INTRODUCTION
Orbiter landing data shows decrements in pilot performance following spaceflight compared to pre-flight simulated landings. This study aimed to characterize pilot head-eye coordination during simulated orbiter landings, and relate findings to microgravity-related spatial disorientation.

METHODS
Orbiter landings were simulated in an A340-300 simulator flown by six pilots. Turns about the Heading Alignment Circle (HAC) to align the orbiter with the runway were simulated by 45° banking turns. Final approach was simulated with an 11° glide slope from an altitude of 4,267 m, with preflare at 610 m and touchdown at 200 kts. Orbiter landings were also performed in the Vertical Motion Simulator (VMS) at Ames by a NASA test pilot.

RESULTS
A340: During the HAC the head and eyes rolled towards the visual horizon with a gain of 0.14 of bank angle. Pilots alternated fixation between the instruments and the runway during final approach, almost exclusively focusing on the runway after preflare. Optokinetic nystagmus was observed during rollout. VMS: Head and eye roll tilt when rounding the HAC were of similar magnitude to that observed in the A340. During final approach the Heads-Up Display (HUD) suppressed head and eye movement.

CONCLUSION
Roll tilt of the head and eyes during the HAC tended to align the retina with the visual horizon. The HUD minimized head and eye movement during orbiter landing (and therefore the potential for spatial disorientation), but hyper-gravity experienced during the HAC and preflare remains an intense, potentially disorienting stimulus for pilots with a maladapted vestibular system.

Head-eye coordination during simulated orbiter landing in the VMS. A. From left to right: head tilt (x 10) during the HAC maneuver; image detail from the scene camera showing the Heads-Up-Display (HUD), with the cross indicating fixation and torsional eye position (x 10); corresponding animation of the orbiter generated by the VMS. B. Eye movements were suppressed during final approach and landing with a HUD. C. Eye movements during approach and landing with a simulated HUD failure. The pilot used three gaze strategies to estimate approach; I vertical saccades between the aim point and runway, II vertical saccades between the start and end of the runway, and III horizontal saccades between the centerline and the edge of the runway. The sequence of fixations 200 ms either side of each scene image are represented as dots.