The +$G_z$ette

Submissions from the International Acceleration Research Workshop Community
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Wright-Patterson AFB Centrifuge Closed After 40 Years of Research Operations; New Centrifuge Planned

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WRIGHT-PATTERSON AIR FORCE BASE, Ohio – The Air Force Research Laboratory's dynamic environment simulator (DES) centrifuge accelerated into its final spin 5 Feb 2007. When it stopped, stopping with it—but perhaps only temporarily—was more than 70 years of Air Force centrifuge-based research at Wright-Patterson AFB, including the last 40 years using the DES. The Air Force has operated a man-rated centrifuge since 1935 to study the effects of acceleration on humans in flight, including cutting-edge research involving women as they entered the Air Force ranks and were granted combat status. A new centrifuge, estimated by an independent consultant to cost $31 million, will be built at Wright-Patterson for pilot training, equipment testing and acceleration research currently conducted at Wright-Patterson, Brooks City-Base and Holloman AFB facilities. As a result of the 2005 Base Realignment and Closure (BRAC) plan, centrifuge projects at Brooks City-Base in Texas will relocate to Wright-Patterson by 2011, and the Brooks centrifuge will remain active until then. The Air Force plans to group its aerospace medical research programs under a new Human Performance Wing at Wright-Patterson AFB. The HPW merges the Human Effectiveness Directorate, the Air Force School of Aerospace Medicine, and the Air Force Institute for Operational Health and the Performance Enhancement Directorate of the 311th Human Systems Wing into a technology directorate of AFRL. The new centrifuge would support these groups, including the ability to accelerate at 6g per second for pilot training, which the DES cannot do. The DES was instrumental in defining and conquering aircrew physical flight acceleration limitations. Many AsMA members were associated with the DES including John Frazier, a 43-year researcher at the DES facility, Dr Bill Albery, Dr Tammy Chelette, Dr Ed Eveland, Lloyd Tripp and Dr Dana Rogers.

Figure 1. The Dynamic Environment Simulator centrifuge at AFRL, Wright-Patterson AFB, OH

Originally built to study escape mechanisms for the Mercury space program, the DES ultimately became a workhorse for studying human flight acceleration and disorientation, logging 3,336,611 million revolutions during a 41-year lifespan.

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ASMA High G Workshop 2007

UK Update

Introduction
The UK conducts acceleration research at the Qinetiq centrifuge facility at Farnborough, and in 2 dedicated Hawk fast jet aircraft operated by the Royal Air Force Centre of Aviation Medicine (RAF CAM) at Boscombe Down. Aircrew training is also conducted on the Farnborough centrifuge – all fast jet aircrew undergo centrifuge training prior to flying the Tucano (T-37 equivalent), and all Typhoon aircrew undergo centrifuge training/conversion to Typhoon life support equipment prior to starting the Typhoon operational conversion unit.

Typhoon aircraft
Centrifuge and flight assessments of life support equipment for the Typhoon aircraft continue. Full coverage anti-G trousers and positive pressure breathing for G protection

(PBG) are now in service in Typhoon. Flight work towards full clearance of the final standard below neck aircrew equipment and life support system is imminent. Work has been conducted on flight clearance of zipped full coverage anti-G trousers (FAGT), following a previous zip failure during a flight test in a Hawk aircraft. A modified run-off of the zip closure is under assessment. Long term assessment of the Typhoon Helmet Equipment Assembly continues, for durability, comfort and longevity. A similar assessment has been carried out for the Typhoon ADOM oxygen mask.

Joint Strike Fighter aircraft
A flight assessment of the JSF helmet mounted display system is due to start in June 2007, with participation from US and UK aircrew. Comfort and stability of the helmet will be assessed under flight conditions in the Hawk aircraft, including 1 vs 1 air combat, and exposure up to +9Gz.

5 bladder anti-G trousers
An centrifuge and flight assessment of RAF Mk10 (fire retardant) anti-G trousers was conducted following reports that the newly introduced garment offered reduced G protection compared with legacy suits. An iterative process was conducted to improve the design of the garment, but it was concluded that the Nomex cover of the garment was excessively compliant, resulting in reduced application of pressure to the limbs and abdomen. At present, UK Hawk aircrew have reverted to using legacy (non fire retardant) anti-G trousers.

Flight assessment of reduced positive pressure breathing schedule
A flight trial comparing a standard PBG schedule (up to 60mmHg at +9Gz) to a schedule capped at 40mmHg above +7.5Gz is underway. The trial includes both FAGT and skeletal anti-G trousers. Initial results indicate that when using FAGT, the reduced PBG schedule does not result in a noticeable reduction in subjective G tolerance, assessed during set-piece high G exposures and air combat manoeuvring in the Hawk aircraft at up to +9Gz. G protection is noticeably degraded when skeletal garments are used in all conditions compared with FAGT.

