

## **Runway Approach Hold Area Signage and Marking Study**

June 2017

DOT/FAA/TC-TN17/32

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16. Abstract  The Federal Aviation Administration (FAA) Office of Airports (ARP) has proposed revising its standards for signage and markings for runway approach hold areas in accordance with recommendations from the FAA Approach Hold Workgroup. The effort aims to standardize approach hold guidance across lines of business. To implement the recommendations, a Safety Risk Management (SRM) panel was formed. The SRM panel participants discussed the lack of standardization for runway approach hold signs, markings and guidance, the proposed changes, and the hazards associated with each. Before the ARP Safety Risk Management Document (SRMD) was finalized, the new approach hold proposed changes were evaluated by the FAA Airport Technology Research and Development Branch at the FAA William J. Hughes Technical Center. The results of these evaluations are described in this technical note.  Data on the proposed approach hold signage and markings changes were collected at the FAA Cockpit Simulation Facility, Chicago O'Hare International Airport (ORD), Cleveland-Hopkins International Airport (CLE), and Nashville International Airport (BNA). Based on the data collected during this research effort, it is projected that the adoption of the proposed approach hold signage and markings standards will have the predicted residual effects of reducing pilot confusion and air traffic control (ATC) workload. However, the results showed that there may be an increase in runway incursions and ATC workload temporarily as individuals adjust to the changes.  This technical note was developed in support of the ARP SRMD. Additional in-depth study information can be found in the final report titled "Evaluation of Enhanced Visual Cues for Runway Approach and Runway Safety Areas," DOT/FAA/TC-16/26.					
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## LIST OF ACRONYMS

AC	Advisory Circular
AIM	Aeronautical Information Manual
APCH	Approach
ARP	Office of Airports
ATC	Air traffic control
ATO	Air Traffic Organization
BNA	Nashville International Airport
CISP	Confidential Information Share Program
CLE	Cleveland-Hopkins International Airport
DEP	Departure
FAA	Federal Aviation Administration
ILS	Instrument landing system
MLS	Microwave landing system
ORD	Chicago O'Hare International Airport
RSA	Runway safety area
RWY	Runway
SRM	Safety Risk Management
SRMD	Safety Risk Management Document
TWY	Taxiway
WJHTC	William J. Hughes Technical Center

## EXECUTIVE SUMMARY

The Federal Aviation Administration (FAA) Office of Airports (ARP) has proposed revising its standards for signage and markings for runway approach hold areas in accordance with recommendations from the FAA Approach Hold Workgroup. This effort aims to standardize approach hold guidance across lines of business. A Safety Risk Management (SRM) panel was formed to implement the recommendations. The SRM panel participants discussed the lack of standardization for runway approach hold signs, markings and guidance, the proposed changes, and the hazards associated with each.

Before the SRM panel finalized the ARP Safety Risk Management Document (SRMD), the proposed approach hold changes were evaluated by the FAA Airport Technology Research and Development Branch at the FAA William J. Hughes Technical Center. Data on the proposed approach hold signage and markings changes were collected at the FAA Cockpit Simulation Facility; and operational evaluations were conducted at Chicago O'Hare International Airport (ORD), Cleveland-Hopkins International Airport (CLE), and Nashville International Airport (BNA) to determine the safety and effectiveness of the changes prior to implementation throughout the airport system. One of the proposed changes added the departure runway information on the approach hold sign (e.g., 33-DEP) and paired it with the standard Pattern B surface marking. This technical note describes the resulting study.

Based on the data collected during this study, it is projected that the adoption of the proposed approach hold signage and markings standards will have the predicted residual effects of reducing pilot confusion and air traffic control (ATC) workload; however, the effect of the changes on the runway incursion rate cannot be confirmed. It was found that seven runway incursions occurred during the study at one of the evaluated approach hold areas; although further analysis revealed that the approach hold changes were not a primary factor for a majority of those incidents. Simulation evaluations showed that 94% of the surveyed pilots reported the proposed signage and markings was logically consistent with ATC instructions compared to 85% for the current signage and marking. In airport evaluations, 67% of the surveyed pilots reported that their situational awareness had increased as a result of the departure runway information being added to the signage. However, additional training and outreach will likely be required to explain the use of the Pattern B marking to pilots, since only 53% of pilots reported understanding the proposed signage and markings combination, compared to 70% for the existing approach hold signage and marking.

The impact of the proposed signage and markings changes on ATC workload was assessed by conducting interviews with ATC personnel at ORD, CLE, and BNA, both before and after the changes took effect. The intention of the proposed signage and markings change was to reduce ATC workload by decreasing the number of aircraft holding short of approach areas when associated runways are inactive. It was found that the level of workload initially increased at ORD during the evaluation, but decreased as pilots adjusted to the changes. The level of workload at CLE and BNA remained unchanged as a result of the low number of aircraft affected by the changes at these airports. Pilot surveys supported the prediction that pilots would be less likely to hold short when not given explicit instructions to do so with the proposed changes in place.



## INTRODUCTION

The Federal Aviation Administration (FAA) Office of Airports (ARP) has proposed revising its standards for signage and markings for runway approach hold areas in effort to standardize approach hold guidance across lines of business. As part of this effort, FAA ARP formed the Approach Hold Workgroup in 2011. This workgroup consisted of subject matter experts and representatives from the FAA ARP, Air Traffic Organization (ATO), Office of Runway Safety, Flight Standards Service, National Air Traffic Controllers Association, and several industry groups. Over the course of several meetings, the workgroup discussed the lack of standardization pertaining to runway approach hold areas and provided recommendations for new proposed changes.

To implement the proposed changes, a Safety Risk Management (SRM) panel was formed to complete the SRM process. The basics of the SRM process included: describing the system, identifying hazards, analyzing risk, assessing and mitigating risk. The findings were recorded in the draft “Approach Hold Signs and Markings Safety Risk Management Document (SRMD).” A similar SRMD was also produced by the panel to address the lack of specific guidance regarding requirements, procedures or phraseology related to air traffic procedures. The ATO’s SRMD, Approach Hold Document Change Proposal Safety Risk Management Document [1] was finalized on October 22, 2013.

Before the ARP SRMD could be finalized, the approach hold proposed changes were evaluated by the FAA Airport Technology Research and Development (R&D) Branch of the FAA William J. Hughes Technical Center (WJHTC). Signs and markings were installed at select airports to evaluate the safety and effectiveness of changes prior to implementation throughout the airport system. This technical note describes the resulting study. Additional in-depth study information can be found in the final report titled “Evaluation of Enhanced Visual Cues for Runway Approach and Runway Safety Areas,” DOT/FAA/TC-16/26 [2].

### PURPOSE.

The technical note provides a summary of the test results from the operational evaluations of the proposed runway approach hold signage and markings as identified in the SRMD.

### OBJECTIVES.

The specific objectives of this research effort were to:

- install and evaluate proposed runway approach hold signage and markings at select airports.
- determine the residual effects of the proposed signage and markings standards with respect to pilot confusion.
- determine the residual effects of the proposed approach hold signage and markings standards with respect to air traffic control (ATC) workload.

## BACKGROUND

Runway approach holding positions are described in Advisory Circular (AC) 150/5340-18F, “Standards for Airport Sign Systems” [3]:

At some airports, it is necessary to hold an aircraft on a taxiway located in the approach or departure area for a runway so that the aircraft does not interfere with operations on that runway. [3]

AC 150/5340-18F also describes the signage for runway approach hold signage and emphasizes that such signage is used only on taxiways [3]:

The inscription on a sign for a runway approach area is the associated runway description followed by a dash and the abbreviation ‘APCH’. The sign is installed on taxiways located in approach areas where an aircraft on a taxiway would either cross through the runway safety area (RSA) or penetrate the airspace required for the approach or departure runway (including clearway). Holding position signs are installed with associated paint marking. The sign is not installed on runways. [3]

The surface marking specified by the FAA for use with approach signage is described in AC 150/5340-1L, “Standards for Airport Markings” [4]:

For a taxiway that does not intersect a runway, but crosses through a runway approach area or runway safety area, the Pattern A marking scheme identifies the location on a taxiway where pilots and vehicle drivers are to stop to receive clearance from the airport traffic control tower before proceeding through the protected area. [4]

Figure 1 shows an example of a graphic of approach hold signage from AC 150/5340-18F, while figure 2 shows an example of the approach hold marking from AC 150/5340-1L. Figure 3 contains an illustrated example of a holding position signage and markings installation from AC 150/5340-18F.



