SELECTING SUITABLE TEST SITES AT HOLUHRAUN, ICELAND, FOR MARS MISSION SIMULATIONS USING ROVERS AND UNMANNED AIRCRAFT SYSTEMS (UAS). Udit Basu[1], Jeffrey Moersch[1], Christopher W. Hamilton[3], Stephen Scheidt[2], Joana R. C. Voigt[3], Kathryn M. Stack[4], Raymond Francis[4], Fred Calef[4], Matthew Golombek[4], Nathan Hadland[3]. [1]Dept of Earth and Planetary Sciences, Univ. of Tennessee, Knoxville, TN. [2]Howard University, Washington, DC. [3]Lunar and Planetary Laboratory, Univ. of Arizona, Tucson, AZ. [4]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA.

Introduction: *Ingenuity*, the small robotic helicopter component of the *Mars 2020* mission, has demonstrated that Unmanned Aircraft Systems (UAS) can fly on Mars [1]. *Ingenuity* has also provided useful scientific data from on-board cameras. In the future, a more scientifically capable UAS mission has the potential to provide increased exploration capability through observations of terrain that is not directly accessible by a rover and/or not resolvable from satellite images.

Rover–Aerial Vehicle Exploration Networks (RAVENs) provide a new paradigm for Mars exploration, and, in a new project funded by NASA's Planetary Science and Technology through Analog Research (PSTAR) program, we are evaluating Mars-relevant mission architectures to assess trafficability and science return provided by: 1) a rover-only mission, 2) a UAS-only mission, and 3) a rover/UAS combined mission (i.e., a RAVEN). Notably, in addition to visible wavelength cameras, the UAS mission component of this project includes both a sampler (including both "claw" and drill-designs) that will be able to retrieve material from the surface for analysis, and a high-resolution, visible/near-infrared hyperspectral imaging capability. The project will evaluate the three mission architectures in three different mission simulations directed by a science operations team that has no prior knowledge of the sites other than from simulated orbital reconnaissance data. Results from the three simulations will be compared to evaluate the strengths and weaknesses of the three architectures in the context of the science understanding they provide in four key science theme areas: volcanology, hydrology, aeolian geomorphology, and astrobiology.

The 2014–2015 Holuhraun lava flow-field in Iceland was the largest effusive eruption in Iceland since 1783–1784 [2]. Holuhraun makes for an excellent Mars analog because the lava flow-field is large, well-preserved, and emplaced over a sand sheet, similar to what we would expect on Mars where large lava flows have inundated valleys and impact craters with sedimentary substrates (e.g., Athabasca Valles [3]).

Goal: The purpose of this presentation is to describe the process by which the RAVEN test sites are selected, and to simulate how surface conditions (e.g., potential hazards and science targets) affect the formulation of the three simulated missions.

Methods: A 20 cm/pixel aerial image mosaic of the region [4] was used as a "basemap" for a Geographic Information System (GIS)-based evaluation of potential test sites. The viability of test sites must be assessed in terms of distance to the lava flow-field, distance from an access road, rover trafficability, and other potential hazards, which we collectively refer to as "physical criteria."

Physical distances are the first-order filter applied in considering where to begin the simulated missions (Figure 1). The starting points must be in proximity (within ~10 m) to an access road, and close enough to the lava flow-field to be reachable within the simulated mission duration, but not so close as to preclude science exploration on the way to it. When taking into consideration the speed at which the rover can travel, starting the mission simulation between 500 m and 1000 m from the margin of the lava flow-field is desired.

The rover (i.e., the Canadian Space Agency's Mars Exploration Science Rover (MESR)) can easily traverse terrain with ≤15° slope. Slopes between 15° and 25° are considered potentially untraversable (though slopes <5° are preferred). Slopes above 25° are considered untraversable. Scattered throughout the area are various fluvial channels, piles of large rocks, and other geological features that would also be hazardous for the rover to traverse over and must be avoided.

After assessing the region in terms of these relatively objective physical criteria, the resulting viable sites are evaluated in the context of their scientific suitability for the three simulated mission architectures. To this end, it is necessary to construct three different science traceability matrices (STMs), one for each simulated mission architecture, that link high-level science priorities in each of the four scientific themes to specific measurements that are needed. By creating these STMs, we can determine which locations have the greatest potential to answer the project's science objectives.

Analysis and Results: Application of the physical constraints resulted in the identification of three potential test sites, labeled Sites A, B, and C in Figure 1. Some of these locations are better-suited than others for each of the three mission architectures that will be simulated. We note that Site A is interesting as a potential testing location near several different facies, but this area includes an "exclusion zone" where part of the terrain has the potential to be flooded and so cannot be entered by the rover. Site B has two clear paths to the lava flow-field; however, the location includes locally steep slopes (>15°). Site C is relatively flat (slopes <15°) and includes a range of volcanic and aeolian deposits but also includes gullies that complicate rover trafficability.

