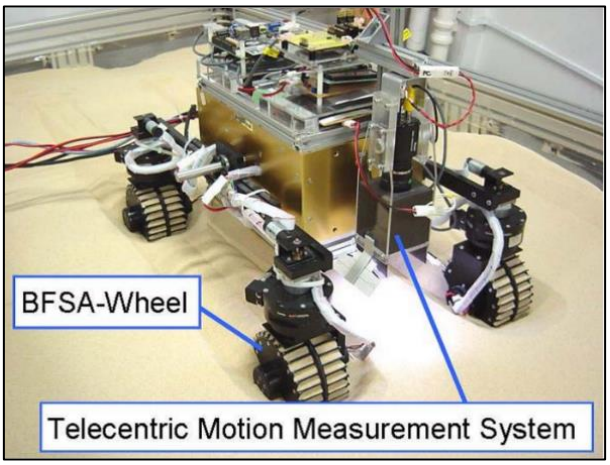
Master Thesis: "Engineering a Two-DOF Single-Wheel Testbed for High-Speed Planetary Robots"



Source: Nagatani et al., Accurate estimation of drawbar pull of wheeled mobile robots traversing sandy terrain using built-in force sensor array wheel

Background and Motivation

Developing high-speed robotic systems capable of traversing extreme terrains remains one of the central challenges in planetary robotics. On extraterrestrial surfaces, regolith with poorly constrained characteristics dominates, and its mechanical behavior critically affects rover mobility.

To ensure reliable operation, rover wheels must be carefully designed and validated, with particular emphasis on enhancing their shear-stress response to enable traversal across unstructured terrains. The Single-Wheel Testbed (SWT) offers a unique platform where wheel–regolith forces and stresses can be systematically measured and analyzed.

Past planetary missions have demonstrated the risks of wheel sinkage and jamming, highlighting the need for dedicated experimental platforms to study wheel–soil interaction under controlled conditions. The SWT will fulfill this role, enabling high-fidelity laboratory experiments that lay the foundation for the next generation of rover wheel and suspension design.

Goal

The primary goal of this thesis is the end-to-end development of a Single-Wheel Testbed (SWT) with two degrees of freedom, covering the complete workflow from conceptual design to final testing and integration.

Objectives

1. Conduct a state-of-the-art review on rover mobility and existing single-wheel testbeds.
2. Design the mechanical structure, sensing elements, and control subsystems of the SWT.
3. Manufacture and assemble the vertical and translational units, including full instrumentation.
4. Perform experimental tests with selected rover wheels using regolith simulants under controlled conditions.
5. Deliver complete documentation and provide guidelines for future extensions and integration into full rover systems.