15 - APCH

Figure 1. Holding Position Sign for Approach Areas [3]



Figure 2. Pattern A Holding Position Marking [4]

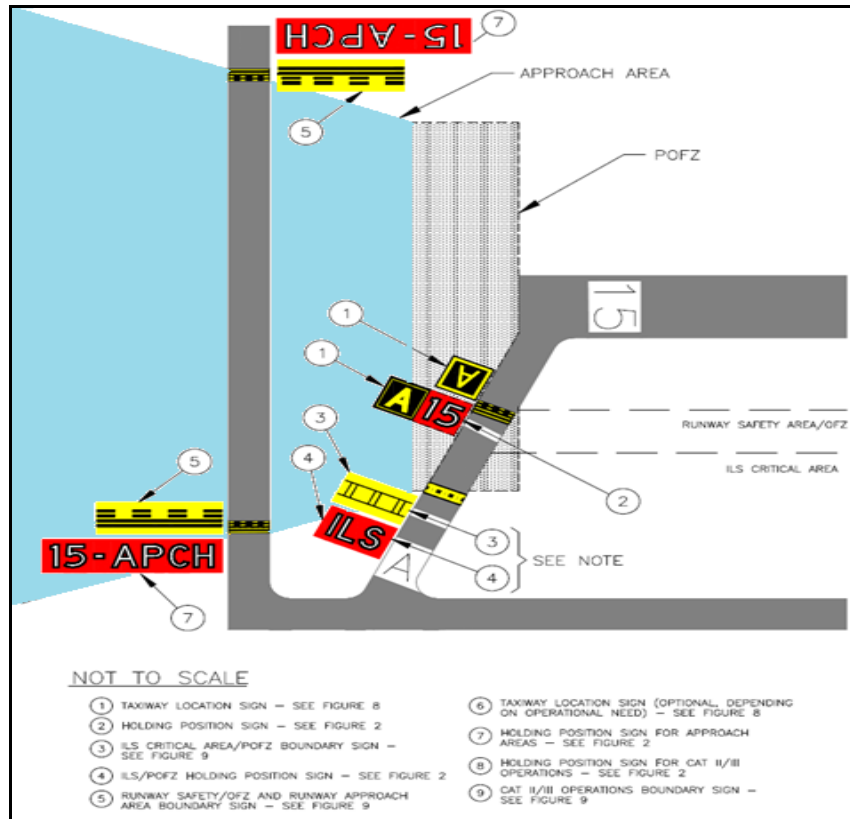


Figure 3. Approach Hold Area Example [3]

THE SRM RISK ASSESSMENT: EXISTING SYSTEM.

The SRM panel members determined two primary hazards resulted from the existing system (the current sign and marking) related to runway approach hold area signage and markings [5], shown in table 1.

Table 1. Primary Hazards Related to Runway Approach Hold Area Signage and Markings [5]

Hazard ID	Hazard Description
AH-E-01	Pilot confusion
AH-E-02	Increase in controller workload

As noted by the SRM panel in table 2, quantitative data had not been tracked on the occurrence of these hazards at runway approach hold areas prior to the study being conducted. Therefore, the hazards of these risks were determined by the knowledge of the subject matter experts on the panel.

Table 2. Hazard Analysis Worksheet [1 and 5]

Hazard ID	Effects	Severity	Severity Rationale	Likelihood	Likelihood Rationale	Initial Risk	Initial Hazard Risk
AH-E-01	Category C Runway Incursion	Minor (4*)	Taxiways in approach hold areas typically either do not intersect the runway or are a sufficient distance from a runway to allow for controller intervention.	Probable (B*)	Quantitative data does not exist; determination was made based on SME knowledge	Medium (4B*)	Medium (4B*)
AH-E-02	A minimal reduction in air traffic control services	Minimal (5*)	Increase in frequency congestion	Remote (C*)	Quantitative data does not exist; determination was made based on SME knowledge.	Low (5C*)	Low (5C*)

\* As described in references 1 and 5, the numbers denote a scale of severity, which ranges from 1 (catastrophic) to 5 (minimal); the letters denote a scale of likelihood ranging from A (frequent) to E (extremely improbable).

**PILOT CONFUSION.** The SRM panel members determined that pilot confusion, hazard AH-E-01, was caused by the following:

- “Regular runway holding position markings in conjunction with approach hold signs result in pilot confusion regarding whether crossing the runway holding position markings requires Air Traffic Control Tower clearance.” [5]
- “Most pilots expect runway holding position markings to be located in the vicinity of a runway entrance; both the approach hold and Precision Obstacle Free Zone hold marking positions may cause confusion when the hold is not directly associated with a runway entrance or when it is a long distance from the runway.” [5]

- “Indicating only one runway on the approach hold sign causes confusion when the approach hold is used for protection with departing traffic at the other end of the runway.” [5]

The effect of this hazard under the existing system was assigned a severity and likelihood classification by the SRM panel, which they referenced from Safety Management System (SMS) Manual Version 3.0 [6]. The SRM panel determined that pilot confusion could cause a Category C runway incursion. The initial risk of having a Category C runway incursion was determined to be medium, due to the probable likelihood of an occurrence; however, the severity was assessed to be minor because of the ample time and distance for controller intervention and the other existing controls in place. It was also noted by the panel that quantitative data did not exist for approach hold events, so this designation was based on subject matter experience and expertise. A runway incursion is defined as “Any occurrence at an aerodrome involving the incorrect presence of an aircraft, vehicle, or person on the protected area of a surface designed for the landing and takeoff of aircraft.” [7] The FAA defines a Category C runway incursion as “An incident characterized by ample time and/or distance to avoid a collision.” [7]

INCREASE IN CONTROLLER WORKLOAD. The other hazard identified by the SRMD panel, hazard AH-E-02, was the increased level of air traffic control workload due to existing approach hold signage and markings standards. This was identified as being caused by “Requiring specific clearance to pass a holding position marking when the associated runway is not active will unnecessarily increase air traffic controller workload.” [5]

Using subject matter expertise and experience as a basis, the SRM panel rated this risk severity as minimal based on the classification of a minimal reduction in ATC services in the SMS Manual Version 3.0 [6]. The likelihood of the ATC workload increase was defined as remote, because the group estimated that approach hold events occur more than once every three years, but less than once per three months. Therefore, this hazard was assigned a risk level of low.

#### THE SRM PANEL RECOMMENDATIONS.

To mitigate the hazards identified in the current system, the SRM panel members made the following recommendations:

- “For taxiways providing access to the runway, the mandatory holding position sign for taxiway/runway intersections and runway holding positions shall be used.” [5]
- “For taxiways that do not provide access to the runway, a new sign in conjunction with the Instrument Landing System/Microwave Landing System Holding Position Marking, also known as ladder marking or conditional hold markings, shall be used.” [5]
- “To remedy confusion occurring when an approach hold is being used for protection with departing traffic at the other end of the runway, the sign shall read, for example, ‘15 APCH – 33 DEP’.” [5]

It should be noted APCH refers to approach, and DEP refers to departure.

Figure 4 shows examples of the signage and markings recommended by the SRM panel. As shown, the signage includes “Runway XX DEP” in addition to the approach runway. The surface marking will be the Pattern B surface marking shown in figure 5.

