A COMPARISON BETWEEN THE NORCAT ROVER TEST RESULTS AND THE ISRU EXCAVATION SYSTEM MODEL PREDICTIONS. Christopher A. Gallo, NASA Glenn Research Center, 21000 Brookpark Road, Cleveland, Ohio 44135 Christopher A Gallo@nasa.gov

A lunar outpost has been proposed for the low gravity environment on the moon. This outpost will be used as a research facility and also as a staging area to launch spacecraft to further destinations. Since breathing oxygen and fuel are required, which will be too costly to transport from earth, a process to extract oxygen from the lunar soil has been developed.

The In-Situ Resource Utilization (ISRU) program involves the excavation, transportation and processing of regolith on the moon to extract oxygen. The ISRU activity at the Glenn Research Center (GRC) involves the continuing development of a code to simulate the excavation and transportation of this regolith. The results from the code require verification against data from actual testing so there is confidence that the predictions are an accurate representation of the activities on the lunar surface.

The ISRU Excavation System Model developed at GRC is used to predict the forces that vehicles and their attached implements encounter during excavation. The rover geometry along with the tire characteristics and plow or bucket dimensions are input to the code as well as the soil characteristics as measured before a test. The Excavation Module includes the Balovnev theoretical equations to estimate forces on both a plow and a bucket. The Bekker traction equations are included in the code to estimate rover drawbar pull.

The Northern Centre for Advanced Technology Inc. (NORCAT) sent two rovers to the NASA Glenn Research Center in Cleveland, Ohio in December of 2010 for a week of testing in the Simulated Lunar Operations (SLOPE) Facility. This testing, performed by both NORCAT and NASA GRC, was in support of the ISRU program Innovative Partnership Program (IPP) that has been established between GRC and NORCAT.

The first test performed in SLOPE was a drawbar pull test. A cable was connected to the rear of the rover while it was being driven with the plow above the soil. An increasing tensile load was applied to the cable until the wheels started slipping. The load at this point is the drawbar pull which is the maximum force the vehicle exerts on the soil while excavating.

One rover tested for excavation included a 1.7 meter wide plow mounted to the front and the other rover included a 0.5 meter wide by 0.5 meter deep bucket. The rovers were driven in the SLOPE facility and load cells mounted between the rover and the implement recorded the horizontal and vertical forces resulting from the plow pushing or the bucket collecting soil.

Additional testing was performed with the bucket detached from the rover. The bucket was tested separately in a small industrial bin referred to as the White Bin. The White Bin was filled with soil designated as GRC-3 whereas the soil in the SLOPE facility was GRC-1. The GRC-1 and GRC-3 soils are a special blend of sands developed at GRC to mimic the lunar regolith particle size distribution. One additional test was performed in JSC-1A soil in a bin adjacent to the White Bin. The bucket tested in the White Bin was mounted to a mechanism that is capable of translating horizontally to simulate the movement of the bucket on the rover and vertically to adjust the bucket cut depth into the soil. A load cell was mounted to this mechanism to record the forces on the plow while translating.

Four different test groups were performed and the experimental data was summarized and compared to the predicted theoretical data. The experimental force results from the bucket tests performed in the White Bin under controlled conditions matched reasonably to the predicted results from the code. In the SLOPE facility, the forces from the drawbar pull test followed similar trends to those predicted by the code. For the excavation testing in SLOPE, the results with the plow mounted to the rover, in general, were near the predicted forces. However, the forces from the rover testing with the bucket mounted to the front were lower than the predicted forces for all tests.

The testing performed by the NORCAT rovers in the SLOPE facility and in the White Bin with the NORCAT bucket was successful. Overall, the experimental results compared reasonably to the predicted results from the code except for the rover bucket results which may be inaccurate. The Excavation System Module coding includes theoretical equations to predict excavation and traction forces which are the basis for the forces presented here. Based on this testing, it can be concluded that the methodology in the code reasonably predicts excavation forces obtained from experimental methods.