

CORE RESEARCH AREA 1: SENSORY PHYSIOLOGY AND MOTION PERCEPTION

Keywords: Vestibular, visual and proprioceptive systems, motion sickness, thresholds, adaptation, sensory interaction, spatial orientation, sensory conflict, vestibulo-ocular reflex, sensorimotor control,vection, space sickness, artificial gravity, balance, posture, locomotion, spatial disorientation illusions, habituation, simulator sickness

Current Ongoing and Completed Projects:

- 1.1 Adaptation to Coriolis Inducing Head Movements in a Sustained-G Flight Simulator
- 1.2 Human Orientation Perception during Vehicle Roll Tilt in Hyper-Gravity
- 1.3 Predicting Adaptation to Altered Gravity
- 1.4 Transference of Virtual Reality Based Sensorimotor Adaptation to Real World Motion Environments
- 1.5 Perception Modeling for Aircraft Accident Investigation

1.1 ADAPTATION TO CORIOLIS INDUCING HEAD MOVEMENTS IN A SUSTAINED-G FLIGHT SIMULATOR



Summary

Experienced pilots made 14 predetermined head movements in a sustained G flight simulator (at 3 Gz+) on five consecutive days and 17 days after training. Symptoms were measured after each head turn using a subjective 0-10 motion sickness (MS) scale. The Simulator Sickness Questionnaire (SSQ) was also administered before and after each daily training session. RESULTS: After five daily training sessions normalized mean MS scores were 58% lower than on day one. Mean total, nausea, and disorientation SSQ scores were 55%, 52%, and 78% lower, respectively. During retesting 17 days after training, nearly all scores indicated 90-100% retention of training benefits. DISCUSSION: The reduction of unpleasant effects associated with sustained-G flight simulation using an adaptation training protocol may enhance the effectiveness of simulation. Practical use of sustained-G simulators is also likely to be interspersed with other types of ground and in-flight training. Hence, it would be undesirable and unpleasant for trainees to lose adaptation benefits after a short gap in centrifuge use. However, current results suggest that training gaps in excess of two weeks may be permissible with almost no loss of adaptation training benefits.

Objectives

- To determine if adaptation to repeated coriolis-inducing head movements in the sustained-G training environment is possible
- To determine the rate, degree and retention of possible adaptation
- To quantify the intensity of head movements at all angles within the cockpit for future software improvements (i.e. at 3Gz pitching head movements become very benign, therefore making it

beneficial to present enemy targets in this plane of head-neck motion in order to significantly reduce motion artifacts)

Customer/Partner

St. Peter's College partnered with ETC

Status

Complete (February – April 2011). Final manuscript is under peer review.

