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From: General Aviation Human Factors Program Manager, ATO-P Human Factors R&D
To: General Aviation TCRG

Subj: GENERAL AVIATION HUMAN FACTORS FOURTH QUARTER '04 REPORT

Ref: General aviation human factors execution plans (http://www.hf.faa.gov/gafunded.htm)

1) Each project is listed below.

a) Human Error and General Aviation Accidents: A Comprehensive, Fine-Grained Analysis using HFACS

Fine-grained analysis of GA accident data. The fine-grained analysis of the GA accident data from 1990-2000 was completed this quarter. A fine-grained analysis was commissioned because simply knowing that skill-based errors (or any other type of error) are a major concern does not provide safety professionals sufficient detail to do anything about it. What was needed was a fine-grained analysis of the specific types of errors within each HFACS causal category, so that targeted interventions can be developed. With this in mind, we compared each HFACS classification with the NTSB's causal factor designation.

To aid in the presentation of the data, we will examine the fine-grained analysis for each type of unsafe act separately. Included in the results will be the "*top 5*" human causal factors overall, across accident severity, and seminal events.

Skill-based errors. The most frequently occurring human error categories within skill-based errors are presented in Table 1. As can be seen, nearly 12% of all skill-based errors involved errors in maintaining direction control, followed by airspeed (10.63%), stall/spin (7.77%), aircraft control (7.62%) and errors associated with compensating for wind conditions (6.18%). Together, these five cause factors accounted for nearly one half of all the skill-based errors in the database. Additionally, the types and frequencies of skill-based errors coded as fatal/non fatal and seminal events are also shown in Table 1. The percentage of skill-based errors involving stall/spin, airspeed, and aircraft control were greater for fatal than non-fatal accidents. In contrast, causal factors such as directional control and compensation for wind conditions were rarely associated with fatal accidents.

Such findings make sense when one considers that errors leading to a stall/spin, as well as airspeed and control of the aircraft in the air typically happen at altitude, making survival less likely. In contrast, errors controlling the aircraft on the ground (such as ground loops) and compensation for winds (typically seen during cross-wind landings), while dangerous, don't necessarily result in fatalities.

Decision Errors. Table 2 presents the most frequently occurring decision errors. Improper in-flight planning tops the list, contributing to roughly 18% of all decision errors. The remaining decision errors, such as preflight planning/decision errors (8.94%), fuel management (8.73%), poor selection of terrain for takeoff/landing/taxi (7.85%), and go-around decisions (6.03), all occurred at approximately the same frequencies. Combined, these five causal categories accounted for roughly half (49.89%) of all decision errors in the database. It should be noted, individual factors related to weather-related decision making did not reach the top of the list (e.g., weather evaluation, flight into adverse weather, and inadvertent VFR flight into IMC). However, when combined, they did constitute a significant portion of the factors related to decision- making (6%).

Table 2 also presents the types and frequencies of decision errors for fatal/non fatal and seminal events. As indicated, the categories in-flight planning and planning/decision making on the ground tended to be associated more often with fatal than non-fatal accidents. Whereas the categories unsuitable terrain, go around, and fuel management were associated more often with non-fatal accidents. This pattern was generally consistent for the overall data, as well as within seminal events.

Perceptual errors. A review of accident causes and factors coded as perceptual errors revealed that misjudging distance was most common, accounting for over a quarter of all perceptual errors (26.4%; see Table 3). The next highest was flare (22.5%), followed by misperceiving altitude (11.4%), misjudging clearance (7.0%) and visual/aural perception (5.1%). Together these errors accounted for nearly three quarters of all perceptual errors in the database.

The types and frequencies of perceptual errors as they occurred within fatal/non-fatal accidents are also shown in Table 3. There was very little difference in the percentage of fatal and non-fatal accidents associated with any particular type of perceptual error. The only exception appears to be perceptual errors related to performing the flare, which in most cases is associated more with non-fatal than fatal accidents.

