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

Subj: AVIATION MAINTENANCE HUMAN FACTORS FOURTH QUARTER '04 REPORT

Ref: (a) Aviation maintenance human factors execution plans (http://www.hf.faa.gov/maintfunded.htm)

1) Each project is listed below.

a) An Evaluation of Broadband Applications to Aircraft Maintenance Safety

A task analysis has been completed at two major air carrier line maintenance facilities. All survey data has been collected and analyzed. An article describing the task analysis and survey work has been submitted. We have begun prototyping a PDA tool that will be used to evaluate usability factors for portable technology used by maintenance technicians while working on the ramp.

All available information indicates the project is on track.

b) Vision Testing Requirements for Certain Persons Maintaining and Inspecting Aircraft and Aircraft Components

NASA Ames: psychophysical data is being collected in 7 maintenance inspectors and 2 non-maintenance participants for multiple airframe crack images over a range of acuities. A publication being written for peer review is nearly complete. This paper will provide the data necessary for the FAA to establish an empirically-based visual acuity standard and will provide industry with a software tool for setting vision requirements in the future.

OSU/CAMI: Dr. Greg Good requested a "no-cost" extension to the NDI/NDT research grant until November 19, 2004. The extension will allow Dr. Good to continue to analyze data and prepare the final report. Dr. Good submitted an abstract, entitled "*Vision Of Aviation Maintenance Inspectors,*" for presentation consideration at the 2005 American Academy of Optometry Annual Scientific Meeting at Tampa, FL (December 9-

12). An abstract, entitled "*Medical Surveillance Programs for Aircraft Maintenance Personnel Performing Visual Inspection and Nondestructive Testing,"* co-authored by V. Nakagawara, R. Montgomery, and G Good, cleared internal CAMI review and was forwarded to AAM-1 clearance for presentation consideration at the 76th Annual Scientific Meeting of the Aerospace Medical Association in Kansas City, MO, May 2005.

Ongoing research activities include managing and evaluating vision and demographic data to determine the time interval for administration of vision screenings, developing draft guidance material for the administration of vision standards, and evaluating the potential impact that possible revisions in the recommended vision standards could have on the current aircraft maintenance workforce.

All available information indicates the project is on track to be completed FY05 Quarter 1.

c) Language Barriers Result in Maintenance Deficiencies

The researchers collected 249 completed questionnaires, to better quantify the incidence of each type of language error identified in the taxonomy from Phase I. Intervention effectiveness data was collected on 254 participants in mainland China, Hong Kong, and Taiwan during two separate trips to Asia in March/April and May, respectively.

GLM ANOVAS of each scenario showed that the four most frequently encountered scenarios (1, 2, 6 and 7) are concerned with directly work related verbal and written ability. The other three scenarios concern regional accents, and less-work-related events. We also asked what factors were associated with each scenario, giving:

Highest Related to Scenarios: Task is Complex, Task Instructions is complex, AMT's inadequate written English, AMT's inadequate verbal English, Time pressure on AMT

Lowest Related to Scenarios: Poor communication equipment, AMT does not ask for help, AMT uses native language under stress, Unwilling to expose lack of English

GLM ANOVA of intervention effectiveness showed Intervention was significant for Performance ($F(3,179) = 2.99$), while Task Card was significant at ($F(1,179) = 5.02$, $p = 0.026$). The Easy task card had a Performance score of 0.058 while the Difficult task card scored 0.052. Interventions grouped into two sets, with all three active interventions faster than the baseline condition.

We are planning data collection visits to Europe and Central / South America in January 2005, and have already received approval from four sites in Mexico and Argentina. A no-cost extension to May 2005 to complete this work have been approved. A paper was presented at the HFES Annual Meeting in September 2004 on this work.

Original objectives for Phase II were to:

1. Better quantify the incidence of each type of language error identified in the taxonomy from Phase I.

2. Quantify the effectiveness of representative intervention strategies to reduce language-related errors.

Deliverables were only defined by Phase II and were:

1. Our final report will provide refined estimates of error frequency, patterns of error types, effectiveness of intervention strategies and recommendations for FAA action to mitigate language related errors. We will provide a report on the activities in Year 3 on time by the end of the project period, to include all Asian sites.

Due to the researcher's inability to access maintenance facilities (current climate in aviation post 9/11), the researcher has not been able to collect the proposed data that was stated in the grant proposal. The researcher will receive a no cost extension to complete the grant by May 2005.

d) General Aviation Alaska Maintenance Accidents

Structured interviews with AK maintenance subject matter experts (SMEs).