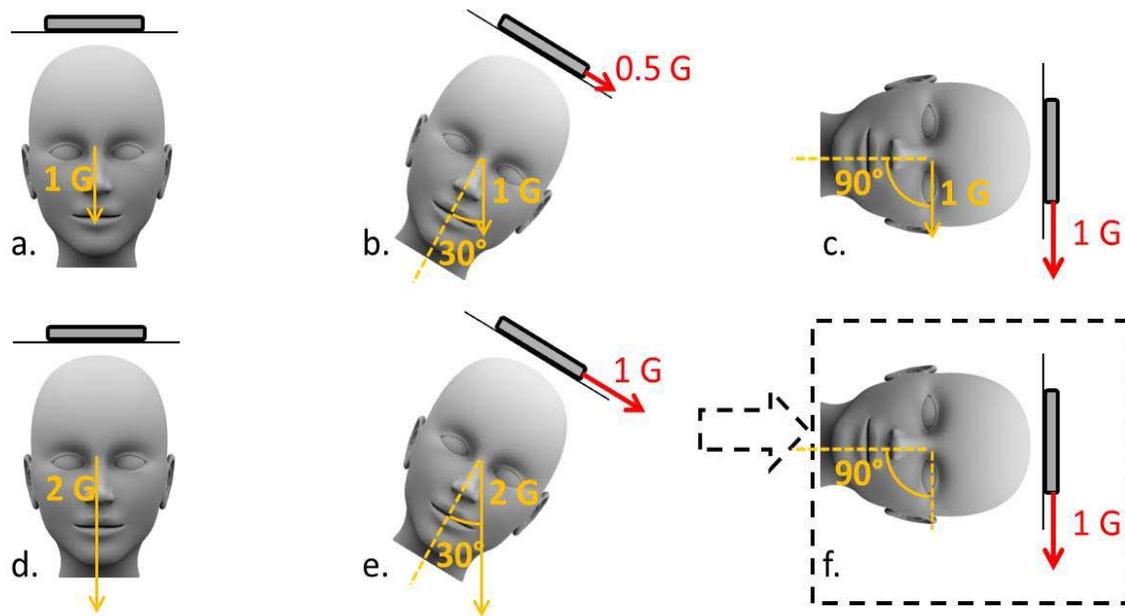
Publications

Aviation Space and Environmental Medicine (*Currently Pending Peer Review*)

Conferences Presented At

American Institute of Aeronautics and Astronautics (AIAA) Guidance Navigation and Control Conference
8th Symposium on the Role of the Vestibular Organs in Space Exploration
59th International Congress of Aviation and Space Medicine
2012 Aerospace Medical Association Annual Meeting – Atlanta, GA

1.2 HUMAN ORIENTATION PERCEPTION DURING VEHICLE ROLL TILT IN HYPER-GRAVITY



Summary

This experiment will study human perception of vehicle roll tilt in different gravitational environments. In the primary experiment, subjects will be placed in the cab of a long-arm centrifuge (AFTS-400), spun up to the desired gravitational level (1, 1.5, or 2 Earth G's aligned with the longitudinal or Z-axis), and then be passively rolled in the dark to a series of angles at different rates. Subjects will continuously report their perception of the roll angle using a somatosensory indicator which they will attempt to keep aligned with the direction of gravity. It is hypothesized that gravitational level, roll angle, and roll rate will effect subjects' perceptions of orientation.

Objectives

- To study the steady-state and transient dynamics of perception of the G-excess illusion during cab rotation in roll
- To improve G-Excess spatial disorientation training at the NASTAR center

Customer/Partner

Massachusetts Institute of Technology partnered with ETC

Status

Under review by the NASTAR Institutional Review Board. Centrifuge runs and subject recruitment will begin in February 2012.

The National AeroSpace Training And Research Center



Future Publications

Journal of Vestibular Research

Aviation Space and Environmental Medicine

Conferences Presented At

NASA NSBRI Investigators Workshop (February 2012).

1.3 PREDICTING ADAPTATION TO ALTERED GRAVITY

Summary

This proposal is in response to a NASA and NSBRI Research Announcement and aims to develop a pre-flight sensorimotor adaptability assessment program that will identify those individuals who are likely to experience difficulty with gravitational transitions and sensorimotor adaptation and validate interventions or countermeasures. ETC will be involved in year 2 of the 3 year effort as a testing facility to support manual control tasking and subjective orientation testing in hyper-G.

Objectives

- To determine if individual differences exist in the ability to adapt to changing environmental parameters, including gravity
- To determine if such adaptability can be estimated quantitatively by measurements of subjective orientation and performance during closed loop manual control tasks
- To determine if the adaptability measured in transitions from 1-G to hyper-gravity (1.5-3-G) will *predict* adaptability in transition form 1-G to hypo-gravity (0-G, 1/6-G, or 3/8-G)

Customer/Partner

The testing of the proposed assessment tool will incorporate a collaborative effort of four different groups, MIT, The Massachusetts Ear and Eye Infirmary's Jenks Vestibular Research Laboratory, the Zero-G Corporation and ETC.

Status

Proposal submitted to National Space Biomedical Research Institute (NSBRI) in December 2011. Results of grant solicitation expected in Spring 2012 for research beginning in Fall 2012.

