AAR-100

Human Factors Newsletter # 02-09

May 4 – May 17, 2002

<u>CAMI Research Reports</u> - Presentations at the 73rd Annual Scientific Meeting of The Aerospace Medical Association:

- **The Relationship of Flight Strip Marking and Strip Usage Preferences** (C. Manning, F. Durso, P. Batsakes, and J. Crutchfield; FAA Civil Aerospace Medical Institute, Oklahoma City, OK, Texas Tech University, Lubbock, TX, The Boeing Company, Seattle, WA). **Purpose:** New air traffic control (ATC) tools will require controllers to eliminate their use of paper flight progress strips. However, because of strip marking requirements and extensive training, controllers' use of strips is a long-established habit. We developed a set of questions about controllers' strip marking preferences to predict those who might have trouble reducing or eliminating strip usage. **Methods:** Two hundred ninety-five controllers at five en route centers were interviewed about why they made certain strip markings. They provided biographical information such as age and number of years as Certified Professional Controllers (CPC). Their preferences for using flight strips and other sources to obtain flight plan information were also obtained. These data were matched with observed counts of strip markings made during ATC operations. **Results:** Controllers who always said they preferred using strips (alone or in combination with other information sources) to obtain flight plan information were older ($X^2(1)=t12.53$, $p<.001$) and had been CPCs longer ($X^2(1)=t=8.49$, $p<.01$) than those who did not always prefer to use strips to obtain information. These controllers also made significantly more total marks ($t(291)=4.02$, $p<.001$) and more marks related to incoming and outgoing radar and communications ($t(291)=3.31$, $p<.01$). Also, those who never said they preferred to use strips to obtain information made significantly fewer clearance-related marks ($t(291)=2.30$, $p<.03$); marked significantly fewer issued clearances ($t(291)=2.20$, $p<.03$); and made significantly fewer marks for incoming and outgoing radar and communications ($t(291)=2.12$, $p<.04$). **Conclusions:** Controllers who said they preferred using strips marked them differently than those who said they did not prefer using strips. Strip marking preferences were also related to age and experience. This information could be useful in identifying controllers who have difficulties reducing their usage of flight progress strips.

- **Joint Safety Analysis Teams: A Cooperative Effort to Improve World-Wide Aviation Safety** (R.E. King; FAA Civil Aerospace Medical Institute, Oklahoma City,

OK). **Introduction**: Manufacturers predict the number of commercial airplanes in worldwide service will increase to 23,000 by the year 2015. An extrapolation of the data suggests nearly one hull-loss accident per week by 2015, even if accident rate remains stable. **Method:** Numerous organizations, including: DoD, FAA air carriers, aircraft manufacturers, and labor unions collaboratively agreed to address problems the data suggest are the biggest risks, focusing on those with the highest probability of reoccurrence. The identified major challenges include Weather, Turbulence, Runway Incursion, Controlled Flight into Terrain, Approach and Landing, and Loss of Control (LoC). The Commercial Aviation Safety Team (CAST) chartered Joint Safety Analysis Teams (JSATs) to analyze representative accidents in these areas. Team members aided by a facilitator, identified Events, generated Standard Problem Statements and Contributing Factors, and developed Intervention Strategies. Interventions were then rated (0 to 6) in three areas: Power (in a "perfect world"), Confidence (considering the real world), and Applicability (generalizability). Mathematically combining these ratings yielded an Overall Effectiveness (OE) rating. CAST then chartered Joint Safety Implementation Teams (JSITs) to assess the feasibility of interventions and to facilitate their implementation. The interventions with the highest ratings were forwarded to their respective JSIT. This presentation will focus on OE ratings from the LoC JSAT, which involved a mathematically refined process. **Results:** OE ratings from the LoC JSAT ranged from 0 to 4.6. As an example, due to it's rating of 3.8, Applying Risk Management to Maintenance Service Bulletins (intervention strategy #532), ranked 9th and was consequently operationalized for implementation by its JSIT. Typically, design changes garnered the highest OEs, while training recommendations tended to earn lower OEs. **Conclusions:** CAST/JSAT/JSIT used group process to develop interventions that may contribute to a significant reduction in aviation accidents and resulting fatalities.

- **The Effects of Task Load on Controller-to-Controller Communications and Situational Awareness** (L.L. Bailey and B.F. Willems; Civil Aerospace Medical Institute, Oklahoma City, OK and W.J. Hughes Technical Center, Atlantic City, NJ). **Purpose:** Recently, the Federal Aviation Administration (FAA) began a program of research to investigate the role that intra-team communication plays in helping radar air traffic control teams coordinate their individual efforts. Based on the literature of controller and pilot communications, it was hypothesized that as task load increased, communications would increase in order to maintain situational awareness. Furthermore, it was hypothesized that there would be an inverse relationship between task load and situational awareness. **Methods:** Using a high-fidelity air traffic control (ATC) simulator, ten 2-person teams, consisting of certified ATC specialists, performed routine ATC tasks within a single factor (low and high workload) repeated measure design. Performance was videotaped and the frequency of intra-team communications was counted. Post scenario perceptions of task load and situational awareness were assessed using a version of the NASA Task load Index (TLX) and a 4-item scale developed at the William J. Hughes Technical Center, respectively. **Results:** Bivariate correlations of intra-team communications (c), task load (t) and situational awareness (s) were separately analyzed for low and high workload. Because the sign of the correlations were established *a priori*, a one tailed test of significance was used with $p<.10$ as a test of significance. Results for the low workload condition were $r(c,t) = -.14$ (ns), $r(c,s) = .38$ (ns), and $r(t,s) = -.62$. Correlations for the high workload conditions were $r(c,t) = .51$,

r(c,s) = .63, r(t,s) = -.30 (ns). **Conclusions:** Under high workload conditions, as perceptions of task load increased, there was a corresponding increase in the frequency of intra-team communications. The data suggest that the increase in communications is used to maintain situational awareness. This conclusion supports the *a priori* hypotheses. However, under low workload conditions, the data fail to support the hypotheses, with the exception that perceptions of situational awareness decreased as task load increased.

