Mitigating Runway Incursions: A Safety Benefits Assessment of Airport Surface Moving Map Displays

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ABSTRACT
Airport surface moving maps vary in the capabilities provided (e.g., the depiction of ownship position and/or traffic, the presentation of taxi route, and indicating or alerting the potential for runway incursions). The purpose of this effort was to understand and to attempt to quantify the benefits offered by these different capabilities using data from runway incursions and surface incidents for Fiscal Year FY2007 and FY2008. Based on the scenarios and errors involved, we estimated the number of these incidents and incursions that may have been mitigated had a surface moving map with specific capabilities been available. The results indicated that a surface moving map with ownship position could mitigate approximately one-third of all runway incursions in FY2007 and FY2008. This benefit doubled with the addition of *all* surface traffic (aircraft and surface vehicles) on the surface moving map display.

Keywords
surface moving map, ownship position, traffic display, route guidance, runway incursion annunciations, benefits assessment.

INTRODUCTION
The complexities of the runway environment require the vigilance of pilots, air traffic controllers, and vehicle drivers to maintain position awareness in regard to their own actions and the actions of others in their immediate environment. When position awareness is lacking, a runway incursion or surface incident may occur. Although runway incursions and surface incidents are relatively infrequent, they are also precursors to accidents which can cause injury or loss of life. For pilots, it is anticipated that an important tool to aid in heightening position awareness is an airport surface moving map display in the flight deck. However, surface moving map displays are not uniform in their capabilities and are continuously evolving due to new technological advances and safety initiatives. The goal of this paper is to provide a safety benefit assessment of different capabilities on an airport surface moving map display. This assessment will give readers a better understanding as to which capabilities aid pilots' position awareness and in turn may mitigate the factors which lead to the occurrence of runway incursions and surface incidents.

Airport surface moving maps can vary widely in the information elements depicted, and functions and capabilities available. For example, the simplest surface moving map may be a raster chart (e.g., a scanned version of a paper airport chart) that is geo-referenced at the runways, and it may not even show ownship position. The capabilities of a surface moving map can be thought of in terms of levels – where each level contains particular features which allow more available real-time information about the immediate operating environment to be shown to the pilot. The depiction of ownship is possible if the aircraft is equipped with a Global Positioning System (GPS) source. Other aircraft or vehicles on the airport surface can be shown on the surface moving map via surveillance technologies such as Automatic Dependent Surveillance – Broadcast (ADS-B) or Traffic Information Service – Broadcast (TIS-B). Information from these technologies can also be used to develop algorithms that annunciate the potential for runway incursions. With datalink comes the potential for automatically depicting taxi guidance information on the surface moving map (manual depiction is already possible).

Past research has explored the impact of the implementation of some of these capabilities for pilots' position awareness on the airport surface. A surface moving map display which shows ownship position and the position of other traffic increases pilot position awareness, and is both beneficial and preferable to a paper airport chart alone. For example, the inclusion of ownship position enables the flight crew to confirm aircraft location on the airport, and thereby avoid spatial disorientation which may result in a runway incursion [7]. The addition of a taxi route allows the display of visual clearance information, which may also assist pilots in adhering to air traffic control instructions. Finally, the inclusion of traffic information can provide the flight crew with an additional level of awareness and support the ability to predict future conflicts with other aircraft or vehicles that the flight crew may encounter on a runway [6]. Furthermore, traffic depiction may also aid in mitigating runway incursions due to controller errors, since the flight crew would be able to identify the incorrect presence of another mobile object on the runway or other active surface area [7].

Yeh and Chandra [8] asked pilots to rate the value of information elements that may be presented on a surface moving map display. The highest rated information for both air transport (AT) and General Aviation (GA) pilots was traffic location information and other traffic data. There was also high value placed on including information regarding taxiways and airport geography for taxi operations on the airport surface. Lastly, the inclusion of ownship position on a surface moving map was rated of high value only for air transport pilots (and less so for GA pilots).

Empirical research with simulation has also illustrated differences in error rates as a function of the different levels of capabilities provided by a surface moving map. For example, Battiste, Downs and McCann [1] found that fewer taxi errors occur when using a surface moving map display with "advanced" capabilities (i.e., the presentation of ownship, traffic, datalinked taxi route and route guidance) compared to an electronic map with ownship position and/or a paper chart. Faster taxi times when using advanced display capabilities were also found, especially as visibility decreased, which suggested a higher level of confidence by the flight crew in their position awareness. Lorenz and Biella [4] reported a similar advantage for reducing taxi errors when pilots used a surface moving map that showed ownship position, traffic position, and datalinked taxi route, although they did not find a difference in taxi time.

