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Evaluation of Pilot and Runway Characteristics Associated with Runway Incursions

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A study was conducted to determine possible pilot and airport characteristics that could be used to predict surface incidents (SI) committed by pilots. The study was conducted by analyzing the videotape data from a previous simulation study (Surface Technology Assessment Product Team, 2004) that tested the ability of dynamic taxiway message signs called Addressable Message Boards (AMB) to enhance pilot situation awareness (SA) and reduce the likelihood of SIs at controlled airports. The current study did not take into consideration the impact of AMBs on SIs, but specifically focused on pilot and scenario characteristics. The results of the study indicate that pilots who committed SIs had logged fewer hours in the past six months than the pilots that did not commit a SI. In addition, pilots who committed SIs also had less experience at controlled airports than pilots who did not commit a SI. Pilots committing SIs also had lower situation awareness and higher levels of workload. It is likely that the combination of less recent flight experience and less experience at controlled airports were the cause of increased workload and lower SA for some pilots. The resultant increased workload and decreased SA led to a higher likelihood of these pilots committing surface incidents.

Introduction

Between FY 2000 and 2003, the National Airspace System (NAS) managed approximately 262 million flight operations. Of these, 1,475 resulted in runway incursions. That averages out to about five runway incursions per million operations (Office of Runway Safety, 2004). The FAA is evaluating and identifying strategies and emerging technologies for increasing runway safety.

The FAA defines a runway incursion as "any occurrence at an airport involving an aircraft, vehicle, person or object on the ground that creates a collision hazard or results in a loss of separation with an aircraft taking off, intending to take off, landing, or intending to land." The FAA categorizes runway incursions into three error types: operational errors, pilot deviations, and vehicle/pedestrian deviations (Office of Runway Safety, 2004). An operational error is defined as an action of an air traffic controller that results in an aircraft landing or departing on a closed runway, or less than the required separation distance between two aircraft, or between an aircraft and another obstacle (such as a vehicle, equipment or personnel). A pilot deviation is an action taken by a pilot that violates any Federal Aviation Regulation, such as if a pilot fails to follow air traffic control (ATC) instructions to hold short and not cross an active runway. A vehicle/pedestrian deviation occurs when pedestrians, vehicles or other objects interfere with airport operations by entering or moving on the runway movement area without authorization (Office of Runway Safety).

The FAA has developed five operational dimensions that affect runway incursions: available reaction time; evasive or corrective action; environmental conditions; speed of aircraft and/or vehicle and; proximity of aircraft and/or vehicle (Office of Runway Safety, 2001). These five dimensions were involved with the development of runway incursion categories based on severity. These categories are:

- Accident: A runway incursion that resulted in a collision.
- A: Separation decreases and participants take extreme action to narrowly avoid a collision.
- B: Separation decreases, and there is significant potential for collision.
- C: Separation decreases, but there is enough time and distance to avoid a collision.
- D: Little or no chance of a collision, but meets the definition of incursion

One of the main safety goals of the FAA is to reduce the rate of runway incursions. In addition to runway incursions, there are also SIs. An SI is any event "where unauthorized or unapproved movement occurs within the movement area associated with the operation of an aircraft that affects or could affect the safety of flight"

(Air Traffic Evaluations and Investigations Staff, 2002). SIs result from the same things as runway incursions: pilot deviations, operational errors, vehicle or pedestrian deviations and operational deviations. These surface incidents would result in a runway incursion if there was another vehicle in conflict at the time the incident occurs (Koenig, 1995).

With the increasing demand on the NAS for air travel, airport surfaces are becoming more crowded. While many air carriers suffered decreases in air traffic following September 11, 2001, demand for air travel is on the rise again. Congestion at airports is a major safety concern, and finding ways to prevent runway incursions is an area of research interest. Runway safety is managed by the pilots and air traffic controllers, who use visual and radio communications to maintain separation on the airport movement area. The airport movement area is the area where aircraft and vehicles are required to have permission from the air traffic control tower to operate (Pope, 1990). The path they are to follow is given to them by radio communication from the ground controller. The ground controller must maintain an awareness of where all aircraft are that they have given taxi instructions to. This is to avoid giving an aircraft a route to follow that will put them in the path of another aircraft or vehicle. The pilot and flight crew must either write down the taxi instructions or memorize them, and then follow the airport signs to their destination (Young and Jones, 1998). Often, position awareness is determined by both pilots and controllers through visual scans of the airport surface, using signs, lights, and pavement markings. Often, pilots use a paper surface map to assist them in determining position awareness. This may be especially true at unfamiliar airports (Young, et al, 1998).