Future Publications

Annals New York Academy of Sciences
Journal of Vestibular Research
Aviation Space and Environmental Medicine

1.4 TRANSFERENCE OF VIRTUAL REALITY BASED SENSORIMOTOR ADAPTATION TO REAL WORLD MOTION ENVIRONMENTS

Summary

The goal of the project is to develop methods for adapting individuals in one environment (on Earth) that will lead to training benefits that will carry over to other environments (e.g. space). Furthermore, our goal is to develop an adaptation training protocol that is robust in that benefits can be applied to a wide range of conditions, including zero gravity, fractional gravity, and hyper-gravity. To accomplish this we propose to use VR and sustained G centrifuge motion platforms to determine if training in VR can lead to resistance to adverse effects in real motion environments

Objectives

- Investigate adaptation training transference using VR and gravity transitions
- Determine if desensitization training is motion type specific
- Test the hypothesis that multiple degrees-of-freedom training will lead to resistance to adverse sensorimotor effects across a wide range of test conditions

Customer/Partner

St. Peter's College partnered with ETC

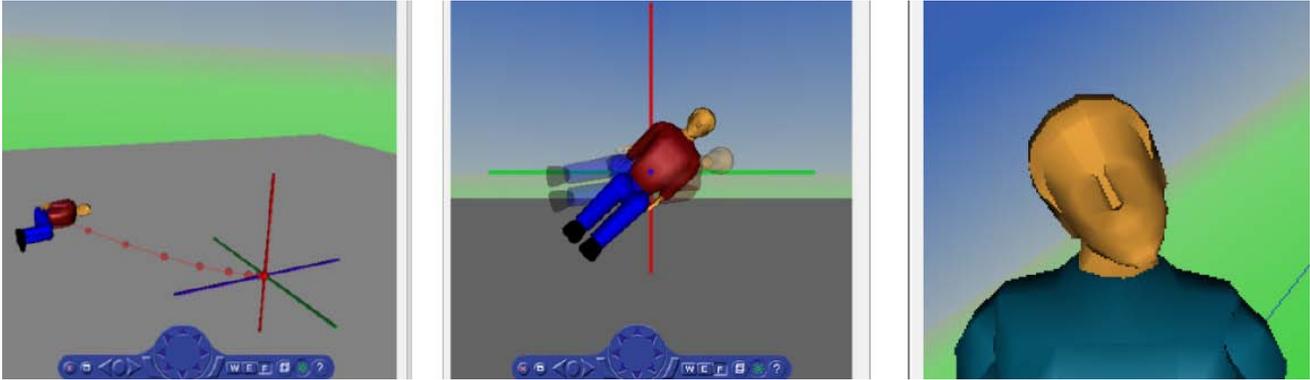
Status

Proposal submitted to National Space Biomedical Research Institute (NSBRI) in December 2011. Results of grant solicitation expected in Spring 2012 for research beginning in Fall 2012.

Future Publications

Aviation Space and Environmental Medicine
American Institute of Aeronautics and Astronautics (AIAA)

1.5 PERCEPTION MODELING FOR AIRCRAFT ACCIDENT INVESTIGATION



Summary

The goal of this effort is to develop a mathematical model of human spatial orientation perception and to determine, based on prior modeling efforts and experimental research, the general utility of the model in predicting spatial disorientation events and analyzing aircraft mishaps and accident scenarios.

Objectives

- Build, program and test past vestibular modeling efforts (i.e. Merfeld 1993, Zupan 2002, Vingerhoets 2007, Haselvanter 2001 etc.)
- Compare and validate each model's response to common experimental vestibular stimuli (i.e. Forward linear acceleration, constant velocity yaw rotation, off vertical axis rotation, post-rotational tilt, fixed and variable radius centrifugation etc.)
- Develop a GUI based analysis tool that unifies the input/output stream of the abovementioned perception models and allows simultaneous simulation and comparison between models

Customer/Partner

USARMY Air force Research Laboratory

Status

Final write up to be completed in the Spring of 2012.

