ATO-P R&D

Human Factors Research and Engineering Division

Human Factors Newsletter

Special Edition

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Researchers from CAMI's Aerospace Human Factors Research Division will be attending the Aerospace Medical Association Annual Conference, May 14-18, 2006. A list of their presentations is provided, followed by abstracts/summaries.

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ATC En Route Operational Errors:
The Centrality of Radar Display and Communication Errors

L. Bailey, J. Pounds, C.A. Manning, and D. Schroeder

Purpose: Reducing the number of severe and high moderate severe air traffic control operational errors (OEs) is one of the primary performance objectives of the Federal Aviation Administrations Air Traffic Control Organization (ATO). Within the En Route environment, the types of errors commonly associated with OEs include: data posting errors (DPE), radar display errors (RDE), communication errors (COME), coordination errors (CORE), and errors associated with a transfer of position responsibility (TPRE). To better understand error types and their interactions we examined the ATO's OE database and compared the percentage of single type OEs with the percentage of multiple type OEs. **Method:** All 1,144 of the en route severe and high moderate severe OEs were extracted from the ATO OE database (June 2001 though June 2004). Variables were created for five mutually exclusive single error types along with various combinations of the error types. **Results:** Sixty-one percent (61%) of en route OEs were the results of four single type errors: 1) RDE (38%), 2) COME (17%), 3) CORE (3%), and 4) DPE (2%). There was no single type TPRE. The remaining 39% of OEs were distributed across three OE clusters: 1) a radar cluster (17%) which included all error types except communications, 2) a communications cluster (20%) which included all error types except radar display errors, and 3) a data posting, coordination and transfer of position cluster (2%). **Discussion:** The results suggest that OE reduction can be best achieved by focusing attention on the human factors surrounding radar display errors (e.g., failure to detect displayed data and/or failure to comprehend displayed data) and communication errors (e.g., misunderstanding and/or failure to read back). Although the other error types have safety ramification, they by themselves do not appear to be sufficient contributors of the more severe types of OEs.

Human Error Associated with Air Medical Transport Accidents in the United States

A.J. Boquet, K. Holcomb, C.A. Detwiler, C.A. Hackworth,
D. Wiegmann, and S.A. Shappell

Introduction: Helicopter emergency medical services (HEMS) play a vital and growing role in the U.S. healthcare industry. However, since 1998, there has been a troubling increase in the accidents associated with this group. Like other aviation platforms, the majority of these accidents are human error related. **Methods:** Human error related HEMS accidents, operating under 14 CFR Part 91 (en route/repositioning flights) and 14 CFR Part 135 (patient transport) that were associated with at least one form of human error, were selected from the National Aviation Safety Data Analysis Center (NASDAC) and National Transportation Safety Board (NTSB) database. This research resulted in 74 accidents that had occurred from 1990 to 2003. Six certified flight instructors classified these accidents using the Human Factors Analysis and Classification System (HFACS). **Results:** Around 60% of the accidents were associated with a skill-based error (SBE), followed by decision errors (DE, 34%), perceptual errors (PE, 19%), and violations (15%). Of those accidents involving a SBE, 32% resulted in a fatality, compared with 20% for DE, and 43% for PE. However, when a violation was involved, 64% of these accidents had a fatality. Accidents were evenly split between day and night, 48% and 52% respectively; however, the occurrence of fatalities was not. For daytime accidents, 23% included fatalities compared with 45% at night. IMC operations took a greater toll with 74% resulting in fatalities, compared with only 20% in VMC. **Conclusions:** These data reveal that we are not facing one problem but numerous issues, all of which must be addressed. The multifaceted nature of this problem has been recognized by the FAA, resulting in collaborative effort with HEMS to institute risk assessment and risk management into emergency transport operations. These data provide a baseline to track the success of FAA-proposed interventions.

