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

Subj: VERTICAL FLIGHT HUMAN FACTORS FOURTH QUARTER '04 REPORT

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

1) Each project is listed below.

a) Night Vision Goggle Lighting Requirement

Purpose and Rationale: Aircraft cockpit lighting can interfere with the proper operation of night vision goggles (NVGs). The accepted military practice to determine whether or not a lighting system is NVG compatible is to compare the visual acuity through the NVGs with and without the cockpit lighting activated. This military procedure requires expensive illumination sources and radiometric measurement equipment that can cost in excess of $100,000. An inexpensive alternative method to assess compatibility, that provides the same quality of results as the accepted military method, is needed for civilian applications. The first part of this project successfully investigated equipment, methods, and procedures that could result in an acceptable, inexpensive alternative method. A method using an inexpensive illuminator validated with an inexpensive illuminance meter was devised and successfully demonstrated in a human use study. An alternative, objective method using the same inexpensive illuminance meter was also included in the study and showed great promise. A second human use study was conducted that was designed to compare the inexpensive, illuminance meter-based assessment method with the visual acuity-based method. **Methodology:** Six trained subjects participated in this second human use study. All subjects had been trained and had participated in the first study. Subjects were instructed in the specific methods of assessing lighting compatibility assessments using visual acuity and in how to use the illuminance meter to measure the average light output of the NVGs. The procedure was exactly like the accepted military procedure in that each subject would determine what acuity pattern was resolvable when viewing through the NVGs with the cockpit lighting off. Then the cockpit lighting was turned on and the subject would determine if they could still see the same element. If there was a loss in visual acuity then, according to the published procedures, the cockpit lighting would be deemed incompatible. This procedure was repeated using the cockpit lighting simulator set for 6 different radiance levels for each of two viewing conditions. The two viewing conditions were 1) viewing through reflections in a simulated windscreen and 2) viewing through the simulated windscreen with no reflections. For the objective method the illuminance meter was attached to the end of the NVG to obtain an average light output reading. The NVG was then point out of the simulated windscreen as a pilot would be looking outside. If the illuminance meter reading increased by more than a certain criterion level when the cockpit lights were turned on (compared to being off) then the cockpit light was deemed unacceptable. Probability of rejection as a function of radiance level curves were then generated for both the visual acuity-based method and the illumiance level based method. **Results:** The results indicate the objective method can provide a much better, more definitive method of accepting or rejecting an NVG cockpit lighting system if used in conjunction with a visual inspection method to insure objectionable reflections are minimized or eliminated.

Project is complete. Deliverables sent to sponsor

b) Simultaneous Non-interfering Operations - Quantify VFR Navigation Performance.

NASA Ames (Eye Tracking Task):

There were three primary accomplishments for this period: first, programs were written to calculate the course deviation of the flight paths, and to segment the flight paths in correspondence with the desired route; second, USGS data (topographic maps, digital elevation maps, and digital orthophotos) covering the area of the flight tests was obtained, and software was developed to allow visualization of the terrain and flight environment; finally, work was initiated on a new method for “image sorting,” which will be used to improve the robustness of measurements made on the eye images, by first sorting the images into broad classes within which specialized heuristics may be applied. Each of these accomplishments is described in more detail below.