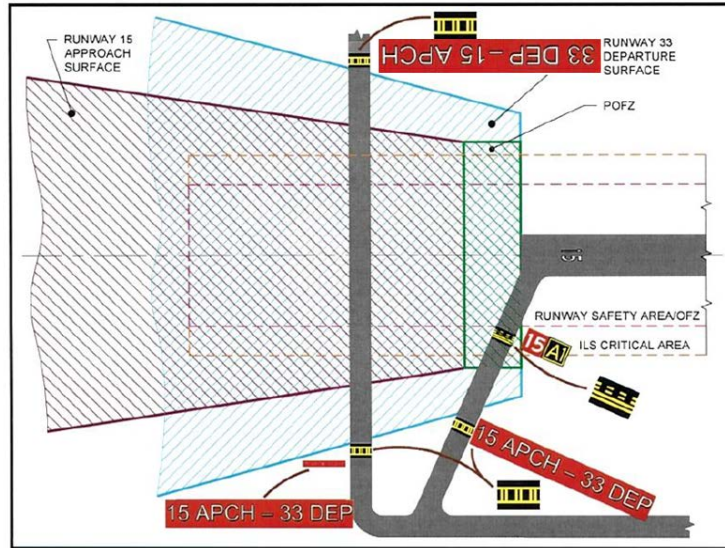


Figure 4. Proposed APCH/DEP Signage and Pattern B Marking [5]

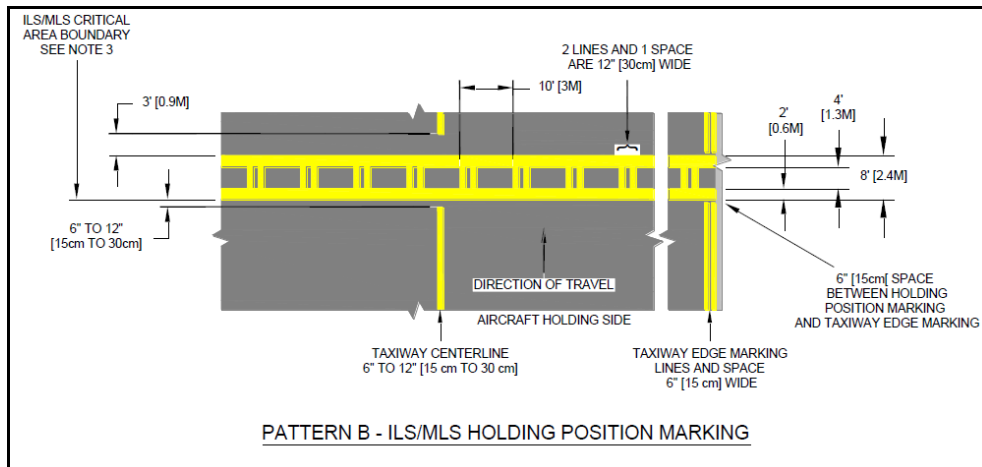


Figure 5. Pattern B Surface Marking [4]

The Pattern B instrument landing system (ILS)/microwave landing system (MLS) holding position marking was recommended by the Approach Hold Workgroup to be positioned adjacent to approach hold signage. Unlike the Pattern A surface marking, the Pattern B marking allows pilots and vehicle operators to cross the marking unless specifically instructed by ATC to hold short. This matches the Aeronautical Information Manual (AIM) definition of an approach

holding position more so than the Pattern A marking, which requires all individuals to hold short unless an explicit instruction is issued to cross the marking [8].

## EVALUATIONS AND FIELD INSTALLATIONS

Simulation evaluations were conducted at the WJHTC, followed by field installations and evaluations at three airports: Chicago O'Hare International Airport (ORD), Nashville International Airport (BNA), and Cleveland-Hopkins International Airport (CLE).

### COCKPIT SIMULATION EVALUATIONS.

The simulation evaluations occurred at the WJHTC Cockpit Simulation Facility. In these evaluations, 35 subjects took part in a series of scenarios using the Airbus A320 simulator. Data collected in the simulations were used in the selection of a design for airport evaluations. All simulation subjects were FAA-certified pilots. Pilot backgrounds included airline, military, and general aviation. The pilots' total flight time varied between 1,750 and 30,000 hours, as self-reported on forms completed prior to the evaluations. The median level of experience was 15,000 hours. The number of hours the subjects reported having flown in the last twelve months also varied, ranging from 0 to 860 hours. The median number of flying hours reported for the previous year was 300 hours.

In the simulation, subjects viewed four distinct runway approach hold/RSA sign designs and the ILS/MLS holding position marking at various locations at ORD. Each subject participated in six simulated evaluations, alternating day and night conditions. The day and night alternation was intended to gather data for each sign configuration in different lighting conditions without increasing the total number of evaluations. The evaluations used three means of data collection. The first method used a distance-measuring program in which the subject was asked to press a button mounted in the cockpit when the sign could be read and understood. The computer program calculated and recorded the distance. The second method was a survey in which the subject was required to record responses to statements regarding the signs and markings. For the third method, subjects were observed and recorded on how they responded to ATC taxi instructions.

Examples of the signage and markings viewed by subjects are shown in figures 6 and 7. Figure 6 shows the standard configuration of runway approach signage and surface marking, while figure 7 shows the simulated version of the signage proposed by the Approach Hold Workgroup. Each sign was evaluated on both runways and taxiways.



Figure 6. Simulated Standard Approach Signage and Markings Example



Figure 7. Simulated Proposed Approach Signage and Markings Example



## AIRPORT EVALUATIONS.

Operational evaluations were conducted at three airports: ORD, CLE, and BNA. Experimental signs and surface markings were installed at each airport by the research team and feedback was gathered from pilots, vehicle operators, and air traffic controllers. During the initial airport interviews, the causes of the identified hazards were also validated.

CHICAGO O'HARE INTERNATIONAL AIRPORT. At ORD, experimental signs and markings were installed at two runway approach hold areas for the research effort. The first was on Runway (RWY) 9L-27R protecting the RWY 14L approach area, as shown in the upper right portion of figure 8. The second location was the RWY 9R approach area on Taxiway (TWY) T, TWY G, and RWY 14R-32L, as shown in the lower right portion of figure 8. The airport operator then elected to install additional prototype signage and markings throughout the northern section of the airport beyond what was provided by the research team.

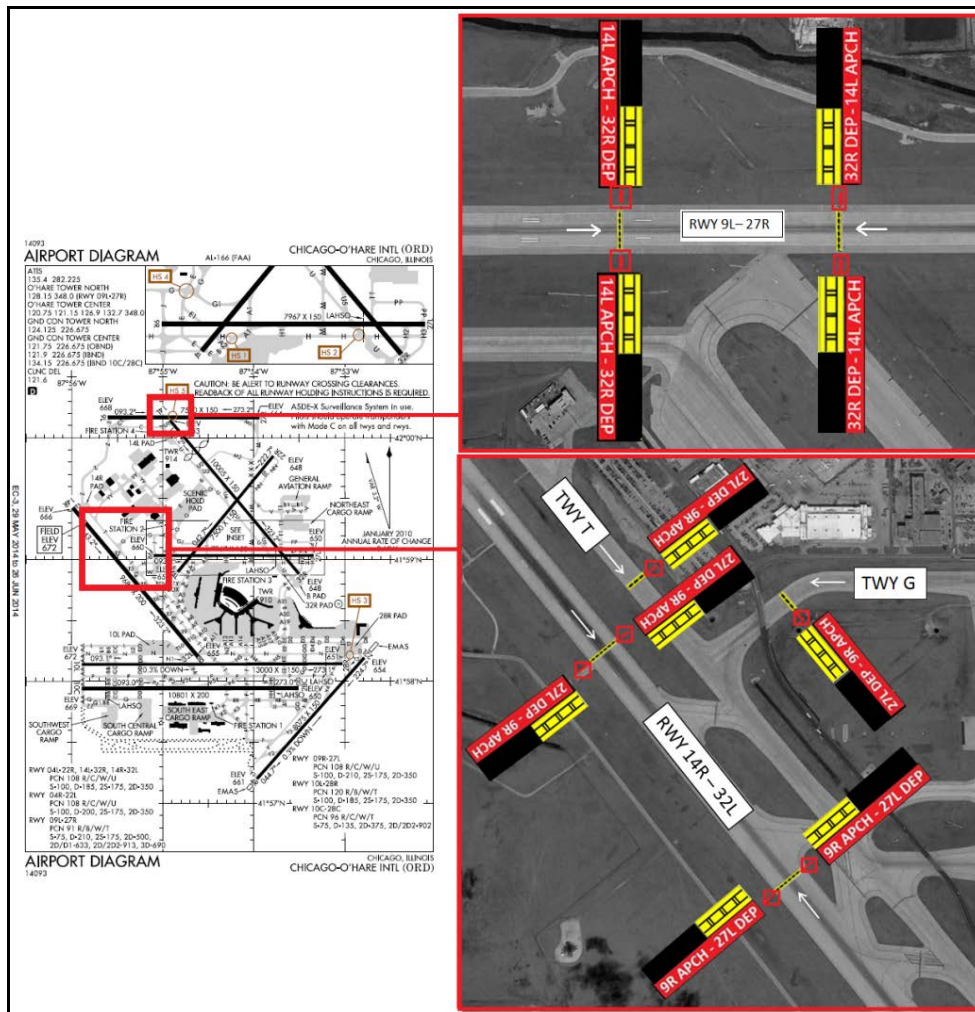


Figure 8. Signage and Markings Evaluation Locations at ORD

Two variations of signs were installed. The first, shown in figure 9, consisted of one, size 2, six-module sign unit. The second variation, shown in figure 10, consisted of a pair of separate, size 2, three-module sign units with the legend text split between the units. The connected, six-module sign was 218 inches long, exceeding the 145-inch maximum length specified in AC 150/5345-44J, “Specifications for Runway and Taxiway Signs” [9].



