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Evaluation of Enhanced Visual Cues for Runway Approach and Runway Safety Areas

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Garrison Canter and Jennifer Klass, A.A.E.	

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The FAA Airport Technology Research and Development Branch Project Manager was Lauren (Vitagliano) Collins.

16. Abstract

In an effort to increase situational awareness among pilots and vehicle operators at U.S. civil airports, the Federal Aviation Administration (FAA) Office of Safety and Standards Airport Engineering Division has proposed updating its standards for runway approach hold position signage and marking based on recommendations proposed by the FAA Approach Hold Workgroup. The Airport Safety Research and Development Branch at the William J. Hughes Technical Center was tasked with evaluating the safety and effectiveness of the recommended signs and markings. Operational evaluations were then conducted at three airports: Chicago O'Hare International Airport, Nashville International Airport, and Cleveland-Hopkins International Airport.

It was found that a majority of aircraft and ground vehicle operators agreed that inclusion of the departure runway increased situational awareness and that the signs were understandable at an adequate distance. However, some aircraft and ground vehicle operators did report the additional information made the signs more difficult to understand. This indicates the meaning of the proposed signage and surface marking may not be intuitive for some aircraft and ground vehicle operators without additional training and familiarization. It was found that the level of air traffic control (ATC) workload initially increased at the Chicago O'Hare International Airport after the signage was installed but decreased over time as aircraft and ground vehicle operators become more accustomed to the changes. The survey data show the proposed signage and Pattern B marking increased awareness that stopping at approach hold locations was conditional on explicit ATC instructions rather than mandatory. It is recommended that this signage be installed as a pair of separate sign units with full-sized legend text. The energy and maintenance costs for airport operators are projected to be proportional to the size of the proposed signs installed. It is advised that extensive pilot and vehicle operator education and outreach be conducted prior to the proposed changes going into effect.

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LIST OF ACRONYMS AND ABBREVIATIONS

AC	Advisory Circular
AIM	Aeronautical Information Manual
APCH	Approach
ARFF	Aircraft Rescue and Fire Fighting
ASRS	Aviation Safety Reporting System
ATC	Air Traffic Control
ATR	Airport Technology Research and Development
BNA	Nashville International Airport
BOS	Boston Logan International Airport
CISP	Confidential Information Share Program
CLE	Cleveland-Hopkins International Airport
DCP	Document Change Proposal
DEP	Departure
FAA	Federal Aviation Administration
HS	Hot Spot
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
JO	Job Order
LNK	Lincoln Airport
MLS	Microwave Landing System
MOS	Modification of Standards
ORD	Chicago O'Hare International Airport
PHL	Philadelphia International Airport
NASA	National Aeronautics and Space Administration
NOTAM	Notice to Airmen
R&D	Research and development
RSA	Runway Safety Area
RWY	Runway
SOP	Standard Operating Procedure
SRMD	Safety Risk Management Document
TUS	Tucson International Airport
TWY	Taxiway
U.S.	United States

EXECUTIVE SUMMARY

In an effort to increase situational awareness among pilots and vehicle operators at U.S. civil airports, the Federal Aviation Administration (FAA) Office of Safety and Standards Airport Engineering Division has proposed updating its standards for runway approach holding position signage and marking based on recommendations proposed by the FAA Approach Hold Workgroup. The FAA Airport Safety Research and Development Branch at the William J. Hughes Technical Center (hereafter referred to as the Technical Center) was tasked with evaluating the safety and effectiveness of the recommended signs and markings prior to their implementation throughout the National Airspace System. Initial evaluations took place at the Technical Center, and operational evaluations were then conducted at three airports: Chicago O'Hare International Airport (ORD), Nashville International Airport, and Cleveland-Hopkins International Airport.

It was found that a majority of aircraft and ground vehicle operators surveyed agreed the inclusion of the departure runway on the proposed approach hold signage provided increased situational awareness and agreed the signage and marking were understandable early enough to identify the location of the holding position. Furthermore, the survey data show a majority of aircraft and ground vehicle operators were in agreement that the proposed signage and surface markings were logically consistent with air traffic control (ATC) instructions. However, it was found that the added departure runway information did make the signage more challenging for some aircraft and ground vehicle operators to understand. Also, fewer aircraft and ground vehicle operators found the proposed signage and Pattern B surface marking understandable than the current signage and Pattern A marking, indicating the proposed signage and surface marking may not be intuitive for some aircraft and ground vehicle operators without training and familiarization. Less than half of both aircraft and vehicle operators were in agreement that the proposed sign and Pattern B marking were suitable for use on a runway.

It was found that the level of ATC workload increased at ORD after the installation of the updated signage and markings, while ATC workload at Cleveland-Hopkins International Airport (CLE) and Nashville International Airport (BNA) was unaffected by the changes in signage and markings. However, the workload at ORD decreased over time as aircraft and ground vehicle operators became more accustomed to the changes. The survey data collected at ORD, CLE, and BNA show the proposed signage and Pattern B marking did increase awareness that stopping at approach hold locations was conditional on explicit ATC instructions rather than mandatory.

It is recommended that this signage be installed as a pair of separate sign units with full-sized legend text. Due to remaining confusion and lack of familiarity regarding approach holding positions, it is advised that extensive aircraft and ground vehicle operator education and outreach be conducted prior to the proposed changes going into effect. To further increase situational awareness, it is also recommended that airport diagrams include approach and departure hold positions at locations with recurring runway incursions. The effects observed for airport operators varied. The long-term energy and maintenance costs for signs are projected to be proportional to the size of the proposed signs installed. Installation costs also depended on the sign concept installed and each airport's terrain and space constraints. Alternative sign designs with reduced-size and stacked legend text were evaluated; however, these signs are not

recommended according to aircraft operator and ground vehicle operator feedback, which indicated these were difficult to understand. Addressable signage may offer a future alternative for airports that are not able to install the proposed approach hold signage. By implementing the recommendations outlined in this report, it is expected that safety will increase at airports with runway approach holding position areas compared to current signage and marking.

1. INTRODUCTION.

In an effort to reduce confusion among pilots and vehicle operators at U.S. civil airports, the Federal Aviation Administration (FAA) Airport Engineering Safety and Standards Office has proposed revising its standards for hold position signage and marking for runway approach hold areas. These holding positions provide protection for landing and departing traffic on taxiways that do not physically intersect a runway but intersect airspace or protected areas surrounding the runway. A research effort was undertaken by the Airport Technology Research and Development (R&D) Branch to evaluate the proposed signage and marking. This report provides a description of each research phase and the research effort's findings.

1.1 PURPOSE.

The purpose of this research effort was to validate the safety and suitability of runway approach holding position signage and marking proposed by the FAA Approach Hold Workgroup.

1.2 OBJECTIVES.

The specific objectives of this research effort included the following:

- Determine the effects of the changes in signage and marking on airfield users.
- Evaluate the impact that installing larger runway approach hold signage will have on airport operators.
- Determine the effects of the proposed signage and marking on air traffic control (ATC) workload.

2. DISCUSSION.

Runway approach hold signage positions are described in Advisory Circular (AC) 150/5340-18F [1]:

> "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." [1]

AC 150/5340-18F goes on to describe runway approach hold signage and emphasizes that it is used only on taxiways:

> "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." [1]

The surface marking specified by the FAA for use with approach signage is described in AC 150/5340-1L [2]:

> "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." [2]

Figure 1 shows an example of runway approach hold signage from AC 150/5340-18F [1], and figure 2 shows an example of the Pattern A runway approach hold marking from AC 150/5340-1L [2]. Figure 3 shows an example of a holding position signage and marking installation from AC 150/5340-18F [1].

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

Figure 2. Pattern A Runway Holding Position Marking [2]

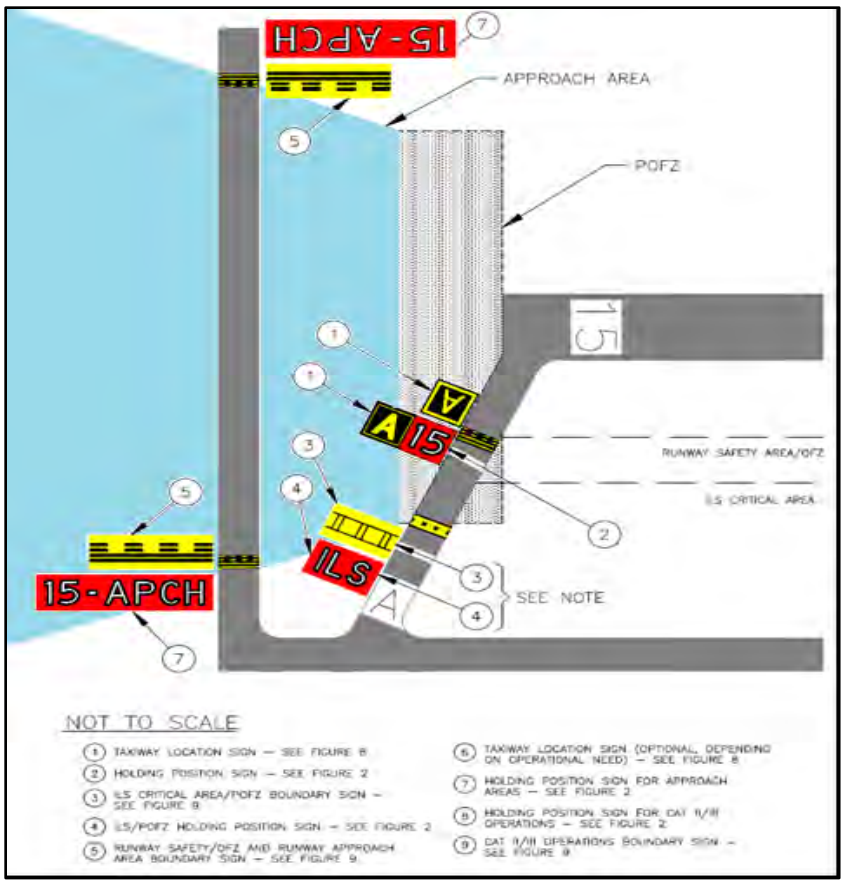
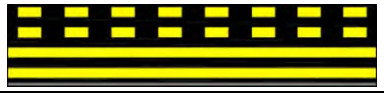


Figure 3. Holding Position Signage and Marking Installation [1]

As shown in table 1, both the International Civil Aviation Organization (ICAO) Annex 14 and FAA AC 150/5340-1 specify the Pattern A marking as standard for runway approach holding positions, but ICAO specifies different signage than the FAA. This signage is called a "Runway-Holding Position Sign" and features both a taxiway letter and a number [3]. Although different, both the ICAO and FAA signs are equivalent in meaning and serve the same purpose.

Table 1. The FAA and ICAO Signage and Marking Comparison

	ICAO	FAA
Signage	"Runway-Holding Position" [3] 	"Runway Approach Holding Position" [1] 
Marking	Pattern A [3] 	Pattern A [2] 

2.1 APPROACH HOLDING POSITION ISSUES.

2.1.1 Surface Marking.

Over time, it has become clear to the FAA that multiple issues exist with the current visual cues used for runway approach hold areas. In December 2011, representatives from the FAA Office of Airports, Air Traffic Organization, Office of Runway Safety, Flight Standards Service, National Air Traffic Controllers' Association, and several industry groups created the Approach Hold Workgroup. The Approach Hold Workgroup identified concerns over the course of several meetings. Three of these concerns focused on the surface marking used for runway approach holding positions:

- "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.

- Most pilots expect runway holding position markings to be located in the vicinity of a runway entrance; both the runway 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.

- Requiring specific clearance to pass a holding position marking when the associated runway is not active will unnecessarily increase air traffic controller workload." [4]

As mentioned in the three points above, the primary concern is the use of the Pattern A marking. As shown in figure 4, the Pattern A marking is used for both a runway entrance and a runway approach holding position. As stated in AC 150/5340-1L:

> "This application serves to stop a taxiing aircraft from penetrating the runway safety area (a runway incursion) or any of several airspace surfaces, for example, those used to define the runway threshold, runway inner approach obstacle free zone, or the runway inner transitional obstacle free zone." [2]

The only distinguishing characteristic between these signs and markings is the APCH inscription. This can lead pilots and vehicle operators to confuse the two, particularly when the sign is not adequately visible. Furthermore, this can increase the likelihood of a runway incursion because an individual may become more likely to enter a runway believing it to be an approach area. ATC workload can also be increased due to individuals holding unnecessarily at approach areas believing they are located at a runway entrance.

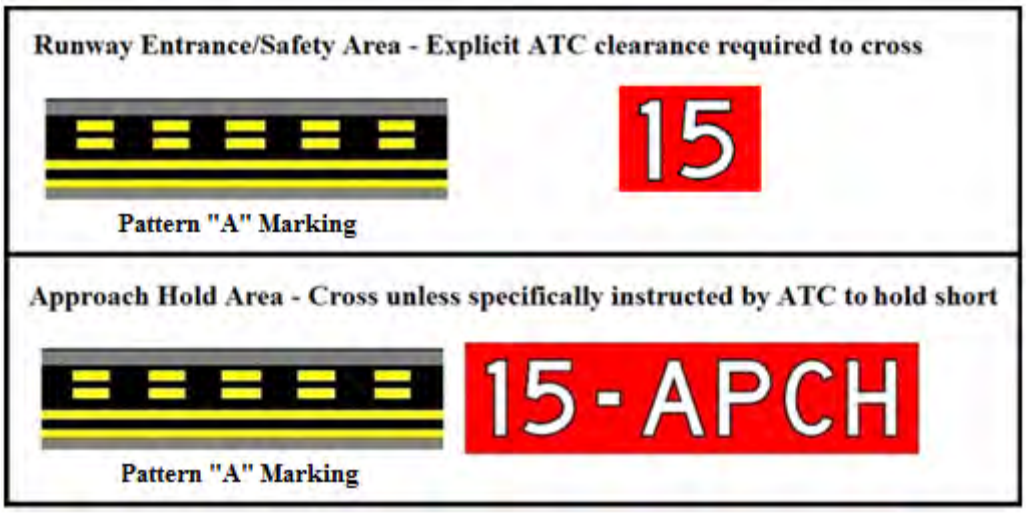


Figure 4. Runway Entrance and Approach Hold Visual Cues Comparison

Another issue adding to the confusion is the long distance between the runway approach hold location and the runway referenced on the signage. Figure 5 shows an example of the long distances that can exist between hold positions and the runway they are protecting. These hold positions, located at Chicago O'Hare International Airport (ORD), are positioned approximately 1600 and 2500 feet from Runway (RWY) 9R, respectively. The pilots and vehicle operators would likely not expect the signage at this location, unless they were already familiar with the airfield.

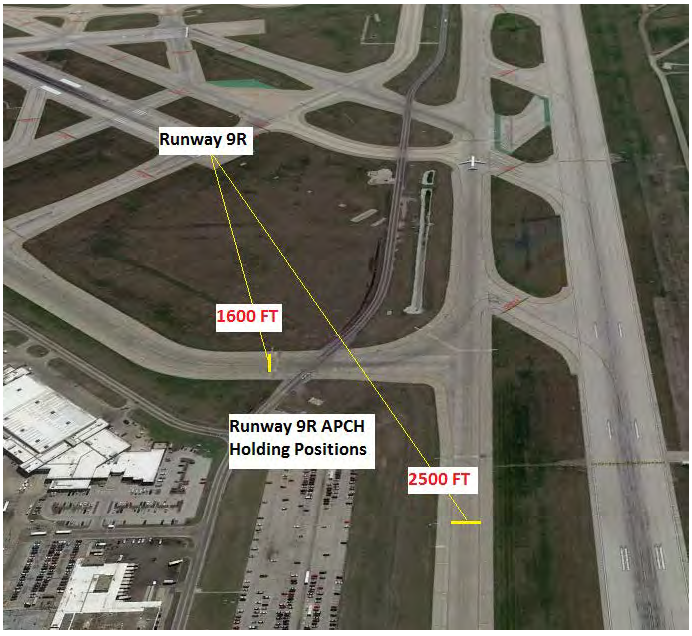


Figure 5. Approach Hold Position Example

One primary source of guidance for pilots regarding runway approach hold signs and markings is the FAA Aeronautical Information Manual (AIM) [5]. Section 2-3-5 of the AIM provides a definition of runway approach holding position markings:

> "These markings are used at some airports where it is necessary to hold an aircraft on a taxiway located in the approach or departure area of a runway so that the aircraft does not interfere with the operations on that runway. This marking is collocated with the runway approach area holding position sign. **When specifically instructed by ATC 'Hold short of (runway xx approach area)' the pilot should stop so no part of the aircraft extends beyond the holding position marking**." [5]

This definition is notable because it is the only description of the runway approach hold area marking that implies that pilots must hold short only when specifically instructed by ATC. However, this definition does not explicitly state that pilots are permitted to proceed through runway approach hold areas when ATC instructions to hold short are not provided.

Signage for approach areas is defined and shown in section 2-3-8 of the AIM. Unlike the description of the markings, this section does not specify that pilots must hold short when specifically instructed by ATC.

> "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. In these situations, a sign with the designation of the approach end of the runway followed by a 'dash' (−) and letters 'APCH' will be located at the holding position on the taxiway." [5]

It should be noted that the AIM's definition of the runway approach hold marking contradicts AC 150/5340-1L because the AIM states that aircraft are to hold short when specific instructions to hold are given by ATC; whereas, AC 150/5340-1L specifies that aircraft must hold short in the absence of ATC instructions [2]. This conflicting guidance is likely a contributing factor to pilot and vehicle operator confusion over this issue.

2.1.2 Departing Traffic Protection Awareness.

The fourth issue brought up by the Approach Hold Workgroup concerned protection for the departure runway.

> "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." [4]

This concern regards the lack of conceptual understanding and situational awareness among some pilots and vehicle operators that runway approach hold position signage and marking can be used to protect departing traffic in addition to arriving traffic. This is stated in the runway approach hold position signage and marking definitions in AC 150/5340-18F and the AIM. However, the signage itself does not give an indication of departure runway protection. For

example, if a controller instructs a pilot or vehicle operator to hold short for departure traffic taking off on RWY 33, the individual may not recognize that the controller expects the individual to hold short at a 15-APCH sign. Figure 6 shows a safety bulletin [5] released by the FAA Runway Safety Office concerning this issue at Tucson International Airport (TUS), in Tucson, Arizona. As shown in the paragraph outlined in red, pilots were not recognizing that the 11R-APCH and 11L-APCH signage also applied to RWYs 29L and 29R.

Figure 6. Excerpt From the Runway Safety Bulletin [6]

This issue was also reported by a pilot at Philadelphia International Airport (PHL) in the National Aeronautics and Space Administration (NASA) Aviation Safety Reporting System (ASRS) Database Report Number 582225 [7]:

> "**The pilot indicated that his main concern was that only RWY (Runway) 9L was identified on Taxiway Y, and suggested that identifying both RWY 9L and 27R would be helpful**. He claimed that during most taxiway Y operations, ATC was continually referring to RWY 27R in their instructions. The pilot also relayed that ATC's technique, of only sometimes requiring aircraft to hold short of RWY 27R – 9L, added to the confusion. He expressed that the new PRM

approach might only add to the existing confusion because of the anticipated increased use of RWYs 27L/27R for both arrivals and departures." [7]

2.1.3 The ATC Workload.

The Approach Hold Workgroup found that the uncertainty of pilots and vehicle operators regarding whether they can proceed through approach hold areas without ATC's explicit instructions has resulted in an increased ATC workload [4]. This is due to aircraft and vehicles stopping unnecessarily when ATC does not provide instructions to hold short. An example from ASRS report number 1104550 [8] highlights this:

> "With the new taxi procedures that were instituted in recent years, pilots are trained never to cross a runway without explicit ATC instructions. The presence of an identical marking, one for which a pilot does not need explicit ATC clearance to cross creates a set up for confusion and ultimate incursion. Recently I landed Runway 32 in BOS clearing at J1. Ground cleared me to taxi via Juliet, Bravo, to hold short of Charlie. **I know they intended for me to cross the 4L approach, but I don't feel right crossing the double yellow without a clearance, particularly in the vicinity of a charted incursion hot spot. I held and asked ground to confirm I was cleared across the 4L approach.** My pause for clarification resulted in a re-sequence. Now I was told to hold short of Kilo in order to give way to jet traffic from right to left. This was no hardship for me, but I am sure it was an annoyance to Ground Control." [8]

This example demonstrates that even pilots who have familiarity with runway approach hold position rules are hesitant to proceed past these due to the current visual cues.

2.2 PROPOSED SIGN AND SURFACE MARKING.

In 2011, the Approach Hold Workgroup recommended the development of new signs and markings, which are documented in the Draft Approach Hold Signs and Markings Safety Risk Management Document (SRMD), to indicate runway approach hold areas [4]. Furthermore, proposed Document Change Proposals (DCP) were put in place to establish uniform procedures and phraseology for runway approach hold areas and address the current lack of a collection process for data related to runway approach hold area events. The DCPs are for (1) FAA Job Order (JO) 7210.3, "Facility Operations and Administration," Paragraph 2-1-20 [9] and (2) FAA Order JO 7110.65, "Air Traffic Control," Paragraph 3-7-2 and Pilot/Controller Glossary [10]. The DCP to FAA Order JO 7210.3 also establishes a requirement for reporting runway approach hold events through Comprehensive Electronic Data Analysis and Reporting [9].

Version 1.2 of the Approach Hold DCP SRMD became available on September 27, 2013 [11]. Stated within this document are the following sign and surface marking recommendations:

> "…the FAA Office of Airports (ARP) is proposing new signs and markings to indicate approach areas. These proposed changes include the following:

- For taxiways providing access to the runway, the mandatory holding position sign for taxiway/runway intersections and runway holding positions shall be used.

- For taxiways that do not provided 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.

- 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'." [11]

Examples of the signage and marking recommended by the Approach Hold Workgroup are shown in figure 7. As the figure shows, the signage will include XX DEP in addition to the approach runway number. The surface marking will be Pattern B, as described in section 2.2.1.

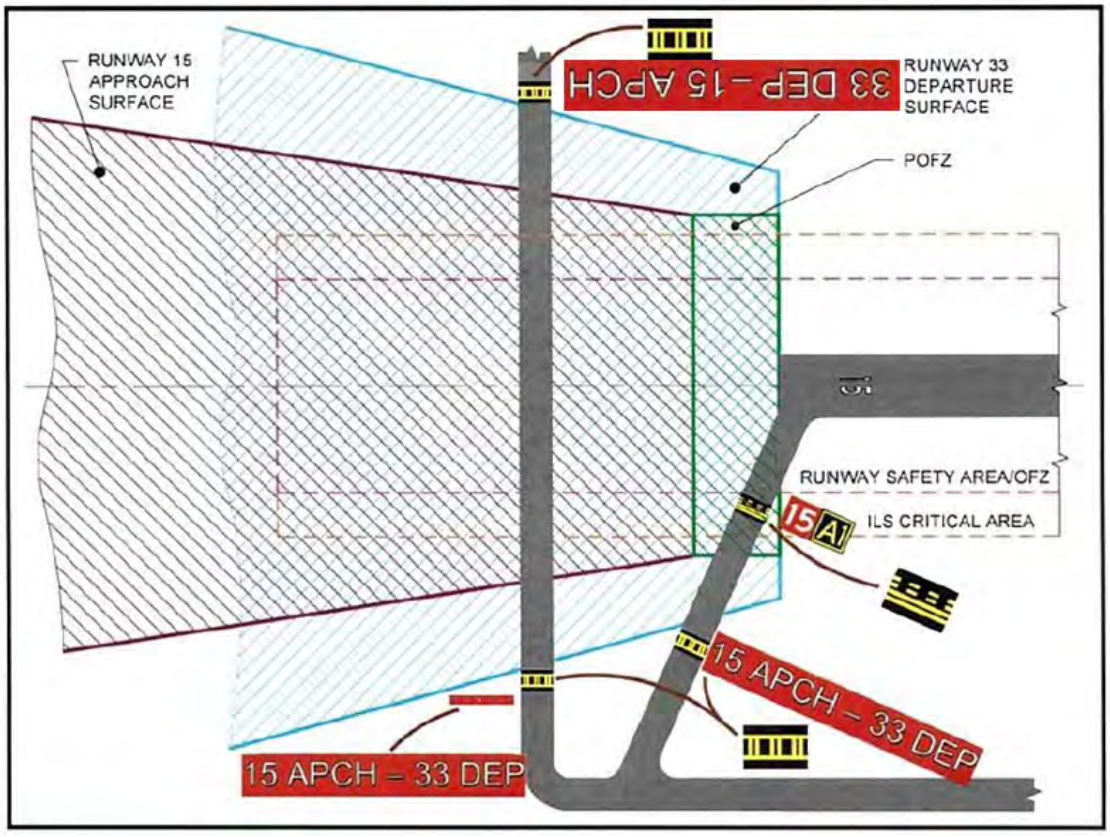


Figure 7. Example of Proposed APCH/DEP Signage and Pattern B Marking [11]

2.2.1 Proposed Surface Marking.

The Approach Hold Workgroup proposed the Pattern B Instrument Landing System (ILS)/Microwave Landing System (MLS) hold position marking to be positioned adjacent to the

runway approach hold signage. Unlike the Pattern A marking, Pattern B allows pilots and ground vehicle operators to cross the marking unless specifically instructed by ATC to hold short, as shown in figure 8. This matches the AIM definition of a runway approach hold 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.

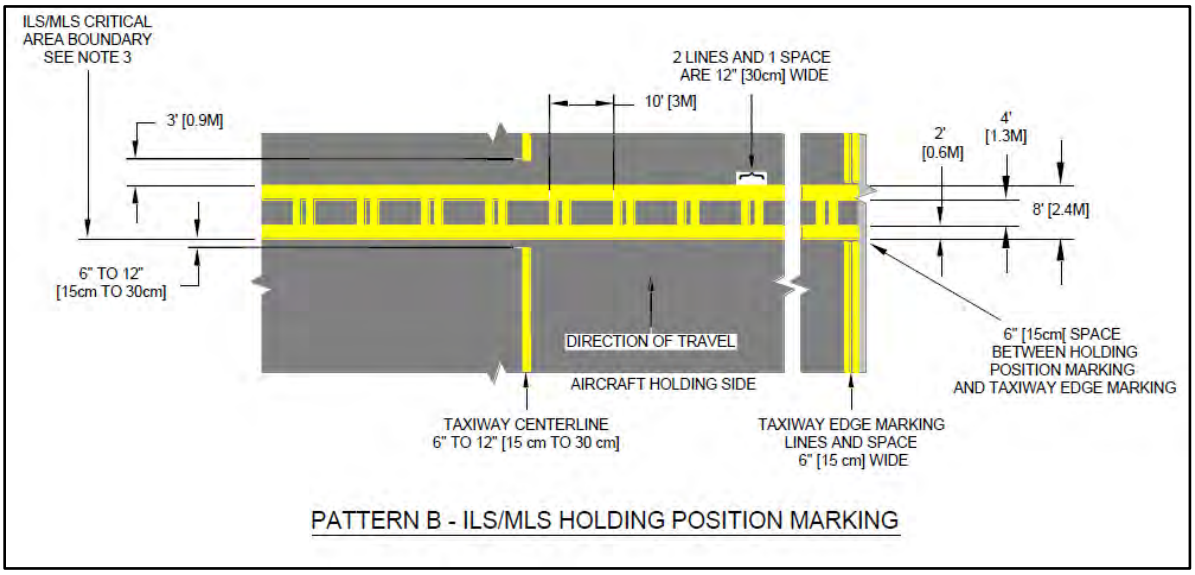


Figure 8. Pattern B Marking [2]

2.2.2 Proposed Signage Concepts.

The research team created four runway approach hold signage concepts based on the Approach Hold Workgroup's recommendations [11]:

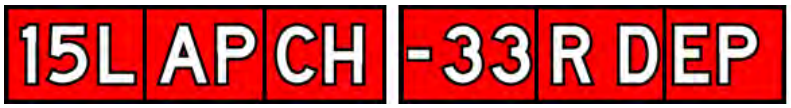
- Concept 1: A two-module sign with reduced-sized, stacked legend text
- Concept 2: A four-module sign with reduced-sized, horizontal legend text
- Concept 3: A pair of three-module signs with standard-sized, horizontal legend text
- Concept 4: A six-module sign with standard-sized, horizontal legend text

For each concept there are two sign sizes: size 2 and size 3. The viewable legend panel heights correspond with size 2 and size 3 sign dimensions in AC 150/5345-44J [12]. As shown in table 2, AC 150/5345-44J specifies the viewable panel height for a size 2 sign is 24 inches, while the viewable panel height for a size 3 sign is 30 inches [12]. The legend text heights for Concepts 1 and 2, however, are smaller than the standard. Legend text heights and illustrations of each sign concept are shown in table 3.