Research has also shown that presenting traffic information is beneficial but only when alerting was provided [3]. In a simulation study, GA pilots completed five flight scenarios using a surface moving map with different levels of capabilities: no ownship, ownship position only, ownship and traffic position, and ownship and traffic position with aural alert of runway incursions. The majority of pilots indicated that a surface moving map showing ownship, traffic, and aural alerting would be most beneficial; ownship alone was considered to be of low safety value. Pilots also expressed an increased sense of safety during runway incursion scenarios when runway incursion alerting was provided.

Therefore, different exploratory measures from past research have provided a foundation for predicting what capabilities may be perceived to be of value to the pilot. However, there is a lack of research examining the potential benefits offered by these capabilities using documented runway incursions and surface incidents in the United States (US). This type of assessment will allow the reader to better understand which scenarios would likely be mitigated due to particular capabilities with a surface moving map. In addition to using the overall number and type of runway incursions that can be mitigated by each capability level of the surface moving maps, additional comparisons can be made by looking at the type of aircraft or vehicle involved in the runway incursion or surface incident, the severity of the event, and who was at fault (type of incident). These additional groupings will provide a better understanding of the type of operations that would most benefit from a particular capability.

METHODS

For this benefits assessment, we compared 6 different levels (and 2 sub-levels) of capabilities. Based on the different capabilities, an estimate of benefits for the mitigation of runway incursions and surface incidents were made.

Level of Capabilities

The levels of capabilities examined in this analysis are defined in Table 1. All levels of capabilities of a surface moving map were created on a continuum so that each level includes the capabilities of the lower levels along with the capabilities available in the present level. Subsections of the two highest levels addressing the presentation of taxi route that is manually or automatically drawn on the surface moving map were created to consider the exclusion of traffic information since the presentation of a taxi route does not require a traffic display. The table also notes the assumptions for each level regarding how the display is expected to be helpful (e.g., incidents resulting from specific errors committed by ownship only) and presents examples of the scenarios and error types. In all levels the following four assumptions apply: (1) the depiction of ownship position and the precision of information elements depicted on the surface moving map are accurate; (2) the pilot is actively utilizing and scanning the surface moving map; (3) the surface moving map is used as intended by the manufacturer; (4) correct communications with ATC if there is no conflict as when a single aircraft or vehicle involved; and (5) all surface traffic (i.e., aircraft and ground vehicles) are depicted on the display.

Runway Incursion and Surface Incident Data

Documented runway incursions and surface incidents were retrieved from the Federal Aviation Administration (FAA) Office of Runway Safety Surface Incident Database for fiscal years (FY) 2007 and 2008. The three main types of runway incursions and surface incidents are defined by who is at fault in the event: Pilot Deviations (PD), Operational Errors (OE), and Vehicle Pedestrian Deviations (V/PD). A *pilot deviation* (PD) is an action of a pilot that violates any Federal Aviation Regulation. For example, a pilot fails to obey air traffic control instructions to not cross an active runway when following the authorized route to an airport gate. An *operational error* (OE) is an action of an air traffic controller that results in one of the following: less than the required minimum separation between two or more aircraft, or between an aircraft and obstacles (e.g., vehicles, equipment, personnel on runways); or an aircraft [cleared] to land or depart on a runway closed to aircraft. A *vehicle or pedestrian deviation* (V/PD) includes pedestrians, vehicles, or other objects interfering with aircraft operations by entering or moving on the movement area without authorization from air traffic control. V/PDs also include aircraft being towed and mechanics taxiing aircraft for maintenance or gate re-positioning [2].

It may seem intuitive to focus only on pilot deviations when assessing the benefits of surface moving maps because the technology provides benefits to pilots in identifying and correcting their own error. However, we also wanted to examine the potential impact of all three errors (PD, OE, and V/PD) in the present analysis to explore the capabilities based on pilots mitigating errors of an air traffic controller, other pilot, or vehicle driver who is involved in the event.

