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From: Vertical Flight Human Factors Program Manager, ATO-P R&D Human Factors
To: Vertical Flight TCRG

Subj: VERTICAL FLIGHT HUMAN FACTORS SECOND QUARTER '05 REPORT

Ref: Vertical flight human factors execution plans (http://www.hf.faa.gov/vffunded.htm)

a. projects listed below

a. Simultaneous Non-interfering Operations - Quantify VFR Navigation Performance.

Naval Postgraduate School (NPS) (Virtual Model Task):

Purpose and Rationale
The overarching objective of this program is to assist in the recommendation of the minimum Required Navigation Performance (RNP) value for a VFR helicopter equipped with an IFR GPS. The results of this study combined with the output from another ATO-P R&D HF's Vertical Flight project entitled "Helicopter SNI helicopter Flight Data" will assist the Federal Aviation Administration flight standards office in determining the minimum RNP value that will be accepted by air traffic office in developing procedures for VFR SNI routes. By correlating human performance data in the simulator to already collected flight data, we will be able to further experiment with new flight patterns towards a decreased minimum RNP value. The purpose of our project is to build and validate the simulation system for further experimentation.

Methodology
A critical element of our study involves a model of pilot performance as a factor of pilotage cues (e.g. landmarks) and radio communications (e.g. GPS receivers). We need to know if a pilot fixates on landmarks versus GPS output. Do they simply "fly the needle" off of the GPS unit, do they carefully observe visual cues, or is it some mix of both? How does this affect the envelope we can assume they

are maintaining, therefore indicating how traffic can be controlled around them? We assume that too much attention to the GPS receiver may adversely affect pilotage performance, but that the reverse may also be sub-optimal. The study conducted in this program investigates in a virtual environment simulation how traffic density, workload, and weather affects the minimum RNP for a qualified VFR helo pilot equipped with an IFR GPS.

Recent Accomplishments

The primary accomplishments for this period center around test subject trials and the FAA site visit conducted at the Naval Postgraduate School on 09 February. The following paragraphs detail this progress.

Trail runs

Several test subjects have evaluated the existing system. These test runs were conducted to validate data collection procedures and subjective information on simulation fidelity. The test runs validated the data collection procedures. Issues related to simulation fidelity are discussed below. A sample of the navigation track information is shown in Figure 1.

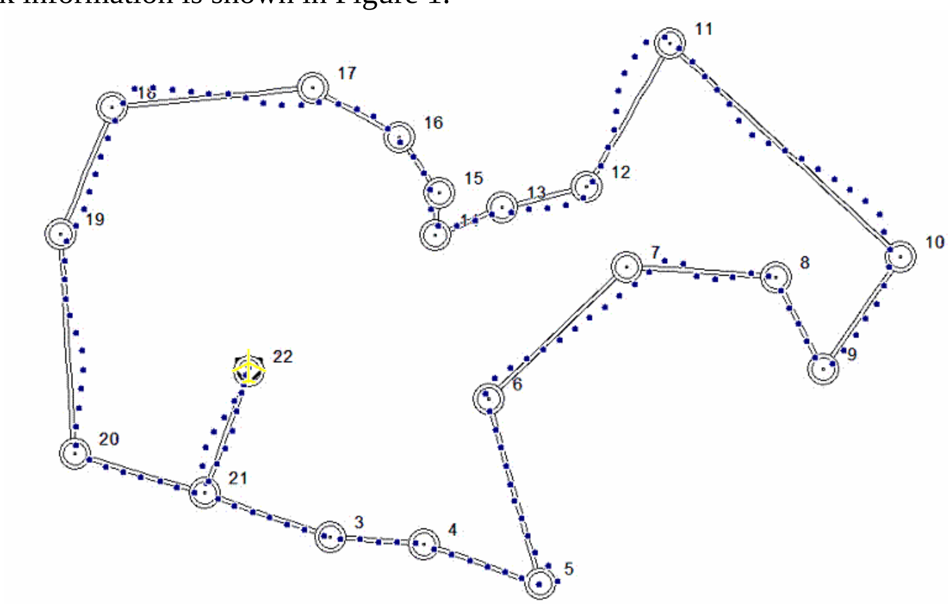

Figure 1. Navigation results of test subject.

Topic:

Simulation of KLN-89B.

Issue:

The original GPS simulation involved an LCD display mounted to the instrument panel. This display was driven by a lightweight graphics application. This application stored waypoints, allowed users to select active waypoints, and used current aircraft position to calculate course deviation and time and distance to waypoint information. A screen capture of this system is shown in Figure 2.

Figure 2. Simulated KLN-89B

Course deviation information is the most difficult variable to calculate. For en-route navigation and fly-over waypoints calculating this course deviation is relatively straightforward. It is based on horizontal difference between the aircraft position and the closest point on the navigation route. Fly-by waypoints involve more complex algorithms. Course deviation is based on difference between current position and a continually updated ideal flight path. The ideal flight path is a function of airspeed, turn radius and closure rate. Recreating this algorithm is problematic. Representatives from Bendix/King were unable to provide any usable form of the algorithm – source code or specifications. It would be extremely difficult to verify the accuracy of any approximations of the algorithm.