Figure 9. Installed Proposed, Connected Signage at ORD



Figure 10. Installed Proposed, Separated Signage at ORD

CLEVELAND-HOPKINS INTERNATIONAL AIRPORT. The second airport included in the evaluations was Cleveland-Hopkins International Airport (CLE). The signage and markings evaluated were located at the positions shown in figure 11. These consisted of four pairs of signage positioned on each side of RWY 10-28. The signs were size 2 panels with nonstandard, reduced, 9.5-inch legend text. This legend text size was used to determine if reduced-size legend text would be viable for use when space was not available to expand the sign units. A photo of the signage evaluated at CLE is shown in figure 12.

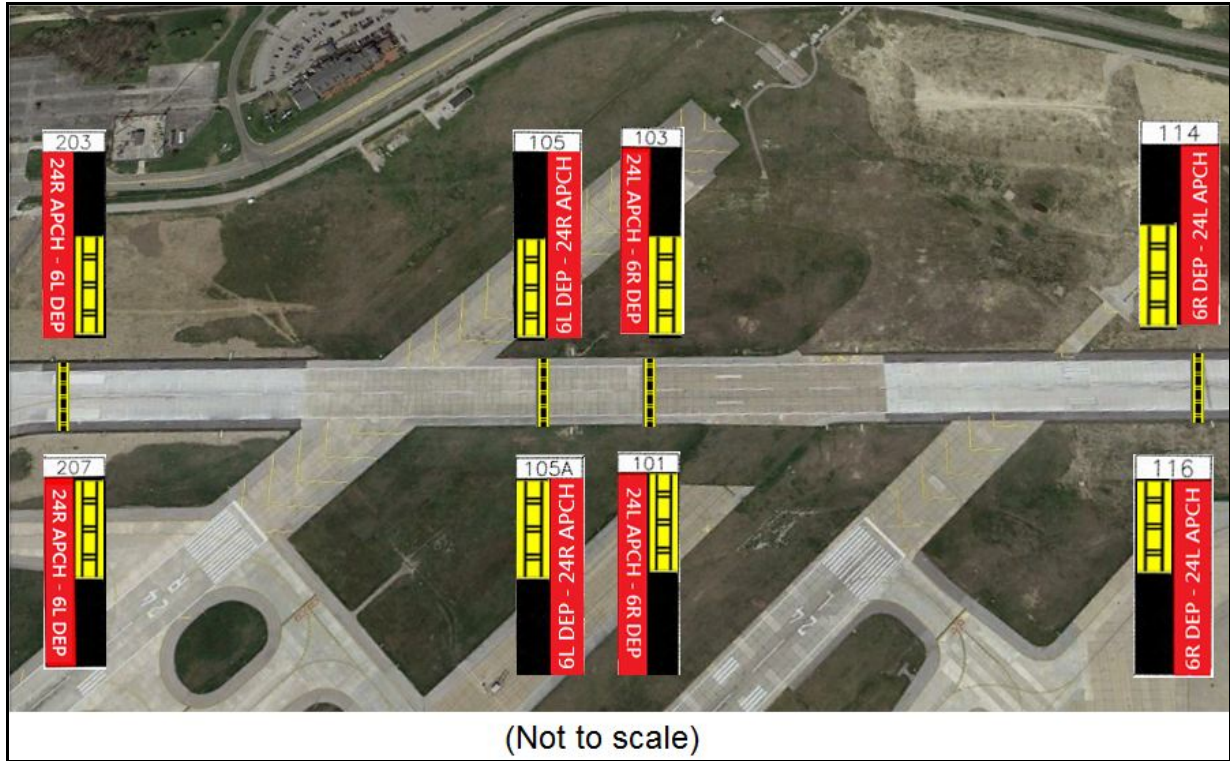


Figure 11. Signage and Markings Evaluation Locations at CLE



Figure 12. Installed Proposed Signage at CLE

NASHVILLE INTERNATIONAL AIRPORT. The third airport included in the evaluation was BNA. This evaluation consisted of installing signage and markings in the approach holding positions for the RWY 20C approach and RWY 2C departure, at the location shown in figure 13. All signs were size 3 modules. As shown in figure 14, the signs featured nonstandard, 11.5-inch legend text size to determine if this would be a viable alternative for airports lacking space for sign unit expansion. Similar to ORD and CLE, surveys were conducted to collect data from pilots and vehicle operators at the airport. ATC representatives at the airport were also interviewed to gather their feedback.

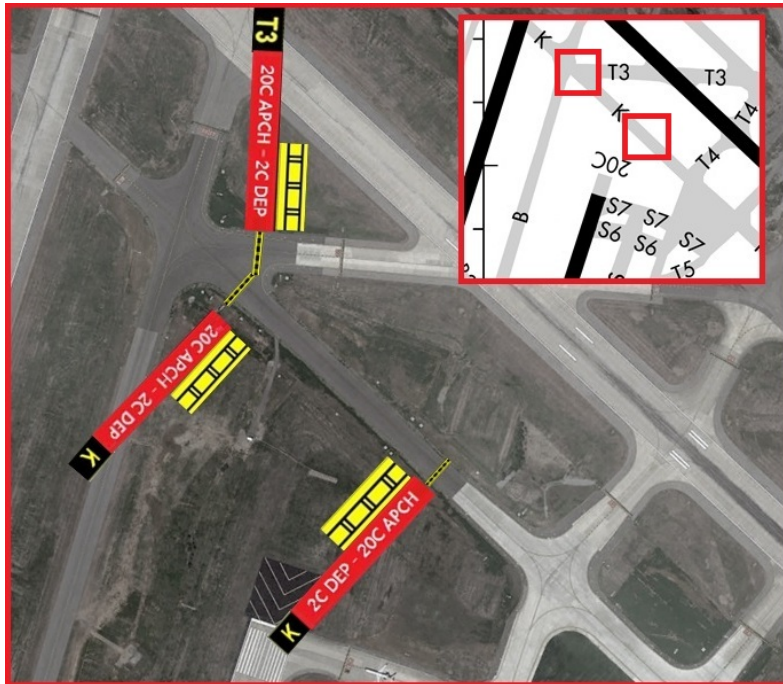


Figure 13. Signage and Markings Evaluation Locations at BNA



Figure 14. Installed Proposed Signage at BNA

## RESULTS

The results included in this technical note address the two hazards identified in the Approach Hold Document Change Proposal Safety Risk Management Document [1]: pilot confusion and increase in controller workload. The results for the existing and proposed signage and markings were compared to determine whether the changes had the intended effects of reducing these hazards, and whether the changes had any unintended, negative effects on safety. Based on the data collected during this research effort, it is projected that the adoption of the proposed approach hold signage and markings standards would have the predicted residual effects of reducing pilot confusion and ATC workload. However, the results showed that there could be an increase in runway incursions and ATC workload temporarily as individuals adjust to the changes.

Included in this section are the results of the collected survey responses of all subjects who reported observing the proposed signage and markings. The findings for both the simulation and airport evaluations are provided in the following sections for the pilot confusion and the increase in controller workload hazards. The simulation evaluations included data for 35 pilots. Of the 206 pilots and vehicle operators that participated in the research effort at ORD, CLE, and BNA, 121 individuals (66 pilots and 45 vehicle operators) reported observing the new signage and markings evaluated.