To understand how the surface incident data was classified for this analysis, it is important to note that in FY2008, the FAA

LEVEL	DEFINITION	ASSUMPTIONS	SAMPLE SCENARIOS	SAMPLE ERRORS
1	Surface map only			
2	Surface moving map with ownship position	May mitigate incidents resulting from specific errors committed by ownship only	Ownship taxiing, departing, landing, taxi into position and hold on runway Ownship departing or landing on taxiway	Ownship taxi errors
3a	Surface moving map with ownship position and aircraft traffic	May mitigate incidents resulting from specific errors committed by ownship, another pilot, or controllers	Same as Level 2+ Ownship taxiing, departing, landing, taxi into position and hold with another aircraft landing/departing same runway (or vice versa) Both aircraft landing or departing intersecting runways	Communication errors (ownship, other traffic aircraft, controller) Taxi errors (ownship, other traffic aircraft) Other controller errors (e.g., memory errors or misjudging separation)
3b	Surface moving map with ownship and all aircraft and vehicle traffic	May mitigate incidents resulting from specific errors committed by ownship, another pilot, vehicle drivers or controllers	Same as Level 3a+ Ownship landing or departing with a vehicle operating on, entering, or crossing the same runway	Same as Level 3a+ Vehicle driver taxi errors and communication errors
4	Same as Level 3b+ Annunciations	Same as Level 3b	Same as Level 3b	Same as Level 3b+ Ownship taxi error due to distraction or heads down time
5a	Same as Level 2+ Taxi route (self entered)	May mitigate incidents resulting from specific errors committed by ownship or controllers	Same as Level 2	Same as Level 2 + Controller omitting runway or taxiway designator in instructions Ownship taxi error due to unfamiliarity with a route or the airport, memory error
5b	Combination of Levels 3b + 5a	Same as Level 3b	Same as Level 3b	Combination of Levels 3b & 5a
6a	Same as Level 2 + Taxi route (datalinked)	Same as Level 5a+ May mitigate incidents involving a temporarily closed runway	Same as Level 2	Ownship taxi errors (e.g., to a closed runway or any construction interfering with active taxi routes) Controller memory error (e.g., forgetting about closed runway)
6b	Combination of Levels 3b + 6a	Combination of Levels 3b, + 6a	Same as Level 3b	Combination of Levels 3b + 6a

Table 1. Definition of the levels of capabilities used in the benefits assessments, the assumptions, and sample scenarios and errors.

adopted the International Civil Aviation Organization (ICAO) definition of a runway incursion as follows [2]:

> *Any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle or person on the protected area of a surface designated for the landing and takeoff of aircraft.*

The FAA also re-defined the scheme used to rate the severity of an incursion [2]. Table 2 presents the definition for each severity category used prior to 2008 and compares it with the current definition. The most noteworthy effect of the definition change is that previous FAA definition required a loss of separation with a landing or departing aircraft to be classified as an incursion whereas the ICAO definition (and present FAA definition) requires no loss of separation [2]. The overall effect is that more incidents will be considered incursions after the change in definition than before. For example, certain incidents that were categorized as a surface incident in FY2007 would need to be re-categorized as a category D runway incursion to make comparisons of incident types in FY2008. Therefore, for consistency in the incidents examined in this analysis, the surface incidents from FY2007 involving the violation of a runway were included.

Category	"Old" Definition of Severity Category (Prior to FY2008)	"New" Definition of Severity Category (used in current document)
A	Separation decreases and participants take extreme action to narrowly avoid a collision, or the event results in a collision	A serious incident in which a collision was narrowly avoided.
B	Separation decreases and there is a significant potential for collision	An incident in which separation decreases and there is a significant potential for collision, which may result in a time critical corrective/evasive response to avoid a collision.
C	Separation decreases but there is ample time and distance to avoid a potential collision	An incident characterized by ample time and/or distance to avoid a collision.
D	Little or no chance of collision but meets the definition of a runway incursion	Incident that meets the definition of runway incursion such as incorrect presence of a single vehicle/person/aircraft on the protected area of a surface designated for the landing and take-off of aircraft but with no immediate safety consequences.

Table 2. Category change of Runway incursions: FY2007 to FY2008 [2].

PROCEDURE

After each level of capability and its criteria of assumptions were established, the scenarios and errors involved in runway incursions and surface incidents were placed within each level. The frequency of each type of error for each level of capability was then computed. The overall frequency gave a total number of incidents which could have been mitigated if the pilot or vehicle driver had been given a surface moving map with the specified level of capabilities. Based on the frequencies of incursions mitigated at each capability level, the benefit of each level of capabilities was computed into percentages.