Table 2. Lighted Sign Dimensions [12]

Sign Size	Legend Height		Viewable Legend Panel Height		Overall Mounting Height		Maximum Overall Length	
	in.	mm	in.	mm	in.	mm	in.	mm
1	12	305	18	457	24-30	610-762	120	3048
2	15	381	24	610	30-36	762-914	145	3683
3	18	4570	30	762	36-42	914-1067	170	4318
4	40	1016	48	1219	54-60	1372-1524		
5	25	635	30	762	36-42	914-1067		

Table 3. Approach Hold Signage Concepts

Concept Number	Legend Height	Sign Length	Legend Text
1	Size 2: 7 inches Size 3: 8 inches	Size 2: 72.5 inches Size 3: 85 inches	
2	Size 2: 9.5 inches Size 3: 11.5 inches	Size 2: 145 inches Size 3: 170 inches	
3	Size 2: 15 inches Size 3: 18 inches	Size 2: 229.5 inches Size 3: 261 inches	
4	Size 2: 15 inches Size 3: 18 inches	Size 2: 218 inches Size 3: 249 inches	

Concepts 1 and 2 were created to comply with the maximum length dimensions published in AC 150/5340-18F [1] and to allow installation of the signs at airports with steeply sloping terrain or space constraints. Concepts 3 and 4 exceed the 145 inches (size 2) and 170 inches (size 3) and may not be practical at all airports. The space between the pair of signs for Concept 3 can vary between 3 and 12 inches, which is the range allowed in AC 150/5345-44J [12].

3. PROTOTYPE SIGNAGE EVALUATIONS.

The first of three evaluation phases for the sign concepts consisted of outdoor evaluations by seven FAA Airport Technology R&D (ATR) personnel at the William J. Hughes Technical Center (hereafter referred to as the Technical Center). The ATR personnel are experienced in airport safety and knowledgeable regarding airport visual cues. Three of the ATR personnel possessed FAA pilot certificates. The prototype evaluations provided distance data describing how far each sign could be viewed and understood, as well as comments regarding the content.

3.1 PROTOTYPE SIGNAGE.

Sign prototypes were fabricated for each of the four concepts described in section 2.2.2. The Concept 1 and Concept 2 sign prototypes, shown in figures 9 and 10, were fabricated in size 2 dimensions, with 24-inch-high viewable legend panels. The legend text of the Concept 1 and Concept 2 sign prototypes were 7 and 9.5 inches in height, respectively.

Figure 9. Concept 1 Sign Prototype

Figure 10. Concept 2 Sign Prototype

Figures 11 and 12 show the Concept 3 and 4 sign prototypes. Both prototypes use the same sign units; the Concept 4 sign prototype was constructed by placing the Concept 3 sign prototypes immediately adjacent to one another so no space was between them. These units were fabricated with size 3 dimensions and featured 30-inch viewable legend panels and 18-inch legend text height.

Figure 11. Concept 3 Sign Prototype

Figure 12. Concept 4 Sign Prototype

3.2 PROTOTYPE SIGNAGE EVALUATIONS: PROCEDURE.

As shown in figure 13, each sign prototype was positioned at one end of a road, which was closed off to other vehicle traffic.

Figure 13. View of Sign Location From a Distance of 200 Feet in the Daytime

ATR personnel drove two small passenger vehicles, a van and sport utility vehicle, carrying the evaluation subjects. The vehicles were driven toward each sign at approximately 10 miles per hour to simulate the speed of an airfield vehicle. Figure 14 shows an aerial image of the road, noting the starting and sign locations. The starting distance was 1200 feet.

Figure 14. Evaluation Layout

Reflective traffic cones were placed along the road at 100-foot increments, beginning from the sign location. The ATR personnel verbally announced each passing distance mark in the following manner, "one-thousand two-hundred feet, one-thousand one-hundred feet, one-thousand feet," etc. These distances were used by the subjects to respond to statements on their evaluation forms. Figure 15 shows an example of one of these distance markers.

Figure 15. View of 100-Foot Distance Marker at Night

One change was made to the Concept 3 sign when it was evaluated at night. This change involved placing a flashlight between the signs, which is shown in figure 16. The purpose of this was to simulate reflected light to determine if this would have an effect on viewing the sign.

Figure 16. Concept 3 Sign Prototype With Added Light Source

3.3 PROTOYPE SIGNAGE EVALUATION: RESULTS.

The data collected from the evaluations consisted of the distances the subjects could discern the background and legend colors, the distances the sign legend was legible to subjects, and written comments the subjects had concerning the signs. Immediately after completing each evaluation, the subjects were asked to answer each statement using the following 5-point Likert Scale responses: Strongly Disagree, Disagree, Undecided, Agree, and Strongly Agree. Subjects were also able to respond with written comments.

3.3.1 Prototype Signage Evaluations: Concept 1 Results.

Concept 1—Statement 1: *As you are proceeding towards the sign, please indicate when the background and legend colors are discernible.*

As table 4 indicates, the distances where each subject was able to discern the background and legend colors of the Concept 1 sign ranged from 400 to 1100 feet in daytime lighting. At night, the distances ranged from 200 to 1200 feet. The median distance for the subjects was 700 feet in daytime lighting, and 850 feet at night. The mean values were 757 and 767 feet for day and nighttime viewing, respectively. This suggests that the background and colors of the sign were able to be discerned at a somewhat greater distance at night.

Table 4. Concept 1 Subject Responses—Background and Legend Color Discernibility

Subject Number	Day (ft)	Night (ft)
1	400	200
2	700	1100
3	700	600
4	400	400
5	1000	N/A
6	1100	1200
7	1000	1100
Mean	757	767
Median	700	850

Concept 1—Statement 2: *As you are proceeding towards the sign, please indicate when the legend text is legible.*

As indicated in table 5, the Concept 1 sign was legible to subjects from 300 to 500 feet in the daytime and 200 to 450 feet at night. The median legible distance during the day was slightly greater than at night, at 350 and 325 feet, respectively. The mean values were generally consistent with these, with legend text visible at 357 feet in the daytime and 333 feet at night.

Table 5. Concept 1 Subject Responses—Sign Legibility

Subject Number	Day (ft)	Night (ft)
1	400	200
2	300	300
3	300	400
4	300	350
5	500	N/A
6	350	300
7	350	450
Mean	357	333
Median	350	325

Concept 1—Statement 3: *It was easy to interpret.*

When asked if the Concept 1 sign was easy to interpret, the subjects' responses varied. As table 6 indicates, for the daytime evaluation, four subjects were undecided and three agreed. The night evaluation yielded a wider range of responses. One subject disagreed that the sign was easy to interpret, two were undecided, two agreed, and one strongly agreed.

Table 6. Concept 1 Subject Responses—Ease of Understanding

Time of Day	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Day (7 responses)	0	0	4	3	0
Night (6 responses)	0	1	2	2	1

Some written comments stated the small text size and character orientation added challenges in interpreting the sign's message. Two subjects cited the arrangement of the text as an issue. For instance, one subject stated, "The spacing around the letter 'A' seemed to separate it from the rest of the message." Another subject said, "I knew what it meant, but it took me a few seconds to interpret." Two subjects mentioned that the size of the legend text was sufficient.

3.3.2 Prototype Signage Evaluations: Concept 2 Results.

Concept 2—Statement 1: *As you are proceeding towards the sign, please indicate when the background and legend colors are discernible.*

As table 7 indicates, the background and legend colors' discernable distances of the Concept 2 sign ranged from 400 to 1200 feet in daytime lighting. At night, the distances ranged from 300 to 1200 feet. The median distance was 800 feet during day conditions and 850 feet at night.

Table 7. Concept 2 Subject Responses—Background and Legend Color Discernibility

Subject Number	Day (ft)	Night (ft)
1	400	300
2	800	900
3	700	700
4	700	800
5	1200	N/A
6	900	1200
7	1100	1100
Mean	829	833
Median	800	850

Concept 2—Statement 2: *As you are proceeding towards the sign, please indicate when the legend is legible.*

Table 8 shows the distances where the legend text was legible to subjects. These distances ranged from 400 to 700 feet in the daytime and 300 to 550 feet at night. The median daytime text legibility distance was greater than at night, at 500 and 425 feet, respectively.

Table 8. Concept 2 Subject Responses—Sign Legibility

Subject Number	Day (ft)	Night (ft)
1	400	300
2	500	400
3	500	500
4	700	450
5	700	N/A
6	500	400
7	450	550
Mean	536	433
Median	500	425

Concept 2—Statement 3: *It was easy to interpret.*

As shown in table 9, during the daylight, all subjects strongly agreed to statement 3. One subject was undecided, one agreed and four strongly disagreed.

Table 9. Concept 2 Subject Responses—Ease of Understanding

Time of Day	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Day (7 responses)	0	0	0	0	7
Night (6 responses)	0	0	1	1	4

3.3.3 Prototype Signage Evaluations: Concept 3 Results.

Concept 3—Statement 1: *As you are proceeding towards the sign, please indicate when the background and legend colors are discernible.*

Table 10 shows the findings of the size 3 sign with a section gap, where the maximum color discernibility distance ranged from 700 to 1200 feet in the daytime and 800 to 1200 feet at night. The median distance was greater at night.

Table 10. Concept 3 Subject Responses—Background and Legend Color Discernibility

Subject Number	Day (ft)	Night (ft)
1	700	800
2	950	900
3	1200	1200
4	900	1200
5	1200	N/A
6	1100	1200
7	1100	1200
Mean	1021	1083
Median	1100	1200

Concept 3—Statement 2: *As you are proceeding towards the sign, please indicate when the legend is legible.*

Detailed in table 11, the average minimum legibility distances were roughly the same overall between night and day. The distances ranged from 700 to 1200 feet in the daytime and 600 to 1200 feet at night.

Table 11. Concept 3 Subject Responses—Sign Legibility

Subject Number	Day (ft)	Night (ft)
1	700	800
2	700	600
3	1000	1200
4	900	1000
5	1200	N/A
6	900	800
7	900	1000
Mean	900	900
Median	900	900

Concept 3—Statement 3: *It was easy to interpret.*

The subjects, unanimously, strongly agreed that the sign was easy to interpret during the day, as indicated in table 12. At night, three subjects agreed and three strongly agreed.

Table 12. Concept 3 Subject Responses—Ease of Understanding

Time of Day	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Day (7 responses)	0	0	0	0	7
Night (6 responses)	0	0	0	3	3

3.3.4 Prototype Signage Evaluations: Concept 4 Results.

Concept 4—Statement 1: *As you are proceeding towards the sign, please indicate when the background and legend colors are discernible.*

As indicated in table 13, the background and legend color discernibility distances of the size 3 sign with connected sign sections ranged from 700 to 1200 feet for both day and night. The median at night, 1200 feet, was 100 feet greater than during the day.

Table 13. Concept 4 Subject Responses—Background and Legend Color Discernibility

Subject Number	Day (ft)	Night (ft)
1	700	700
2	700	800
3	1100	1200
4	900	1200
5	1200	N/A
6	1200	1200
7	1200	1200
Mean	1000	1050
Median	1100	1200

Concept 4—Statement 2: *As you are proceeding towards the sign, please indicate when the legend is legible.*

The distances that subjects were able to read the signs ranged from 650 to 1200 feet in the daytime and 500 to 1200 feet at night, as indicated in table 14. The median distance for both day and night was 900 feet.

Table 14. Concept 4 Subject Responses—Sign Legibility

Subject Number	Day (ft)	Night (ft)
1	700	700
2	650	500
3	800	1200
4	900	1000
5	1200	N/A
6	900	800
7	900	1000
Mean	864	867
Median	900	900

Concept 4—Statement 3: *It was easy to interpret.*

All subjects that viewed the sign during the day strongly agreed that the sign was easy to interpret, as shown in table 15. At night, two subjects agreed and four strongly agreed with the statement.

Table 15. Concept 4 Subject Responses—Ease of Understanding

Time of Day	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Day (7 responses)	0	0	0	0	7
Night (6 responses)	0	0	0	2	4

3.4 PROTOTYPE SIGNAGE EVALUATION: FINDINGS.

Distance data, Likert responses, and subject comments were compared to determine the relative effectiveness of each sign. The distances at which subjects were able to discern the signs' backgrounds and legend colors were consistent with expectations. The signs' text size strongly correlated to both the distances at which the background and legend colors were discernible, and the distances at which the legend text was legible.

Table 16 shows the Concept 1 sign had the lowest median distances that subjects were able to discern the background and legend colors. As stated in AC 150/5345-44J, a sign of this type "must be readily identifiable up to 800 feet (ft.) (244 meters (m)) when it is viewed during the day or lighted at night." [12] The initial data from this evaluation indicated the Concept 1 sign, with background and legend colors discernible at a median distance of 700 feet during the day, did not meet this criterion. The other signs, however, were identified by subjects at or above 800 feet. The background and colors of the Concept 2 sign were discernible at 800 feet in the daytime and 850 feet at night. The Concept 3 and 4 signs were both equally discernible, 1100 feet during the day and 1200 feet at night.

Table 16. Sign Prototype Results: Background and Color Discernibility

	Mean		Median	
Concept	Day (ft)	Night (ft)	Day (ft)	Night (ft)
1	757	767	700	850
2	829	833	800	850
3	1021	1083	1100	1200
4	1000	1050	1100	1200

The difference between signs was greater regarding the distances at which the sign legend was legible. As table 17 shows, the median distance of the size 3 signs, 900 feet, is more than twice that of both the day and night distances of Concept 1, 350 and 325 feet, respectively. The Concept 2 sign was legible at a greater distance than the Concept 1 sign, with median distances of 500 feet during the day and 425 feet at night.

Table 17. Sign Prototype Results: Sign Legibility

Concept	Mean		Median	
	Day (ft)	Night (ft)	Day (ft)	Night (ft)
1	357	333	350	325
2	536	433	500	425
3	900	900	900	900
4	864	867	900	900

As indicated in table 18, the most variation in daytime responses to the statement "The Sign Was Easy to Interpret" applied to the Concept 1 sign. Four subjects were undecided and three agreed. For the other concepts, all the subjects strongly agreed that these signs were easy to interpret during the day.

As the night results in table 18 show, there were no unanimous responses for any of the signs when viewed at night. The Concept 1 sign again had the most variation, with one subject disagreeing, two undecided, two agreeing, and one strongly agreeing that the sign was easily readable. The responses to the other signs were more conclusive. For the Concept 2 sign, one subject was undecided about whether the sign was easily read, and the other five either agreed or strongly agreed. All the subjects agreed or strongly agreed the Concept 3 and 4 signs were easy to read.

Table 18. Sign Prototype Results: Ease of Understanding

Time of Day	Concept	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Day (7 responses)	1	0	0	4	3	0
	2	0	0	0	0	7
	3	0	0	0	0	7
	4	0	0	0	0	7
Night (6 responses)	1	0	1	2	2	1
	2	0	0	1	1	4
	3	0	0	0	3	3
	4	0	0	0	2	4

4. COCKPIT SIMULATION EVALUATIONS.

In the second phase of evaluations, 35 subjects took part in a series of simulated scenarios at the Technical Center's Cockpit Simulation Facility. Data collected in the simulations were used to select the design for airport evaluations. The simulations entailed having the subjects view four distinct runway approach hold/RSA sign designs and the ILS/MLS holding position marking at various locations at ORD. The signs and markings viewed included the current approach hold signage with Pattern A surface marking, as well as the Concepts 1, 2, and 4 signs with the Pattern B surface marking. Concept 3 signs were not evaluated due to the simulator's inability to

accurately recreate the gap between sign sections; however, the Concept 4 sign features identically sized legend text as the Concept 3 sign. Each subject participated in six simulated evaluations, alternating day and night conditions. This alternation was intended to gather data for each sign configuration in different lighting conditions without increasing the total number of evaluations. Examples of the signs, shown in day and night lighting, are shown in appendix B.

Three means of data collection were used in the cockpit simulation facility evaluations: a distance-measuring program, a survey, and the observation of subjects recording their responses to ATC taxi instructions.

The distance at which the subjects were able to read and understand each sign was computed by a program in the simulator. These distances indicated the overall readability of the signs. A sign that was understood at a greater distance was considered easier to read, relative to signs with a lesser distance. It should be noted that due to screen resolution limits, the simulated distances likely were underestimated compared with the actual distances subjects would be able to read the signs. Therefore, the relative distances were more informative than the absolute distances. To activate the distance-measuring program, a button mounted in the simulated cockpit was pressed, as shown in figure 17. ATC gave the subjects the following instruction prior to each evaluation: "Press the red-button when you can read and understand the sign." Once the button was pressed, the simulator facility's mathematician recorded the distance.

Figure 17. Distance-Measuring Program Activation Button

Subject surveys, shown in appendix C, contained a series of statements about the signs and markings viewed on each evaluation. Immediately after the completion of each evaluation, the subjects were asked to respond to each statement using a 5-point Likert Scale with the following responses: Strongly Disagree, Disagree, Undecided, Agree, and Strongly Agree. The subjects also were able to respond with written comments.

The ATR personnel conducting the evaluation also recorded the subjects' decision to hold short or not at each location to determine if the sign and marking had an effect on the subjects' actions. Prior to the simulation, the ATR personnel told the subjects, "The decision to hold short is at your discretion, based on your experience, training, and the ATC instructions you will be given." The subjects were explicitly told by ATR personnel acting in the role of ATC to hold short at certain locations, and at other locations, this instruction was not given in order to see what the subjects' reactions would be.

The four sign locations for this simulation are shown in figure 18. One pair of signs was on Taxiway (TWY) T south of TWY Z, as shown in figure 19. Two pairs of signs were on RWY 9L-27R, as shown in figure 20. One pair of signs was on TWY T, as shown in figure 21. The RWY 9L-27R RSA signs were located at the beginning and end of the chevrons.

Figure 18. Route and Sign Evaluation Locations

Figure 19. Sign and Marking Placement on TWY T South of TWY Z

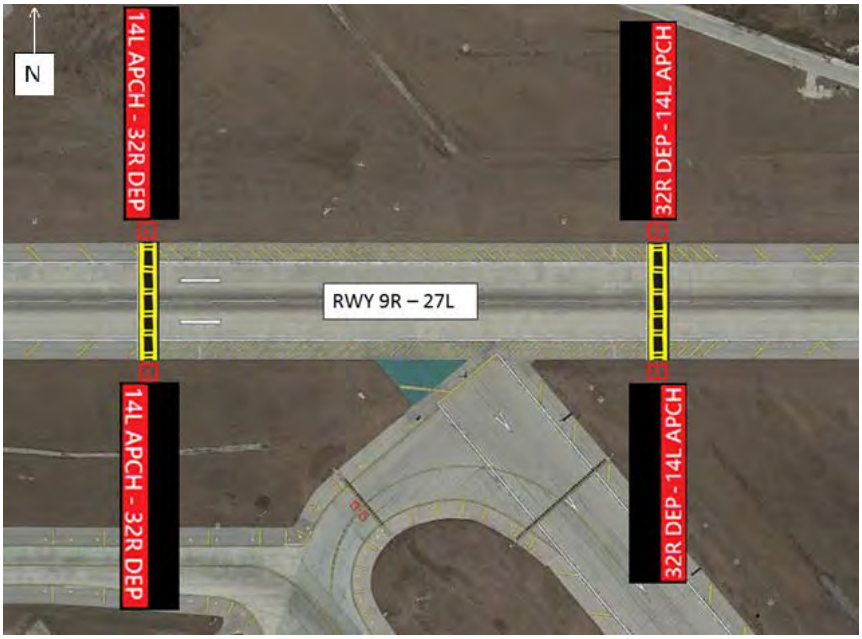


Figure 20. Sign and Marking Placement on RWY 9L-27R

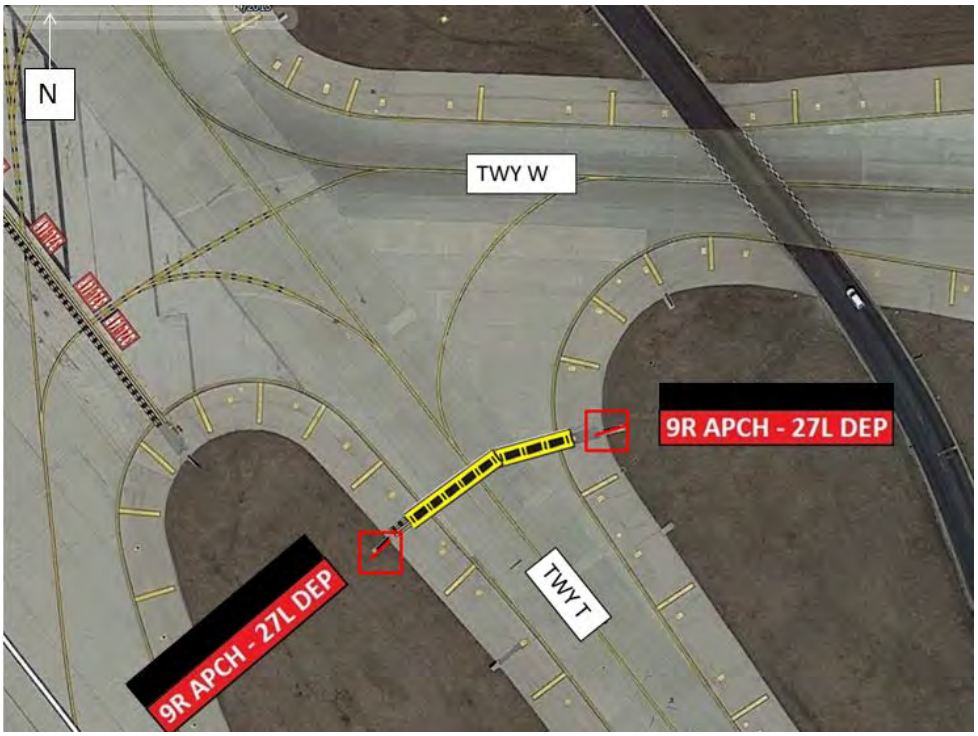


Figure 21. Sign and Marking Placement on TWY T, South of TWY W

4.1 COCKPIT SIMULATION SUBJECTS.

All cockpit simulation subjects were FAA-certified pilots. Pilot backgrounds included airline, military, and general aviation. The pilots' total flight time varied between 1,750 hours 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 12 months also varied, ranging from 0 to 860 hours. The median number of flying hours reported for 2013 was 300 hours.

4.2 EVALUATION DESCRIPTIONS.

Each evaluation was comprised of two sections: A and B. Upon reaching the end of section A, the simulated aircraft was relocated from TWY C to TWY T or from TWY T to TWY C, depending on the direction of travel. These locations are indicated by the dark-blue line with arrows in figure 18. Appendix B contains figures of each simulated sign viewed.

4.2.1 Evaluation 1.

For evaluation 1a, the subject began at the approach end of RWY 27R. ATC taxi instructions were as follows: "Proceed down Runway 27R, exit left on C1." At location A, the subject viewed the current 14L-APCH signs on RWY 27R and the RSA hold short markings shown in figure B-1. Once clear of RWY 27R, the subject completed the first portion of the survey.

Evaluation 1b began on the north end of TWY T. ATC gave the subject the following instructions: "Taxi to parking via T, T7, A7." The subject viewed the current 9R-APCH sign at location C as well as the hold position marking, as shown in figure B-3. Once the aircraft was brought to a stop, the subject completed the relevant portion of the survey.

4.2.2 Evaluation 2.

For evaluation 2a, the subject began on the ramp adjacent to TWY A7, as shown in figure 18. Taxi instructions were "Taxi to Runway 14R via A7, T7, T." The subject viewed the current 9R-APCH sign and Pattern A marking south of TWY W at location D, as shown in figure B-5. Upon reaching the end of TWY T, the evaluation ended, and the subject completed the survey section.

Evaluation 2b began on TWY C. When the subject was reported holding short of RWY 9L, ATC instructed the subject to "Proceed onto Runway 9L and continue to the end of the runway." The subject then taxied eastbound on RWY 9L, as shown in figure 18. The current 14L-APCH signage was viewed at location B on RWY 9L with a Pattern A marking, as shown in figure B-7. The evaluation concluded when the subject reached the departure end of RWY 9L and was asked to complete the relevant survey section.

4.2.3 Evaluation 3.

For evaluation 3a, the subject began at the approach end of RWY 27R, shown in figure 18. Taxi instructions were "Proceed down Runway 27R, hold short Runway 32R departure." At location A on RWY 27R, the subject viewed the Concept 4, 32R DEP-14L APCH signs with 15-inch character legend, as shown in figure B-9. The subject also viewed the Pattern B holding position marking at this location. Once clear of RWY 27R, the subject was asked to complete the relevant portion of the survey.

Evaluation 3b began on the north end of TWY T. At this location, ATC told the subject "Taxi to parking via T, T7, A7." At location C, the subject viewed the size 2, 27L Concept 4 DEP-9R APCH signs with 15-inch character legend, as shown in figure B-11. The subject also viewed the Pattern B holding position marking at this location. Once the aircraft was brought to a stop, the subject completed the relevant portion of the survey.

4.2.4 Evaluation 4.

For evaluation 4a, the subject began on the ramp adjacent to TWY A7. Taxi instructions provided by ATC were as follows: "Taxi to runway 14R via A7, T7, T. Hold short Runway 27L Departure." The subject viewed the Concept 1 9R APCH – 27L DEP signs with 7-inch character legend, as shown in figure B-13, and Pattern B holding position marking at location D, south of TWY W. Upon reaching the end of TWY T, the subject was asked to complete the relevant survey section.

Evaluation 4b began with the subject positioned on TWY C. When the subject reported holding short of RWY 9L, ATC gave the following instructions: "Proceed onto Runway 9L and continue to the end of the runway." The subject then taxied eastbound on RWY 9L, as shown in figure

18. The subject viewed the current 14L-APCH signage at location B on RWY 9L, as shown in figure B-15. The evaluation was concluded when the subject reached the departure end of RWY 9L and was asked to complete the relevant section of the survey.

4.2.5 Evaluation 5.

Evaluation 5a started at the approach end of RWY 27R, as shown in figure 18. Taxi instructions provided by ATC were as follows: "Proceed down Runway 27R, hold short Runway 32R departure." At location A on RWY 27R, the subject viewed the Concept 2, 32R DEP-14L APCH signs, as shown in figure B-17. The subject also viewed the Pattern B hold position marking at this location. Next, the subject was instructed to continue taxiing and exit on TWY C. Once the subject was clear of RWY 27R, evaluation 5a was completed. Then, the aircraft was repositioned on TWY T while the subject was asked to respond to the evaluation 5a survey statements.

Evaluation 5b began on the north end of TWY T. The subject was instructed to taxi to parking via TWY T and A7. At location C, the subject viewed the Concept 2, 27L DEP – 9R APCH signs and the Pattern B hold position marking, as shown in figure B-19. Once the subject parked at the ramp, the remaining survey statements were responded to, and evaluation 5b was completed.

4.2.6 Evaluation 6.

Evaluation 6a began on the ramp adjacent to TWY A7, as shown in figure 18. The taxi instructions were "Taxi to Runway 14R via A7, T7, T. Hold short Runway 27L departure." The subject viewed the Concept 2, 27L DEP-9R APCH signs, shown in figure B-21, as well as the Pattern B hold position marking at location D. Then, the subject was told to continue taxiing down TWY T. Once the subject reported reaching the end of TWY T, the aircraft was transitioned to evaluation 6b, and the subject was asked to respond to the evaluation 6a survey statements.

Evaluation 6b began on TWY C. When the subject reported holding short of RWY 9L, ATC cleared the subject to taxi eastbound on RWY 9L, as shown in figure 18. The subject viewed the Concept 2, 14L APCH-32R DEP signage on RWY 9L, shown in figure B-23. The evaluation concluded when the departure end of RWY 9L was reached, at which time the subject responded to the evaluation 6b survey statements.

4.3 RESULTS OF COCKPIT SIMULATION FACILITY EVALUATIONS.

Data for the sign and surface markings were collected and used for comparison. These comparisons were based on survey responses and comments, relative distances of sign legibility, and the relative tendencies of subjects to hold short based on the visual cues. Because each sign was evaluated more than once by each subject, the findings have been combined for each sign and expressed as percentages.

4.3.1 Cockpit Simulation Facility: Survey Results.

Statement 1: *The text on the signs is distinguishable from the background.*

As shown in table 19, the subjects had similar levels of agreement with this statement for both the current approach hold signage with Pattern A markings and the Concepts 2 and 4 signs with Pattern B markings. The Concept 4 signage had the most favorable response, with 37% of responses agreeing and 60% strongly agreeing that the text was distinguishable from the background. The Concept 1 sign had the least amount of favorable response. Twenty percent of responses for the Concept 1 sign disagreed that the text was distinguishable from the background and three percent strongly disagreed with this statement.

Table 19. Cockpit Simulation Statement 1 Response Comparison

"The text on the sign was distinguishable from the background."					
Sign/Marking Viewed	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Current Approach Sign/ Pattern A Marking	0%	3%	9%	44%	44%
Concept 1 Sign/ Pattern B Marking	3%	20%	11%	57%	9%
Concept 2 Sign/ Pattern B Marking	1%	7%	3%	47%	41%
Concept 4 Sign/ Pattern B Marking	0%	3%	0%	37%	60%

Statement 2: *The surface markings adjacent to the signs expressed the same message (or idea) with the signs.*

When asked if the surface markings expressed the same message or idea with the signs, the results indicated a small difference among the signs and markings evaluated, as shown in table 20. The runway hold position marking and the current APCH signage, serving as a baseline, had more overall agreement than the new sign and marking combinations. For the Pattern B marking, the number of undecided responses was higher than the current marking, varying between 11% and 13% for the Pattern B marking compared to 4% undecided for the current marking. This indicates some subjects were uncertain about how to relate the Pattern B marking to the APCH signage.