### FINDINGS: PILOT CONFUSION.

This section provides results of the study with respect to the hazard AH-E-01—Pilot Confusion, as identified by the SRM panel. To determine if the proposed signs and markings were effective in reducing pilot confusion, the existing and proposed signage and markings standards were compared.

SIMULATION EVALUATIONS. For the simulation evaluations, the level of understanding for the signage and markings was consistent between the current signage and markings and the proposed signage and markings. As indicated in figure 15, a slightly higher percentage of subjects (95%) agreed the meaning of the existing APCH signs and runway holding position markings were understandable compared to the proposed signs and markings (83%). This was expected because of the increased familiarity individuals had with the current approach signage compared to the new signage and markings being viewed for the first time.

### "The Meaning of the Signs and Markings Was Understandable"

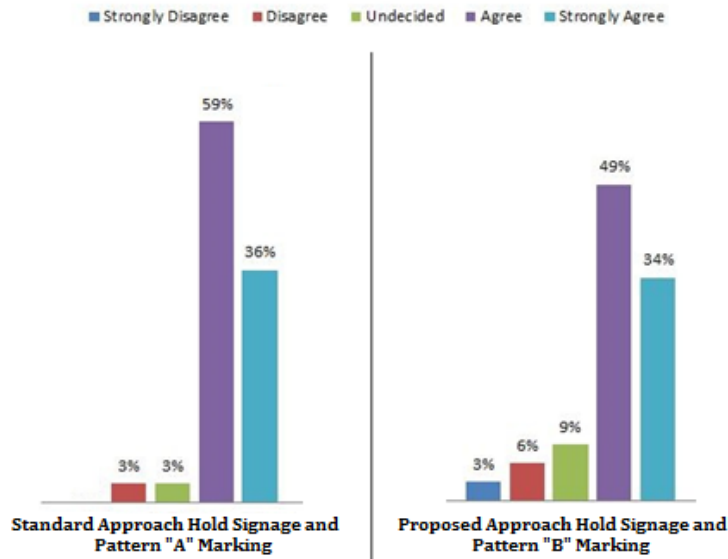


Figure 15. Simulation Results: Sign and Markings General Understanding

Throughout the simulations, subjects were instructed by ATC to hold short at certain approach hold locations, but at other locations they were not provided with any holding instructions. As shown in figure 16, 94% of subjects reported the proposed signage and markings were logically consistent with these ATC instructions compared to 70% for the current signage and marking.

### "The Signs and Markings Were Logically Consistent with Instructions Provided by ATC."

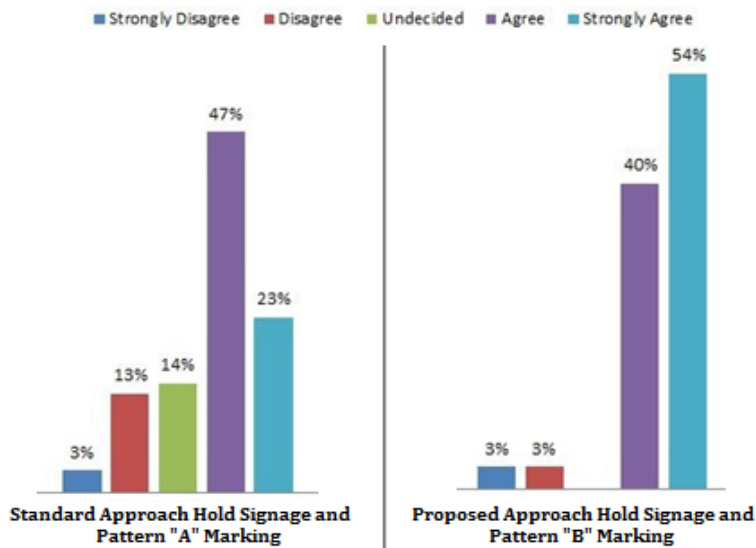


Figure 16. Simulation Results: Logical Consistency

Furthermore, as shown in figure 17, results from the simulations indicated the proposed signage and markings were more likely than the current signage and markings to be understood early enough to identify the location of the hold position.

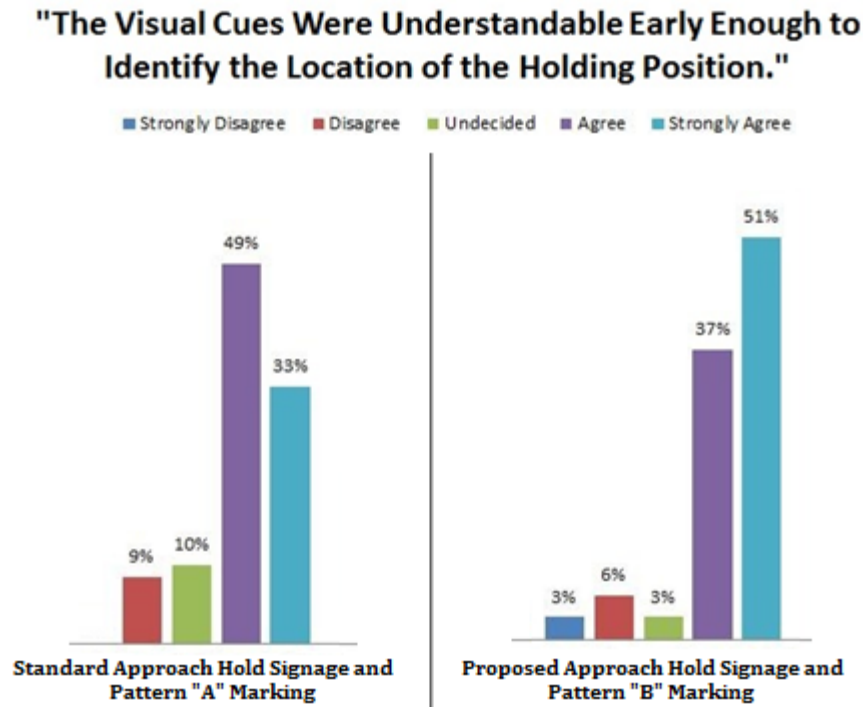


Figure 17. Sign and Markings Comprehension Time

**AIRPORT EVALUATIONS.** The survey results for ORD, CLE, and BNA were then compiled to examine how pilots reacted to the signage and markings in an airport environment. Prior to installing the proposed signage and markings at ORD, interviews were conducted with eight commercial pilots operating at ORD. This created a baseline for the current marking and sign combination. When researchers showed the subjects photographs of the 9R-APCH sign with Pattern A surface markings, six of the eight pilots agreed that these created confusion when operating on the airfield. Several pilots noted that because both the sign and the marking were on the runway, they thought this meant that there was another runway ahead. One pilot commented, “When you have an APCH sign corresponding with a runway hold line and no runway there, it is conflicting signals.”

Survey results for overall understanding of the proposed signage and markings was lower than for the current signage and marking. Figure 18 shows the level of agreement that the signage and markings were understandable fell from 68% to 53%. However, the level of disagreement that the signage and markings were understandable remained unchanged, with a greater percentage being undecided. This indicates that the lack of familiarity with the signage and markings is likely a significant factor contributing to the lack of understanding among some pilots. It is expected that as pilots are trained under the new guidance for the signage and marking, they will become more knowledgeable of their meaning.