RESULTS

Overall, the data indicated that a surface moving map with ownship position (Level 2) could mitigate approximately 30% of all runway incidents that occurred in FY2007 and FY2008. Adding the display of other traffic aircraft (Level 3a) increased these benefits to 50% overall, and the presentation of *all* surface traffic *(*aircraft and non-aircraft surface vehicles) (Level 3b) provided another 9% advantage. Thus, in total, the benefits of a surface moving map displaying ownship position and all traffic information had the potential of reducing the number and/or severity of runway incidents by 59%. Surprisingly, the addition of runway incursion annunciations or the display of taxi route information did not increase the anticipated benefits.

Results within each level of capability were divided into subcategories (and in some cases analyzed separately) by year (FY2007 and FY2008), incident type (PD, OE, V/PD), severity of runway incursions (Category A and B only), and who was involved in the event (GA aircraft, air transport aircraft, military aircraft, surface vehicle). The rate of runway incursions mitigated by each level of capability is presented in Figures 1 and 2 for FY2007 and FY2008 respectively.

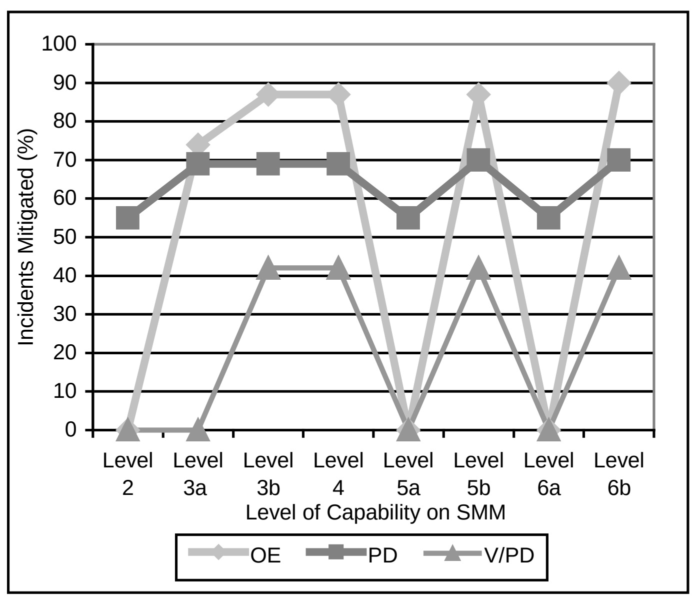

Figure 1. Percent FY2007 Runway Incidents Mitigated within Incident Type and Capability Level of SMM

As shown in Figure 1, a surface moving map with ownship alone (Level 2) could have mitigated 55% of the PDs in FY2007. (Note that no mitigation was expected at this level for OEs and V/PDs since the definition used to identify relevant scenarios and errors were pilot-centric or in relation to a PD definition).

As Figure 1 shows, the presentation of runway incursion annunciations (Level 4) did not increase the anticipated benefits any further. The presentation of taxi route information (Level 5a, Level 5b) had a similar impact to the use of a surface moving map with ownship position alone or the use of a surface moving map with all traffic information, but the data did not show any additional benefit to depicting a taxi route, regardless of whether this information was entered manually (Level 5a, Level 5b) or automatically (Level 6a, Level 6b). Although not depicted in the figures, further analysis of the runway incidents by severity type indicated that the most serious type of runway incursions ("A" runway incursions) may have been mitigated by a surface moving map showing ownship in FY2007 (40%). Adding the depiction of other aircraft traffic (Level 3b) could mitigate all runway incursions by another 40%. The benefit of depicting other aircraft traffic is not only observed in PDs (100%) but also observed in the impact on OEs, and the potential for pilots to see other aircraft traffic that the air traffic controller may or may not see. The data indicated that 84% of OEs could have been avoided when depicting other aircraft traffic. Examination of only the most serious runway incursions indicated that 100% of the "A" runway incursions may have been preventable if the pilot was equipped with a surface moving map that displayed ownship and all surface traffic