Table 20. Cockpit Simulation Statement 2 Response Comparison

"The Surface Markings Adjacent to the Signs Expressed the Same Message (Or Idea) With the Signs."					
Sign/Marking Viewed	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Current Approach Sign/ Pattern A Marking	1%	4%	4%	64%	26%
Concept 1 Sign/ Pattern B Marking	3%	6%	11%	57%	23%
Concept 2 Sign/ Pattern B Marking	0%	6%	13%	51%	30%
Concept 4 Sign/ Pattern B Marking	3%	6%	11%	43%	37%

Statement 3a: *The message conveyed by the signs and surface markings was understandable.*

As indicated in table 21, more subjects agreed the meaning of the current APCH signs and runway hold position markings were more understandable than the proposed signs and markings. However, the difference was relatively small. The Concept 1 sign had the most disagreement and most undecided responses.

Table 21. Cockpit Simulation Statement 3a Response Comparison

"The Meaning of the Signs and Markings Was Understandable."					
Sign/Marking Viewed	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Current Approach Sign/ Pattern A Marking	0%	3%	3%	59%	36%
Concept 1 Sign/ Pattern B Marking	3%	9%	17%	46%	26%
Concept 2 Sign/ Pattern B Marking	0%	4%	7%	54%	34%
Concept 4 Sign/ Pattern B Marking	3%	6%	9%	49%	34%

Statement 3b: *The signs and surface markings were logically consistent with the instructions provided by ATC.*

As table 22 shows, the subjects agreed the new signs, positioned with the Pattern B marking, had more logical consistency with ATC instructions than the current signage and marking. The current signage had the highest amount of disagreeing and undecided responses to the statement, and the subjects reported the Concept 4 sign and Pattern B marking had the strongest agreement.

Table 22. Cockpit Simulation Statement 3b Response Comparison

"The Signs and Markings Were Logically Consistent with Instructions Provided by ATC."					
Sign/Marking Viewed	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Current Approach Sign/ Pattern A Marking	3%	13%	14%	47%	23%
Concept 1 Sign/ Pattern B Marking	6%	9%	3%	51%	31%
Concept 2 Sign/ Pattern B Marking	0%	7%	4%	53%	36%
Concept 4 Sign/ Pattern B Marking	3%	3%	0%	40%	54%

Statement 3c: *The visual cues were understandable early enough to identify the location of the holding position.*

The results of statement 3c indicate a strong relationship between legend text height and the distance the visual cues were observable. There were significant differences between the signs and marking combinations, as shown in table 23. The Concept 1 sign had the most varied response, with 3% of the subjects strongly disagreeing, 23% disagreeing, and 29% undecided.

Table 23. Cockpit Simulation Statement 3c Response Comparison

"The Visual Cues Were Understandable Early Enough to Identify the Location of the Holding Position."					
Sign/Marking Viewed	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Current Approach Sign/ Pattern A Marking	0%	9%	10%	49%	33%
Concept 1 Sign/ Pattern B Marking	3%	23%	29%	29%	17%
Concept 2 Sign/ Pattern B Marking	9%	10%	10%	36%	36%
Concept 4 Sign/ Pattern B Marking	3%	6%	3%	37%	51%

Statement 4: *The surface markings adjacent to the signs expressed the same message with the signs.*

As shown in table 24, the results for the Concept 1 sign showed the most disagreement that these signs expressed the same message of the markings. Among the other three sign designs, the results were nearly identical in their agreement with the statement.

Table 24. Cockpit Simulation Statement 4 Response Comparison

"The Surface Markings Adjacent to the Signs Expressed the Same Message with the Signs."					
Sign/Marking Viewed	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Current Approach Sign/ Pattern A Marking	3%	4%	3%	54%	36%
Concept 1 Sign/ Pattern B Marking	0%	17%	6%	54%	23%
Concept 2 Sign/ Pattern B Marking	1%	7%	9%	50%	33%
Concept 4 Sign/ Pattern B Marking	6%	3%	9%	49%	34%

Statement 5: *The amount of information on the signs was clear and understandable.*

As indicated in table 25, the Concept 1 sign had the least favorable results when the subjects were asked if the amount of information on the sign was clear and understandable, with 17% of subjects disagreeing. Among the other signs, the results do not show a significant difference and were in overall agreement with the statement.

Table 25. Cockpit Simulation Statement 5 Response Comparison

"The Amount of Information on the Sign was Clear and Understandable."					
Sign/Marking Viewed	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Current Approach Sign/ Pattern A Marking	3%	4%	3%	54%	36%
Concept 1 Sign/ Pattern B Marking	0%	17%	6%	54%	23%
Concept 2 Sign/ Pattern B Marking	1%	7%	9%	50%	33%
Concept 4 Sign/ Pattern B Marking	6%	3%	9%	49%	34%

Statement 6: *Please list any further comments regarding the signs and surface markings you have viewed.*

Comments regarding the current signage and marking combination mentioned some confusion about what action to take when a hold short instruction was not given by ATC. One subject mentioned the hold short marking as a factor leading to confusion: "Taxiing might lead to confusion with hold short marking on pavement." Another subject mentioned that, although the meanings of the sign and marking were understandable individually, they reported the

combinations were conflicting. Generally, pilots mentioned that having ATC clear them to cross into the approach hold area/RSA gave them more confidence to continue taxiing.

The subjects' comments generally regarded the larger signs as more effective than the smaller sign variations. One subject stated, "The longer length signs are easier to see and recognize at farther distance." There was still confusion from pilots about whether or not to hold short of the markings when ATC did not give instructions referring to the locations where the signs are located. For instance, one subject commented, "Necessary to Hold Short of Runway Approach Zone not clear," and another commented, "…a pilot not familiar with ORD might get confused crossing the mandatory signs without asking ATC for clearance to cross." One subject reported there was too much information on the sign.

Comments regarding Concept 1 were generally concerned with the difficulty in reading the legend text due to the small size. For example, one subject wrote, "The signs and writing is small and packed." Another wrote, "Text size on signs was too small and confusing." More than half of the subjects had similar comments.

Comments regarding the Concept 2 sign touched on several issues. The first was that the added departure information on the sign was preferred overall, although a small number said this provided too much information. One subject said the sign was, "Too wordy," while another wrote, "Too many letters/numbers." Some subjects were still unclear about what action to take. One subject mentioned the sign as the issue, commenting, "Since the 9R approach is the same as a runway sign, confusing if cleared to cross it without questioning ATC." Another subject mentioned the surface marking created uncertainty, writing, "Needed ATC help; not sure this is the right marking to use."

Statement 7: *Having the departure runway included on the signs improves situational awareness.*

Most subjects agreed that having the departure runway on the sign, in addition to the approach runway, had a positive effect on situational awareness. Table 26 shows the subjects' response to this statement.

Table 26. Cockpit Simulation Responses Regarding Effect of Departure Runway Information on Situational Awareness

"Having the Departure Runway on the Signs Increases Situational Awareness."					
Sign(s) Viewed	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Concepts 1, 2, and 4 (Combined)	3%	6%	3%	49%	40%

4.3.2 Cockpit Simulation Facility: Distance Results.

As indicated in table 27, the median distance each type of sign design was understandable by the subjects was consistent with the expectation that larger text sizes would be legible from greater distances. It should be noted that these simulated distances underestimate the distances the signs would be legible in reality, due to limitations in the simulator's viewable resolution. The current signs featuring the current APCH legend were able to be read and understood at a median distance of 460 feet. In comparison, the median distance the subjects could read and understand the Concept 2 sign was 13% lower than for the current signage. It took more than twice the distance for subjects to read and understand the Concept 1 sign versus the current sign. Thus, it was unlikely the Concept 1 sign will satisfy the requirement in AC 150/5345-44J, which stipulates that airfield signs of this type must be identifiable at 800 feet [12].

Table 27. Median Distances at Which Signs Were Understood by Cockpit Simulation Subjects

Sign Concept	Median Distance (ft)
Concept 1	207
Concept 2	398
Current APCH Signage	460
Concept 4	641

4.3.3 Cockpit Simulation Facility: ATC Workload.

To measure the effect of the signs and surface markings on the decisions to hold short at a given location, the subjects' actions were recorded for each combination of sign and marking. To reduce ATC workload when APCH or DEP runways are not active, it is desirable by ATC to have aircraft and ground vehicle operators proceed through these inactive runway approach hold areas rather than holding short and contacting ATC for permission to proceed. It was observed that just over one-third of subjects chose to hold short when given instructions to taxi to a location beyond a runway approach hold or RSA. The subject who held short did not proceed past the APCH signs and marking until explicit instructions to cross the APCH hold/RSA area were provided. As shown in table 28, there was some effect from changing the signs and markings; however, the effect was relatively small.

Table 28. Percentages of Subjects Holding Short at APCH Hold/RSA Locations Without an ATC Instruction to Hold Short

Sign Concept	Percentage of Subjects Holding Short
Current Approach Sign/ Pattern A Marking	37%
Concept 1 Sign/ Pattern B Marking	34%
Concept 2 Sign/ Pattern B Marking	34%
Concept 4 Sign/ Pattern B Marking	31%

When not being given an instruction to hold short, the existing combination of current APCH hold signs with Pattern A runway holding position markings caused subjects to hold short in 37% of instances. Both the Concept 1 and 2 signs caused the subjects to hold short 34% of the time when paired with the Pattern B hold position marking. Thirty-one percent of subjects held short of the Concept 4 sign paired with the Pattern B hold position marking. Twenty-five percent of subjects held short at all runway approach hold/RSA locations, regardless of the sign and surface marking present. Comments from subjects who held short mentioned that this was due to the perceived message of the signs (to hold short) overriding the message they interpreted from the surface marking. Thus, for these subjects, the conditional nature of the Pattern B surface marking was understood but not acted upon due to perceived conflict with the sign. Regarding the stated goals of reducing the workload of ATC, the new signs and Pattern B surface markings resulted in a difference of 3% to 6% in instances of subjects holding short unnecessarily, versus the current signs and marking.

5. AIRPORT EVALUATIONS.

Airport evaluations were conducted at ORD, Cleveland-Hopkins International Airport (CLE), and Nashville International Airport (BNA). Site visits were made to each airport to collect information regarding the airports' runway approach hold issues prior to the installation of the proposed signage and marking. Site visits consisted of meetings with personnel from each airport, including airport operations and maintenance, air carriers, and local FAA Airports Division personnel. These researchers conducted interviews with the pilots, ground vehicle operators, and air traffic controllers to evaluate the effectiveness of the current runway holding position signs and markings in accordance with the airports' Modifications of Standards (MOS), as shown in appendices D through M. The visits provided background information regarding each airport's runway approach hold and RSA procedures and gave a better understanding of runway approach hold and RSA issues for this phase of the research effort.

A survey was also conducted at each airport following the installation of the proposed signage runway approach holding position signage and marking. The subjects for these surveys consisted of aircraft operators, which included pilots and taxi mechanics, and ground vehicle operators such as firefighters, operations staff, and other personnel with airfield driving privileges. As table 29 shows, a total of 269 individuals took part in this survey among the three airports, including a combined group of 208 aircraft operators and 61 ground vehicle operators. Of these, 66 aircraft operators and 45 ground vehicle operators observed the proposed runway approach holding position signage and marking.

The survey results in this section include only survey data from aircraft observers and ground vehicle operators who reported observing the proposed signage and Pattern B surface marking. This decision was made to ensure the survey opinions reflected observations of the actual signs and markings in an operational setting. Some respondents declined to provide a response to one or more questions on the survey. Therefore, all results in this section contain a "Sample Size" field, indicating how many individuals provided responses for each statement.

Table 29. Airport Survey Response Summary

Airport	Subject Type	Survey Responses	Number of Subjects who Observed Proposed Signage and Marking
ORD	Aircraft Operators	87	34
	Ground Vehicle Operators	42	30
	Total:	129	64
BNA	Aircraft Operators	30	7
	Ground Vehicle Operators	14	10
	Total:	44	17
CLE	Aircraft Operators	91	25
	Ground Vehicle Operators	5	5
	Total:	96	30
Combined	Aircraft Operators	208	66
	Ground Vehicle Operators	61	45
	Total:	269	111

5.1 AIRPORT EVALUATION 1: ORD.

ORD was the first airport at which the proposed approach signage and markings were evaluated in an operational environment. This airport has a complex layout with five approach/RSA areas that affect nonintersecting taxiways and runways, as shown in figure 22. Two runway approach hold areas, for RWYs 14R-32L and 14L-32R, protect RSAs. The remaining three runway approach hold areas protect approaches and departures for RWYs 9R-27L, 10L-28R/10C-28C, and 4R-22L.

Figure 22. View of Approach Hold and RSA Signs and Marking Areas at ORD

5.1.1 The ORD Background.

Researchers were informed that ground vehicle operators at ORD do not require ATC clearance while operating on the taxiways but need clearance to use or cross the runways. Ground vehicle operators monitor ground frequencies when not on the runways; however, if the vehicle is on a taxiway next to a runway exit, they need to monitor runway frequencies. Runway approach hold signs do not relate to ground vehicles since the vehicle is less than 10 feet high and do not penetrate the approach surfaces. Ground vehicle operators typically only contact ATC when the visibility is low or marginal. Additionally, pilots did not typically hold short of a Pattern A hold position marking located with an runway approach hold sign unless ATC instructed the pilot to do so.

The airport operator provided the researchers an escort and showed the locations of the signs and markings, as seen in figure 23. The evaluation took place on RWY 9L-27R and TWY T, as shown in figures 23 and 24. The new signs will include APCH and DEP along with the Pattern B Hold Position Marking.

Figure 23. Location of Signs and Markings on ORD RWY 9L-27R

Figure 24. Location of Signs and Markings on ORD TWY T

A total of 8 pilots, 1 air traffic controller, and 14 ground vehicle operators were interviewed at ORD. This created a baseline of the current markings/sign combination according to the airport's MOS.

5.1.1.1 The ORD Background: MOS.

ORD personnel requested two MOSs within a period of a year. The first MOS, dated August 4, 2010, addressed three areas to protect the RSA of a runway that intersected another runway. This MOS had an expiration date of 1 year from the date it was approved by the FAA. The MOS included:

- "The runway holding position signs and markings that will be used at the RSA intersections between runway 14R/32L and Runway 10/28.
- The chevrons southeast of the relocated Runway 32L threshold are placed north of Runway 10/28.
- The runway shoulder markings in the area where runway intersect other runway RSA will be spaced at 25 feet." [13]

An ORD MOS, dated May 27, 2011, requested to "install signs that read 'RSA' in place of the runway intersection signs and place RSA signs outboard of the taxiway location signs where entry into an RSA would occur immediately after entering the runway." [14] Due to runway geometry, ORD has four locations on the airport where the RSA of one runway intersects with another runway. These two-dimensional RSA surfaces and the runways intersect. The actual physical runways do not intersect [14]. In addition, ORD personnel needed to provide the ground vehicle operators with visual aids to delineate the RSA of a runway that intersects the runway the ground vehicle operator is operating on [14]. The locations within the MOS that relate to the RSA in two areas of the airfield included the following.

- Intersection of Runway 9L-27R and the RSA of Runway 14L-32R. As well as, the intersection of Runway 14L-32R and the RSA of Runway 9L-27R.

- Intersection of Runway 4R-22L and the RSA of Runway 10L-28R. [14]

Furthermore, the MOS provided further information regarding replacing the mandatory hold sign with an RSA sign.

Eight pilots were interviewed at ORD. One pilot commented, "when you have an APCH sign corresponding and a runway hold line and no runway there, [there are] conflicting signals." When shown the proposed signs, both pilots preferred the long text to the Concept 1 sign. In addition, using the Pattern B holding position marking would alleviate some confusion. Pilots were asked if the 32R-14L sign or marking created confusion for them on RWY 9L. Five pilots commented that this scenario was confusing. Several pilots noted that since the sign and marking was on the runway, they thought this meant there was another runway ahead. Researchers also asked the pilots if the associated marking and signage for 9R-APCH confused them. Four pilots stated yes, and two commented that the marking conflicts with the sign. The ORD pilots' answers are shown in appendices D and E.

Training and staffing restrictions at ORD meant that only the tower manager was available to discuss the research effort. The tower manager indicated that he needed to know both the phraseology and what the signs would look like. Researchers asked the tower manager whether a waiver was in place, and the response was to ask the Lead Certification Safety Inspector. Researchers also inquired from ATC about the current hold short phraseology to pilots regarding these particular signs. The tower manager responded that the pilot would be told to "Hold short of 9-APCH" as an example. When not given an explicit instruction to hold short, ATC expects pilots to continue taxiing through these areas without holding short. Researchers made the tower manager aware of the DEP application on the prototype signs and inquired about the gain from the DEP application. The response given was that if the phraseology does not change, they were not sure what the pilot would think of the sign.

Researchers interviewed 14 ORD ground vehicle operators regarding runway hold position marking and signage as it related to the RSA and the runway approach hold areas. If a ground vehicle was not as high as an aircraft's vertical stabilizer, it would be below the approach surface and may not have to hold for approach. Ground vehicle operators said the marking and signage was adequate to mark the RSA. All 14 ground vehicle operators did not think the runway hold position marking along with the 32R-14L sign was confusing. Several ground vehicle operators indicated that everyone was familiar with the marking and signage. When asked if there were any special movement area procedures in place when operating in these areas, the ground vehicle operators indicated permission to cross from ATC was required. For ORD ground vehicle operator survey responses, see appendices F and G.

5.1.1.2 The ORD Background: Sign and Marking Evaluation Locations.

The signs and markings were installed at two runway approach hold areas for the research effort. The first was on RWY 9L-27R protecting the RWY 14L approach area, as shown in the upper portion of figure 25. The second location was the RWY 9R approach area on TWYs T and G, as

shown in the lower portion of figure 25. The airport operator then elected to install additional prototype signage and marking beyond what was provided by the research team throughout the northern section of the airport.

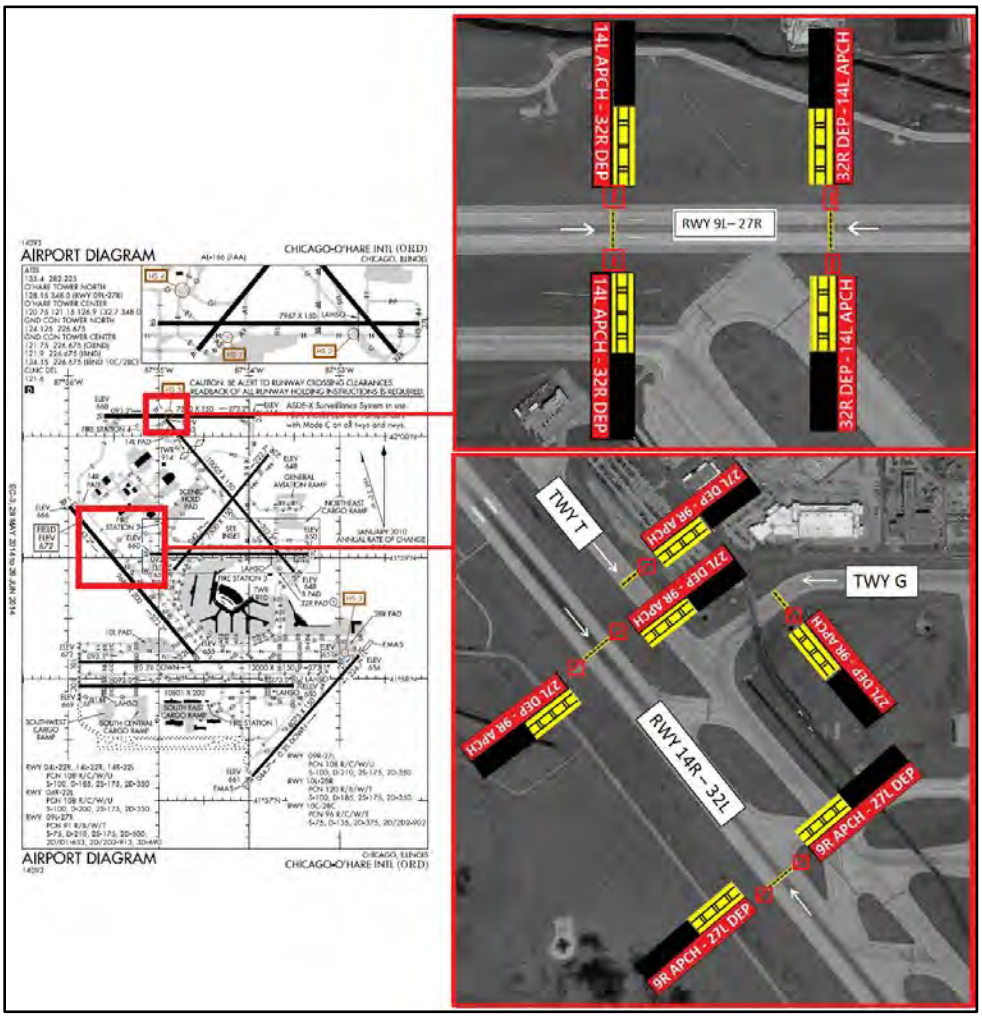


Figure 25. Signage and Marking Evaluation Locations at ORD

5.1.2 The ORD Results.

The ORD results include feedback from the airport operator regarding installation and maintenance as well as feedback from ground vehicle operator surveys. The aircraft operator and ground vehicle operator surveys, shown in appendix H, also include data from air carrier and others operating at the airport as well as feedback from ATC regarding workload.

5.1.2.1 The ORD Findings: Installation and Maintenance.

ORD electricians and operations personnel were interviewed to determine the impact the signage would have on the airport. To accommodate the increased length of the signs, all sign bases were required to be lengthened by 120-150 inches. The signage evaluated at ORD consisted of

both Concept 3 and Concept 4 units. Two signs were Concept 4 signs, one example of which is shown in figure 26. The other proposed signage throughout the airport consisted of Concept 3 signs, as shown in figure 27.

Figure 26. Concept 4 Signage Example at ORD

Figure 27. Concept 3 Signage Example at ORD

Airport personnel used two different methods for installing the Concept 4 signs to determine which was most effective. The first method involved assembling the sign inside an airport facility and transporting it to the site fully assembled. Due to the sign's increased weight, a crane was used to position the sign in place at the site. The other Concept 4 sign was assembled on-site. This involved being on the taxiway for more time and exposing the installation personnel to precipitation and other weather, increasing the difficulty of the assembly. The crane method was the most efficient; however, many airports will not have this capability.

Based on conversations with airport maintenance and operations personnel, it is expected that the long-term maintenance costs will be roughly twice the cost of the current signage in terms of energy usage for both the Concept 3 and Concept 4 signs. The personnel mentioned that the time and expense of replacing the Concept 4 signs would likely be higher due to the need for a crane or extra personnel to lift the signs. Also, the personnel mentioned that if an aircraft or ground vehicle hits one part of the sign, the entire unit would be out of service. The personnel contrasted this with the Concept 3 signs, where hitting one sign would not dislodge or damage the other, requiring half the work to replace the Concept 3 signs compared to the Concept 4 signs. Therefore, from a practicality standpoint, airport maintenance and operations personnel recommended using the Concept 3 signs.

5.1.2.2 The ORD Results: Survey Responses.

The research team surveyed a group of 129 subjects consisting of 87 aircraft operators and 42 ground vehicle operators. Of these subjects, 34 aircraft operators and 30 ground vehicle operators reported observing the proposed signs and markings on the airfield. These subjects were shown an illustration of a standard 15-APCH sign with Pattern A surface marking along with an illustration of a 15 APCH-33 DEP sign and Pattern B surface marking. For each sign, the subjects were asked to respond to a series of statements. Only responses from subjects who reported observing the proposed signs and markings on the airfield were included in the results to ensure the responses reflect actual experience with the new signs and markings.

As shown in table 30, overall, a higher percentage of aircraft operators and ground vehicle operators at ORD reported the quantity of information on the current approach hold signage was appropriate compared to the proposed approach/departure hold signage. The results showed that 20% of aircraft operators and ground vehicle operators were undecided regarding the quantity of information being appropriate for the proposed signage.

Table 30. The ORD Subject Responses: "The sign contains an appropriate quantity of information."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	Current Signage/ Pattern A Marking	34	6%	18%	14%	44%	18%
	Proposed APCH-DEP Signage/Pattern B Marking	34	12%	12%	20%	38%	18%
Ground Vehicle Operators	Current Signage/ Pattern A Marking	29	0%	14%	20%	52%	14%
	Proposed APCH-DEP Signage/Pattern B Marking	30	7%	20%	20%	46%	7%

Aircraft operators at ORD had a higher level of understanding for the proposed signage and Pattern B surface marking than the current signage and Pattern A marking. As shown in table

31, 15% of surveyed aircraft operators were in strong agreement with this statement for the current signage and marking versus 23% for the proposed signage and marking. Ground vehicle operators, however, found the current signage and marking to be more understandable, with 20% of surveyed ground vehicle operators strongly agreeing the current signage and marking were understandable compared to 10% for the proposed signage and marking.

Table 31. The ORD Subject Responses: "If positioned together at a location which did not lead to a runway entrance, the meaning of the sign and surface marking would be understandable."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	Current Signage/ Pattern A Marking	34	18%	32%	0%	35%	15%
	Proposed APCH-DEP Signage/Pattern B Marking	34	3%	21%	18%	35%	23%
Ground Vehicle Operators	Current Signage/ Pattern A Marking	30	0%	27%	20%	33%	20%
	Proposed APCH-DEP Signage/Pattern B Marking	30	3%	24%	30%	33%	10%

As shown in table 32, the subjects at ORD were also asked to respond to a statement regarding the suitability of the current and proposed signage and marking on a runway. The results for aircraft operators were mixed, with fewer aircraft operator subjects in agreement that the proposed signage and Pattern B marking were appropriate compared to the current signage and Pattern A marking, but also fewer in disagreement as well. This resulted from an increase in undecided opinions from 0% to 18%. The opinions of ground vehicle operators showed a clear preference for using the current signage and proposed signage and Pattern A marking on a runway compared to the proposed signage and Pattern B marking.

Table 32. The ORD Subject Responses: "The sign and surface marking are suitable for use on a runway."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	Current Signage/ Pattern A Marking	34	18%	32%	0%	35%	15%
	Proposed APCH-DEP Signage/Pattern B Marking	34	15%	23%	18%	29%	15%
Ground Vehicle Operators	Current Signage/ Pattern A Marking	29	3%	23%	7%	60%	7%
	Proposed APCH-DEP Signage/Pattern B Marking	30	13%	30%	10%	40%	7%

As shown in table 33, roughly two-thirds of both aircraft operators and ground vehicle operators were in agreement that seeing the departure runway on the signage increased their situational awareness. The results showed that 52% of aircraft operators and 54% of ground vehicle operators agreed with the statement, and 12% of aircraft operators and 13% of ground vehicle operators strongly agreed.

Table 33. The ORD Survey Reponses: "Seeing the departure runway on the sign(s) increased your situational awareness."

Signage/ Marking	Subject Type	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Proposed APCH-DEP Signage/ Pattern B Marking	Aircraft Operators	25	4%	16%	16%	52%	12%
	Ground Vehicle Operators	30	3%	20%	10%	54%	13%

To determine the legibility and general conspicuity of the signage and markings, aircraft operators and ground vehicle operators were asked whether they could identify the proposed visual cues early enough to identify the holding position. As shown in table 34, a majority of aircraft operators and ground vehicle operators agreed or strongly agreed the visual cues were understandable at an adequate distance.

Table 34. The ORD Subject Responses: "The visual cues were understandable early enough to identify the location of the holding position."

Signage/ Marking	Subject Type	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Proposed APCH-DEP Signage/ Pattern B Marking	Aircraft Operators	25	12%	0%	12%	64%	12%
	Ground Vehicle Operators	30	0%	3%	10%	74%	13%

As shown in table 35, a greater percentage of aircraft operators were in agreement that the proposed signs and markings were logically consistent with ATC instructions compared to ground vehicle operators. The results showed 4% of the surveyed ORD aircraft operators were undecided regarding the logical consistency of the proposed signage and Pattern B marking compared to 30% for ground vehicle operators.

Table 35. The ORD Subject Responses: "The sign(s) and surface marking(s) were logically consistent with the instructions provided by ATC."

Signage/ Marking	Subject Type	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Proposed APCH-DEP Signage/ Pattern B Marking	Aircraft Operators	25	8%	12%	4%	64%	12%
	Ground Vehicle Operators	30	7%	10%	30%	53%	0%

5.1.2.3 The ORD Findings: ATC Workload.

Researchers interviewed five active air traffic controllers at ORD. These controllers said their level of workload has increased since the introduction of the proposed approach/departure hold signage, and associated markings and phraseology. According to controllers, the increase was primarily due to the pilots' unfamiliarity with the proposed signage and marking. For example, when viewing the signs and markings without being given a hold short instruction, no significant confusion was 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 became confused and called ATC for further direction, not knowing to which the ATC was referring. One controller estimated that 33% to 50% of the pilots who received these instructions called back asking for further clarification before taxiing. These radio calls increased frequency congestion by increasing the quantity 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."

A contributing factor for the confusion is that runway approach hold locations are not depicted on the ORD airport diagram, as shown in figure 28. Thus, even for a pilot familiar with the concept of the runway approach hold, it may be difficult to anticipate where a specific runway approach hold will be located if the pilot is unfamiliar with the airport's specific signage and marking layout.

