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Development of the FASTER Wheeled Bevameter

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This paper describes the development of a Wheeled Bevameter (WB) within the FASTER project (Forward Acquisition of Soil and Terrain Data for Exploration Rovers), funded by the European Union's FP7 programme. In FASTER, novel and innovative concepts for in situ forward sensing of soil properties and terrain conditions in the planned path of a planetary rover are developed. Terrain strength measurements for assessment of the mobility of cross-country vehicles have decades of heritage on Earth, but typically trafficability of terrains is only gauged by human operators ahead of vehicle operations rather than in-line by probes deployed from the vehicle itself, as is intended for FASTER. For FASTER, a Wheeled Bevameter (WB) has been selected as the terrain sensing instrument for the vehicle. Wheeled Bevameters are suitable for terrain measurements while driving but traditionally have mostly been employed on terrestrial vehicles to evaluate particular wheel designs. The WB as conceived in FASTER uses a dedicated, passive-rolling test wheel (‚test wheel') placed on the terrain as the loading device to enable to determine bearing strength, compressive strength and shear strength of the terrain immediately ahead of the vehicle, as well as rover-terrain interaction parameters used in semi-empirical vehicle-terrain traction models. The WB includes a placement mechanism for the test wheel. The test wheel would remain lowered onto the ground during nominal rover motion, including when climbing and descending slopes. During normal operations, the placement mechanism assumes the function of a passive suspension of the wheel, allowing it to follow the terrain contour. Quantities measured with the WB are: test wheel sinkage (through a laser sensor), test wheel vertical load, test wheel horizontal reaction force, and test wheel rotation rate. Measurements are performed while the rover is in motion. Measured test wheel rotation rate (with appropriate corrections for slight skid) can be continually processed with rover wheel rotation rates to obtain real-time estimates of rover slip, which in itself provides for an in-line warning of incipient immobilisation of the vehicle due to high slip and associated large slip-sinkage events. A brake incorporated on the test wheel is applied at regular intervals while the rover continues driving, in order to incur local terrain shearing under the test wheel which leads to the soil shear resistance measured by the horizontal force sensor.

The paper reports on the design of the WB, and on test results of a fully functional demonstrator which has been developed and evaluated on known test soils. Results from stand-alone testing indicate that the system mechanically behaves as expected (including during slope climbing and movement over rocks). In addition, the data acquired are meaningful and indicate clear differences in the measured forces acting on the test wheel among the different soils, both related to soil bearing strength and soil shear strength. Currently, system-level testing is on-going with the WB mounted to a full-scale mock-up of the ESA ExoMars rover. In this context, the WB data reduction and trafficability rating algorithms are presently being refined to account for a scale difference between the diameters of the WB test wheel and the rover wheel which causes the WB system to interpret passes through small-scale soil undulations as false positives for locally weak terrain which in actuality are not affecting rover mobility.