

## **Enhancing Airport Surface Markings to Support Pilot Awareness about Runway Location**

Peter M. Moertl, Steven L. Estes, Cheryl R. Andrews, Oscar B. Olmos

### **Abstract**

Enhancements to airport surface markings were developed to facilitate pilot awareness of the runway location and to increase the conspicuity of the holding position markings, see Olmos, Andrews, and Estes (2003). The marking enhancements were evaluated in a simulation and two field studies. In a simulation study, general aviation (GA) pilots as well as transport category pilots performed taxi operations using a cockpit simulator. The simulated airport surface included enhanced surface markings and the distance at which pilots detected the runway environment was measured under various conditions. The results indicate that marking enhancements were associated with an earlier detection of the runway in some but not in all conditions. Specifically, transport category pilots detected simple taxiway-runway intersections with enhanced markings earlier than with current markings. No such perceptual advantage was found for GA pilots or at complex intersections. Most pilots, however, subjectively preferred the marking enhancements over the current marking standard. These positive evaluations of enhanced markings were confirmed by two field demonstrations where two sets of enhanced markings were implemented at two US airports. Pilots perceived the benefits of the marking enhancements to depend on pilot experience, familiarity with the airport, aircraft type, and knowledge about the marking enhancements. For certain airport situations, the enhanced markings in the hold-short environment of runways can be expected to aid pilot awareness about the runway location.

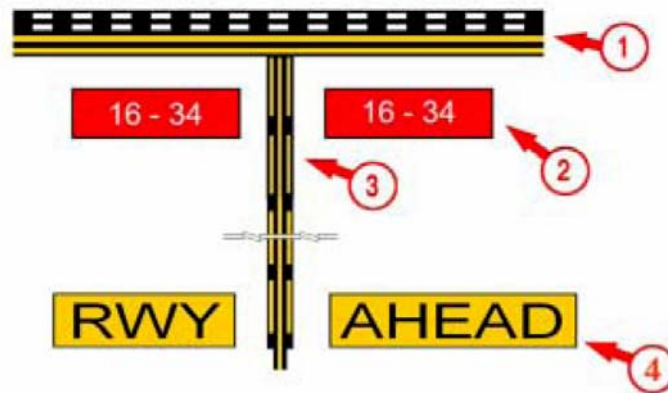
### **Introduction**

Runway incursions at towered airports in the United States (US) have been a major area of concern for the Federal Aviation Administration (FAA) for the past several years. The United States' National Airspace System (NAS) has approximately 490 FAA/contract towered airports that handle nearly 67 million airport operations per year. Of the approximately 268 million operations at US towered airports from fiscal year (FY) 2000 through FY 2003, there were 1,475 runway incursions. That is approximately six runway incursions for every one million operations. Seven of the 1,475 incursions resulted in collisions on the runway. One of these collisions involved four fatalities. Of the 490 towered airports, 308 airports reported at least one runway incursion during this four-year period (FAA 2004).

In response, the FAA formulated objectives to increase NAS safety (FAA Flight Plan for 2004 – 2008) by reducing commercial airline and General Aviation's (GA's) fatal accident rates and to reduce the risk for runway incursions. For this purpose, strategies were undertaken to continue research to identify human factors that may cause accidents and develop strategies, methods, and technologies that will reduce those accidents. The FAA develops and refines airport design standards, surface movement strategies, surface movement procedures, infrastructure, and training to enhance the efficiency of aircraft movement and reduce the risk of aircraft collisions.

Modifying airport surface markings for taxi-operations represents one among several strategies that have been recently investigated by the FAA to increase airport surface safety. Modifications of airport surface markings are a relative low cost safety solution when compared to other safety solutions such as the installation of ground traffic surveillance radars. Therefore, enhancements of the current airport surface markings in the hold-short environment were proposed, developed, and evaluated (see Olmos, Andre, Chrysler, Hannon, and Andrews, 2002; Estes, Olmos, Andre, Chrysler, Hannon, and Andrews, 2003). Industry representatives, FAA, human factors and technical experts participated in a series of structured discussions and pilot cockpit evaluations to identify opportunities to support pilot awareness of the runway. The surface marking modifications were developed and became the consensus recommendation of the development team (Figure 1):

