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From: UAS Human Factors Program Manager, ATO-P R&D Human Factors
To: Unmanned Aerial Systems (UAS) TCRG

Subj: UAS HUMAN FACTORS SECOND QUARTER '06 REPORT

The following projects are funded by the Human Factors Research and Engineering Aviation Maintenance, General Aviation and Vertical Flight research programs.

a) Unmanned Aircraft Operator Qualification and Training Requirements

The draft final report is being reviewed by UAS Program Office. The goal is to complete the final report by FY06Q4.

b) Human Factors Maintenance Considerations of Unmanned Aircraft - One member of the researcher's team attended the meeting of the RTCA Special Committee 203 on Unmanned Aircraft Systems in San Diego in January 2006. Although the research is focused on smaller UAVs, an on-site visit with Northrop Grumman maintenance personnel responsible for Global Hawk was made in late January 2006 in order to achieve an overview of the UAV industry. Visits also were made to NASA Wallops, Aerosonde, and the Boeing Insitu Group.

During this quarter, the 10 month interim report for the project was completed and delivered to the FAA on time. The report identifies maintenance tasks and human factor issues unique to UAVs. We grouped the issues into four categories: (1) hardware; (2) software/documentation; (3) environment; and (4) personnel. In summary, hardware issues include the frequent assembly and disassembly of systems, and a lack of information on component failure patterns that would enable maintenance personnel to plan maintenance effectively. Hazards associated with certain types of batteries are emerging as major safety issues. Software/documentation issues include the need to maintain computer systems, and difficulties associated with absent or poor maintenance documentation. Environmental issues include the extreme operational conditions that can be experienced by non-pressurized vehicles not well-sealed against water ingress. The degradation of components through water damage or other environmental threats is likely to be a common problem faced by UAV maintenance personnel. Personnel issues include the influence of the remote-controlled aircraft culture and the skill requirements for maintenance personnel. UAV systems rely on computer technology, autopilots, radio transmission and allied fields to a greater extent than conventional general aviation airplanes. For this reason, many of the skill and knowledge requirements critical to UAV maintenance will be in the avionics field. In addition, an emerging distinction between field maintenance and major shop maintenance has implications for the skill and knowledge requirements for UAV maintainers.

During FY06Q3, interviews with UAV operational personnel will continue and visits will be made to additional UAV operators. An abstract for a presentation on the current findings has been submitted to the Third Annual Human Factors of UAVs Workshop to be held in Mesa, AZ in May 2006. An interim report dealing with maintenance resources and facilities will be delivered at the end of June 2006.

All available information indicates the project is on track

c) Low Visibility and Visual Detection: Design and Development of a Visibility Analysis Tool - The overall objective for this fiscal year is to provide the FAA with two user-friendly software tools that 1) provides quantitative information on the impact of Air Traffic Control Tower (ATCT) height and placement on aircraft visibility (the FAA Vis tool), and 2) provides quantitative information on the available time that a unmanned aerial vehicle (UAV) operator would have to respond to a potential conflict with other manned and unmanned aircraft (the See-And-Avoid tool). The technical approach that ARL Sensors and Electron Devices Directorate (SEDD) will utilize is to team with the U.S. Army's Night Vision and Electronics Sensor Directorate (NVESD) to complete the development and functional testing of the FAA Vis and the See-And-Avoid software tools (developed and enhanced for the FAA by ARL and NVESD in FY04 and FY05), and to calibrate these tools by experimentally determining the field-of-view (FOV) search-time equations, the target (aircraft) *discrimination* difficulty criteria, and *characteristic* target (aircraft) dimensions, through execution of two human perception (HP) experiments/tests. The first HP experiment will be a "time-limited search" experiment designed to yield FOV search time equations as well as aircraft *detection* difficulty criteria (N_{50} for *detection*) and appropriate *characteristic* target (aircraft) dimensions. The general approach will be to collect high-contrast, high-resolution, visible-band digital images of several scale-model aircraft from several perspectives, and high-resolution, visible-band images of real (natural) sky backgrounds, for use in the HP experiment. The HP experiment will measure human response time and *detection* accuracy to displayed images containing variably-*sized* aircraft images synthetically placed into real sky backgrounds at random locations in the FOV. The second experiment will be a classic HP experiment designed to yield both *recognition* and *identification* difficulty criteria (N_{50} for *recognition* and *identification*), and the proper *characteristic* dimensions for *aircraft*. The approach for the second experiment will also utilize high-resolution, visible-band digital images of several scale-model aircraft synthetically placed into either a real (natural) background, e.g., an airport runway scene as viewed from an ATCT, or a homogeneous synthetic background. This second experiment will measure the ability of human observers to *recognize* and *identify* aircraft images synthetically placed into a selected background image with a range of spatial *blurs* applied to the displayed images. The use of scale-model aircraft will significantly reduce both the cost and timelines of these experiments relative to using actual-size aircraft, and should yield more consistent results through better control of experimental conditions. The sets of imagery generated from these experiments will be made available to NASA-Ames researchers for use in an experiment aimed at independently determining task difficulty criteria (N_{50}'s) for *aircraft* using their Standard-Observer-Model-based methodology.

