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A Field Demonstration of Alternative Enhanced Runway Holding Position Markings

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Abstract

Modifications of the airport surface marking standard have been considered by the Federal Aviation Administration (FAA) as one way to increase safety of airport surface operations. This report summarizes the results of a demonstration of two alternative enhanced airport surface marking concepts for the hold-short environment. The two enhanced marking concepts had been derived from recommendations that were made by aviation industry representatives, the FAA, and MITRE Center of Advanced Aviation System Development (CAASD) (Olmos, Andrews and Estes, 2003). The two enhanced marking concepts were implemented at two United States (US) airports, at T.F. Green airport in Providence (PVD) and at Boston Logan International airport (BOS). Ninety-seven pilots assessed the safety related benefits of the marking concepts after they had acquired operational experience with the marking concepts at BOS. Pilots completed survey questionnaires and reported their experience in interviews.

Overall, pilots found that enhancing the holdline as well as the taxiway centerline marking provided greater benefits over the current marking standard than enhancing only the holdline markings in isolation. This indicates a general preference of pilots for a modification of the taxiway centerline prior to the hold-short environment. The perceived utility of a modified taxiway centerline was found to be reduced for pilots who were highly familiar with the airport, for pilots with little or no information about the marking modification and for pilots who viewed the markings from a certain aircraft type such as a Cessna 402 where a large extended nose reduced the visibility on the taxiway centerline.

KEYWORDS: Airport Surface Markings, Surface Marking Enhancement, BOS Field Demonstration

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BOS holdline marking enhancement specifications were developed by Mr. Bob David, Federal Aviation Administration (FAA) Office of Runway Safety and Operational Services, and Ms. Cheryl Andrews, MITRE/CAASD.

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Executive Summary

Modifications of the airport surface marking standard have been considered by the Federal Aviation Administration (FAA) as one way to increase safety of airport surface operations. This report summarizes the results of a demonstration of two alternative enhanced airport surface marking concepts for the hold-short environment. The two enhanced marking concepts had been derived from recommendations that were made by aviation industry representatives, the FAA, and MITRE Center of Advanced Aviation System Development (CAASD) (Olmos, Andrews and Estes, 2003). The two enhanced marking concepts were implemented at two United States (US) airports, at T.F. Green airport in Providence (PVD) and at Boston Logan International airport (BOS). In this field demonstration pilots assessed the safety related benefits of both marking concepts after they had acquired operational experience with them. These pilots completed survey questionnaires and reported their experience in interviews where they compared the enhanced marking concepts with each other and with the current marking standard. No objective performance data were collected due to the fact that the low rate of runway incursions relative to the number of actual operations would require an unwieldy data collection process.

Both enhanced marking concepts included modifications to the hold-line. The enhanced hold-line is extended onto the shoulders and contains white instead of yellow dashes. In addition both marking concepts contain surface painted holding position signs indicating the runway. One of the two concepts also included a modified taxiway centerline (referred to as holdline and taxiway centerline marking enhancement or HTME) whereas the other did not (referred to as holdline marking enhancement or HME). The difference between the two marking concepts is that the modified taxiway centerline of the HTME concept informs pilots upon approaching a taxiway-runway intersection that a hold-line lies ahead.

Evaluation data for the HME concept were collected during a field demonstration at BOS. A group of 74 pilots compared the HME concept at BOS with the current marking standard. These evaluations were compared with historical evaluation data of the HTME concept that had been reported by Olmos, Andrews, and Estes (2003) at PVD. Overall, pilots found that the HTME provided greater benefit over the current marking standard than the HME concept. This indicates a general preference of pilots for the modified taxiway centerline.

The HME concept was directly compared with the HTME concept by a group of 23 pilots with high familiarity with BOS and PVD airport. These pilots did not agree about the benefits of a modified taxiway centerline. Based on pilot comments, the perceived utility of a modified taxiway centerline mainly depended on three factors:

- the pilot's familiarity with an airport

- the type of aircraft from which the markings were viewed
- the amount of information about the marking enhancements that was available to pilots.

The features that were common to both, the HME and HTME, concepts were evaluated by a group of 97 pilots who had seen these markings at BOS and PVD airport A majority of these pilots preferred the enhanced markings when comparing them with the current marking standard. The same group of pilots expressed a preference for implementing the markings at all runways at an airport. These pilots also expressed a preference for implementing the enhanced markings as a common standard at all airports.

Section 1

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 USs' National Airspace System (NAS) has approximately 490 FAA/contract towered airports that handle about 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, objectives 1, 2, and 4) 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 continues to develop and refine airport design standards, surface movement strategies, surface movement procedures, infrastructure, and training to enhance the efficiency of aircraft movement and reduce the risk of commercial aircraft collisions.

Airport surface markings for taxi-operations represent one among several components that have been recently investigated by the FAA to increase airport surface safety. Specifically, enhanced airport surface markings for the hold-short environment were proposed, developed, and evaluated (Estes, Olmos, Andrews, Andre, Chrysler, and Hannon, 2003). Olmos, Andrews, and Estes (2003) demonstrated perceptual and subjective benefits of a set of three enhanced airport surface markings that consisted of modifications to the holdline and the taxiway centerline markings prior to the runway intersection at T.F. Green State Airport (PVD).

Boston Logan International Airport (BOS) implemented modifications to the holdline markings without modifying the taxiway centerline. This report describes the results of a comparison between these two airport surface marking concepts.

Section 2

Background

2.1 Enhanced Markings Development

The development and demonstration of enhanced airport surface markings was sponsored by the FAA's Office of Runway Safety and Operational Services and the Office of Airport Safety and Standards to support potential revisions to Advisory Circular (AC) 150/5340-1H, Standards for Airport Markings.

During 2002, the FAA in cooperation with MITRE's Center for Advanced Aviation Systems and Development (CAASD) invited several industry representatives and technical experts to participate in a series of structured discussions and pilot cockpit laboratory evaluations to identify opportunities to use enhanced markings to improve pilot situation awareness (Olmos, Andre, and Chrysler 2002). These discussions focused on three areas within the runway holding position environment (Figure 2-1):

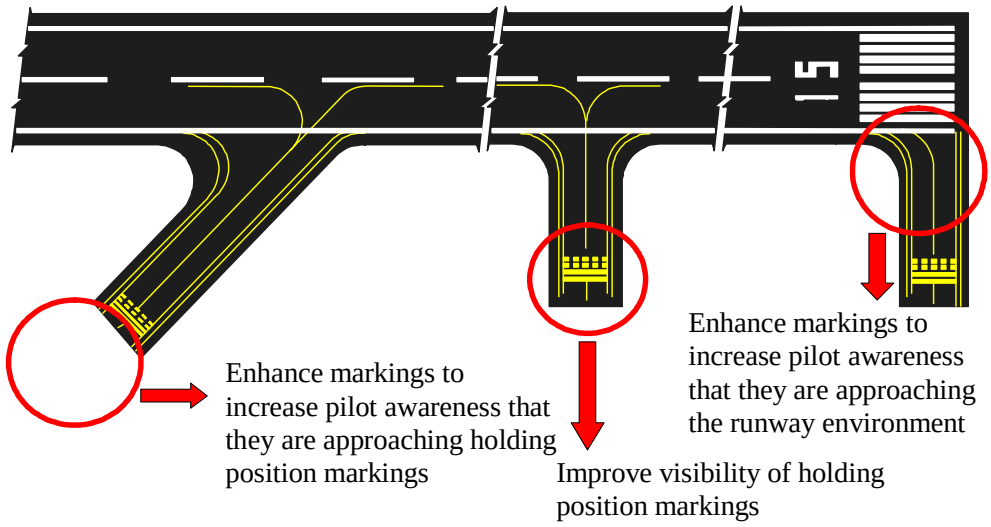

Figure 2-1. Runway Holding Position Environment: Areas for Potential Improvements

Based on results of these discussions the following surface marking modifications were developed and became the consensus recommendation of the development team:

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). Also, the dashed portion of the current runway holding position markings would be painted white instead of yellow. This should help to convey directionality to the pilot, that is the white portion of the position marking will always be on the runways 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 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 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 beginning of the taxiway-runway intersection. This feature was recommended as an optional feature.

2.2 Evaluation of the Enhanced Airport Surface Markings in a Simulation Study

In a simulation study, Estes, Olmos, Andrews, Andre, Chrysler, and Hannon (2003) evaluated the previously described four enhanced surface markings. Overall, they found that the combinations of enhanced marking features reduced the distance it took pilots to detect the runway environment when compared to the current markings standard. This perceptual advantage was associated with simple taxiway-runway intersections and for transport pilots. No advantages of increased runway detection distance were found for GA-pilots or in complex taxiway-runway intersections (i.e. intersections more than 200 feet in width and with more than one taxiway centerline intersecting the runway holding position marking).

Beside the combination of the markings, each of the marking modifications was also evaluated separately. No significant increase in the detection distance for the hold-short

environment or for the runway was found. However, pilots subjectively preferred the modified markings over the current airport surface markings in terms of visual clarity and runway awareness.

2.3 Demonstration of HTME

Based on findings of the simulation study (Estes et al. 2003), enhanced hold-short line and taxiway centerline markings (HTME see Figure 2-2) were implemented and demonstrated in June 2003 on all runways at PVD[1]. The implemented markings included three of the four originally recommended marking features omitting the optional "Runway Ahead" labeling. Pilots who had seen the HTME concept at PVD evaluated it by completing survey questionnaires.

