CARTOGRAPHIC AND GEOSPATIAL INFRASTRUCTURE PLANNING IN SUPPORT OF HUMAN PLANETARY EXPLORATION BASED ON LESSONS LEARNED FROM THE DESERT RESEARCH AND TECHNOLOGY STUDIES.

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Introduction: In preparation for all surface planetary exploration missions a reconnaissance campaign is conducted to collect relevant data. These data include information designed to support both landing and subsequent surface operations. Landed missions that include humans on the surface add complexity and drive a desire for increased reconnaissance both with respect to basic science as well as in situ resource utilization (ISRU) during long duration stays. Furthermore, humans on the surface will enable the collection of a significant amount of data for both science and ISRU purposes. Here, we discuss lessons learned about cartographic and geospatial infrastructure needs related to human missions as learned from the Desert Research And Technology Studies (Desert RATS).

Background and Approach: Desert RATS is a multi-year series of tests of NASA hardware and operations deployed in the high desert of Arizona. Conducted annually between 1997 and 2011, these activities exercised planetary surface hardware and operations in difficult conditions where traverses are conducted to explore geologic planetary analogs. Such activities test vehicle subsystems and stress communications and operations systems thereby enabling tests of science operations approaches that advance human and robotic surface exploration capabilities [1]. These mission simulations included the collection of significant amounts of data and geologic samples as well as the inclusion of on-site laboratory facilities. A communications infrastructure enabled crews to remain in contact with Mission Control, science backrooms and other crewmembers. A significant part of the science operations management activity was dedicated to assessing what data was (and was not) useful to science ground controllers and what was the best way for science ground controllers to interact with surface crewmembers.

Following the completion of the 2010 Desert RATS test [2] a research team conducted analyses of the mission data to determine what would have been learned by the science community [3]. This effort was compared against field work conducted at the same site with a traditional field geology approach [4] to determine how well the mission-constrained approach could match an “ideal” geologic exploration approach [5]. Synchronously, the Desert RATS science team conducted a study involving interns from the United States Naval Academy (USNA) in which they used the data collected during Desert RATS 2010 to evaluate their ability to spatially track sample locations, crew movements and the quality of data acquired. Based on these studies, we discuss observations about the cartographic and geospatial infrastructure needs related to human exploration.

Results: Human missions will involve the integration of orbital data/data products with ongoing collection of data from the surface. We do not discuss data collected in preparation for a landing, focusing rather on what occurs after humans have begun surface operations. We assume that landing site reconnaissance will include a topographic data product and some form of image mosaic for which the resolution is dictated by needs related to enabling a safe landing. These data products will likely serve as the base-map to which additional data acquired on the surface will be registered.

A major question related to data and data products concerns their accuracy within the base-maps and the desired resolution needed to conduct surface operations. Even if the landing process produces a topographic map of high detail, it might not entirely cover the desired area of exploration, or Exploration Zone (EZ), which was recently defined for a Mars human mission as having a diameter of 100 km [6].

Different aspects of mission success will require different accuracies or level of location awareness. For instance, most terrestrial geologists use GPS for location knowledge with an accuracy of ~ 3m. This might be sufficient for geologic studies of regional scale deposits and unit relationship on another planet as well. However, ISRU considerations might require precise knowledge of the distance from one point to another in order to properly estimate the amount of connecting material (power cords, data cables, conveyor belts) required to access valuable resources. 3-D precision higher than 3m might be important across longer distances between assets. Another consideration related to topographic accuracy is related to surface communications. As humans become mobile across an EZ they will likely need to move and deploy communications assets as they explore increasingly complicated terrains beyond the landing site. Experience from the Desert RATS tests indicates that maps of communication-enabled areas were not always accurate. During traverses crews would often need to backtrack when communications were compromised by terrain masking, in order to reacquire those communications links. This can be a costly endeavor if repeated many times during a long range traverse across the EZ. However, collection of additional topographic data from the surface throughout a traverse could be conducted to routinely upgrade the accuracy of communications maps.

The key recommendation for a human mission is that factors beyond science goals will likely drive a desire for routine, possibly near real-time integration of topographic data acquired from mobile surface assets. This will ensure that accurate estimates for deployed resources such as cables and cords will be made and that communication capability estimates will routinely be upgraded and decrease time lost attempting to reconnect between mobile rovers or a mobile rover and a base station. Here, we compare only the location requirements of regional mapping, ISRU activities, and communications mapping at a very basic level. The main point to be made is that multiple aspects of mission success might have different requirements, all of which must be considered as the data collection and cartographic and geospatial infrastructure develop and evolve.

A distinction must also be made between data usage in real-time during a mission vs. data analyzed in retrospect, whether that be on the time scale of hours, days, or years. Future human missions will likely involve longer stays on the surface than experienced during the Apollo Missions, and depending on location experience communications delays of 20 minutes or more. Longer surface stay times and communications delays will result in crewmembers taking over much of the real-time mission management tasks now handled on the ground. Consequently, crew will need to be able to prepare and review data in preparation for subsequent traverses or EVAs, and scientists on Earth will surely be analyzing data throughout a mission. This will require spatially tied data to be available throughout the mission, rather than simply for post-mission analysis.

Although geospatial integration of data where possible is highly desired, the post-mission study of Desert RATS data determined that the temporal relationship between data streams is the most critical link between threads of information, some of which cannot simply be spatially integrated (for instance, crew voice notes and images taken to document sample bags are better linked through time tags, not spatial tags). Participants from the USNA who were not involved in the Desert RATS missions concluded the two most important steps in data processing were to 1) convert audio data to text and 2) link all of the data threads temporally. This temporal linking provides an awareness of other data that were acquired roughly simultaneously during an event, but for which no relationship other than temporal was obvious. Spatial integration of those data threads, while helpful, was not as critical as the temporal link.

Conclusions: Topographic accuracy might be of higher importance during human missions than during robotic surface missions where additional factors such as ISRU or communications needs are considered. However, geospatial integration of data sets and development of data products related to human missions likely involves requirements that differ from prior surface missions. Analog field tests such as Desert RATS heavily relied upon audio voice notes from the crew, even those inside pressurized rovers or habitats. As seen with the Apollo Lunar Surface Journal, voice descriptions, when converted to text, become the critical "audio" field notebook, forming the first order data set for geologic investigations. It is important that these audio notes are converted to searchable text as quickly as possible, and that this data stream is segmented in a manner in which they can be temporally tracked in relationship to other data streams. A first order data set from any surface exploration will include the voice notes and images, all of which must be spatial and temporally linked to form a permanent, retrievable record of planetary surface exploration.

References: [1] Ross et al. (2013) Acta Astronautica, 90, 182-202. [2] Eppler et al. (2013) Acta Astronautica, 90, 224-241. [3] Feng et al. (2014) LPSC, abstract 1023. [4] Bleacher et al. (2014) LPSC, abstract 2504. [5] Eppler et al. (2014) LPSC, abstract 2078. [6] Mars landing site workshop: http://www.hou.usra.edu/meetings/explorationzone2015/.

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