OVERVIEW AND INITIAL RESULTS OF SAND-E: SEMI-AUTONOMOUS NAVIGATION FOR DETRITAL ENVIRONMENTS. R. C. Ewing[1] , E. B. Rampe[2], B. Horgan[4], M. G. A. Lapotre[5] , M. Nachon[1] , M. T. Thorpe[1], C. C. Bedford[3], P. Sinha[4], , K. Mason[1], E. Champion[1], P. Gray[6], A. Soto[7], Michele Faragalli[8] and E. Reid[8], [1]NASA Johnson Space Center, Houston, TX (email: rce@tamu.edu), [2]Texas A&M Univ., [3]LPI/USRA/JSC, [4]Purdue Univ., [5]Stanford Univ., [6]Duke Univ., [7]Southwest Research Institute, [8]Mission Control Space Services.

Introduction: Unmanned aerial systems (UAS) and automated terrain analysis for science and navigation are new technologies for planetary exploration. The Mars Helicopter will fly with the Mars2020 rover, the Dragonfly quadcopter will explore Titan, and Soil Properties and Object Classification (SPOC) software will be used for path planning and navigation on the Mars2020 rover. Using an Argo J5 rover instrumented with stereo cameras and Autonomous Soil Assessment System (ASAS) software, and an off the shelf quadcopter, SAND-E tested the use of automated terrain analysis and UAS data for science operations in a Mars-analog environment in Iceland during July of 2019. Scientifically, we sought to determine changes in the physical and chemical properties of sediments along a glacial-fluvial-aeolian transport pathway. Operationally, we tested rover mission-like scenarios that included UAS images and classified terrain images. Here, we present the initial results for both the operations and science elements of the study.

Site Selection: A goal of SAND-E is examine sorting and alteration of sediments in fluvial and aeolian environments in both mineral-dominated and glass-dominated basaltic settings. During the first year of the project we focused on a mineral-dominated environment. Selection of the location was based on prior publications that indicated our selected region had a greater abundance of crystalline sediments than other areas fluvial-aeolian settings in Iceland [1,2]. Other criteria included the presence of both fluvial and aeolian landforms along a transport pathway such that the sediments in transport could be linked to their source rocks. We chose the Skjaldbreidauhraun glacial outwash plain, which sits at the base of Thórisjökull glacier. The site is 30 km north of Thingvellir National Park and ~2 hours from Reykjavik. The outwash plain is fed by two small catchments that drain from the base of the glacier and cut through hyaloclastite and shield volcano bedrock. The drainage progresses from steep alluvial fans near the glacier into a low-sloping fluvial braidplain that becomes confined by the Skjaldbreidur shield volcano and creates a shallow canyon cut into lava bedrock. The fluvial system was a typical braided alluvial environment composed pebble- and cobble-bedded longitudinal bars and sandy channel beds. The river remained active and fluctuated in response to diurnal runoff cycles near the glacier before disappearing into the sandy substrate downstream. The high concentration of suspended sediment in the river was evident by the cloudy water and the silt and clay-sized sediments that draped the channel beds after abandonment and created playas in the lowest sloping areas of the catchment. The entire fluvial system was affected by the winds generated by frontal systems and katabatic flows descending the glacier. This resulted in the formation of aeolian lag deposits and a wind-deflation plain where the fluvial system was not active. Wind ripples and drifts formed in abandoned fluvial channels from aeolian reworking of the sand-sized fluvial sediments. The silt- and clay-sized sediments found in fluvial channels, bar tops, and playas generated dust plumes during high wind events. Our operation sought to capture the variability in this system by sampling from the range of fluvial and aeolian features 6.3 km (proximal), 11.3 km (medial), and 14.4 km (distal) along the river from its origin at the base of glacier.