Future Publications

Technical Report to the USARMY Air force Research Laboratory
American Institute of Aeronautics and Astronautics (AIAA)

CORE RESEARCH AREA 2: LEARNING AND TRAINING METHODOLOGIES

Keywords: Upset Prevention and Recovery Training (UPRT), Spatial Disorientation, Situational Awareness, adaptive training, loss of control, sub-orbital space flight training, training course design, transfer of training, training evaluation metrics

Current Ongoing and Completed Projects:

2.1 GL4000 Sustained-G Flight Simulator Pilot Assessment and Motion Fidelity Analysis

2.2 GL4000 Sustained-G Flight Simulator Upset Prevention and Recovery Training Investigation

2.3 Effectiveness of Sustained-G Simulation in Loss of Control and Upset Recovery Training

2.4 An experiment to evaluate transfer of upset recovery training conducted using two different flight simulation devices

2.1 GL 4000 SUSTAINED-G FLIGHT SIMULATOR PILOT ASSESSMENT AND MOTION FIDELITY ANALYSIS



Summary

The goal of this study is to acquire expert opinions on the capabilities of the GYROLAB GL-4000 Continuous G Device (CGD) utilizing the NASA GTM aeromodel for Upset Prevention and Recovery Training (UPRT). Twenty air transport pilots were invited to the NASTAR Center to fly the GL-4000 and were asked to give Cooper Harper ratings for various maneuvers and complete a questionnaire about their experience. The answers to these questionnaires will be used for device improvements and a possible statistical analysis depending on the outcome of the data.

Objectives

- To improve GL-4000 fidelity by assessing device characteristics and automated upset recovery profiles
- To develop a simulator Cooper-Harper type rating system for quantitative simulator fidelity analysis
- To determine physiological and motion sickness symptom development of GL4000 pilots in order to develop appropriate training protocols

Customer/Partner

ETC Internal Research

Status

Complete. Final report will be presented at AIAA Modeling and Simulation Conference Summer 2012.

The National AeroSpace Training And Research Center



Future Publications

Aviation Space and Environmental Medicine

American Institute of Aeronautics and Astronautics (AIAA)

2.2 GL 4000 SUSTAINED-G FLIGHT SIMULATOR UPSET PREVENTION AND RECOVERY TRAINING INVESTIGATION



Summary

This study seeks to determine the effectiveness of simulator based UPRT using sustained-G and non-motion based flight simulation platforms. Twenty (20) Air Transport Pilot's (ATPs) were trained at the NASTAR Center in Southampton PA for UPRT in the GYROLAB-4000 (GL4K) Sustained-G Flight Simulator. Ten pilots trained using the GL4K's full motion and sustained-G capabilities while the remaining pilots operated the GL4K as a traditional fixed-based flight simulator with all motion disabled. Both groups received identical classroom training. Pilots were evaluated before and after training on their proficiency to recover from a series of randomly presented preprogrammed upset scenarios. Pilot's additionally provided feedback indicating their personal self-assessment of UPRT skill level, comfort, and overall ability before and after training. For the motion group, physiological and motion sickness symptoms were evaluated using the Simulator Sickness Questionnaire to determine potential training limitations associated with sustained-G training.

Objectives

- Compare pilot's proficiency in ability to recover from upset recovery scenarios following motion and non-motion flight simulator based UPRT.
- Develop metrics to grade UPRT recovery ability
- Optimize training methods for sustained-G based UPRT

Customer/Partner

ETC Internal Research

Status

Complete. Final report will be presented at AIAA Modeling and Simulation Conference Summer 2012.

The National AeroSpace Training And Research Center



Future Publications

Aviation Space and Environmental Medicine

American Institute of Aeronautics and Astronautics (AIAA)



2.3

EFFECTIVENESS OF SUSTAINED-G SIMULATION IN LOSS OF CONTROL AND UPSET RECOVERY TRAINING

Summary

This study is part of a larger body of research aimed at understanding man-machine interaction in aviation, and its influence on aviation safety. In part one of this study a group of pilots experienced flight upset profiles in the GYROLAB GL-2000 centrifuge-based simulator and evaluated the simulator to determine if sustained motion simulation is of sufficient fidelity to improve pilot-reaction to unplanned, simulated, aircraft upsets. In part two of this study pilots were monitored with a variety of physiological sensors to determine if there are identifiable psychological and physiological responses that occur in pilots when their exposure to an unplanned upset results in a mishap.