Tasks/Status:

1. Complete the development and functional testing of the enhanced version of FAA Vis and the baseline version of the See-And-Avoid software tools.

Status: The enhanced desktop version of the FAA Vis tool and the baseline version of the See-And-Avoid software tool have been completed and tested. The only remaining activities under this task are to: 1) add additional rain and fog aerosol modeling capabilities to the MODTRAN atmospheric attenuation calculation sections of the two desktop software tools (when the new MODTRAN interface program becomes available from Ontar Corp. – see below), and 2) add additional camera/sensor input files/selections to the See-And-Avoid tool, as requested by the FAA.

2. Work w/ FAA IT specialists to migrate the current desktop versions of the FAA Vis and the See-And-Avoid software tools to the FAA's Website environment. (This will require negotiations and licensing of the MODTRAN components of these tools with Ontar Corp.)

   Status: The enhanced desktop version of the FAA Vis tool and the baseline version of the See-And-Avoid software tool have been migrated to the FAA's Website environment. Negotiations for the licensing of the MODTRAN components of these tools have recently been finalized; the MODTRAN components of the subject tools can now be activated. Furthermore, negotiations for the addition of several rain and fog aerosol models to the presently available set of MODTRAN atmospheric attenuation aerosol models have been completed; an upgraded MODTRAN interface program has recently been developed by Ontar Corp. and is presently being tested. The expanded aerosol modeling capability is expected to be available by mid-June '06.

3. Execute the "time-limited-search" HP experiment for *aircraft* described above.

   Status: Because of unexpected delays in completing tasks 1 & 2 above and unexpected delays in receipt of FY06 funding, work on this task has just recently started. However, in order remain on track for completing and documenting both experiments (tasks 3, 4 & 5) by the end of the fiscal year, we have revised our approach to include a document-as-we-go process and adjusted the performance schedule (see below) accordingly. ARL and NVESD personnel have had preliminary discussions on the design of the "time-limited-search" experiment and have started an experiment design document. This document will be sent to the FAA and NASA-Ames for review and comment in approximately two weeks. The design document will include (among several items) a list of the set of scale-model aircraft that we propose to use in this experiment. (Expected completion date: Jun '06)

4. Execute the *recognition* and *identification* HP experiment for *aircraft* described above.

   Status: Work has not formally started on this task. (Expected completion date: Sep '06)

5. Document the results of both HP experiments.

   Status: Work has just started on this task in the form of an experiment design document for the "time-limited-search" experiment. (Expected completion date: Sep '06)

6. Participate with NASA-Ames in the design and execution of a Standard-Observer-based experiment to determine *discrimination* criteria for *aircraft*.

   Status: As reported previously, we have had several conversations with NASA-Ames (Dr. Andrew Watson) regarding their preliminary results of simulating human target *identification* performance using the Spatial Standard Observer (SSO) model on ground vehicle targets, and on plans to perform a similar experiment on *aircraft* target imagery obtained as part of this research. ARL and NVESD researchers plan and look forward to feedback from NASA-Ames on the experiment design document(s), and to continued collaboration with the NASA-Ames and FAA researchers as this research year progresses.

Schedule: Shown below is the revised schedule for the IAA tasks funded for FY06, along with the estimated progress to date.

	2005	2006								
Task: Month:	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Complete and test desktop versions of the FAA Vis and the See-And-Avoid tools										
Migrate and license desktop tools to and for the FAA's Web environment										
Execute "time-limited-search" HP experiment for *aircraft*										
Execute *discrimination* task difficulty HP experiment for *aircraft*										
Document results of HP experiments										
Participate in NASA-Ames discrimination criteria HP experiment for *aircraft*										

Period of Performance: The starting date for this work is December 2005 and the approximate completion date is September 2006.

This effort is cost shared with Army Research Lab and US Army CECOM NVESD.

d) An Assessment of the Effectiveness of Unmanned Aircraft Control Systems - The schedule for this task called for a completion of the control architecture inventory during the second quarter of 2006. The inventory was completed in February and given to the UAS Program Office for review. Four research questions were addressed by the research. They were:

a. What kinds of control architectures are currently being used in commercial applications?