Operations Concept: We tested six operational scenarios at each proximal, medial, and distal location. We aimed to identify the capabilities and efficiencies of using optical images from UAS and terrain-classified optical images from the rover for science decision making and path planning. At each site, the team planned a notional strategic path using 25 cm/pixel UAS images of the field site. Our first tactical rover scenario consisted of *state-of-the-art* Mars Science Laboratory *Curiosity*-like operations in which scientists, who were isolated from the field site, used rover navigation and science cameras to plan the rover path and identify targets. Each scenario included a traverse that consisted of 5 drives and 5 science stops. Other scenarios iterated from this baseline scenario to include navigation camera images that were segmented by ASAS into hazard maps and terrain classes (Scenarios 2 and 5) following [3] and UAS images that covered an area 40 x 60 m (Scenario 4) around the rover or the entire ~250 m x 250 m field area (Scenario 5). We tested a walk-about scenario in which the strategic path was driven and ASAS data was provided to the scientists from that drive to identify 5 stops along the path (Scenario 3). Scenario 6 was a human field geologists, who approximately walked the notional path and similarly made 5 stops.

At each stop, scientists used rover images to specify 2 targets for handheld XRF, VNIR, and microimaging, and an unlimited number of additional targets for handheld VNIR spectroscopy (typically 3-6). Samples were collected where the XRF data were taken. Samples consisted of unconsolidated silts and sands, individual pebbles and cobbles, and bedrock. Laboratory methods following the operation included grain size and shape analysis [4,7,9], XRD [5], XRF [6], µXRF [7], TEM [8], ICP-MS [9], and image processing and analysis [10].

Science Results: The fluvial and aeolian sediments carry the mineralogical and elemental fingerprint of source rocks, which derive from plagioclase-phyric and olivine-phyric basaltic source rocks from hyaloclastite and shield volcano lava flows [5,6]. XRF data reveals that over the 8 km of river transport sand-sized sediments tend toward the olivine-phyric source material indicating enrichment that could be linked to transport processes selecting for olivine or abrasion of weakly lithified hyaloclastite cobbles, or to adding new source material [6]. Pebble-to-cobble-sized clasts tend toward the plagioclase-phyric source material, which is likely derived from shield volcano lava flow source. XRD analyses shows a similar fractionation between mafic and plagioclase minerals [5]. The most distal fluvial sands have a lower plagioclase/pyroxene and plagioclase/mafic ratio compared to the proximal or medial sites. Fluvial silts are generally more enriched in plagioclase than mafic minerals compared with the fluvial sands. Aeolian sands have similar compositions to the fluvial sands, but show less variability. No evidence exists for phyllosilicates in the bulk powder analyzed with the XRD, which is consistent with other analyses of the $<2\mu m$ size fraction [8]. The lack of phyllosilicates and, and generally, the little mineralogical and geochemical variability in the system may arise due to short transport distances and proximity to source compared to other systems in Iceland [8].

Grainsize and shape showed a similar lack of strong variability across the proximal-to-distal transect. Cobbles and pebbles measured in situ show a small decrease in the size of their intermediate axis and a small increase in their aspect ratios over the 8 km of river transport, which likely reflects sorting and abrasion in the system [4]. Sand-sized sediments derived from the channel bed and aeolian ripples are similar in their median size distributions [4], but the aeolian sands are better sorted [4, 7]. Dust collected in traps during wind transport events show that a majority of the suspended sediment fraction is composed of medium silt-sized sediment and smaller [9] and particles in saltation were uniformly distributed from very fine sand to greater than medium sand.

Two field and laboratory imaging techniques highlight methods to discriminate among different types of grains [7,9]. Decorrelation stretch (DCS) performed on optical images at the catchment, field site, and grain scales show a correlation of color to VNIR spectra such that it would be feasible to use the DCS reliably to target and analyze sediments over a wide range of spatial scales [9]. µXRF analysis of different grainsize fractions shows sub-grainscale variations is elemental distribution that could relate to different mineral phases and surface alteration products [7].

Operations Results: Metrics collected for each scenario at each location include time of science decision making, drive time, total length of drive path, path segment length and time, and average speed. Overall science decision making time decreased during the course of the project and the overall distance driven during each scenario increased. This likely signals the teams increased familiarity with both the operation and the geology of the field areas. Future analyses will incorporate spatial data such as slope, curvature, aspect for the drive paths and all metrics will be correlated to the science outcomes associated with each scenario.

SAND-E 2020: The second year operation will occur during June-July of 2020 in Vatnajokull National Park at three sites along the Jökulsá á Fjöllum River. This region is recognized to have a greater abundance of glassy sediments compared to the mineral-dominated sediments form our initial field site [1,2]. We plan to perform the same operational scenarios and collect similar type and amount of data.

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