ATC personnel said that prior to the research effort they would instruct pilots to hold short of specific taxiways, such as TWYs T or G, to avoid the problems caused by using approach holds. One source of confusion in communications is related to using the terms "approach" and "departure." These can be confused with the departure and approach ends of the runway itself rather than the approach and departure protected areas. The controllers said 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 turn 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 RWY 9R). This resulted in the need for extra coordination between the ground and local controllers 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 the taxiway before reaching the approach hold location on TWY T.

Figure 28. The RWY 9R/27L Approach Hold Area

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 said cargo pilots on the south end of the airport call more often to confirm being able to cross APCH areas than pilots on the north end of the airport where the new markings are installed, saying this may be due to the standard operating procedures (SOP) of these companies (mainly foreign carriers) not allowing them to cross mandatory markings without clearance. One controller also noticed a decrease in ground vehicle operator confusion with the new markings in place.

The controllers then brought up the issue that the approach and departure signs and phraseology are not applicable for some runways. For example, RWY 32L is used for departures, therefore, referring to the approach would not be needed. Also, the APCH/DEP signage on RWY 9L-27R is used solely for protecting the RWY 32L-14R RSA, therefore using the approach and departure phraseology is seen as unnecessary. The controllers recommended creating a new name for areas needing to be kept clear of aircraft and ground vehicles during approaches and departures, such as "Runway xx protected area" along with a unique symbol and/or legend text for the sign.

The research team was unable to record how many pilots proceeded through the APCH hold areas prior to and after the installation of the proposed signs and markings due to the limited scope of the data collection effort. Therefore, to estimate the effect of the changes, the 87 aircraft operators and 42 ground vehicle operators who took part in the survey were asked to respond to the statement, "To proceed past the sign and surface marking, explicit permission from air traffic control would be needed." This was asked for both the current approach hold

signage and proposed approach/departure hold signage to compare the understanding of aircraft operators and ground vehicle operators of each.

As shown in table 36, the results from this statement showed 15% of aircraft operators disagreed and 24% of ground vehicle operators strongly disagreed or disagreed that explicit clearance would be needed to proceed past the current approach hold signage and Pattern A marking without explicit ATC clearance. This indicates a majority of the surveyed subjects were not aware that explicit ATC clearance is not required to proceed to the current approach holding position signage and Pattern A marking. When asked to respond to the same statement for the proposed approach/departure hold signage with Pattern B marking, these percentages rose to 35% and 30% for aircraft operators and ground vehicle operators, respectively. This indicates that the signs and markings would likely have the intended effect of reducing the number of individuals stopping unnecessarily at approach areas. However, a majority of aircraft operators and ground vehicle operators remain under the impression that explicit clearance is required to pass an approach hold position despite the signage and markings changes.

Table 36. The ORD Subject Responses: "To proceed past the sign and surface marking, explicit permission from air traffic control would be needed."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	Current Signage/ Pattern A Marking	34	0%	15%	12%	44%	29%
	Proposed APCH-DEP Signage/Pattern B Marking	34	9%	26%	9%	35%	21%
Ground Vehicle Operators	Current Signage/ Pattern A Marking	30	7%	17%	17%	36%	23%
	Proposed APCH-DEP Signage/Pattern B Marking	30	3%	27%	33%	27%	10%

5.1.2.4 The ORD Runway Incursions.

As indicated in table 37, seven runway incursions occurred at ORD within a 6-month period at locations where the proposed signs and markings were installed. All incursions occurred in the RWY 9R approach hold area. Because this data of approach hold locations had not been tracked previously, it is unknown if any incursions had occurred at this location prior to the study.

One runway incursion (ODM20150207005) was due to controller error. Incursion report number PGLTORD15011 was due to the crew mistaking another aircraft's call sign for its own. The remaining five runway incursion events consisted of individuals failing to hold short of the approach after being instructed by ATC. One deviation (VGLTORD15001) involved a mechanic taxiing an aircraft, and the remaining four incursions were pilot deviations.

Table 37. The ORD RWY 9R Approach Hold Incursions During Evaluation Period

Date of Event	Report Number	Report Narrative
1/21/2015	PGLTORD15002	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	VGLTORD15001	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	ORDM201502070005	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	PGLTORD15005	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	PGLTORD15006	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.
4/24/2015	PGLTORD15007	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	PGLTORD15011	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.

Unclear phraseology may be a contributing factor based on Confidential Information Share Program (CISP) reports analyzed by the research team. Five reports involving the RWY 9R approach were shared on the CISP system. As shown in table 38, three of these reports indicate issues with ATC phraseology used to instruct pilots to hold short of approach hold areas.

Table 38. The ORD CISP Reports

Report Number	Report Narrative
CISPID: 15760	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.
CISPID: 20438	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. 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.
CISPID: 21798	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'.
CISPID: 27309	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.
CISPID: 27310	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.

It is unclear to what degree the proposed signage and marking played as a contributing factor in the incursions that occurred during the study. No approach hold-related runway incursions were recorded in this area prior to the signage and marking installation, as well as during the first 6 months the signage and markings were in place. A lack of familiarity with the signage and marking could also play a role. However, other areas of the airfield have not experienced runway incursions; therefore, the probability of this is likely minimal.

Due to the high rate of incursions during the evaluation, Hot Spot 6 (HS 6) was created at ORD to alert pilots and ground vehicle operators of this risk. HS 6 is shown in figure 29 and includes the entire protected area for RWY 9R. It is clear that controllers, pilots, and all ground vehicle operators should exercise caution and vigilance regarding this approach area.

Figure 29. Hot Spot 6 at ORD

5.2 AIRPORT EVALUATION 2: CLE.

The second airport included in the evaluations was CLE. As shown in figure 30, CLE has two approach/departure hold areas. These areas are located on RWY 10-28, and they protect the approach and departures for RWYs 6L-24R and 6R-24L.

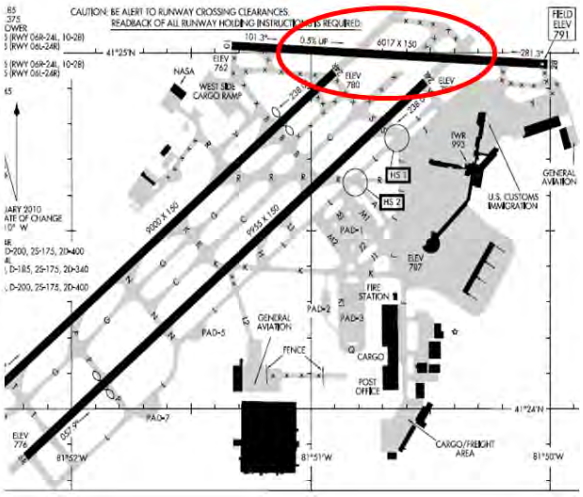


Figure 30. Evaluation Area at CLE

5.2.1 The CLE Background.

During April 23-24, 2013, researchers visited CLE and briefed the airport operator and airline representatives on this research effort. The group discussed several locations that dealt with the RSA and runway approach hold issues. Several slides were shown of RWY 10-28 that had runway hold position signage and markings used to delineate the RSA. The group discussed both areas and what they meant to pilots and the ground vehicle operators. Researchers learned that pilots did not use RWY 10-28 as much as RWYs 6R-24L and 6L-24R because of the RSA, approach and departure surfaces, and traffic flow. Also, due to runway length, commuter jets were the only aircraft to use RWY 10-28. The runway did not have any runway approach hold signage; however, the signs and associated markings on RWY 10-28 were for ground vehicle use only, and ground vehicle height was restricted to a maximum of 15 feet. These signs are shown in figure 31.

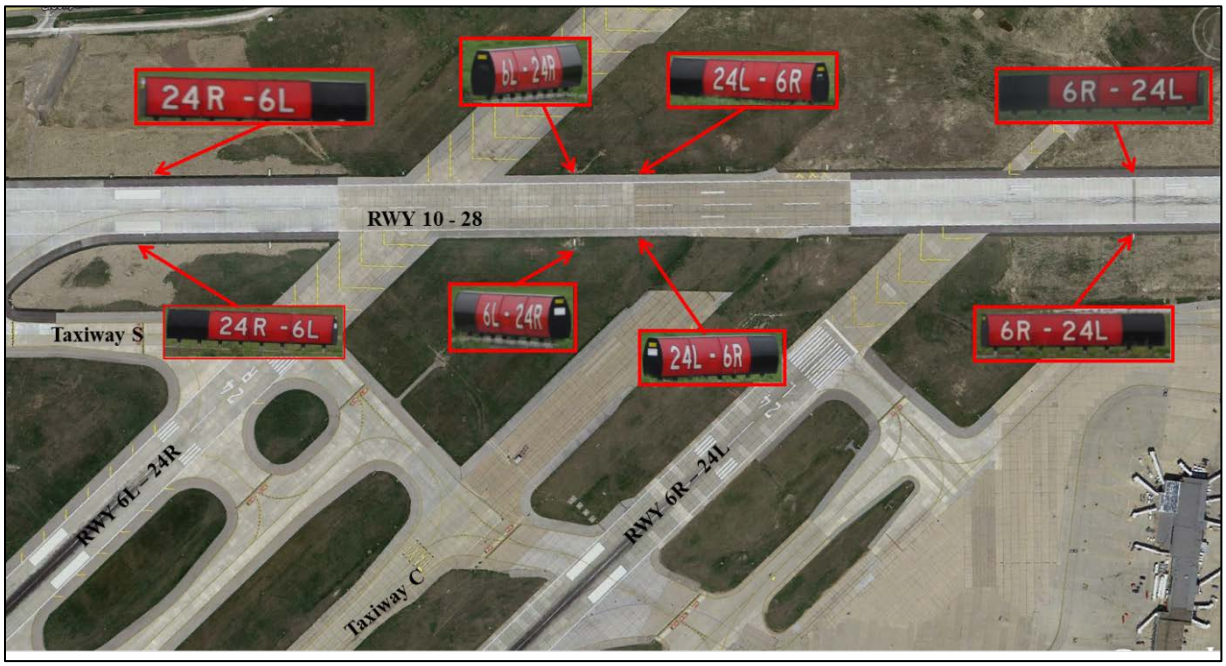


Figure 31. The RSA Locations Where RWYs 6L-24R and 6R-24L Intersect With RWY 10-28 at CLE

Following the briefing, the airport operator escorted the researchers onto the airfield and showed the locations of the signs and markings on RWY 10-28, as shown in figure 32. This location was selected for evaluation of new signs to include the proposed approach/departure hold signage with the Pattern B hold position marking.

Researchers interviewed 4 pilots, 2 air traffic controllers, and 11 ground vehicle operators at CLE. The interviews created a baseline for the current markings according to the airport MOS. Once installed, responses to the new signage and marking would be compared with baseline answers.

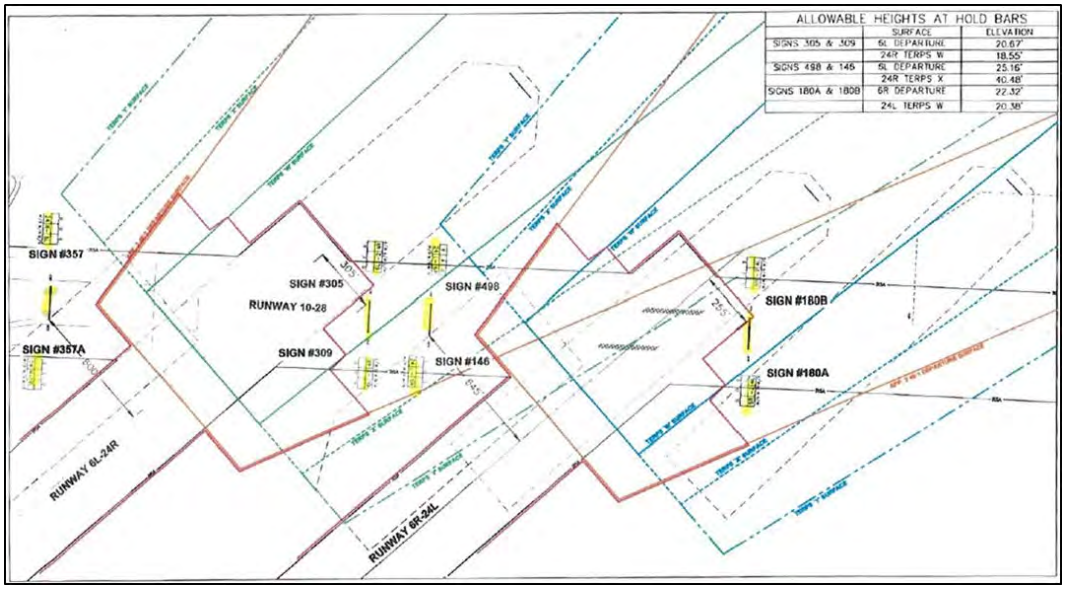


Figure 32. The RSA and Approach Hold Sign Locations and Critical Surfaces at CLE [15]

5.2.1.1 The CLE Background: MOS.

The May 24, 2012, memorandum regarding the MOS amendment request for hold position signs and markings on RWY 10-28 stated that the runway would only be used by ground vehicles with a maximum restricted height of 15 feet [15]. Figure 33 shows the signs that are referenced in the MOS and the critical surfaces that need to be protected.

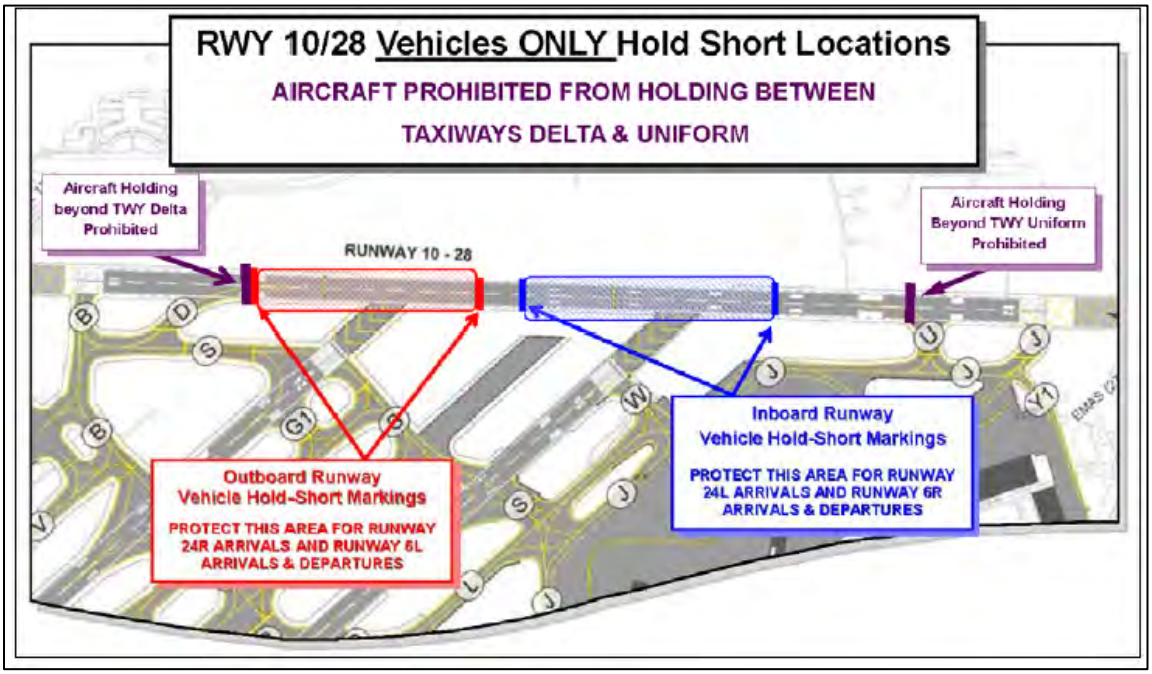


Figure 33. The RWY 10-28 Hold Short Locations for Ground Vehicle Operators at CLE [16]

Furthermore, there is an SOP between the airport operator and CLE ATC that explains the use of the signs and markings as well as restrictions. Within the MOS, the airport operator had to implement a driver training program that incorporated the use of the signs, markings, and restrictions into the Airport Certification Manual so the ground vehicle operators are aware of this information [16].

5.2.1.2 The CLE Background: Interviews.

Appendix I includes pilot feedback for signage and markings on RWY 10-28. It was discussed that the runway is used less now than when the pavement of RWY 10-28 was connected to RWY 24L for taxiing onto RWY 10-28 while waiting to line up for RWY 24L. The pilots also commented on confusion regarding the current approach hold signage paired with the runway hold position marking. The pilots commented, "The hold short line is supreme, so when we see the hold short line, we want to stop. Having opposite end (33-DEP) on sign might be confusing. Having one or both isn't really an issue. When we used 28 as a taxiway there was a taxiway after TWY U to make the turn and hold. Our pilots would feel uncomfortable taxiing on a runway." Appendix I contains more detailed pilot responses, and interviews with two ATC personnel are shown in appendix J.

The tower manager indicated that RWY 10-28 is not often used for taxiing. The signage and markings on RWY 10-28 are for ground vehicles, protecting the RSA. Figure 33 is from the CLE ATC SOP, and it indicates where ground vehicles should hold short on RWY 10-28 to protect the RSA when RWYs 6L-24R and 6R-24L are in use. The hold positions are based on numerous surface protections required for aircraft using the parallel runways. Prior to installing the signage and runway hold position marking, aircraft would hold short of TWYs D and U. The tower manager stated there had always been some sort of sign/marking for ground vehicles. Appendix J contains the responses from the ATC personnel.

Next, ground vehicle operators were interviewed regarding the signage and runway holding position marking on RWY 10-28. All 11 ground vehicle operators commented that there was no confusion regarding the RWY 6R-24L sign paired with the runway holding position marking. Several ground vehicle operators provided additional information and commented that changing the marking from a runway holding position to a Pattern B would create more confusion for ground vehicle operators. Furthermore, two ground vehicle operators indicated that they are confused when "ATC tells you to cross one but hold short of the other" and that "In the middle there is some confusion because there's too many markings." The ground vehicle operators' responses are shown in appendix K.

5.2.1.3 The CLE Background: Sign and Marking Evaluation Locations.

Figures 34 and 35 show where the evaluated signs and markings were located. They consisted of four pairs of signs positioned on each side of RWY 10-28.

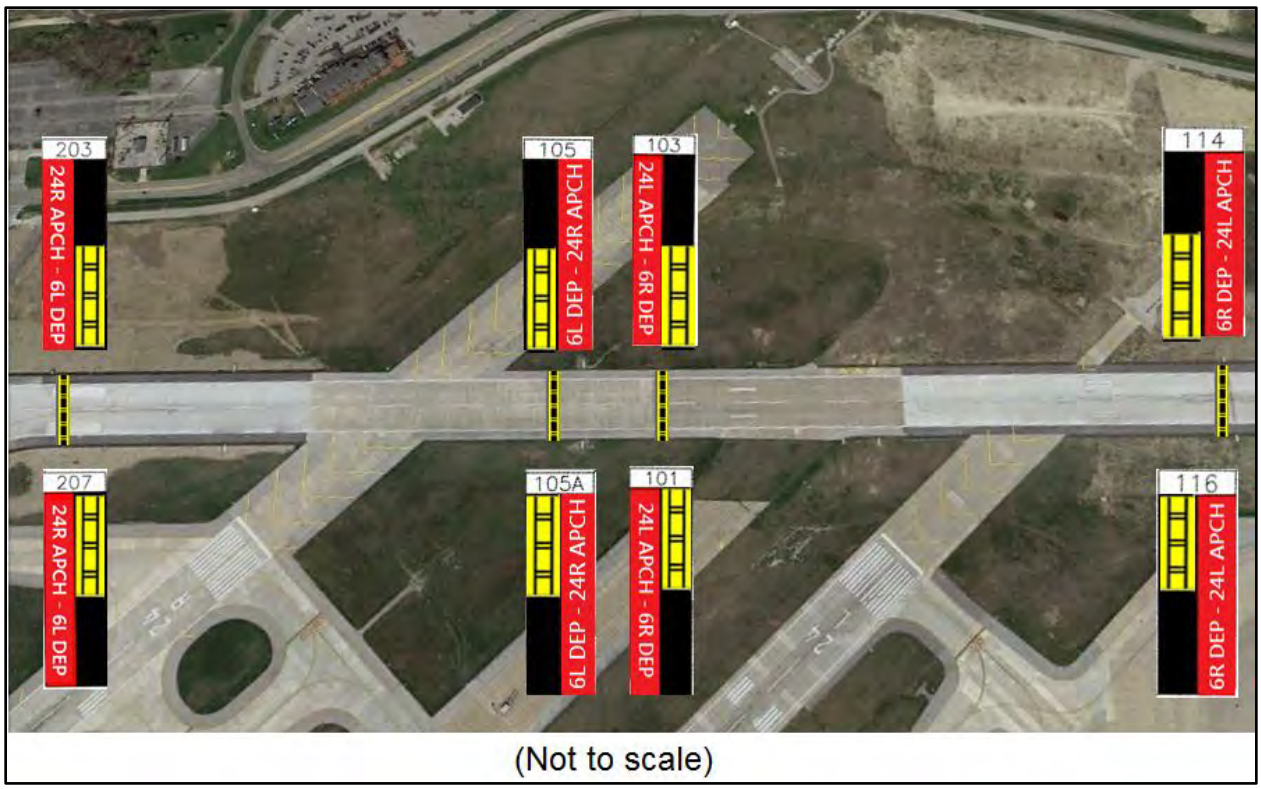


Figure 34. Signage Diagram at CLE

Figure 35. Surface Marking Locations at CLE

The CLE airport operator issued the following Notices to Airmen (NOTAM) indicating the presence of the nonstandard signage and marking being evaluated.

> !CLE 05/461 (KCLE A1687/15) CLE RWY 10 HOLDING POSITION MARKINGS AT RWY 6R/24L RSA NOT STD 1505271237-1510302359EST
>
> !CLE 05/460 (KCLE A1685/15) CLE RWY 10 HOLDING POSITION MARKINGS AT RWY 6L/24R SAFETY AREA NOT STD 1505271235-1510302359EST
>
> !CLE 05/459 (KCLE A1686/15) CLE RWY 10 HOLDING POSITION SIGN AT RWY 6R/24L SAFETY AREA NOT STD 1505271235-1510302359EST
>
> !CLE 05/458 (KCLE A1684/15) CLE RWY 10 HOLDING POSITION SIGN AT RWY 6L/24R SAFETY AREA NOT STD 1505271233-1510302359EST
>
> !CLE 05/457 (KCLE A1683/15) CLE RWY 28 HOLDING POSITION SIGN AT RWY 6L/24R SAFETY AREA NOT STD 1505271232-1510302359EST
>
> !CLE 05/456 CLE RWY 28 HOLDING POSITION MARKINGS AT RWY 6L/24R SAFETY AREA NOT STD 1505271231-1510302359EST
>
> !CLE 05/455 (KCLE A1681/15) CLE RWY 28 HOLDING POSITION MARKINGS AT RWY 6R/24R SAFETY AREA NOT STD 1505271230-1510302359EST
>
> !CLE 05/454 (KCLE A1680/15) CLE RWY 28 HOLDING POSITION SIGN AT RWY 6R/24L SAFETY AREA NOT STD 1505271229-1510302359EST

5.2.2 The CLE Results.

The CLE results included an analysis of installation and maintenance requirements, survey data from aircraft operators and ground vehicle operators, and feedback from ATC. The aircraft operator and ground vehicle operator surveys are included in appendix L.

5.2.2.1 The CLE Results: Installation and Maintenance.

The signage on RWY 10-28 at CLE consisted of size 2, Concept 2 signs. Due to the reduction in legend text height, the installation of the signage at CLE required minimal time and expense. As shown in figure 36, the proposed signage consisted of four panels, which gave sufficient space to contain the full legend text of the proposed signage. The installation required only switching panels from the current signage to the proposed signage without any further modification, as shown in figure 37. An example of the proposed signage in place at CLE is shown in figure 38.

Figure 36. Current Signage at CLE

Figure 37. Installation of Proposed Sign Panels at CLE

Figure 38. Concept 2 Signage Installed at CLE

When asked what maintenance burden the signs may have if their length was increased, field maintenance personnel said it would take somewhat more time to change more lamps, but the use of light-emitting diode lighting would mitigate this to a large extent. For the reduced-size text signage, maintenance personnel said one issue may be the text getting covered more easily with snow, obstructing the ability to read the signs.

5.2.2.2 The CLE Results: Survey Responses.

Ninety-one aircraft operators and five ground vehicle operators took part in the survey conducted at CLE. Of these, 25 aircraft operators and 5 ground vehicle operators observed the proposed signage. Similarly with the survey at ORD, the subjects were shown an illustration of a standard 15-APCH sign with Pattern A surface marking along with an illustration of a 15 APCH-33 DEP sign and Pattern B surface marking. For each sign, subjects were asked to respond to a series of statements. Only responses from subjects who reported observing the proposed signs and markings on the airfield were included in the results to ensure the responses reflect actual experience with the new signs and markings.

As shown in table 39, 44% of aircraft operators surveyed agreed and 4% strongly agreed the proposed signage contained an appropriate quantity of information compared to 60% and 20% for the current signage, respectively. Furthermore, 60% of ground vehicle operators agreed and 20% strongly agreed the quantity of information on the current approach hold signage was appropriate compared to the 40% in agreement for the proposed signage. This indicates both aircraft and ground vehicle operators overall preferred the quantity of information on the current signage.

Table 39. The CLE Subject Responses: "The sign contains an appropriate quantity of information."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	Current Signage/ Pattern A Marking	25	0%	12%	8%	60%	20%
	Proposed APCH-DEP Signage/Pattern B Marking	25	16%	12%	24%	44%	4%
Ground Vehicle Operators	Current Signage/ Pattern A Marking	5	20%	0%	0%	60%	20%
	Proposed APCH-DEP Signage/Pattern B Marking	5	40%	20%	0%	40%	0%

When asked if each sign and surface marking was understandable when not leading to a runway entrance, aircraft and ground vehicle operators both had lower levels of understanding for the proposed signage and marking versus the current signage and marking. For example as shown in table 40, 48% aircraft operators agreed and 24% strongly agreed the current signage and marking were understandable compared to 32% and 8%, respectively, for the proposed sign and marking. Furthermore, 40% of ground vehicle operators agreed and an additional 40% strongly agreed the current signage and marking were understandable compared to 40% agreeing and 20% strongly agreeing for the proposed sign and marking. It should be noted that 28% of aircraft operators and 40% of ground vehicle operators were undecided about whether they understood the proposed signage and marking, possibly due to a general lack of familiarity with the signs and markings.

Table 40. The CLE Subject Responses: "If positioned together at a location which did not lead to a runway entrance, the meaning of the sign and surface marking would be understandable."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	Current Signage/ Pattern A Marking	25	8%	12%	8%	48%	24%
	Proposed APCH-DEP Signage/Pattern B Marking	25	16%	16%	28%	32%	8%
Ground Vehicle Operators	Current Signage/ Pattern A Marking	5	0%	0%	20%	40%	40%
	Proposed APCH-DEP Signage/Pattern B Marking	5	0%	0%	40%	40%	20%

As shown in table 41, aircraft operators and ground vehicle operators at CLE were more likely to be in agreement or strong agreement that the current approach signage and Pattern A surface

marking be used on a runway compared to the proposed sign and Pattern B marking. Aircraft operators overall did not agree that either sign and marking combination was appropriate on a runway, with 32% in agreement and 16% in strong agreement that the current approach signage and Pattern A surface marking was suitable for use on a runway and 12% in agreement and an additional 12% in strong agreement for the proposed sign and Pattern B marking. Ground vehicle operators were more receptive to the use of both sign and marking combinations on a runway. It should be noted that 20% of both aircraft operators and ground vehicle operators strongly disagreed the current signage and Pattern A surface marking are suitable for use on a runway, which is comparable to the rates of 28% of aircraft operators and 20% of ground vehicle operators for the proposed sign and Pattern B marking. This indicates approximately one-fifth of aircraft operators and ground vehicle operators at CLE strongly oppose both sign and marking combinations for approach holding positions on runways.

Table 41. The CLE Subject Responses: "The sign and surface marking are suitable for use on a runway."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	Current Signage/ Pattern A Marking	25	20%	20%	12%	32%	16%
	Proposed APCH-DEP Signage/Pattern B Marking	25	28%	32%	16%	12%	12%
Ground Vehicle Operators	Current Signage/ Pattern A Marking	5	20%	0%	20%	40%	20%
	Proposed APCH-DEP Signage/Pattern B Marking	5	20%	20%	20%	40%	0%

As shown in table 42, aircraft operators at CLE were more likely to be in agreement that the departure runway information on the sign increased their situational awareness than ground vehicle operators. The results showed 52% of aircraft operators surveyed agreed and 9% strongly agreed seeing the departure runway on the sign increased their situational awareness compared to 40% of ground vehicle operators agreeing and 0% strongly agreeing. It should be noted that the departure runway had been on the signs previously; however, the DEP designation was not included. Therefore, ground vehicle operators would likely already be familiar with the departure runway information and see minimal benefit of additional DEP text.

Table 42. The CLE Survey Reponses: "Seeing the departure runway on the sign(s) increased your situational awareness."

