SPACE FLIGHT AND MANUAL CONTROL: IMPLICATIONS FOR SENSORIMOTOR FUNCTION ON FUTURE MISSIONS

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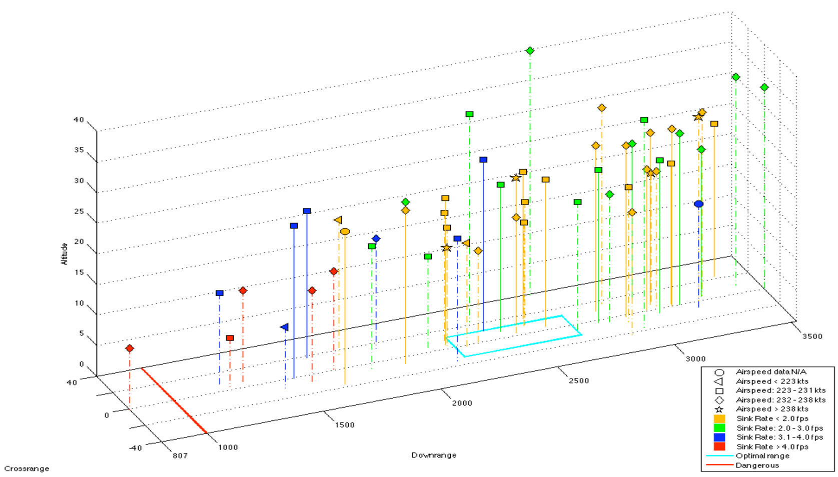
Control of vehicles, and other complex mechanical motion systems, is a high-level integrative function of the central nervous system (CNS) that requires good visual acuity, eye-hand coordination, spatial (and, in some cases, geographic) orientation perception, and cognitive function. Existing evidence from space flight research (Paloski et.al., 2008, Clement and Reschke 2008, Reschke et al., 2007) demonstrates that the function of each of these systems is altered by removing (and subsequently by reintroducing) a gravitational field that can be sensed by vestibular, proprioceptive, and haptic receptors and used by the CNS for spatial orientation, navigation, and coordination of movements. Furthermore, much of the operational performance data collected as a function of space flight has not been available for independent analysis, and those data that have been reviewed are equivocal owing to uncontrolled environmental and/or engineering factors. Thus, our current understanding, when it comes to manual control, is limited primarily to a review of those situations where manual control has been a factor. One of the simplest approaches to the manual control problem is to review shuttle landing data. See the Figure below for those landing for which we have Shuttle velocities over the runway threshold.



This plot shows a runway with the minimum allowable touchdown point noted at 1000 ft, and the optimal range between 2200 and 2700 ft. . Sink rates are indicated by specific colors (yellow = <2 fps, green = 2 to 3 fps, blue = 3.1 – 4 fps and red indicates sink rates greater than 4 fps). Airspeed velocities over the runway threshold are shown as symbols (Circle indicates no data is available, left facing triangle = < 223 kts, square = 223 – 231 kts, diamond = 232–238 kts and the star = velocities > 238 kts. The dashed and solid lines connecting the pinheads to the runway show altitude (solid = optimal height off of the runway surface and dashed = altitudes either higher or lower than optimal). The blue square represents the optimal runway touchdown area, and the red line on the Z-axis shows touchdown clearly short of the optimal downrange distance required for a safe landing.

Fortunately, more than 500 international sensorimotor experiments have been performed during and/or after space flight missions since 1959. While not all of these experiments were directly relevant to the question of manual control, many provide insight into changes in sensorimotor control that might have a bearing on the physiological subsystems underlying the high-level integrated CNS function associated with manual control. It is therefore the intention of this paper to review how sensorimotor impairment, induced as a function of space flight, will affect the ability of crewmembers to perform spacecraft landings, on-orbit control of remote manipulator (robotic) arms, and Lunar or Mars surface activities that require sensorimotor performance (e.g., rover operations, robotics, operation of tools, locomotion).