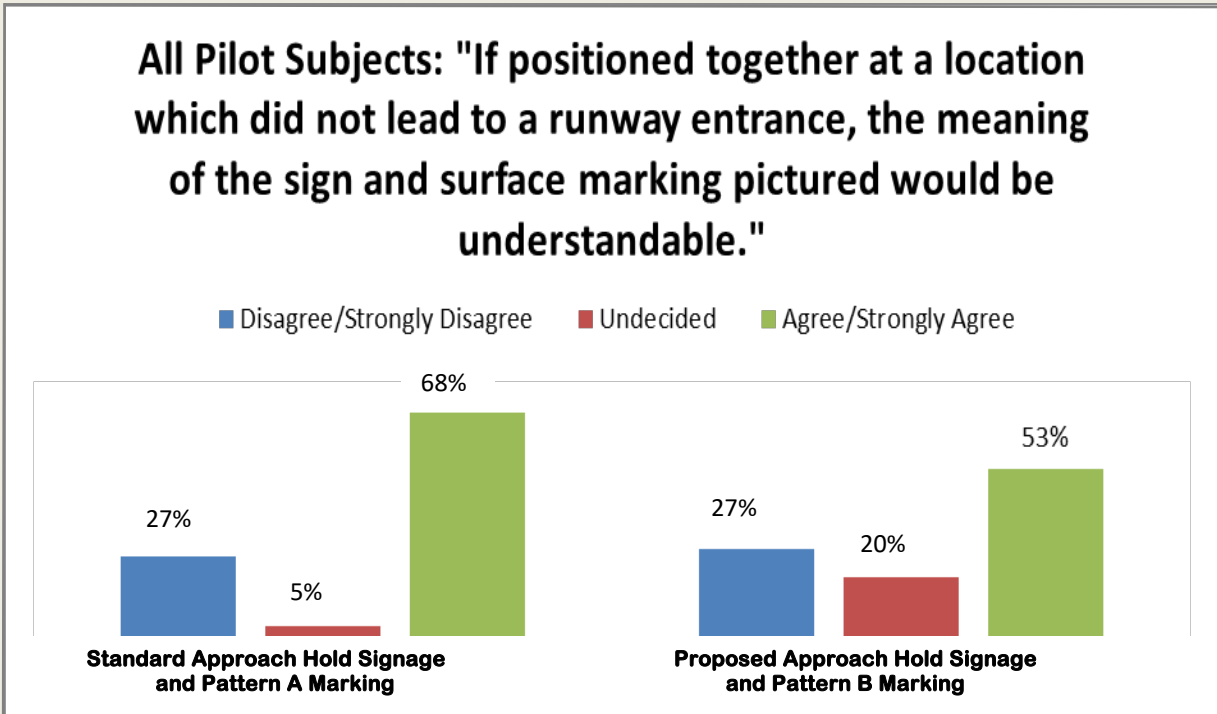


Figure 18. Airport Results: Signage and Markings Understanding

Several comments were received indicating that the proposed signage and markings were effective and were an improvement over the current signage and marking.

- “This makes it clear that this sign is not just for one runway end but affects holding instructions for both directions of use.”
- “I think it is a smart idea to change the marking from a runway holding position marking to an ILS holding marking. It will take a little time for everyone to learn, but it is a smart idea.
- “It’s like the ILS critical area, unless stated otherwise you can go past the critical area.”
- “Clearly describes what the protected area is and why.”
- “Much better than past.”
- “Tells you where you at and what you are coming to.”
- “It’s not the same as the markings at the end of a runway. This makes me think its purpose is other than entering an actual runway.”



However, some pilots were confused by the proposed signage and markings combination, as indicated in the comments below:

- “The surface marking doesn't seem to go with the signs.”
- “The ILS hold bar represents low-visibility hold short instruction. A pilot would be confused if he was told to hold short of 15-33 and just sees an ILS hold bar. I believe the pilot would cross the ILS hold bar and look for a standard hold bar.”
- “I didn't quite understand the relationship with the 33DEP sign and the ILS critical area.”
- “You are about to enter the approach area of RWY 15 or departure end area of RWY 33 which has an ILS component to it. It sends mixed message.”

As shown in figure 19, the level of agreement with the statement, “The sign(s) and surface marking(s) were logically consistent with the instructions provided by ATC,” was 69%. This indicates that a majority of the pilots thought there was logical agreement between the signage and markings and the ATC instructions, but some confusion remained among just under a third of the pilots.

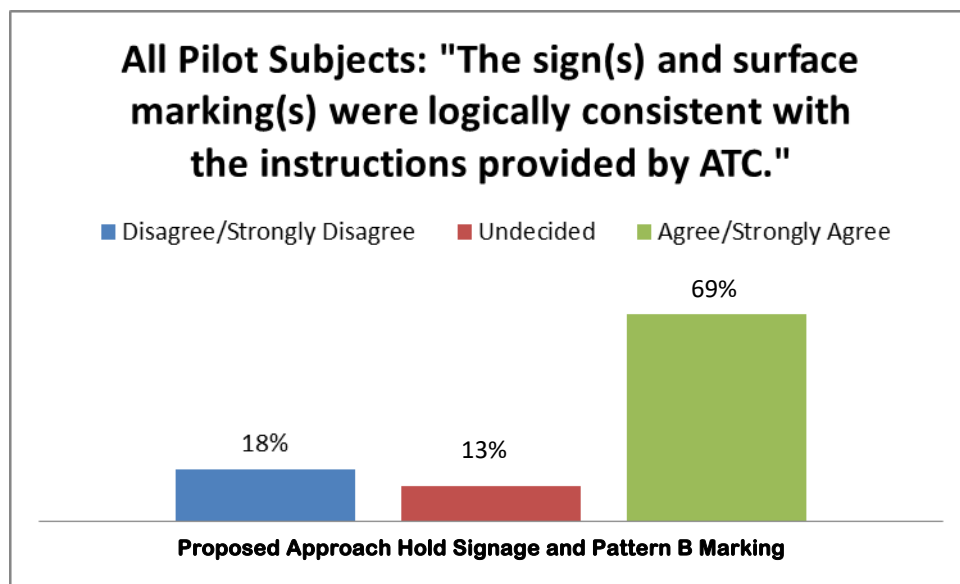


Figure 19. Airport Results: Logical Consistency

Pilots taking part in the airport evaluations were also asked to respond to a statement regarding the situational awareness benefits of the new signage compared to the existing signage. As shown in figure 20, 65% of pilots were in agreement that the inclusion of the departure runway information increased their situational awareness. However, 22% disagreed that the departure runway improved situational awareness, and 13% were unsure whether their situational awareness was increased relative to the current approach hold signage standards.

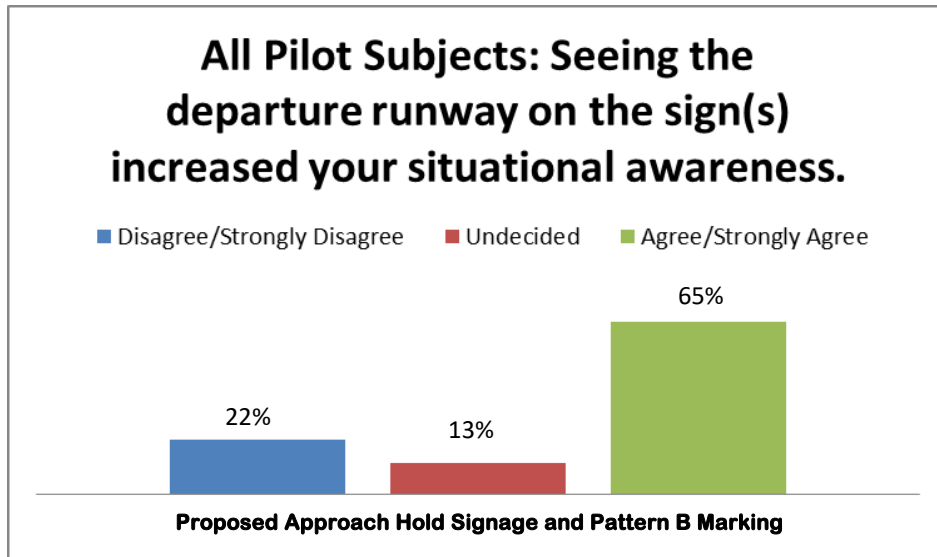


Figure 20. Airport Results: Situational Awareness

As shown in figure 21, the rate of disagreement with the statement, “To proceed past the sign and surface marking, explicit permission from ATC would be needed,” increased from 17% to 40%. This indicates some pilots would be less likely to hold short when not given explicit instructions to do so. Furthermore, the level of agreement with the statement fell from 76% to 51%. However, 16% of pilots reported being undecided regarding the statement. These results indicate that ATC workload will likely decrease when the signage and markings are adopted, but further training and guidance may be necessary to inform pilots that holding short at approach hold areas is only required when instructed by ATC.

