Research in a High-Fidelity Acceleration Environment

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ABSTRACT

With advances in acceleration protection for the tactical pilot there arises a need for advances in the testing environment for these protective systems. The lightweight cockpit (LWC) installed in the human centrifuge at NADC is one approach to creating an acceleration environment similar to tactical aircraft. This centrifuge is capable of very high onset / high sustained accelerations. A pilot in the human centrifuge flies an aircraft simulation to maintain a target aircraft inside the gun pipe of a head-up display. The pilot is in complete control of the centrifuge through the simulation and if the target tracking is accomplished successfully, the centrifuge will produce an acceleration profile that matches the target aircraft. The LWC starts with an enhanced aircraft simulation with a performance envelope that exceeds current inventory aircraft. The centrifuge is equipped with the flight controls necessary to fly the simulation in an air combat scenario. The display system is a high-resolution wide field of view computer graphics system that is used to present a real world gaming area, an aerial target aircraft, and a high fidelity head-up display. The aerial target flies profiles that are either actual engagements recorded from air combat maneuvering ranges or flights recorded using the enhanced aircraft model simulation.

INTRODUCTION

Until recently, research efforts concerning the pilots of tactical aircraft were on two parallel courses. Investigations of the man-machine interface, workload assessment, and flying qualities are among those utilizing ground based flight simulators as a research platform (Rolfe & Staples 1986). Explanations of the effects of sustained acceleration on the physiology of the pilots rely on the human centrifuge as the main tool of the studies (Burton, Cohen, & Guedry 1986). While the idea of integrating a high-fidelity flight simulator with the human centrifuge has been around since 1981 (Albery 1981; Crosbie & Eyth 1983), there have been no physiological studies performed using this enhancement to the centrifuge.

Acceleration research on the human centrifuge historically has used only a limited number of +Gz acceleration profiles. Among them, the Gradual Onset Rate ramp profile (onset rate less than or equal to 0.1 G/second) and the Rapid Onset Rate to plateau profile (onset rate greater than or equal to 1.0 G/second). In an effort to expose human subjects to +Gz accelerations similar to that of tactical aircraft, the Simulated Aerial Combat Maneuver (SACM) is often included in centrifuge experiments (Burton 1986; Glaister, Vliet 1988). The typical SACM consists of alternating moderate and high +Gz plateaus (figure 1a). Specific programs have made modifications to the basic structure of the SACM (Gillingham & Fosdick 1986; Cammarota 1987), but the centrifuge profile is very different from the time history +Gz accelerations encountered during an actual aerial combat exercise (figure 1b, from Gillingham, Pientzas & Lewis 1985). Besides the dissimilar time history of acceleration, the centrifuge experiment also lacks realism since the subject is a passive passenger and not in control of his own accelerations.

The centrifuge subject in a typical experiment is asked to perform two tasks. The main concern is the effective execution of an anti-G straining maneuver (LU/M1) with a secondary task to monitor the degradation of peripheral vision. In comparison, the dual task responsibility of the centrifuge subject bears little resemblance to the workload of a pilot in the cockpit of a modern high-performance fighter aircraft. This may be an important factor when the preparatory aspects of a pilot in control of the aircraft's flight path are considered. While the centrifuge subject can concentrate most of his resources on the anti-G straining maneuver, the tactical pilot cannot afford this luxury. However, since the pilot is in control of the aircraft, he can prepare for a maximal effort straining maneuver based on anticipated aerial tactics.

Some proposals for acceleration protection involve complex, high-
technology systems. In order to adequately evaluate these new systems, acceleration researchers need a firm foundation on which to base recommendations. This foundation will come from conducting studies using an acceleration and workload environment that approaches that of the tactical aircraft. The topic of a Gz-Induced Loss of Consciousness Monitoring, Warning and Recovery System is of particular concern to the acceleration research community (Whinnery 1967; Van Patten 1987; Cammarota 1986; Lloyd & Darrah 1988). Such a system must reliably operate using signals from various sensors with signals that are not statistically "clean". To maximize the chances of developing a dependable system, the research, development, and testing must be done in a laboratory environment that closely matches the real world environment of the tactical aircraft cockpit. Experiments conducted under higher fidelity conditions will ensure a greater confidence in the transfer of systems from the laboratory to the cockpit.

THE TESTING ENVIRONMENT

A possible solution to the unrealistic environment of the human centrifuge is to conduct studies using in-flight evaluations (Campbell, et al. 1987; Cresswell, et al. 1988). Flight tests of Gz protective systems have concentrated on acceptability and qualitative performance assessment rather than the physiologic response to acceleration and quantitative analysis of Gz protection that can be effectively accomplished on the human centrifuge. The light weight cockpit (LWC), through its use of closed-loop pilot control of the centrifuge, will fill the gap between the acceleration laboratory and tactical fighter cockpit.

The LWC starts with a modified version of a NAVY fighter simulation. The aerodynamic model has been modified to enhance its performance to levels above that of current inventory aircraft. The subject in the LWC has the task of flying the simulator to maintain a six o'clock position on a target aircraft. The target aircraft follows a pre-programmed flight path that was obtained either from aerial combat or aerial combat scenario but would not provide enough visual cues for a low-level/terrain following sortie. Through database management techniques a selected area may be given a suitable level of detail (figure 3).

The feed-back up display (figure 4) features active symbology for airspeed, altitude, heading, angle-of-attack, mach number, Gz, peak Gz, roll angle, velocity vector, target designator, gun reticle including range bar, weapons status, and a 360 degree pitch ladder. The HUD frame, glass, HUD camera, and angle-of-attack index are also depicted and obscure the real world scene.