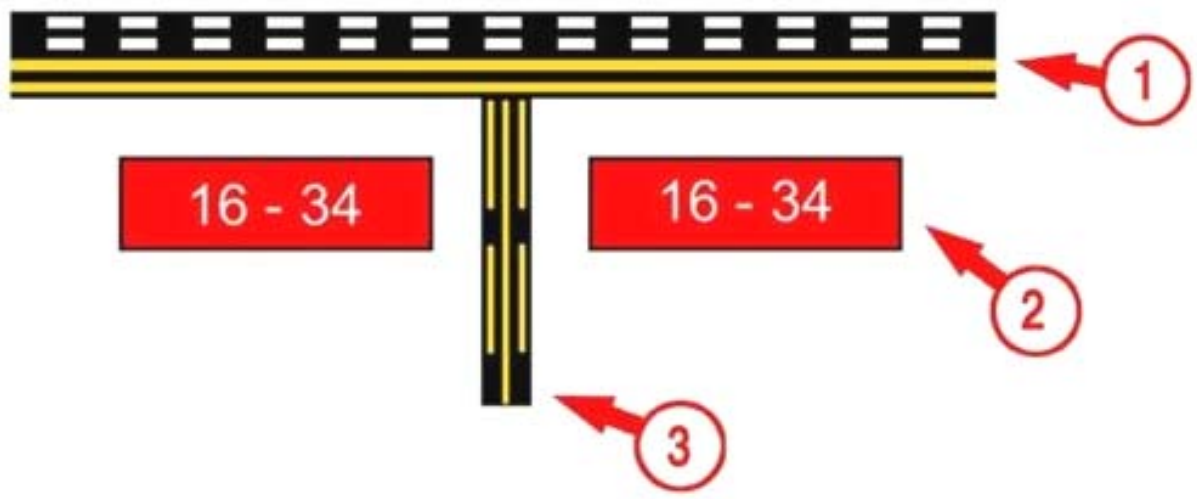

Figure 2-2. Overview of the HTME Concept in the PVD Field Demonstration

The results of this demonstration indicated that more than 98 percent (%) of 127 pilots found the HTME concept to be an improvement over the current marking standard, more than 90 % of pilots indicated that the visibility of the enhanced markings was improved under low visibility or night conditions, and 88 % of pilots recommended that the FAA implement the markings as a standard (Olmos et. al. 2003). When asked about each of the HTME features separately, the recommendations for implementation ranged between 87 % for the modified taxiway-centerline to 99 % for the surface painted holding position signs (feature 2 in Figure 2-2).

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1 For the demonstration, the size of the PVD SPHPS inscription was nine feet and Type 1 reflective beads were used for increased light reflection.

Though a majority of the pilots recommended implementation of each feature in isolation, 5 of 127 pilots (4 %) raised the concern that the modified taxiway centerline might potentially cause clutter at intersections where multiple taxiways intersect with a runway. At those intersections, because of the close proximity of many markings, the perceptual distinctiveness of the marking features might be reduced and therefore slow down the pilot's recognition of these features. Because of this concern and because of cost-advantages that resulted from the application of less surface paint, the FAA Office of Airport Safety and Standards encouraged the demonstration of an alternative airport surface marking concept that retained two of the recommended features, runway holding position markings on taxiways and surface painted holding position signs, but excluded the modified taxiway centerline, see Figure 2-3. This concept is referred to as Holdline Marking Enhancement or HME. The field demonstration of the HME concept was conducted at BOS from August to October 2004 and is described in the next section.

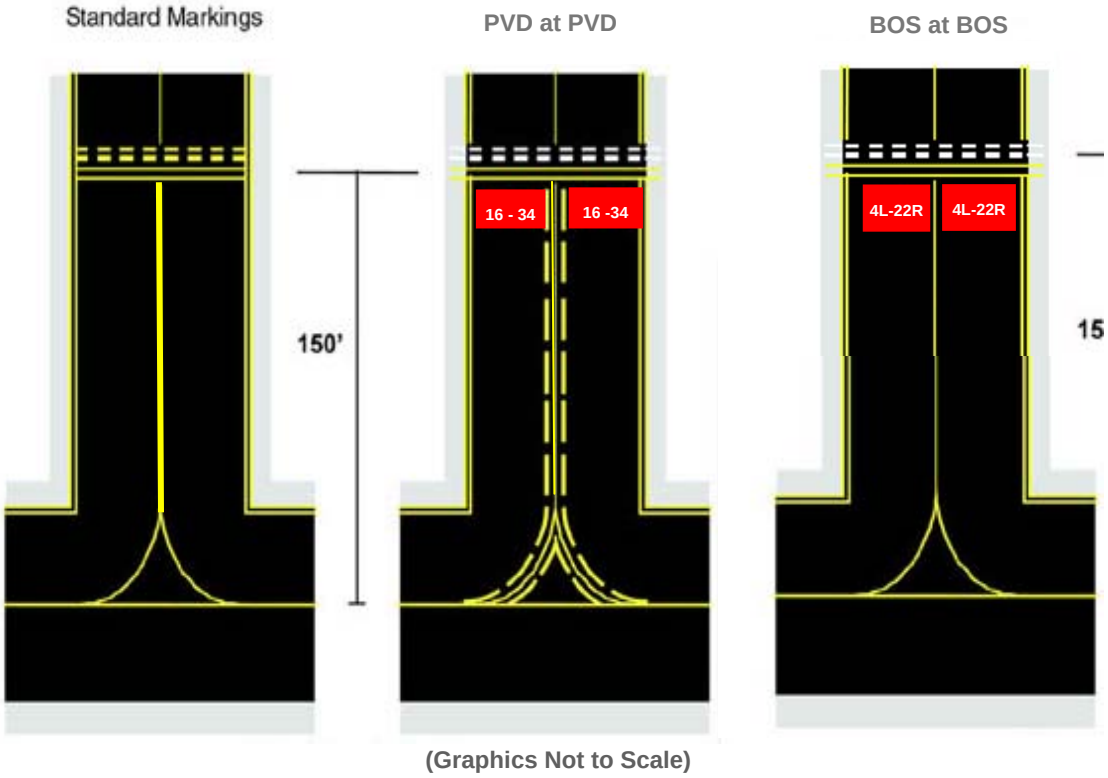


Figure 2-3. Comparison of the Three Marking Options: Standard, HTME, and HME

Section 3

Demonstration of the HME at BOS Airport

3.1 The HME Concept

The HME concept retains two enhanced marking features, see Figure 3-1, without the modified taxiway centerline. Elimination of the modified taxiway centerline reduces the number of markings and represents an advantage in terms of cost compared to the complete set of enhanced markings. Without the modified taxiway centerline, a pilot approaching a runway does not receive advanced notice of the runway.

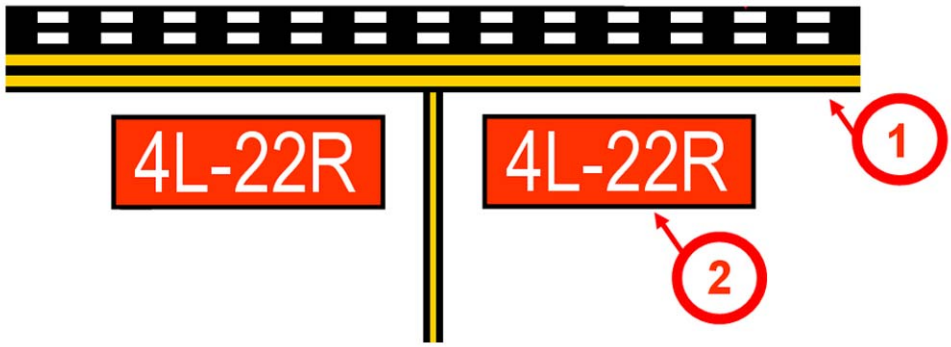


Figure 3-1. The HME Concept Evaluated at BOS Airport

3.2 Implementation of the HME Concept

The HME concept was implemented at runway 4L – 22R at BOS airport. This particular runway was selected because of its heavy surface movement as most aircraft traffic crosses this runway en route to and from the four active terminals and the GA parking and cargo areas. Approximately 20 % of all BOS departures use runway 4L – 22R. Figure 3-2 indicates the locations where the markings were implemented. Appendix A provides details on the HME dimensions and Appendix B provides details on runway 4L – 22R intersection locations and comparison of installation costs between PVD and BOS. The size of the inscription used at BOS is 12 feet[2].

[2] Type I beads were used for the markings.

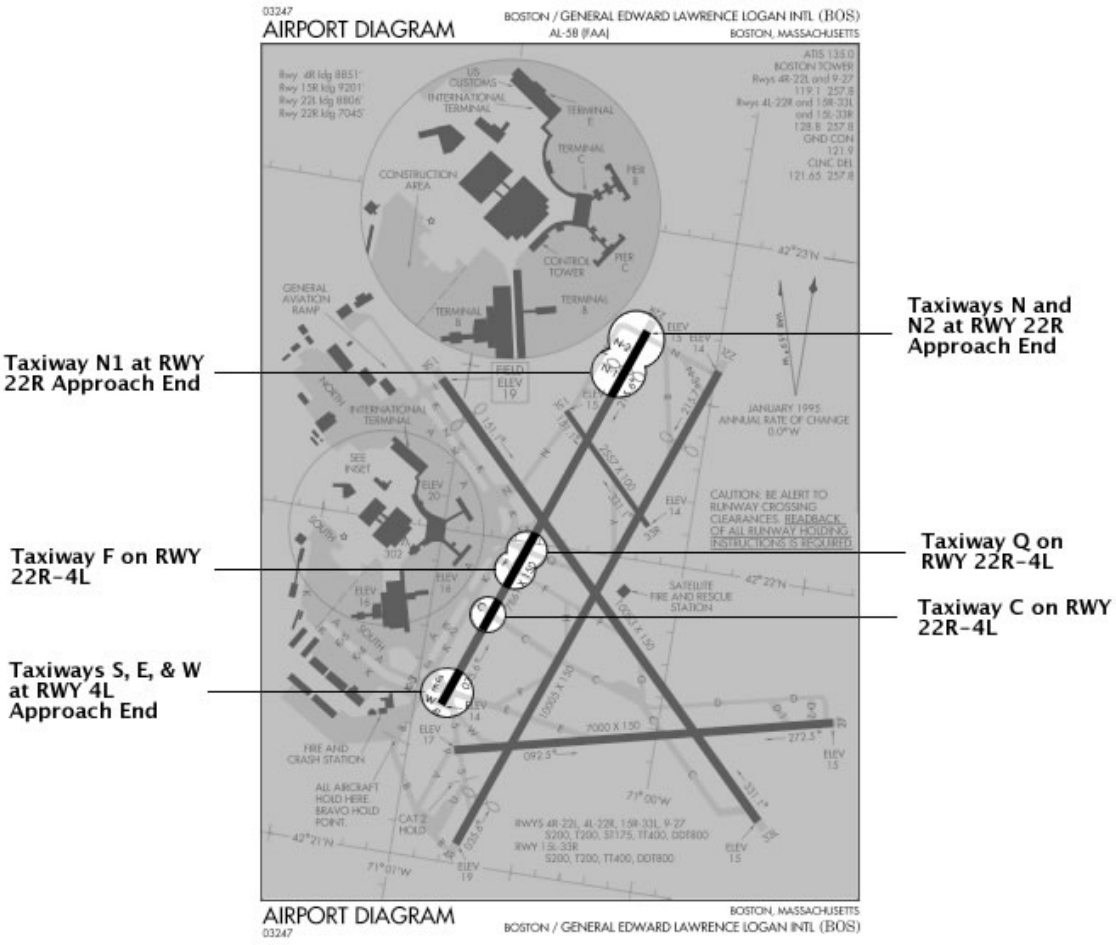


Figure 3-2. The HME Concept Implemented at Taxiway Intersections with Runway 4L – 22R at BOS

3.3 Field Demonstration Objectives

The field demonstration had the following objectives:

Objective 1: Determine if pilots find the HME concept to be as effective as the HTME concept.