Human Error Associated with Commercial Aviation Accidents

C. Detwiler, K. Holcomb, C. Hackworth, A. Boquet,
D. Wiegmann, and S. Shappell

Introduction: Aviation safety has made huge strides over the past decades, so much so that it is rare to read about a U.S. commercial aviation accident. Today, commercial accident rates are unprecedented and the lowest in history; nonetheless, there are concerted efforts by government and civil organizations to maintain these levels and further reduce commercial accident rates. Past research has generally focused on contextual factors instead of the human error that is often associated with accidents. Analyses coupling the contextual factors and the underlying human error could aid in further accident reduction among commercial aviation operations. **Method:** Using the Human Factors Analysis and Classification System (HFACS), six pilots coded 1,020 14 CFR Part 121 and Part 135 commercial aviation accidents occurring between 1990 and 2002. **Results:** Consistent with previous findings, 68% of the commercial accidents involved at least one form of aircrew or supervisory error. Skill-based errors occurred most frequently, with Part 135 commuter pilots being almost 2 times more likely to commit this error than Part 121 air carrier pilots (odds ratio = 1.982, $X^2 = 16.670$, $p < .001$). There were also higher percentages of

perceptual errors and violations for Part 135 accidents but fewer decision errors. When examining unsafe acts that occurred in fatal versus non-fatal accidents, Part 135 accidents were almost 3 times more likely to result in a fatality if a violation was involved, (odds ratio = 3.145, $X^2 = 46.958$, $p < .001$). Fine-grained analyses of the unsafe acts associated with fatalities revealed that VFR into IMC conditions accounted for 31% of the violations. **Conclusions:** These data support the benefit of current intervention strategies recently introduced by government and civil organizations. Furthermore, by identifying the specific human error causal factors within Part 121 and 135 accidents, organizations can track current and future interventions.

Comparison of Intent-to-Leave with Actual Turnover within the FAA

C.S. Dollar and D. Broach

Introduction: Human capital planning in the federal sector relies upon past losses to estimate future turnover. Since the historical loss rate is a lagging indicator, an alternative estimate of future turnover might be derived from information about employee intent to leave. However, results from studies of the relationship between intent to leave and actual behavior have been mixed. Given the conflicting research findings, we investigated the correspondence between intent to leave and actual aggregate turnover rates in the Federal Aviation Administration (FAA). **Method:** Data describing intent-to-leave in the next 12 months were obtained in Employee Attitude Surveys of employees in the last quarters of fiscal years 1997 (N=25,004), 2000 (N=24,469), and 2003 (N=22,720). Actual turnover rates for the following fiscal years (FY1998, 2001, 2004) were calculated from data extracted from the Agency's official system of personnel records. The proportions of employees indicating intent to leave on each survey were compared with actual turnover using a Z-test of proportions. **Results:** Intent-to-leave expressed in each survey year significantly overestimated actual turnover in the year following the survey (1997 versus 1998, $Z = 37.77$, $p < .001$; 2000 versus 2001, $Z = 13.74$, $p < .001$; and 2003 versus 2004, $Z = 3.46$, $p < .001$). When analyzed by gender, intent-to-leave significantly overestimated actual turnover for both men and women. Analysis by minority status indicated that intent-to-leave overestimated actual turnover for minorities and non-minorities for the 1997/1998 and 2000/2001 but not for the 2003/2004 comparisons. **Discussion:** While overall, intent-to-leave expressed in surveys of employees does not appear to be of much use in predicting future turnover for the FAA, other variables (i.e., reasons for that intent, employee engagement, or organizational commitment) might prove beneficial in the Agency's Human Capital planning. We recommend that future research focus on analyses of those variables.

Static Sector Characteristics and Operational Errors

S.M. Goldman, E. Pfleiderer, and C.A. Manning

Introduction: Previous studies have identified airspace sector characteristics related to the complexity of air traffic control (ATC) operations. While the results of these studies have demonstrated a strong case for a relationship between complexity and operational errors (OEs), the relationship between sector characteristics and OEs has not been fully explored. The objective of this study was to determine if static sector characteristics are related to the

