**SAMPLE SELECTION UNDER A HIGHLY CONSTRAINED TACTICAL TIMELINE: A GHOST TERRESTRIAL ANALOG FIELD STUDY.** R.A. Yingst[1], R.M.E Williams[1], J. Bartley[2], T. Chidsey[3], B.A. Cohen[4], B.M. Hynek[5], L.C. Kah[6], M.E. Minitti[7], M. Vanden Berg[3], M. Adams[2], B. Bartley[2], N. Curran[4], J. Gemperline[5], M. Lotto[5], and T. Pearson[2]; [1]Planetary Science Institute (1700 E. Fort Lowell, Suite 106, Tucson, AZ 85719; yingst@psi.edu); [2]Gustavus Adolphus; [3]Utah Geological Survey; [4]Marshall Space Flight Center; [5]Univ. Colorado-Boulder; [6]Univ. Tennessee-Knoxville; [7]Framework.

**Introduction:** The GeoHeuristic Operational Strategies (GHOST) field tests are designed to isolate and test science-driven lander and rover operations scenarios, to determine best practices in maximizing science return from planetary missions. In May 2019 we conducted a GHOST field test at a Mars 2020 landing site analog, where we tested two science operations methods for data acquisition and decision-making protocols. These methods were: (1) the typical sol planning scenario used on the Mars Science Laboratory (MSL) mission, where the tactical day is pre-planned the day before, but adjustments to the plan of observations (including scrapping the entire plan for another) may still be made prior to plan delivery [1]; and (2) a scenario in which the sol path must largely be planned prior to a given tactical planning day, and very few adjustments to the plan may be made. The goal was to provide field-tested insight into planning for missions such as Mars 2020 (M2020), where science operations must facilitate efficient choice of sampling locations. Our research question was: What is the effect on *science knowledge* and *sample variety* in a science operations tactical scenario in which the number of sols and the sol path are both highly constrained?

**Field Site:** Similar to the M2020 Jezero landing site, the GHOST field site has evidence for once habitable environments including standing bodies of water, as well as promising indicators of high biosignature preservation potential (e.g., spectral detection of clay and carbonate minerals coupled with geologic context). The exercise was conducted in the southern Grassy Mountains overlooking Puddle Valley (40° 51 ' 10" N, 113° 1' 20" W, ~130 km west of Salt Lake City, Utah), on Bureau of Land Management land. The GHOST exercise examined Lower Permian carbonate bedrock and the two highest shoreline terraces from late Pleistocene Lake Bonneville.

Bedrock at the site is Lower Permian limestone, dolomite and sandstone of the Oquirrh Group deposited in inland seas [2]. Subsequent Basin and Range extension resulted in multiple N-to-S trending normal fault zones in the area [3]. Finally, the landscape was modified by the late Pleistocene pluvial Lake Bonneville, which deposited silt, sand and gravels in the lowlands, and created multiple shorelines around the basin. Lake Bonneville developed beginning 30,000 years ago, reached its maximum extent at 18,000 years ago, and regressed to an "overflowing phase" level at 15,000 years ago [4,5] before closed-basin regression. These lake levels are prominent shoreline platforms at the study site, the upper Bonneville (~1551 m) and lower Provo shoreline (~1445 m) [2]. Lake Bonneville covered ~50,000 km$^2$ across one-third of Utah, with maximum depths of ~300 m near the study site [6]. For comparison, the putative lake at Jezero crater is less than half that size with a surface area of 1885 km$^2$, and a comparable water depth of ~270 m constrained by the minimum basin breach level (-2395 m MOLA) [7].

**Approach:** GHOST adopts a "roverless roving" approach that isolates science-driven decision-making from decisions driven by the requirements of the engineering or operations systems [8-10]. We use a suite of commercial, off-the-shelf instruments that provides visual, compositional and geochemical data similar to flight-ready instruments. Humans provide mobility and run the instruments, but do not inject their geologic knowledge into data acquisition. This yields a high-fidelity test because testing science decision-making protocols (which instruments to use, when and how often to use them), and assessing the science results, require as input only data gathered by those instruments, not the hardware or the instruments themselves.