The fact that much of positional awareness is based on visual scans of the airport surface makes it difficult to maintain awareness if visibility drops, if there is uncertainty regarding the correct path, or if there are obstacles such as other traffic in the way. This is true especially at unfamiliar airports. Position uncertainty can cause pilots to slow down until they gain a better idea of their position. It can also cause them to continue at speed, but with a lowered level of comfort (Young, et al 1998). The way that route information is given - voice communications - can be unsafe, if the communications are misunderstood or unclear. Pilots occasionally have difficulty understanding clearances, especially if the airport has a complex configuration. The pilots may also mis-hear messages intended for another aircraft, especially if the call sign for the intended aircraft is similar. Pilots can 'hear' a clearance that is expected, even if it is not given. They may act on their expectations, and not on the actual clearance given (Pope, 1990).

There are many factors that go into the cause of a runway incursion. The factors that go into the human error that cause runway incursions have been examined in previous research. The factors include: how pilots navigate the airport surface; how the runways and taxiways are identified (signs, lights, etc); communications (message content and message delivery); pilot and controller memory; situation awareness; lack of standardization; variability of training; pilots knowing where they are located; pilots knowing where other traffic is located; pilots knowing where to go on the airport surface (Jones, 2002; Adam, Lentz & Blair, 1992).

Study Objectives

The purpose of this study was to examine questions emanating from the simulation data collected during the AMB study involving runway incursion prevention technology (Surface Technology Assessment Product Team, 2004). The current research endeavored to identify factors that can be used to predict and prevent runway incursions based on pilot performance in the AMB taxi scenarios. A second objective was to examine whether the methodology utilized in the previous study can be used to learn more about SIs in the NAS to predict airport surface safety risks. The study investigated whether or not the methodology used in the AMB study would be useful in attempting to predict runway incursions based on knowledge of pilots and the scenarios that they typically experience.

Also of interest was whether or not violations of hold short instructions were predictable from the AMB scenarios. If they are, 'typical' surface scenarios for an airport could be assessed, and used in conjunction with knowledge about the pilot population to predict 'typical' airport safety risk areas. The scenario characteristics examined included: surface traffic, airport layout, unexpected surface characteristics, and radio communication.

Method

This research was an extension of a previous simulation study examining the use of dynamic message signs as a method of mitigating runway incursions (Surface Technology Assessment Product Team, 2004). This study extracted data from the AMB videotapes for use in the analysis of pilot characteristics and performance to look for possible causal factors and predictors of runway incursions and SIs.

Researchers used video and questionnaire data from the 28 pilots who participated in the AMB study. The pilots performed taxi operations in a Cessna 421 in a simulated environment in six scenarios from four different airports. The airports, selected based on the Runway Incursion Assessment Report (FAA, TAT 2002), were: Long Beach Airport, California (LGB); Crystal Airport, Minnesota (MIC); Flying Cloud Airport, Minnesota (FCM); and Centennial Airport, Colorado (APA). Crystal Airport had two scenarios, SOD and MIC. For each airport, researchers replicated one or two specific intersections identified as runway incursion hotspots and used them as the basis for a taxi scenario in the simulator. Objective and subjective data were collected throughout the simulation. Researchers analyzed the data to look for any patterns that are suggestive of runway incursion causal factors. Researchers viewed video tapes of pilots performing taxiing operations. The data collected included: total taxi time, taxi speed, number of stops, time spent looking at airport surface map, whether or not a surface incident occurred, scan time, and head-up time.

Apparatus

The original AMB study was conducted using a real-time, high fidelity general aviation cockpit simulator at the William J. Hughes Technical Center Cockpit Simulation Facility (CSF), configured as a Cessna 421. The visual system was a projector-based display system designed to provide the pilot/copilot with an Out of the Window (OTW) display on the windscreen. Three high resolution projectors were used to project the OTW view. Their purpose was to display a scene with realistic depth of field cues for the pilot. Microsoft Flight-simulator 2002 was used to generate and display the visual scenes. In addition, the audio system allowed for radio communication between pilot and controller, and provided simulated engine sounds.