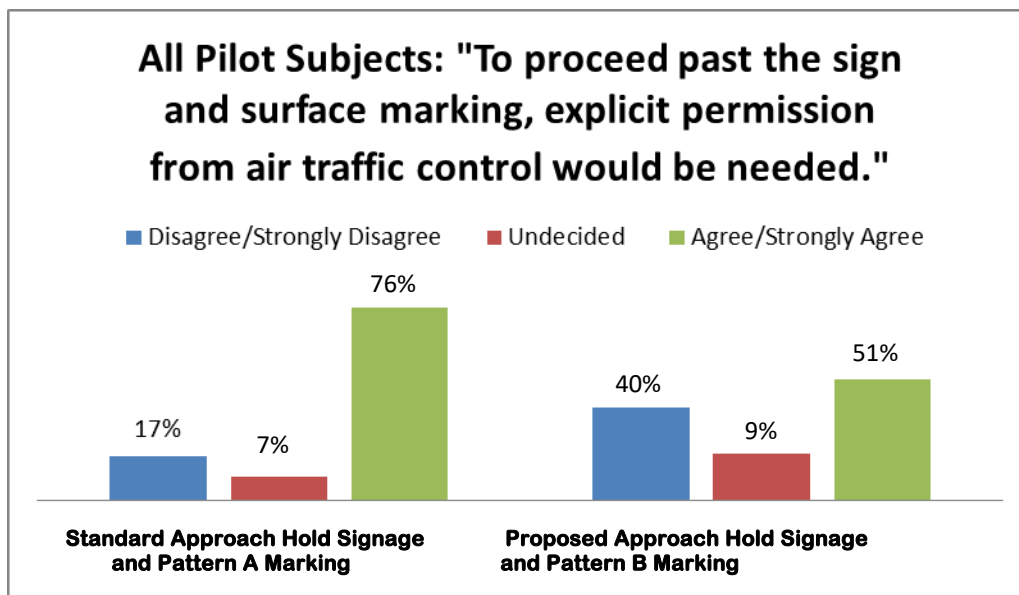


Figure 21. Airport Results: Approach Holding Requirements

RUNWAY INCURSION DATA. As described in The SRM Risk Assessment: Pilot Confusion section of this technical note, one of the risks identified by the SRM panel was the occurrence of runway incursions. It was found that seven Category C runway incursions occurred during the study at a location where the proposed approach hold signs and markings were installed. All the runway incursions that occurred during the study occurred at one approach hold area at ORD. This approach hold area, protecting RWY 9R-27L, is shown in figure 22. This approach hold area is identified as Hot Spot 6 (HS6). A hot spot is defined by the FAA as, “A location on an airport movement area with a history of potential risk of collision or runway incursion, and where heightened attention by pilots and drivers is necessary.” [10] Therefore, the complex taxiway geometry likely was a contributing factor for these events. Since runway approach hold incident data were not tracked prior to the study, it was not possible for researchers to compare the number of past events. It should be noted that no runway incursions were recorded during the first 6 months of the study (July 2014- January 2015), and none were reported after June 2015. The reason for the runway incursions occurring within this timeframe are not known, but could potentially be a result of changes in ATC procedures beyond the scope of the study.

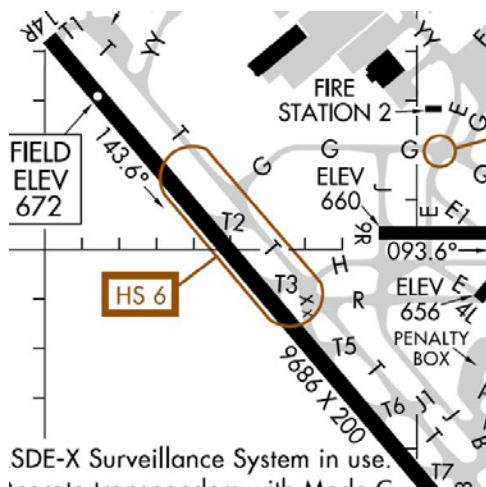


Figure 22. Hot Spot 6 at ORD

The narratives for these runway incursions are shown in table 3. One of the runway incursion events was because of controller error, and another was a result of a pilot mistaking a call sign of another aircraft for his or her own. The remaining five runway incursion events consisted of individuals failing to hold short of the approach after being instructed by air traffic controllers. One deviation involved a mechanic taxiing an aircraft; the remaining four were pilot deviations.

Unclear and misleading phraseology was found to be a contributing factor based on Confidential Information Share Program (CISP) reports [11] analyzed by the research team. Five reports involving the RWY 9R approach were shared on the CISP system, shown in table 4. In two of these reports (CISP 20438 and 21798), the ATC phraseology used was nonstandard and not expected by the pilots. In CISP 15760, the pilots were instructed to hold short at a taxiway intersection rather than at the runway approach holding position.

Table 3. Approach Hold Incursions During Evaluation Period for ORD RWY 9R

Date of Event	Runway Incursion Category	Report Narrative
1/21/2015	C	Ground Control instructed E145 to hold short at the Runway 9R approach hold at Taxiway Golf. Read back was correct. E145 continued past the hold line and turned southbound on Taxiway Tango. E170 was landing Runway 9R over Runway 14R and issued a go around.
1/28/2015	C	Inbound Ground Control (IGC) instructed Maintenance taxi E145 to taxi instructions via Taxiways Alpha, Alpha 10, Tango 10, Runway 32L, hold short of Runway 9R approach. Read back was correct. IGC transferred communication to North Ground Control (NGC) prior to the maintenance E145 reaching the approach hold. Maintenance E145 passed the approach hold without stopping. Second E145 was on short final for Runway 9R and sent around. Maintenance E145 mechanic did not contact NGC until about two and half minutes after the frequency change was issued. E145 on arrival overflew the taxiing maintenance E145 by 300-400 feet.
2/7/2015	C	GALX was departing Runway 27L. North Local Control coordinated the departure with Ground Control (GC). GC forgot and permitted a maintenance taxi/CRJ to cross the hold line for the protected area on Taxiway Tango and turn onto Taxiway Golf. Although the taxiing aircraft did not physically break the departure surface, the hold short markings define the protected area. ASDE indicates closes proximity when GALX crossed over Taxiway Tango as 745 feet lateral and 470 feet vertical.
3/11/2015	C	Ground Control observed E145 cross the approach hold line on Taxiway Golf and informed the pilot. B77W was landing Runway 9R and sent around. E145 was instructed to continue through the protected area.
3/19/2015	C	B738 landed Runway 9L and issued standard taxi with instruction to hold short Runway 9R approach hold on Taxiway Golf. Read back was correct. B738 passed the hold line and was stopped by the Ground Control prior to reaching Taxiway Tango. Second B738 landing Runway 9R was on approach inside of 1 mile and sent around.

Table 3. Approach Hold Incursions During Evaluation Period for ORD RWY 9R (Continued)

Date of Event	Severity Category	Report Narrative
4/24/2015	C	Ground Control (GC) instructed first B738 to cross Runway 32R and hold short of Runway 9R approach hold. Read back was correct. B738 continued past the hold line and was stopped by GC. Second B738 was an approach to Runway 9R inside of 1 mile and sent around.
6/6/2015	C	CRJ7 passed Runway 9R Approach Hold without ATC authorization, resulting in a conflict with a B772 landing Runway 9R. GC instructed CRJ to hold short of the 9R approach, which the pilot read back. GC issued a B739 (ahead of CRJ7) instructions to continue past the approach hold. The crew of the CRJ7 mistook the instruction for them and read it back with their call sign. GC did not catch the incorrect read back. B772 was sent around on short final when CRJ7 was observed in the protected area, passing approximately 120 feet behind and 200 feet above CRJ7.