- **Pilot Responses to Vacuum Failure in Flight Simulators and Aircraft** (D. B. Beringer, J. D. Ball, and K. Roy; FAA Civil Aerospace Medical Institute, Oklahoma City, OK, Air Safety Foundation, AOPA). **Purpose:** The General Aviation (GA) community has indicated an interest in employing a back-up attitude indicator in GA aircraft, possibly to the exclusion of the turn coordinator. Partial-panel flight has been shown to be challenging and to produce elevated workload, and a number of fatal accidents have been attributed to it. These studies gathered data on responses of instrument-rated GA pilots to simulated vacuum failures, both in flight simulators and in aircraft, to evaluate potential interventions. **Methods:** Two parallel studies were undertaken, one in flight simulators at the Civil Aerospace Medical Institute (Piper Malibu and Cessna 172), and one in two aircraft (Air Safety Foundation Piper Archer and Beechcraft Bonanza). Sixty instrument-rated pilots flew the simulators in 5 different display configurations (various combinations of attitude indicator, back-up attitude indicator, turn coordinator, and HSI or directional gyro). Thirty-six pilots flew the aircraft (24 in the Archer, 12 in the Bonanza). Data collected included flight performance, eye movement, and cockpit activity. **Results:** Loss of control occurred most frequently in the Advanced General Aviation Research Simulator with the most impoverished instrumentation condition (75%; partial panel and magnetic compass). Addition of other instrumentation decreased the frequency of control loss; specifically, adding an HSI and/or back-up attitude indicator. The simplex (Cessna simulator, Archer aircraft) models appeared more immune to control losses (Bonanza data are being collected at this time). Linear correlations with age and currency were weak or nonexistent in most cases. **Discussion:** It was evident that complex aircraft are more likely to produce flight-terminating outcomes in vacuum-failure conditions than are simplex aircraft. Recent experience with a vacuum failure appears to have a beneficial effect on performance, but simple recency of instrument flight does not (nor does total flight experience). There was a weak second-order effect for age, with slightly more losses associated with the oldest and youngest participants.

- **Comparisons of Sleep Duration, Subjective Fatigue, and Mood Among Four Air Traffic Control Shift Schedule Types** (T.E. Nesthus, K. Holcomb, C. Cruz, L. Dobbins, and J.T. Becker; FAA Civil Aerospace Medical Institute, Oklahoma City, OK, University of Pittsburgh Medical Center, Pittsburgh, PA). **Purpose:** A field study was designed to evaluate Air Traffic Control Specialists' (ATCSs) sleep duration, wakefulness, subjective fatigue, mood, and computer-based test performance during routine operational shift schedules. The field study was associated with a Congressional request to investigate the effects of shift work and fatigue on ATCSs. This presentation compares measures of sleep duration, subjective fatigue, and mood among four different shift schedule types, including: 2-2-1 (2 evenings, 2 early mornings, 1 midnight); 2-3 (2 evenings, 3 early mornings); 2-1-2 (2 evenings, 1 midday, 2 early mornings); and SS (5 straight early

mornings). **Methods:** Forty-four ATCS volunteers from two air traffic facilities were evaluated in this comparison. Performance testing, wrist activity monitoring, and logbook entries were integrated into each volunteer's workweek and off-time schedules. Sleep duration and subjective reports were evaluated relative to each shift schedule type for one week plus one day off. **Results:** As expected, significant main effects for day, and day-by-shift type interactions were found for the following measures: sleep duration, sleep quality ratings, pre- and post-shift sleepiness, and pre-shift positive affect scores. Sleep duration, sleep ratings, and mood for the first day off after the workweek followed trends consistent with recovery effects for the more difficult shift-types. **Discussion:** These results support previous research showing changes in reported sleep duration, sleep quality, mood, and fatigue associated with specific shift schedule features such as start times (e.g., early mornings, afternoons, midnights) and cumulative effects (e.g., progressive work-week fatigue). Of the 4 shift-type schedules evaluated in this study, the 2-1-2 generally showed better sleep quality, reduced fatigue, and improved mood scores across the week. The 2-2-1 and 2-3 schedules showed greater sleep duration during the day off which may indicate a greater need for sleep (i.e., sleep debt) by the end of the week.

- **A Comparison of the Effects of Clockwise and Counter-Clockwise Rapidly Rotating Shift Schedules on Complex Task Performance** (C. Cruz, A. Boquet, C. Detwiler, and T. Nesthus; FAA Civil Aerospace Medical Institute, Oklahoma City, OK 73125). **Introduction:** Many Air Traffic Control Specialists (ATCSs) work a relatively unique counter-clockwise, rapidly rotating shift schedule. Although arguments against these kinds of schedules are prevalent in the literature, few studies have examined rotating shifts such as those seen with ATCSs. The present study directly compared clockwise and counter-clockwise rapidly rotating shift work schedules on measures of complex task performance from the Multiple Task Performance Battery (MTPB). **Methods:** Participants (n=28) worked day shifts for the first week of the study (0800-1600), followed by two weeks of either a clockwise (n=14) or counter-clockwise (n=14) shift work schedule. Participants completed three 1.5-hour sessions on the MTPB on each shift following the first day of training. Each session contained low, medium, and high workload periods, as well as active- and passive-task components. **Results:** There were no group differences in the passive task composite scores. Instead, a shift-by-session interaction, $F(8, 19)=2.5$, $p=.048$, indicated that, while performance was generally lower on the last session of each shift, scores were lower by a much greater margin at the end of the midnight shift. Results for the active task composite scores indicated a 3-way interaction between week, shift, and rotation condition, $F(4, 23)=4.7$, $p=.006$. This complex relationship indicated that performance was consistently higher in the counter-clockwise rotation and was less variable across shifts than in the clockwise rotation. **Discussion:** These data do not support the hypothesis that a clockwise rotation will result in better outcomes on complex task performance. If anything, performance during the counter-clockwise condition was the same in the case of passive tasks or better and more stable in the case of active tasks. The empirical evidence gained from this study suggests that particular shifts, such as early morning and midnight shifts, may adversely affect sleep and performance more than the direction of shift rotation.