occurrence of OEs at the Indianapolis Air Route Traffic Control Center (ZID). **Method:** Sector characteristic data were combined with OE report data obtained from January 2001 to May 2005. Sectors were treated as the unit of analysis (N=40). Some of the static characteristics included: cubic volume in nautical miles, number of shelves, number of VORTACs, and number of intersections. These sector characteristics were entered into a standard regression procedure to predict the number of OEs occurring in each sector. **Results:** Only cubic volume in nm ($r = -.38$, $p = .01$) and sector strata ($r = .36$, $p = .02$) were significantly correlated with number of OEs. The regression analysis produced a model that accounted for 49% of the variance in OEs ($R = .70$). Both cubic volume and sector strata were significant predictors. **Discussion:** The correlation between cubic volume and OEs indicated that, as sector-size decreased, the number of OEs increased. However, the predictive utility of cubic volume may be due to underlying dynamic traffic characteristics inherent in different-sized sectors, rather than a direct relationship between sector size and OE incidence. The correlation between sector strata and OEs indicates that high-altitude sectors were associated with more OEs relative to low-altitude sectors. These results suggest that there is a relationship between some static sector characteristics and OE incidence in ZID airspace.

Aviation Maintenance Accidents: An Analysis Using HFACS

C. Hackworth, C. Detwiler, K. Holcomb, C. Bates, A. Boquet,
D. Wiegmann, and S. Shappell

Introduction: While maintenance-related problems are involved in fewer accidents when compared with aircrew errors, they involve significant financial costs for the aviation industry. Maintenance has been cited as a contributor to commercial and general aviation (GA) accidents. To understand human error maintenance factors linked to aviation accidents, the Human Factors Analysis and Classification System (HFACS) was used to classify GA and commercial accidents that occurred in the United States from 1990 to 2002. Due to differences in geography and reliance upon aviation as a mode of transportation, comparisons were made between accidents that occurred in Alaska versus the rest of the United States (RoUS). **Method:** Six certified instructor-level aviation maintenance technicians (AMTs) applied the HFACS taxonomy to code 1,725 accidents that occurred between 1990 and 2002 that had at least one maintenance-related factor. There were 1,569 GA (Part 91) and 156 commercial (Parts 121 and 135) accidents. **Results:** Analyses revealed that skill-based errors by maintainers were the most frequent factor associated with accidents, followed by violations committed by maintainers. This pattern was found for GA in Alaska, the RoUS, and commercial accidents in the RoUS. In contrast, violations by maintainers surpassed skill-based errors as the most frequent unsafe act for commercial accidents in Alaska. Errors in installation and inspection were the most common forms of skill-based errors. Additionally, maintainers were found to commit violations regarding installation and inspection. **Conclusions:** By identifying maintenance-related human error causal factors within Parts 91, 121, and 135 accidents, organizations are better prepared to track current and future interventions. These data suggest that effective error management should include targeted interventions aimed at installation and inspection, coupled with continuous monitoring of installation and inspection procedures. Educating owner-operators on proper maintenance and the risks associated with failing to obtain adequate inspections will foster the reduction of these maintenance-related accidents.

Human Factors Analysis of Agricultural Aviation Accidents

K. Holcomb, C. Detwiler, C. Hackworth, A. Boquet,
D. Wiegmann, and S. Shappell

Introduction: Aviation accident research has primarily focused on general aviation, commercial aviation, and military aviation. Little has been done in the area of aerial application flights, more specifically known as 14 CFR Part 137 operations. Agricultural flights require skilled pilots who are trained to operate in demanding environments. This study examined the human error associated with these accidents. **Method:** Between 1990 and 2002, 1,693 Part 137 accidents were classified using the Human Factors Analysis and Classification System (HFACS) by six pilot-raters. Of these accidents, 63% were associated with an aircrew error and submitted for further analyses. **Results:** Part 137 operations utilize both fixed- and rotary-wing aircraft; fixed-wing constituted 82% of the accidents, and helicopters were involved in 18%. Fatalities occurred in 12% of the accidents; however, there was a higher percentage that occurred in fixed-wing (14%) versus rotary-wing (6%). Skill-based errors (SBE) were associated with 76% of the accidents, followed by decision errors (DE), 19%; violations (V), 6%; and perceptual errors (PE), 6%. This trend for SBEs and DEs is consistent with previous HFACS findings. However, when comparing fixed- versus rotary-wing accidents, fixed-wing had a slightly higher percentage of SBEs (77% vs. 71%) and DEs (19% vs. 16%) but a lower percentage of Vs (6% vs. 8%). Agricultural accidents occurred in day conditions (92%), and relatively few happened in impoverished conditions (8%; i.e., at night, twilight, or in IMC). Over 30% of the accidents ended in controlled flight into terrain or obstacles (CFIT), with obstacles contributing to 73% of these CFIT accidents, the majority of which involved wire strikes. **Conclusions:** These data will aid in reducing human error related accidents among agricultural operations. Educating those involved with agricultural operations on the relevance of human error, particularly the issue of wire strikes, in these accidents will allow for data-driven intervention strategies.