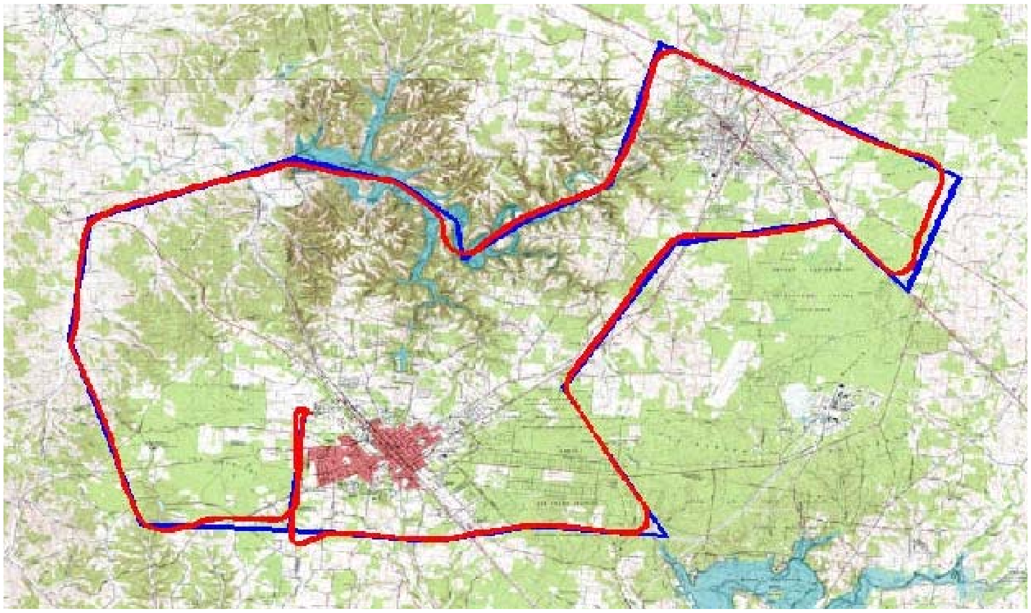

Figure 1. A typical flight path (red), and the desired route (blue) overlaid on a topographic map of the Tullahoma area.

The raw data recordings from the flight tests provide the three dimensional position of the aircraft sampled at one second intervals. In order to compare the various flights, it is necessary to be able to index the records by position instead of time. Additionally, because no two flights followed exactly the same course, each flight path must be segmented in accordance with the segments of the desired route. The desired route and a typical flight path are shown in figure 1.

We compute the flight path segmentation as follows: for each sample from the flight path, we compute the distance to the current segment, which is either the perpendicular distance to the route segment, or the distance to the nearest waypoint if the perpendicular does not intersect the segment within its boundaries (see figure 2). We also compute the distance to the next segment in the route; when this distance becomes smaller than the distance to the current segment, we advance the current segment.

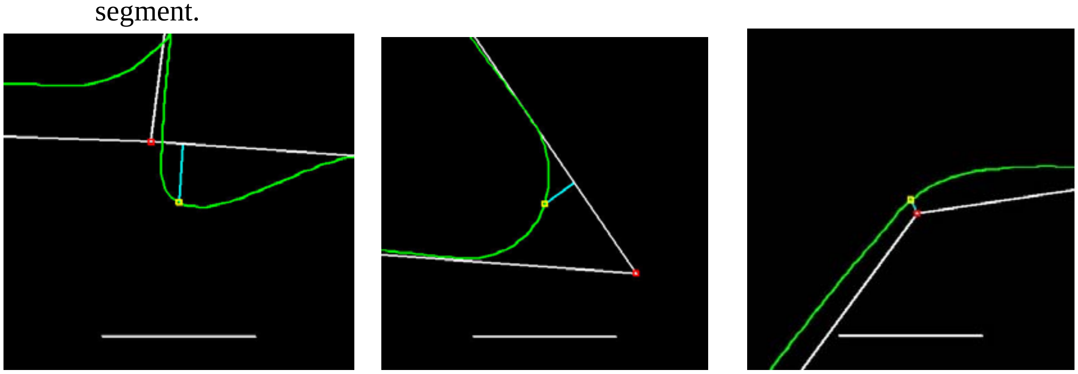

Figure 2: Lateral course deviation is shown in blue for three points in the flight path. The desired route is shown in white, with waypoints shown in red. The bar near the bottom of each panel indicates 1 kilometer.

The result of this process is that for each sample in the flight path we obtain the lateral course deviation, the route segment index, and the distance to the nearest waypoint (used to determine the "center" of each leg). These quantities are shown in figure 3 (corresponding to the flight path shown in figure 1). Figure 3 also indicates the segment boundaries (the yellow line segments at the lower portion of the graph) and the segment centers (indicated by the white line segments at the upper part of the graph). These are used to divide each trajectory into "waypoint" and "segment" intervals as follows: for each waypoint, the midpoint (in time) between the segment transition and the segment midpoint is determined, on each side of the waypoint. These "quartile" points are then used to divide the route into waypoint and segment intervals, with each "waypoint" segment consisting of the two quartiles bracketing the waypoint, and each "segment" leg consisting of the two central quartiles. Figures 4 and 5 show mean and maximum error as a function of route segment for day and night flights, respectively.