Objectives

- To observe trends between the success of recovery attempts and the physiological and psychological response of the pilots
- To validate the GYROLAB GL-2000, as a research and training tool for replication of pilot-in-the-loop control system performance and aircraft response in upset and off-nominal flight conditions
- To identify trends in the physiological and psychological responses of pilots recovering from upset conditions in large transport aircraft

Customer/Partner

NASA (Grant NNLO6AA21G)

Status

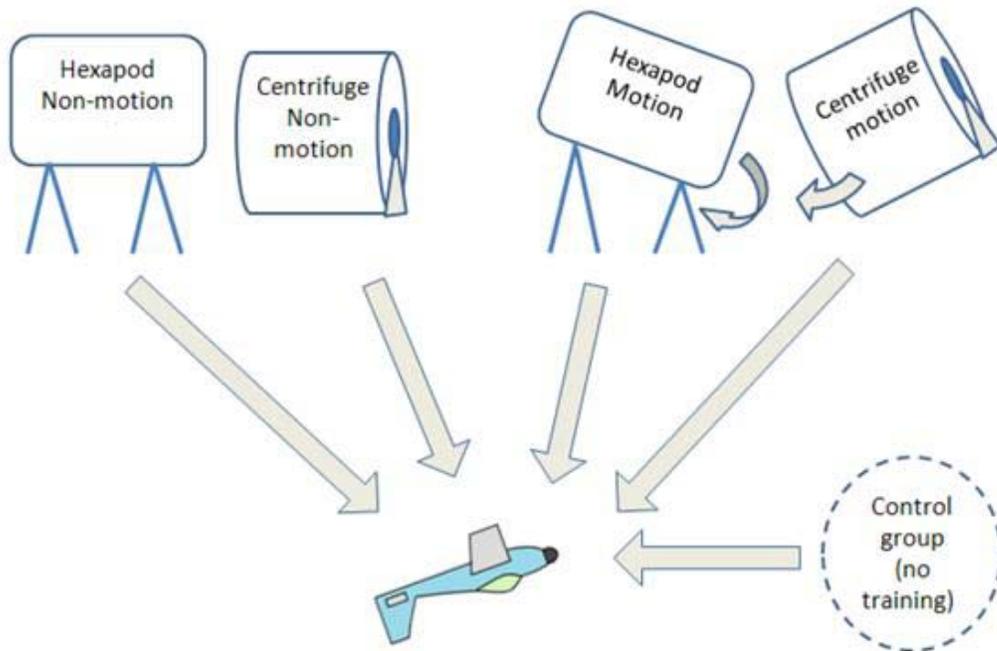
Complete (2009)

Publications

Final report complete and available online

http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20110008036_2011007963.pdf

2.4 AN EXPERIMENT TO EVALUATE TRANSFER OF UPSET RECOVERY TRAINING CONDUCTED USING TWO DIFFERENT FLIGHT SIMULATION DEVICES



Summary

Air transport training programs provide simulator-based upset-recovery instruction for company pilots. However, no prior research demonstrates that such training transfers to an airplane in flight. This FAA-funded research experiment was designed to evaluate upset-recovery training transfer. Two groups of participants were given simulator-based training in upset-recovery, one in a high-end centrifuge-based device, the other using Microsoft Flight Simulator running on desktop computers. A third control group received no upset-recovery training at all. All three groups were then subjected to serious in-flight upsets in an aerobatic airplane. Pilots from both trained groups significantly outperformed control group pilots in upset-recovery maneuvering. However, performance differences between pilots from the two trained groups were less distinct. Moreover, pilot performance in both trained groups fell well short of the performance exhibited by pilots experienced in all attitude flight. Although we conducted flight testing in a general aviation airplane, our research has important implications for heavy aircraft upset-recovery trainers.

Objectives

- Compare pilot's proficiency in ability to recover from upset recovery scenarios following motion and non-motion flight simulator based UPRT
- Develop metrics to grade UPRT recovery ability
- Quantify transfer of desktop and simulator based UPRT to aircraft

Customer/Partner

Embry-Riddle Aeronautical University, FAA

Status

Complete (2009)

Publication

Final report for FAA available online

<http://www.faa.gov/library/reports/medical/oamtechreports/2000s/media/200917.pdf>

CORE RESEARCH AREA 3: STRESS, COGNITION AND HUMAN PERFORMANCE

Keywords: Stress, anxiety, arousal, salivary cortisol, fatigue and circadian rhythm, memory, workload assessment, information processing, decision making

Current Ongoing and Completed Projects:

3.1 Pilot Reactions to Unusual Aircraft Attitudes: A Physiological, Bio-Chemical and Psychology Assessment.

3.2 Training effects on anxiety, arousal, and performance in simulated sub-orbital spaceflight

3.3 Optical Brain Monitoring using Functional Near Infrared (fNIR) Spectroscopy to Measure Cognitive Workload While Under G.