- **An Experimental Analysis of the Effects of Clockwise and Counter-Clockwise Shift Rotations on Three Biological Markers** (A. Boquet, C. Cruz, C. Detwiler, and T. Nesthus; FAA Civil Aerospace Medical Institute, Oklahoma City, OK 73125). **Introduction:** Most researchers recommend that shift rotation in a forward or clockwise direction will produce less disruption of circadian rhythms than those that rotate in a backward or counter-clockwise direction. This is based upon extrapolation from quasi-experimental studies of shift-workers and research on the effects of jet lag, which indicate that westward travel results in less disruption of circadian rhythms. This investigation examined the effects of direction of rotation on cortisol, melatonin, and temperature in participants randomly assigned to either a clockwise or counter-clockwise shift rotation. **Methods:** Twenty-eight participants worked a day shift (0800-1600) for one week followed by either a clockwise (n=14) or counter-clockwise (n=14) shift rotation for two weeks. Participants wore a flexible rectal temperature sensor for the three weeks of the study and were allowed to remove the probe for 90 minutes each day. Saliva samples were collected at the end of the baseline week for later assay for melatonin and cortisol, and were time-locked to collection times during the two "shift work" weeks. **Results:** No group differences were found for cortisol for either of the workweeks. The clockwise group, however, had a significantly greater increase in melatonin during the midnight shift, compared with the counter-clockwise group. Finally, analyses of core body temperature revealed greater amplitude for the clockwise group and a delay of the acrophase for the counter-clockwise group of 84 minutes during both weeks of testing. **Discussion:** While cortisol levels did not appear to differ based on direction of shift rotation, there were inherent differences with melatonin secretion and core body temperature. Precisely why such differences exist remains unclear but may be similar to that seen with circadian resynchronization during westward travel. Furthermore, it is not clear if these differences would persist in individuals exposed to longer periods of shift rotations.

- **The Relationship between Gluccocorticoid Activity and Cognitive Performance in the Bakan Vigilance Task** (C. Detwiler, A. Boquet, C. Cruz, and T. Nesthus; FAA Civil Aerospace Medical Institute, Oklahoma City, OK 73125). **Introduction:** There is a growing body of evidence suggesting that chronic exposure to increased levels of circulating gluccocorticoids (GC) can impair cognitive performance. Specifically, it appears that up-regulation of the hypothalamic-pituitary-adrenocortical (HPAC) axis results in inhibition of the negative feedback loop through the binding of cortisol to GC receptors in key cortical structures. The goal of the present study was to test the effects of clockwise and counter-clockwise shift rotation and HPAC activity on vigilance. **Methods:** Participants in the study worked one week of day shifts (0800-1600), followed by two weeks of either a clockwise (n=14) or a counter-clockwise (n=14) shift rotation. Saliva samples were collected for later assay of cortisol at the end of the baseline week and during the two "shift work" weeks. High and low cortisol reactors (HCR/LCR) were determined by a median split of their delta scores. **Results:** Analyses of the midnight shift yielded significantly fewer correct responses on the Bakan Vigilance Task for the HCR group compared with the LCR group, $F(1,24) = 5.9$, $p = .023$. Furthermore, the analysis of the afternoon shift revealed a significant shift by reactor group interaction, $F(3,22) = 3.6$, $p = .031$. Specifically, the HCR group had significantly fewer correct

responses for the last three measures obtained during the afternoon shift, compared with the LRC group. **Discussion:** The results support the hypothesis that higher levels of circulating gluccocorticoids are associated with decrements in cognitive performance. Indeed, those individuals susceptible to greater increases in gluccocorticoid activity may be at risk for concommitant decreases in cognitive performance.

- **Relationship of Employee Attitudes and Supervisor-Controller Ratio to En Route Operational Error Rates** (D. Broach and C. S. Dollar; FAA Civil Aerospace Medical Institute, Oklahoma City, OK). **Introduction:** An operational error (OE) results when an Air Traffic Control Specialist (ATCS) fails to maintain appropriate separation between aircraft, obstacles, etc. Recent research on OEs has focused on situational and individual characteristics (Center for Naval Analyses Corporation, 1995; Della Rocco, 1999; Rodgers, Mogford, Mogford, 1998). In this study, the relationship of organizational factors to en route OE rates was investigated, based on an adaptation of the Human Factors Analysis and Classification System (HFACS; Shappell & Wiegmann, 2000) to air traffic control as HFACS-ATC (Scarborough & Pounds, 2001). **Method:** 1997 and 2000 air route traffic control center (ARTCC) OE rates (errors per 100,000 operations) were obtained from the National Airspace Incident Monitoring System (NAIMS). Organizational factors were represented by facility mean scores on scales constructed from 1997 and 2000 FAA Employee Attitude Survey (EAS) data. Factors included employee perceptions of equipment/facilities, performance management, overall job satisfaction, and perceptions of other human resources management practices. The supervisor-controller ratio (SCR) was calculated for each ARTCC by year from agency personnel data. SCR and organizational factors facility mean scores were regressed on OE rate *(*N=42). **Results:** Two organizational factors and SCR accounted for 50% (adjusted R 2 = .505, $p < .001$) of the variance in OE rates across ARTCCs for the two years. The standardized regression coefficients were -.290 for perceptions of equipment/facilities *(*t=-2.07, $p < .05$), -.302 for perceptions of performance management *(*t=-2.28, $p < .05$), and -.395 for SCR *(*t=-3.360, $p < .01$). **Discussion:** As expected from prior research, SCR was a significant predictor of en route OE rates. In addition, the results indicated that perceptions of how performance was managed and of facilities and equipment were also predictors of OE rates. Overall, the results support the inclusion of organizational factors as well as individual and situational characteristics in the investigation of ATCS operational errors.