For horizontal and vertical control of the aircraft, the research identified four kinds of control architectures. The lowest level imposes direct control of the aircraft surfaces through the use of a joystick. The highest level imposes control of the aircraft through the use of programmed waypoints that determine the location and altitude of the aircraft at a given point in time. Waypoint programming is accomplished through a "point and click" computer interface. Two intermediate levels of control allow the command of either bank angle/turn rate or heading and either vertical speed or altitude. Intermediate levels of control use physical controls for some systems such as a joystick or knob, or a computer interface that either requires a pull-down menu selection or interaction with a virtual control using a computer pointing device such as a mouse or trackball. All of the systems inventoried allowed waypoint control of the aircraft. Those that allowed direct control of aircraft surfaces only did so using an external line-of-sight pilot that handled takeoffs and landings only. There is a trend to eliminate the use of external pilots in favor of automated takeoff and landing systems.

b. What is a common control architecture for controlling UA through direct line-of-sight?

Direct line-of-sight control is most commonly accomplished using an interface similar or identical to a radio-controlled hobbyist control box. Some systems (e.g., Aerostar) have a modified control box that commands bank and vertical speed rather than controlling the aircraft surfaces directly. Only 3 of the 15 systems inventoried use direct line-of-sight control. Other systems, such as the Bell Eagle Eye, have a control box available for testing the movement of aircraft surfaces but it is not used during normal flight.

c. How do different control systems (i.e., stick, menu, knobs, etc.) affect the pilot regarding basic flight and navigation parameters?

The analysis of control levels that was accomplished in this research suggests that the manner in which flight commands are input is not as important as the level of the command that is input. Lower levels of control provide more immediate ability to change aircraft attitude but require more integration by the pilot to achieve a particular flight goal. Higher levels of control require less integration but do not allow immediate access to lower level control needs. For example, a control system that allows direct input of vertical speed means various values of vertical speed can be achieved but requires the pilot to monitor changes in altitude to establish a particular altitude goal. In other words, the pilot has to fly the aircraft to an altitude using changes in vertical speed. On the other hand, a control system that allows direct input of altitude does not require the pilot to fly the aircraft to that altitude but also does not allow a range of vertical speeds to be input. Higher levels of control make flying the aircraft easier but restrict the flight options available.

d. *Is there a lowest level of flight control that can be mandated for certain systems? In other words, what level of automation should be required for UA systems?*

Previous research indicates that the performance level control joystick, which commands bank angle and vertical speed, is more effective than the direct control of aircraft surfaces. There is no need to allow control inputs below this level of control because there is no need to perform aerobatic maneuvers with these aircraft and because of the benefits to the pilot due to not requiring the integration of lower levels of inputs (see the report for more details).Whether control at this level is accomplished using a joystick or some other method is not relevant. The question of whether higher levels of control should be allowed as a minimum level depends on the type of flight activities anticipated for the system.

A draft report was submitted to sponsor February 28th, 2006. I'm waiting for feedback from sponsor.

e) <u>Lowering GA Accidents in Low Visibility: UAV See-and-Avoid Requirements</u> - The goal of this project is to assess the feasibility of using the Spatial Standard Observer, or derivatives, to compute N50 values for target image sets. Currently N50 values are obtained empirically, through an expensive and time consuming psychophysical experiment using human observers. Because the SSO attempts to model human image discrimination, it offers the possibility of replacing human observers with computer calculations.

During this quarter the researcher made the following progress toward plan objectives.

Article on modeling letter acuity

The researcher completed a draft of a paper that describes a model of letter acuity, capable of predicting the effects of induced higher order optical aberrations. The model incorporates the Spatial Standard Observer, along with template matching. The researcher also completed over 2000 hours of computer simulations of the model, exploring various matching rules and templates, that will be reported upon in the paper. This model will also serve as the basis for predicting visibility of aircraft and UAVs elsewhere in this project. In particular, the simulations will assist in selection of appropriate matching rules for visibility simulations.

Development of Psychophysical Apparatus

Two of the objectives of this project involve psychophysical experiments (visibility and search). During this quarter the researcher continued development of software for the experiments. Work continued on the development of the Showtime library framework. The Showtime's is capable of creating and displaying video in a number of formats utilizing the underlying QuickTime API including HD video. It is also capable of reading raw data files, such as those used for VQEG experiments, without the need for advance preparation of

QuickTime movie files. Current efforts include enhancing Showtime to use OpenGL based display routines to render video in lieu of the default graphics port used by QuickTime. Using OpenGL based display routines will provide greater control, flexibility, and speed. The researcher's current primary focus is in modifying the CLUTs (color look-up tables) used by the graphics card for use in psychophysics experiments. Some work was done to update the display routines to OpenGL but there remains additional work and some troubleshooting. One problem encountered is that some formats are not displaying properly where format choice should be independent of display capability. This issue should be resolved soon.