Objective 2: Assess pilot perceived benefits and disadvantages of white dashes and of extended holdline markings at BOS.

Objective 3: Determine the pilots' preferences regarding applying enhanced surface markings at specific runways. In addition, assess the pilots' preferences about applying the enhanced surface markings at specific airports versus all airports.

No objective safety data (e.g. pilot deviations) were collected for this study because of the historically low occurrence of these events relative to the number of actual operations. For example, approximately 6 of 1,000,000 operations are reported as runway incursions in the NAS (FAA, 2004). Due to this low number of occurrences, an unwieldy data collection process would be required to observe objective safety benefits related to the enhanced marking concept.

The following sections are organized around the objectives of the field demonstration. Section 3.3.1 reports the pilot perceived benefits for HTME and HME concepts. These perceived benefits were assessed using two approaches. First, pilots compared HTME and HME concepts to the current markings standard. Second, pilots directly compared HTME and HME concepts to each other. Section 3.3.2 reports the perceived benefits about the white dashes and hold-line extension when compared to the current marking standard. For this purpose, pilots compared these features that were common to the HTME as well as the HME concepts to the current marking standard. Section 3.3.3 reports the pilot's preferences about implementation locations of the enhanced markings. These preferences were collected from the same group of pilots who had provided input to the previous objectives.

3.3.1 Evaluation of HME and HTME Marking Concepts: Method and Results

The first objective was to determine if pilots find the HME concept to be as effective as the HTME concept. Section 3.3.1.1 reports the results of pilots comparing HTME and HME concepts with the current marking standard. Section 3.3.1.2 reports the results of pilots comparing HTME and HME concepts directly with each other.

3.3.1.1 Comparison of the HME and HTME Concepts with the Current Marking Standard

The HME concept at runway 4L - 22R was evaluated by 74 pilots using survey questions (see Appendix C). All pilots were familiar with BOS. Surface painted holding position signs were not evaluated because they were not unique to the evaluated markings and pilots might have seen them previously at various other airports. In the following, this group of pilots is referred to as group "BOS". Pilots were informed about the modification of the markings through a notice to airmen message (Notice to Airmen, NOTAM, see Appendix D), through their station managers, company notices and e-mails (see Appendix E).

The HME evaluations were then compared to evaluations of the HTME concept at PVD that were reported by Olmos et al. (2003). In their study, 127 pilots had compared the HTME concept with the current marking standard. In the following, this group of pilots is referred

to as group "PVD". Descriptive data about the participating pilots in both groups are contained in Appendix F.

First, it was tested whether the two pilot groups "BOS" and "PVD" showed a different bias in their evaluation of airport surface markings. Potentially the two groups could differ in their assessment of the same surface marking enhancements which in turn would make a comparison of their evaluations for different surface marking enhancements meaningless.

It was found that the two groups of pilots agreed in their evaluations of the "white-dashes" on the holdline and the "holdline extension" for the HTME and HME concepts. Table 3-1 indicates that the average evaluation scores for the "white-dashes" and the "holdline extension" were consistently similar between the two groups for all of the evaluated questions and, using independent t-tests[3] no statistically significant differences were found between the averaged responses. The two groups of pilots had no different bias when evaluating the same surface marking enhancements. Therefore, their evaluations for the HME and the HTME concepts can be meaningfully compared. These results are reported next.

Table 3-1. Average Evaluation for the Marking Feature "White-Dashes" and "Holdline Extension" at Both Airports

	White Dashes		**Holdline Extension**	
	PVD	**BOS**	**PVD**	**BOS**
Direction^{+}	4.5	4.3	4.4	4.4
Visibility^{+}	4.5	4.4	-	-
Ease of understanding^{++}	2.9	3.0	3.2	3.1
Cause confusion^{++}	2.0	2.1	1.8	1.9
Recommendation^{++}	3.0	2.8	3.0	3.1

Note: $^{+}$Response scale from 1 to 6, 1 indicating dramatically worse; 6 indicating dramatically better. $^{++}$Response scale from 1 to 4, 1 indicating strongly disagree; 4 indicating strongly agree.

[3] Simplifying assumptions about the underlying normal distribution and the appropriateness of an interval scale measurement level were taken for the application of this statistical procedure and no inferential conclusions were drawn.

When comparing the combination of the enhanced markings at their respective airport with the current marking standard, the HTME concept received higher ratings for the visibility of the holding-position markings[4], for direction indication toward the runway[5], for awareness about approaching a runway[6], for minimal confusion[7], and for ease of understanding[8] than the HME concept. Both marking alternatives were about equally recommended for implementation. Also, pilots did not indicate a difference in the amount of clutter as a result of the HME and HTME concepts. Table 3-2 indicates that pilots preferred markings that include a modified taxiway centerline.

Table 3-2. Average Ratings for the Comparison of Markings at BOS and PVD with the Current Marking Standard

	PVD	**BOS**	**t-values for an independent t-test (degrees of freedom)**
Visibility^{+}	5.4	4.9	4.37* (175)
Direction^{+}	5.0	4.5	3.58* (171)
Awareness^{+}	5.4	5.0	3.06* (155)
Minimize Confusion^{+}	5.1	4.7	2.45* (152)
Easy to Understand^{++}	3.3	3.1	3.64* (164)
Cause Clutter^{++}	1.8	1.8	1.20 (154)
Recommendation++	3.2	3.2	0.39 (139)

[4] Independent t-test, Df = 175, $p < 0.001$. All following reported statistics in this paragraph refer to this test

[5] Df = 171, $p < 0.001$

[6] Df = 155, $p < 0.001$

[7] Df = 152, $p < 0.05$

[8] Df =164, $p < 0.001$

Note: [+] Response scale from 1 to 6, 1 indicating dramatically worse; 6 indicating dramatically better than the current marking standard. [++] Response scale from 1 to 4, 1 indicating strongly disagree; 4 indicating strongly agree to a statement concerning the evaluated markings aspect. *Indicates statistically significant difference using independent t-tests.

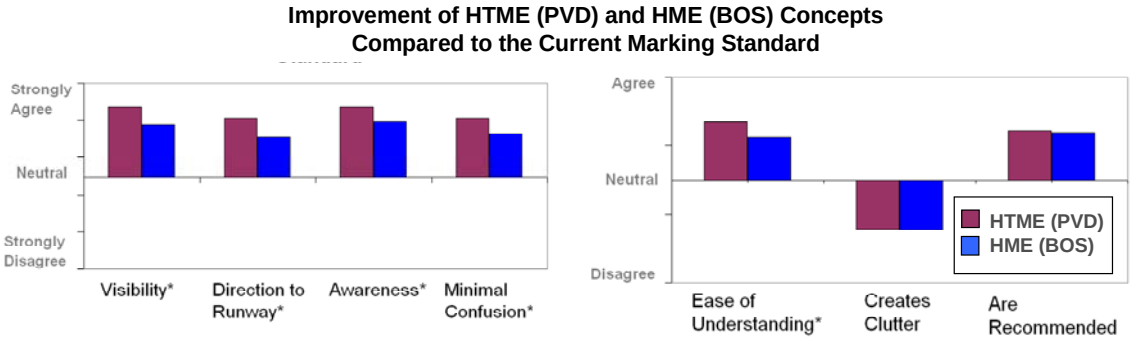


Figure 3-3. The Average Ratings for Perceived Improvements of Markings at BOS and PVD over the Current Marking Standard

Notes: *Indicate statistically significant differences between the evaluations of the two groups as reported in Table 3-2.

3.3.1.2 Direct Comparison of the HME and the HTME Concepts

A group of pilots who had seen both the HME- and the HTME concepts at BOS and PVD compared these two marking alternatives.

Twenty-three pilots who were familiar with both, the HME and HTME concepts at BOS and at PVD directly compared the set of markings by completing survey questionnaires (see Appendix G). This group is referred to as group "BOS and PVD". Descriptive data about the participating pilots are printed in appendix H. Surveys were distributed to 17 different airlines and one Fixed Base Operator (FBO) with operations at BOS. Airline station managers were asked to cooperate by distributing the surveys to the pilots. Surveys were made available in paper form as well as in electronic form via a link to a website. Participants were able to choose the way they preferred to complete the survey.

The surveyed pilots did not agree on the benefits of the modified taxiway centerline. About 36 % of pilots thought that the HTME concept improved the visibility of the holding position markings, see Figure 3-4. About 55 % of pilots thought that the HTME concept improved the pilots' awareness about the hold-short environment and 40 % of the pilots

thought that these markings improved direction indication toward the runway[9]. A majority of the pilots indicated that the HME concept at BOS was better for minimal confusion than the HTME concept (78 %)[10].

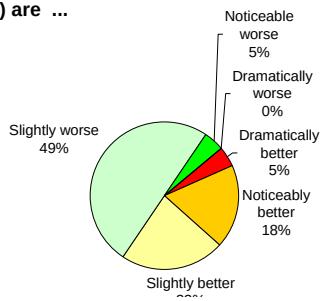
Overall, the participating pilots did not agree about a recommendation for the HME- or the HTME concept. Of the 23 pilots, 55 % recommended the HTME concept at PVD to be implemented as a marking standard and 45 % did not. Also, when pilots were explicitly asked if the modified taxiway centerline should be made part of a marking standard, 59 % of the pilots agreed and 41 % did not[11].

[9] None of these percentages are significantly different from a neutral midpoint of 50 %, as indicated by a Pearson's' Chi-square test.

[10] This percentage deviates significantly from a neutral midpoint as measured by a Pearson Chi-square test ($p < 0.05$).

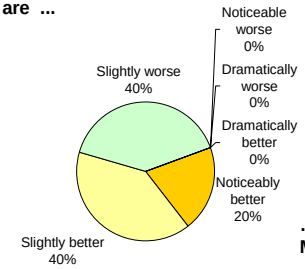
[11] None of these percentages are significantly different from a neutral midpoint of 50 %, as indicated by a Pearson's' Chi-square test.

