LASSIE: Legged Autonomous Surface Science In Analogue Environments. K. R. Fisher[1], F. Qian[2], D. Jerolmack[3], F. Rivera-Hernandez[4], C. Wilson[5], R.C. Ewing[6], M. Nachon[6], T. Shipley[7], and D. Koditschek[3]. [1]NASA Johnson Space Center (Kenton.r.fisher@nasa.gov), [2]University of Southern California (feifeiqi@usc.edu), [3]University of Pennsylvania, [4]Georgia Institute of Technology, [5]Oregon State University, [6]Texas A&M University, and [7]Temple University.

Introduction: Roving planetary surface exploration missions operate using a pre-programmed plan that can limit the capability to effectively detect unexpected changes in terrain properties, adjust locomotion or sampling strategies, and autonomously identify scientifically valuable observations and adjust exploration strategies. In particular, the inability to measure and react to unexpected changes in regolith properties can negatively impact mission operations. The Mars Exploration Rover Spirit and InSight lander both experienced challenges related to understanding the geotechnical properties of regolith [1,2]. The advancements in legged robotic platforms hold potential to address these challenges through greater sensitivity to changing surface properties. The Legged Autonomous Surface Science In Analogue Environments (LASSIE) project explores how legged roving platforms can use the leg motors to measure geotechnical properties of crusted and icy surface regolith and utilize those measurements to autonomously update the science operations plans. These tests will be performed in martian and lunar analog environments and also within lab settings.

Analog Field Site Selection: Field sites with spatially varying surface sediment properties were selected to evaluate how a legged platform could detect these changes and how the science and engineering could adapt to the detected changes. White Sands Dune Field, New Mexico, and Mt. Hood, Oregon, were chosen as field analogs while laboratory experiments will provide additional opportunities to evaluate crusted and icy regolith scenarios.

White Sands Dune Field. White Sands is an active gypsum dune field in a playa-lake setting that features varied sedimentary textures including loose sand and crusts (biotic and abiotic) made of salt, calcium carbonate, and microbes [3]. Surface crusts have been observed on Mars [4] and inferred on other planetary bodies [5]. These crusts can alter erosion and sediment transport, contribute to lithification, and impact mobility and sample excavation including during activities by the Curiosity and Perseverance rovers [5,6]. Crusts display markedly different mechanical responses to stress than unconsolidated grains and the mix of crusts and loose sand at White Sands makes it an ideal aeolian Martian analog location to test the LASSIE platform.

Mt. Hood. Mt. Hood is a stratovolcano located along the Cascade Mountain Range. The Mt. Hood field site provides access to an icy volcanic setting consisting of debris covered glaciers, glacial till, andesite and dacite lava flows, and pyroclastic and debris flows [8]. Although Mt. Hood is composed of more evolved silica-rich volcanic rocks than are expected for martian and lunar environments, the juxtaposition of ice and steep terrain comprised of immature volcanic unconsolidated sediments provides a robust analog to lunar cratered icy landscapes and to martian icy areas at mid- and high-latitudes. The presence of ice can also have a strong effect on the geotechnical properties of regolith [9]. Ice has been identified on many planetary bodies including the polar regions of the Moon [10, 11]. These surfaces are high priorities for future exploration missions, yet we have a relatively poor understanding of how varying ice content affects trafficability on other planetary surfaces. Additionally, the field area is ideal to test how ice content alters soil strength in a range of different ice-regolith admixtures.

Field and Lab Methods: The primary testing campaigns are designed to measure variations in soil strength across various environmental gradients using the built-in motors in the legs of the robotic platform (Ghost Robotics Spirit robot). Compression and shearing tests can be performed with one leg to measure the mechanical response of the upper few centimeters of regolith. The proprioceptive capabilities of the direct drive and quasi-direct-drive actuators used within the LASSIE platform enable highly sensitive measurements of these sediment properties [3,12], please see the accompanying abstract by Qian et al for more detail on the regolith strength tests. The environmental gradients tested will primarily focus on transitions in sediment cohesion from loose sand to fully cohesive crusts at White Sands and the transition from pure regolith to pure ice (with various ice-regolith admixtures in between) at Mt. Hood. Accompanying instrumentation including a laser-induced breakdown spectrometer (LIBS), an x-ray fluorescence spectrometer (XRF), a microscopic imaging system, and soil moisture resistivity probe will provide additional physical and compositional information about the surface regolith during tests. Field tests will be supplemented with lab studies to refine the testing process and provide additional data on the mechanical responses of various crust and ice-regolith admixtures measured in a controlled lab setting. The lab tests will also allow for the collection of measurements that are not possible in the field, such as within thermal vacuum conditions similar to those at the lunar poles for the ice-regolith tests.

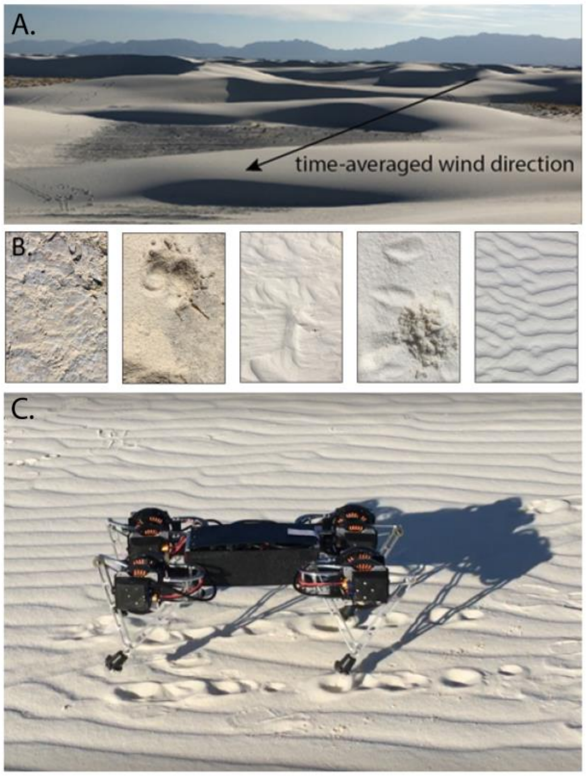

Figure 1: Field deployment of the direct drive (legged) robot in White Sands National Park. A) Image showing dunes at White Sands with resultant wind direction. B) Various types of surface features to be tested including different crusts and loose sand C) Robot traversing ripples.

Operational Workflow for Robot-assisted Interpretation of Surface Properties: The lab and first year field data collected will provide multiple different data sets on shear response, grain size, composition, and other variables which will be used to create terradynamic terrain models for crusty and icy regolith. These models will then be used to create a sensing interpretation that connects multi-leg measurements to crust and ice gradients in simulated environments. The sensing interpretation model will be integrated with a multi-objective based reactive planning tool which will allow the robot to generate suggestions on combinations of sampling protocols. These workflows will be evaluated during subsequent field tests based on expert field decision data. Cognitive ethnographic tracking work will be performed to observe how the science team incorporates the robotic planning aids into the operations workflow. These tests will allow a better understanding of how robotic decision making can influence science operations and traverse planning in planetary exploration missions.

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