most instrument vertical visual angles of the MQ-9 GCS lay outside the cone of "Easy Eye Movement", though all were within the cone of "Maximum Eye Movement". All the horizontal visual angles for the MQ-9 GCS were within the cone of "Easy Eye Movement". **Discussion:** Most instrument displays in conventional aircraft lay within the cone of "Easy Eye Movement", though mission-critical instruments sometimes displaced less important instruments outside this area. Many of the MQ-9 GCS systems lay outside this area. Specific training for MQ-9 pilots may be needed to avoid increased response time and potential error during flight.

Learning Objectives: 1. Know the three physiologic cones of eye/head movement. 2. Understand how instrument displays comply with these design principles in conventional aircraft and an uninhabited aerial vehicle system.

[507] EFFECT OF DOCKED SPACECRAFT CONFIGURATION ON SPATIAL ORIENTATION

C. M. OMAN, C. CIZAIRE, A. NATAPOFF, H. AOKI, D. A. BUCKLAND and A. M. LIU
Massachusetts Institute of Technology, Cambridge, MA

Introduction: Many Apollo, Mir and ISS astronauts reported difficulty visualizing spatial relationships between adjacent modules with differently aligned interior visual verticals, and that traversing between them was disorienting. Prior research suggests that cognitive maps of each module are remembered in visually upright reference frame, as defined by rack surface orientation and equipment placement and labeling. We hypothesized that when the module visual verticals are incongruent, mental rotations and rules are required to visualize spatial relationships between them, and that some configurations are more difficult to interrelate than others. We used VR techniques to investigate, comparing performance in 6 different geometric module configurations. **Methods:** 20 subjects wearing a color stereo HMD first learned the interior layout of two different modules separately and then learned to visualize spatial relationships between the modules when "docked" in 6 different configurations in a variety of relative body orientations. In each docked configuration, subjects were shown a "cue" wall in the local module, so they could determine their local orientation, and were then asked to visualize, place and orient a "target" wall within a wireframe view of the adjacent module. **Results:** Mixed regression analyses showed significant trends in log(time to respond) and % correct. As hypothesized, the fastest responses were in configurations where visual verticals were aligned - as they normally are in buildings on Earth. Pitching the second module 90 deg was the most difficult configuration tested. Subjects required 3 sec longer do the task. 180 deg pitch produced an intermediate result, perhaps because "walls" remain "walls". When subjects tilted their heads toward the local visual vertical they responded faster. **Conclusions:** A regression model including the number of pitches and yaws interrelating the two modules fits performance data. Supported by NASA Cooperative Agreement NCC9-58 with NSBRI.

Learning Objectives: 1. How the relative orientation of docked spacecraft affects ability to visualize spatial relationships between modules is described.

[508] ASTRONAUT SLOPE AND SURFACE ESTIMATION FOR LUNAR EXPLORATION

C. T. ORAVETZ, K. INGLE, L. YOUNG and A. M. LIU
Massachusetts Institute of Technology, Cambridge, MA

Introduction: Lunar exploration will require astronauts to traverse unfamiliar terrain. Map resources and distance measuring equipment may be available for calculating the metabolic costs and safety risks of sloped surfaces. In addition, the astronaut perception of slope, distance, height, and terrain properties can largely impact the route selection. However, human perception of unfamiliar environments is known to introduce both systematic and random error. Accordingly, there is a need to quantify and understand the nature of these errors to optimize the trajectory planning protocols of future lunar excursions. **Methods:** This purpose of this study is to measure the human perception of simulated lunar terrain. The study is composed of three experiments, including a field study on slope estimation of earth terrain, a Virtual Reality (VR) study of stereo images of the same terrain, and a VR study of images collected from the lunar surface. The field study measures visual and haptic slope estimations using a set of reference slopes, angle magnitude estimation, and a pivoted palm board. The hills measured vary in terrain roughness and reflectivity under different lighting conditions. The VR experiments also measure visual and haptic slope estimations. **Results/Discussion:** Initial results from the field study have confirmed a significant overestimation of slopes in a highly textured Earth environment. Differences between sighting perspectives have also been explored and confirmed greater overestimations from an uphill point of view. As testing continues, further results are expected to reveal the magnitude of estimation error for each of the independent variables, including the actual slope, distance to the hill, terrain roughness, location and brightness of sunlight, and body orientation. The results are likely to be used in future studies to develop a model that astronauts will use during navigation along the lunar surface.