For awareness when the pilot is approaching a runway, the markings without MTC* (at BOS) are ...



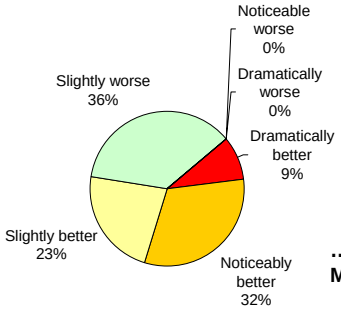
...than with MTC (at PVD).

For indicating direction to the runway, the markings without MTC (at BOS) are ...



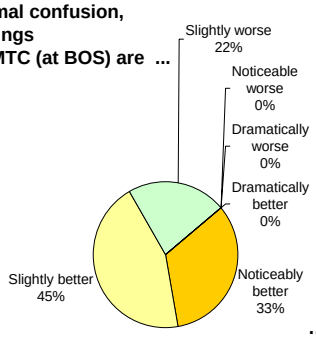
...than with MTC (at PVD).

For visibility of the holding position markings the markings without MTC (at BOS) are ...



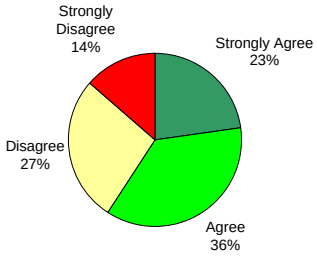
...than with MTC (at PVD).

For minimal confusion, the markings without MTC (at BOS) are ...



...than at PVD

The MTC should be included in the marking standard.



Recommend markings without MTC (BOS) rather than with (PVD) to be implemented as a marking standard.

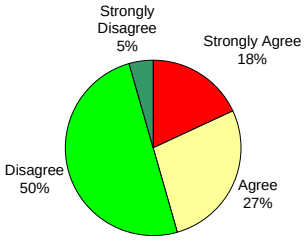


Figure 3-4. Results for Evaluating the HME and the HTME Markings for Group "BOS and PVD"

Note: *MTC: Modified Taxiway Centerline

3.3.1.2.1 Structured Interviews

Structured interviews were conducted with 13 pilots who had seen both, the HME and the HTME concepts at BOS and at PVD. In contrast to the survey methodology which allowed the collection of subjective data from a large number of pilots, the structured interview questions focused more on the pilots' experiences with the proposed markings. The interview questions are printed in Appendix J. Eleven of the thirteen interviews were conducted in a face-to-face setting and two interviews were performed via telephone. All interviews except one were recorded on audio tape and then later transcribed. Twelve of the 13 interviewed pilots also had completed the surveys. All interviewees had the set of questions available to them upon start of the interview.

3.3.1.2.2 Perceived Benefits of a Modified Taxiway Centerline

Six of the 13 pilots thought that the modified taxiway centerline increased their awareness about the hold-short environment. Six of the 13 pilots also thought that the modified taxiway centerline increased their awareness about the hold-short environment.

Four pilots indicated that they thought that pilots who were less familiar with the airport might benefit more from the modified taxiway centerline than pilots who are highly familiar with the airport.

Two of 13 pilots commented that the modified taxiway centerline could be especially useful for single pilots who cannot share the task of perceptually locating the hold-short markings with a crew. In addition, two pilots commented that the modified taxiway centerline could be especially useful at taxiway – runway intersections with rather shallow intersection angles. At such runway – taxiway geometries, the view of the runway can be obscured by the limited angle of view from the cockpit window.

3.3.1.2.3 Perceived Disadvantages of a Modified Taxiway Centerline

Five pilots indicated that they preferred receiving more information about purpose and design intent of the modified taxiway centerline as they felt that this feature was more ambiguous than the other marking enhancements. Four of the 13 pilots expressed the opinion that they were too familiar with the airport to benefit from the markings. They reported flying several times a day to BOS and PVD and felt that the modified taxiway centerline did not add any benefits.

Four pilots pointed out that their aircraft, a Cessna 402, has an extended nose which made it hard for them to see the taxiway centerline from their seating position in the cockpit. They therefore did not think a modification of the taxiway centerline would provide any benefit to them.

Four pilots indicated that the proposed modification of the taxiway centerline would add clutter to the markings on the airport surface.

3.3.1.2.4 Conclusions

Overall pilots preferred markings that included a modified taxiway centerline over the current marking standard. The perceived utility of the modified taxiway centerline was found to be moderated by various factors including the aircraft design from which they were viewed, pilots' familiarity with the airport, and the amount of information that pilots had received about the markings.

3.3.2 Evaluation of the HME: Method and Results

The second objective of this evaluation was to assess pilot perceived benefits and disadvantages of white dashes and of extended holdline markings at BOS. These features were contained in both the HME and the HTME concepts.

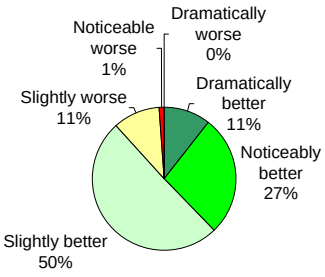
Ninety-seven pilots completed survey questions asking them about their preferences about white dashes and the extended holdline. Descriptions of these pilots were provided in the previous sections; 23 of these pilots had seen the white dashes and the holdline extension at both BOS and PVD, 74 of them had seen the markings only at BOS.

3.3.2.1 White Dashes at the Hold Short Line

The majority of pilots indicated a preference for the white dashes over the current marking standard. Among the 97 pilots, 84 % indicated that the white dashes increased direction indication, 91 % thought that they improved awareness about the runway environment, 92 % thought that they improved the visibility of the holding position markings and 84 % of the pilots thought that the white dashes were easy to understand, see Figure 3-5. Three % of the pilots commented that the white dashes helped clarify on which side of the holdline the runway was, and another three % of the pilots thought that the white dashes increased the contrast against the black background of the taxiway surface.

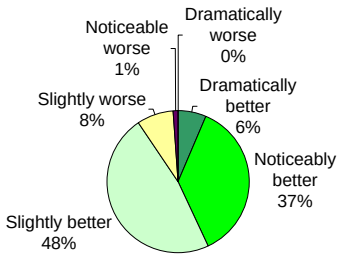
When asked about potential disadvantages of the markings, 86 % of the pilots did not think that the markings caused additional clutter, and 82 % did not think that the white dashes could be confused with other markings on the surface. Overall, 74 % of the pilots recommended including the white dashes into an airport surface marking standard. All reported percentages deviated significantly from a neutral midpoint as measured by a Pearson Chi-square test ($p < 0.05$), indicating that the majority of pilots reported benefits for the white dashes.

For indicating direction to the runway the change to white dashes is ...



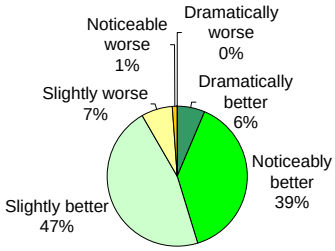
...than the current standard

For awareness the pilot is approaching a runway the change to white dashes is ...



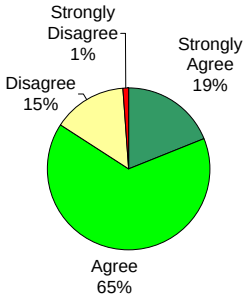
...than the current standard

For visibility of the holding position marking the change to white dashes is ...

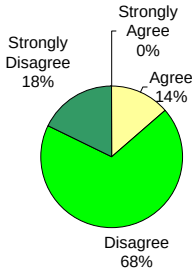


...than the current standard

The change to white dashes on the runway holding position marking is easy to understand.



The change to white dashes creates an unacceptable amount of clutter.



I would recommend the change to white dashes be implemented as a marking standard.

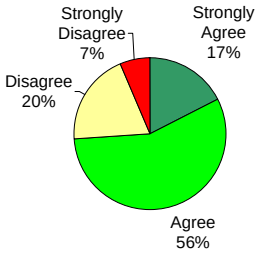


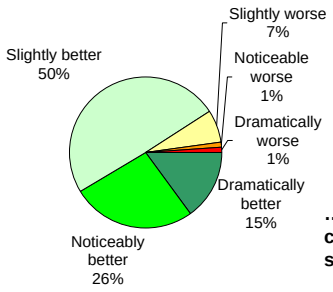
Figure 3-5. Responses of 97 Pilots who Evaluated the White-Dash Marking Feature

3.3.2.2 Extension of the Hold-Short Line onto the Shoulder

A majority of pilots preferred the holdline extension over the current marking standard. Ninety-one percent of the 97 pilots indicated that the holdline extension increased direction indication and improved awareness about the runway environment, 98 % that it improved the visibility of the holding position markings, and 70 % of the pilots thought that the holdline extension was easy to understand, see Figure 3-6. Ninety-two percent of the pilots thought that the holdline extension allowed them to taxi closer toward the runway.

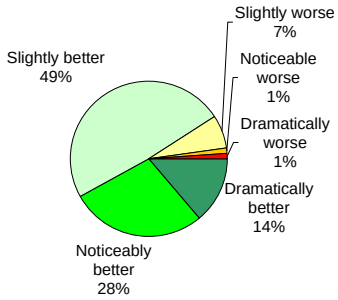
Finally, 86 % of the pilots did not think that the markings could be confused with other markings on the airport surface and 87 % of the pilots recommended including the centerline extension into an airport surface marking standard. All reported percentages deviate significantly from a neutral midpoint as measured by a Pearson Chi-square test ($p < 0.05$), indicating that the majority of pilots reported benefits for the extended holdline.

For visibility of the holding position marking the extension is ...



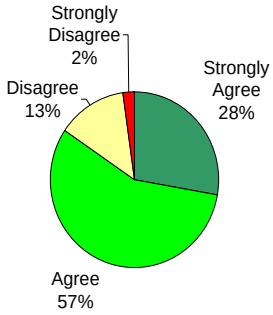
...than the current standard

For awareness the pilot is approaching a runway the extension is ...

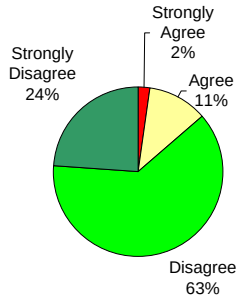


...than the current standard

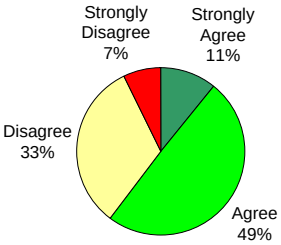
The extension is easy to understand.