- **Stress, Anxiety, and Well-Being in Air Traffic Controllers** (D.J. Schroeder, P. Della Rocco, T. Nesthus, C. Cruz, and D. Thompson; William J. Hughes Technical Center, Atlantic City, NJ; FAA Civil Aerospace Medical Institute; and OMNI Corporation, Oklahoma City). **Introduction:** Scientific evidence has provided limited support for the commonly held view that air traffic control is a uniquely stressful occupation. Recent surveys indicate that occupational stress is evident in most work settings, with more than half of all employees (53%) reporting that they are generally "somewhat" to "extremely" stressed on the job. This study reports on the relationship between a single item measure of occupational stress and selected individual and organizational factors often associated with occupational stress. **Methods:** A total of 6,854 ATCSs responded to a modified version of the Standard Shift Work Index (SSI), including a single item used in a

nationwide survey asking ATCSs to indicate "In general, how stressed do you feel at work," using a 5-point Likert response scale. For purposes of this study, we were interested in controller responses to scales assessing fatigue, psychological well-being, cognitive and somatic anxiety, neuroticism, extraversion, digestive problems, cardiovascular problems, general job satisfaction, and circadian types. Analyses included ANOVAs correlation coefficients, and multiple regression analyses to determine factors associated with self-reported job stress. **Results:** Compared with the normative sample where 8% of employees reported "extreme" stress on their jobs, only 3% of controllers selected that category. On the other hand, only 12.8% of controllers indicated "not at all," compared with 22% in the national sample. Higher levels of self-reported job stress were associated with en route controllers, developmentals, and middle age (41-45). **Conclusions:** Consistent with previous findings, the level of stress and anxiety reported by personnel in the air traffic control profession was comparable to that noted in other occupations. While the level of cognitive anxiety was lower than that reported by Italian controllers, the extent of somatic anxiety was comparable for the two groups. The level of minor psychological disorders, cardiovascular complaints, and digestive complaints was relatively low.

- **General Aviation Accidents: An Assessment of Risk in Maintenance Activities** (S. M. Goldman, E. Fiedler, and R. King; FAA Civil Aerospace Medical Institute, Oklahoma City, OK). **Introduction:** The FAA's Safer Skies Initiative is designed to identify selected interventions for reducing commercial and general aviation (GA) fatal accidents. From 1988 to 1997, more than 4,000 fatal GA accidents have accounted for nearly 7,500 deaths. To date, efforts within the GA community have largely focused on evaluating human error associated with the flight crew, giving limited attention to the role of human error in maintenance. **Method:** Final reports for all maintenance-related accident investigations involving GA aircraft between 1988 and 1997 were obtained from the National Transportation Safety Board (N = 1,503). Study 1 analyzed the frequency of type of maintenance activity, type of aircraft, and number of fatalities. Study 2, which flowed from Study 1, analyzed reports involving only maintenance installation. **Results:** Study 1 found that over 7% of all GA accidents occurring between 1988 and 1997 were attributed to maintenance-related activities. Of these 1,503 maintenance reports, 300 (19.9%) cited installation as a cause or factor in the accident. Additionally, installation was the maintenance activity most likely to result in an injury or fatality *versus* no injury or fatality (odds = 1.40). Study 2 found that *incorrect attachment* (cited in 28.7% of the 300 installation reports) was the most frequent type of installation error. However, installing the *wrong part* (also categorized as an installation error) resulted in a greater likelihood of producing an injury or fatality *versus* no injury or fatality (odds = 1.88). **Conclusion:** Aviation maintenance technicians must perform many different maintenance tasks to keep aircraft in an airworthy condition. Understanding which maintenance activities pose the greatest safety risk is crucial to developing an effective error management program. This study found that installation error is not only the most often cited cause or factor in GA maintenance-related accidents but is also the maintenance activity most likely to result in death or injury.

- **WAIS Correlates of Cogscreen-AE Performance for Older Aviators** (M. M. Hawkins, E. R. Fiedler and J. L. Moore; FAA Civil Aerospace Medical Institute,

Oklahoma City OK and R.E. Mitchell Center for POW Studies, Pensacola FL). **Introduction:** The Wechsler Adult Intelligence Scale (WAIS) is a well-respected test of intelligence often used as part of a neuropsychological test battery. CogScreen-AE (CS-AE) is the only neuropsychological test battery with comprehensive aviator norms. The original validation of CS-AE (Kay, 1995) included information on the relationship of estimated IQ scores to CS-AE performance in a population of U.S. aviators (mean age 44 years). As part of a CS-AE revalidation, we studied the relationship of CS-AE performance to WAIS subtest and Full, Verbal and Performance IQ scores for an older group of aviators (mean age 57 years). **Method:** Participants were 86 male active or former military aviators, ages 48 to 69 years at the time of testing. Participants completed CS-AE and the full WAIS. Descriptive and correlational analyses were completed. **Results:** WAIS Full Scale IQ is significantly related to scores on three Speed (r = -.20 through -.37), six Accuracy (r = .18 through .31), five Thru-put (r = .24 through .35), and three Process (r = -.19 through .25) CS-AE variables. Verbal IQ is significantly related to scores on two speed (r = -.21 and -.38), five accuracy (r = .22 through .37), four Thru-put (r = -.19 through .37), and one process (r = .20) variable(s). Performance IQ is significantly related to scores on 11 Speed (r = -.18 through -.36), three Accuracy (r = .20 through .24), 12 Thru-put (r = .18 through .36), and two Process (r = -.19 and .28) variables. Nearly every CS-AE variable correlated with one or more of the 11 WAIS subtests. **Discussion:** Current results are discussed and contrasted with Kay's earlier findings. Comparing our results to Kay's, we found that the number of WAIS subtests that were significantly correlated to specific CS-AE variables was different for the two studies.