Gauging the Impact of the Reweighting of AT-SAT

R.E. King and A.R. Dattel

Introduction: The Air Traffic Selection and Training (AT-SAT) test battery is the selection tool for applicants without previous experience for FAA Air Traffic Control Specialist (ATCS) positions. AT-SAT is an aptitude test developed to predict successful ATCS performance, and replaces the previous written test and lengthy screening program that had a high attrition rate. Before operational use, however, concerns were raised about potential overall low AT-SAT passing rates and score differences between groups. To address these concerns, the eight sub-scores of AT-SAT were re-weighted, and the overall constant was changed to yield a new total score without significantly reducing the battery's high criterion-related validity. **Method:** The present study compares the original and new scoring methods using data from 724 developmental ATCSs who volunteered to take AT-SAT. Their data were scored, subtest by subtest, under both systems and then compared by ethnic/racial group and gender, subtest and overall score. Results. Group and gender subtest differences were minimized under the re-weighting scheme. Also, an average increase of 4.86 points was found with the new scoring method; the passing (scoring 70 or above) rate changed from 58.8% to 80%. American

Indian/Alaskan Native, Hispanic, and black participants showed the largest average increases in overall scores. The increase in scores of Hispanic and black participants was significantly higher than the increase in scores for white participants [$F(4, 689) = 6.186$, $p < .001$]. **Conclusion:** While the use of research participants, who had previously passed a selection process, rather than actual applicants, calls for a degree of caution in predicting the behavior of future applicants; using the new weighting scheme for the eight subtests resulted in significantly fewer group score differences, thus reducing the potential of adverse impact. Overall, the re-weighting is benefiting all groups. Test validity, however, is an issue that needs to be continually assessed.

Describing Specific Air Traffic Controller Data Entries

C.A. Manning and E. Pfleiderer

Purpose:. We have been developing measures of air traffic controller task load and performance using software called Performance and Objective Workload Evaluation Research (POWER.) We have examined relationships between aircraft and controller activity but have not previously looked at how specific controller activities may inter-relate. That is the focus of this presentation. **Methods:** Ninety six-minute traffic samples were obtained from the Atlanta and Ft. Worth Air Route Traffic Control Centers. Specific controller data entries were compared with other measures of aircraft activity, such as the number and movements of aircraft, complexity ratings, amount of communications, and facility differences using Principal Components Analysis with Varimax rotation. **Results:** An extraction criterion of eigen values greater than or equal to 1 produced a nine-component solution. However, upon examination of the screen plot, a seven-component solution, accounting for 61% of the variance in the data, was found to be more interpretable. The components appeared to describe overall sector and Radar controller activity, climbing and descending aircraft, inter-facility differences, Radar Associate controller activity, conflict avoidance activities, VFR pop-ups, and longer sector transit time. Only data block offsets and handoffs accepted were related to the activity component. **Conclusions:** The results suggest that most controller data entries were not related to increases in overall sector activity. Instead, the entries tended to vary more by facility, type of traffic controlled, and support activities. Rather than simply describing workload, specific data entries appear to be more closely related to strategies for managing different types of air traffic.