The extension creates an unacceptable amount of clutter.



The extension allows me to taxi closer to the hold-short line while still being able to see the hold short line.



I would recommend the extension be implemented as a marking standard.

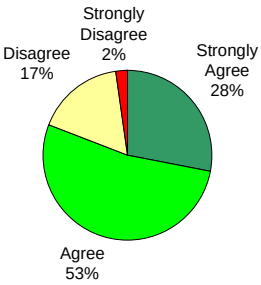


Figure 3-6. Responses of 97 Pilots Concerning the Hold-Short Line Extension Marking Feature

3.3.3 Preference Concerning Implementation of Markings: Method and Results

The third objective of this study was to determine the pilots' preferences regarding applying enhanced surface markings at specific runways and to assess the pilots' preferences about applying the enhanced surface markings at specific airports versus all airports.

The same 97 pilots who had participated in the first part of this study also provided feedback to this question. Among 23 pilots who were familiar with the markings at both BOS and PVD, a majority (80 %) preferred the markings to be placed at all runways (like at PVD).[12] Among all 97 pilots, the majority of pilots (80 %) indicated that they were not confused when the markings were placed only at one runway.[13] When asked in interviews, all pilots indicated that they would prefer the markings to be implemented at all runways on an airport. They indicated that standardized markings across all runways at an airport would simplify their taxiing and help them build correct expectations.

Only one pilot thought that placing the enhanced markings at specific runways with either high traffic or where historic incursions had happened might increase a pilots' attention for such intersections. However, the same pilot also thought that the benefits of applying the markings to all runways outweighed the benefits of placing enhanced markings only at one runway.

Eleven of 13 pilots (85 %) indicated in interviews that they preferred the marking enhancements to be implemented at all airports. As main reason for this position, pilots indicated that as they started to rely on enhanced markings they would expect them on different airports. However, five of the 13 pilots (38 %) indicated they understood if the markings were not implemented at all airports and large airports would benefit most from the implementation of these markings. Two of the 13 pilots (15 %) indicated that they thought the markings did not need to be implemented at all airports.

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[12] This percentage deviates significantly from a neutral midpoint of 50 % as measured by a Pearson Chi-square test ($p < 0.05$).

[13] This percentage deviates significantly from a neutral midpoint of 50 % as measured by a Pearson Chi-square test ($p < 0.05$).

Section 4

Conclusion

Evaluations of three groups of pilots evaluating two enhanced surface marking concepts indicate increased perceived benefits of the HTME concept over the HME concept as well as over the current marking standard. Pilots evaluated two enhanced marking concepts based on their experience at BOS and PVD airports where the two markings concepts had been implemented. Pilots indicated a general preference for a modified taxiway centerline and no differences in clutter were reported between the HME and HTME concept when they were compared with the current marking standard. Both types of markings were about equally recommended by both groups of pilots.

However, it was found that the perceived utility of the modified taxiway centerline depended on three factors:

- the pilot's familiarity with an airport
- the type of aircraft from which the markings were viewed
- the information that was distributed to pilots about the markings.

Pilots who are highly familiar with the airport (e.g. have seen the markings on average more than 100 times in about three months) did not perceive increased benefits of a modified taxiway centerline.

Pilots expressed a preference for implementing the markings at all runways at an airport and preferred the white dashes and the holdline extension over the current standard. Pilots also expressed a preference for implementing the markings at all airports[14] and some pilots indicated that they thought the greatest benefit of such markings would be realized at the largest airports. Standardization of the enhanced markings across all runways at an airport and across airports was explicitly recommended by pilots.

---

[14] Standardization and consistency of human factors elements are general design requirements as specified in the FAA Human Factors Design Standard [9].

List of References

1. Olmos, O. B., Estes, S. L., and Andrews, C. R. (2003). Analysis of the Providence Surface Marking Field Evaluation. (Report No. MP03W0000028). McLean, VA.: The MITRE Corporation.
2. Andrews, C., R. (2002). Airport and Highway Surface Marking Literature Review. (Report No. MP02W0000015). Mc Lean, VA.: The MITRE Corporation.
3. Federal Aviation Administration Office of Runway Safety (2004). FAA Runway Safety Report: Runway Incursion and Trends at Towered Airports in the United States.
4. Federal Aviation Administration (2004). FAA Flight Plan 2004-2008.
5. Estes, S. L., Olmos, B. O., Andrews, C. R., Andre, A. D., Chrysler, S. T., and Hannon, D. (2003). Simulation Evaluation of Proposed Airport Surface Markings. (Report No. MP03W0000030). McLean, VA.: The MITRE Corporation.
6. Olmos, B. O., Andre, and A. D., Chrysler, (2002). Airport Surface Paint Markings: Evaluation Recommendations. (Report No. MP02W0000161). McLean, VA.: The MITRE Corporation.
7. Andrews, C. R., Olmos, B. O., and Estes, S. L. (September 2003). Theodore Francis (T. F.) Green State Airport - Airport Surface Marking Field Demonstration Plan. (Report No. MP03W0000190). McLean, VA.: The MITRE Corporation.
8. Kelly, D., and Steinbacher, M. (1993). Pilot Surface Incident Safety Study. (Report MTR 92W0000116). McLean, VA.: The MITRE Corporation.
9. Cardosi, K., and Yost, A. (2001). Controller and Pilot Error in Airport Operations: A Review of Previous Research and Analysis of Safety Data. DOT/FAA/AR-00/51l.
10. Federal Aviation Administration (2003). Human Factors Design Standard for Acquisition of Commercial-Off-The-Shelf Subsystems, Non-Developmental Items, and Developmental Systems. DOT/FAA/CT-03/05.
11. Andrews, C. R., (2002). Airport and Highway Surface Marking Literature Review. (Report No. MP02W0000015). McLean, VA.: The MITRE Corporation.
12. Army Air Forces Technical Order No. 00-25-7, “Numbering and Marking of Airfield Runways, Landing Strips, and Taxiways,” 23 Aug 1944.
13. Douglas, C.A., 25 August 1978, Lighting and Marking of Exit Taxiways, FAA-RD-78-94.
14. FAA Advisory Circular (AC) 150/5340-1H Change 1, Standards for Airport Markings (12-01-2000).

Appendix A

Specification of the Holdline Marking Enhancement (HME) Concept at Boston Logan International Airport (BOS)