Participants

28 pilots participated in the simulation study. The pilots were all General Aviation pilots, and had an average age of 43 years. They had an average of 13 years flight experience. Participants had logged an average of 1400 hours total flight time, and an average of 82 hours logged in the past 6 months.

Results

The results attempted to look at different aspects of pilot performance and behavior to see if there are any links to RIs/SIs. Statistical analyses were performed on the data and the results of these analyses are reported below. Communications data analysis is not reported here due to loss of sound in over 50% of the videotapes.

Out of 140 experimental runs in the simulation, there were 13 SIs, committed by 10 pilots. Three of these pilots committed two SIs. These were all violation of hold-short instructions.

The 10 pilots who committed SIs were on average less experienced than the other 18 pilots who did not commit SIs. In terms of overall flight experience, pilots who had SIs had logged fewer flight hours than pilots without incidents (482 flight hours versus 1940 hours). However, the test showed that this did not reach statistical significance $F(1, 25) = 3.956$, $p = .058$, as shown in Figure 1; therefore, the null hypothesis could not be rejected.

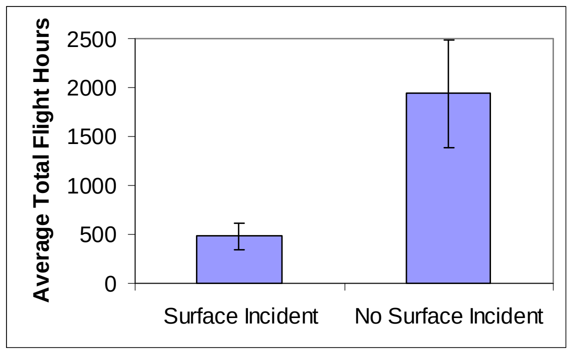

Figure 1. *Surface incidents as a function of overall experience level*

There was a statistically significant difference in number of flight hours in the past six months between those pilots who had at least one SI and those who did not (32.7 hours vs. 97.9 hours); $F(1,25) = 7.213$, $p < .05$, as shown in Figure 2. The recent flight hour data of one participant was excluded from analysis because the participant was also a commercial pilot who had many more flight hours than any of the other participants.

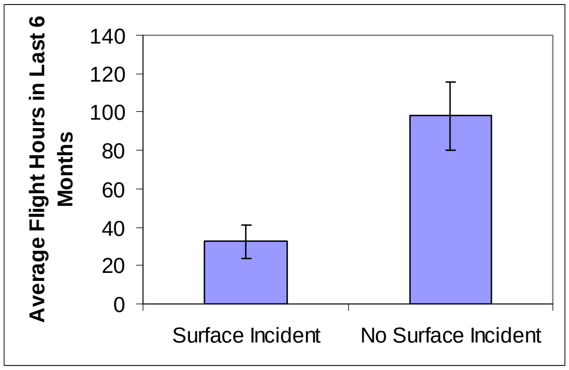

Figure 2. *Surface incidents as a function of recent flight time*

On average, those pilots with the lowest number of flight hours in the past six months had more SIs than those with higher numbers of recent flight hours; $F(2,24) = 3.578$, $p < .05$ (see Figure 3).

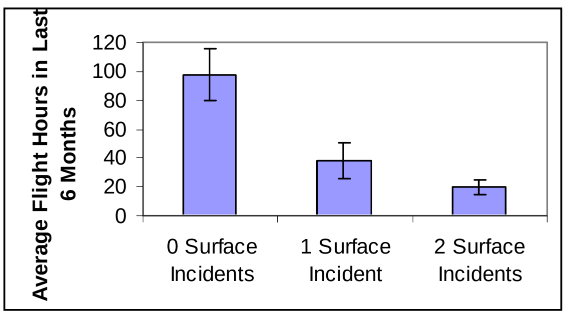

Figure 3. *Number of surface incidents committed by pilots as a function of average flight hours*

It was found that on average, pilots who committed SIs reported a smaller percentage of their flight experience at towered airports than those pilots that did not have SIs; $F(1,25) = 6.438$, $p < .05$. Those who committed SIs estimated that 26.6% of their flight operations were conducted at towered airports, while those who did not commit SIs estimated conducting of 55.1% of their flight operations at towered airports.