Violations. The *top five* violations are presented in Table 4. Analysis of the fundamental types of unsafe acts that are included within the violations categories reveals that the most common violation involved visual flight rules (VFR) flight into instrument meteorological conditions (IMC) (15.5%) and not following known procedures or directives (10.9%). The remaining top violations included operating aircraft with known deficiencies (9.9%), performing hazardous maneuvers, such as low altitude flight or buzzing (8.7%), and flight into adverse weather (8.5%). Together, these five variables accounted for over half of all violations in the database.

The types and frequencies of violations for fatal/non-fatal and seminal events are also presented in Table 4. As indicated, the categories VFR flight into IMC, hazardous maneuver, and flight into known adverse weather were much more likely to be fatal than non-fatal, both overall and for seminal events only. This pattern is consistent with the observation that accidents involving violations of the rules are, in general, more likely to be fatal.

Table 1. **Five Most Frequent Skill-based Error Categories for Fatal and Non-fatal Accidents.**

ERROR CATEGORY	***OVERALL Frequency (%)***			**SEMINAL Frequency (%)**		
	Fatal	**Non-fatal**	**Total**	**Fatal**	**Non-fatal**	**Total**
Directional Control	20 (0.50)	2018 (15.2)	2038 (11.8)	9 (0.57)	1326 (17.5)	1335 (14.6)
Airspeed	713 (17.9)	1127 (8.5)	1840 (10.6)	302 (19.2)	605 (8.0)	907 (9.9)
Stall/Spin	592 (14.9)	753 (5.7)	1345 (7.8)	84 (5.3)	144 (1.9)	228 (2.5)
Aircraft Control	654 (16.5)	665 (5.0)	1319 (7.6)	311 (19.8)	429 (5.7)	740 (8.1)
Compensation for winds	23 (0.6)	1046 (6.2)	1069 (6.2)	12 (0.8	859 (11.4)	871 (9.5)

Table 2. **Five Most Frequent Decision Error Categories for Fatal and Non-fatal Accidents.**

ERROR CATEGORY	***OVERALL Frequency (%)***			**SEMINAL Frequency (%)**		
	Fatal	**Non-fatal**	**Total**	**Fatal**	**Non-fatal**	**Total**
In-flight Planning	268 (22.9)	683 (17.0)	951 (18.3)	133 (22.6)	427 (19.8)	560 (20.4)
Planning/Decision-making on the Ground	115 (9.8)	349 (8.7)	464 (8.9)	89 (15.1)	284 (13.1)	373 (13.6)
Fuel Management	40 (3.4)	413 (10.3)	453 (8.7)	20 (3.4)	252 (11.7)	272 (9.9)
Unsuitable Terrain Selection	16 (1.4)	391 (9.8)	407 (7.8)	5 (.85)	284 (13.1)	289 (10.5)
Go Around	22 (1.9)	291 (7.3)	313 (6.0)	5 (.85)	70 (3.2)	75 (2.7)

Table 3. **Five Most Frequent Perceptual Error Categories for Fatal and Non-fatal Accidents.**

ERROR CATEGORY	***OVERALL Frequency (%)***			**SEMINAL Frequency (%)**		
	Fatal	**Non-fatal**	**Total**	**Fatal**	**Non-fatal**	**Total**
Distance	26 (17.8)	233 (27.7)	259 (26.4)	23 (33.8)	135 (26.5)	158 (27.4)
Flare	5 (3.4)	217 (25.8)	222 (22.5)	4 (5.9)	163 (32.0)	167 (28.9)
Altitude	22 (15.1)	91 (10.8)	113 (11.4)	9 (13.2)	51 (10.0)	60 (10.4)
Clearance	18 (12.3)	51 (6.1)	69 (7.0)	14 (20.6)	41 (8.1)	55 (9.5)
Visual/Aural Perception	15 (9.6)	36 (4.2)	50 (5.1)	3 (4.4)	5 (1.0)	8 (1.4)