Solution:
Several simulator manufactures were contacted for proposed solutions. Frasca provided the most viable solution. They currently manufacture an emulator for the KLN-89B's GPS receiver. This emulator can be fed GPS position information from a PC via a standard serial (RS-232) connection. This emulator is connected to and drives an actual KLN-89B. This solution completely eliminates the need to recreate and validate the algorithm for fly-by waypoints. It is competitively priced based on the engineering effort required to implement alternative solutions.

Current Status:
A purchase request for this system has been submitted. We do not currently have an estimated shipping date.

Topic:
Visual fidelity of database may affect pilot scan.

Discussion:
Based on trial subject feedback and previous helicopter terrain navigation cognitive task analysis work, a number of issues related to visual fidelity of the geometric model of Tullahoma have been raised and addressed. Several of these issues stemmed from the technique to model forested areas. Forested areas of the terrain database were modeling using 'tree blocks'. These tree blocks are shown in Figure 3. Essentially a tree block is a polygon raised above the underlying terrain. This polygon is textured with small image that represent a typical top-down view of a forest canopy. This small texture is then tiled across the entire face of the polygon. To avoid visual artifacts, these small images are manipulated to avoid borders or seams when tiled. To make the images tile seamlessly, distinct features are removed. Thus, by definition forest canopies do not have salient

navigation features. This technique was generated based on graphics hardware limitations and generally produces satisfactory results for high-level simulations where top-down views are sufficient. This technique may not be appropriate for simulations that involve low-level navigation. For the virtual Tullahoma model, an alternative method for modeling forested areas was used. In the revised geometric database, forested areas are modeled by randomly placing a variety of tree models at a pre-defined coverage factor. The specific motivation and results are described below:

- **Heading maintenance via reference to external visual cues is more difficult in the virtual environment**. Pilots often use distinct features ahead of the aircraft or along the anticipated track as a reference for maintaining heading. If the visual cues available in the real environment are not available in the virtual environment pilots may rely on cockpit instrumentation more in the virtual environment. For route segments along or nearby cultural features there are generally sufficient external visual cues. However in forested regions these cues were not available in the virtual environment. With the revised model, individual trees can be used as course maintenance visual cues.
- **Linear features are much more prominent in the virtual environment**. This can be seen in Figure 3. Where highways and power lines cut through forested areas, the distinct boundaries associated with the tree block highlight these features. As a result linear features in the database were much more prominent compared to the real environment. When forested areas are modeled using individual trees, linear cultural features are no longer artificially highlighted.
- **Detailed cultural models are much more prominent in the virtual environment.** This is also depicted in Figure 3. With the tree block technique, the radio tower in the center of the scene appears much more prominent than it does in the real world. When individual trees are modeled, the tower's visual prominence is much closer to the real world scene.
- **Estimating above ground level altitude and ground speed is more difficult in the virtual environment.** When flying at relatively low altitude above tree blocks the view is essentially the same as flying over any flat, featureless region. Estimating height above ground and ground speed in these conditions is much harder than it would be over a forest canopy typical of the Tullahoma region. As seen in Figure 4, irregularly space tree models provide better visual cues for estimating height above ground and ground speed.

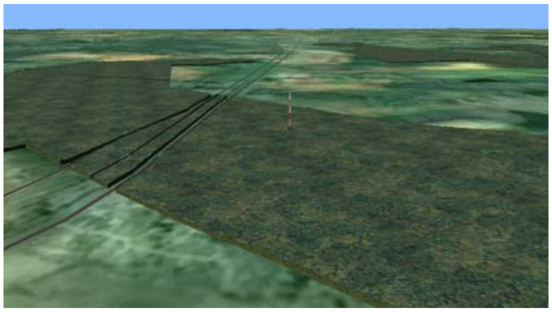

Figure 3. Tree block technique for modeling forested areas.

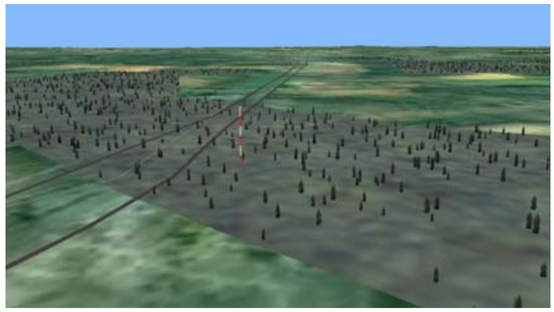

Figure 4. Scene modeled with individual trees.

Topic:
Limitation of aircraft engine and system instrumentation may affect pilot scan.

Discussion:
The original cockpit was modeled to accurately recreate the primary scan instrument cluster. During trial subject debrief, it was noted that some subjects devoted less of their scan time to the cockpit because of the absence of engine performance and aircraft system gauges. To correct this and to improve the environmental fidelity the existing instrument panel is being replaced and engine performance gauges are being added. The new instrument panel is shown in Figure 5.