Signage/ Marking	Subject Type	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Proposed APCH-DEP Signage/ Pattern B Marking	Aircraft Operators	23	9%	17%	13%	52%	9%
	Ground Vehicle Operators	5	20%	40%	0%	40%	0%

As shown in table 43, aircraft operators at CLE were more likely to understand the proposed sign early enough to identify the location of the holding position compared to ground vehicle operators. For instance, 40% of ground vehicle operators agreed that the visual cues were understandable early enough to identify the holding positions on RWY 10-28 compared to 73% agree/strongly agree for aircraft operators. The aircraft operator agreement rate is similar to that measured at ORD (76% agree/strongly agree); however, the ground vehicle operator rate is significantly lower than the rate of agreement to this statement at ORD (87% agree/strongly agree). This indicates the text size may be a greater factor for ground vehicle operators than it is for aircraft operators in understanding the signage.

Table 43. The CLE Survey Reponses: "The visual cues were understandable early enough to identify the location of the holding position."

Signage/ Marking	Subject Type	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Proposed APCH-DEP Signage/ Pattern B Marking	Aircraft Operators	22	9%	18%	0%	68%	5%
	Ground Vehicle Operators	5	20%	40%	0%	40%	0%

As shown in table 44, ground vehicle operators and aircraft operators at CLE had mixed opinions regarding the logical consistency of the proposed sign and Pattern B surface marking and the ATC instructions. For example, 48% of aircraft operators agreed and 4% strongly agreed. These were logically consistent, while 40% of ground vehicle operators were in agreement. Interviews conducted with ground vehicle operators indicated that the low level of ground vehicle operator agreement may be because these individuals are trained to request clearance across the safety areas being protected by the signage and marking being validated. Therefore, using a conditional marking may introduce confusion initially.

Table 44. The CLE Subject Responses: "The sign(s) and surface marking(s) were logically consistent with the instructions provided by ATC."

Signage/ Marking	Subject Type	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Proposed APCH-DEP Signage/ Pattern B Marking	Aircraft Operators	23	9%	13%	26%	48%	4%
	Ground Vehicle Operators	5	0%	20%	40%	40%	0%

The research team interviewed aircraft rescue and firefighting (ARFF) personnel, airport operations personnel, and other ground vehicle operators to get further insight and feedback on their opinions. ARFF staff members had some difficulty with the signage initially, saying the meaning of the signs was not intuitive without training. They said they learned how to react to the signs, but because the signs were different from other mandatory hold signs, the amount of information that drivers had to be mindful of increased. One ARFF employee mentioned that due to this confusion, some ground vehicle operators tended to avoid the area with the signs and markings because they were apprehensive about making a mistake. The ARFF employee preferred as much simplicity as possible, especially in intense situations such as responding to an aircraft accident.

A CLE airport operations manager who was interviewed reported that there were no issues with airport operations employees understanding the proposed signs and markings. This individual said the training for drivers prior to these being installed was effective, and no runway incursions or deviations have occurred. A second operations manager reported anticipating an increase in runway incursions due to ground vehicle operator confusion when the Pattern B markings were installed. However, this individual reported that these fears turned out to be unfounded, as no incursions have occurred since the signs and markings were installed. Regarding the signs' content, the second operations manager said the added information was not necessary, but it could be useful to some drivers. This individual mentioned that the text should be full size to reduce the chances that a pilot or driver could miss it if instructed to hold short. Despite the markings not causing any observed issues, the second operations manager said, in his opinion, the original Pattern A markings were safer and less ambiguous than the proposed markings.

To learn how maintenance department staff members were reacting to the signs and markings, four ARFF personnel, including a supervisor, were interviewed. The supervisor mentioned that some personnel reported the text was difficult to read, but they understood the signs once they could read the message. The three other ARFF personnel reported having extensive driving experience on the airfield. Two of the three said the additional APCH and DEP legend was beneficial, but one said that there was too much information. This individual did feel that having both runways on the sign was preferable to a standard APCH sign (CLE uses nonstandard mandatory hold position signage for the APCH hold). Three field operations employees were also interviewed about the proposed signs and markings. All three reported the text was

problematic due to its small size. They mentioned having difficulty reading the sign in low-visibility situations such as plowing during snow events.

Finally, an interview was conducted with a consulting engineer at the airport. This individual reported the signage as being understandable and added to situational awareness, but did not feel the Pattern B markings were as clear in meaning as Pattern A markings. The engineer associates these with ILS critical areas, and the fact that the markings were not protecting one of these areas made the combination of signs and markings somewhat confusing.

5.2.2.3 The CLE Findings: ATC Workload.

Paper surveys were distributed to ATC to provide feedback; however, the surveys 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 ground vehicle operators. The representative 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 these were occurring. The tower representative and the controllers did not fully understand the purpose of changing the paint markings. This individual said that ground vehicles are proceeding through the approach or departure areas when cleared to proceed "full length" on RWY 10-28 unless told to hold short. Overall, controllers mentioned that the changes have had no observable effects on workload.

To estimate the effects of the signs and markings on aircraft operator and ground vehicle operator behavior, ground vehicle operators and aircraft operators were asked to respond to the statement, "To proceed past the sign and surface marking shown, explicit permission from air traffic control would be needed." As shown in table 45, the changes indicated that aircraft operators had a lower tendency to agree the signage and markings required explicit ATC instructions to proceed compared to the current signage and marking. For instance, 48% of aircraft operators agreed and 36% strongly agreed that explicit permission was needed for the current signage and Pattern A marking compared to 28% agreeing and 20% strongly agreeing that this was needed for the proposed sign and Pattern B marking. Ground vehicle operator responses also indicated an increase in understanding that the sign and marking were conditional, with 20% agreeing and 80% strongly agreeing that the current signage and marking requires explicit ATC instructions compared to 20% agreeing and 20% strongly agreeing this was the case for the proposed sign and markings.

Table 45. The CLE Subject Responses: "To proceed past the sign and surface marking, explicit permission from air traffic control would be needed."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	Current Signage/ Pattern A Marking	25	4%	12%	0%	48%	36%
	Proposed APCH-DEP Signage/Pattern B Marking	25	4%	36%	12%	28%	20%
Ground Vehicle Operators	Current Signage/ Pattern A Marking	5	0%	0%	0%	20%	80%
	Proposed APCH-DEP Signage/Pattern B Marking	5	20%	0%	40%	20%	20%

5.3 AIRPORT EVALUATION 3: BNA.

The third and final airport included in the evaluation was BNA. This evaluation consisted of installing signage and marking at the runway approach hold positions for the RWY 20C approach and 2C departure at the location shown in figure 39. Similar to ORD and CLE, surveys were conducted to collect data from aircraft operators and ground vehicle operators at the airport. ATC representatives at the airport were also interviewed to gather their feedback.

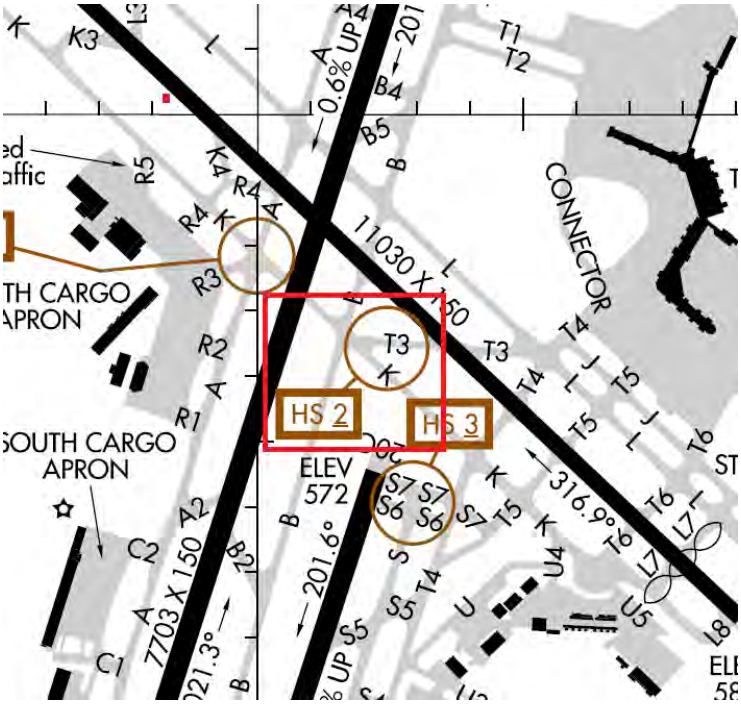


Figure 39. The RWY 20C Approach and 2C Departure Area at BNA

5.3.1 The BNA Background.

On September 25, 2013, BNA airport operator representatives were briefed on the research effort. During the presentation, the group discussed a location that dealt with the RSA and runway approach hold issues for RWYs 20C and 31, shown in figure 40.

Figure 40. The RWY 20C-APCH Locations at BNA

The runway approach hold signage and markings on TWYs K and T3 were inspected. After consulting with the airport operator regarding these locations, it was determined the two RWY 20C-APCH locations would receive the most feedback from the aircraft operators and ground vehicle operators. Researchers noted a slope on TWY K prior to TWY T3 that would need to be taken into account for a sign installed in that location. It was mentioned by the airport operator that the holding position markings in the TWY K/T3 area have confused ground vehicle operators. An excerpt of the BNA sign plan for RWY 20C APCH area is shown in figure 41 inside the red boxes.

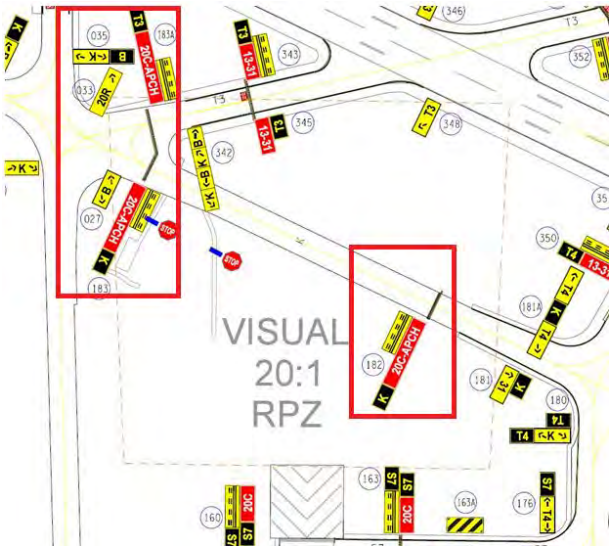


Figure 41. Sign Plan at BNA

5.3.1.1 The BNA Background: Sign and Marking Evaluation Locations.

The proposed signs and markings were installed on TWY K between TWYs T3 and T4, as shown in figure 42. The signs were collocated with taxiway location signage for TWYs K and T3.

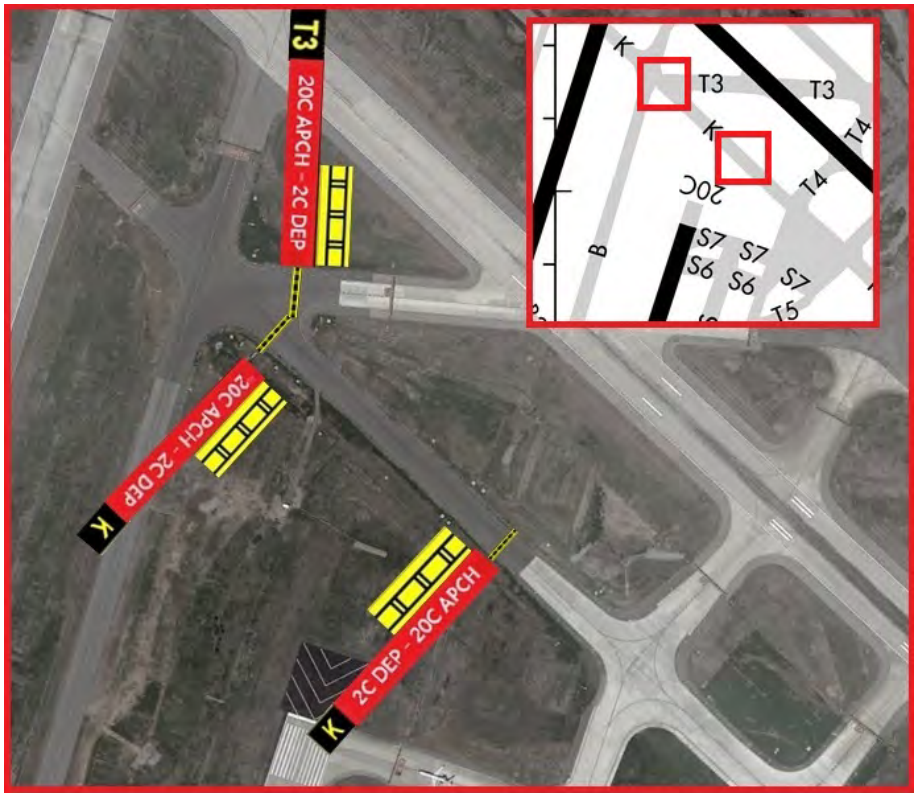


Figure 42. The BNA Sign Evaluation Locations

The BNA airport operator issued the following NOTAMs regarding the nonstandard signage and markings.

> !BNA 06/100 (KBNA A0721/15) BNA TWY T3 HOLDING POSITION SFC MARKING AT RWY 2C/20C SAFETY AREA NOT STD 1506051416-1512041800
>
> !BNA 06/099 (KBNA A0720/15) BNA TWY T3 HOLDING POSITION SIGN AT RWY 2C/20C SAFETY AREA NOT STD 1506051416-1512041800
>
> !BNA 06/098 (KBNA A0719/15) BNA TWY K HOLDING POSITION SFC MARKING AT RWY 2C/20C SAFETY AREA NOT STD 1506051414-1512041800
>
> !BNA 06/097 (KBNA A0718/15) BNA TWY K HOLDING POSITION SIGN AT RWY 2C/20C SAFETY AREA NOT STD 1506051414-1512041800

5.3.2 The BNA Results.

The BNA results included an analysis of installation and maintenance requirements, aircraft operator and ground vehicle operator survey data, and ATC feedback.

5.3.2.1 The BNA Results: Installation and Maintenance.

The signs installed at BNA consisted of size 3, Concept 2 signs. An example of this signage is shown in figure 43.

Figure 43. Concept 2 Signage Installed at BNA

The reduction in legend text was due to sloping terrain, which prevented significant lengthening of the concrete pads to accommodate a Concept 3 or 4 sign. An example of this terrain is shown in figure 44.

Figure 44. Sloping Terrain at BNA

This reduced the extra length required for the sign from 132 to 46 inches. It was decided that the 46-inch extension would be more practical. However, even this 46-inch expansion required the slope to be graded and sodded, as shown in figure 45.

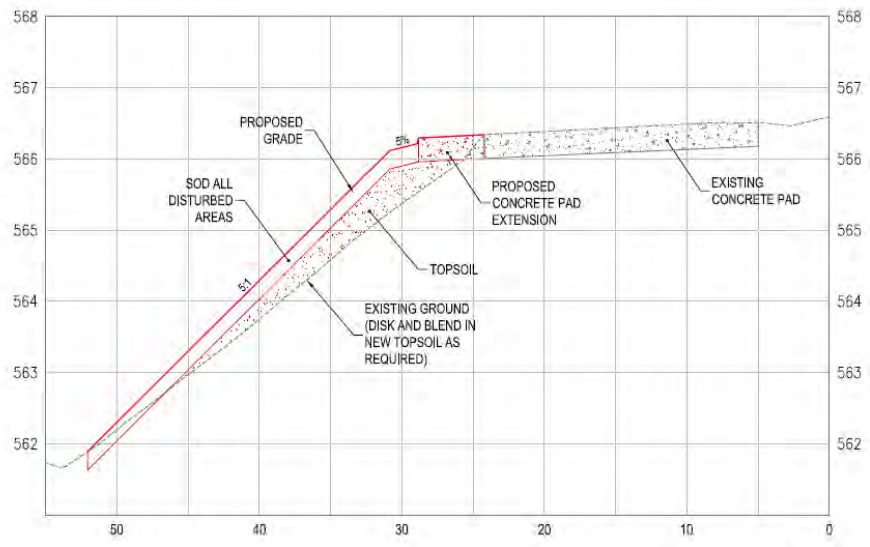


Figure 45. The BNA Sign Pad Extension Grading Plan Excerpt [17]

The maintenance requirements for the new signage are expected to be minimal due to the lengths. An airport electrician indicated that once installed, the signs would not represent a significant burden for the airport relative to the current signs in these locations. The primary cost would be the operation of an additional lamp in each sign.

5.3.2.2 The BNA Results: Survey Responses.

Forty-four individuals, consisting of 30 aircraft operators and 14 ground vehicle operators, took part in an online survey at BNA. Of these individuals, 7 aircraft operators and 10 ground vehicle operators observed the signage and marking installed at BNA for this research effort. Similar to the surveys at ORD and CLE, the subjects were shown an illustration of a standard 15-APCH sign with Pattern A surface marking along with an illustration of a 15 APCH-33 DEP sign and Pattern B surface marking. For each sign, the subjects were asked to respond to a series of statements. Only responses from subjects who reported observing the proposed signs and markings on the airfield were included in the results to ensure the responses reflect actual experience with the new signs and markings.

To determine if the addition of the departure runway on the signage created an information overload, aircraft operators and ground vehicle operators were asked to respond to the statement, "The sign contains an appropriate quantity of information," for both the current and proposed signage. As shown in table 46, 72% of BNA aircraft operators agreed the current approach signage contained an appropriate quantity of information compared to 42% agreeing and 29% strongly agreeing for the proposed signage, a total of 71% agreement. The results also showed 80% of ground vehicle operators agreed the quantity of information on both the proposed and current signage was appropriate, with 30% agreeing strongly that the current signage contained

an appropriate quantity of information and 40% agreeing strongly that the proposed signage contained an appropriate quantity of information.

Table 46. The BNA Subject Responses: "The sign contains an appropriate quantity of information."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	Current Signage/ Pattern A Marking	7	14%	14%	0%	72%	0%
	Proposed APCH-DEP Signage/Pattern B Marking	7	0%	0%	29%	42%	29%
Ground Vehicle Operators	Current Signage/ Pattern A Marking	10	0%	20%	0%	50%	30%
	Proposed APCH-DEP Signage/Pattern B Marking	10	0%	10%	10%	40%	40%

As shown in table 47, a higher percentage of aircraft and ground vehicle operators at BNA agreed the proposed signage and Pattern B marking were understandable compared to the current signage and Pattern A marking. For instance, 43% of aircraft operators were in agreement that both the current signage/Pattern A marking and the proposed signage/Pattern B marking were understandable; however, 29% agreed strongly with this statement for the proposed signage and Pattern B marking compared to 14% for the current signage and Pattern A marking. Furthermore, 30% of ground vehicle operators at BNA were in strong agreement that both signage and marking combinations were understandable, but an additional 40% answered "agree" for the proposed signage and marking versus 30% for the current signage and Pattern A marking.

Table 47. The BNA Subject Responses: "If positioned together at a location which did not lead to a runway entrance, the meaning of the sign and surface marking would be understandable."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	Current Signage/ Pattern A Marking	7	29%	0%	14%	43%	14%
	Proposed APCH-DEP Signage/Pattern B Marking	7	14%	14%	0%	43%	29%
Ground Vehicle Operators	Current Signage/ Pattern A Marking	10	0%	20%	20%	30%	30%
	Proposed APCH-DEP Signage/Pattern B Marking	10	0%	20%	10%	40%	30%

As shown in table 48, both aircraft and ground vehicle operator subjects were more likely to agree the current signage and Pattern A marking were suitable for use on a runway compared to the proposed sign and Pattern B marking. For example, 72% of aircraft operators agreed the current signage and Pattern A marking were suitable for use on a runway, compared to 57% agreeing the proposed signage and Pattern B marking were suitable. Similarly, 67% of ground vehicle operators agreed and 22% strongly agreed that current signage and Pattern A marking were suitable on a runway compared to 40% agreeing and 20% strongly agreeing the proposed signage and Pattern B marking were suitable.

Table 48. The BNA Subject Responses: "The sign and surface marking are suitable for use on a runway."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	Current Signage/ Pattern A Marking	7	14%	14%	0%	72%	0%
	Proposed APCH-DEP Signage/Pattern B Marking	7	14%	29%	0%	57%	0%
Ground Vehicle Operators	Current Signage/ Pattern A Marking	9	11%	0%	0%	67%	22%
	Proposed APCH-DEP Signage/Pattern B Marking	10	10%	10%	20%	40%	20%

Aircraft operators and ground vehicle operators agreed that seeing the departure runway on the proposed sign increased their situation awareness. For instance, as shown in table 49, 86% of aircraft operators were in agreement that their situational awareness increased due to seeing the departure runway information. Furthermore, 50% of ground vehicle operators agreed and 40% strongly agreed with this statement.

Table 49. The BNA Survey Reponses: "Seeing the departure runway on the sign(s) increased your situational awareness."

Signage/ Marking	Subject Type	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Proposed APCH-DEP Signage/ Pattern B Marking	Aircraft Operators	7	0%	14%	0%	86%	0%
	Ground Vehicle Operators	10	0%	0%	10%	50%	40%

As shown in table 50, 83% of aircraft operators who observed the proposed signage agreed with the statement, "The visual cues were understandable early enough to identify the location of the holding position," and 17% strongly agreed. For ground vehicle operators at BNA, 40% agreed

and 30% strongly agreed. Thus, aircraft operators at BNA were more likely than ground vehicle operators to agree that seeing the departure runway on the proposed signage increased their situation awareness, but both sets of subjects were in overall agreement with the statement.

Table 50. The BNA Survey Reponses: "The visual cues were understandable early enough to identify the location of the holding position."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Proposed APCH-DEP Signage/ Pattern B Marking	Aircraft Operators	6	0%	0%	0%	83%	17%
	Ground Vehicle Operators	10	0%	10%	20%	40%	30%

As shown in table 51, all aircraft operators surveyed at BNA agreed the proposed signage and markings were logically consistent with ATC instructions, along with 80% of ground vehicle operators. This indicates there may be some remaining confusion for 20% of ground vehicle operators regarding ATC instructions relating to the proposed approach hold sign and Pattern B marking.

Table 51. The BNA Subject Responses: "The sign(s) and surface marking(s) were logically consistent with the instructions provided by ATC."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Proposed APCH-DEP Signage/ Pattern B Marking	Aircraft Operators	7	0%	0%	0%	86%	14%
	Ground Vehicle Operators	10	0%	0%	20%	40%	40%

5.3.2.3 The BNA Results: ATC Workload.

Similar to ORD and CLE, ATC personnel declined to complete surveys due to their workload levels. 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.

Based on survey responses completed by aircraft operators at BNA who had observed the new signage and markings, the changes have a noticeable effect on their decision to hold short. As shown in table 52, the percentage of aircraft operators disagreeing with the statement, "To proceed past the sign and surface marking, explicit permission from air traffic control would be needed," increased from 14% disagreeing and 14% strongly disagreeing (28% total) for the

current signage and Pattern A marking to 17% strongly disagreeing and 50% disagreeing (67% total) for the proposed signage and Pattern B marking. The signs were also effective for ground vehicle operators, but not to the same degree as with aircraft operators. For instance, the percentage of ground vehicle operators who disagreed that explicit ATC permission would be required rose from 20% disagreeing and 0% strongly disagreeing (20% total) for the current signage and Pattern A marking to 30% disagreeing and 10% strongly disagreeing for the proposed signage and Pattern B marking.

Table 52. The BNA Subject Responses: "To proceed past the sign and surface marking, explicit permission from air traffic control would be needed."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	Current Signage/ Pattern A Marking	7	14%	14%	14%	29%	29%
	Proposed APCH-DEP Signage/Pattern B Marking	6	17%	50%	0%	33%	0%
Ground Vehicle Operators	Current Signage/ Pattern A Marking	10	0%	20%	0%	40%	40%
	Proposed APCH-DEP Signage/Pattern B Marking	10	10%	30%	10%	20%	30%

5.4 SURVEY RESPONSE DATA SUMMARY.

At the conclusion of the research effort, the researchers combined the survey responses from ORD, CLE, and BNA. These responses were then sorted by subject type, as shown in table 53.

This section includes all subjects who participated in the survey and reported observing the evaluated signage. Of the 208 aircraft operators and 61 ground vehicle operators that participated in the online surveys at ORD, CLE, and BNA, 111 individuals (66 aircraft operators and 45 ground vehicle operators) observed the new signage and markings. However, it should be noted that some subjects declined to provide responses to individual questions. Therefore, the number of responses for each statement are shown in the Sample Size field.

5.4.1 Combined Results.

As shown in table 53, fewer subjects overall reported the proposed 15 APCH-33 DEP signage contained an appropriate quantity of information compared to the current 15-APCH signage. For example, 53% of aircraft operators agreed and 17% strongly agreed the quantity of information on the current signage was appropriate compared to 41% agreeing and 14% strongly agreeing for the proposed signage. Ground vehicle operators had similar opinions regarding whether the current approach hold sign contained an appropriate quantity of information. For example, 52% of ground vehicle operators agreed and 18% strongly agreed the information quantity was

appropriate on the current signage, whereas 44% agreed and 13% strongly agreed the quantity of information was appropriate for the proposed signage.

Table 53. All Subjects: "The sign contains an appropriate quantity of information."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	Current Signage/ Pattern A Marking	66	4%	15%	11%	53%	17%
	Proposed APCH-DEP Signage/Pattern B Marking	66	12%	10%	23%	41%	14%
Ground Vehicle Operators	Current Signage/ Pattern A Marking	44	2%	14%	14%	52%	18%
	Proposed APCH-DEP Signage/Pattern B Marking	45	9%	18%	15%	44%	13%

The combined results showed that aircraft and ground vehicle operators had lower overall levels of understanding for the proposed signage and Pattern B marking compared to the current signage and Pattern A marking. For instance, as shown in table 54, 47% of aircraft operators agreed and 21% strongly agreed the current signage and Pattern A marking were understandable compared to 35% of aircraft operators agreeing and 18% strongly agreeing the proposed signage and Pattern B marking were understandable. Also, 33% of ground vehicle operators agreed and 25% strongly agreed the current signage and Pattern A marking were understandable compared to 36% agreeing and 15% strongly agreeing this was the case for the proposed signage and Pattern B marking combination.

Table 54. All Subjects: "If positioned together at a location which did not lead to a runway entrance, the meaning of the sign and surface marking would be understandable."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	Current Signage/ Pattern A Marking	66	15%	12%	5%	47%	21%
	Proposed APCH-DEP Signage/Pattern B Marking	66	9%	18%	20%	35%	18%
Ground Vehicle Operators	Current Signage/ Pattern A Marking	45	0%	22%	20%	33%	25%
	Proposed APCH-DEP Signage/Pattern B Marking	45	2%	20%	27%	36%	15%

As shown in table 55, fewer aircraft and vehicle operators were in agreement that the proposed sign and Pattern B marking were suitable for use on a runway compared to the current signage

and Pattern A marking. For example, the results showed that 38% of aircraft operators agreed and 14% strongly agreed the current signage and Pattern A were suitable on a runway, and 26% agreed and 12% strongly agreed the proposed signage and Pattern B were suitable. Ground vehicle operators showed similar results, with 59% agreeing and 11% strongly agreeing the current signage and Pattern A marking was suitable on a runway, while 40% agreed and 9% strongly agreed the proposed signage and Pattern B marking was suitable.

Table 55. All Subjects: "The sign and surface marking are suitable for use on a runway."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	Current Signage/ Pattern A Marking	66	18%	26%	4%	38%	14%
	Proposed APCH-DEP Signage/Pattern B Marking	66	20%	27%	15%	26%	12%
Ground Vehicle Operators	Current Signage/ Pattern A Marking	44	7%	16%	7%	59%	11%
	Proposed APCH-DEP Signage/Pattern B Marking	45	13%	25%	13%	40%	9%

As table 56 shows, 68% of aircraft operators agreed and 9% strongly agreed that the visual cues were understandable early enough to identify the location of the holding position. The results for ground vehicle operators were similar, 62% agreeing and 18% strongly agreeing the visual cues were understandable early enough for location of the holding position. This indicates the signage and marking may pose some difficulty for certain individuals, but overall, individuals reported the signage and marking were understandable at a distance they considered adequate.

Table 56. All Subjects: "The visual cues were understandable early enough to identify the location of the holding position."

Signage/ Marking	Subject Type	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Proposed APCH-DEP Signage/ Pattern B Marking	Aircraft Operators	53	9%	8%	6%	68%	9%
	Ground Vehicle Operators	45	2%	7%	11%	62%	18%

As table 57 shows, more than half of aircraft and ground vehicle operators surveyed were in agreement that the inclusion of the departure runway information increased their situational awareness. For example, 56% of aircraft operators agreed and 9% strongly agreed that the inclusion of the departure runway on the proposed signage increased situational awareness. Among ground vehicle operators, 51% agreed and 18% strongly agreed that seeing the departure runway increased their situational awareness.

Table 57. All Survey Reponses: "Seeing the departure runway on the sign(s) increased your situational awareness."

Signage/ Marking	Subject Type	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Proposed APCH-DEP Signage/ Pattern B Marking	Aircraft Operators	55	6%	16%	13%	56%	9%
	Ground Vehicle Operators	45	4%	18%	9%	51%	18%

A majority of aircraft and ground vehicle operators were in agreement that the proposed signage and surface markings were logically consistent with ATC instructions. As shown in table 58, 60% of aircraft operators agreed and 9% strongly agreed with this statement, while 49% of ground vehicle operators agreed and 9% strongly agreed.