Table 4. **Five Most Frequent Violations for Fatal and Non-fatal Accidents.**

ERROR CATEGORY	***OVERALL Frequency (%)***			**SEMINAL Frequency (%)**		
	Fatal	**Non-fatal**	**Total**	**Fatal**	**Non-fatal**	**Total**
VFR Flight into IMC	305 (25.8)	53 (4.7)	358 (15.5)	182 (30.5)	29 (5.2)	211 (25.8)
Procedures/Directives Not Followed	75 (6.3)	176 (15.6)	251 (10.9)	37 (6.2)	109 (19.6)	146 (12.7)
Operating Aircraft with Known Deficiencies	61 (5.2)	168 (14.9)	229 (9.9)	27 (4.5)	97 (17.4)	124 (10.8)
Hazardous Maneuver	154 (13.0)	47 (4.2)	201 (8.7)	83 (13.9)	24 (13.9)	107 (9.3)
Flight into Known Adverse Weather	135 (11.4)	61 (5.4)	196 (8.5)	85 (14.3)	41 (7.4)	126 (10.9)

The requirement is complete. Reports are available at http://www.hf.faa.gov/gafunded.htm

b) Comparison of the Effectiveness of a Personal Computer Aviation Training Device, a Flight Training Device and an Airplane in Conducting Instrument Proficiency Checks.

This project has been completed and a final report was submitted for approval to the COTR (Dr. Dennis Beringer) and AAR-100 (Dr. William "Kip" Krebs). The study was conducted to compare the performance of pilots receiving an instrument proficiency check (IPC) in a personal computer aviation training device (PCATD), a flight training device (FTD) or an airplane (IPC #1) with their performance in an airplane (IPC #2). The comparison of performance in a PCATD to that in an airplane investigates the effectiveness of the PCATD as a device in which to administer an IPC. Currently, the PCATD is not approved to administer IPCs.

The comparison of performance in a FTD with performance in an airplane will help determine whether the current rule to permit IPCs in a FTD is warranted. The comparison of the performance in a PCATD and a FTD permits a comparison of the relative effectiveness of the respective devices. Finally, the comparison of performance of pilots receiving IPC #1 in an airplane and IPC #2 in an airplane with a second CFII will permit the determination of the reliability of IPCs conducted in an airplane.

This study involved 75 participants (25 participants in each group: FTD, PCATD and airplane). Each participant agreed to refrain from instrument flight (either in flight or in a ground-based device) between IPCs #1 and #2. They also flew a familiarization flight in the FTD, the PCATD and the airplane prior to being randomly assigned to one of the three groups (FTD, PCATD and airplane). The participating instrument pilots in the study were in one of four categories of instrument currency: (1) instrument current, (2) within one year of currency, (3) between one and two years of currency, and (4) between 2 and 5 years of currency and they were balanced among the three groups. Pilots in the 2 to 5 year category received up to five hours of instrument proficiency training in either a FTD or a PCATD prior to the experiment.

The results indicated no significant differences in performance by instrument pilots on an IPC given in either a PCATD, and FTD or an airplane. Performance on the IPC of the PCATD group was statistically indistinguishable from both the airplane and the FTD groups. In addition, there was no difference in performance between the aircraft and the FTD groups.

It was expected that performance on IPC #1 would be a good predictor of performance on IPC#2. The results indicated that the prediction was no better than chance. The change in performance between IPC #1 and IPC #2 for all participants was statistically significant, but none of the comparison experimental groups were significant. Analyses to determine the performance changes between IPC #1 and the IPC #2 for each experimental group were conducted and improvement and deterioration ratios were calculated. The improvement and deterioration ratios for the three groups were very similar.

Notably, only 24 of the 75 participants passed IPC #1 (32%), and 51 failed (68%). Of the 53 instrument current pilots, only 19 (36%) passed IPC #1 and 34 failed (64%), but 30 passed IPC # 2 (57%) in the aircraft and 23 failed (43%). These results are comparable to those of an earlier study by Taylor, Talleur, Bradshaw, Emanuel, Rantanen, Hulin and Lendrum (2001).