The amount of 'head-up' time spent in the scenarios show that those who committed SIs tended to spend less time looking out the window than those who did not commit surface incidents. However, there was not a statistically significant difference in overall percentage of head-up time between those who committed SIs and those who did not. The average percentage of time spent looking out the window by those who committed SI was 93.9%, while average head up time was 94.4% for those who did not commit an SI.

There was a significant difference in pilot-reported SA between scenarios, $F(4,24)=3.026$, $p < .05$. There was also a trend of lower SA with increasing numbers of SIs across scenarios (see Figure 4), with the exception of the LGB scenario. The LGB scenario had the second lowest SA rating, but only had one SI.

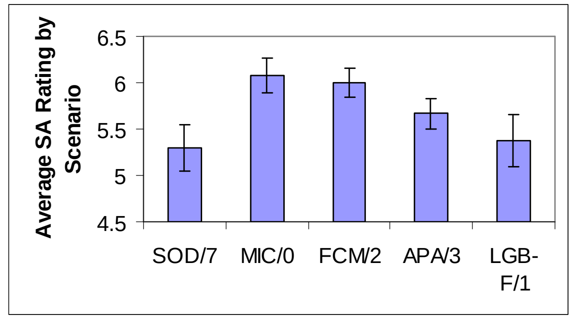

Figure 4. *Average situation awareness ratings as a function of number of surface incidents*

Pilots who committed SIs reported significantly lower SA than pilots without SIs; $F(9, 18) = 4.165$, $p < .05$ (see Figure 5).

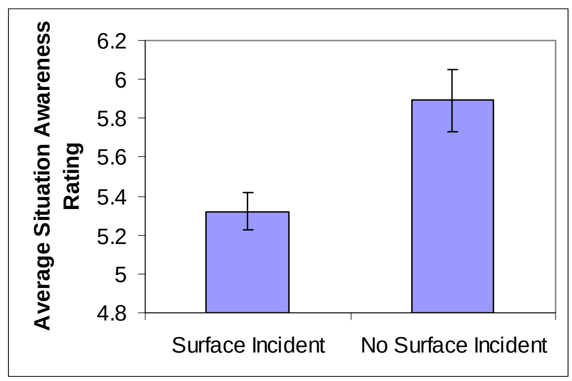

Figure 5. *Average situation awareness ratings as a function of surface incidents*

When looking at situation awareness ratings by scenario, there were some significant differences, as shown in Figure 6. In the MIC SOD scenario, those pilots who had an SI reported significantly lower SA than those pilots who did not have an SI; $F(1, 250) = 14.306$; $p < .01$. In the LGB scenario, pilots who had SIs also reported significantly lower SA; $F(1,25) = 14.389$; $p < .01$. In the FCM scenario, pilots who committed SIs tended to report lower SA. However, the difference was not statistically significant: $F(1,250) = 3.902$; $p = .059$.

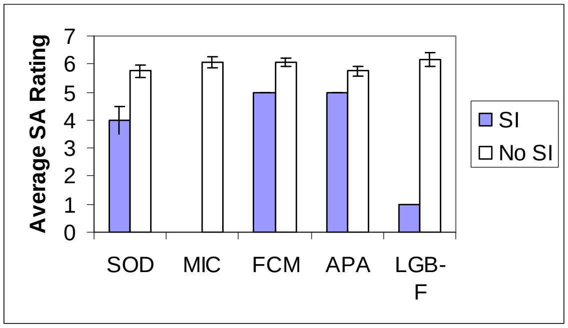

Figure 6. *Average situation awareness ratings as a function of scenario and occurrence of surface incidents*

Pilots who committed SIs tend to report higher mental workload (as measured by the NASA TLX) than pilots without incidents. However, the difference in reported workload ratings for those who had SIs and those who did not was not statistically significant: $F(1, 25)=3.205$, $p=.08$. The average reported workload for those participants who committed an SI was 47.78, and for those who did not commit an SI it was 40.196 (see Figure 7).