Site A would be suitable for an UAS-only mission because targets of interest can be accessed by air, but would be difficult to access directly via rover due to local hazards that would require circumvention of the exclusion zone. Site B would be suitable for a rover-only mission as this is the only location where all target sites can be reached via safe routes on the ground. Site C would be suitable for our rover/UAS combined mission as the lava flow-field is accessible by UAS, and there are locations with evidence of hydrothermal and volcanic vent activity that would be safely reachable by rover. Furthermore, the wide variety of facies [4] at the boundary of the lava flow-field would facilitate acquisition of different lava samples by the UAS. Future work will include developing specific traverse plans for each site based on local terrain constraints and objective defined in the STM.

References: [1] Balaram, J., et al. (2021). *Space Sci Rev* 217, 56. [2] Voigt, J. R. C., et al. (2021) *Geology* v. 50 no. 1 71–75. [3] Jaeger, W. L., et al. (2007) *Science*, *317* no. 5845, 1709–1711. [4] Voigt, J. R. C., et al. (2021b) *J. Volcanol. Geotherm. Res.* [5] Ilyinskaya, E., et al. (2017). *Earth Planet. Sci. Let.*, *472*, 309–322.

Acknowledgements: Funding was provided by NASA's PSTAR program (Grant # 80NSSC21K0011). We also thank Honeybee Robotics (Kris Zacny and Ameila Grossman) and MacDonald Dettwiler and Associates (MDA) Corporation (Chris Langley and Joseph Bakambu) for their engineering support.

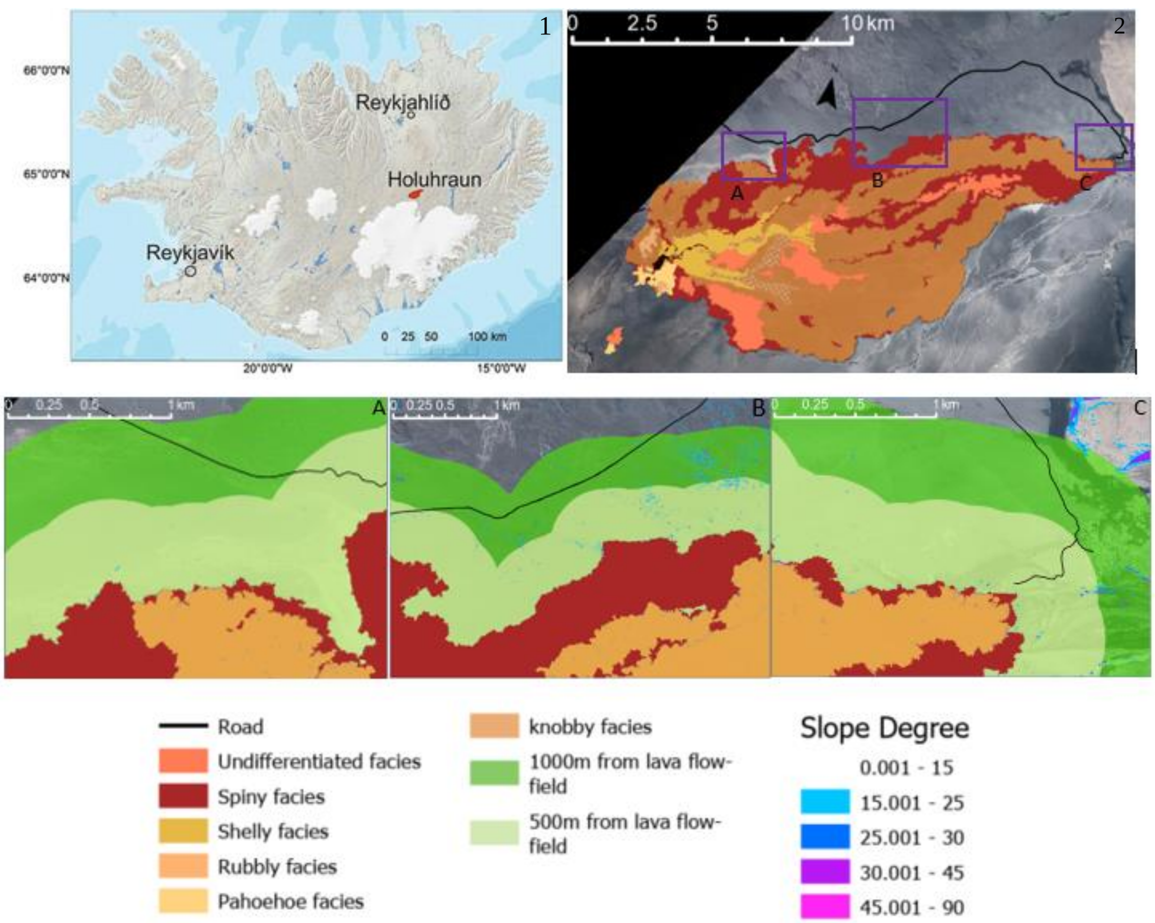

Figure 1: Panel 1 shows the location of the 2014–2015 Holuhraun eruption site in the greater context of Iceland [5]. Panel 2 shows the UltraCam-XP basemap with a pixel scale of 20 m/pixel, showing the 2014–2015 Holuhraun lava flow-field in Iceland [4]. Panels A–C show the three potential test sites (namely Sites A, B, and C) that fit the physical criteria described in the text. The light-green region indicates an area that is less than 500 m from the lava flow-field margin, and the dark green area indicates a region that is between 500 m and 1000 m from the lava flow-field margin.