This project has been completed and a final report has been submitted for approval.

c) <u>Credit for Instrument Rating in a Flight Training Device or Personal Computer: Phase III: Transfer of Training Effectiveness of a Flight Training Device (FTD).</u>

During the quarter, 7 students enrolled in AVI 140 (Advanced Instruments) for the summer semester. An additional 13 students enrolled in AVI 140 for the fall semester and were making satisfactory progress as of the end of the quarter. These enrollment levels created the following expected sample sizes at the conclusion of the study this fall: Airplane = 18; P5 = 17; F5 = 18; F10 = 17; F15 = 16; F20 = 18. (The expected drop-out rate may decrease these numbers by one per group.) Descriptive statistics for the groups through summer 2004 are presented below in Table 1.

Table 1. Flight Lesson 60 Statistics (including semesters from Spring 2003 through Summer 2004) summarizing outcomes by training device and number of hours on device.

	Airplane Only	***PCATD***	***Frasca Trainer***			
Hours in training device	*(NA)*	*5*	*5*	*10*	*15*	*20*
Number of Students reaching check ride (lesson 60)	17	17	17	15	13	16
% Students taking 1st check ride who passed *(numbers of students)*	47.1 *(8 of 17)*	52.9 *(9 of 17)*	52.9 *(9 of 17)*	40.0 *(6 of 15)*	46.2 *(6 of 13)*	62.5 *(10 of 16)*
% Students requiring 2nd check ride who passed *(numbers of students)*	100.0 *(9 of 9)*	75.0 *(6 of 8)*	100.0 *(6 of 6)*	88.9 *(8 of 9)*	100.0 *(7 of 7)*	66.7 *(4 of 6)*
Number of Students requiring 3rd check ride who passed	0	1	0	1	0	1
Students failing 1st or 2nd check ride and not receiving 3rd	0	1	2	0	0	1
Mean Total Dual hours (in airplane) to Completion for those passing the check ride on 1st, 2nd, or 3rd attempt *(& sample size)*	26.02 *(n=17)*	25.77 *(n=16)*	24.55 *(n=15)*	23.78 *(n=15)*	22.18 *(n=13)*	20.11 *(n=15)*
Variance in Total Dual hours to Completion	15.10	6.43	7.74	8.87	11.25	11.30

All available information indicates the project is on track.

d) Visibility in the Aviation Environment

Dr. Mizokami has continued to apply Dr. Bruno Olshausen's "sparse coding" analysis to natural images in the aviation environment. We have continued to develop training software to teach pilots how to recognize distance, relative direction, and altitude of targets. Further advances towards a basic "beta" version of this have been made incorporating relative altitude. Data collection has continued for images in the aviation environment as proposed in Phase 1 of the project. We have also continued to collect a series of in-flight images of other aircraft using a stabilized telephoto lens. We continue to evaluate and adapt vision detection models to the visibility issue. From this work it is clear that current detection models do well in specific applications. However, additional complex parameters that account for search behavior and limitations need to be incorporated into these models. We have continued to develop software to test pilot target detection capabilities on various backgrounds composed of aviation images. We have started developing detection experiments designed to evaluate the utility of synchronous and asynchronous strobe lights as aids to detection. We have also started developing experiments that will objectively measure performance under simulated flat light conditions.

Our best accomplishment this quarter is the continued progress in evaluation of detection models to the application and Dr Mizokami's continued progress in learning and implementing sparse coding algorithms for aviation scenes.

Anne Graham (AFS-800) who is the sponsor point-of-contact of this requirement visited Dr. Crognale last month to review the project's progress and suggest changes to some upcoming deliverables. She reported that the project deliverables are on track.