In an effort to understand the issues facing AMTs in today's GA environment, a series of focus group surveys were carried out both in AK and in OK. Although far from complete, this initial effort was initiated to get a better understanding of those areas of GA maintenance that need to be addressed both from a regulatory, as well as from a maintenance/system safety, standpoint. Further interviews are planned for other regions of the U.S. in FY05. A summary of the data obtained from Alaska and Oklahoma are briefly summarized:

Alaska. A number of problems were mentioned by the Alaskan focus groups, ranging from training programs to oversight by regulatory agencies. One area of concern mentioned by our focus group members was licensing. Separate licensing for large aircraft, GA, and rotorcraft, in addition to doing away with endorsements was one possible remedy mentioned. Presumably, this would open the door for advanced training and recognize maintainers for the professionals that they are, not just technicians.

Also obtained from the focus groups was the apparent lack of qualified maintenance personnel in Alaska. A number of reasons were cited for this with the distinct lack of training facilities topping the list. Poor remuneration for GA maintenance personnel also makes retention difficult. Also of concern was the fact that training beyond certification is hard to come by in Alaska, not to mention expensive. Lack of training in basic mechanics in technical programs was also cited as a problem. Finally, the focus groups suggested that the pressure to graduate students from programs results in teaching to certification exams, rather than focusing on core subject matter.

Oklahoma. The focus group established in the Oklahoma City area echoed many of the same sentiments of the Alaska focus groups. For instance, the group was unanimous in their assertion that there were not enough qualified GA mechanics to meet industry demands. Furthermore, they also cited training as a major shortcoming in the industry. Specifically, a lack of training facilities and lack of ongoing training and certification opportunities in the GA sector were a major concern.

Oversight by the FAA was also voiced as a concern by the Oklahoma focus group. In addition, follow-up on manuals once they are submitted, surveillance of pilots performing

their own maintenance, and oversight of maintenance performed on weekends and after hours were all cited as issues. Finally, they were concerned that pay rates for GA mechanics were too low, which might make it difficult to keep people in the field.

HFACS analysis of maintenance data.

The analysis of GA maintenance data was completed this quarter. The results demonstrated that similar to other areas of aviation, skill-based errors (SBEs) were associated with the largest percentage of maintenance related accidents (Wiegmann & Shappell, 2003; Figure 1). These types of errors were followed by violations committed by AMTs (VMAINT) at 23.9%, violations by owner/operators (VOO) at 12.1% and decision errors (DE) at 8.2%. Of note, no perceptual errors were reported by the SMEs for maintenance related data.

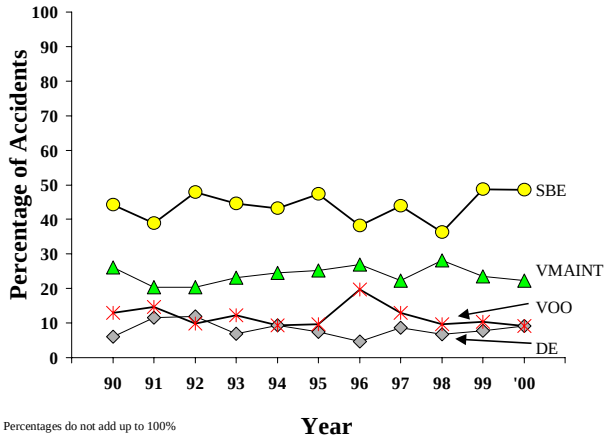

Figure 1. Overall accident rate by year and unsafe act.

Fine-grained analysis. In order to gain a better understanding of the specific types of errors committed, a fine-grained analysis was conducted for each of the unsafe acts reported above. Those errors, which comprised at least 5% of the unsafe acts within each HFACS error category, were reported. A brief summary of those results follows:

The most common decision error was the failure to comply with a service bulletin or letter. This comprised 35.2% of the decision errors in the sample. These decision errors were followed by maintenance overhaul (11.2%), and replacement of parts (8.0%).

The fine-grained analysis revealed that the most common skill-based error was installation, which accounted for 29.3%, followed by inspection errors accounting for 16.7%.

Violations attributed to AMTs were similar to skill-based errors in that the most common violation involved installation (16.7%), while the failure to follow procedures and directives were the second highest violation committed by an AMT at 12.6%.

Violations committed by owner-operators performing their own maintenance were somewhat different from those committed by AMTs. The most common violation in this case was the failure to obtain an annual inspection (18.2%). Following that, aircraft service and maintenance represented the next highest percentage of violations seen with owner/operators (10.6% each). Improper installation resulted in 10.9% of the violations, and unauthorized design change, modifications, and non-compliance with airmen's directives each accounted for 5.2% of violations observed in this causal category.