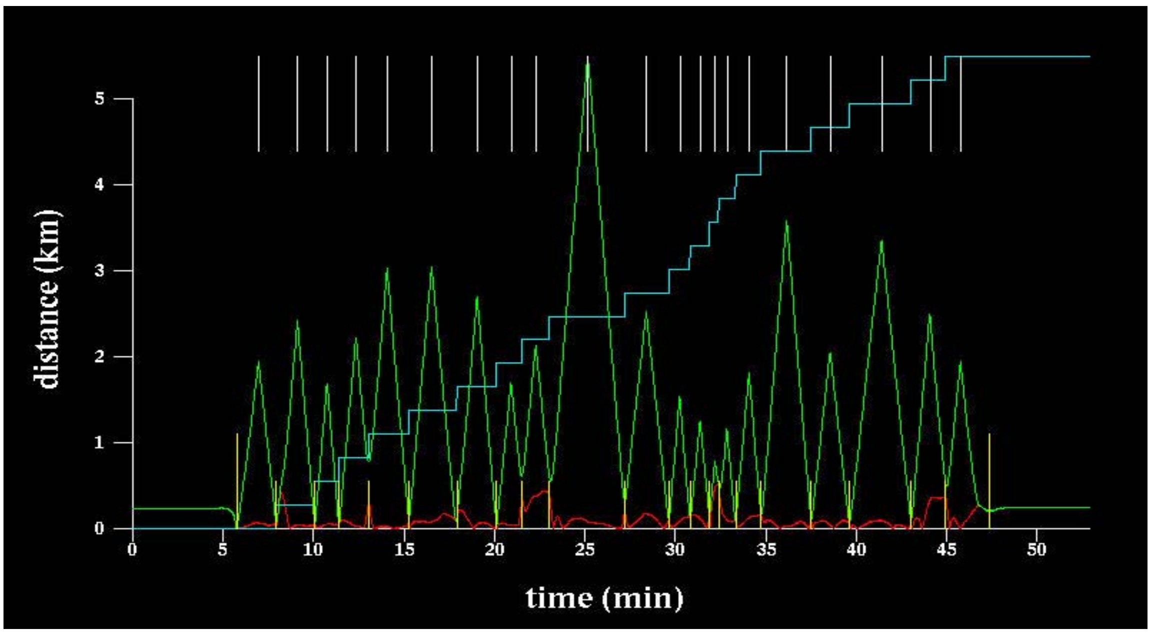

Figure 3: Lateral course deviation (red) and distance to nearest waypoint (green) is plotted as a function of time. The blue stair-step trace represents the route segment index; segment transition times are indicated by the yellow vertical line segments at the bottom part of the figure, while the segment midpoints (determined from the local maxima of the waypoint distances) are indicated in white at the upper part of the graph.

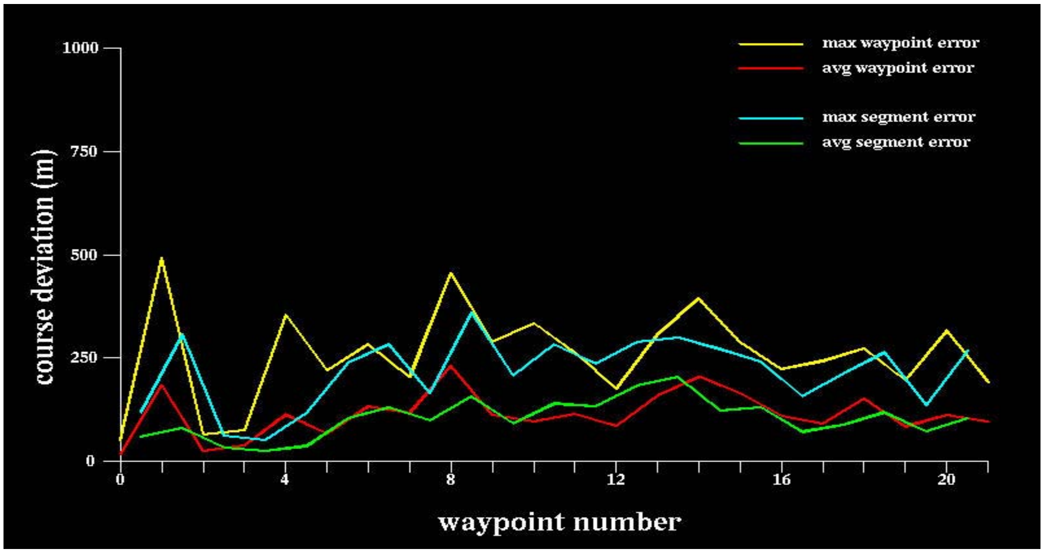

Figure 4: Mean and max course deviation, plotted separately for waypoint and course leg segments.