- **Developing Power (Performance and Objective Workload Evaluation Research) Measures for En Route Air Traffic Control** (E. M. Pfleiderer, C. A. Manning and S. H. Mills; FAA Civil Aerospace Medical Institute, SBC Technology Resources, Inc.). **Purpose:** Performance and Objective Workload Evaluation Research (POWER) measures are being developed to provide a platform for quantifying activity and task load in the en route air traffic control (ATC) work environment using routinely recorded National Airspace System (NAS) data. POWER measures represent an outgrowth of lists of variables previously identified by researchers in simulation studies and from verbal reports by controllers. The development and use of objective indicators of ATC activity and task load are requisite tools for establishing baseline measures for evaluating the effects of modifications to ATC systems. **Method:** NAS System Analysis Recording (SAR) data were collected from the Jacksonville en route center between 8:30-10:30 a.m. and between 12:00-2:00 p.m. (local time) for each of four consecutive days. POWER measures were computed in 30-minute intervals for all active sectors, yielding a total of 913 observations for each measure. A Principal Components Analysis (PCA) was conducted to evaluate the current set of POWER variables and provide guidelines for the addition of new measures or the modification of existing ones. **Results:** PCA with Varimax rotation converged in six iterations and produced four components with eigenvalues > 1. Cumulatively, the four components accounted for approximately 65% of the variability in the data set: Component 1 (Activity) accounted for 30%, Component 2 (Objective Workload) accounted for nearly 13%, Component 3 (D-side Activity) accounted for 12%, and Component 4 (Overload) accounted for 10%. **Conclusions:**

Variables comprising the four extracted components provided valuable information about the underlying dimensions of the NAS data set. Additions or modifications that might improve the ability of POWER to describe ATC activity and task load were identified.

- **A Multidimensional Approach to Test Item Selection in a Practical Color Vision Test** (N.J.Milburn, and H.W. Mertens; FAA Civil Aerospace Medical Institute). **Purpose:** Previous research evaluated the color vision requirements and perceptual factors related to interpretation of color-coded weather radar information and resulted in an 84-item developmental test. The objective of this study was to use Item Response Theory (IRT) methods to select the most efficient set of those items without adversely affecting the reliability or item domain of the test. **Method:** The participants were 335 individuals with normal color vision and 200 with varying degrees of red-green types of color vision deficiency. BILOG-3, using a specified 3-parameter IRT model, provided indices for discrimination, item difficulty, and guessing. The greater the discrimination value, the better the item discriminates high performers from low performers. Likewise, large difficulty values (in the positive direction) indicate more difficult items. Higher guessing values indicate a greater probability of guessing the correct choice. BILOG-3 also calculates an estimate of each individual's ability using the same scale as the item difficulty index. Using these indices, a composite scatterplot was constructed. With the item discrimination plotted on the Y-axis, and the item difficulty/ability estimate on the X-axis, boundary lines were drawn for the guessing parameter in addition to the minimum and maximum ability estimates for each anomaloscope diagnosis. Once the item's content was coded onto the scatterplot, items were evaluated on several dimensions to select the most efficient items. **Results:** Maintaining the original passing criterion of no more than 1 error, high consistency was found between the original 84 items and the 50-item test ($K_{(172)}$=.95). Correlation between percent correct scores was also very high ($r_{(172)}$=.99). The original inter-item reliability (α=.96) and item content were unaltered by shortening the test. **Conclusions:** The unique, multidimensional approach to item selection using the 3-parameter estimates coupled with item content and ability range information yielded 50 highly reliable items.

- **Automatic Dependent Surveillance - Broadcast (ADS-B) / Cockpit Display of Traffic Information (CDTI): Innovations in Pilot Managed Departures (**O. Veronika Prinzo, Ph.D.; FAA Civil Aerospace Medical Institute, Oklahoma City, OK). **Introduction:** Avionics devices that provide a cockpit display of traffic information (CDTI) enable pilots to acquire, verify, and maintain pre-defined spacing intervals from other aircraft. It is of interest to the FAA to determine how the use of these displays influences pilot/controller operational communications. The operational evaluation of the CDTI in October 2000 provided an opportunity to examine some of these issues. **Method:** Departure profiles (13 without CDTI, 32 with CDTI) were established to evaluate the ability of flight crews and air traffic controllers to manage long (6 nm) and short (4.5 nm) spacing intervals between departing aircraft during 3 day and 2 night operations. Subject matter experts evaluated 15 hours of verbatim transcripts and audiotapes for the presence of misidentified aircraft, confusions, uncertainty, and operational concerns. Computed for each departure was the time the aircraft was under local control, runway ownership time, and the number and duration of messages. **Results:** Approximately 4% of the departures conducted when CDTI was not used, and 9% when it was, involved communication

problems. In particular, for pilot messages during CDTI departures, aircraft call signs were misstated or incorrect. However, when CDTI was not used, controller messages included the correct flight identifier but the wrong company name. When CDTI was not used, more messages were exchanged during the short spacing interval. In contrast, when pilots executed CDTI departures, in addition to an overall increased time on frequency, more time was spent under local control during the day, and departures were completed in less time when assigned the short spacing interval. **Conclusions:** Communication problems occurred from the call sign procedure that distinguished between aircraft being talked to versus talked about. Fortunately these problems were detected and corrected mid-stream by the controllers and pilots, and statistically, communication efficiency was not impacted. In light of the findings and comments from the controllers and pilots, alternative call sign procedures will be constructed and evaluated for the departure spacing application.