Figure 5. OH-58 instrument panel

In addition to the instruments from the current simulation, it will be populated with engine performance gauges similar to those shown in Figure 6. Additionally, the brief for the subject pilot has been amended. Pilots will be briefed that they are responsible for reporting and correctly responding to an abnormal engine or aircraft system conditions.

Figure 6. Engine oil temperature/pressure gauge.

Current Status:
The new instrument panel has been ordered and recently arrived. Transferring the existing gauges and installing the new instrument panel should be completed by 31 March. The additional gauges have been ordered; we do not currently have an expected delivery date.

Topic:
Scan pattern may be affected if modeled cultural features are assumed to be significant navigation landmarks.

Discussion:
During test runs several of the subjects commented that they assumed any cultural feature that was modeled must be a significant navigational landmark. To help minimize this effect, cultural features that are not depicted on the PVFR route chart were added to the database.

Topic:
Scan pattern may be affected by lack of concern with collision avoidance in the virtual environment.

Discussion:

During simulated flight, pilots may not devote as much time to outside scan to ensure collision avoidance as they would in the real environment. Subjects may perceive that the risk (chance of occurrence) and threat (negative results of occurrence) of a midair collision are negligible in a simulator. To counter this possible effect, the pilot pre-flight brief has been modified. Pilots will be briefed that they are responsible for collision avoidance during the simulated flight. Additionally, they will be responsible for reporting visual contact with all traffic. The capability to add additional rotary or fixed wing traffic to the simulation has been incorporated. Additionally, the audio portion of the simulation has been modified to approximate radio calls for contacts that may be within visual range.

NASA Ames (Eye Tracking Task):

Presented a conference paper entitled "Pilot Behavior and Course Deviations During Precision Flight", the paper can be found at http://www.hf.faa.gov/docs/508/docs/vfSPIE05.pdf

The researcher has improved utility programs for handling topographic maps and digital elevation data. He has developed programs to categorize head pose data explore the relations between head pose and gaze direction and developed projected-distance method for mapping flight trajectories onto GPS route.

In coordination with program sponsor, new milestones have been established. Final report will be delivered at the end of FY06Q1.

b. Lowering GA Accidents in Low Visibility: UAV See-and-Avoid Requirements

This is a new start. NASA Ames will cost share this research requirement with the Federal Aviation Administration. The researcher will collaborate with researchers at the Army Research Lab and US Army CECOM NVESD. The requirement can be found at http://www.hf.faa.gov/docs/508/docs/GA_SeeAvoid_Req.pdf. The execution plan can be found at http://www.hf.faa.gov/docs/508/docs/VFsee_avoid.pdf.

Requirement Background: This research will compile and review the characteristics and performance of existing optical systems that could be used to enhance the human UAV operator's ability to see-and-avoid potential conflicts with other manned and unmanned aircraft. Data will be collected for those sensor systems that are currently being used in Commercial UAV operations (e.g., surveillance, search-and-rescue, law enforcement, etc.) to determine their ability to be used to detect and avoid conflicting aircraft. The types of systems (cameras) will be characterized by their performance characteristics: field-of-view, field-of-regard, modulation transfer function, focal point, and lens quality. This comparison will be used to determine the ability of these systems to detect static images of differing sizes, at a range of distances in, variety of visibility conditions, i.e., sense-and-avoid. Existing optical models will be used to analyze the performance of these systems for detecting when the optics are integrated with a processor and data link system to determine the effects of bandwidth, image compression, and latency on see-and-avoid performance for large and small conflicting aircraft operating at a range of speeds with both vertical and horizontal path variations leading to the conflict. Finally, the utilization of these systems will be evaluated considering the performance of the human operator's eyes in the role of see-and-avoid (human-in-the-loop).

This quarter the researcher corresponded with Eddie Jacobs, Performance Modeling Team, US Army CECOM NVESD, to arrange transfer of image databases. Clearances are being obtained by NVESD to allow the transfer. The researcher continued development of SSO-based image discrimination model. Prior model used sub-optimal discrimination algorithm. Optimal Bayesian algorithm has been added and tested. The researcher continued preparations for presentation at ARVO conference, May, 2005. This presentation will report results of application of optimal model to letter discrimination with various wavefront aberrations.

The researcher conducted a literature analysis. Papers read and analyzed.

Moyer, S., Driggers, R. G., Wilson, D., Welch, G., & Rhodes, W. T. (2005). Cycle criterion for fifty-percent probability of identification for small handheld objects: US Army CECOM, RDEC Night Vision and Electronic Sensors Directorate Ft. Belvoir, VA.

McCarley, J. S., & Wickens, C. D. (2005). Human factors implications of uavs in the national airspace: FAA.

Limitations of the see-and avoid principle. (1991). Bureau of Air Safety Investigation, Australia.

On February 7th, the researcher met with the ATO-P R&D HF Program Manager to discuss status and direction of project. On March 15th, the researcher hired a student intern to assist with project.

William K. Krebs