All available information indicates the project is on track.

e) <u>Electronic Primary and Multi-function Flight Displays for GA; Certification Criteria and Usability Assessments.</u>

The first experiment planned for this project was completed and results communicated to the sponsor. Details of the findings were submitted in the report for the third quarter of this year and in the FY04 annual report. Findings were also briefed to the Human Factors Coordinating Team in Seattle (Transport Directorate). An abstract of the work was submitted for review to the International Symposium on Aviation Psychology to be held in Oklahoma City in April, 2005 (D. Beringer site chairman). Technical report and proceedings article manuscripts are in preparation. Follow-on evaluations that would be warranted in light of the reported results being discussed with the sponsor.

All indications indicate that this project is on track to complete the milestones as planned.

f) <u>FAA/Industry Training Standards (FITS)</u>

Final Report Executive Summary: In 2002 the FAA, academic and industry partners established the FAA/Industry Training Standards (FITS) program whose purpose is to modernize General Aviation (GA) pilot training. The FAA recognized the need to modernize training standards for pilots who would use new avionics technology that integrate the GPS (Global Positioning Systems) with the autopilot along with multifunction displays capable of depicting flight path, weather, terrain and traffic information. These avionics and displays are touted as improving safety by enhancing pilot *Situational Awareness* and reducing pilot workload. The new technology has highlighted the need for programs to train and certify pilots to use the avionics suites. The instrumentation places new demands on pilots including changes in the level and distribution of pilot workload during a flight, the need to manage and integrate information from multiple displays, navigate complex menu structures, and program navigation computers. The literature describing the FITS program argues that the current structure and content of GA pilot training programs will not adequately prepare pilots for the challenges of using these technologies (FAA, 2003a; Glista, 2003b; Wright, 2002). The FITS curriculum attempts to address these issues by stressing training of risk management, information management, aeronautical decision making and the use of computer-based education. It also proposes to change pilot instruction to make it more *relevant* to real world flying by relying on scenario-based training (SBT) Rather than the traditional sequential skill acquisition approach to instruction, FITS stresses a SBT program wherein individual flying skills are practiced as part of a larger scenario. For instance, a student pilot might be instructed to plan a flight from Wichita, KS to Kansas City, MO. The student would perform all the tasks necessary to plan the flight including preflight checks, route planning, checking the weather reroute etc. During the flight the student would demonstrate individual flight skills including turns, climbs, navigation, and communication while executing the scenario. The purpose of this project was to review research related to the proposed initiatives and to identify future research needs to support the long term objectives of FITS. In addition to reviewing pertinent academic and government literature, the objectives of FITS were reviewed with representatives of the FAA, academic and industry partners. It is concluded that a case has not been made justifying important FITS initiatives (i.e., SBT). Few details are available regarding important components of the training initiative including decision making, the training requirements of advanced avionics technology and its effects on situation awareness. The program would benefit by drawing on an extensive academic literature and on lessons learned from prior industry experience when similar avionics technology were introduced to commercial aviation.

This project has been completed and a final report has been submitted for approval.

g) Migration of HFACS database to a web-based interface

The HFACS system (http://www.hf.faa.gov/hfacs/) advanced search was completed. A basic search screen was then developed and implemented that mimics the functionality of the NTSB accident/incident search. Also during this time, a significant portion of the pilot data entry and analysis code was completed. This will eliminate the need for a 3rd party to interact with HFACS analysts for coding of cases in the NTSB database.

Work is still ongoing to standardize and automate data importation from the FAA NASDAC system. Also still pending is the administrative section of the application, which will allow CAMI personnel to analyze data entry for consistency and problems.

