SIMULATING MARS SCIENCE LABORATORY CURiosity ROVER TRAVERSES USING ARTEMIS

F. Zhou, R. E. Arvidson, A. M. Zastrow, Earth and Planetary Sciences, Washington University in Saint Louis, Saint Louis, MO, 63130 (chow@wunder.wustl.edu)

Introduction: Curiosity has been traversing across the northern plains of Gale Crater since August 2012 and on 1/6/17 (Sol 1571) has traveled over ~15 km (based on wheel odometry). The rover is approaching a prominent hematite-bearing ridge, which it will ascend to make measurements, thereafter continuing south up the slopes of Mount Sharp. Curiosity has already encountered multiple mobility issues, including generation of punctures and cracks in the thin aluminum wheel skins when crossing sharp sandstone outcrops [1] and high wheel sinkage and slip when crossing megaripple deposits [2]. To better understand these conditions and to support future path planning, a software package called Artemis (Adams-based Rover Terramechanics and Mobility Interaction Simulator) has been used to simulate Curiosity’s existing or potential drives [1, 2]. This abstract summarizes simulations of Curiosity’s expected performance while crossing the hematite ridge and also megaripples found within a canyon cut into Mount Sharp strata.

Background: Artemis is a software tool used to simulate the motion of rovers over realistic terrains [3]. Artemis contains multiple components: a mechanical model of the rover, a wheel-terrain module that models wheel-terrain interactions on deformable and non-deformable surfaces, and terrain topographic models. The mechanical model includes a 6-wheel drive, 4-wheel steered vehicle model, with a rocker-bogie suspension system, as well as rover motion controls to simulate actual drive commands. Artemis employs a classical Coulomb friction contact model for wheel-bedrock interactions and a classic terramechanics-based model for wheel-soil interactions. Soil and rock properties are based on the best estimate from in-situ observations as well as relevant laboratory tests. Terrain surfaces are modeled using digital elevation models derived from orbital and rover-based images. Surface roughness can be modeled as a fractal surface using Perlin noise to approximate natural terrains. Artemis has been validated using single-wheel laboratory-based, JPL Mars yard tests, and field tests on bedrock and dunes in the Mojave Desert. More details about Artemis and validation approaches can be found in [2, 3].

Hematite-Bearing Ridge: The ridge is about 200 meters wide and extends about 6.5 kilometers from northeast to southwest, approximately parallel with Mount Sharp [4]. The potential path to reach the hematite exposures on the ridge top will necessarily include traversing up steep slopes with bedrock partially covered by rubble and soil. Driving uphill will be problematic because the trailing wheels (the downhill wheels) will bear more weight and the other wheels might not provide sufficient traction to keep from reaching high rover-based slip values.

Fig. 1 – Curiosity’s nominal path for ascending the ridge and for nominal extended mission to access the canyon. The white box shows the nominal traverse plan for crossing the ridge and the orange box shows the location of a megaripple field with an overall tilt of 15°.

Ascending the Hematite-Bearing Ridge: To simulate the expected performance of Curiosity while ascending the ridge an elevation model for the nominal path was retrieved from HiRISE-based data and the wheel-rock contact model was utilized because of the expected rocky nature of the slopes. The Coulomb friction parameters were based on [3]. One of these simulations is presented in this abstract.

Fig. 2 – Perspective view of the simulation model ascending the ridge with no vertical exaggeration of the terrain tilt.

The rover pitch angle along the drive is shown in Fig. 3 and Fig. 4 shows the rover 3D slip. The results, matching Scarecrow Tecopa bedrock tests [5], indicate that Curiosity is able to ascend even the steepest slopes with modest slip values. As the rover nears the ridge additional simulations of actual drives will be done to update the terramechanical nature of the terrain and thus to improve the predicted performance while ascending the ridge.
Traversing Canyon Megaripples: The nominal extended mission traverse includes crossing a megaripple field in a canyon, where HiRISE-based elevation data suggest that the ripple field has an overall 15° tilt. (Fig. 1). To evaluate likely mobility issues Artemis simulations were conducted for the ripple fields using 0, 5, 10, and 15° tilts. Both single and multiple ripple crossings were simulated. Three sets of soil properties were used for each case based on data in [2]. Fig. 6 plots the rover 3D slips of a single ripple on 5° slope with varying soil properties. The tilts could present mobility difficulties for crossing even one ripple and multiple ripple crossings would be even more problematic. Results will continue to be refined but already point to updates needed to the strategic path to avoid ripples on highly tilted terrains.

Corridor Traverse Planning: Based on mobility issues such as those discussed in this abstract, together with science interests to go to specific targets, the Strategic Route Planning Group is developing a suite of possible traverses, thereby defining a corridor of approaches to continue to ascend Mount Sharp. Continued analysis of mobility performance and Artemis modeling to understand the terramechanics will be included in the corridor deliberations.