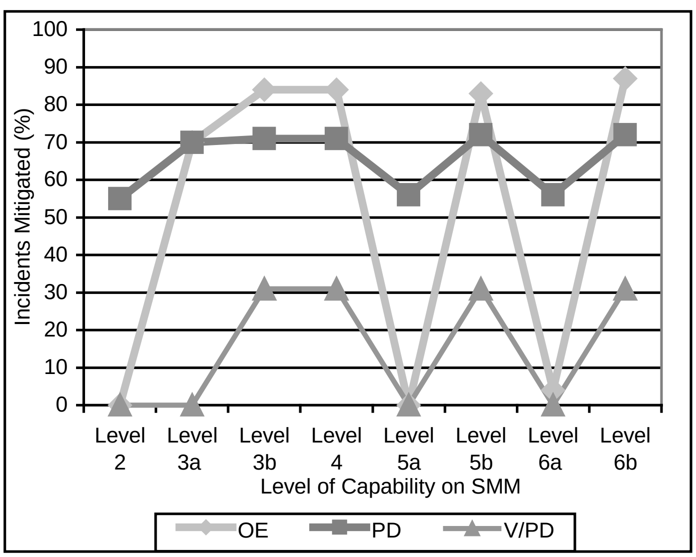

Figure 2. Percent FY2008 Runway Incidents Mitigated within Incident Type and Capability Level of SMM

In FY2008, a surface moving map with ownship may have mitigated 31% of all runway incidents and 55% of all PDs. Examination of the most serious "A" incursions indicated that 40% of these may have been mitigated.

The addition of traffic aircraft on the surface moving map provided a similar impact in FY2008 as that shown in FY2007. The percent of PDs mitigated with a surface moving map with Level 3a capabilities increased to just over 70%, and the percentage of OEs mitigated was also at 70%, though no benefit (0%) was seen for V/PD runway incursions. Presenting *all* surface traffic (i.e., other aircraft *and* surface vehicles) provided further mitigation of OEs (84%) and V/PDs (31%), although there was no further change in PDs. Thus, as noted previously, the benefits in presenting traffic information was predominately in reducing the number of OEs and V/PDs. Similar to the data reported for FY2007, the presentation of runway incursion annunciations (Level 4) and taxi route information (Level 5a, Level 5b, Level 6a, Level 6b) did not increase the anticipated benefits any further in FY2008.

We were also interested in looking at who received the greatest benefits from being equipped with a surface moving map (i.e., the type of aircraft involved). Since every incident involved at least 1 aircraft, the type of aircraft(s) in each incident (also know as "traffic mix") were assessed in terms of the benefits with each traffic mix combination (See Figure 3 for the type and number of incidents mitigated by capability level for different categories of traffic mix). Looking across all incident types, when the surface moving map displayed only ownship (level 2), only PD incidents were mitigated, with the projected benefit to be in a range of 39% to 55% for the different traffic mix combinations. The traffic mix with the most benefit of being equipped with a surface moving map occurred when a general aviation and air transport aircraft were involved (49% in FY2007 and 55% in FY2008). Traffic mix involving two general aviation aircrafts was also found to have roughly the same benefit (incidents mitigated). Runway Incidents involving only one aircraft were found to have a slightly lower number of mitigations when equipped with surface moving maps displaying ownship only. For traffic mix combinations involving two aircraft, the depiction of traffic provided the most benefits on a surface moving map; the depiction of traffic information almost doubled the percentage of incidents mitigated compared to the presentation of ownship only. In some cases, 100% of the incidents were mitigated, such as with general aviation-air transport (AT-GA) in 2008 (with aircraft traffic only – level 3a) and air transport-air transport (AT-AT) in 2007 (with all surface vehicle traffic depicted – level 3b). Including the addition of taxi-route guidance, a modest increase was seen when only 1 aircraft was involved and no benefit when 2 aircrafts are involved. Annunciations (level 4) did not increase the number of incidents that were mitigated for any traffic mix combination.