Comparison between Alaska and the Rest of the U.S. Because of the disparity in total events between AK and the RoUS, the comparison between the two will reflect aggregate numbers collapsed across the 10-year period rather than an annual comparison. This was done to account for the relatively small cell sizes found in the AK data.

The percentage of skill-based errors associated with maintenance related accidents for AK and the RoUS were essentially the same (AK=43.4%; RoUS=46.7%). Similar patterns were noted for decision errors with 8.1% of the maintenance-related accidents in AK associated with decision errors versus 11.2% in the RoUS. Likewise, violations for both AMTs and owner-operators revealed almost identical patterns whether they occurred in AK or the RoUS (AK = 23.9%, RoUS = 22.2% and AK = 12.1%, RoUS = 13.3%).

Fatal Events Related to Maintenance Unsafe Acts. In an effort to quantify a worst-case scenario of maintenance-related accidents, the unsafe acts were examined with respect to the degree that they factored into a fatal event.

The percentage of fatal and non-fatal maintenance related accidents associated with each of the unsafe acts is presented in Figure 2. What is evident is that skill-based errors are least likely to be associated with fatal accidents while violations attributed to owner/operators were most often associated with fatal accidents by an almost 3 to 1 margin. Indeed, nearly 1/3 of the accidents attributed in part to a maintenance violation committed by an owner/operator were associated with fatalities. Decidedly, fewer fatalities were attributed to violations committed by AMTs, although even they were twice as likely to result in fatalities when compared with skill-based errors.

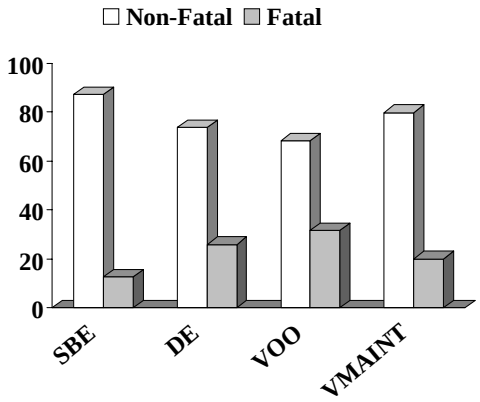

Figure 2. Percentage of maintenance related unsafe acts associated with fatal and non-fatal accidents.

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

e) Using Technology to Support Inspector Training

Incorporated multimedia data [text information, images of structures/defects, videos, and voice over support] into the training system. Developed version 1.0 of Design and Analysis module. Sought feedback from the users on the version 1.0 of Design and Analysis module. Refer to http://www.hf.faa.gov/docs/508/docs/GAITS_Design_module.pdf to view a demonstration of the Design and Analysis interface module.

Presented a poster at the Human Factors and Ergonomics Society (HFES) annual conference entitled "Improving Inspector's performance and reducing errors - The General Aviation Inspection Training Systems (GAITS)." The paper can be found at http://www.hf.faa.gov/docs/508/docs/maintGAHFES04.pdf.

Abstract: Inspection is an important step in ensuring product quality especially in aircraft industry where safety is the highest priority. Since safety is involved, effective strategies need to be set to improve quality and reliability of aircraft inspection/maintenance and for reducing errors. Humans play a critical role in visual inspection of airframe structures. Major advancements have been made in aircraft inspection, but General Aviation (GA) lags behind. Strategies that lead to improvement in inspection processes with GA environment will ensure reliability of the overall air transportation system. Training is one such strategy where advanced technology can be used for inspection training and reducing errors. A hierarchical task analytic (HTA) approach was used to systematically record and analyze the aircraft inspection/maintenance systems in geographically dispersed GA facilities. Using the task analytic approach a computer based training system (GAITS: General Aviation Inspection Training System) was developed for aircraft inspection that is anticipated to standardize and systematize the inspection process in GA. This paper documents the work involved in the development of General Aviation Inspection Training Systems.

Researcher continues to develop the simulation module, incorporate feedback from the users in the Design and Analysis module, seek feedback from the users in the Training module (Initiate, Access, Search, Decision, Respond and Return), and develop Introduction module prototype.

All available information indicates the project is on track.

f) An Assessment of Barriers to Implementation of Aviation Safety Programs (ASAP) in Maintenance Organizations

Based on the survey data, the factors that tend to contribute toward a successful ASAP program in aviation maintenance organizations are as follows:

- There is a significantly higher level of trust between mechanics and their supervisors
- End-users perceive ASAP programs to be very valuable in improving the overall safety
- Good communication about the ASAP program and a standardized or a well-understood report handling process exists

Factors that contribute toward the failure of an ASAP program in aviation maintenance organizations are as follows:

- There is a significantly lower levels of trust between mechanics and their supervisors
- End-users don't seem to see a significant benefit in having an ASAP program—it is likely that they are satisfied with their internal error/hazard reporting program
- There is a severe lack of awareness about ASAP programs

Ultimately, one could combine the above success/failure factors into two key themes:

- Level of employee-management-FAA trust
- Level of awareness about ASAP programs

Focus group discussions on this topic indicate that this trust is influenced by experience with internal safety programs, success with past safety programs, and general labor-management relationship. Awareness, on the other hand, is a matter of consistent and concerted advertising of the effects of ASAP programs as well as soliciting of feedback to improve the program.