- **Preliminary Analysis of Human Causal Factors in Runway Incursions** (A. Scarborough and J. Pounds; FAA Civil Aerospace Medical Institute, Oklahoma City, OK). **Introduction:** Runway incursions have steadily increased over the past four years and they continue to be one of the Federal Aviation Administration's top focal issues. Both technological and human-centered solutions are receiving increased attention. To identify strategies for mitigation of human factors in runway incursions, a retrospective analysis of 347 existing operational error narrative reports from runway incursions was conducted. **Method:** Air traffic control subject matter experts classified critical points (separate points where ATC action or inaction negatively influenced the incident) in each runway incursion using HFACS-ATC within 14 ATC tasks according to whether the critical point was related to ATC decisions, skills, or perceptions. **Results:** Of 459 critical points available for analysis, 290 (63%) were associated with two tasks: controller-pilot communications ($N = 230$) and tower observation ($N = 60$). For the 230 critical points that involved controller-pilot communications, 178 were classified as skill-based errors and 52 were decision errors. Of the skill-based errors, 84 were attention failures (e.g., the controller failed to catch the pilot's inaccurate read-back of the clearance). Of the 60 critical points associated with tower observation, 40 were classified as failures of attention (e.g., the controller did not notice the aircraft.). **Conclusions:** Although preliminary, these results suggest that interventions directed at improving controller attention would have the most immediate impact on reducing the number of runway incursions. Based on the potential benefits from using this human factors approach, CAMI is currently working with the FAA Offices of Investigations (AAT-200) and Runway Safety (ARI-100) to develop the technique and expand the application of the taxonomy to classify a broader set of operational errors and runway incursions.

- **HFACS Analysis of Aviation Accidents: A North American Comparison** (D. A. Wiegmann, S. A. Shappell, and J. Fraser; University of Illinois at Urbana-Champaign, Savoy, IL, FAA Civil Aerospace Medical Institute, Oklahoma City, OK, U.S. Navy Safety Center, Norfolk, VA*).* **Introduction:** Over the past several years, the Human Factors Analysis and Classification system (HFACS) has been used to analyze nearly a decade of accidents involving the U.S. military, commercial, and general aviation aircraft. However, the results of these analyses have yet to be compared directly to determined similarities and differences in human error tends across these seemingly

diverse aviation communities. The purpose of the present paper is to provide this comparison of North American aviation accidents. **Method:** A review of the HFACS data for accidents involving the U.S. Navy, Army, Air Force, Scheduled and unscheduled air carriers (FAR Part 121 and 135), and general aviation aircraft (FAR Part 19) that occurred during the 1990's was conducted using previously disseminated reports. **Results:** Across all types of operations, skill-based errors were the primary human factors cause of these accidents, followed by decision errors, violations, and perceptual errors. Few latent factors, such as preconditions, unsafe supervision, or organizational factors were uniformly identified across all categories of aviation operations. However, analyses did reveal some differences in the types of pilot errors between the different aviation communities. **Discussion:** The present study provides the first ever comparison of human error causes of accidents across different types of North American aviation operations. Although similar error patterns were observed, differences in the types of errors committed by these diverse aviation communities have direct implications for the development and sharing of safety programs that address specific types of human error in aviation.

- **An HFACS Analysis of General Aviation Data 1990-98: Implications for Training** (S.A. Shappell and D.A. Wiegmann; FAA Civil Aerospace Medical Institute, Oklahoma City, OK and University of Illinois at Urbana-Champaign). **Introduction:** A large effort has been expended over the last several decades to lower the military and commercial aviation accident rates. Unfortunately, until recently, a similar effort has not occurred within the general aviation (GA) community even though the total number of accidents is considerably greater. Therefore, as part of the FAA's effort to better understand the causal genesis of GA accidents we previously analyzed nine years (1990-98) of fatal GA accidents using the Human Factors Analysis and Classification System (HFACS). The findings, though significant, reflected only about 20% of the total GA accidents that occurred during the time period of the study. Therefore, an analysis of the remaining non-fatal GA accidents was conducted to provide a more complete picture of the human factors associated with GA accidents. **Methods:** Using HFACS, five pilots independently coded the cause factors associated with 15,744 GA accidents occurring between 1990-98. Of these, 12,033 accidents were associated with some form of aircrew unsafe act (i.e., decision error, skill-based error, perceptual error, and/or violation). Our findings with regard to these aircrew-related accidents will be reported here. **Results:** With the exception of violations that were more common during fatal (35%) than non-fatal (10%) accidents, the pattern of unsafe acts committed by aircrew was similar between fatal and non-fatal accidents. Furthermore, skill-based errors (primarily technique errors) have been associated with nearly 4 out of every 5 accidents since 1990, followed by decision (38%) and perceptual errors (less than 10%). **Discussion:** These analyses have provided unique insight into the genesis of GA accidents. Implications for GA *ab initio* and recurrent training will be discussed.

- **A Comparison of Head-Out Time Between Conventional Cockpit Instruments and a Highway-in-the-Sky Display** (Kevin W. Williams, Ph.D.; FAA Civil Aerospace Medical Institute, Oklahoma City, OK). **Introduction:** While the advantages of Highway-in-the-Sky (HITS) displays over conventional aircraft displays for precise navigation are well established, there are still questions regarding other aspects of HITS

displays. One question is whether pilots are more prone to focusing their attention on the HITS display at the expense of maintaining an out-the-window visual scan. Using the Advanced General Aviation Research Simulator (AGARS), a comparison was performed between 18 pilots flying a HITS display and 18 pilots flying conventional cockpit instruments on the proportion of time that was spent looking both inside and outside of the cockpit. **Method:** Each pilot flew 6 ten-minute flights. The HITS pathway had the form of an extended runway pattern around runway 08 at Albuquerque International Airport. Pilots flying the conventional displays were given altitude and heading vectors that were similar to the HITS pathway. All pilots were instructed to watch for and call out traffic in the area during the flight. A video eye-tracking system was used to record pilot gaze position. **Result:** Pilots flying the HITS display looked outside of the cockpit approximately 16% of the time, while pilots flying the conventional instruments were head-out approximately 40% of the time. A t-test showed these differences to be significant, $t(17) = 5.83$, $p < 0.01$. **Conclusion:** As more advanced displays become available in general aviation cockpits, both pilots and aviation officials need to be aware of the potential hazards these displays could impose. One of these hazards is that pilots might fixate on displays at the expense of scanning for traffic. Training will be necessary to increase pilot awareness of potential problems and eliminate the initial fascination associated with these displays. Sometimes "duller" is better.