A Comparison of Computer-Based Test Scores with the Performance Effectiveness Predictions of the Fatigue Avoidance Scheduling Tool

T.E. Nesthus, J. Ball, and L. Dobbins

Introduction: FAA international flight inspection operations involve trans-meridian travel that affects circadian rhythms and sleep. A tool that can effectively predict human performance would be useful for managing operational risk and maximizing operational efficiency. The Fatigue Avoidance Scheduling Tool (FAST™) incorporates a sleep-based model to predict performance task effectiveness (SAFTE™ Model). **Methods:** Eight FAA pilots, electronics, and research technicians conducting flight inspection operations participated in this study. Measures included actigraphy, sleep/fatigue/mood scales, and computer test performance. Data were

collected twice per day prior to, throughout, and following 14-day trans-meridian flight inspections. **Results:** Pearson Correlations examined observed test performance throughput scores (choice reaction time [CRT], mental arithmetic [MA], and grammatical reasoning [GR] tasks) and the FAST™ effectiveness predictions (FAST-E). Although relationships were weak, the FAST-E was negatively correlated with both MA (r = -.153, p = .003, n = 331) and GR (r = -.132, p = .01, n = 304) but not with CRT. Separate linear regressions using the FAST-E as the independent variable with MA and GA throughput as dependent variables. The MA model was a poor fit (R^2_{adj} = 0.023), but the overall relationship was significant ($F_{1,329}$ = 7.891, p = 0.005). The GR model also accounted for limited variance (R^2_{adj} = 0.018) but, again, the overall relationship was significant ($F_{1,302}$ = 5.387, p = 0.021). **Discussion:** This study compared the performance effectiveness predictions of the scheduling tool with results of a selection of computer tasks acquired during routine IFIO operations. The FAST™/SAFTE™ model's algorithms were developed primarily with laboratory data. Data for our study were acquired under operational field-study conditions. FAST™ fluctuations depicted both the negative effects of trans-meridian travel and improvement with adaptation, though our field-study results provided limited coherence with the tools' prediction-scores. This may reflect unknown field-environment conditions and/or less sensitive computer tests.

Comparison of Principal Components Analyses of Sector Complexity Ratings Conducted at Two En Route Facilities

E. M. Pfleiderer, C.A. Manning, and S.M. Goldman

Purpose: Environmental and contextual factors affecting controller workload and performance – often referred to as sector complexity – have been the focus of numerous studies. It is difficult to compare the results of these studies because of the variety of methods and measures used to assess complexity. In spite of the "embarrassment of riches" represented by the literature, one precept is evident: It is extremely important to compare complexity factors in as many environments as possible. The present study is a comparison of a Principal Components Analysis (PCA) of sector complexity factor ratings collected at the Atlanta air route traffic control center (ZTL) by Rodgers, Mogford, and Mogford (1998) with a similar PCA of sector complexity factor ratings collected at the Indianapolis air route traffic control center (ZID). **Method:** Participants were 36 volunteers (32 controllers and 4 operational supervisors) from ZID who rated the level of influence of 22 static and dynamic complexity factors for the various sectors within their area of expertise, producing a total of 181 observations. **Results:** PCA of the complexity ratings produced four components with eigen values >1.00, accounting for 62% of the variance in the data. Component 1 seemed to describe activity related to climbing and descending aircraft in the vicinity of major airports. Component 2 comprised complexity issues associated with low-altitude sectors providing approach services into non-towered airports. Component 3 was related to military operations and other Special Use Area (SUA) restrictions. Component 4 related to difficulties associated with inclement weather. **Conclusions:** The concordance of Components 1 and 3 with the first and third components in Rodgers et. al. suggests that these dimensions may be common to more than one facility. Given the large number of possible measures of sector complexity in the scientific literature, the discovery of two potentially stable dimensions is a major finding.

Terminal Radar Approach Control: Measures of Voice Communications System Performance