3.1 PILOT REACTIONS TO UNUSUAL AIRCRAFT ATTITUDES: A PHYSIOLOGICAL, BIO-CHEMICAL AND PSYCHOLOGY ASSESSMENT



Summary

The goal of this project is to research the effects of anxiety in airline pilots who have never experienced extreme maneuvering in an aircraft. Specifically, we will analyze and compare the manifestation of anxiety and fear symptoms during upsets for two groups of pilot trainees; those that undergo NASTAR Non-Motion Upset Recovery Training and those that train in a full-fidelity sustained G flight simulator completing the NASTAR GL-2000 Full Motion Upset Recovery Training program. Physiological data, bio-chemical hormone levels (salivary cortisol levels), and subjective psychological questionnaires will be recorded and compared.

Objectives

- To determine if training in a realistic physiologically stressing simulated flight environment is superior to traditional classroom and non-motion based training at reducing anxiety, fear and startle during a real in-aircraft upset.
- This experiment will put the ETC slogan, “flight training without physiological stress is not flight training,” to the test. The resultant physiological, psychological and bio-chemical data will provide objective evidence to back or refute this claim as applied to UPRT.
- Additionally, this experiment will determine the effectiveness of sustained-G UPRT compared to traditional methods.

Customer/Partner

Embry-Riddle Aeronautical University partnered with ETC



Status

Under review by ERAU Institutional Review Board. Flights to be scheduled for March – April 2012

Future Publications

Aviation Space and Environmental Medicine

American Institute of Aeronautics and Astronautics (AIAA)

3.2 TRAINING EFFECTS OF ANXIETY, AROUSAL AND PERFORMANCE IN SIMULATED SUBORBITAL SPACEFLIGHT



Summary

Thus far, space travel has been limited to a small group of highly screened and selected test-test pilot astronauts. Soon, commercial space vehicles will provide public access to space for the first time in history. Although exciting, this poses a serious concern due to the limited knowledge on how the medically variant, general human population will subsist in space. This study will examine the effect of full versus minimal/no training on subject performance, anxiety and arousal during simulated sub-orbital spaceflight in the ATFS-400 man rated centrifuge. A battery of physiological and psychology assessment tests and data will be recorded and compared.

Objectives

- Compare anxiety and arousal for trained and untrained sub-orbital space flight passengers
- Quantify physiological changes and challenges for the general population of potential sub-orbital space flight participants
- Determine effectiveness of ground based space flight training