- **A Comparison of the Legibility of Overlapping Symbols in a Simulated Air Traffic Control Radar Situation Display in Controllers and Non-Controllers** (H. W. Mertens and H. C. Harris. FAA Civil Aerospace Medical Institute; Oklahoma City, OK, 73125). **Problem:** Air traffic control (ATC) radar situation displays become very congested at times of heavy traffic. Symbols for the controller's "owned" aircraft are sometimes overwritten and obscured by symbols for "non-owned" aircraft. Non-controllers serving as observers would facilitate the research to optimize the legibility of the controller's "owned" aircraft data blocks by eliminating the interference with ATC work schedules, travel expenses, and back-fill costs. Responses of highly experienced controllers with non-controllers as a function of color, contrast, and overwriting conditions in an air traffic control situation display evaluated this possibility. **Methods:** Twelve controllers, with 6 to 36 years of experience, and 12 non-controllers matched for visual function, age and IQ, were presented information digitally on the display monitor (Sony Model DDM2801C) that is used in new workstations at FAA Terminal and En Route radar control facilities. Twenty-four conditions involving the combinations of 6 target colors (white, red, yellow, cyan, magenta, and green), two target contrasts (1:1 or 2:1) and two overwriting conditions (target overwrites or non-target overwrites) were presented in each of 12 blocks of 24 test trials. Non-target symbols were always green. After familiarization with the alphanumeric symbols, subjects practiced identifying symbols with zero and 50% overlap. The degree of overlap in test trials was 75%. **Results and Discussion:** ATCSs generally responded faster than non-ATCSs, but their accuracy was lower. An efficiency measure, computed to compensate for the speed-accuracy tradeoff, i.e. the number of symbols correctly identified per minute, showed no significant difference between groups. The speed-accuracy tradeoff accounted for the differences between groups in accuracy and response time. **Conclusions:** Since the effects of color, contrast, and overwriting on legibility are very similar in controllers and non-controllers,

it is appropriate to utilize non-ATCSs in future research to improve the legibility of air traffic control displays.

Aerospace Human Factors Association: As President of the Aerospace Human Factors Association, Dr. Scott Shappell/CAMI conducted the recent business meeting. The following individuals received recognition during the awards ceremony: Drs. Shappell and Weigmann (U. of Illinois) received the first annual W.E. Collins award for the best aviation-related human factors paper published during 2001; Dr. Henry Mertens/CAMI received the Henry L. Taylor Founders Award for his contributions to aviation human factors research. Dr. Tom Nesthus/ CAMI is the new president of the association. (D. Schroeder, CAMI)

Laboratory Tour: The William J. Hughes Technical Center's Research, Development and Human Factors laboratory (RDHFL) hosted 20 eighth grade students on a field trip from Marlton Middle School. The students had just completed a unit on computer graphics and virtual reality (VR) in school and came to a working VR laboratory. The students donned the laboratory's head-mounted display and 3-D goggles and were able to "walk around" in a virtual air traffic control facility. The students also were able to play the role of air traffic controllers and simulation pilots in the RDHFL Distributed Environment for Simulation, Rapid Engineering, and Experimentation (DESIREE) high-fidelity air traffic control simulator. RDHFL personnel served as tour guides and instructors during the field trip, sharing their knowledge and expertise with the next generation of scientists and engineers. (K. Allendoerfer, WJHTC/ACB-220)

Integrated Control Center Evaluation: On April 29-30, 2002, the first group of controllers completed nine 50-minute scenarios simulating New York arrivals as part of the New York Integrated Control Center Evaluation. One third of the scenarios were under current conditions (separate facilities), one third under co-located conditions (terminal and en route in one building), and one third under co-located conditions and one low altitude en route sector using terminal separation procedures. Overall the results were highly successful, with complete runs and great cooperation from the controller participants and Airspace Redesign Team representatives. Group 2 will run on May 9-10, 2002 and Group 3 on May 13-14, 2002. ACB-220 will deliver a preliminary briefing on May 29, 2002 to support the JRC. The researchers have also initiated scenario development for the Departure Simulation, which is scheduled to be conducted the weeks of June 17 and 24, 2002. (D. McAnulty, WJHTC/ACB-220)

Electronic Flight Bag (EFB): On April 25, 2002, a contributing editor for Pilot Journal Quarterly interviewed a researcher from the Volpe National Transportation Systems Center (VNTSC) regarding EFB research. The magazine is a publication for pilots of single-engine piston aircraft, and is sold at national bookstores. Recent articles on EFBs that have appeared in the press have been on airline and corporate aircraft; this is the first article directed at Part 91 (private) operators. The Volpe researcher highlighted some human factors issues that would be important to private pilots, e.g., training, display quality, workload, distraction, etc. The journalist's expectation is that the price of EFBs may drop in the near future, so EFBs may become very popular with the publication's readership. There was discussion about the benefits of EFBs and some of the cautions that need to be taken in using them. The EFB feature article will appear in two to three months. (D. Chandra, VNTSC)

Amateur-Built Aircraft: CAMI representatives traveled to FAA headquarters to meet with AAR-100 and AFS to discuss the amateur-built aircraft maintenance research project. It was agreed that AAM-510 would research the human factors involving the cockpit and pilot, while AAM-520 would focus on the maintenance issues. (E. Fiedler, S. Shappell, CAMI)

Air Traffic Control: The William J. Hughes Technical Center's NAS Human Factors Group (ACB-220) completed data collection for the New York Integrated Control Complex arrival flow simulations on May 14, 2002. Nine controllers from New York TRACON and nine from New York Center participated. Each controller completed three scenarios under different conditions in each of three positions (two radar and one handoff position each in the Center and TRACON sides). In one condition, the controllers worked under current conditions (separate facilities, standard procedures). In the second condition, the TRACON and Center controllers were in a collocated facility so they could observe each other's displays and coordinate face-to-face. In the final condition, the en route sector handing off traffic to the TRACON used terminal separation procedures. The simulations were run in the re-configurable Experiment Rooms 1 and 2 of the Research Development and Human Factors Laboratory. Data analyses and preparations for a departure flow simulation in June 2002 are in progress.(T. Truitt, M. McAnulty, WJHTC).