O.V. Prinzo

Introduction: Effective communications is an essential safety component of successful air travel. As technological advances lead to innovations in communication systems development, the National Airspace System may replace its current system with one encompassing both ground and airborne systems. Proposed replacements will be evaluated against the existing system's performance parameters. The presented data provide objective and quantifiable communications system performance metrics that may prove valuable to communication systems developers and personnel charged with evaluating, certifying, and deploying the next generation of communications systems. **Method:** The five busiest terminal radar approach control facilities in the contiguous United States each provided 10 hr of taped communications from which verbatim transcripts were created. For each facility, a frequency analysis identified eight 15 min samples that contained the highest frequency of air-ground transmissions. Voice and push-to-talk (PTT) onset and offset times were extracted (using Adobe Audition software) as were blocked, stepped-on, and clipped transmissions. **Results:** Nearly 8,000 transmissions were analyzed. Typically, utterances began 81 ms following PTT onset, lasted about 2.5 sec, and were followed by 127 ms of silence. The communications system could receive another transmission 73 ms following release of the PTT switch. A comparison between aircraft with and without disruptions revealed 14.54 messages were transmitted when a disruption was present and 9.90 messages when absent, [$t(735)=-7.257$], $p<.01$. **Conclusions:** Approximately 70% of each minute was devoted to air-ground communications (39 sec communicating, 2.5 sec for the systems to return to a resting state). Add in land-line transmissions and it is easy to determine that there are times when the current system nears saturation. Disruptions to efficient information transfer were rare events occurring in 1.16% of the sampled transmissions. Even so, there were indications that some type of a detection mechanism exists that alerted controllers to the presence of blocked transmissions.

Evaluation of Several Color Vision Screening Tests for Predicting Performance on Simulated Precision Approach Path Indicator (PAPI) Landing Lights

M.L.Rodriguez-Carmona, N. J. Milburn, and J. Barbur

The National Transportation Safety Board (NTSB) determined that the first officer's color vision deficiency was a contributing factor in the collision of FedEx Flight 1478 in Tallahassee, Florida in 2002. Consequently, the NTSB recommended that the Federal Aviation Administration (FAA) set up a program to evaluate the effectiveness of current color vision tests and protocols in screening out effectively those pilots considered "safe" in the aviation environment. We are therefore faced with two tasks; the need to establish minimum, safe limits of color discrimination sensitivity and, the development of a color vision test identifying with certainty those pilot applicants that do not meet these requirements. Visual task analysis carried out by the civil Aviation Authority (CAA) has identified the Precision Approach Path Indicator (PAPI) lights and the signal light colors as the most important color-critical tasks. We therefore propose to

establish how the applicant's color vision sensitivity assessed with the Color assessment and Diagnosis (CAD) test (Rodrigues-Carmona et al. 2005) correlates with his/her performance on the PAPI lights and the recognition of signal lights. In the laboratory, an optical system has been constructed reproducing accurately the spatial, radiometric and photometric characteristics of PAPI and signal lights. In addition to the CAD test, a number of occupational color vision tests will also be employed to assess the subject's color vision performance, including the Nagel anomaloscope, Ishihara plates, Dvorine plates and the FAA's Aviation Lights test. Both normal trichromats and color deficient observers will be examined in this study. The color discrimination limits beyond which color deficient observers behave differently to the group of normal trichromats on the simulated PAPI and signal lights test will be established. These results will then be used to set minimum color vision requirements that can be considered "safe" in the aviation environment.

ATC En Route Operational Errors: The Position Relief Briefing

A. Scarborough, and L. Bailey

Purpose: The Federal Aviation Administration's (FAA) Air Traffic Organization (ATO) has focused considerable attention on reducing the number and the severity of air traffic control operational errors (OEs) that occur as a result of the controller position relief briefings (PRBs). OEs that are associated with PRB errors are assumed to occur during the first few minutes following the transfer of position (i.e., when one controller relieves another). The purpose of this study is to test this assumption. **Method:** Two hundred seventy-two high severity and high moderate en route narratives of OEs attributed to PRBs were extracted from the ATO's OE database for June 2001 to June 2003. The narratives were organized in ten-minute intervals (10 to 90 minutes) from the initial transfer of position. Eight en route subject matter experts identified the ATC position that was being relieved, the reason for the transfer of position, and why the briefing played a factor in the OE. **Results:** The results identified two types of briefings: (1) replacement (79%), when one controller was being relieved of his/her job responsibilities, and (2) assistance (21%), when one controller was being relieved of part of his job responsibilities. Whereas 68% of all briefings of replacement occurred within the first 20 minutes on position, 85% of the briefings of assistance occurred 20 minutes or more following a controller entering on position. **Discussion:** These results challenged the assumption that PRB OEs occur shortly after the transfer of position. It appears that a PRB OE can occur anytime a person is on position depending on whether assistance is being provided or whether a controller is being replaced. Additional research is needed to determine whether a generic PRB checklist can adequately address all the transfer of position requirements associated with replacement and/or assistance or whether each type of transfer requires a specialized checklist.