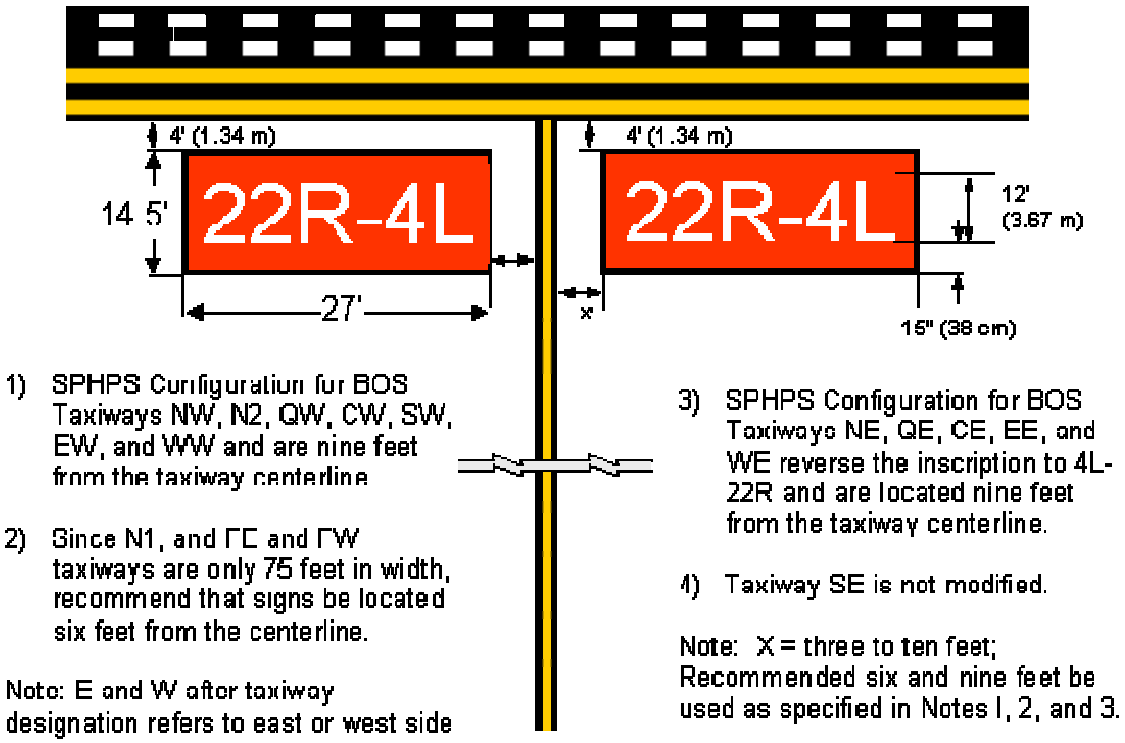


Figure A-1. BOS HME Concept with 12-foot Inscription

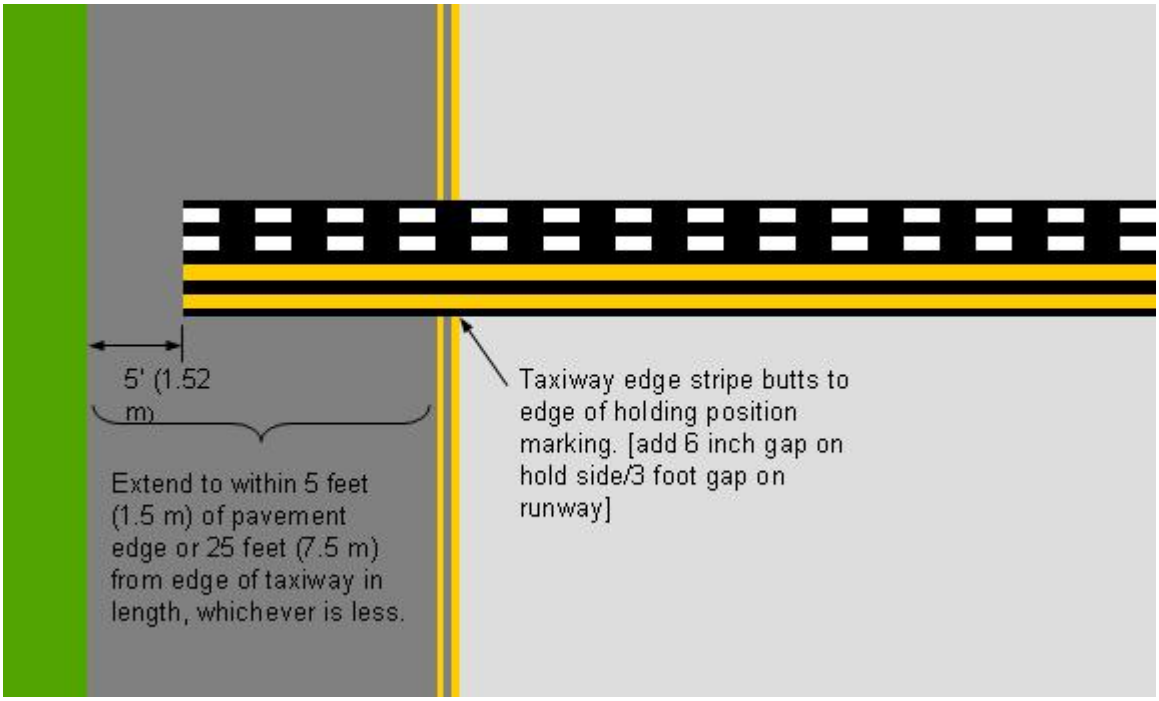


Figure A-2. Detail of Runway Holding Position Dashed Marking Color Change and Extension Used at Both T. F. Green State Airport (PVD) and BOS

Appendix B

List of Boston Logan International Airport (BOS) Intersections with Marking Modifications and Comparison between T. F. Green State Airport (PVD) and BOS Installation Costs

Table B-1. List of Intersections at BOS Runway 4L – 22R with Modifications of Holding Position Markings

Intersection	Width (ft)	# of Centerlines
West Side		
N	98	1
N2	97	1
N1	73	1
Q	99	1
F	74	1
C	104	1
S	91	1
E	97	1
W	100	1
East Side		
N	98	1
Q	97	1
F	73	1
C	99	1
E	98	1
W	50*	1
S	93	1

Table B-2 provides a cost comparison between the holdline and taxiway centerline marking enhancement (HTME) concept painted at all taxiway-runway intersections at PVD in 2003 and the holdline marking enhancement (HME) concept painted at all taxiway-runway intersections on a single runway at BOS in 2004.

Table B-2. PVD and BOS Markings' Cost Comparison

Airport	Installation Method	Number of Runways	Number of Holdlines	Enhanced Marking Type	Bead Type	Size of Inscription (in feet)	Labor and Material Total Cost (without stencil)	Estimated Cost per Runway Holding Position
PVD	In-house	2	19	HTME	I	9	18,000	$950
BOS	Contracted	1	16	HME	I	12	11,600	$725

Notes:

1. The cost of PVD plywood stencils was estimated at $1,000 and the cost of BOS sheet-metal stencils was estimated at $1,500.
2. The costs at PVD included removal of old markings. The cost at BOS did not, due to the new surfaces on Runway 4L – 22R.

The following Table represents the labor hours expended to install the markings initially in 2003 at PVD and at BOS in 2004, and the subsequent repainting at PVD in 2004.

Table B-3. Comparison of Installation Labor Hours between PVD and BOS Markings

Airport	Initial Installation Labor hours/holdline	Repainting Labor hours/holdline
PVD	9	4
BOS	6	TBD

Appendix C

Surveys

SURFACE MARKINGS SURVEY
"BOS and PVD"

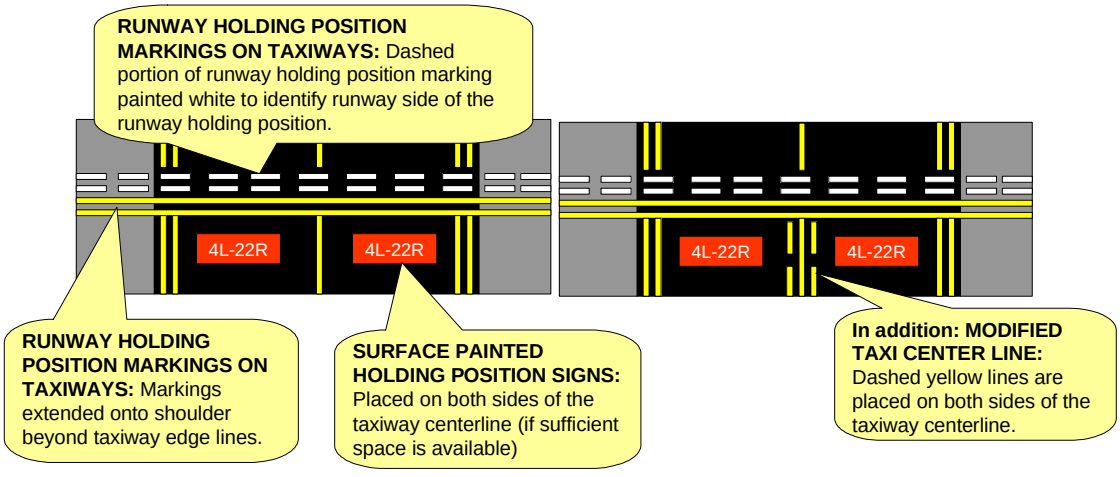
Only pilots who have seen the proposed markings at Boston Logan International Airport (BOS) and at T. F. Green State Airport (PVD) should complete this survey.

Under the sponsorship of the Federal Aviation Administration (FAA) Office of Runway Safety and Operational Services and the Office of Airport Safety and Standards, the Center for Advanced Aviation System Development (CAASD) at the MITRE Corporation is conducting research evaluating proposed changes to the current marking standard. This survey will take approximately 5-10 minutes to complete.
If you would prefer to complete the survey electronically, it can be accessed online at

http://www.mitrecaasd.org/bosmarkings.

All data gathered from this survey will remain completely anonymous.

DESCRIPTION OF PROPOSED MARKINGS TO BE COMPARED



Proposed Markings at BOS
(implemented at Runway 4L – 22R)

Proposed Markings at PVD
(implemented at all Runways)

BACKGROUND INFORMATION

Today's Date _____ Flight Hours _____

Type Ratings _____ Type of Aircraft Flown at BOS / PVD_____

How many times would you estimate you have seen the proposed markings at Boston Airport (BOS)? (An arrival and a departure would count as two viewings.) _____

How many times would you estimate you have seen the proposed markings at T. F. Green State Airport (PVD)? (An arrival and a departure would count as two viewings.) _____

For what airline are you flying (if not applicable, mark an X)? _____

COMPARE PROPOSED MARKINGS AT BOS (RUNWAY 4L – 22R) WITH THE MARKINGS AT PVD **(complete only if you have seen the markings at PVD and BOS).**

Using the following scale, place the letter that best completes the statement in the box beside questions 1 through 4. For any question that you feel you have not had enough experience with the proposed markings to answer, select "Not applicable".

A	B	C	D	E	F	G
Dramatically Better	Noticeably Better	Slightly Better	Slightly Worse	Noticeably Worse	Dramatically Worse	Not Applicable

☐ 1. For visibility of the holding position marking, the proposed markings at BOS are _____ than at PVD.

☐ 2. For awareness when the pilot is approaching a runway, the proposed markings at BOS are _____ than at PVD.

☐ 3. For indicating direction to the runway the proposed markings at BOS are _____ than at PVD.

☐ 4. For minimal confusion at intersections where multiple taxiway centerlines intersect at the runway, the proposed markings at BOS are _____ than at PVD.

Use the following scale to indicate your agreement/disagreement with questions 5 through 9. For any question that you feel you have not had enough experience with the proposed markings to answer, place an X in the box beside the question.

A	B	C	D	E
Strongly Agree	Agree	Disagree	Strongly Disagree	Not Applicable

☐ 5. I prefer the markings at BOS (standard taxi centerline) over the markings at PVD (modified taxiway centerline).

☐ 6. The modified taxiway centerline should be included in the marking standard.

☐ 7. The proposed markings should be placed on all taxiway – runway intersections at a specific airport (like at PVD).

☐ 8. I found it confusing that the proposed markings at BOS were placed only at runway 4L – 22R.

☐ 9. I would recommend the proposed markings at BOS rather than at PVD to be implemented as a marking standard.

If you would like to comment further on the proposed markings, please use the following space.

_____

_____

_____

_____

_____

EVALUATE THE PROPOSED CHANGE FROM YELLOW TO WHITE DASHES ON THE RUNWAY HOLDING POSITION MARKINGS (currently implemented at runway 4L – 22R at BOS and at PVD).

Current standard

Change to white dashes

If you feel you do not have enough experience with the change to white dashes on the holding position marking to answer the following questions, select "Not applicable".

Using the following scale, place the letter that best completes the statement in the box beside questions 1 through 3.

A	B	C	D	E	F	G
Dramatically Better	Noticeably Better	Slightly Better	Slightly Worse	Noticeably Worse	Dramatically Worse	Not Applicable

☐ 1. For indicating direction to the runway, the change to white dashes is _____ than the current standard.

☐ 2. For awareness the pilot is approaching a runway, the change to white dashes is _____ than the current standard.

☐ 3. For visibility of the holding position marking, the change to white dashes is _____ than the current standard.

Use the following scale to indicate your agreement/disagreement with questions 4 through 7.

A	B	C	D	G
Strongly Agree	Agree	Disagree	Strongly Disagree	Not Applicable

☐ 4. The change to white dashes on the runway holding position marking is easy to understand (the purpose of the markings is clear).

☐ 5. The change to white dashes creates an unacceptable amount of clutter (that can lead to confusion about where to proceed).

☐ 6. The change to white dashes on the runway holding position marking could easily be confused with other airport surface markings.

☐ 7. I would recommend the change to white dashes on the holding position marking be implemented as a marking standard.

If you would like to comment further on the change from yellow to white dashes on the runway holding position marking, please use the following space.