The results of the second year of this research were presented at the *Shared Vision* conference in San Diego, CA, Oct 13, 2004. This presentation allowed the researchers to facilitate discussions regarding maintenance ASAP programs in the context of four other voluntary safety programs (Advanced Qualification Program, Flight Operations Quality Assurance, Internal Evaluation Program, and Voluntary Disclosure) and increase the overall visibility of maintenance ASAP programs among the industry as well as FAA representatives.

All available information indicates the project is on track.

g) Auditing and Surveillance Maintenance Error Tool

The researchers accomplished the following this quarter: conducted interview sessions with key members in the Quality Assurance and Audit departments at the FedEx facility in Memphis, TN; used task analysis to identify needs to support surveillance and inspection performance; created a process measures definition document for the departments of Surveillance, Auditing, and Airworthiness Directives; defined the impact variables to be considered for WebSAT, in association with key members in the Quality Assurance and Audit departments, at the FedEx facility at Memphis, TN and other variables; conducted a web based process measures validation survey with FedEx to ascertain the accuracy of the process measures defined by the research team; designed a framework of the WebSAT tool which would include the goals and the functions that would be accomplished by WebSAT.

The researchers presented a number of papers this quarter: (1) presented a paper at the SAHI conference at St Louis, MO, in March 2004. Presented two research papers have been accepted for presentation at Houston, TX, at the IERC conference, in May 2004, (2) presented the research in 2 poster competitions in the department of Industrial Engineering, Clemson University, (3) presented a poster at the research at the Clemson University research forum, and (4) presented a poster at the HFES conference at New Orleans, LA, in September 2004.

Next quarter, the researchers plan to conduct a web based process measures validation survey with other airlines to ascertain the accuracy of the selected process measures. Identify process measures using the need-metrics matrix. (October 20th , 2004), identify the modules that will be incorporated in WebSAT. (October 20th , 2004), develop the goals and functions to be included in each module.(October 20th , 2004), and to develop objectives for each module and sub – objectives for modules. (October 20th, 2004), schedule a trip to a participating airline company to validate the selected impact variables, started preliminary work on designing the iteration prototype for each module

using the conceptual design methodology. (October 31st, 2004), to write papers for ISAP 2005, IJAAS 2005, and IERC 2005.

All available information indicates the project is on track.

h) Effects of Fatigue, Vigilance, Environment on Inspectors Performing Fluorescent Penetrant and/or Magnetic Particle Inspections

After pilot testing of the simulation program for FPI inspection of engine blades, using six UB students and six NDI technicians from a partner airline, the program was modified and finalized.

Fourteen participants from the local community were tested initially. However, difficulties with the training program and data analysis meant that six of these have been discarded from the experimental design. Typical problems were rejecting almost all blades for indications that participants were told were not defects, and rushing through the whole blade library at unrealistic speeds. The training program has been strengthened and a re-familiarization session incorporated before each test.

So far, 8 participants from the local community have been run successfully. They are taking an average of 116 seconds per blade to search for a defect, and finding 66% of the defects. The False Alarm rate is 8.5%. Participants either perform for 1 or 2 hours, with or without breaks each 20 minutes, and start at 0300 or 0900 to test circadian effects. So far there is typical learning in performance times, but no change in either p(hit) or p(False Alarm) over time periods. No statistical analyses have been performed as the 8 participants represent only 10% of the complete 2^5 experimental design.

A paper was presented at the HFES Annual Meeting in September 2004 on this work.

Status of deliverables is as follows:

Phase I:

i. Report on comprehensive literature reviews on Vigilance, Inspection, Fatigue and hours of work. Status Green: completed by Jan 31 2004.
ii. Report on findings for distribution of working times, fatigue strategies, inspection environments. Have collected data from approximately 30 inspectors, and will collect additional data from our contacts in Year 2. Status Yellow
iii. Report on design of experiment and result of pre-tests. Status Green, FPI simulation tested on two groups of pilot subjects, and 8 actual participants. In process of completing report on initial analysis of these 8 participants.

All available information indicates the project is on track.

i) Human Factors Maintenance Considerations of Unmanned Aircraft

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 first report will be due to AVR on December 31st, 2005.

William K. Krebs