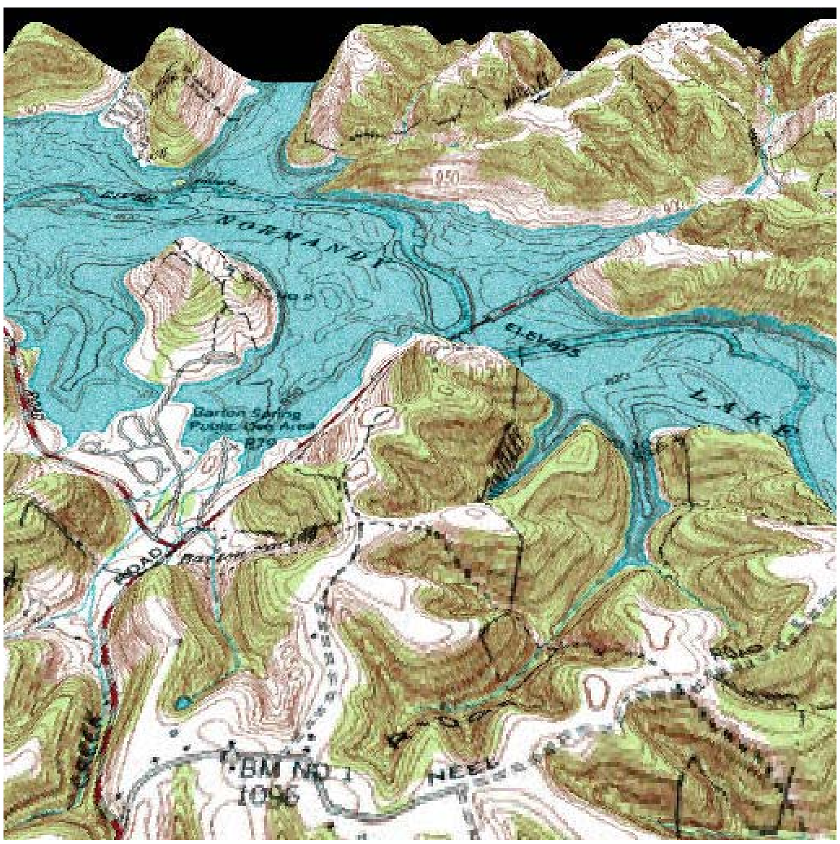

Figure 5: A small portion of the "Normandy Lake" quadrangle, texture mapped onto a surface generated from Digital Elevation Map (DEM) data. Relief is exaggerated here to illustrate the principle.

A second accomplishment for this period was the acquisition of topographic and image data for the region covered by the flight tests. Figure 4 shows an example of a small portion of the flight route, where we have taken image data from a topographic map, and "texture mapped" it onto a three-dimensional surface constructed using Digital Elevation Map (DEM) data. This capability has two purposes: the first is simply to allow us to visualize the flight trajectories in the context of the terrain. More importantly, it also allows us to generate a synthetic view of the terrain from the pilot's point of view at each point in the flight. (For this purpose we will use aerial photo imagery rather than the topo map shown in figure 5.) Assuming that the lighting conditions in the aerial photos did not differ too much from the conditions during the flight tests, these synthetic images will allow us to compute a "visible landmark index" to express the amount of visible information available for navigation. Additionally, we can use the synthetic views to compute the attitude of the vehicle using the views of the terrain captured by the forward-looking scene camera.

The final accomplishment for this period was the development of an "image sorting" algorithm which will be applied to the eye image sequences. Our laboratory algorithms for localizing features in the eye images have not performed well, primarily due to the large variations in lighting encountered during the day flights. The idea behind image sorting is that in spite of the large number of images of the eye collected, many of these depict the eye in more-or-less the same position. Rather than applying a computationally expensive (and unreliable) feature detection algorithm to each image, we instead simply match each image to a similar exemplar. Once the images have been grouped in this way, we then may apply an algorithm specialized for the particular class of images. Additionally, we expect that the clusters of images themselves will exhibit a topology related to the parameters of interest. For example, we might expect to map the images into a three-dimensional space parameterized by two gaze angles and the degree of eyelid closure. Lighting variations add extra dimensions, and some "teaching" will be necessary to discount these. The progress made during this period resulted in large part from the realization that the correlation coefficient (which we compute as a measure of similarity between images) can be transformed to a "distance" which obeys the triangle inequality by the use of the inverse cosine function. This is work in progress.

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

Task 7. Conduct simulation using multiple SNI scenarios provided by ATO-P Human Factors R&D

- Human performance and modeling data
- Not started. Awaiting ATO-P Human Factors R&D input.

Task 8. Complete analysis and write report

- Report specifying the minimal RNP value for various SNI scenarios
- Not started. Follows task 7.

Indications are that there are risks to the activity being completed as planned. NASA Ames eye tracking analysis should be completed by December 2004. NPS simulation will begin without task (c) input. ATO-P Human Factors R&D will request NPS to collect PVFR data based on October 2003 flight notes.

William K. Krebs