_____

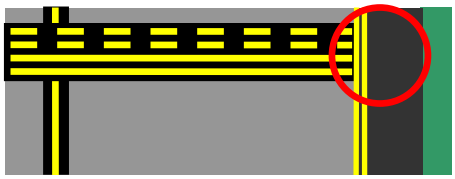
_____

_____

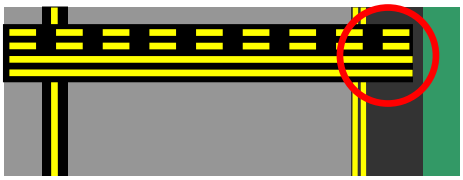
_____

_____

EVALUATE THE PROPOSED CHANGE TO EXTEND THE RUNWAY HOLDING POSITION MARKINGS (currently implemented at runway 4L – 22R at BOS and at PVD).



Current standard



Extension past taxiway edge markings

If you feel you do not have enough experience with the extension past the taxiway edge markings to answer the following questions, select "Not applicable".

Using the following scale, place the letter that best completes the statement in the box beside questions 1 and 2.

A	B	C	D	E	F	G
Dramatically Better	Noticeably Better	Slightly Better	Slightly Worse	Noticeably Worse	Dramatically Worse	Not Applicable

☐ 1. For visibility of the holding position marking, the extension is _____ than the current standard.

☐ 2. For awareness the pilot is approaching a runway, the extension is _____ than the current standard.

Use the following scale to indicate your agreement/disagreement with questions 3 through 7.

A	B	C	D	G
Strongly Agree	Agree	Disagree	Strongly Disagree	Not Applicable

☐ 3. The extension of the runway holding position marking beyond the taxiway edge lines is easy to understand (the purpose of the markings is clear).

☐ 4. The extension of the runway holding position marking beyond the taxiway edge lines creates an unacceptable amount of clutter (that can lead to confusion about where to proceed).

☐ 5. The extension of the runway holding position marking allows me to taxi closer to the hold-short line while still being able to see the hold-short line.

☐ 6. The extension of the runway holding position marking beyond the taxiway edge lines could easily be confused with other airport surface markings.

☐ 7. I would recommend the extension of the runway holding position markings beyond the taxiway edge lines be implemented as a marking standard.

If you would like to comment further on the extension of the runway holding position markings beyond the taxiway edge lines, please use the following space.

_____

_____

_____

_____

_____

If you have questions or would like more information about this project, please email us at bosmarkings@mitre.org

THANK YOU FOR YOUR TIME AND PARTICIPATION

Appendix D

Boston Logan International Airport Notice to Airmen

OCT-19-2004 13:19 MASS PORT AUTHORITY 6175611889 P.01/01

FCR-5/7

Date : Sun, 17 Oct 2004 11:45:27 -0400
From : Ops1@fcr1.massport.com
To : Airlines
Subject: FCR # 005
Mail ID: <200410171545.i9HFjR103624@fcr1.massport.com>

FCR Issued By: RC/JZ

FCR # 005

Boston-Logan Airport

Runway/Taxiway	Status	Remarks
4R/22L	OPEN	
4L/22R	OPEN	
15R/33L	OPEN	
15L/33R	OPEN	
9/27	OPEN	
*Kilo	OPEN	

Comments:

NONSTANDARD CNTRLN LEADOFF MARKING ON RWY 4R FOR YANKEE TWY.
MIGRATORY BIRD THRU THE AIRPORT BOUNDRY.
METAL CVRD TRENCH (12 IN LIP TRANSITIONING TO 2 IN LIP) 100FT LONG BY 13FT WIDE BY 2FT DEEP 980FT WEST OF AER9.
METAL CVRD TRENCH 10FT LONG BY 10FT WIDE BY 5FT DEEP 150FT EAST OF TWY BRAVO CNTRLN.
TRENCH COVERED WITH METAL PLATE 120 FT LONG 6 FT WIDE AND 5 FT DEEP 230 FT FROM RWY 9/27 CNTLN AT VICTOR TWY, AND EQUIPMENT STAGED AT SAME LOCATION.
CRANE 160FT IN HGT AGL 800FT W OF THE CONTROL TOWER.
FLIGHT CREWS USE CAUTION, INTERMITTENT FREQ INTERFERENCE ON FAA CONTROL TWR FREQ 119.1.
→ RWY 4L/22R HAS NON STANDARD ENHANCED RWY HOLD LINE MARKINGS ON TWYS N, N2, N1, Q, F, C, S, E AND W INTXNS.
NMRS CRANES MAX HGT 250 FT (FLAGGED AND LGTD), LCTD 1600-2100 FT SW OF RWY 15R DISPLACED THRD.

FCR-5/7

End of Message

TOTAL P.01

Appendix E

Contacted and/or Participating Organizations

United States (US) Carriers

American Airlines
American Eagle Airlines
AirTran Airways
ATA
Bank Air
CapeAir
Chautauqua Airlines
Colgan
Continental
Delta
Midwest Airlines
Northwest
Trans States Airlines d/b/a US Airways Express & United Express
USAirways

Foreign Carriers

Air Canada
Aer Lingus
Air France
Swiss
Virgin Atlantic Airways

Fixed Base Operator

Signature Flight Support

Associations

Allied Pilots Association
Regional Airline Association

Appendix F

Description of Pilots in Group "Boston Logan International Airport (BOS)" and Group "T. F. Green State Airport (PVD)"

Table F-1. Description of Participants in Groups "PVD" and "BOS" (The data group "PVD" were reported by Olmos et al. (2003))

	PVD	BOS
Participants	127 pilots	74 pilots
Data Collection	Apr-May 2003 (Olmos et al. 2003)	Sep-Oct 2004
Average Flight Experience	8,959 hours	10,177 hours
Pilots have seen markings on average	18 times	23 times
Pilot Type	16 GA 101 Transport (10 N/A)	No GA pilots 74 Transport pilots
Most Common Aircraft (Size)	B737 (tall)	B717, EMB 145 (medium)

Appendix G

Survey

SURFACE MARKINGS SURVEY
"BOS"

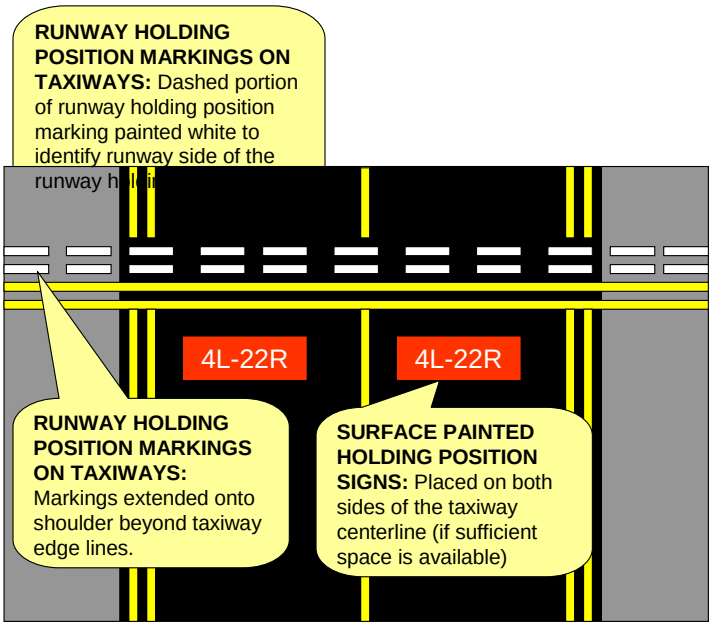
Only pilots who have seen the proposed markings at taxiways intersecting runway 4L – 22R at Boston Logan Airport (BOS) should complete this survey.

Under the sponsorship of the Federal Aviation Administration (FAA) Office of Runway Safety and Operational Services and the Office of Airport Safety and Standards, the Center for Advanced Aviation System Development (CAASD) at the MITRE Corporation is conducting research evaluating proposed changes to the current marking standard. This survey will take approximately 5-10 minutes to complete.

If you would prefer to complete the survey electronically, it can be accessed online at http://www.mitrecaasd.org/bosmarkings

All data gathered from this survey will remain completely anonymous.

DESCRIPTION OF PROPOSED MARKINGS AT RUNWAY 4L – 22R



BACKGROUND INFORMATION

Today's Date _____ Flight Hours _____

Type Ratings _____ Type of Aircraft Flown at BOS _____

How many times would you estimate you have seen the proposed markings at Boston Airport (BOS)? (An arrival and a departure would count as two viewings.) _____

For what airline are you flying (if not applicable, mark N/A)? _____

EVALUATION OF THE COMBINATION OF ALL PROPOSED MARKINGS

(Extension and change to white dashes on the runway holding position marking, and surface painted holding signs; currently implemented at runway 4L – 22R at BOS).

Using the following scale, place the letter that best completes the statement in the box beside questions 1 through 4. For any question that you feel you have not had enough experience with the proposed markings to answer, select "Not applicable".

A	B	C	D	E	F	G
Dramatically Better	Noticeably Better	Slightly Better	Slightly Worse	Noticeably Worse	Dramatically Worse	Not Applicable

☐ 1. For visibility of the holding position marking, the proposed markings are _____ than the current standard.

☐ 2. For awareness the pilot is approaching a runway, the proposed markings are _____ than the current standard.

☐ 3. For indicating direction to the runway the proposed markings are _____ than the current standard.

☐ 4. For minimal confusion at intersections where multiple taxiway centerlines intersect at the runway holding position, the proposed markings are _____ than the current standard.

Use the following scale to indicate your agreement/disagreement with questions 5 through 9.

A	B	C	D	E
Strongly Agree	Agree	Disagree	Strongly Disagree	Not Applicable

☐ 5. From my own taxiing experience, I have found the proposed markings to be very useful.

☐ 6. The proposed markings create an unacceptable amount of clutter (that can lead to confusion about where to proceed).

☐ 7. The proposed markings are easy to understand (the purpose of the markings is clear).

☐ 8. I found it confusing that the proposed markings were placed only at runway 4L – 22R.

☐ 9. I would recommend the proposed markings be implemented as a marking standard.

If you would like to comment further on the proposed markings, please use the following space.

_____

_____

_____

_____

_____

EVALUATION OF THE PROPOSED CHANGE FROM YELLOW TO WHITE DASHES ON THE RUNWAY HOLDING POSITION MARKINGS (currently implemented at runway 4L – 22R at BOS).

Current standard

Change to white dashes

If you feel you do not have enough experience with the change to white dashes on the holding position marking to answer the following questions, select "Not applicable".

Using the following scale, place the letter that best completes the statement in the box beside questions 1 through 3.