Aeronautical Decision-Making JSAT: CAMI continued its role with the Aeronautical Decision Making (ADM) Joint Safety Analysis Team (JSAT) meeting May 14 and 15, 2002. The group of government and industry representatives completed its detailed analyses of 30 general aviation decision-making accidents using the root cause analysis technique and the Human Factors Analysis and Classification System (HFACS). Results of this effort will be used to validate earlier findings of CAMI and University of Illinois scientists who have analyzed all general aviation accidents from 1990-98 using the HFACS framework. Earlier in the year, an expert panel of university scholars completed a third effort, the identification of potential intervention strategies. The June 11-12, 2002 meeting is aimed at bringing all three efforts together so that focused ADM intervention strategies can be identified. A final report is planned for later this summer. (S. Shappell, CAMI)

Knowledge Management: During the week of April 29th**,** FAA representatives received briefings at the Team Technology Center on what is being done in Knowledge Management. Gisele Mohler, the Terminal Business Unit (ATB); Bud Morgan and Perley Eaton, Traffic Flow & Enterprise Management IPT (AUA-700); Dennis Kolb, Navigation IPT (AND-700), and Mike Webb, the FAA Vertical Flight Office (AFS-410), discussed what's happening in their particular areas. All of them are doing some very interesting things in terms of integrating people, processes, technology, and training to get people the information they need, when they need it, so they can do their jobs better. In concept, once you de-mythologize it, knowledge management is basically that simple. The reason that knowledge management is catching on to some degree is that some people are starting to see it for what it is – not as a program or a management imposed initiative, but a common-sense means of getting their work done better and more efficiently. Aiding in this effort are people like Ron Simmons, AAR-100, who was a major catalyst and resource for several of the initiatives mentioned above, as well as Bob Turner, AHD, and Giora Hadar, ASU, who also have been working with various offices to help them get started. Another encouraging note: Ann Harlan, Director of the William J. Hughes Technical Center, has established an Office of Knowledge Management as part of the Center's new organization, and

recently selected Dennis Filler to head that office. Incidentally, the April 2002 issue of the FAA's knowledge management newsletter, KnowledgeLink, edited by Giora Hadar, is now posted. You can also access it through the FAA Knowledge Sharing site on the VOICE page http://intranet.faa.gov/voice. Click on "Knowledge Sharing" in the left column. (G. Lavey, AOA-5)

More information on human factors research can be found at the FAA Human Factors (AAR-100) web site: http://www.hf.faa.gov

Mark D. Rodgers
FAA (AAR-100)

CALENDAR

May 20-22, 2002 – 11th Annual Phoenix International Aviation Symposium, The Phoenician Resort, Phoenix, AZ http://www.phxskyharbor.com/

May 28-30, 2002 – EBACE2002, Geneva, Switzerland http://www.ebace.com/

June 13-14, 2002 – Aviation Conference and Exposition, Oklahoma City, OK mailto:skymarket@aol.com

June 25-27, 2002 – FAA ARA ISS Workshop/Conference, Clarion Hotel and Convention Center, Atlantic City, NJ mailto:Meredith.Gibbs@faa.gov

August 27-30, 2002 – Measuring Behavior 2002, 4th International Conference on Methods and Techniques in Behavioral Research, University of Amsterdam, Amsterdam, The Netherlands http://www.noldus.com/events/mb2002/index.html

September 16-18, 2002 – Conference on Aerospace Materials, Processes and Environmental Technology, Huntsville, AL http://ampet.msfc.nasa.gov/

September 17-18, 2002 – FAA R,E&D Advisory Committee, Holiday Inn Rosslyn Westpark Hotel, Arlington, VA mailto:gloria.ctr.dunderman@faa.gov

September 17-20, 2002 – International Air Cargo Forum, Hong Kong http://tiaca.org/

September 30- October 4, 2002 – Human Factors and Ergonomics Society 46th Annual Meeting, Baltimore Waterfront Marriott Hotel, Baltimore, MD http://www.hfes.org/

October 14-16, 2002 – Third LOSA Week, Dubai, United Arab Emirates mailto:dmaurino@icao.int

October 23-25, 2002 – International Conference on Human-Computer Interaction in Aeronautics, Massachusetts Institute of Technology, Cambridge, MA http://www-eurisco.onecert.fr/events/hci-aero2002.html/

October 27-31, 2002 – 21st Digital Avionics Systems Conference, Hyatt Regency Hotel, Irvine, CA http://www.dasconline.org/

April 7-27, 2003 – Aviation World's Fair, Newport News/Williamsburg, VA http://www.worlds-fair.com/ or http://aviation-worlds-fair.com/

May 4-9, 2003 – 74th Annual Scientific Meeting of the Aerospace Medical Association, Convention Center, San Antonio, TX http://www.asma.org/

October 13-17, 2003 – Human Factors and Ergonomics Society 47th Annual Meeting, Adams Mark Denver Hotel, Denver, CO http://www.hfes.org/

May 2-7, 2004 – 75th Annual Scientific Meeting of the Aerospace Medical Association, Egan Convention Center, Anchorage, AK http://www.asma.org/

September 20-24, 2004 – Human Factors and Ergonomics Society 48th Annual Meeting, Sheraton New Orleans Hotel, New Orleans, LA http://www.hfes.org/

Note: Calendar events in Italics are new since the last Newsletter

Comments or questions regarding this newsletter?
Please contact Bill Berger at (334) 271-2928
or via e-mail at bill.ctr.berger @faa.gov