The Effect of Pressure Breathing and Chest Counter-pressure Garment Inflation on Apical Lung Expansion during Sustained +Gz Acceleration
A novel imaging technique called electrical impedance tomography (EIT) has been investigated for measurements of apical lung volume at accelerations up to +6.6Gz (30mmHg PBG) to investigate the effect of chest counter-pressure in reducing lung distension. Chest counter-pressure was found to have a statistically significant effect on ERV/VC (at the apex) though this effect was relatively small. Studies are ongoing using the technique, to measure apical lung distension at accelerations up to +9Gz. EIT has also been used to investigate regional lung deflation curves during exposure to +Gx acceleration. The data obtained from six subjects at +1 and +3Gx are in agreement with those changes predicted to occur in the presence of an exaggerated pleural pressure gradient.

Mask tensioning study
An investigation is underway to determine the feasibility of using smart materials to automatically tension an aircrew mask during PBG and pressure breathing for altitude protection. A small study has been undertaken to calculate the degree of tension necessary to maintain a sufficient seal and a concept demonstrator is being produced.

An evaluation of the risk to aircrew of concomitant exposure to +Gz acceleration and rapid decompression in the Typhoon aircraft

To date two phases of this assessment have been completed:
Phase 1: Arterial oxygen saturation was measured non-invasively by pulse oximetry at the ear lobe in six subjects at accelerations up to +7Gz wearing Typhoon aircrew equipment. The data recorded were used to extract a simple mathematical relationship between SpO_2, +Gz level and duration of exposure. At +7Gz SpO_2 decreased to around 87±2% at the end of the 30 second plateau.
Phase 2: End tidal concentrations of oxygen and carbon dioxide were measured by mass spectrometry in eight subjects during exposure to accelerations up to +8Gz wearing Typhoon aircrew equipment. Prior to commencing the trial the performance of the mass spectrometer and sampling line (~14m) was tested at accelerations up to +9Gz. Measurements made during manned running indicated large changes in end tidal gas concentrations with acceleration; $PetO_2$ increased and $PetCO_2$ decreased, the magnitude of changes being linearly related to the G load. At +8Gz mean $PetO_2$ and $PetCO_2$ were 132.5 and 20.7mmHg respectively. When PBG was applied, $PetO_2$ increased and $PetCO_2$ decreased further. These effects could not be ascribed merely to the increase in breathing pressure afforded by PBG and it is probable that PBG results in an increase in the physiological dead space.

2006-7 Activities at Wright-Patt AFB DES Centrifuge

Long term Fatigue Related to Heavy Helmet Systems

There has been much interest among the agencies in the Department of Defense (DoD) in learning the effects of heavier helmet systems and how to reduce or eliminate neck pain or injury. Researchers from the Air Force are collaborating with their counterparts from the Army and Navy. These groups are also represented in meetings of scientists of NATO countries and the TTCP who lead research efforts of their own.

AFRL/HEPG recently conducted a helmet biodynamics research program that focused on finding gender differences in response to “heavier helmets” under high G acceleration. In that effort, the female test subjects used approximately 80% of their maximal voluntary contraction (MVC) in neck extension. The males used only about 30% of their maximal effort (Eveland and Goodyear, 2001). Since then, flight line testing, intended to examine indications of muscle fatigue during flight have been conducted. There was not enough data to draw definite conclusions after these tests but the goal was to compare results using helmets currently in use with developmental versions of helmet systems. The acquisition process can benefit from knowledge of how new systems affect the humans using them and how the results might differ from those already in use.

Examination of neck muscle fatigue is continuing but, in AFRL/HEPG, the focus is shifting away from high G acceleration to longer duration. The emphasis is on finding the effects of multiple missions over longer time on the human user. There is interest in fast jets as well as slower movers that might be in flight for long periods. Those slower movers might have even heavier helmets than those used in the jet aircraft. The latest HEPG research utilizes this scenario to investigate how a proposed heavier helmet might be tolerated compared to a system in use now. The upper weight limit of the helmet system represents the upper limit proposed for a new design. The goal of the research effort is to determine if that helmet affects the human user differently than a lighter helmet system in use. That information will serve as guidance for design criteria and the developers.

In the most recent HEPG scientific research, data was collected from eight male and four female military volunteers. These data are from four basic sets and include neck muscle maximal volunteer contractions (MVCs) in extension, endurance based on sustained extensions pulling against 70% of their baseline MVC, a target recognition task, and a target acquisition task. Volunteer test subjects were seated for MVC determination. They were given three attempts to pull against a load cell using a strap connected using a weight-lifting style head harness. The attempt generating the highest force was considered the MVC. Endurance testing was done using 70% of this MVC. A computer display provided a subject feedback indication of force level. Subjects maintained force between horizontal limit lines. Subjects were asked to pull until could no longer keep the indicator between the lines.

The next two tests were related to findings targets. The first required subjects to examine a series of 50 computer screens containing random mixes of red squares and blue circles. One distinctive target (red circle) was included on some screens. The goal was to examine each screen and decide if this target was present. Responses were recorded from keystrokes on a keyboard. Time to make the decision, up to 5 seconds, was also recorded. The final test took place in a static cockpit simulator. A visual system provided targets projected for the subjects via a display within a set of goggles. The simulations required the subjects to move their heads in response to pointers extending out toward the target from the center of a set of crosshairs. Subjects saw target aircraft at various locations forward and out to the sides of the cockpit. Their chore was to find each target, hold the pair of crosshairs on it, and move on to the next target in the least time possible. Time and position data was saved to allow examination of time taken to complete the task.