Aircraft models

The existing online visibility tool relies on simple Mathematica rendering of aircraft and UAV images from 3D models. Likewise the psychophysical experiments will use similar renderings of 3D models. Therefore this task we have been looking for 3D models of relevant UAV craft. The manufacturer has been asked to provide models, but none have yet been received. The researcher has obtained a model of the Global Hawk, and Predator aircrafts. The figure below shows the models rendered against a cloud background.

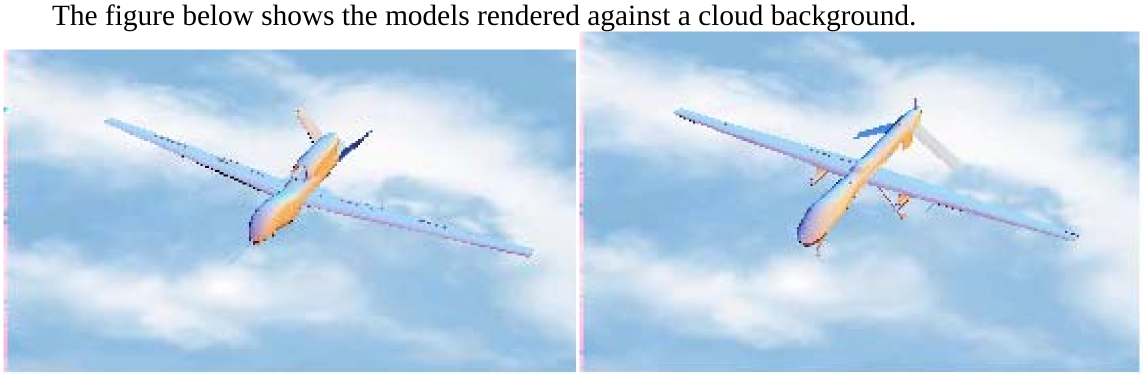

Figure 1. Renderings of 3D models of Global Hawk (left) and Predator (right) UAVs.

We are continuing to work on integration of these models into the psychophysics experiments and the online visibility prototype.

Other activities:

Dr. Watson appointed member of VESA FPDM Committee

Dr. Andrew B. Watson, Senior Scientist for Vision Research and Chief Scientist of the Human Factors Research Division, was appointed to membership in the important VESA (Video Electronics Standards association) FPDM (flat panel display measurement) Committee. This is the primary international standards body for flat panel displays.

Human Vision and Electronic Imaging Conference

Dr. Andrew B. Watson attended the Human Vision and Electronic Imaging Conference in San Jose, CA. Dr Watson serves on the program committee for this conference.

Spatial Standard Observer: Technology Transfer

During the last quarter the researcher delivered presentations and held discussions with a number of companies that are interested in commercial development of the Spatial Standard Observer. Success in this direction will assist this project by providing further development and additional impetus for adoption of the standard observers as a metric for visibility in a wide variety of applications. The companies visited include Photon Dynamics, Westar Display Technologies, Radiant Imaging, KLA Tencor, and Applied Materials.

Spatial Standard Observer International Patent

ARC-14569-1PCT International Patent filed for spatial Standard Observer.

Invited to address Society for Information Display

Dr. Andrew B. Watson was invited to present keynote address on Display Quality at the annual meeting of the Society for Information Display, San Francisco, CA, June, 2006.

Editor for OSA Special Issue on Image Quality

Dr. Andrew B. Watson was invited to serve as guest editor for a special issue on Image Quality in the Journal of the Optical Society of America.

Draft of Article on "Motion picture response time: Simulation, verification, and subjective impact"

This article, to be included as part of an invited presentation at the Society for Information Display in June in San Francisco, CA, describes a new method for quantifying the visual effects of slow response times in liquid crystal displays (LCD). This work will also be presented to the Video Electronics Standards Association (VESA) meeting in April in Boulder CO. A NASA disclosure of invention has been submitted related to this work.

Lecture at Google

Dr. Watson presented a lecture at Google, Inc. entitled "Developing Human Vision Models for Video Compression, Display Design, and Other Visual Technologies." This lecture is part of the ongoing exchange between NASA/ARC and Google to explore areas of mutual research interest.

Human Factors Engineering Society Symposium

Invited to participate in ARC-led symposium proposal on Human Performance Modeling. Submitted abstract on Vision Science and Visual Technology.

This effort is cost shared with NASA Ames. Year two proposal has been accepted and funding will be transferred to NASA Ames.

William K. Krebs, Ph.D.