Table 58. All Subject Responses: "The sign(s) and surface marking(s) were logically consistent with the instructions provided by ATC."

Signage/ Marking	Subject Type	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Proposed APCH-DEP Signage/ Pattern B Marking	Aircraft Operators	55	7%	11%	13%	60%	9%
	Ground Vehicle Operators	45	4%	9%	29%	49%	9%

The responses for all subjects were compared for the current signage and Pattern A marking and the proposed signage and Pattern B marking to determine the proportion of individuals aware of the conditional nature of the runway approach hold signage and markings. The results indicate the change in signage and markings did have an effect in increasing understanding, but the effect was relatively small. As shown in table 59, 14% of aircraft operators disagreed and 3% strongly disagreed that explicit permission would be needed to proceed past the current approach holding position signage and Pattern A marking compared to 32% disagreeing and 8% strongly disagreeing for the proposed signage and Pattern B marking. This indicates the rate at which aircraft operators hold short unnecessarily would likely decline by half, decreasing ATC workload. However, 32% of the aircraft operators agreed, 19% strongly agreed, and 9% were undecided regarding this statement. This indicates that more than half of the aircraft operators will continue to hold short unnecessarily with the new signage and marking in place, though this would likely decrease over time. The effects of the signage and Pattern B marking on ground vehicle operators was similar to that of aircraft operators, with increases in the number of individuals disagreeing and strongly disagreeing with that explicit permission is necessary to pass the signage and marking. However, despite the changes in signage and marking, 24% agreed and 16% strongly agreed explicit permission was necessary and 29% remained undecided.

Table 59. All Subject Responses: "To proceed past the sign and surface marking, explicit permission from air traffic control would be needed."

Subject Type	Signage/Marking	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	Current Signage/ Pattern A Marking	66	3%	14%	7%	44%	32%
	Proposed APCH-DEP Signage/Pattern B Marking	65	8%	32%	9%	32%	19%
Ground Vehicle Operators	Current Signage/ Pattern A Marking	45	4%	16%	11%	36%	33%
	Proposed APCH-DEP Signage/Pattern B Marking	45	7%	24%	29%	24%	16%

5.4.2 Airport Comparisons.

This section contains the comparisons of aircraft and ground vehicle operator responses regarding the proposed signage and Pattern B marking for the three airports at which surveys were conducted.

Table 60 shows a comparison of results for the statement, "The sign contains an appropriate quantity of information," for the proposed approach hold signage for ORD, CLE, and BNA. Ground vehicle operator perception regarding the quantity of sign information varied. Approximately half of the ground vehicle operators at ORD (53%) were in agreement that the quantity of information on the signage was appropriate and 20% were undecided. At CLE, in contrast, 40% of ground vehicle operators agreed that the quantity of information was appropriate and 60% strongly disagreed/disagreed. Ground vehicle operators at BNA had the most favorable opinions regarding the quantity of sign information with 80% agreeing and 10% disagreeing.

Table 60. Airport Response Comparison: "The sign contains an appropriate quantity of information."

Subject Type	Airport	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	ORD	34	12%	12%	20%	38%	18%
	CLE	25	16%	12%	24%	44%	4%
	BNA	7	0%	0%	29%	42%	29%
Ground Vehicle Operators	ORD	30	7%	20%	20%	46%	7%
	CLE	5	40%	20%	0%	40%	0%
	BNA	10	0%	10%	10%	40%	40%

As shown in table 61, when comparing aircraft operator responses for the statement, "if positioned together at a location which did not lead to a runway entrance, the meaning of the sign and surface marking would be understandable," for the proposed signage and Pattern B surface marking, BNA aircraft operators had the highest levels of agreement (43% agreeing and 29% strongly agreeing) followed by ORD (35% agreeing and 23% strongly agreeing), and CLE had the lowest level of agreement (32% agreeing and 8% strongly agreeing). CLE also had the highest percentage of undecided aircraft operators (28%). Among ground vehicle operator responses, BNA also had the highest level of agreement that the signs and markings were understandable (40% agreeing and 30% strongly agreeing) followed by CLE (40% agreeing and 20% strongly agreeing), and ORD had the lowest level of agreement for ground vehicle operators (33% agreeing and 10% strongly agreeing). Because the proposed signage and Pattern B marking were installed on runways at ORD and CLE, which is a nonstandard location for approach hold signage, the results indicate this may introduce confusion for aircraft and ground vehicle operators; although, this effect may be temporary. BNA, by contrast, only featured the proposed signage and marking on taxiways, which matches more closely with the current FAA standard, and had the highest levels of understanding reported by aircraft and ground vehicle operators.

Table 61. Airport Response Comparison: "If positioned together at a location which did not lead to a runway entrance, the meaning of the sign and surface marking would be understandable."

Subject Type	Airport	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	ORD	34	3%	21%	18%	35%	23%
	CLE	25	16%	16%	28%	32%	8%
	BNA	7	14%	14%	0%	43%	29%
Ground Vehicle Operators	ORD	30	3%	24%	30%	33%	10%
	CLE	5	0%	0%	40%	40%	20%
	BNA	10	0%	20%	10%	40%	30%

To determine the effects of the reduction in legend text size at CLE and BNA, the aircraft operator and ground vehicle operator responses to the statement, "The visual cues were understandable early enough to identify the location of the holding position," were compared for each of the three airports. As shown in table 62, BNA had the highest rate of agreement for aircraft operators, with 83% agreeing and 17% strongly agreeing the signage and marking were understandable at an adequate distance. ORD had the second-highest rate of agreement, with 64% agreeing and 12% strongly agreeing. CLE had the lowest rate of agreement, with 68% of aircraft operators agreeing and 5% strongly agreeing with the statement. For ground vehicle operators, ORD had the highest level of agreement, with 74% agreeing and 13% strongly agreeing, followed by BNA (40% agreeing and 30% strongly agreeing), and CLE had the lowest level of agreement (40% agreeing and 0% strongly agreeing). These results indicate the Concept 2 signage may be adequately understandable when installed on a taxiway, such as at BNA, but

not be adequately understandable on a runway, such as at CLE. This would likely be due to the increased width of the runway creating more distance between the observer and the signage.

Table 62. Airport Response Comparison: "The visual cues were understandable early enough to identify the location of the holding position."

Subject Type	Airport	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	ORD	25	12%	0%	12%	64%	12%
	CLE	22	9%	18%	0%	68%	5%
	BNA	6	0%	0%	0%	83%	17%
Ground Vehicle Operators	ORD	30	0%	3%	10%	74%	13%
	CLE	5	20%	40%	0%	40%	0%
	BNA	10	0%	10%	20%	40%	30%

Regarding logical consistency of signs and surface markings, BNA had the greatest quantity of positive responses from both aircraft operators (86% agreeing and 14% strongly agreeing) and ground vehicle operators (40% agreeing and 40% strongly agreeing) among the three airports, as shown in table 63. The lowest levels of positive responses came from CLE, with 48% of aircraft operators agreeing and 4% strongly agreeing and 40% of ground vehicle operators agreeing and 0% strongly agreeing that the proposed signage and Pattern B marking were logically consistent with ATC instructions. CLE also had the largest number of undecided responses, with 26% of aircraft operators and 40% of ground vehicle operators giving this response. This indicates the use of the signage and surface marking in a runway environment may diminish understanding.

Table 63. Airport Response Comparison: "The sign(s) and surface marking(s) were logically consistent with the instructions provided by ATC."

Subject Type	Airport	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	ORD	25	8%	12%	4%	64%	12%
	CLE	23	9%	13%	26%	48%	4%
	BNA	7	0%	0%	0%	86%	14%
Ground Vehicle Operators	ORD	30	7%	10%	30%	53%	0%
	CLE	5	0%	20%	40%	40%	0%
	BNA	10	0%	0%	20%	40%	40%

As shown in table 64, the proportion of aircraft operators who reported their situational awareness was improved by the departure runway information on the signage ranged from 57% (agreed/strongly agreed) at BNA to 64% at ORD. The proportion of ground vehicle operators who agreed the inclusion of the departure runway information improved situational awareness ranged from 40% at CLE to 90% (agreed/strongly agreed) at BNA.

Table 64. Airport Response Comparison: "Seeing the departure runway on the sign(s) increased your situational awareness."

Subject Type	Airport	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	ORD	25	4%	16%	16%	52%	12%
	CLE	23	9%	17%	13%	52%	9%
	BNA	7	14%	29%	0%	57%	0%
Ground Vehicle Operators	ORD	30	3%	20%	10%	40%	7%
	CLE	5	20%	40%	0%	40%	0%
	BNA	10	0%	0%	10%	50%	40%

Finally, as shown in table 65, significant percentages of subjects at each of the three airports disagreed or were undecided regarding the suitability of the proposed approach/departure hold signage and marking on a runway. The responses for BNA, an airport at which the signage and marking were not installed on a runway, had the highest levels of agreement. By contrast, the highest rate of disagreement was reported at CLE, an airport at which the proposed signage and marking were installed exclusively on a runway. At CLE, 12% of aircraft operators agreed and 12% strongly agreed the signage and marking were suitable on a runway compared to 28% strongly disagreeing and 32% disagreeing. Furthermore, 20% of ground vehicle operators at CLE strongly disagreed and 20% disagreed the signage and marking were suitable on a runway.

Table 65. Airport Response Comparison: "The sign and surface marking are suitable for use on a runway."

Subject Type	Airport	Sample Size	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
Aircraft Operators	ORD	34	15%	23%	18%	29%	15%
	CLE	25	28%	32%	16%	12%	12%
	BNA	7	14%	29%	0%	57%	0%
Ground Vehicle Operators	ORD	30	13%	30%	10%	40%	7%
	CLE	5	20%	20%	20%	40%	0%
	BNA	10	10%	10%	20%	40%	20%

5.4.3 Subject Comments.

Subjects who viewed the proposed signage and markings at ORD, CLE, or BNA were given the chance to share open-ended comments, concerns, and other feedback regarding the signage marking at the end of the survey.

5.4.3.1 Positive Comments Regarding Proposed Visual Cues.

Samples of positive comments received from the subjects are listed below. These comments indicate that some aircraft and ground vehicle operators thought the signage and markings were an effective improvement over the current visual cues.

- "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."
- "The detail of information is sufficient."

5.4.3.2 Negative Comments Regarding Proposed Visual Cues.

Below are samples of comments received from subjects with concerns over the quantity of information displayed on the signage.

- "Too much information on the new signs - will cause information overload for some pilots and vehicle operators. Also, the use of ILS Critical Area holding position markings is inappropriate, as these markings convey a different message. Our brains are conditioned to hold short of ILS areas during IFR conditions, and ignore them in VFR."
- "I just think there is a lot of information (text) on the signs to comprehend. I had clearance full length on runway 10/28 and as I approached the signage, I felt it was a little too much. We had training about these signs prior so I already knew what to expect and what they meant. Just having the runway #'s would be sufficient in my opinion."
- "The new signage/markings/verbiage are causing more confusion than awareness."

- "Not appropriate - Too much information. Signs need to be concise and understandable at first glance."

- "Too much information that causes airports to change signage with little or no additional benefit. Current approach/departure end signs are perfectly understandable."

- "Sign contains too much information to read, digest, and understand during normal runway speeds."

- "I would suggest simplifying this to just "15" or "RWY 15", since you're at the end. The APCH and DEP makes the sign huge and I have to do some mental gymnastics to envision myself approaching or departing for it to make sense which runway I'm on. And I can only be on 15 (...no pavement left on 33), so why not make it say that?"

- "Too much quantity. I work at one of the "test-bed" airports and have seen them in use."

- "Still think calling to drive through the RSA was better. The new way seems too confusing to pilots and drivers."
- "Too much text."

- "What does the additional info 33 DEP information tell me? How does it help me. I think it's unnecessary. As a pilot, if a sign says 15 Apprch, I already know that it also includes opposite direction departures."

- "Too much information to take in while moving towards and to take in and comprehend."

Three comments reported issues with the legibility of the reduced-size legend text at CLE and BNA.

- "The letter sizes were made smaller in order to fit on the existing panel. It's too small, confusing, and looks like alphabet soup."

- "The signs themselves are VERY difficult to read. The size of the font is so small its almost ridiculous. Since there is so much information on the signs it actually makes the red more difficult to see because now a majority of the sign is black with very little white letters. The black outlining obscures the letters even more. Now that its snowing just the tiniest bit of snow in the wrong spot could cause an incident or worse."

- "There is too much info on the sign and is difficult to read quickly - especially when it is crammed onto 2 sign panels rather than the required

4+ panels for the amount of info. This scenario would be better with the hold bar if you want people to stop."

Others were confused and/or concerned about using the Pattern B marking for runway approach hold areas and RSAs.

- "The surface marking doesn't seem to go with the signs."
- "On a runway, you cannot tell from the marking which side is the protected side."
- "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 a ILS hold bar. I believe the pilot would cross the ILS hold bar and look for a standard hold bar."
- "More than just Airport Ops drives the airfield. Its not as common to have to hold short of an ILS, folks aren't used to it. I believe you're asking for trouble to use an ILS painted hold marking where a hold bar used to be. The red hold box still conveys a hold short message, but the box is too cramped and may be confusing to some operators."
- "There should be a separate standard developed to show areas that are Runway Safety Areas."
- "I didn't quite understand the relationship with the 33DEP sign and the ILS critical area."
- "Type 1 hold markings in conjunction with standard runway mandatory hold signs should be used whenever the safety area of a runway is being used."
- "I am not comfortable with the pattern b marking protecting a safety 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"
- "One thing that is crucial and complementary to the signage/markings is the appropriate airport diagram chart. Without that chart telling you approximately where the hold point is, you really wouldn't be looking for it."
- "Clearance to taxi across should be in the taxi clearance if not being used."

6. SUMMARY OF FINDINGS.

The interview and survey response data conducted for this study led to several findings. These were sorted into three categories: (1) effects on aircraft and ground vehicle operators, (2) effects on ATC workload, and (3) effects on airport operators.

6.1 EFFECTS ON AIRCRAFT AND GROUND VEHICLE OPERATORS.

A majority of aircraft and ground vehicle operators agreed the inclusion of the departure runway on the proposed approach hold signage provided increased situational awareness. From the airport surveys, 56% of aircraft operators agreed and 9% strongly agreed that the inclusion of the departure runway increased their situational awareness. The results from simulated tests conducted with pilots at the FAA Cockpit Simulation Laboratory supported this, with 40% of pilots agreeing and 49% strongly agreeing that seeing the departure runway on the signage increased their situational awareness. For ground vehicle operators, 51% agreed and 18% strongly agreed that situational awareness would increase with the inclusion of the departure runway on approach hold signage. However, subjects did not favor using the proposed signage and Pattern B marking on a runway. Less than half of both aircraft and vehicle operators were in agreement that the proposed sign and Pattern B marking were suitable for use on a runway.

Although aircraft and ground vehicle operators generally agreed situational awareness was increased from seeing the departure runway on approach holding position signage, it was found that the added information made the signage more challenging for some aircraft and ground vehicle operators to understand. Fewer subjects overall agreed that the proposed 15 APCH-33 DEP signage contained an appropriate quantity of information compared to the current 15-APCH signage. However, a majority of aircraft and ground vehicle operators agreed that the visual cues were understandable early enough to identify the location of the holding position. This indicates that although the signage and marking may pose some difficulty for certain individuals, overall, individuals reported the signage and markings were understandable at a distance they considered adequate. The survey data show a majority of aircraft and ground vehicle operators were in agreement that the proposed signage and surface markings were logically consistent with ATC instructions. Aircraft operators were more likely than ground vehicle operators to find the proposed signage and Pattern B marking logically consistent with ATC instructions.

When asked the statement, “If positioned together at a location which did not lead to a runway entrance, the meaning of the sign and surface marking would be understandable,” the subjects were more likely to be in agreement for the current signage and Pattern A marking compared to the proposed signage and Pattern B marking. This indicates the meaning of the proposed signage and surface marking may not be intuitive for some aircraft and ground vehicle operators without training and familiarization concerning the proposed signage and marking.

Of the 49 subjects who submitted comments and considered the quantity of information on the proposed signage appropriate, 17 (37%) indicated understanding of the intended meaning of the signage as conditionally protecting approach, departure, and RSAs. However, 28 (61%) indicated confusion about the intended purpose of the holding position signage and marking, believing it was protecting an ILS critical area. One individual reported the visual cues were acceptable, but this person was confused about the ATC instructions. It was found that 15 of the

subjects indicated confusion between an approach holding position and an ILS critical area holding position. Six subjects had general confusion about the purpose of the signage, such as believing it was intended for a runway entrance. Three reported difficulty in reading the reduced-size text at CLE and BNA, and one subject reported being confused as to which side of the Pattern B marking was being protected.

6.2 EFFECTS ON ATC WORKLOAD.

The intended outcome of the proposed signage and marking changes was to reduce ATC workload by decreasing the number of aircraft and ground vehicles holding short of approach areas when the associated runway is inactive. Based on interviews with ATC personnel, it was found that the level of workload has in fact increased rather than decreased at ORD since the installation of the updated signage and markings. However, this workload decreased over time as individuals become more accustomed to the changes. ATC workload at CLE and BNA were unaffected by the changes in signage and markings.

Simulation results showed that replacement of the Pattern A surface marking at an approach holding position with a Pattern B (ladder) ILS surface marking had a small but noticeable effect in decreasing the tendency of subject pilots to hold short when ATC instructions to hold were not given. In a series of simulated scenarios conducted for this study with 35 subject pilots, the subjects held short of the Pattern A surface marking in 37% of scenarios when ATC instructions to hold short were not provided compared to holding short in 34% of these scenarios with the Pattern B surface marking present.

Survey data from operational testing at ORD, CLE, and BNA showed the proposed signage and marking had their intended effect of reducing the perception of aircraft and ground vehicle operators that approach holds are mandatory when explicit ATC instructions are not provided. For instance, the percentage of aircraft operators disagreeing or strongly disagreeing with the statement "To proceed past the sign and surface marking, explicit permission from air traffic control would be needed," rose from 17% (14% disagreeing and 3% strongly disagreeing) for the Pattern A marking to 40% (32% disagreeing and 8% strongly disagreeing) for the Pattern B marking. For ground vehicle operators, this percentage rose from 20% (16% disagreeing and 4% strongly disagreeing) to 31% (24% disagreeing and 7% strongly disagreeing). This indicates aircraft and vehicle operators may be less likely to hold short unnecessarily with the proposed signage and Pattern B marking compared to the current signage and Pattern A marking.

It should be noted that within a 6-month period during the study, seven runway incursions occurred at ORD where the proposed signage and markings were installed. It is unclear to what degree the proposed signage and markings played as a contributing factor in the incursions that occurred during the study. These incursions all occurred in the RWY 9R approach hold area, which is located over 2000 feet from its associated runway threshold. This is a location many individuals may not expect to see a hold position, particularly those unfamiliar with the airport; therefore, the taxiway geometry played a contributing factor for these events. One runway incursion event was due to controller error, and one was due to the crew of one aircraft mistaking a call sign of another aircraft for its own call sign. The remaining five runway incursion events consisted of individuals failing to hold short of the approach after being instructed by ATC. One

of these five deviations involved a mechanic taxiing an aircraft, and the remaining four were aircraft operator deviations.

6.3 EFFECTS ON AIRPORT OPERATORS.

The effects observed for airport operators varied. The long-term energy and maintenance costs for signs are projected to be proportional to the size of the proposed signs installed. Thus, the Concept 3 and 4 signs would have costs approximately twice those of current approach hold signage, and Concept 2 signage would cost approximately 25% more than current signage. Concept 3 signage are expected to require less time to replace than Concept 4 signage since the units are smaller and more easily maneuvered by maintenance personnel. In addition, the likelihood that damage from a ground vehicle or aircraft collision would likely only affect one of the three-panel sign units rather than an entire six-panel sign unit.

Installation costs also depended on the sign concept installed and each airport's terrain and space constraints. The Concept 3 and 4 signage installed at ORD required lengthening all concrete sign pads. The Concept 4 signage installation required additional manpower and equipment compared to the Concept 3 signage. This was due to the Concept 4 signage consisting of a single six-module unit compared to the Concept 3 signage, which consisted of two, three-module units which could be moved individually. The Concept 2 signage at CLE had the least impact on the airport operator since each of the signs already had an adequate number of modules, requiring only the sign panels to be replaced.

Although BNA also had Concept 2 signage installed, two concrete sign bases needed to be expanded approximately 4 feet to accommodate additional modules. At BNA, there were steep drainage ditches adjacent to current APCH signage. These ditches required an erosion control plan to be drafted and implemented to extend these sign bases, which included earthwork, installation of soil-retaining fences, and extensive sodding. Alternative sign designs were evaluated with reduced-size legend text. However, using these signs is not recommended due to aircraft operator and ground vehicle operator feedback indicating these were difficult to understand.

At airports where space constraints prevent the approach and departure runways to be displayed simultaneously, repositioning other signage around the approach signage may be necessary. Airport signage companies are currently testing full-color, addressable signage capable of dynamic changes to legend text. Addressable signage may offer a viable alternative for airports that are not able to install the proposed approach hold signage. For instance, an addressable sign could display "15 - APCH" when Runway 15 is active and "33 - DEP" when Runway 33 becomes the active runway.

7. RECOMMENDATIONS.

Based on the results of this research effort, it is suggested that the Concept 3 signage and Pattern B marking proposed by the Approach Hold Workgroup be adopted in accordance with the recommendations outlined in sections 7.1 through 7.3.

7.1 SIGN SPECIFICATIONS.

It is recommended that the signage be installed in a Concept 3 configuration as two, three-panel sign units with standard-sized legend text, as shown in figure 46, to ensure adequate frangibility. It is also recommended that the spacing between these signs remain between 3 and 12 inches, as specified in AC 150/5345-44J [12]. It is further recommended that the signage legend correspond with the operations for which the associated runway is used. For instance, for a runway used exclusively for departing traffic, it is recommended that associated holding positions only include the runway and the legend text DEP. Likewise, for a runway only used for landing traffic, it is recommended that the associated runway remain with only the APCH text currently used. Concept 1 and 2 signage is not recommended due to feedback, which indicates these lowered situational awareness and legibility.

Figure 46. Concept 3 Signage Configuration Example

For consistency with existing standards for holding position signage used at runway intersections, it is recommended that the approach and departure elements of the signage be arranged according to the orientation of their associated runways. For instance, as shown in figure 47, the APCH and DEP were reversed when placed on the opposite side of the runway protected areas. During the evaluations at the Technical Center, this increased situational awareness.

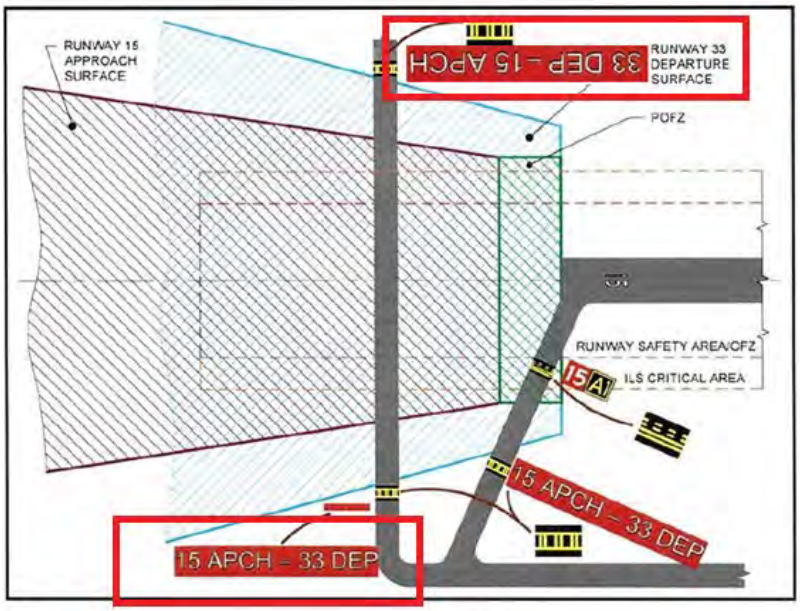


Figure 47. Proposed Signage Orientation Example

7.2 SURFACE MARKING.

It is recommended that the Pattern B marking be made standard for runway approach holding positions. These markings should be painted in accordance with the current version of AC 150/5340-1.

7.3 EDUCATION AND GUIDANCE.

Because a large segment of aircraft and ground vehicle operators remain unaware of the holding position requirements despite the signage and marking changes, it is advised that extensive pilot and airport vehicle operator education and guidance be conducted prior to the proposed changes going into effect.

To further improve situational awareness, it is also recommended that official FAA airport diagrams include approach/departure holding positions at locations with recurring runway incursions, such as the example at Lincoln Airport (LNK) shown at HS 2 in figure 48. This practice is currently not standard, and few airports provide this information.

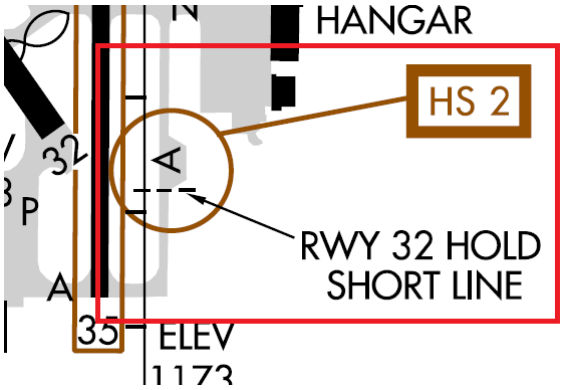


Figure 48. The 32-APCH Holding Indication at LNK

This practice would provide pilots with advance notice of a holding position at an unexpected location. At some airports, the airport diagram provides specific instructions to aircraft, as shown in the red box in figure 49. This airport diagram for Boston Logan International Airport (BOS) contains the message, "All Aircraft Hold Here (4L-APCH)." It is advised that coordination take place at such airports before visual cues are modified to avoid conflict with ATC procedures.

Figure 49. Airport Diagram 4L-APCH Indication at BOS

By implementing the recommendations outlined in sections 7.1 through 7.3, it is expected that safety will be increased at airports with runway approach holding position areas compared to current signage and markings.

8. REFERENCES.

1. Federal Aviation Administration, Advisory Circular 150/5340-18F, Standards for Airport Sign Systems, August 16, 2010.

2. Federal Aviation Administration, Advisory Circular 150/5340-1L, Standards for Airport Markings, September 27, 2013.

3. International Civil Aviation Organization, Annex 14 to the Convention on International Civil Aviation: Volume 1 Aerodrome Design and Operations, 6th Edition, July 2013.

4. Federal Aviation Administration, Approach Hold Document Change Proposal Safety Risk Management Document Version 0.2, January 10, 2013.

5. Federal Aviation Administration, Aeronautical Information Manual, April 4, 2014.

6. Federal Aviation Administration, Runway Safety Operations Field Group, Tucson International Airport (TUS) Hot Spot Information, October 2010, available at https://www.faasafety.gov/files/notices/2009/Oct/TUS_FAASTeam_.pdf, date last visited 1/8/16.

7. National Aeronautics and Space Administration, Aviation Safety Reporting System, Report 582225, available at http://asrs.arc.nasa.gov/search/database.html, date last visited 1/8/16.

8. National Aeronautics and Space Administration, Aviation Safety Reporting System, Report 1104550, available at http://asrs.arc.nasa.gov/search/database.html, date last visited 1/8/16.

9. Federal Aviation Administration, FAA Job Order 7210.3Z, "Facility Operation and Administration," November 10, 2015.

10. Federal Aviation Administration, Job Order 7110.65W, "Air Traffic Control," October 27, 2015.

11. Federal Aviation Administration, Approach Hold Document Change Proposal Safety Risk Management Document Version 1.2, September 27, 2013.

12. Federal Aviation Administration, Advisory Circular 150/5345-44J, "Specifications for Runway and Taxiway Signs," September 29, 2010.

13. Federal Aviation Administration Memorandum, Chicago O'Hare International Airport, IL, Runway 32L RSA Signage and Marking-Modification of Standard (MOS) Request, Aeronautical Research effort No. 2010-AGL-973-NRA, August 4, 2010.

14. Chicago Department of Aviation Modifications to Standards for Runway Safety Area Signage and Marking letter dated May 27, 2011.

15. Federal Aviation Administration Memorandum, Cleveland Hopkins International Airport (CLE), OH, Holding Position Signs and Markings on Runway 10-28 Modification of Standard (MOS) Amendment Request dated May 24, 2012.

16. Air Traffic Control Standard Operating Procedures Manual, Cleveland Hopkins International Airport, document CLE 7110.65K, page 2-2-5.

17. Schilling, David, "FAA Sign Pad Extensions Grading Plan: Nashville International Airport," Atkins Global, September 26, 2014.

APPENDIX A—APPROACH HOLD SIGNAGE AND RUNWAY SAFETY AREA EVALUATION

This appendix shows the form that the subjects completed for each approach hold signage and runway safety area evaluation.

Name:	Date and Time:	Weather:

After each evaluation, complete the following questions.