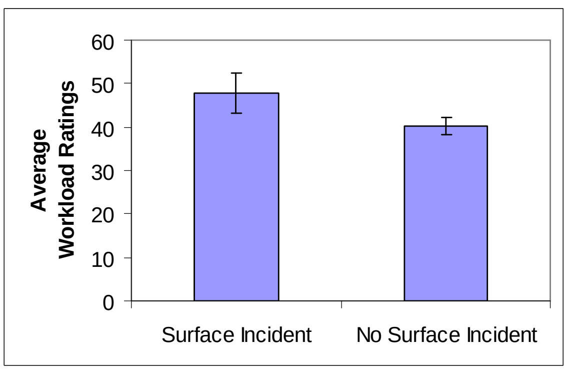

Figure 7. *Average workload ratings as a function of surface incidents*

No other data from the simulations indicated statistically significant differences. This data included the number of times pilots stopped during taxi, how long pilots spent looking at the taxi diagram (both before and during taxi), the rate of taxi speed, the number of times pilots scanned outside the cockpit and the amount of time spent scanning.

Discussion

This study examined pilot and scenario characteristics that may aid in pointing out causal factors for runway incursions and SIs. The results of this study suggest that there are some pilot characteristics that may be associated with a higher probability of committing SIs. Those pilots with fewer flight hours total tended to be more likely to commit SIs. Pilots with fewer flight hours in the past six months also tended to have more SIs. Pilots who spent less time at towered airports were more likely to have SIs. The amount of time spent looking out of the cockpit was found to be related to occurrence of SIs, but was not enough to be used as a predictor of SIs. Those pilots who commited SIs tended to report lower levels of SA, and higher levels of workload than those pilots who did not commit SIs.

The finding of a significant difference in flight hours during the past 6 months suggests that pilot training/experience may have an effect on the rate of SIs. The results suggest that the more recent flight experience a pilot has, the less likely the pilot is to commit an SI. Logging more recent flight hours aids the pilot in maintaining proficiency with proper procedures and pilot skills. The amount of total flight time and experience a pilot has is also related to whether or not they had a SI. Those pilots who had a SI tended to have fewer total flight hours than those who did not have a SI. Taken with the findings on recent flight hours, this suggests that experience and training may be predictive which pilots are more likely to commit an SI.

Pilots who committed SIs reported a lower percentage of their flight operations being conducted at towered airports. This finding suggests that pilots who do not have much experience at towered airports are more likely to commit an SI. The larger size and higher complexity of towered airport layouts may contribute to pilots who are not used to the size and complexity being more likely to commit an SI. In addition, the increased amount of traffic and the need to communicate with ATC may also increase the workload of pilots not used to operations in the towered environment. The increased workload may reduce the SA of pilots who are not as familiar with towered airports.

There appears to be a trend relating reported SA and scenarios. Pilots generally reported lower SA in the scenarios with higher incident rates. Although all of the scenarios were chosen for the simulation because they were known to have a high frequency of pilots committing SIs, the pilot participants had more difficultly with certain scenarios than others, as evidenced by both the higher frequency of SIs committed, and the lower average SA ratings for those scenarios.

Overall, pilots who committed an SI had lower SA than pilots who did not. In addition, although the difference was not statistically significant, pilots who committed an SI had higher average workload ratings. It is likely that the combination of less recent flight experience and less experience at controlled airports were the cause of increased workload and lower SA for some pilots. The fact that the pilots were taxiing for the first time at airports known for high rates of SIs also likely led to increased workload and lowered SA. For example, the MIC SOD scenario instructed pilots to hold short of a sod runway. This is an unusual element on the airport surface, and pilots may not have had the necessary experience with it to know what to look for. As a result, there was lowered SA, seemingly attributed to the airport surface. The resultant increased workload and decreased SA led to a higher likelihood of these pilots committing SIs.

The fact that those pilot who had higher levels of recent flight hours also tended to not have SIs suggests that experience and/or training may help in reducing incidents. The recency of experience may also be predictive of surface safety. Continued training, and keeping pilots current with flight hours may be a way to help reduce SIs.

While there were some factors identified from this research that are suggestive of predictors of who will commit an SI, the study was not designed with this in mind. In order to confirm the predictive factors of who will commit SIs, it would be necessary to design a study with that purpose in mind.

Future efforts to continue to examine runway safety should include the development of a model to synthesize these results. The model may be used to predict SIs, thereby generalizing the results to other airports and scenarios, as well as confirming and identifying additional pilot characteristics that increase the likelihood of SIs. Therefore, current knowledge of the airport surface and pilot characteristics could be used to more accurately predict and reduce the likelihood of SIs.

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