Customer/Partner

ETC Internal Research and St. Peter's University

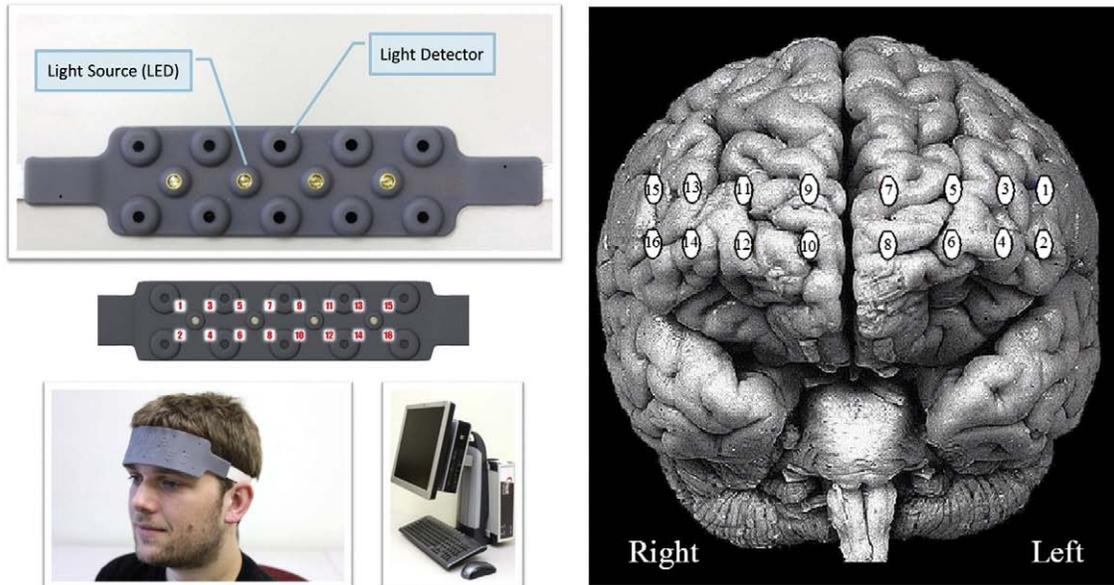
Status

Experimental design and IRB preparation. Centrifuge runs and subject recruitment will begin in March 2012.

Future Publications

Aviation Space and Environmental Medicine

3.3 OPTICAL BRAIN MONITORING USING FUNCTIONAL NEAR INFRARED (FNIR) SPECTROSCOPY TO MEASURE COGNITIVE WORKLOAD WHILE UNDER G



Summary

An accurate measure of mental workload in human operators is a critical element of monitoring and adaptive aiding systems that are designed to improve the efficiency and safety of human-machine systems during critical tasks. Functional near infrared (fNIR) spectroscopy is a field-deployable non-invasive optical brain monitoring technology that provides a measure of cerebral hemodynamics within the prefrontal cortex in response to sensory, motor, or cognitive activation. This study seeks to determine the efficacy of using fNIR spectroscopy to measure cognitive workload while under G by testing a group of naive subjects at several standardized mental workload, memory and cognition tasks at various G levels in the ATFS-400.

Objectives

- To determine differences in cognitive performance and mental workload at various G levels
- To validate the fNIR optical brain monitoring system under G loading
- To develop protocols and metrics for future testing of aviators during UPRT, SD and Tactical flight training at NASTAR
- To develop potential cognitive screening mechanisms for pilot selection

Customer/Partner

Drexel University Cognitive Neuro-engineering and Quantitative Experimental Research (CONQUER) program partnered with ETC



Status

Under review by the NASTAR Institutional Review Board. Centrifuge runs and subject recruitment will begin in February 2012.

Future Publications

NeuroImage

Journal of Biomedical Optics

Aviation Space and Environmental Medicine

CORE RESEARCH AREA 4: HUMAN FACTORS AND MAN-MACHINE INTERACTION

Keywords: Ergonomics, seat and cockpit design, switchology, displays, automation, control systems, human life support systems, feedback response, human-system interface, attention, group interaction and flight crew performance

Current Ongoing and Completed Projects:

4.1 The Effect of Hyper Gravity on Manual Control Tasking Ability

4.2 Centrifuge Evaluation of Chemical Biological Aircrew Respirator (CBAR)

4.3 Evaluation of commercial space pressure suit as an approach to enhance safety and health of commercial spaceflight travelers

4.1 THE EFFECT OF HYPER GRAVITY ON MANUAL CONTROL TASKING ABILITY

Summary

This experiment will be the first to study the effect of the G-Excess illusion on a subject's ability to manually control and stabilize a vehicle's tilt angle. While perceptions are interesting from theoretical perspective, the true concern is that illusory perceptions will impact piloting performance resulting in accidents. This experiment will study the impact on pilot manual control in a controlled task across a range of angular roll tilt frequencies. Pilots will be tasked with keeping the ATFS-400 gondola upright (in reference to the net gravitational vector) in response to a pseudorandom roll disturbance at varying G levels.

Objectives

- To study the effect of the G-excess illusion on the manual stabilization of a rate-controlled vehicle
- To provide data to support the development of future countermeasures to the G-excess illusion, including displays, training, and different vehicle designs, which can be tested in a controlled laboratory setting
- To adapt the ATFS-400 for manual stability and control testing for future sub-orbital pilot testing and more general academic research

Customer/Partner

Massachusetts Institute of Technology partnered with ETC

Status

Experimental design and IRB preparation. This project will begin after the MIT "Human Orientation Perception during Vehicle Roll Tilt in Hyper-Gravity" project is completed (Spring - Summer 2012).