The head down display (figure 5) is a God's eye view centered on own aircraft. The display also presents indications of own airspeed and altitude (white bars) and target airspeed and altitude (chevron & numbers). At the start of the simulation the target position is fixed so that upon matching own aircraft airspeed, altitude and heading the...
target will be positioned 12 o'clock level. The display is also used to re-acquire a target that has flown beyond the field of view of the real world display. The display mode may be changed to function as a Horizontal Situation Indicator so that TACAN navigation procedures could be incorporated into the simulation. The display is also used as a terminal for auto-recovery procedures following a G-induced Loss of Consciousness (GLOC) episode.

The cockpit is interfaced to the aircraft model through a network of computers (figure 8). The control inputs are processed through an LSI-11/23 computer that automatically nulls the controls when neutralized, adds a breakout level and scaling, and adjusts the controls in response to trim commands from the simulation. This computer is also responsible for receiving the aircraft state parameters from the simulation, controls the simulation modalities, generates an event marker, updates video documentation, and records timing signals for switch closures. The final task is to send a packet of data to the LSI-11/73 computer under interrupt control.

The LSI-11/73 computer has the master clock in this tight network. At 100mS intervals the computer requests the aircraft position, integrates this with the target position and sends both data segments to the display buffer computer. The 11/73 is also responsible for generating the head down display, managing target data files, sequencing events following a GLOC episode, processing switch closures, driving the TACAN navigation simulation, and generating the flight deck display.

The flight deck display (figure 6) provides the experimenter with real time status on control manipulations and also shows instantaneous aircraft Gz and previews the target's acceleration profile with a lead time of 8 seconds. This preview alerts the investigators to imminent maneuvers which may be stressful to the subject.

The LSI-11/23+ computer serves as a buffer between the 11/73 and the graphics generating computer. This added computing power allows for real-time data collection of aircraft and target attitude, control manipulation, and the event marker. In addition this computer may be tasked to calculate a real time performance metric and run a weapons simulation.

The PARAGON computer system consists of a high performance 3D graphics engine and an IBM AT compatible I/O interface. The AT computer's main responsibility is the management of the real world databases. The system has the capability to handle 256 dynamic coordinate systems. This means that in addition to presenting a target aircraft, the system can also display moving control surfaces, flaps, slats, multiple weapon launches, and landing gear deployment.

LWC OPERATION

The simulation starts with the aircraft trimmed in level flight at a given altitude and airspeed. Since the LWC was designed to be used for a study involving GLOC the subject must first disengage a simulated auto-pilot. The first step is to extinguish a Master Caution light to measure the total incapacitation time (Whitney, Burton, Boll & Eddy 1987). To investigate the recovery of higher mental functions the subject must then enter a sequential code on the up front control panel (figure 7). The cockpit controls must then be adjusted to the positions expected by the model so that there is no step change during a transition from the "TRIM" mode to the "RUN" mode. In normal operation, the stick is electronically offset and the throttle is mechanically driven to the correct position. An error signal is displayed on the head down display and if there is a failure in the automatic trim system the subject can adjust the controls. When proper trim is achieved, the subject may then transition to the "RUN" mode by activating a paddle switch on the control stick.

The air-to-air target is initially acquired by executing the Lost Target Procedure. The sequence is started by pressing the "LOST TARGET" button on the up front display. The target is frozen and its altitude, airspeed, and heading are depicted on the head down display. The subject must then maneuver his own aircraft to match those parameters. If done correctly, the target will appear at the 12 o'clock level position. With the aircraft in sight, the subject will again activate the paddle switch on the stick to "release" the target and start the air-to-air tracking task. The subject can use the head down display to re-acquire a target that has left the field of view, or may invoke the "lost target" sequence at any time. At the end of the target file a new target will be displayed and the subject will line up the new target and continue. Should a subject lose consciousness during any engagement, the simulation will be placed back into the "TRIM" mode and the subject must disengage the auto-pilot starting with the Master Caution

Figure 4 - Integrated Head-up Display

Figure 5 - Head Down Display

Figure 6 - Fight Deck Display

Figure 7 - Code Entry Display
The light. The target profile presented to the subject immediately following a GLOC episode will be the same target that the subject had on the first engagement of the day. This is so that direct comparisons of tracking performance may be made pre and post LOC. Timing measurements for each procedure will also be recorded for later comparison (Table 1). Following completion of the last target profile, the subject must then navigate back to home base using the available TACAN stations. The tasks involve tuning the radio receiver to the correct frequencies to navigate to one of ten preassigned air stations, tracking the radio beacon, and joining the pattern at the correct altitude, airspeed and runway alignment. The performance tasks for this experiment were chosen to exercise increasingly higher levels of cognitive function after a GLOC episode.

CONCLUSION

The LWC is an effective bridge between the acceleration laboratory and the cockpit of fighter aircraft. It can be utilized to impart realistic +Gz accelerations on a human subject that has a workload more representative of a pilot than a passive centrifuge subject. In earlier tests, six volunteer subjects were able to control the NADC centrifuge through the simulation to +Gz levels of 7.0G at onset rates up to 8.0 Gz/second. The LWC is currently committed for use in an investigation of GLOC in which the subjects will be heavily instrumented with up to 30 channels of physiologic measurements. This study will also measure behavior changes after the relative incapacitation period following a loss of consciousness as well as attempting to find physiologic indices leading to GLOC.
REFERENCES