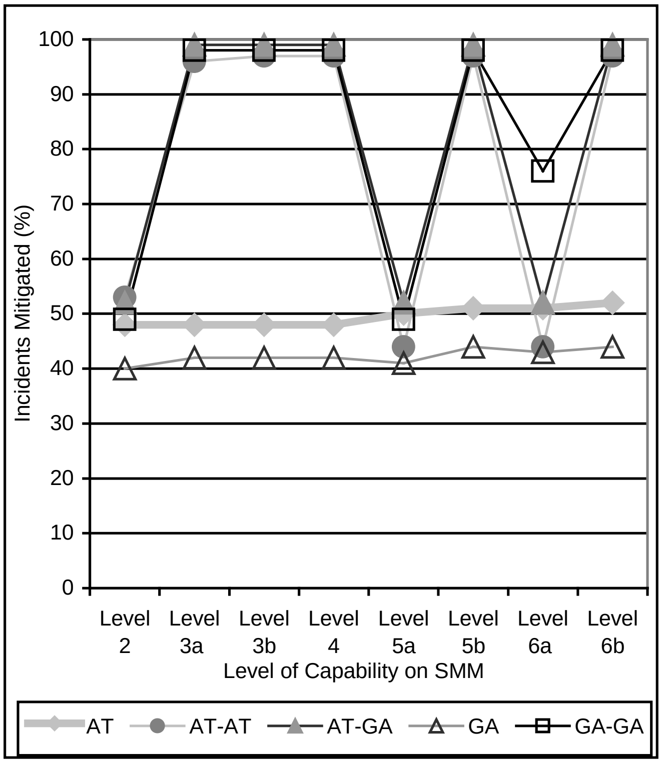

Figure 3. Combine FY2007 & FY2008 Runway Incidents Mitigated by Traffic Mix and Capability Level of SMM

We were also interested in understanding the potential impact of the capability levels on the type of aircraft at fault in these runway incident scenarios. GA pilot deviations were the most common type of runway incursion and surface incident overall in both FY2007 (48%) and FY2008 (44%). As a result, it was not surprising that the analysis showed that the number of incidents potentially mitigated was actually higher for GA aircraft than air transport aircraft in both FY2007 and FY2008. Figure 4 shows the number of incidents for the type of aircraft at fault as a function of capability level for FY2007; Figure 5 shows identical levels and incident types for FY2008.

As both figures illustrate, simply having a surface moving map with ownship position can mitigate a number of PD runway incidents and incursions (an average of approximately 32% of such incidents when a GA aircraft was at fault, and 16% when an air transport (AT) aircraft was at fault). The benefits for showing other traffic aircraft can also be seen in both figures – approximately 42% of incidents could be mitigated when a GA aircraft was at fault and 19% of incidents when an air transport aircraft (AT) was at fault. The addition of the depiction of surface vehicles did not further increase the benefits for either of these groups, nor did the presentation of runway incursion annunciations or taxi route.

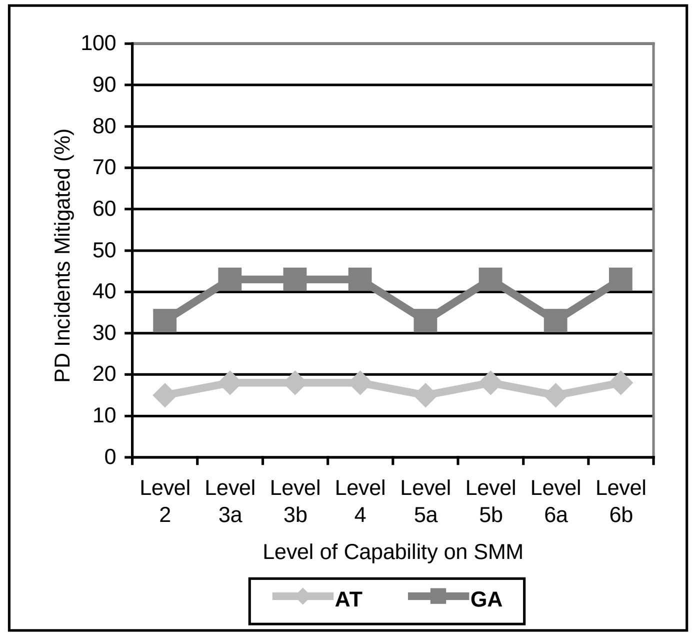

Figure 4. FY2007 PD Runway Incidents Mitigated by Aircraft at Fault and Capability Level of SMM

