ASSESSING THE VALUE OF ANALOG "MISSION" DATA SETS BEYOND THE TESTING TIMELINE.

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Introduction: One of the most fundamental ways that federal and/or private sector entities actively plan for expanding the human presence into the solar system is through the use of analog "mission" tests. These Multiple analog missions have been completed in recent years and more are in the planning stages, which collectively address both manned and robotic missions [1-6]. These efforts provide an expansive knowledge base to help scientists and engineers design, build, and operate improved equipment and establish requirements for operational procedures [3-6]. Although the advent of increased online digital storage capacities, search functions, and virtual linkages has led to the increased distribution of actual mission data (landed and orbital), we have not observed a similar trend for analog (test) mission data. This is despite an understanding that such tests help ensure that science, safety, and financial return are maximized [1-2].

Here, we promote a community discussion focused on whether analog mission data sets can (and should) be a resource for cross-discipline investigations after the actual tests have been completed [3]. Such a discussion must first examine whether there are sufficient scientific merit and community interest in data sets accumulated from analog missions to justify the costs related to their dissemination. We must then outline specifics regarding how those data are collected, collated, stored, and accessed. As a primer to a broader community discussion, we provide (1) a rationale for distributing data by summarizing their potential post-test uses, (2) technical approaches for distributing such data, and (3) recommend steps to assist the process.

Rationale: One of the key investigative points that should be examined when considering the distribution of analog mission data through a dedicated clearinghouse is whether a real need exists within the science and engineering community. A strength of analog mission data is that observations are typically well-documented and are gathered from locations to which other researchers might not have access to (J. Bleacher, pers. comm.). Another strength is that these data sets – similar to those of actualized missions [7] – have demonstrable strategic and tactical heritage [1]. Joining the observations with the rationale for their acquisition offers a unique opportunity for quality assessment of the analog test's design and execution. Some questions and hypotheses that can be addressed with analog data sets after the mission timeline, including:

- Can the differences in sample and location descriptions between crew astronauts and geologists be used to design training programs in advance of the analog mission? [1-2, 5]
- Did analog mission observations efficiently address scientific hypotheses over the mission timeline? [6]
- Which types of data sets are most critical to crew and backroom tasks and work flow? [3]
- What quantitative measures allow for the assessment of scientific observation (or limitation thereof) under differing communication scenarios?
- How can metrics that assess the quality of process or observation be improved so that they are comparable across workflows and analog tests?
- What are the most critical observations that should be made in the field and can templates be developed to assist in consistent, succinct observations?

Technical Approaches: Collation and distribution of analog mission data sets provide an effective means to improve upon mission architectures by allowing analysis from the broadest possible audience. Digital distribution must rely heavily on data standards and ancillary information – metadata [8] – to ensure that observations are clearly understood, searchable, linked, and comparable. To adequately distribute analog mission data sets, we must first determine what elements of the data are the most desired by the science and engineering community. This is not necessarily an easy task when confronted with the amount and diversity of analog mission data.

Similar to actualized planetary missions, terrestrial analog missions are complex operations that result in an array of observations [3], including still photos, audio files, satellite images, topography, geologic and traverse maps, trafficability statistics, human factors, scientific hypothesis tests, samples, lab analyses, communication integrity, and observational productivity. These types of data sets have the potential to enhance cross-discipline analysis of mission architectures, including means to balance science observation and the resources that allow their acquisition [1-2].

One goal for examining the rationale and approach for distributing analog mission data is the need for compatibility across simulated missions. This can be accomplished through standardized labels accumulated in two ways. Auto-collection occurs "on-the-fly" during data acquisition. These types of ancillary data may include instrument and observation type, time/date stamp, spatial location (x, y, z), environment and instrument temperature, duration of observation, and file type (to name only a few). This is similar to those data sets acquired by spacecraft, as summarized in PDS standards [9]. These data sets can also include fields that are merged with pre-planned data sets such as association with remote-based geological unit, surface slope (across various baselines), communication integrity at time of acquisition, and any "special scenario" that was imposed during the analog mission timeline. Second, manually-collected data can augment and expand auto-collected information and can include quality control checks and hierarchical associations with other data sets. Though the robustness of the data can be expanded with manually collected metadata, the process is time consuming and error-prone.

Multiple actualized missions use clearinghouse mechanisms to propagate acquired data (and ancillary information) to mission analysts both during and after the mission timeline [e.g., 10]. However, it is unclear to what extent these have been designed from past missions and whether the clearinghouse structure is decided upon prior to mission execution. As a result, such mechanisms have the potential to be available only to a limited audience and become unwieldy in size and/or extraction of relevant data.

Recommendations: The scope of analog missions is variable, and results largely from the analog location as well as the observations that are made therein. Yet, as summarized by NASA's Research and Technology Studies, the purpose of any analog missions is essentially the same: to help "validate future spaceflight mission concepts, conduct technology demonstrations, and understand system-wide technical and operational challenges." We suggest that this purpose cannot be adequately achieved without thorough and ongoing analysis of accumulated observations – both scientific and engineering – by the entire scientific community. The research and engineering community need a serious, sustained discussion related to how analog mission data can be squeezed for information beyond the timeline of the actual tests. We underscore that the intent should be to make diverse, seemingly unrelated mission data easily searchable and comparable for not only scientific analysis but also improvement of mission architectures. To assist, we make the following recommendations:

- Use several small suites of analog mission data as proto-types in order to evaluate existing compatibility of data sets and missions, dissemination techniques, minimal standards, and required infrastructure for maintenance.
- Encourage the inclusion of data preservation plans in the request for analog mission funding.
- Assign an "assessor/evaluator" to be responsible not just for documentation of strategic and tactical discussion but also for adherence to standards.
- Promote continuous discussion of technical approaches and standards within the community as well as cross-discipline research to help highlight the needs related to the use of analog mission data.
- Examine current functioning examples of data portals, such as the MER Analyst's Notebook and the proposed PDS Astropedia Annex [10-12].

Conclusions: The knowledge obtained by modern analog mission tests is primarily intended for training astronauts and engineers and improving system architectures *within the mission timeline* [3]. (This is evidenced in part by the preponderance of gray literature related to such tests as opposed to accessible, peer-reviewed manuscripts). However, over time (as with the knowledge obtained with the lunar landings) this knowledge has a tendency to be diluted or lost [1-2]. Observations accumulated through analog missions, whether scientific or engineering in nature, are just that – "simple" observations. The more difficult step in any test is to make sense of the observations in order to create knowledge. Knowledge in the case of analog missions must eventually be the identification of (or convergence on) observational "best practices" so that the tests can be useful for future analog tests and/or actualized missions. This second – and more complicated – step requires assimilation and integration so that the body of observations is linked together. A community accepted standardization and distribution system can provide a way to accumulate the lessons learned so that resources are not wasted downstream due to repetition and "re-discovery."

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