Baseline data (A) was collected at the beginning of each test day for all of the four tests. After that, each subject was exposed to a high-G acceleration profile based on data taken from Nellis AFB Red Flag training flights. The profiles controlled the G load experienced in the Dynamic Environment Simulator (DES), a man-rated, human use centrifuge. The profile contained a mix of low G exposure near the beginning and higher loads later, as if they traveled to a mission then engaged the adversary. A second set of data was collected after this exposure (B) and again after a second similar high-G exposure later in the day (C). A final, fourth, data set (D) was collected at the end of the day, after the subject performed a static flight simulator period with no high-G exposure. Data collection and strength measurements were done as soon as possible after each exposure. Helmets were worn for approximately 6 hours over the day, with limited removal during times set aside for lunch breaks.

Indications show that subjects were physically fatigued as illustrated by changes in MVC and endurance over test days. Preliminary results have not yet provided answers to questions such as “Is fatigue more prevalent with one helmet than another?” or “Is fatigue more evident after 2 DES exposures?” or “Does a short time with no G exposure allow significant recovery” or “Does target tracking or acquisition skills degrade as a result of the fatigue experienced”? Those analyses, as well as examination of electromyography (EMG) remain to be accomplished.

Human Information Processing in the Dynamic Environment (HIPDE)

This effort was aimed at evaluating human cognitive performance during high-G stress. A battery of twelve different tasks was developed to analyze the wide range of abilities crucial for flying an aircraft and neutralizing targets. This year, the final two studies (Visual Monitoring; Short Term Memory) were completed. Prior to participation, each subject completed extensive static training followed by dynamic or "blend" training in the Dynamic Flight Simulator (DES) human centrifuge located at Wright-Patterson AFB, OH. Next, participants completed the given performance task during the following G_z profiles in the DES: a 3 G_z, 5 G_z, and 7 G_z plateau lasting 15 seconds followed by a Simulated Aerial Combat Maneuver (SACM) that included two peaks to 7 G_z. Prior to the exposures, each subject performed the task at 1.0 G_z, which served as the baseline data. The data collected during each of the peaks was compared to the subject's baseline performance. The results of all twelve studies are being used to verify two separate models that predict human information processing decrements caused by the stress of the inertial environment. The first was developed by NTI, Inc. as part of a phase II SBIR effort an the other was a modular model created in-house at Wright-Patterson AFB. The model that aligns more closely with the collected data (highest agreement) will be delivered to SIMAF and incorporated into current flight simulation models. The goal is to enhance the realism of current simulations and allow modeled representations of pilots to be degraded as a function of G_z.

Acceleration Research Report from the Swedish Defence Research Agency

Acceleration Physiology

Ola Eiken / Mikael Grönkvist

Research projects concerning acceleration physiology and spatial disorientation have been undertaken both at the Dynamic Flight Simulator (DFS) and at the centrifuge at the Karolinska Institute. The projects/problems that have been dealt with during the past year are for the most part, continuations of those presented at last years Acceleration Work Shop, and can be summarized as follows.

• G-tolerance and G-comfort
  - G-tolerance and cardiovascular control as influenced by long duration fighter aircraft missions.
  - Interaction of G-protective measures *(Eiken et al., ASEM. 78: 392-399, 2007)*.
  - Effects of the counter-pressure jerkin during pressure breathing at high G-loads *(Grönkvist et al., ASEM; 76: 833-40, 2005)*.
  - Pulmonary gas distribution at increased G-load as influenced by the different components of the anti-G-suit *(Grönkvist et al., Abstract Asma meeting 2007)*
  - Pressure habituation of arm and leg vessels – relations to G-induced arm pain and relaxed G-tolerance and to release of vasoactive substances at high G-loads *(Eiken, Proceedings Scand. Physiol. Soc. Annual meeting, 2006).*

• Spatial disorientation and motion sickness
  - Spatial orientation as influenced by complex vestibular stimulation *(Tribukait et al., J Vestib Res 16: 1-12, 2006, ASEM; 77: 695-703, 2006, Brain & Cognition 63: 24-30, 2007)*.

- Effects of motion sickness on autonomic functions *(Nobel et al., Eur. J. Appl. Physiol 98: 48-55, 2006)*

Man Systems Interaction

Britta Levin/Lars Eriksson

Research projects concerning perceptual and cognitive effects of acceleration and spatial disorientation have been conducted at the Dynamic Flight Simulator (DFS) in Linköping.

A follow-up study has been performed on findings from the previously investigated somatogravic illusion *(Eriksson et al., Proceedings Human Factors Erg Soc Annual meeting 2006)*. The present study focused on the effects of; no visual cues, HMD conveyed stationary horizon, and HMD conveyed visual flow during onset to 0, 57 Gx.