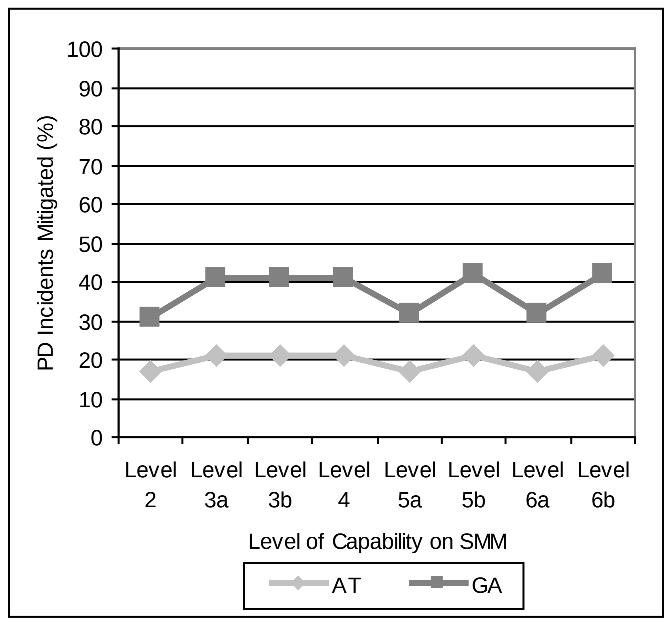

Figure 5. FY2008 PD Runway Incursions Mitigated by Aircraft at Fault and Capability Level of SMM

Although the main interest of this assessment was the benefits that could be gained for pilots equipped with a surface moving map on the flight deck, we were also interested in examining if vehicle drivers could benefit from being equipped with surface moving maps. Vehicle drivers were involved in 151 of the incidents in FY2007 and 182 in FY2008 in which they were found to be at fault (V/PD's). We did not specify type of vehicle for this assessment due to the exploratory nature of vehicles being equipped with surface moving maps. We also included the assumption that only vehicles and not the aircraft involved were equipped with a surface moving map. (See

Figure 6 for benefits; percent incidents mitigated, at each capability level of surface moving map for vehicle drivers). The greatest benefits were found (most incursions mitigated) when vehicles were equipped with a surface moving map with a combination of "ownship", all surface traffic depicted, and a self entered or datalinked taxi-route (level 5b or level 6b, respectively); with this information, 41% of the incursion in FY2007 and 55% in FY2008 could have been mitigated. Additionally in FY2008, the capability to depict ownship position accounted for 19% of the incidents mitigated. Depicting aircraft traffic accounted for another 18%, and the additional capability of showing the taxi route added another 1%. Thus, equipping a surface vehicle showed a lower value of benefits compared to incidents when only aircraft are equipped in most OE and PD incidents. This finding suggests that incidents which include vehicles may have additional factors involved that are not such that a vehicle driver can themselves mitigate their error successfully with only the capabilities of surface moving maps defined in this paper. Otherwise, we would predict benefits at consistent levels across all equipped surface vehicles and aircrafts.

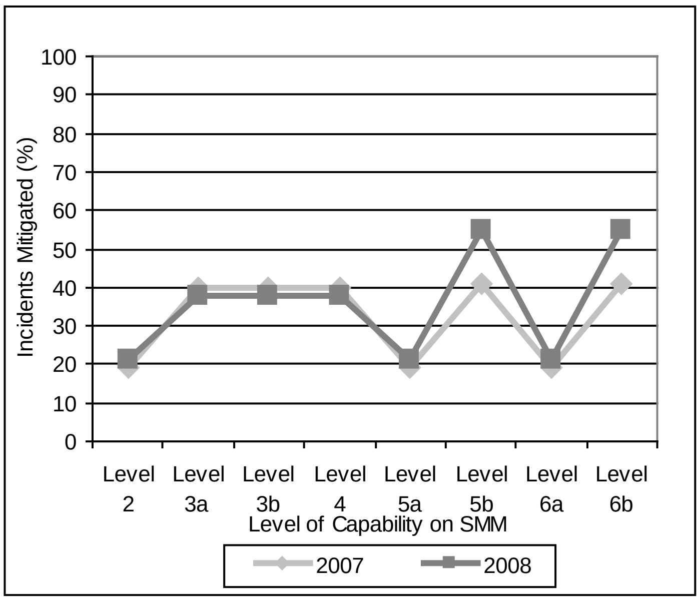

Figure 6. FY2007 and FY2008 V/PD Runway Incidents Mitigated by Surface Vehicle Equipped and Capability Level of SMM