1. **Runway Holding Position Markings on Taxiways:** The runway holding position markings would be extended onto the taxiway shoulder beyond the taxiway edge lines. This should help pilots of transport type aircraft to better position themselves with respect to the holding position markings (i.e., they can continue to see the position markings out the sides of the cockpit) and should also assist other surface operators (e.g., vehicles). Additionally, the dashed portion of the current runway holding position marking pattern would be painted white instead of yellow. This should convey directionality to the pilot. That is, the white portion of the position marking will always be on the runway side (where white is primarily used) with the yellow portion being on the taxiway side (where yellow is primarily used).
2. **Surface Painted Holding Position Signs (SPHS):** These markings would indicate the runway name in white letters on a red background. They would be placed prior to the taxiway-runway intersection on both sides of the taxiway centerline, if sufficient space is available. This should increase the conspicuity of the actual runway holding position markings, convey directionality (i.e., when turning off the runway, text would be upside-down), and provide visible cues to both sides of an approaching aircraft.
3. **Modified Taxiway Centerline:** Dashed yellow lines would be placed on both sides of the taxiway centerline. The modified taxiway centerline would start approximately 150 feet prior to the runway holding position markings (if sufficient space is available). The purpose of the modified taxiway centerline is to inform pilots as they approach a taxiway-runway intersection that a runway is ahead. For an aircraft taxiing at 14 knots, pilots would see the modified centerline up to six seconds before arriving at the hold-short line. In addition, upon exiting a runway, pilots could use the modified taxiway centerline as a distance indicator for having cleared the runway environment.
4. **Runway Ahead Labels:** Yellow “runway ahead” labels would be placed on both sides of the taxiway centerline 150 feet prior to the taxiway-runway intersection, if sufficient space is available. The purpose of the runway ahead labels is to provide an indication of orientation and the beginning of the taxiway-runway intersection. This feature was recommended as an optional feature.



**Figure 1. Enhancement of Airport Surface Markings at Runway - Taxiway Intersections.**

### **Simulation Study**

The enhanced surface marking concepts were implemented in a non-motion based cockpit simulator. The visual scene consisted of a 130 degree lateral by 50 degree vertical field of view onto a single curved screen on which the view was projected (Estes et al., 2003).

### **Method**

Twenty-four participants, 12 Transport and 12 GA pilots participated in the study. Transport pilots had on average 6939 flight hours logged. GA pilots had on average 2930 flights hours logged. Each pilot completed 24 experimental trials. For each trial, airport surface markings and intersection complexity were varied. Each pilot was shown each of the four marking enhancements as described above, either in isolation or in combination. Additionally, each pilot was shown the current markings as baseline. Intersection complexity was also varied. Complex intersections were defined as being more than 200 feet wide and having more than one taxiway centerline intersecting the runway holding position marking. Simple intersections were defined as being less than 200 feet wide and only one taxiway centerline intersected the runway.

Transport pilots viewed the surface from an eye-height of 20 feet, while GA pilots were at eight feet. To examine the effect of the enhanced markings on pilots' orientation, all vertical runway signs were removed and visibility was reduced to 500 feet by simulating fog in the scenario. Also, the location of the aircraft was different for each experimental trial and pilots were not informed of the aircraft's location. Pilots were asked to pull a trigger on the side stick the moment they could detect the runway environment. This trigger pull provided an indication of the aircraft's distance from the holding position marking when the runway environment was detected.

