Phoenix Mars Lander Robotic Arm Mission Operations

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ABSTRACT

The Phoenix Lander safely reached the Martian polar terrain on May 25, 2008. Beneath it was a rolling polygonal plain to the horizon, and above the summer sun was in the sky for the full Martian day, or sol. After five sols in which all spacecraft subsystem were deployed and checked, the Robotic Arm (RA) subsystem was also ready for operation. Thus began another 85 sols of the primary mission with densely packed RA activity, highlighted by excavation and confirmation of water ice under the surface.

During the mission, RA activity was daily and diverse. In addition to its primary function of digging with a scoop, the arm also had tools for scraping icy soil, grinding hard terrain with a rotary rasp, imaging with a forearm mounted robotic arm camera (RAC), and precision placements of a thermal and electrical conductivity probe (TECP). The arm was central to the operation of the RAC and TECP, as well as four other deck mounted instruments which relied on the arm to deliver terrain samples for analysis, thereby completing mission objectives. Additionally, two optical instruments, the panoramic camera and atmospheric lidar, required the arm to be sufficiently away from their optics and fields of view to ensure their viable operation. Satisfying the objectives of these instruments, while not violating their constraints, ensured that robotic arm operation was central to the mission and very laborious.

Given these objectives and constraints, this talk will provide an overview of several facets of arm operations: human factors, mission process flow, operations tools, discovery driven goals, and unexpected problem resolution. Regarding human factors, the main problem was one of team fatigue while working long shifts under Mars time. Mission process flow included daily downlink analysis and uplink sequence construction, as well as strategic science planning support. RA operation was performed using two primary operations tools: a JPL-developed 3D graphical interface for visualization of telemetry and motion commands, complemented by a scripting tool for sequence creation. Other than some engineering analysis, most RA activities were driven by science team requests, which continuously evolved as new qualities of the environment were discovered. This included expected discoveries, such as visually revealing ice under the surface, as well as unexpected problem encounters, such as unforeseen soil qualities that hampered efforts to transfer regolith from the scoop into the science instruments.

Overall, the RA subsystem proved to be robust and reliable, and part of many successes of Phoenix's 152 sols of primary and extended mission. The RA successfully excavated a dozen trench complexes, delivered 31 samples to the science instruments onboard, performed 10 TECP soil insertions, and positioned the RAC for numerous images, including unique under-the-lander views revealing ice exposed by the lander thrusters.