DISCUSSION

In general, the runway incursion and surface incident data from FY2007 and FY2008 confirm the expectation that a surface moving map in the flight deck may reduce the number of runway incursions and their severity. It is estimated that by providing pilots with a surface moving map showing ownship, runway incursions may be reduced by 30%. The data also suggests that runway incursion severity would likely be reduced due to the equipped pilot avoiding potential conflict situations. For example, an equipped pilot may be able to prevent a conflict caused by an unauthorized aircraft or vehicle on a runway, therefore reducing the severity of the event to a D-category incursion. For OE incursions, pilots could benefit from a surface moving map in instances with incorrect communication. For example, a clearance with an incorrect callsign could cause an aircraft to cross in front of ownship. If ownship did not hear the incorrect callsign but was given traffic information on their surface moving map display; then ownship could either relay the movement of traffic in front of them to the air traffic controller or stop taxiing so that loss of separation does not occur.

Although ownship alone shows a significant level of benefit, it is not without limitation, as its primary mitigation is in reducing PDs where the aircraft at fault is equipped. A surface moving map with ownship position is not expected to mitigate communication errors or radio and frequency problems. However, the addition of aircraft and vehicle traffic provides pilots with the ability to address these additional situations and may reduce the frequency of runway incursions by approximately 60% overall.

Surprisingly, the analysis indicated that there was little benefit for including runway incursion annunciations in the surface moving map technology. However, this finding may partially be the direct result of our assumption that pilots are already actively utilizing the surface moving map and doing so in an optimal fashion. As a result, the pilot would not need annunciations to attract attention to an impending conflict. Another consideration is if the presentation of an annunciation is perceived to be unnecessary or overused, it may become overlooked or ignored. For example, some runway status annunciations are intended to inform the pilot of runway occupancy, but depending on the number of operations at the airport, the runway may be constantly in use making the annunciation less meaningful. Therefore, it is important to acknowledge that there may be benefits that are not reflected in the current data

Pilot-entered and datalinked route guidance also did not show much benefit beyond the depiction of ownship position and traffic information. Visual route guidance is expected to mitigate incidents where a pilot is unfamiliar with an airport or taxi route, including when the airport changes (e.g., construction, etc.), or when impoverished weather with /reduced visibility occurs. Again, the results may partially be attributable to the assumptions we made in designing this analysis. Communication errors that may be mitigated by taxi route information could possibly be mitigated by the presentation of traffic. Therefore, we acknowledge that there may be benefits to the depiction of a taxi route which was not identified in this analysis.

Recommendations from past research have expressed the opinion that improving positional awareness of airport vehicle drivers could be done by equipping drivers with surface moving maps in vehicles [5]. Although the recommendation was based on the idea that vehicle drivers would notice and catch their own errors, the current assessment suggests that vehicle drivers could also use the information provided on a surface moving map to prevent the errors of pilots and air traffic controllers. The largest benefits were found (most incursions mitigated) when vehicles were equipped with a surface moving map with "ownship", aircraft traffic depicted, and a self entered taxi-route (level 5b) or datalink (level 6b) with 41% of the incursions mitigated in FY2007 and 38% in FY2008. However an overall comparison to equipping aircrafts the benefits are considerably lower.

Though the assumptions used in this assessment could cause one to underestimate the benefits of particular capabilities to the pilot, the data quality of the incident reports is another factor to consider. The data documented in incursion reports is not always consistent, such that every factor is accounted for in every incident. For example, in one incident the availability of a surface moving map or the pilots' action of scanning the surface moving map display in the cockpit might be mentioned, but neglected in another.

It is important to note that the quantification of the benefits identified assumes the maximum benefits that may be provided in the most optimal of circumstances. Therefore the number of pilots, 1 vs. 2 is a consideration in assessing the benefits of a surface moving map. When two pilots are in the cockpit sharing tasks the workload is lower and benefits could potentially to be greater. The human factors of the surface moving map display must also be considered, since the usability of the surface moving map or the depiction of traffic information could moderate the anticipated benefits. For example, important human factors considerations in the design and evaluation of surface moving map displays include the appropriate use of color and whether the symbology is consistent and can be interpreted; the use of a traffic display in a mixed equipage environment; and the effects of clutter (e.g., in defining which aircraft or non-aircraft surface vehicles should be depicted). As with any new technology, the functions and capabilities for surface moving maps will continue to evolve, and it will be important to stay abreast of this evolution to understand the human factors implications.

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