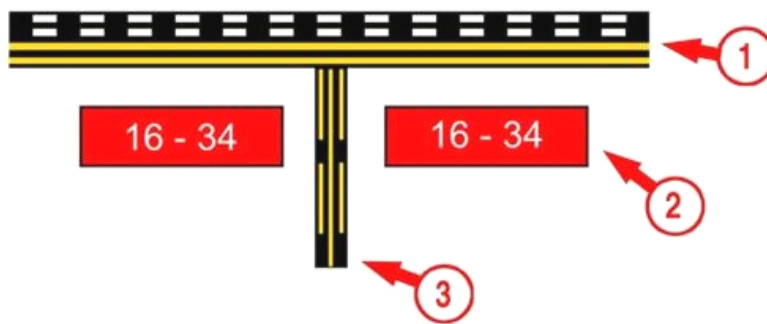
### **Results**

Runway-taxiway intersections with marking enhancements were detected earlier than intersections with current markings in some, but not all, conditions. Simple taxiway-runway intersections with enhanced markings were detected statistically significantly earlier than those without enhancements by transport pilots (significant interaction in a repeated measures analysis of variance  $F(5,55) = 4.583, p < .05$ ). This difference was found only when pilots viewed all marking enhancements in combination, but not when they saw each of the marking enhancements in isolation. No statistically significant difference was found for GA pilots. Additionally, neither transport pilots nor GA pilots detected enhanced markings earlier than current markings at complex intersections. The results indicate a perceptual advantage of enhanced markings for the more experienced group of pilots who also saw the markings from a higher seating position. Transport pilots had on average about 60 percent more flight hours logged than the group of GA pilots and were seated about 12 feet higher. However, transport pilots only showed perceptual benefits when viewing enhanced markings at simple runway-taxiway intersections, not at complex intersections.

Survey results indicated that overall, participants rated the marking enhancements higher in terms of visual clarity and runway awareness than the current marking standard.

### Field Studies

A subset of proposed markings, (see Figure 2) were evaluated in a field evaluation at T. F. Green State Airport (PVD) in June of 2003 (Andrews, Olmos, and Estes, 2003). Figure 2 shows the evaluated marking proposals, the numbers refer to the marking descriptions in the introduction section. The optional 'Runway Ahead' labels were not implemented.



**Figure 2. Enhanced Airport Surface Markings Evaluated at PVD.**

One hundred twenty eight pilots completed surveys after seeing the enhanced markings at PVD and compared them with the current marking standard. A majority of the pilots rated the enhanced markings higher than the current markings. Pilots indicated that the marking enhancements provided beneficial redundancy. In structured interviews pilots indicated that confused or distracted pilots would receive the greatest benefits. Pilots indicated that benefits would be greatest under reduced visibility as well as for pilots who are unfamiliar with the airport. Training requirements were judged to be minimal.

A second subset of enhanced markings was evaluated at Boston Logan International Airport (BOS) (Moertl and Andrews, 2005). Figure 3 shows the evaluated marking

proposals, the numbers refer to the marking descriptions in the introduction section. Ninety-seven pilots completed surveys after having seen the enhanced markings. Seventy-four of them compared the enhanced markings at BOS with the current marking standard. The other 23 pilots compared the enhanced markings at BOS with the enhanced markings at PVD (see above). A majority of the pilots preferred the enhanced markings over the current markings. Whereas the modification of the hold-short line (white dashes and holdline extended onto the shoulder) was evaluated similarly by pilots in BOS as well as in PVD, the markings that included a modified taxiway centerline (PVD) received overall higher evaluations than the markings without (BOS). In structured interviews pilots indicated that they saw the greatest benefits of enhanced markings for pilots who were unfamiliar with the airport but familiar with the marking enhancements, and who taxied in aircraft that allowed a direct view of the taxiway centerline ahead of them (as opposed to an aircraft with restricted forward visibility).



**Figure 3. Enhanced Airport Surface Markings Evaluated at BOS.**

### Conclusions

Three studies were conducted to investigate the impact of enhanced airport surface markings on pilots during taxiing operations. The results indicate that though most of the pilots preferred the enhanced markings over the current markings, perceptual benefits of enhanced markings were only detectable under some conditions. Pilots with more taxi experience who were also seated higher detected simple, but not complex runway – taxiway intersection earlier with enhanced markings. Context dependency was also found in interviews where pilots suggested that pilots who are unfamiliar with an airport should benefit more from the marking enhancements than pilots who are highly familiar with an airport. Enhanced markings in the hold-short environment of runways can therefore be expected to provide awareness about the runway location to pilots in certain situations. The integration of marking enhancements with other solutions that assist pilots and air traffic controllers in their tasks of maneuvering aircraft on the airport surface will be essential to significantly increase runway safety.

### References

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