Run #__

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1. As you are proceeding towards the sign, please indicate when the background and legend colors are discernible.					
2. At a close distance the information can be viewed easily.	**1**	**2**	**3**	**4**	**5**
3. It was easy to interpret.	**1**	**2**	**3**	**4**	**5**

a. What is your interpretation of the sign?

APPENDIX B—COCKPIT SIMULATION SIGN PHOTOGRAPHS

Figures B-1 through B-24 are photographs of runway (RWY) and taxiway (TWY) signs used in the cockpit simulation method of evaluations.

Figure B-1. Standard Sign With Only Approach RWY: RWY 27R Facing Westbound, Day

Figure B-2. Standard Sign With Only Approach RWY: RWY 27R Facing Westbound, Night

Figure B-3. Standard Sign With Only Approach RWY: TWY T, North of TWY Z Intersection, Day

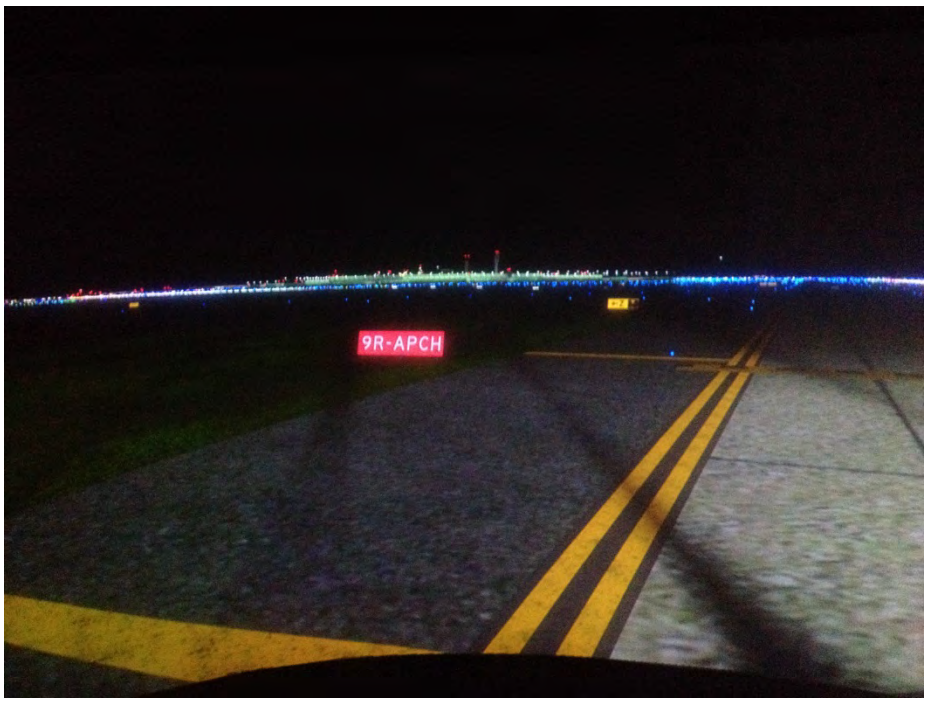


Figure B-4. Standard Sign With Only Approach RWY: TWY T, North of TWY Z Intersection, Night

Figure B-5. Standard Sign With Only Approach RWY: TWY T, South of TWY W Intersection, Day

Figure B-6. Standard Sign With Only Approach RWY: TWY T, South of TWY W Intersection, Night

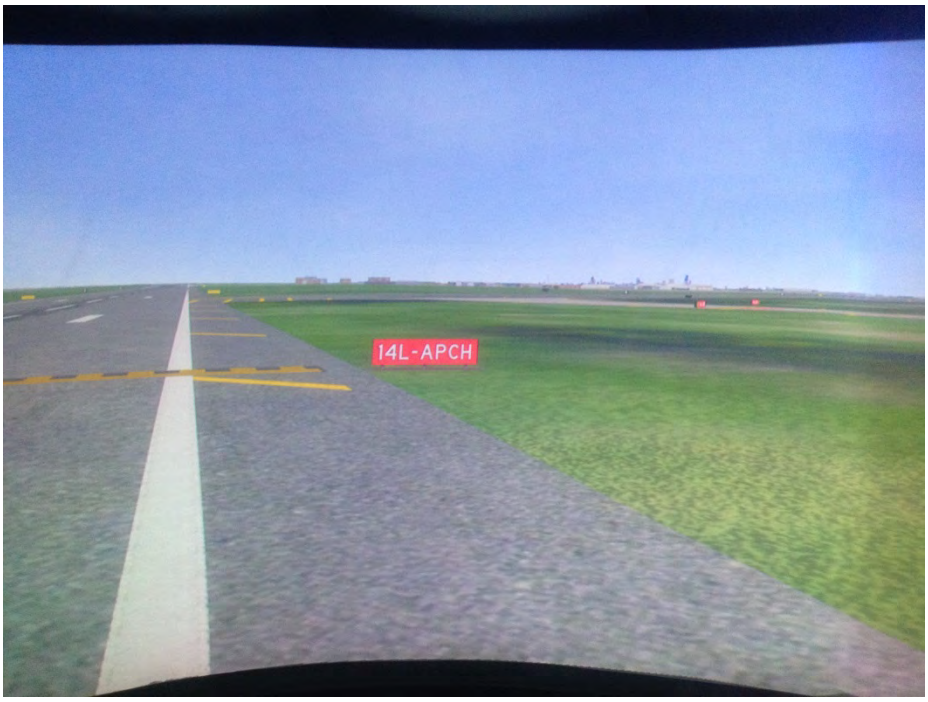


Figure B-7. Standard Sign With Only Approach RWY: RWY 9L, Facing Eastbound, Day

Figure B-8. Standard Sign With Only Approach RWY: RWY 9L, Facing Eastbound, Night

Figure B-9. Concept 4 Sign: RWY 27R Facing Westbound, Day

Figure B-10. Concept 4 Sign: RWY 27R Facing Westbound, Night

Figure B-11. Concept 4 Sign: TWY T, South of TWY Z, Day

Figure B-12. Concept 4 Sign: TWY T, South of TWY Z, Night

Figure B-13. Concept 1 Sign: TWY T, South of TWY W, Day

Figure B-14. Concept 1 Sign: TWY T, South of TWY W, Night

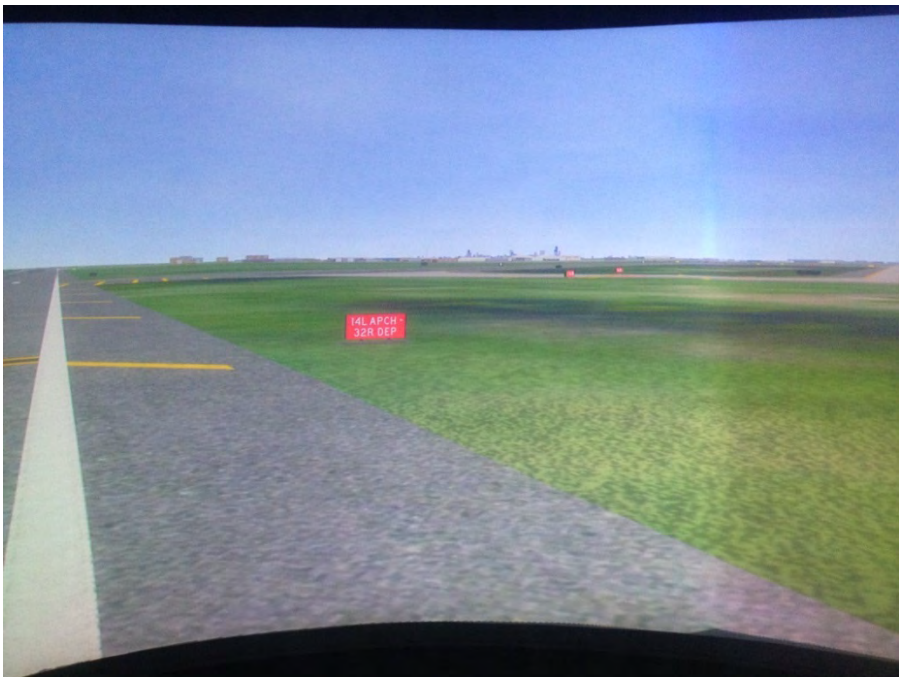


Figure B-15. Concept 1 Sign: RWY 9L, Facing Eastbound, Day

Figure B-16. Concept 1 Sign: RWY 9L, Facing Eastbound, Night

Figure B-17. Concept 2 Sign: RWY 27R, Facing Westbound, Day

Figure B-18. Concept 2 Sign: RWY 27R, Facing Westbound, Night

Figure B-19. Concept 2 Sign: TWY T, South of TWY Z, Day

Figure B-20. Concept 2 Sign: TWY T, South of TWY Z, Night

Figure B-21. Concept 2 Sign: TWY T South of TWY W, Day

Figure B-22. Concept 2 Sign: TWY T South of TWY W, Night

Figure B-23. Concept 2 Sign: RWY 9L, Facing Eastbound, Day

Figure B-24. Concept 2 Sign: RWY 9L, Facing Eastbound, Night

APPENDIX C—COCKPIT SIMULATION SUBJECT SURVEYS

This appendix shows the survey the subjects completed for each cockpit simulation evaluation.

Evaluation 1 **Time (Circle One): Day / Night**

As you proceed towards the signs, press the red button when the signs become readable.

Complete at the conclusion of Evaluation 1a:

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1. The text on the signs was distinguishable from the background.					
2. The surface markings adjacent to the signs on Runway 27R expressed the same message (or idea) with the signs.	1	2	3	4	5
3. a. The meaning of the signs and surface markings was understandable.	1	2	3	4	5
b. The signs and surface markings were logically consistent with the instructions provided by ATC.	1	2	3	4	5
c. The visual cues were understandable early enough to identify the location of the holding position.	1	2	3	4	5

Complete at the conclusion of Evaluation 1b:

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
4. The surface markings adjacent to the signs on Taxiway T expressed the same message with the signs.	1	2	3	4	5
5. The amount of information on the signs was clear and understandable.	1	2	3	4	5

6. Please list any further comments regarding the signs and surface markings you have viewed.

Evaluation 2 **Time (Circle One): Day / Night**

As you proceed towards the signs, press the red button when the signs become readable.

Complete at the conclusion of Evaluation 2a:

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1. The text on the signs was distinguishable from the background.					
2. The surface markings adjacent to the signs on TWY T expressed the same message (or idea) with the signs.	1	2	3	4	5
3. a. The meaning of the signs and surface markings was understandable.	1	2	3	4	5
b. The signs and surface markings were logically consistent with the instructions provided by ATC.	1	2	3	4	5
c. The visual cues were understandable early enough to identify the location of the holding position.	1	2	3	4	5

Complete at the conclusion of Evaluation 2b:

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
4. The surface markings adjacent to the signs on TWY T expressed the same message with the signs.	1	2	3	4	5
5. The amount of information on the signs was clear and understandable.	1	2	3	4	5

6. Please list any further comments regarding the signs and surface markings you have viewed.

Evaluation 3 **Time (Circle One): Day / Night**

As you proceed towards the signs, press the red button when the signs become readable.

Complete at the conclusion of Evaluation 3a:

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1. The text on the signs is distinguishable from the background.	1	2	3	4	5
2. The surface markings adjacent to the signs on RWY 27R expressed the same message (or idea) with the signs.	1	2	3	4	5
3. a. The message conveyed by this combination of surface markings and signs was understandable.	1	2	3	4	5
b The signs and surface markings are logically consistent with the instructions provided by ATC.	1	2	3	4	5
c. The visual cues were understandable early enough to identify the location of the holding position.	1	2	3	4	5

Complete at the conclusion of Evaluation 3b:

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
4. The surface markings adjacent to the signs on TWY T expressed the same message with the signs.	1	2	3	4	5
5. The amount of information on the signs was clear and understandable.	1	2	3	4	5

6. Please list any further comments regarding the signs and surface markings you have viewed.

Evaluation 4 **Time (Circle One): Day / Night**

As you proceed towards the signs, press the red button when the signs become readable.

Complete at the conclusion of Evaluation 4a:	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1. The text on the signs is distinguishable from the background.	1	2	3	4	5
2. The surface markings adjacent to the signs on TWY T expressed the same message (or idea) with the signs.	1	2	3	4	5
3. a. The message conveyed by this combination of surface markings and signs was understandable.	1	2	3	4	5
b. The signs and surface markings are logically consistent with the instructions provided by ATC.	1	2	3	4	5
c. The visual cues were understandable early enough to identify the location of the holding position.	1	2	3	4	5

Complete at the conclusion of Evaluation 4b:	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
4. The surface markings adjacent to the signs on RWY 9L expressed the same message with the signs.	1	2	3	4	5
5. The amount of information on the signs was clear and understandable.	1	2	3	4	5

6. Please list any further comments regarding the signs and surface markings you have viewed.

Evaluation 5 **Time (Circle One): Day / Night**

As you proceed towards the signs, press the red button when the signs become readable.

Complete at the conclusion of Evaluation 5a:

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1. The text on the signs is distinguishable from the background.	1	2	3	4	5
2. The surface markings adjacent to the signs on RWY 27R expressed the same message (or idea) with the signs.	1	2	3	4	5
3. a. The message conveyed by this combination of surface markings and signs was understandable.	1	2	3	4	5
b. The signs and surface markings are logically consistent with the instructions provided by ATC.	1	2	3	4	5
c. The visual cues were understandable early enough to identify the location of the holding position.	1	2	3	4	5

Complete at the conclusion of Evaluation 5b:

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
4. The surface markings adjacent to the signs on TWY T expressed the same message with the signs.	1	2	3	4	5
5. The amount of information on the signs was clear and understandable.	1	2	3	4	5

6. Please list any further comments regarding the signs and surface markings you have viewed.

Evaluation 6 **Time (Circle One): Day / Night**

As you proceed towards the signs, press the red button when the signs become readable.

Complete at the conclusion of Evaluation 6a.

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
1. The text on the signs is distinguishable from the background.	1	2	3	4	5
2. The surface markings adjacent to the signs on TWY T expressed the same message (or idea) with the signs.	1	2	3	4	5
3. a. The message conveyed by this combination of surface markings and signs was understandable.	1	2	3	4	5
b. The signs and surface markings are logically consistent with the instructions provided by ATC.	1	2	3	4	5
c. The visual cues were understandable early enough to identify the location of the holding position.	1	2	3	4	5

Complete at the conclusion of Evaluation 6b:

(Note: This section continues on next page)

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
4. The surface markings adjacent to the signs on RWY 9L expressed the same message with the signs.	1	2	3	4	5
5. The amount of information on the signs was clear and understandable.	1	2	3	4	5

6. Please list any further comments regarding the signs and surface markings you have viewed.

	Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
7. Having the departure runway included on the signs improves situational awareness (refer to figures C-1, C-2, and C-3 for comparison).	1	2	3	4	5
8. a. Arranging text in the way shown on the handout sheet in figure C-3 would affect situational awareness.	1	2	3	4	5

b. Why, or why not?

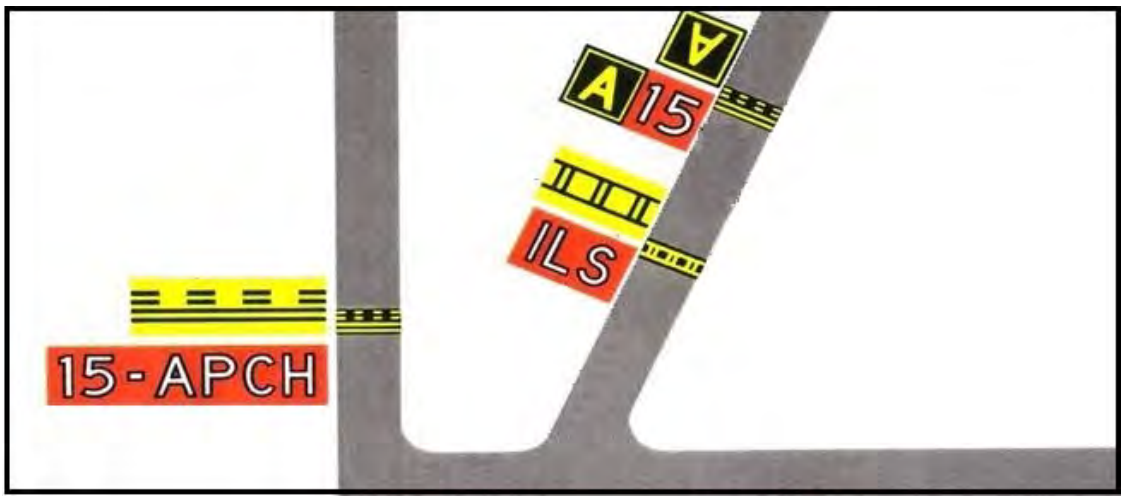


Figure C-1. Current Signs and Surface Markings

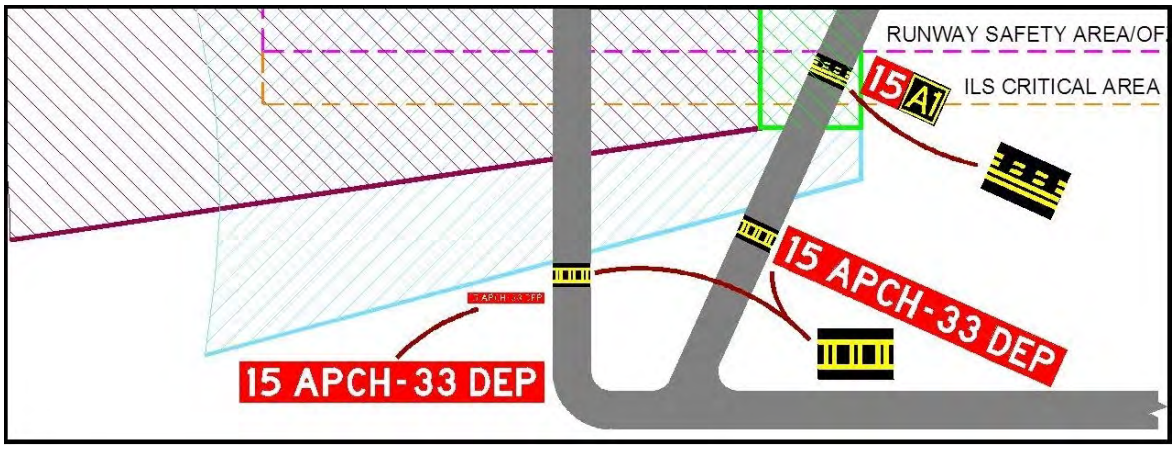


Figure C-2. Proposed Signs and Surface Markings

Figure C-3. Stacked Runway Safety Area/Approach Hold Signage

APPENDIX D—CHICAGO O'HARE INTERNATIONAL AIRPORT PILOT RESPONSES

Pilot 1 and 2 responses to the Chicago O'Hare International Airport (ORD) pilot questions are presented below.

1. Are you familiar with the location of the Runway Hold Position marking and signage on the airfield at Chicago O'Hare International Airport? How are they delineated?

   Pilot #1: *Yes, by the hold short markings and signs*
   Pilot #2: *Same*

2. How were you first made aware of the Runway Hold Position marking and signage at ORD?
   Pilot #1: *I know about them because I'm in touch with the airport. Most people don't know why it's there. The line on 4R, people commented, "What's that?"*
   Pilot #2: *No, I've actually never noticed it and I land 27R a lot. At some point our company gave us a card for signage and markings.*

3. During your briefing, do you discuss the Runway Hold Position marking and signage locations on the airfield prior to taxing on the airfield at ORD?
   Pilot #1: *No, there's too many other thing that affect you. And it's not part of a Jep chart. ILS sign and ILS marking guidance are different.*
   Pilot #2: *no, it's just assumed you know what you're doing.*

4. At ORD you are taxing down Runway 9L and approach this sign and marking (show printout of runway hold position sign and marking 32R-14L). What does this mean to you?
   Pilot #1: *It all depends on what ATC tells you to do. We're really going too fast to pay attention, but if you're taxing to the end of the runway, then you should be given a hold short by ATC. If I were taxiway and told to hold short, I would know where to stop because of the marking.*
   Pilot #2: *It really depends. If landing 27R and no LASO and cleared to land, then that runway is mine.*

5. At ORD you are on Taxiway T heading SE, and approach this sign and marking (show printout of approach hold sign and runway hold position marking 9R-APCH). What does this mean to you?
   Pilot #1: *Confusion. I've done that many times and he's given me clearance to a point further on, then I don't stop. If ATC tells us to hold*
   Pilot #2: *I see them, but no one stops for anything (especially in ORD). I wouldn't do that at another airport, but here I would.*

6. What is the difference between the two signs?
   Pilots #1 and 2:
   32R-14L – if I'm taxing I'll stop. I'm not at the end of the runway, more of intersection
   9R-APCH – tells you you're coming up on the approach of a runway.

7. Do either of them create any confusion for you when operating on the airfield?
   Pilot #1: *it's when you have conflicting information is when you are confused. When you have an APCH sign corresponding and a runway hold line and no runway there, it's conflicting signals. Just go with what ATC tells you.*
   Pilot #2: *yes. But I carry a level of awareness and pay attention to ATC*

   Pilots #1 and 2:
   New proposed sign – long text is better than stacked (both pilots). Using the ladder would alleviate confusion to some extent.
   Pilot #2: *line painted. We look for reason to cross the line, but if we don't understand it does lead to confusion.*

APPENDIX E—CHICAGO O'HARE INTERNATIONAL AIRPORT PILOT RESPONSES TO REVISED QUESTIONS

Pilot 3 through 9 responses to the Chicago O'Hare International Airport (ORD) revised pilot questions are presented below.

Chicago O'Hare International Airport (ORD)
Pilot Questions **Revised** (Pilot #3-9)

1. At ORD you are taxing down Runway 9L and approach this sign and marking (show printout of runway hold position sign and marking 32R-14L).
   What does this mean to you?
   Pilot # 3: *The RSA for 32R-14L*
   Pilot # 4-5*: I'm getting ready to cross 32r-14r and I need to stop. Approaching runway in front of you and if you keep going you cross it. (x2)*
   Pilot # 6*: runway 32R going that way, 14L going that way, but would not tell me if that's the end of the runway.*
   Pilot # 7: *I was crossing an active runway, but really it's the approach*
   Pilot # 8: *if I was taxing I would hold short and get clearance*

2. Does this sign create any confusion for you?
   Pilot # 3: *Yes, I would be confused if this marking stretched across the runway.*
   Pilot # 4: *At times yes, because when you see a sign like that it means runway ahead.*
   Pilot # 5: *For us we don't do anything, because if we're landing were cleared – more for vehicles***.**
   Pilot # 6: *you need to stop. I wonder if that's the end of the runway?*
   Pilot # 7: *with diagram no, without diagram yes*
   Pilot # 8: *it's confusing because you're at the end of the runway yet both runways are on the sign. Even through there's pavement there, I know they don't intersect.*

3. At ORD you are on Taxiway T heading SE, and approach this sign and marking (show printout of approach hold sign and runway hold position marking 9R-APCH). What does this mean to you?
   Pilot # 3: *ILS APCH hold line for 9R. If ATC didn't say anything, then we just keep going. I'm not concerned with crossing this and going onto a runway.*
   Pilot # 5: *coming up to protected hold short area and would stop if ATC said so*
   Pilot # 6: *about to cross the end of the runway, but in ORD I know that I can go through it (unless evaluating ILS's), but any other airport I would stop.*
   Pilot # 7: *crossing the 9R APCH*
   Pilot # 8: *hold short, but only if instructed*
   Pilot # 9: *APCH end, hold short.*

4. Does this sign create any confusion for you?
   Pilot # 3: *No*
   Pilot # 4: *Yes, in the heat of the battle, checklist, if you don't see it ahead of time. If you see in passing you think you missed something.*

Pilot # 6: *when I first come here it did because other airports we stop at this sign/marking.*
Pilot # 7: *no*
Pilot # 8: *marking says hold short yet sign is APCH. Remove the DASH on the sign. I equate this sign with an ILS line.*
Pilot # 9: *marking is conflicting with sign. Because we know the area I know I'm approaching the corridor for 9R APCH. If you're not familiar you may not know.*

5. From a pilot's point of view, what is the difference between the two signs?
Pilot # 3: *One is for a RSA and one is for APCH.*
Pilot # 5: *One is a runway, one is protected airspace you're taxiing. Pavement vs.air (x2). We weren't thinking of protecting the 27L Departure surface.*
Pilot # 6: *One is crossing APCH end (end of runway), other sign is for in the middle of runway (intersection).*
Pilot # 7: *Actual runway (concrete) and APCH end.*
Pilot # 8: *this is a taxiway meeting runway intersection and protected airspace corridor, not actual runway***.**

APPENDIX F—CHICAGO O'HARE INTERNATIONAL AIRPORT GROUND VEHICLE OPERATOR RESPONSES

Vehicle Operator 1 and 2 responses to the Chicago O'Hare International Airport (ORD) airfield vehicle operators questions are presented below.

1. Are you familiar with the locations of the Runway Hold Position marking and signage in areas where an RSA intersects with a runway? How are they delineated?
   Vehicle Operator #1: *yes, sign and marking*
   Vehicle Operator #2: *yes, sign and marking*

2. In your opinion, is this marking and sign adequate to mark the Runway Safety Area (RSA)?
   Vehicle Operator #1: *Yes, we treat it the same way as a mandatory hold sign. I prefer the hold position sign/marking.*
   Vehicle Operator #2: *Yes*

3. Is this marking/sign confusing? If so, why? (show printout of runway hold position sign and marking 32R-14L)
   Vehicle Operator #1: *No, that's not confusing at all. The only confusing part was getting used to what we needed to say to the tower. Once we established the phraseology, it was easy. Not to say "cross", say "drive through"*
   Vehicle Operator #2: *No*

4. How were you first made aware of the Runway Hold Position marking and signage?
   Vehicle Operator #1: *Emails, maps, everything. Training, plus we're outside all the time and got used to it.*
   Vehicle Operator #2: *Email, contractor training facility, went out and saw them, put on training maps.*

5. Prior to the airport installing the Runway Hold Position marking and signage in these areas, how did you know where to stop when ATC instructed you to hold short of the intersecting APCH/RSA area?
   Vehicle Operator #1: *Just kinda visualized where it would be. 14R, when that was longer, we always had some type of marking.*
   Vehicle Operator #2: *Guestimate, after being here for a while you just learn where to stop. The further back the better.*

6. What does this sign mean to you? (APCH)
   Vehicle Operator #1: *You just know that you're at an APCH, but as a driver we don't stop for it. I may look if they're landing 9R.*
   Vehicle Operator #2: *Approach hold for aircraft*

7. In your opinion, is this marking and sign adequate to mark the Approach Hold?
   Vehicle Operator #1: *Yes, it's adequate.*

Vehicle Operator #2: *Yes, but it's confusing because there's a service road beyond the approach area.*

8. Are there any special movement area procedures in place when operating in these areas? If so, please explain.
   Vehicle Operator #1: *For the runways, just crossing through the RSA.*
   Vehicle Operator #2: *APCH – in low visibility we're extra cautious in that area.*

APPENDIX G—CHICAGO O'HARE INTERNATIONAL AIRPORT GROUND VEHICLE OPERATOR RESPONSES TO REVISED QUESTIONS

Vehicle Operator 3 through 14 responses to the Chicago O'Hare International Airport (ORD) airfield vehicle operators revised questions are presented below.