A	B	C	D	E	F	G
Dramatically Better	Noticeably Better	Slightly Better	Slightly Worse	Noticeably Worse	Dramatically Worse	Not Applicable

☐ 1. For indicating direction to the runway, the change to white dashes is _____ than the current standard.

☐ 2. For awareness the pilot is approaching a runway, the change to white dashes is _____ than the current standard.

☐ 3. For visibility of the holding position marking, the change to white dashes is _____ than the current standard.

Use the following scale to indicate your agreement/disagreement with questions 4 through 7.

A	B	C	D	G
Strongly Agree	Agree	Disagree	Strongly Disagree	Not applicable

☐ 4. The change to white dashes on the runway holding position marking is easy to understand (the purpose of the markings is clear).

☐ 5. The change to white dashes creates an unacceptable amount of clutter (that can lead to confusion about where to proceed).

☐ 6. The change to white dashes on the runway holding position marking could easily be confused with other airport surface markings.

☐ 7. I would recommend the change to white dashes on the holding position marking be implemented as a marking standard.

If you would like to comment further on the change from yellow to white dashes on the runway holding position marking, please use the following space.

_____

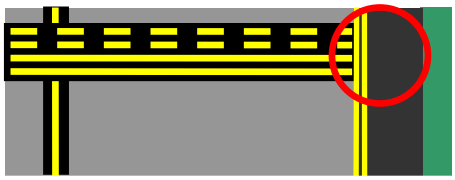
_____

_____

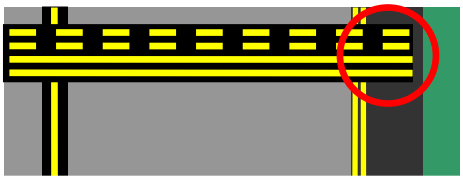
_____

_____

EVALUATION OF THE PROPOSED CHANGE TO EXTEND THE RUNWAY HOLDING POSITION MARKINGS (currently implemented at runway 4L – 22R at BOS).



Current standard



Extension past taxiway edge markings

If you feel you do not have enough experience with the extension past the taxiway edge markings to answer the following questions, select "Not applicable".

Using the following scale, place the letter that best completes the statement in the box beside questions 1 and 2.

A	B	C	D	E	F	G
Dramatically Better	Noticeably Better	Slightly Better	Slightly Worse	Noticeably Worse	Dramatically Worse	Not Applicable

☐ 1. For visibility of the holding position marking, the extension is _____ than the current standard.

☐ 2. For awareness the pilot is approaching a runway, the extension is _____ than the current standard.

Use the following scale to indicate your agreement/disagreement with questions 3 through 7.

A	B	C	D	G
Strongly Agree	Agree	Disagree	Strongly Disagree	Not applicable

☐ 3. The extension of the runway holding position marking beyond the taxiway edge lines is easy to understand (the purpose of the markings is clear).

☐ 4. The extension of the runway holding position marking beyond the taxiway edge lines creates an unacceptable amount of clutter (that can lead to confusion about where to proceed).

☐ 5. The extension of the runway holding position marking allows me to taxi closer to the hold-short line while still being able to see the hold-short line.

☐ 6. The extension of the runway holding position marking beyond the taxiway edge lines could easily be confused with other airport surface markings.

☐ 7. I would recommend the extension of the runway holding position markings beyond the taxiway edge lines be implemented as a marking standard.

If you would like to comment further on the extension of the runway holding position markings beyond the taxiway edge lines, please use the following space.

_____

_____

_____

_____

_____

If you have questions or would like more information about this project, please email us at bosmarkings@mitre.org

THANK YOU FOR YOUR TIME AND PARTICIPATION

Appendix H

Description of Pilots in Group "Boston Logan International Airport (BOS)" and "T. F. Green State Airport (PVD)"

Table H-1. Summary Description of Participants for the Participating Pilots in Group "BOS and PVD"

Participants	23 airline pilots
Data Collection	Aug – Oct 2004
Average Flight Experience	14,313
Pilots have seen markings on average	at BOS: 100 times at PVD: 50 times
Aircraft Flown	Embraer EMB145, Cessna 402

Appendix I

Summary Description of Pilots Participating in Interviews

Table I-1. Summary Description of Participants for Structured Interviews

Participants	13 pilots
Data Collection	Sep – Oct 2004
Average Flight Experience	8,600 hours
Pilots have seen markings on average	at BOS: 176 times at PVD: 58 times
Aircraft Flown	Embraer EMB145, Cessna 402

Appendix J

Structured Interview Questions

INFORMED CONSENT

Evaluation of Surface Painted Markings

The MITRE Corporation Center for Advanced Aviation System Development

(CAASD)

McLean, Virginia

The purpose of these structured interviews is to evaluate proposed modifications to the current surface painted marking patterns as seen at the taxiway intersections at runway 4L – 22R at Boston Logan International Airport. During the interview, you will be asked a series of questions relevant to the proposed surface markings. The interviewer will make an audio recording of your responses for later transcription. There are no known risks or physical discomforts associated with this interview beyond those of ordinary life. You may terminate your participation at any time. Your participation in this research will provide for the development of better surface painted marking patterns as well as for a better understanding of how pilot awareness can be benefited through the use of surface painted markings. We thank you for your involvement. If you have any further questions, please direct them to your interviewer or Peter Moertl (703-883-1080).

Statement of Consent

I acknowledge that my participation in these structured interviews is entirely voluntary and that I am free to withdraw at any time. I have been informed of the general research purpose of this study. I understand that my data will be maintained in confidence, and that I may have a copy of this consent form.

Please indicate your consent when asked by the interviewer. Your consent will be recorded on audio tape.

STRUCTURED INTERVIEW QUESTIONS

BACKGROUND

Name: _____

Date: _____

Time: _____

Flight Hours: _____

How many times would you estimate you have seen the proposed markings at runway 4L – 22R at Boston Logan International Airport (BOS)? (An arrival and a departure would count as two viewings.) _____

How many times would you estimate you have seen the proposed markings at T. F. Green State Airport (PVD)? (An arrival and a departure would count as two viewings.) _____

Aircraft Flown into BOS: _____

Aircraft Flown into PVD: _____

Airline: _____

Circle one:

Captain / First / Officer / N/A

Completed the survey in: Electronic Form - Paper Form

QUESTIONS

1. Compare the proposed markings at PVD with the markings at runway 4L – 22R at BOS: The markings at BOS do not have a modified taxiway centerline, but the markings at PVD do (see pictures below). What, if any benefits do you see in the modified taxiway centerline? Would you recommend that the modified taxiway centerline should be made part of the standard?

2. What advantages or disadvantages do you see in placing the proposed markings only at one specific runway (like at BOS) versus placing them at all runways (like at PVD)?

All following questions refer to the proposed markings at the taxiway intersections with runway 4L – 22R at BOS airport:

3. Under what conditions have you used the markings (day / night / low visibility)? At any specific intersections? Describe some of the ways you found the proposed markings at BOS to be useful.

4. Have you been in a situation at other airports where you think the proposed markings may have improved your awareness about the hold short location if the markings had been there? If yes, please describe that situation.

5. Have you had discussions with other pilots about the proposed markings at BOS? If yes, could you summarize their perceptions?

6. Did the proposed markings at BOS provide you with increased benefits compared to the current taxiway markings?

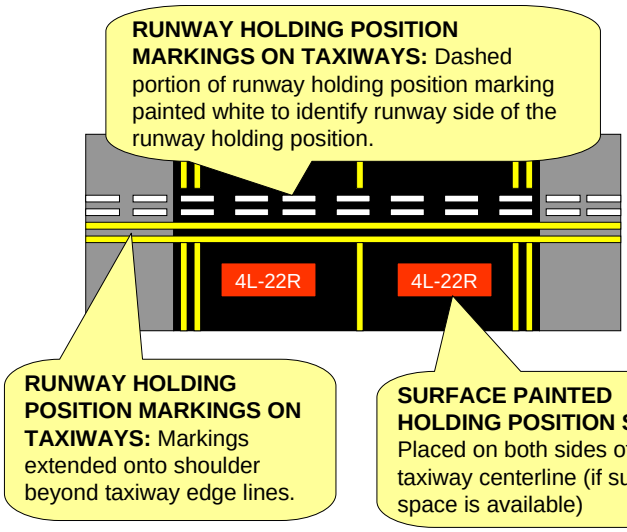
7. Do you believe other pilots will understand the purpose of the proposed markings the first time they see them? Why or Why not? Under what conditions?

8. What are the training issues associated with the proposed markings? How do you think they should be addressed?

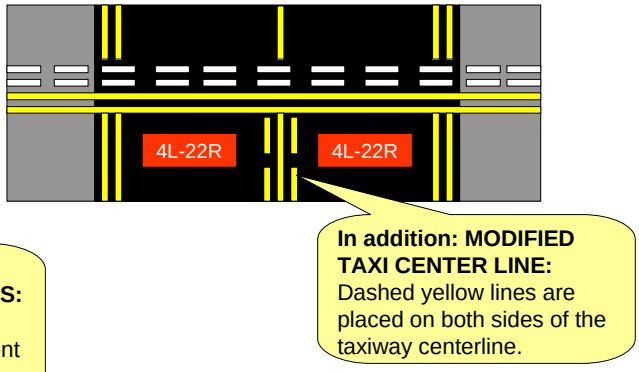
9. Do you see advantages or disadvantages such as potential confusion for pilots if some airports had the proposed markings but others did not?

10. Can you think of reasons NOT to change to the proposed markings at BOS? What are some of those reasons?

11. Is there anything about the proposed markings at BOS we did not cover and that you would like to comment on?



Proposed Markings at BOS



Proposed Markings at PVD

Glossary

%	Percent
AC	Advisory Circular
BOS	Boston Logan International Airport, Boston, MA
CAASD	Center for Advanced Aviation System Development
d/b/a	doing business as
Df	degrees of freedom
DFW	Dallas Fort Worth International Airport, Dallas, TX
DOT	Department of Transportation
FAA	Federal Aviation Administration
FBO	Fixed Base Operator
FY	Fiscal Year
GA	General Aviation
HME	Holdline Marking Enhancement
HTME	Holdline and Taxiway Centerline Marking Enhancement
N/A	Not Applicable
NAS	National Airspace System
PVD	T. F. Green State Airport, Warwick, RI
RWY	Runway
SPHPS	Surface Painted Holding Position Sign
TERPS	Terminal Instrument Procedures
US	United States