Table 4. The ORD CISP Reports [11]

CISP Identification	Event Narrative
15760	<p>We landed at KORD runway 9L. Visual conditions. Started the long taxi to the terminal through the “hanger area”. We landed up on Gulf taxiway holding short of taxiway Tango. We held behind a UAL A320. The A320 was given instructions to turn left on taxiway Tango and proceed. We stopped short of the “roadway” and short of Tango taxiway. We were then given clearance to “Turn left onto Tango hold short of Tango 2 intersection.” Numerous vehicles continued to cross the roadway. Finally underway, we turned left onto Tango and continued. As we made the turn SE bound on Tango, did not realize that Tango 2 required almost an immediate stop after turning onto Tango. As we are heading SE on Tango, Tango 2 is about 135 degrees off our right as a high speed exit from runway 14R. No signage was visible on the left side of aircraft. The only sign visible on the ground was a “T2” sign at a 135 degree off the 5 o’clock position over the F/O’s right shoulder. We continued to pass the intersection when Grnd Control said we missed the stop at T2. We stopped about midway in T2 intersection. The 9R approach path goes right over T2. At that time and RJ passed about 200’ over us landing for runway 9R. The controller said “no problem” as everyone is trying to get used to new taxi program at KORD.</p>
20438	<p>After Landing on short runway 9L, we were given a long taxi clearance. This is not used often by wide bodies. The key phrase was G to T to hold short of 9R approach path. We taxied on G and made left turn at T where we were looking for red hold short taxi markings for the 9R approach. Ground control told us to stop which we did. Then proceeded after new clearance to cross approach path of 9R. After block in, the crew reviewed the taxi chart 10-9 and found no hold short markings for this route. I then went to Flight Office and talked to manager who said there were issues previously as the hold short sign is actually on G prior to T.</p> <p>Do not include the taxiway T in clearance if we are to hold short while on taxiway G for 9R. This hold marking is in a strange and hard to see spot. Also, have the widebody aircraft not land on 9R/27L. Many times we are too heavy due to stopping performance for this runway.</p>
21798	<p>Landed 9L ord, standard taxi, instructed from taxiway g, turn left on T, hold short of Runway 9R approach hold short line. I was surprised to encounter the approach hold line BEFORE the turn onto T was completed. It is misleading to say ‘turn onto T, hold short of approach path.’</p>
27309	<p>Was told to hold short of the 9r approach area, but because of the distraction of shutting down an engine did not remain clear. Also reduced visibility with 1 mile of rain obscures the holding markers.</p>
27310	<p>We landed on runway 9R at O’Hare in marginal conditions. We were given lengthy taxi instructions with multiple taxiway changes, a clearance to cross a runway and a hold short of the arrival approach for another landing runway all at the same time after landing. The conditions were rainy and the hold short markings for the 9R approach are not well marked. We were also configuring the aircraft for a single engine taxi. The taxi in from runway 9 R was over 20 minutes. After a long duty day and marginal weather approach, we noticed the hold short after slightly encroaching on it and stopping.</p>

## FINDINGS: ATC WORKLOAD.

The impact of the proposed signage and markings changes on ATC workload was assessed by conducting interviews with ATC personnel at each of the three airports, both before and after the changes took effect. The intended outcome of the proposed signage and markings change was to reduce ATC workload by decreasing the number of aircraft holding short of runway approach areas when associated runways are inactive. It was found that the level of workload increased at ORD since the installation of the updated signage and marking, but the level of workload at CLE and BNA remained the same as that prior to the new signs and markings being installed.

Air traffic controllers at ORD reported their level of workload increased since the introduction of the APCH/DEP signs, markings, and phraseology. According to controllers, the increase was primarily a result of the unfamiliarity of pilots with the experimental signage and marking. For example, when viewing the signs and markings without being given a hold short instruction, there was no significant confusion reported. However, when pilots were issued hold short instructions prior to observing the signs and markings, such as “Hold Short Runway 9R Approach” or “Hold Short Runway 27L Departure,” pilots would not understand the instruction and proceed to call ATC for further direction. One controller estimated that 33% to 50% of the pilots to whom he issued these instructions called back asking for further clarification before taxiing. These radio calls increased frequency congestion by increasing the amount of time spent communicating to each pilot. To clarify their intent, controllers said they sometimes needed to use the phraseology “Hold short of the 9R APCH Sign” and “Hold short of the 27L DEP Sign.”

Air traffic controllers at ORD reported prior to the research effort they would instruct pilots to hold short of specific taxiways, such as at TWY T or TWY G, to avoid the problems caused by the use of APCH holds. One source of confusion in communications was related to the use of the terms “approach” and “departure.” These can be confused with the approach and departure ends of the runway itself rather than the approach and departure protected areas. The controllers reported that this is mainly an issue where pilots must decide whether to continue on a given taxiway or to turn onto another taxiway. For instance, some pilots mistakenly turned onto TWY J and hold short of Runway 9R when told to “hold short 9R approach” (under the assumption that this meant hold short of the approach end entrance to Runway 9R). This resulted in the need for extra coordination between the ground controller and local controller for authorization to cross the runway. The controllers said the confusion was not an issue for aircraft on TWY T taxiing southbound, because there are no opportunities to turn off of the taxiway before reaching the approach hold location on this taxiway.

Despite the confusion when pilots were told to hold short, the controllers agreed that the new markings have had some benefit in cases when hold short instructions were not given. Pilots were more likely to proceed past the signs and markings in these cases. The controllers reported that cargo pilots on the south end of the airport called more often to confirm being able to cross APCH areas than pilots on the north end of the airport where the new markings were installed, saying this may be a result of the standard operating procedures of these companies (mainly foreign carriers) not allowing them to cross mandatory markings without clearance. One

controller said he also noticed a decrease in vehicle operator confusion with the new markings in place.

At CLE, paper surveys were distributed to controllers to provide feedback; however, these were not completed. A representative from tower management said the controllers at CLE have not noticed issues with the signs and markings, adding that there have not been any incursions or observed confusion by vehicle operators. He mentioned that controllers are always looking for possible safety or operational problems and would have reported any issues caused by the signs and markings (or phraseology for these) if they were occurring. The tower representative said he and the controllers he spoke with did not fully understand the purpose of changing the paint markings. He said vehicles are proceeding through the approach or departure areas when cleared to proceed “full length” on Runway 10-28 unless told to hold short. Overall, controllers mentioned that the changes have had no observable effects on workload.

At BNA, controllers declined to complete surveys for this research effort regarding their levels of workload. A union representative for controllers at the facility reported that traffic at the runway approach areas complied with instructions. ATC management at BNA reported that workload levels were generally unaffected by the changes.

## CONCLUSIONS

During the Safety Risk Management (SRM) panel, members identified two hazards associated with the current system (current signage and marking) for the Hazards Analysis Worksheet: pilot confusion and increase in controller workload. The panel members also plotted the associated severity and likelihood of these hazards on a risk matrix. With the implementation of the proposed change, the panel believed the likelihood of pilot confusion would decrease from probable to remote, and the likelihood of increase in controller workload would also decrease, but not enough to move it from remote to extremely remote.

Based on the data collected during this research effort, it is projected that the adoption of the proposed approach hold signage and markings standards will have the predicted residual effects of reducing pilot confusion and air traffic control (ATC) workload; however, the effect of the changes on the runway incursion rate cannot be confirmed. It was found that seven runway incursions occurred during the study at one of the evaluated approach hold areas; although further analysis revealed that the approach hold changes were not a primary factor for a majority of these incidents. Simulation evaluations showed that 94% of surveyed pilots reported the proposed signage and markings was logically consistent with ATC instructions compared to 70% for the current signage and marking. In airport evaluations, 65% of surveyed pilots reported that their situational awareness had increased because of the departure runway information added to the signage. However, additional training and outreach will likely be required to explain the use of the Pattern B marking to pilots since only 53% of pilots reported understanding the proposed signage and markings combination, compared to 68% for the existing approach hold signage and marking.

The impact of the proposed signage and markings changes on ATC workload was assessed by conducting interviews with ATC personnel at each of the three airports assessed, Chicago



O'Hare International Airport (ORD), Cleveland-Hopkins International Airport (CLE), and Nashville International Airport (BNA), both before and after the changes took effect. The intended outcome of the proposed signage and markings change was to reduce ATC workload by decreasing the number of aircraft holding short of approach areas when associated runways are inactive. It was found that the level of workload initially increased at ORD during the evaluation, but decreased as pilots adjusted to the changes. The level of workload at CLE and BNA remained unchanged as a result of the low number of aircraft affected by the changes at these airports. In pilot surveys, the level of agreement with the statement, "To proceed past the sign and surface marking, explicit permission from ATC would be needed," fell from 76% to 51%. This supports the prediction that pilots would be less likely to hold short when not given explicit instructions to do so with the proposed changes in place. Overall, the results of this study show that the proposed signage and markings changes will assist alignment of pilot and ATC expectations regarding the holding requirements for runway approach holding positions and contribute to a safer operating environment.

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