**Fieldwork:** Our science team comprised three field teams (Team MSL, Team M2020, Tiger Team) and a Site Expert (known colloquially by the teams as the Site Goddess). The Site Expert reconnoitered the site prior to fieldwork, to allow the rest of the team to approach the site blind. She then provided the rest of the field team with "orbital" data similar to what might be produced for a rover mission (e.g., analogs for Mars Reconnaissance Orbiter CTX and HiRISE resolution visible-wavelength images, CRISM spectroscopic images). Using these data, the teams each planned a traverse; Team MSL planned based on the tactical cadence used by the MSL team, while Team M2020 created a traverse plan with the expectation that few changes could be made to it tactically (e.g., a type of planning currently being tested for Mars 2020). The Tiger Team also pre-planned field work using the available data, but examined the site using traditional field methods, thus providing a direct comparison between results using rover-driven methods and those achieved by a "standard" terrestrial field exercise. All teams developed hypotheses to be tested during fieldwork. Teams

followed their traverses, but for the MSL-style traverse, data acquired at each stop was used in the decision-making process for making changes to the traverse, while the M2020-style team was limited in the changes they could make based on real-time discoveries and interpretation.

**Methodology:** We used instruments that could produce data generally similar in type and resolution to those produced by current or future Mars missions. These included a digital SLR camera with a macro lens to cover the range of resolutions produced by Mastcam/Mastcam-Z [11,12] and MAHLI/WATSON [13,14]. The SHERLOC/PIXL instruments [14,15] were assumed to be integral to the actual sampling process, rather than the process of choosing samples. A handheld spectrometer (generously furnished by Analytical Spectral Devices) yielded multispectral whole-rock data in the visible-near infrared wavelengths, and a field XRD produced mineral abundances.

To estimate how time in the field translated to time acquiring data on Mars, we calculated the resources employed by the MSL mission (averaged over the last 7 years of operations [1]) to execute common observations and mobility commands, and used this as an approximation. We assumed 1 hour of active remote data acquisition (imaging, whole-rock multispectral data from Mastcam/Mastcam-Z or ChemCam/Supercam) could occur on 1 sol, along with one choice of either a drive (50-100 m per sol) or multiple observations using the instruments mimicking those that come into contact with the surface (e.g, MAHLI/WATSON, APXS).

**Preliminary lessons learned:** (1) For site characterization, all teams noted the crucial need to acquire systematic observations, such as stopping at reconnaissance stations or acquiring 360° panoramic color mosaics. Facies variations in an environment can be subtle, evident only at scales below orbital resolution. Although somewhat large in data volume, color mosaics allow a survey of the terrain and evaluation of the frequency of rock texture changes. An example that highlights the value of systematic surveying is the A3 station, which contained deposits of lacustrine near-shore carbonate precipitates and capping tufa, not recognizable in orbital data (**Figure 1**). Although it was identified in the strategic plan as a station of interest, this location was not well evaluated during the test: the MSL team reviewed the data only after the rover exited the region of interest (ROI) (too late to make changes to the plan) and the M2020 team descoped the site to save time. (2) Caution must be exercised in balancing time spent gathering chemical data at the expense of systematic site characterization. Spectral data provided insight into chemical components as a whole at this site, but did not provide a guide to geologically unique targets. These data provide important insight in the strategic formulation of the geologic hypotheses to be tested *in situ*, but should not be the sole reason for selecting a route. (3) Teams stressed the utility of a walkabout methodology [9,10], specifically in providing geologic context early in the analysis process. We suggest using the walkabout-first approach (reconnoitering portions of the ROI using remote instruments, before choosing areas to use more resource-intensive contact instruments) where possible to provide early context and time for the science team to develop reasonable hypotheses and robust ways to test them.

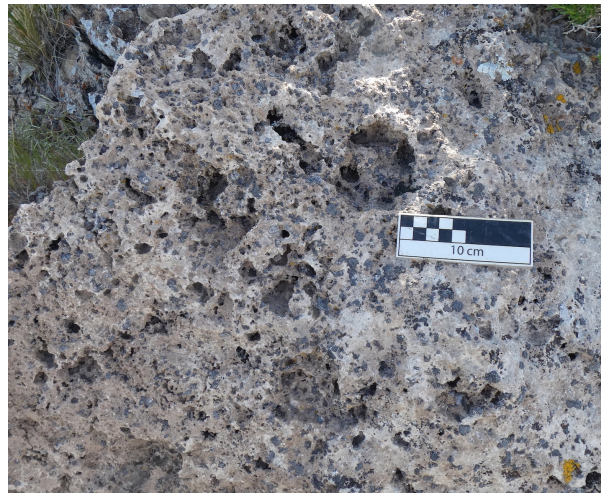


**Figure 1.** Tufa deposit at Station A3.

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