Learning Objectives: 1. The systematic errors of terrain slope estimation of earth and lunar terrain will be discussed. 2. The audience will learn the effects of the variables that influence slope estimation.

[509] NAVAL NUCLEAR SUBMARINES AS A SPACE TRAVEL ANALOG

J. M. RICCITELLO
University of Texas Medical Branch at Galveston, Galveston, TX

Introduction: Mankind has ventured beyond low Earth orbit only nine times. None of those Apollo missions lasted longer than two weeks. Therefore analog environments are used to simulate the extreme isolation that will be encountered during exploration-class operations. Arctic stations, underwater habitats and nuclear submarines can approximate the remoteness of long duration space travel. **Methods:** This study will compare and contrast how well aerospace human factors are simulated in the undersea environment of a naval nuclear submarine. **Results:** Applicable topics include radiation monitoring, decompression illness, life support systems, casualty and medical procedures, psychiatric and behavioral responses to isolation and circadian disturbance. Discussion: Submarines differ from the spacecraft environment in a number of important ways. At sea there is an unlimited supply of water and the nuclear reactor provides vast amounts of electrical power. The pressure gradient across the hull is reversed. Equipment volume and weight limits are much less restrictive. Nevertheless, the effects of isolation on medical contingencies are quite similar, as are the psychiatric and behavioral issues involved. Also analogous to space travel, there is a severe circadian disturbance. This is endured by crewmembers that must maintain a high degree of vigilance under demanding conditions in order to ensure mission success. **Conclusion:** Studies of submarine personnel have high utility for predicting crew response to extended duration space travel.

Learning Objectives: 1. Be able to name the various analogs used for studying aerospace human factors. 2. Understand how the naval nuclear submarine environment can be used as an analog for long duration space missions.

Thursday, May 15 *8:30 AM*

SLIDE: Fluids, Flow, & Fatigue--Aerospace Physiology

[510] INSPIRATORY RESISTANCE INCREASES OSCILLATIONS IN CEREBRAL BLOOD FLOW VELOCITY, REDUCING SYMPTOMS ASSOCIATED WITH ACUTE HYPOTENSION

C. A. RICKARDS[1], K. D. COHEN[2], L. L. BERGERON[3], L. BURTON[3], P. J. KHATRI[3], C. T. LEE[3], K. L. RYAN[1], W. H. COOKE[4], D. F. DOERR[2], K. G. LURIE[5] and V. A. CONVERTINO[1]
[1]U.S. Army Institute of Surgical Research, Fort Sam Houston, TX; [2]NASA, Kennedy Space Center, FL; [3]NASA Spaceflight and Life Sciences Training Program, Kennedy Space Center, FL; [4]University of Texas at San Antonio, San Antonio, TX; [5]Advanced Circulatory Systems, Inc., Minneapolis, MN

Introduction: Symptoms of orthostatic intolerance that may be elicited by prolonged bed-rest and microgravity exposure, are associated with reductions in cerebral blood flow. We tested the hypothesis that spontaneously breathing through an impedance threshold device (ITD) would attenuate the fall in cerebral blood flow velocity (CBFV) during a hypotensive orthostatic challenge and reduce the severity of reported symptoms. **Methods**: Nineteen subjects performed a squat stand test (SST) while breathing through either an active ITD (-7 cmH_2O inspiratory impedance) or a sham ITD (no impedance). Symptoms upon stand were recorded on a 5-point scale (1=normal; 5=faint) of subject perceived rating (SPR). To address our hypothesis, only data from symptomatic subjects (SPR > 1 during the sham trial) were analyzed (n=9). Mean arterial blood pressure (MAP) and mean CBFV were measured continuously throughout