1. Are you familiar with the locations of the Runway Hold Position marking and signage in areas where an RSA intersects with a runway? How are they delineated?
   Vehicle Operators #3-11: *Yes*
   Vehicle Operator #12: *Yes, mandatory hold line and signage.*
   Vehicle Operators #13: *Yes*
   Vehicle Operators #14: *Yes*

2. In your opinion, is this marking and sign adequate to mark the Approach Hold/Runway Safety Area (RSA)? If no, why?
   Vehicle Operator #3: *APCH is a little trickier – more of an ILS situation. Sometimes the tower will hold us at Z rather than up at the 9R APCH sign/marking. Worst about this sign (9R APCH) is teaching people about them.*
   Vehicle Operator #4: *RSA sign is very adequate for us. When cutting grass we won't cross the hold bars and signs. APCH sign is more for pilots. On T, pilots will get told to hold short on T at 9R APCH. Ground vehicles are lower.*
   Vehicle Operators #5-11: *yes*
   Vehicle Operator #12: *Yes, currently. I think it should say "RSA" because ATC should say hold short of the RSA. Pilots don't need to know what it is, it's not for them. But everyone knows you have to stop at that sign.*
   Vehicle Operators #13: *Yes, because that's what we're used to. If mins, then we'll put out notices to stay out of APCH.*
   Vehicle Operators #14: *9R-APCH most people aren't going to hold there. Only for Aircraft, drivers at ORD don't have to talk to ATC. But on the runways, we're used to it and it has been effective and adequate.*

3. Is this marking/sign confusing? If so, why? (show printout of runway hold position sign and marking 32R-14L)
   Vehicle Operator #3: *No*
   Vehicle Operator #4: *No*
   Vehicle Operators #5-11: *No, not all. Everyone knows what it is. We know it's not a runway because there's no lights.*
   Vehicle Operator #12: *No, personally. Everyone knows what this sign mean. You need to stop.*
   Vehicle Operators #13: *No, because we're all familiar with it. ATC had a lot of issues, because we went so long without it and they don't know RSA.*
   Vehicle Operators #14: *No, to drivers, not at all.*

4. How were you first made aware of the Runway Hold Position marking and signage?
   Vehicle Operators #3-4: *We currently make a new employee work all 3 shifts, written test, practical driver.*

Vehicle Operators #5-11: *Training, maps, retest every year, memos and take it upon yourself to familiarize.*
Vehicle Operator #12: *Probably by an airfield driver briefing. And every year in the recurrent training.*
Vehicle Operators #13*: We pushed for it because we weren't following rules, causing runway incursions. We needed something to delineate the RSA, then the information was disseminated. We call across the RSA no matter what configuration.*
Vehicle Operators #14: *Emails, bulletins, from management.*

5. Prior to the airport installing the Runway Hold Position marking and signage in these areas, how did you know where to stop when ATC instructed you to hold short of the intersecting APCH/RSA area?
Vehicle Operators #3-11: *We just guessed, used RDR signs. 3000' or 5000' marker, so you'd be outside the 22L we're able to judge, used S5. Used the APCH to call ahead of time. Something was put out so we knew where the RSA was.*
Vehicle Operator #12: *Just kind of took a guess, but gave yourself plenty of room. Or ATC would clear you up to an intersection and tell you to hold***.**
Vehicle Operators #13: *Originally, they never did tell us, but after that it was just a guess. We used the 3,000' marker. Used other things for reference back when the 2 runways intersected.*
Vehicle Operators #14: *If you were cleared on the runway, then you were cleared full length 22L. Unlit signs, reflective as a temporary solution.*

6. Are there any special movement area procedures in place when operating in these areas? If so, please explain.
Vehicle Operator #3: *Yes, we have to call to cross the RSA. If we're working in the RSA, we'll get permission for longer times. We treat it just as if we were working in the intersection of two runways.*
Vehicle Operators 4-11: *APCH signs don't affect us. We've never had any issues with them.*
Vehicle Operator #12: *Yes, they're just treated as a normal runway hold position.*
Vehicle Operators #13: *Yes you have to call to proceed through the RSA.*
Vehicle Operators #14: *You have to have permission to be in there longer than for a crossing. Call tower, just ask for clearance. No difference. You treat it as if it's intersecting pavement.*

APPENDIX H—CHICAGO O'HARE INTERNATIONAL AIRPORT AIRCRAFT AND GROUND VEHICLE OPERATOR SURVEY

The Chicago O'Hare International Airport pilot and vehicle operator survey is presented below.

The Federal Aviation Administration (FAA) is currently conducting research to improve the signage and marking related to approach, departure, and other critical surfaces. Your feedback will help address inconsistencies at locations where runways or taxiways intersect the protected areas of other runways.

Any questions or comments can be directed to: Garrison Canter, Airport Operations Research Analyst, SRA International, 1201 New Road, Suite 242, Linwood, NJ 08221, (609) 601-6800 x117, Garrison_Canter@sra.com.

1. Have you taken this survey previously?

(Individuals who have taken the survey before but have observed the signage and marking described in the survey since that time may provide additional feedback by selecting "Yes")

- ◯ No
- ◯ Yes

Figure 1

Not to Scale

2. If positioned together at a location which did not lead to a runway entrance, the meaning of the sign and surface marking pictured in figure 1 would be understandable.

Strongly Disagree ◯ Disagree ◯ Undecided ◯ Agree ◯ Strongly Agree ◯

3. What do the sign and surface marking shown in figure 1 mean to you when located together?

4. The sign and surface marking pictured in figure 1 are suitable for use on a runway.

Strongly Disagree ◯ Disagree ◯ Undecided ◯ Agree ◯ Strongly Agree ◯

5. To proceed past the sign and surface marking shown in figure 1, explicit permission from air traffic control would be needed.

Strongly Disagree ◯ Disagree ◯ Undecided ◯ Agree ◯ Strongly Agree ◯

6. The sign shown in figure 1 contains an appropriate quantity of information.

Strongly Disagree ◯ Disagree ◯ Undecided ◯ Agree ◯ Strongly Agree ◯

7. Why, or why not, is the quantity of information on the sign in figure 1 appropriate?

Figure 2

Not to Scale

8. If positioned together at a location which did not lead to a runway entrance, the meaning of the sign and surface marking pictured in figure 2 would be understandable.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

9. What do the sign and surface marking shown in figure 2 mean to you when located together?

10. The sign and surface marking pictured in figure 2 are suitable for use on a runway.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

11. To proceed past the sign and surface marking shown in figure 2, explicit permission from air traffic control would be needed.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

12. The sign shown in figure 2 contains an appropriate quantity of information.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

13. Why, or why not, is the quantity of information on the sign in figure 2 appropriate?

Figure 3

Not to Scale

14. If positioned together at a location which did not lead to a runway entrance, the meaning of the sign and surface marking pictured in figure 3 would be understandable.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

15. What do the sign and surface marking shown in figure 3 mean to you when located together?

16. The sign and surface marking pictured in figure 3 are suitable for use on a runway.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

17. To proceed past the sign and surface marking shown in figure 3, explicit permission from air traffic control would be needed.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

18. The sign shown in figure 3 contains an appropriate quantity of information.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

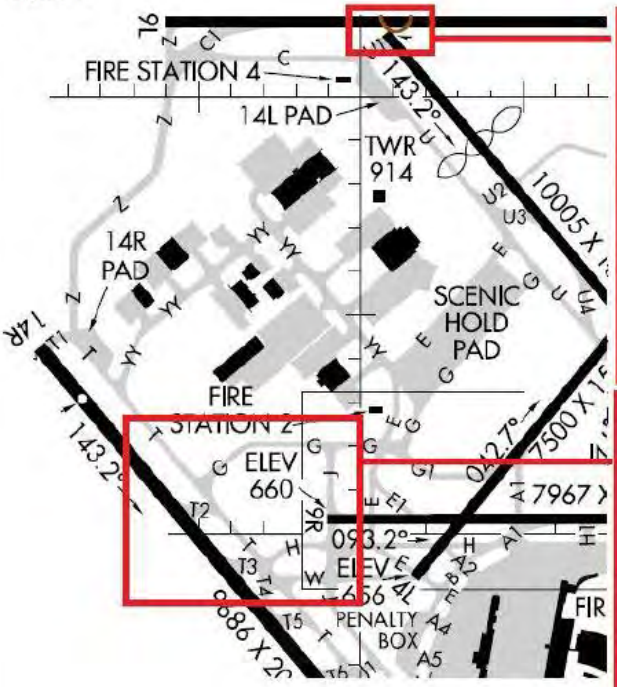
19. Why, or why not, is the quantity of information on the sign appropriate?

20. Did you observe new signage on RWY 9L-27R, RWY 14R-32L, TWY G, or TWY T at one of the locations shown in figure 4? (Click "Next" at the bottom of the page to continue)

◯ Yes

◯ No

Figure 4


FIRE STATION 4
14L PAD
TWR
914
14R
PAD
SCENIC
HOLD
PAD
FIRE
STATION 2
ELEV
660
PENALTY
BOX
143.2°
093.2°
10005 X
7500 X
7967 X
686 X


14L APCH - 32R DEP
32R DEP - 14L APCH


27L DEP - 9R APCH
27L DEP - 9R APCH
9R APCH - 27L DEP

21. Which location(s) did you view the signs and surface marking depicted in figure 4? (Select all that apply)

- ☐ TWY T
- ☐ TWY G
- ☐ RWY 27R
- ☐ RWY 9L
- ☐ RWY 14R
- ☐ RWY 32L

22. Were you instructed by ATC to hold short at the location(s) you observed the sign(s) depicted in figure 4?

- ◯ Yes
- ◯ No

23. Seeing the departure runway on the sign(s) increased your situational awareness.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

24. The visual cues were understandable early enough to identify the location of the holding position.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

25. The sign(s) and surface marking(s) were logically consistent with the instructions provided by ATC.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

26. The surface marking adjacent to the sign(s) expressed the same message with the sign(s).

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

27. Please provide any further comments or concerns you may have regarding any aspect of the APCH/DEP signage and/or accompanying surface marking(s) you have viewed. (For example: regarding workload, situational awareness, ATC instructions, etc.)

APPENDIX I—CLEVELAND HOPKINS INTERNATIONAL AIRPORT PILOT RESPONSES

Pilot responses to the Cleveland Hopkins International Airport (CLE) pilot questions are presented below.

Signage/marking on RWY 10-28:
More used by commuter pilots. Never departed off 10, more used as a taxiway waiting to line up for 24L (when pavement was connected). These don't apply to pilots, just for vehicle drivers.

Signage/Marking confusing to pilots?
A little confusing because the sign indicates pavement. It makes more sense to have APCH-DEP sign since pavement is uncoupled.

Does the 15-Apch with runway hold marking present confusion to pilot?
The hold short line is supreme, so when we see the hold short line, we want to stop. Having opposite end 33dep on sign would be confusing. Having one or both isn't really an issue. When we used 28 as a taxiway there was a taxiway after U to make the turn and hold. Our pilots would feel uncomfortable taxing on a runway. Couple wrong runway takeoffs. But we don't use 10-28 as a taxiway anymore.

(Runway guard lights really get my attention, elevated are especially useful in snow conditions. Illuminate the runway guard or ILS lights when those protected areas are in use. Should be required in more areas.)

APPENDIX J—CLEVELAND HOPKINS INTERNATIONAL AIRPORT AIR TRAFFIC CONTROL RESPONSES

Air traffic control (ATC) responses to the Cleveland Hopkins International Airport (CLE) ATC questions are presented below.

1. As a controller are you aware of the protected surfaces around a runway such as ILS Critical Areas and Runway Safety Areas?
   Yes, We have ILS critical areas, on P North side, S of Twy G.
   We have a SOP and a map with all critical areas depicted

2. At CLE do you know where these areas intersect with other protected runway surfaces?
   Yes, see diagrams.

3. Prior to the airport installing the Runway Hold Position marking and signage to protect the RSA and critical areas of other non-intersecting runways, how did you inform pilots and vehicle operators to hold short of those areas?
   SOP we hold short of D and U for aircraft. There's always been some sort of sign/marking for vehicles.

   How often do you find yourself explaining to pilots what the Runway Hold Position marking and signage means if they are unfamiliar with it?
   N/A

4. How do you inform the pilots or vehicle operators to hold short or cross the Runway Hold Position marking and signage?
   Hold short of 24R APCH.

5. How often do you need to remind the pilots or vehicle operators to hold short of the Runway Hold Position marking and signage when the need arises?
   Not often as 10-28 is not used for taxiing much.

6. What waivers are in place? *N/A*
   We do not hold aircraft in between the lines – only vehicles.
   Standard phraseology = yes, for the most part.
   It is very confusing as a pilot and as a controller of where to hold short.
   The area in between the runways on 10-28 - need to be able to keep the vehicles moving through there and be clear in the middle to facilitate snow removal.
   Land rwy 10, off on U, Land rwy 29 off on D or end. So they don't have much traffic on 10-28. They wouldn't be able to provide much feedback in regards to aircraft usage.

APPENDIX K—CLEVELAND HOPKINS INTERNATIONAL AIRPORT GROUND VEHICLE OPERATOR RESPONSES

Vehicle operator responses to the Cleveland Hopkins International Airport (CLE) airfield vehicle operators questions are presented below.

1. Are you familiar with the locations where the RSAs of one runway intersect with another runway? Where? How are they delineated?
   Vehicle Operator #1: *Yes, intersection 6R-24L and 6L-24R. RSA extends into 10-28. Hold lines and mandatory instruction signs.*
   Vehicle Operator #2: *Yes, on runway 10-28 for the APCH of 6-24*
   Vehicle Operator #3: *Yes, on 10-28 past U and past D from other end. Hold bars and signage*
   Vehicle Operator #4: *Yes, 4 locations on 10-28 for the 2 runways.*
   Vehicle Operator #5: *Yes, I use the hold bars and signage. And the ILS signs for those conditions.*
   Vehicle Operator #6: *Yes, hold bar and sign*
   Vehicle Operator #7: *Yes, hold bar and sign*
   Vehicle Operator #8: *Yes, signs and markings*
   Vehicle Operator #9: *Yes, signs both sides of runway*
   Vehicle Operator #10: *Yes, 4 signs on the runway*
   Vehicle Operator #11: *Yes, on 10-28. 4 Signs and markings*

2. In your opinion, is this marking and sign adequate to mark the Runway Safety Area (RSA)? If no, why?
   Vehicle Operator #1: *Yes*
   Vehicle Operator #2: *Yes*
   Vehicle Operator #3: *Yes*
   Vehicle Operator #4: *Yes*
   Vehicle Operator #5: *Yes*
   Vehicle Operator #6: *Yes*
   Vehicle Operator #7: *Yes*
   Vehicle Operator #8: *Yes*
   Vehicle Operator #9: *I have no problem, but maybe the new guys?*
   Vehicle Operator #10: *Yes*
   Vehicle Operator #11: *Yes*

   Is this marking/sign confusing? If so, why? (show printout of runway holding position sign and marking 6R-24L)
   Vehicle Operator #1: *No, it lets you know you can't go there without permission.*
   Vehicle Operator #2: *I'm used to it and know what to look for. Keep it maintained.*
   Vehicle Operator #3: *No*
   Vehicle Operator #4: *No, but there was some confusion when there was the center runway*
   Vehicle Operator #5: *No, 15 years, never an incursion*
   Vehicle Operator #6: *Not at all*

Vehicle Operator #7: *No*
Vehicle Operator #8: *No*
Vehicle Operator #9: *No*
Vehicle Operator #10: *No*
Vehicle Operator #11: *No, I've been out on the field for many years.*

3. How were you first made aware of the Runway Hold Position marking and signage?
Vehicle Operator #1: *We've always had a hold position there since the runways did intersect at one time. The positions have moved twice now, spread out further out to protect APCH slopes. In 2011, it went back to RSA locations. Prior sign was 24L-APCH and hold marking. Driver's class, blast fax.*
Vehicle Operator #2: *Yes, We all went over the plans, being involved in the construction and seeing it firsthand. Emails.*
Vehicle Operator #3: *12 years ago when I started (ASOS school) plus on-job-training. Manager told us. There used to be an issue where people would get confusing. Only time the hold short is an issue is during snow operations. 16 vehicles is almost impossible to gather in between the safety areas.*
Vehicle Operator #4: *Drive arounds*
Vehicle Operator #5: *First they'd say don't go on 10-28 (hold short at U and D), then when signage was put in Ops notified and we put in the signage (electrician)*
Vehicle Operator #6: *New people drive with experienced*
Vehicle Operator #7: *Email*
Vehicle Operator #8: *Email, map*
Vehicle Operator #9: *Circular*
Vehicle Operator #10: *Training*
Vehicle Operator #11: *Big meeting, told which areas to hold short of and get clearance, yearly driving courses*

4. Prior to the airport installing the Runway Hold Position marking and signage in these areas, how did you know where to stop when ATC instructed you to hold short of the intersecting APCH/RSA area?
Vehicle Operator #1: *We've always had something there. And they're also used to indicate the RSA from the mid-field area.*

5. Are there any special movement area procedures in place when operating in these areas? If so, please explain.
Vehicle Operator #1: *Need permission from ATC to cross Safety Area.*
Vehicle Operator #2: *No, not special because you still have to contact ground. Pavement and safety area is one in the same.*
Vehicle Operator #3: *Car 5, I'm at, I would like to inspect runway 10-28. Proceed, hold short 6R safety area. They're always say "safety area".*

Vehicle Operator #4: *I'm holding short of approach of 24R/24L. ATC references the area better with "APCH" because it gives them a better idea of where I am.*
Vehicle Operator #5: *Hold in between the 2 safety area. "Would like to drive across both runways, cross the safety area"*
Vehicle Operator #6: *(Electrician) 90% of the time we don't hold in between.*
Vehicle Operator #8: *Tower says to hold short of 24L or 24R and we just repeat it back.*
Vehicle Operator #9: *Tower says to hold short of 24L or 24R and we just repeat it back.*
Vehicle Operator #10: *Tower says to hold short of 24L or 24R and we just repeat it back.*

Additional Info:
Vehicle Operator #1: *Changing the marking would create more confusion for vehicle drivers because they wouldn't stop. Having an ILS ladder on the runway is not a good idea. Best to keep it the way it is.*
Vehicle Operator #3: *In the middle there is some confusion because there's too many markings. Are you clear of one safety and inside the other or clear of both? You better be paying attention to the markings and which way the lines are facing.*
Vehicle Operator #4: *Here they very rarely taxi anyone on 10-28. You shouldn't change the marking because vehicles need to know to stop and hold short. Ok to change sign, leave runway hold short marking.*
Vehicle Operator #5: *All size 2, Lumacurve*
Vehicle Operator #6: *(Electrician) 90% of the time we don't hold in between. We get 30 min closures once a week. So it wouldn't be a problem for us if in the inner signage went away. We know to hold at the ILS line when the conditions indicate, so if the line was changed to ILS ladder, we'd just have to learn it. ATC tells us what to do, so if ATC said to hold, we'd hold.*
Vehicle Operator #7: *Whatever you put out there, we'd know it because we know the procedures. As long as the sign stays red, we know we have to stop regardless of the marking.*
Vehicle Operators #8-10: *stacked sign is not good for drivers, bottom half of sign could be obscured by snow. We wouldn't be confused hold sign with ILS marking as long as the sign is still a hold sign. Just do whatever ATC tell you. Stopping at only one spot would be helpful.*
Vehicle Operator #11: *confusing when ATC tells you to cross one but hold short of the other. Smaller sign, the better for airfield electricians.*

APPENDIX L—CLEVELAND HOPKINS INTERNATIONAL AIRPORT AIRCRAFT AND GROUND VEHICLE OPERATOR SURVEY

Pilot and vehicle operator responses to the Cleveland Hopkins International Airport (CLE) pilot and vehicle operator survey are presented below.

The Federal Aviation Administration (FAA) is currently conducting research to improve the signage and marking related to approach, departure, and other critical surfaces. Your feedback will help address inconsistencies at locations where runways or taxiways intersect the protected areas of other runways. All responses are anonymous.

Any questions or comments can be directed to: Garrison Canter, Airport Operations Research Analyst, SRA International, 1201 New Road, Suite 242, Linwood, NJ 08221, (609) 601-6800 x117, Garrison_Canter@sra.com.

Figure 1

Not to Scale

1. If positioned together at a location which did not lead to a runway entrance, the meaning of the sign and surface marking pictured in figure 1 would be understandable.

Strongly Disagree ○ Disagree ○ Undecided ○ Agree ○ Strongly Agree ○

2. What do the sign and surface marking shown in figure 1 mean to you when located together?

3. The sign and surface marking pictured in figure 1 are suitable for use on a runway.

Strongly Disagree ○ Disagree ○ Undecided ○ Agree ○ Strongly Agree ○

4. To proceed past the sign and surface marking shown in figure 1, explicit permission from air traffic control would be needed.

Strongly Disagree ○ Disagree ○ Undecided ○ Agree ○ Strongly Agree ○

5. The sign shown in figure 1 contains an appropriate quantity of information.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

6. Why, or why not, is the quantity of information on the sign in figure 1 appropriate?

Figure 2

Not to Scale

7. If positioned together at a location which did not lead to a runway entrance, the meaning of the sign and surface marking pictured in figure 2 would be understandable.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

8. What do the sign and surface marking shown in figure 2 mean to you when located together?

9. The sign and surface marking pictured in figure 2 are suitable for use on a runway.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

10. To proceed past the sign and surface marking shown in figure 2, explicit permission from air traffic control would be needed.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

11. The sign shown in figure 2 contains an appropriate quantity of information.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

12. Why, or why not, is the quantity of information on the sign in figure 2 appropriate?

Figure 3

Not to Scale

13. If positioned together at a location which did not lead to a runway entrance, the meaning of the sign and surface marking pictured in figure 3 would be understandable.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

14. What do the sign and surface marking shown in figure 3 mean to you when located together?

15. The sign and surface marking pictured in figure 3 are suitable for use on a runway.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

16. To proceed past the sign and surface marking shown in figure 3, explicit permission from air traffic control would be needed.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

17. The sign shown in figure 3 contains an appropriate quantity of information.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

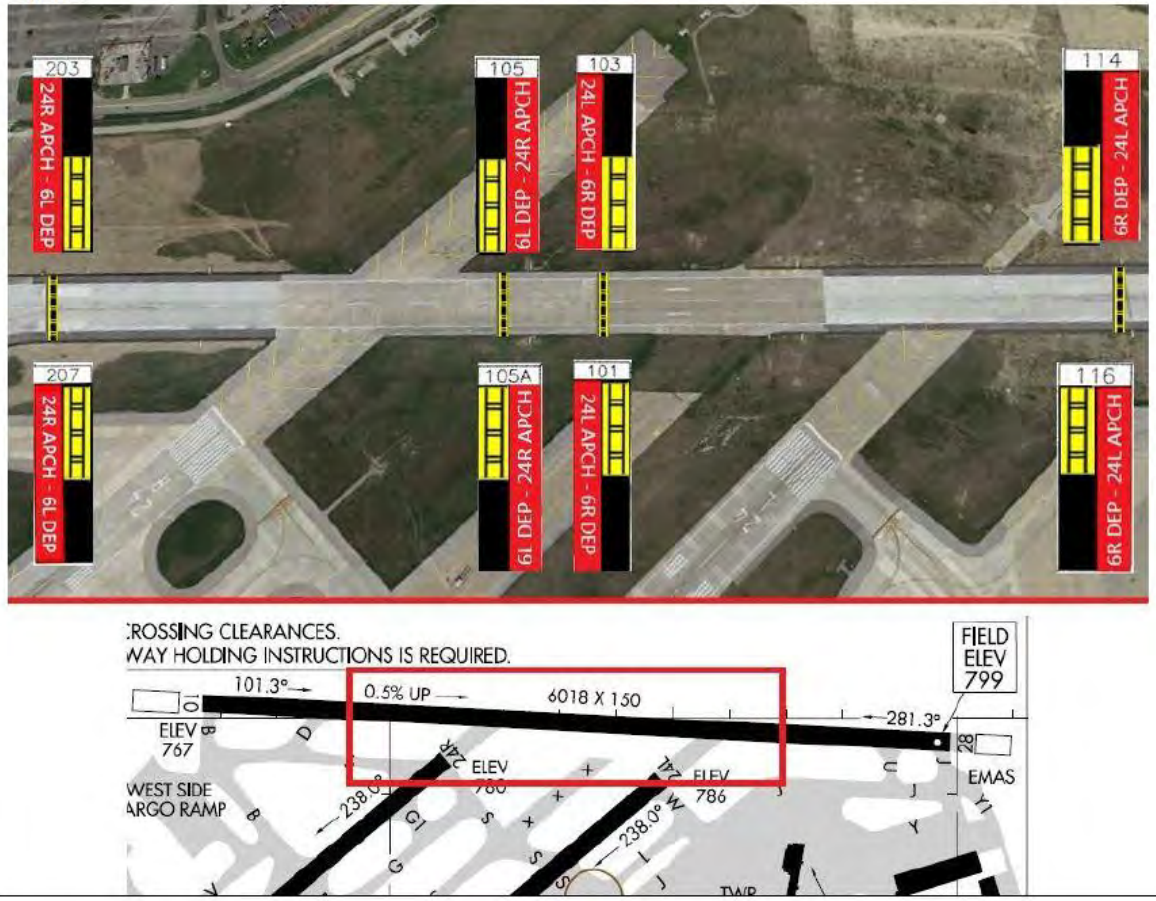
18. Why, or why not, is the quantity of information on the sign appropriate?

***19. Did you observe new signage on RWY 10-28 at one of the locations shown in figure 4? (Click "Next" at the bottom of the page to continue)**

◯ Yes

◯ No

Figure 4


203
24R APCH - 6L DEP
105
6L DEP - 24R APCH
103
24L APCH - 6R DEP
114
6R DEP - 24L APCH
207
24R APCH - 6L DEP
105A
6L DEP - 24R APCH
101
24L APCH - 6R DEP
116
6R DEP - 24L APCH
:ROSSING CLEARANCES.
WAY HOLDING INSTRUCTIONS IS REQUIRED.
FIELD ELEV 799
101.3°
0.5% UP
6018 X 150
281.3°
ELEV 767
ELEV 780
ELEV 786
EMAS
WEST SIDE ARGO RAMP
238.0°
238.0°
TWR

20. Seeing the departure runway on the sign(s) increased your situational awareness.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

21. The visual cues were understandable early enough to identify the location of the holding position.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

22. The sign(s) and surface marking(s) were logically consistent with the instructions provided by ATC.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

23. The surface marking adjacent to the sign(s) expressed the same message with the sign(s).

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

24. Please provide any further comments or concerns you may have regarding any aspect of the APCH/DEP signage and/or accompanying surface marking(s) you have viewed. (For example: regarding workload, situational awareness, ATC instructions, etc.)

APPENDIX M—NASHVILLE INTERNATIONAL AIRPORT AIRCRAFT AND GROUND VEHICLE OPERATOR SURVEY

Pilot and vehicle operator responses to the Nashville International Airport (BNA) pilot and vehicle operator survey are presented below.

BNA APCH Hold Questionnaire

The Federal Aviation Administration (FAA) is currently conducting research to improve the signage and marking related to approach, departure, and other critical surfaces. Your feedback will help address inconsistencies at locations where runways or taxiways intersect the protected areas of other runways.

Any questions or comments can be directed to: Garrison Canter, Airport Operations Research Analyst, SRA International, 1201 New Road, Suite 242, Linwood, NJ 08221, (609) 601-6800 x117, Garrison_Canter@sra.com.

*** 1. Please select the option that describes your role on the airfield.**

- ◯ Pilot
- ◯ Vehicle Operator
- ◯ Other (please specify)

2. Have you taken this survey previously?

(Individuals who have taken the survey before but have observed the signage and marking described in the survey since that time may provide additional feedback by selecting "Yes")

- ◯ No
- ◯ Yes

BNA APCH Hold Questionnaire

Figure 1

Not to Scale

3. If positioned together on a taxiway or runway, the meaning of the sign and surface marking pictured in figure 1 would be understandable.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

4. What do the sign and surface marking shown in figure 1 mean to you when located together?

5. The sign and surface marking pictured in figure 1 are suitable for use on a runway.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

6. To proceed past the sign and surface marking shown in figure 1, explicit permission from air traffic control would be needed.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

BNA APCH Hold Questionnaire

7. The sign shown in figure 1 contains an appropriate quantity of information.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

8. Why, or why not, is the quantity of information on the sign in figure 1 appropriate?

BNA APCH Hold Questionnaire

Figure 2

Not to Scale

9. If positioned together at a location which did not lead to a runway entrance, the meaning of the sign and surface marking pictured in figure 2 would be understandable.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

10. What do the sign and surface marking shown in figure 2 mean to you when located together?

11. The sign and surface marking pictured in figure 2 are suitable for use on a runway.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

12. To proceed past the sign and surface marking shown in figure 2, explicit permission from air traffic control would be needed.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

BNA APCH Hold Questionnaire

13. The sign shown in figure 2 contains an appropriate quantity of information.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

14. Why, or why not, is the quantity of information on the sign in figure 2 appropriate?

BNA APCH Hold Questionnaire

Figure 3

Not to Scale

15. If positioned together at a location which did not lead to a runway entrance, the meaning of the sign and surface marking pictured in figure 3 would be understandable.

Strongly Disagree ◯ Disagree ◯ Undecided ◯ Agree ◯ Strongly Agree ◯

16. What do the sign and surface marking shown in figure 3 mean to you when located together?

17. The sign and surface marking pictured in figure 3 are suitable for use on a runway.

Strongly Disagree ◯ Disagree ◯ Undecided ◯ Agree ◯ Strongly Agree ◯

18. To proceed past the sign and surface marking shown in figure 3, explicit permission from air traffic control would be needed.

Strongly Disagree ◯ Disagree ◯ Undecided ◯ Agree ◯ Strongly Agree ◯

19. The sign shown in figure 3 contains an appropriate quantity of information.

Strongly Disagree ◯ Disagree ◯ Undecided ◯ Agree ◯ Strongly Agree ◯

BNA APCH Hold Questionnaire

20. Why, or why not, is the quantity of information on the sign appropriate?

***21. Did you observe new signage on TWY K or T3 at one of the locations shown in figure 4? (Click "Next" at the bottom of the page to continue)**

- ◯ Yes
- ◯ No

BNA APCH Hold Questionnaire

Figure 4

BNA APCH Hold Questionnaire

22. Were you instructed by ATC to hold short at the location(s) you observed the sign(s) depicted in figure 4?

- ◯ Yes
- ◯ No

23. Seeing the departure runway on the sign(s) increased your situational awareness.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

24. The visual cues were understandable early enough to identify the location of the holding position.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

25. The sign(s) and surface marking(s) were logically consistent with the instructions provided by ATC.

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

26. The surface marking adjacent to the sign(s) expressed the same message as the sign(s).

Strongly Disagree	Disagree	Undecided	Agree	Strongly Agree
◯	◯	◯	◯	◯

27. Please provide any further comments or concerns you may have regarding any aspect of the APCH/DEP signage and/or accompanying surface marking(s) you have viewed. (For example: regarding workload, situational awareness, ATC instructions, etc.)