2004, Rutgers University* [6] Stoker C. R. et al. (2003) *Eos. Trans. AGU, 84 (46), Fall Meet. Suppl., Abstract B51G-05.*