Future Publications

Annals New York Academy of Sciences
Journal of Vestibular Research
Aviation Space and Environmental Medicine

4.2 CENTRIFUGE EVALUATION OF CHEMICAL BIOLOGICAL AIRCREW RESPIRATOR (CBAR)



Summary

The U.S. Navy is developing a new Chemical-Biological Aircrew Respirator (CBAR) to replace the legacy system. Prior to flight testing, the system was evaluated at ETC by subjecting human volunteers to acceleration stress to determine if the CBAR, along with a standard US military breathing regulator, provides sufficient air to perform anti-G straining maneuvers during high Gz conditions.

Ten (10) volunteers were exposed to a series of acceleration profiles in the ETC centrifuge while wearing the legacy respirator and CBAR on separate days. Mask performance, physiologic and subjective responses were recorded for comparisons.

Objectives

- To compare the performance characteristics of a new Chemical-Biological Aircrew Respirator to the legacy system during a series of high-G centrifuge acceleration profiles
- To determine if the new CBAR system provides sufficient air to perform anti-G straining maneuvers during high Gz conditions

Customer/Partner

US NAVY (PMA-202 Aircrew Systems)

Status

Complete (July – October 2011)

The National AeroSpace Training And Research Center



Future Publications

Final Report delivered to US NAVY

4.3 EVALUATION OF COMMERCIAL SPACE PRESSURE SUIT AS AN APPROACH TO ENHANCE SAFETY AND HEALTH OF COMMERCIAL SPACEFLIGHT TRAVELERS



Summary

The purpose of this study is to evaluate the use of a new generation life support space suit as means to optimize human safety, protection, and performance during upcoming commercial space flights. As limited to no publically available data exists on commercial human spaceflight, this study is the first of its kind to understand the impact of a pressure suit during commercial suborbital flights.

Two subjects will evaluate a Contingency Hypobaric Astronaut Protective Suit (CHAPS) under G during a series of centrifuge runs at the National AeroSpace Training and Research(NASTAR) Center. Use of the Phoenix Centrifuge at NASTAR Center will permit realistic evaluation due to the replication of acceleration forces and physiologic conditions encountered upon humans during launch and reentry phases of suborbital space flight.

Objectives

- To elicit detailed feedback to enhance spacecraft seat and life support equipment designs
- To aid in the development of protocols associated with future suborbital research
- To integrate feedback into space training programs to provide space travelers with the best, most realistic training available that focuses on optimizing their health, safety and enjoyment in overall space flight experience



Customer/Partner

Drs. S. Alan Stern and Dan Durda of Southwest Research Institute (SwRI) in Boulder, CO and The David Clark Company, Incorporated (DCCI)

Status

Complete (January 2012)

Publications

Research summary available online

www.nastarcenter.com/nastar-center-supports-commercial-space-pressure-suit-evaluation-in-centrifuge

FUTURE EXAMPLE PROJECTS

1. Measuring sensorimotor control of reaching movements during sub-orbital space flight take off manual control tasking
2. Developing advanced eye-movement based detection algorithms for G-induced Loss of Consciousness (GLOC)
3. Comparing motion sickness symptom development during sinusoidal oscillations with and without concordant visual, proprioceptive and auditory cues
4. Determining human physiological response to various potential sub orbital space flight acceleration profiles
5. Tracking human performance degradation of aircraft carrier launch and landing following prolonged sleep deprivation
6. Developing advanced motion cueing algorithms for driving, locomotive and aviation simulator design
7. Evaluating Artificial Gravity (AG) simulation for Orbital and Suborbital space research
8. Analyzing pilot performance during simulated Lunar and Martin landing gravity transitions
9. Performing motion sickness desensitization and adaptation research to unusual G-environments
10. Studying the effects of stress, mental workload and fatigue on performance and manual control
11. Comparing human spatial orientation and motion perception in unusual rotational and gravity environments
12. Simulating and recreating aircraft accidents