All available information indicates the project is on track.

h) Unmanned Aircraft Vehicle Mishap Analysis

In July, the principle investigator (Dr. Kevin Williams, CAMI) traveled to King Salmon, AK to act as an observer for the operational test of a UA system called the Altair, made by General Atomics, Inc. The operational test was sponsored by the Coast Guard. The NASA Access 5 group acted as observers for the missions and Dr. Williams traveled in support of their activity. A report summarizing the operational test observations is being written. Additionally, a report was written outlining See-and-Avoid problems that were documented at King Salmon. Summaries of observations of the King Salmon, AK operational test of the unmanned aircraft in July have been provided to the NASA Access 5 group. A report is being written by the group. In addition, the report entitled, "*A Summary of Unmanned Aircraft Accident/Incident Data: Human Factors Implications*" has been completed and is undergoing review. A tour of NASA Ames Research Center UA lab was conducted in July. The lab has a Shadow simulation, which is an Army UA. A request was made for the Dr. Williams to participate as a panel member for the evaluation of proposals to perform a market survey entitled "The Role of Human Factors in Unmanned Aerial Vehicles". Approximately 15 entities have submitted proposals. A request was received from a Colonel Brian Keatings (RAF) liaison attached to the

Pentagon for information regarding medical qualifications for UA pilots. Information about current efforts by ASTM, NASA Access 5, and the FAA was provided.

All indications indicate that this project is on track to complete the milestones as planned.

i) National Airspace Human Factors Integration Plan for Unmanned Aerial Vehicles

Investigators collected and summarized additional reports on the human factors of UAV flight; prepared a preliminary list of research questions that remain to be addressed before the integration of UAVs into the NAS; and prepared a five-page interim report for the FAA surveying the research issues of importance that have been identified thus far along with the relevant existing scientific literature. One of the investigators (C.D. Wickens) also met for discussions on research topics with a group of prominent UAV human factors scientists at the HFES in September.

The final report is due to AVR on December 31st, 2004

j) Symbol Set Discriminability Metrics

Dr. Al Ahumada, NASA Ames, will extend the Flight Deck Technologies and Procedures, Discriminability Assessment of Proposed Traffic Symbol Set research requirement. *Objective:* to investigate whether the luminance image discrimination model be modified to include color and extended to a multiple image classification model be used to predict text or symbol discriminability? The model input parameters will include: (1) CIE Yxy images of the actual images computed from display characteristics (number of pixels, CIE values, gamma, spatial size, etc), and (2) 'ideal' text or symbols (obtained from a look-up-table of accepted AVR symbols). The model will be tested on text and symbol data and if successful it will allow the user to predict users' text or symbol discriminability for a given display using accepted AVR text and symbols. *Approach*: the study will be divided into two phases: (1) create symbol library and (2) develop discriminability model to predict observers' ability to detect symbols on a given display. *Symbol Library*: task will primarily consist of psychophysical experiments and image processing. The Federal Aviation Administration will submit a proposed list of symbols to NASA Ames for evaluation. NASA Ames will characterize each symbol's CIE Yxy value of the actual images computed from display characteristics (number of pixels, CIE values, gamma, spatial size, etc). For each symbol in the library, CIE Yxy minimum and maximum values will be specified as well as the minimum spatial dimensions. *Discriminability model*: task will modify Ahumada's luminance model (Ahumada, 1996) to include color and extended to a multiple image classification model be used to predict text or symbol discriminability. The web based model will allow applicants to evaluate a given monitor's performance. The applicant will run the model by selecting symbols from the Symbol Library then entering the monitor's performance characteristics. The model output will state whether a selected symbol will be discriminated for that display. If the symbol is outside the desired performance, the model will recommend changes to increase symbol discriminability. *Deliverables:* (1) library of CDTI symbols to be used as the standard set of symbols to assess displays. (2) web application color vision model to predict users' text readability and symbol discriminability for a given display using accepted AVR text and symbols.

All available information indicates the project is on track.

k) Unmanned Aircraft Operator Qualification and Training Requirements

ASU market survey announcement was posted on May 28th 2004. Twenty-eight institutions responded to the announcement. ATO-P Human Factors R&D formed a review panel to down select some of the institutions to submit a cost proposal. The panel will then review the second round to select the final institution(s) for this requirement. ATO-P Human Factors R&D anticipated start date is December 2004.

The final report will be due to AVR on December 31st, 2005

William K. Krebs