Lunar dust challenges to astronaut landing

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Abstract. Lunar landings require the identification and selection of a suitable landing zone, followed by a controlled descent to the surface. In piloted landings, astronauts are expected to participate in hazard identification, landing zone selection, and vehicle navigation and control in cooperation with automatic landing systems. Accurate perception of vehicle orientation is a necessity. A variety of environmental factors may interfere with perception of vehicle orientation approaching the moon, including deep shadows, non-Lambertian lighting conditions, and first exposure to lunar gravity following three or more days in weightlessness. To further add to the challenge, lunar dust blowback may be expected to degrade visual cues during the final landing stages. The descent engine thruster of the landing vehicle blows lunar dust particles at high velocities, obscuring the astronauts' view out the window. Apollo astronauts all reported lunar dust blowback making it difficult to identify terrain hazards such as rocks and craters. On Apollo 12 the dust began at altitudes as high as 200 ft. Commander Pete Conrad reported, "All I knew was there was ground underneath that dust. I couldn't tell what was underneath me. I knew I was in a generally good area and I was just going to have to bite the bullet and land, because I couldn't tell what was underneath me."

In preparation for future planetary landings, we have studied the effect of lunar dust blowback on astronaut perception of vehicle orientation. A physiologically based mathematical model of human orientation perception was implemented, using lunar landing trajectories with pilot control inputs as recorded from a fixed-based simulator. The model predicts that dust blowback may cause astronauts to rely more heavily on vestibular sensory cues which may result in underestimation of any vehicle tilt. To validate the model predictions, we are performing a human subject experiment in a moving-base helicopter simulator. The simulator visual displays have been modified to include a lunar landing-like dust blowback simulation. Since the intensity of dust blowback appears to depend upon landing site location, a series of dust intensity levels are being tested representative of those seen during the Apollo landings. During simulated landings, subjects indicate subjective perceptions of vehicle orientation and horizontal velocity. Preliminary results support the hypothesis that dust blowback has a substantial impact on astronaut perception of vehicle orientation. In particular, horizontal velocity and any tilt maneuvers experienced are difficult to perceive following the onset of dust blowback. When considered along with our previously reported misperception of lunar terrain distance and slope, these attitude misperceptions may cause incorrect pilot control inputs, which could result in an accident or an abort.

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