Temporal Factors in Air Traffic Control Operational Errors

D.J. Schroeder, L.E. Bailey, C. Manning, and J. Pounds

Introduction: Of the thousands of operations handled by controllers each day, only a small number result in an OE, the rate per 100,000 operations in 2003 was only .78. As part of the

continuing effort to improve safety, the FAA Administrator's Flight Plan calls for efforts to reduce the number of more severe OEs. Historically, the data show that many OEs occur during the first 20 minutes after a controller assumes responsibility for a position. This study was designed to assess the human factors most closely associated with time-on-position. **Method:** OE data were extracted from the FAA database (1996 through 2004). Analyses were directed toward understanding the relationship between time-on-position and amount of traffic, time of day, day of the week and several other factors, including OE severity. **Results:** Of the 8,887 errors in the database, 16% occurred in the first 10 minutes on-position, another 16% took place during the next 10 minutes. The percentage (62%) that occurred during the first 30 minutes of the workday was considerably more than the percentage that occurred in the first 30 minutes on position during the remainder of the workday (38% to 47%). The results were roughly consistent across years and type of facility (en route center, terminal, and tower cab). Controller workload (number of aircraft) remained relatively consistent across time-on-position, with 60% to 74% of OEs involving 9 or fewer aircraft. Using a subset of data, the average severity rating remained relatively unchanged across time-on-position and time of day. **Conclusions:** Temporal factors appear to have a clear role in the occurrence of an operational error. However, we do not have sufficient baseline data to know the extent to which these differences reflect a departure from traditional scheduling practices. The higher incidence of OEs during the first duty period in the work day suggests that "readiness to perform" may be a factor. Additional human factors data are needed to clarify the role of several factors.

Establishing Unmanned Pilot Medical and Airmen Qualifications

K. W. Williams

This presentation is a summary of efforts undertaken to establish unmanned aircraft pilot medical and airmen certification requirements. Both political and safety considerations effected the establishment of medical certification requirement recommendations. The efforts included the convening of a panel of subject matter experts from across industry, government, military, and academia. There were also interactions with groups engaged in the process of establishing unmanned aircraft pilot guidelines. Results of this effort will be discussed, as well as recommendations for future efforts.

The Effects of Redundant Cues in ATC Color Displays

J. Xing

Introduction: The purpose of this study was to assess the effects of color use in air traffic control (ATC) displays for individuals who have color vision deficiencies, denoted as CVD. At present, color is widely used in many ATC displays, while the current vision standard used by the Federal Aviation Administration allows certain types of CVDs to enter the ATC workforce. One argument is that CVDs can use achromatic redundant cues to acquire the information represented by colors. Therefore, it is necessary to understand how CVDs use color in displays and whether redundant cues are helpful. **Methods:** Previously, we collected data from several

ATC facilities about how color was used in displays. The data revealed that controllers mainly use color for three purposes: drawing attention, identifying data categories, and segmenting complex scenes. In this study, based on the literature of vision research, we developed computational algorithms that could assess the effects of color vision deficiencies on the performance of color-related ATC tasks. The algorithms were used to a) compare the effectiveness of using color-coded information between CVDs and observers with normal color vision, and b) to compute the effectiveness of redundant visual cues relative to colors. We then applied the algorithms to six frequently used ATC displays to estimate the effectiveness of color and redundant cues for CVDs. **Results:** The main findings are summarized as follows: (1) Among the instances where color is used to draw controller's attention, 9% did not have redundant cues; in 43% of the occasions where there were redundant cues, they could not effectively draw users' attention; (2) 13% of the colors used for identification did not have redundant cues, and the redundant cues for 34% of the colors were not effective for users to identify information of a given category; (3) 35% of the colors used in text resulted in text readability lower than the threshold for error-free reading; (4) The percentage of colors used without redundant cues was higher among the decision-support displays than the operational displays. **Conclusions:** Having redundant cues is necessary but not a sufficient solution for ensuring CVDs' performance.

More information on human factors research can be found at the FAA Human Factors (ATOP-R&D) web site: http://www.hf.faa.gov

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