technical note technical note

Identification Techniques to Reduce Confusion Between Taxiways and Adjacent Runways

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16. Abstract

The National Transportation Safety Board accident/incident database and the Aviation Safety Reporting System have reported pilots mistakenly landing on the taxiways adjacent to runways. As of August 23, 2007, 267 such events have occurred at 110 airports in the United States. These inadvertent landings create a safety hazard that must be eliminated. This technical note provides guidance on techniques that can be implemented at airports to reduce or eliminate this problem. Two scenarios were considered during this research effort: (1) prevent the pilot from inadvertently lining up with the taxiway during the approach, and (2) prevent the pilot from landing on the taxiway if the first effort fails. Four visual aid enhancements were tested at Seattle-Tacoma International Airport and Palm Beach International Airport: an elevated lighted X, artificial turf, omnidirectional runway end identifier lights, and an in-pavement lighted X. Each piece of equipment was placed on the taxiway and was evaluated one at a time while making final approaches to the runway with the exception of the artificial turf and omnidirectional lights, which were turned on constantly. Based on the results, it was concluded that an elevated lighted X and an in-pavement lighted X were seen at an average distance of 4.5 nm. Omnidirectional lights and green artificial turf were seen at a distance of 5.0 nm.

To eliminate similar occurrences at Lincoln Airport, the Airport Authority has implemented installation of nonstandard taxiway markings, such as surface-painted A, surface-painted TAXI ONLY, and a painted serpentine marking. This investigation found that all solutions have some deficiencies: the painted A looks similar to a displaced threshold chevron, the word TAXI in the painted TAXI ONLY is sufficient to perform the intended task, and the serpentine markings were not clearly visible from the air. It was concluded that airport geometry is a major causal factor in all these incidents and should be eliminated in the early design phases of the airport.

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LIST OF ACRONYMS

AC	Advisory Circular
ACY	Atlantic City International Airport
ALS	Approach lighting system
ATC	Air traffic control
ATIS	Automated Terminal Information System
DME	Distance measuring equipment
FAA	Federal Aviation Administration
LED	Light-emitting diode
LNK	Lincoln Airport
MALSR	Medium-intensity approach lighting system with runway alignment indicator
nm	Nautical mile
NTSB	National Transport Safety Board
ODALS	Omnidirectional approach lighting system
PBI	Palm Beach International Airport
R&D	Research and development
REIL	Runway end identifier light
SEA-TAC	Seattle-Tacoma International Airport
VFR	Visual flight rule

EXECUTIVE SUMMARY

According to recent findings from the National Transportation Safety Board accident/incident database and the Aviation Safety Reporting System, some airports have been experiencing problems with pilots mistakenly identifying taxiways, which run parallel to an adjacent runway, as runways, resulting in pilots landing on the taxiway instead of the runway. These events have occurred 267 times at 110 airports in the United States, current as of August 23, 2007 (including general aviation and air carrier airports). The search criteria for these findings did not include pilots who made emergency landings on the taxiway or landed on the wrong runway.

This research was conducted in an effort to identify visual aid enhancement solutions that may reduce or eliminate inadvertent landings on taxiways. Two components were considered during this research effort: (1) prevent the pilot from inadvertently lining up with the taxiway during the approach, and (2) prevent the pilot from landing on the taxiway if the first effort fails. This technical note will provide airports guidance on proven techniques that can be implemented to reduce or eliminate this problem.

Personnel from the Airport Technology Research and Development Branch and Hi-Tec Systems (collectively called the Visual Guidance Team or the Team) traveled to Seattle-Tacoma International Airport (SEA-TAC) and Palm Beach International Airport (PBI) to test possible visual aid enhancement solutions to resolve the issue. In addition, the Visual Guidance Team traveled to Lincoln Airport to perform a thorough review of the nonstandard taxiway markings installed on taxiway Alpha to make recommendations on whether or not the existing markings should remain in place and to determine if anything else could be done to improve the situation.

Based on the results from SEA-TAC and PBI, it was concluded that an elevated lighted X situated beyond the taxiway threshold would be a simple solution to implement. Omnidirectional runway end identifier lights and green artificial turf are also simple solutions to install. Omnidirectional runway end identifier lights make the runway threshold more conspicuous for the pilot on approach. The green artificial turf visually narrows the size of the taxiway or can visually mask a squared taxiway surface. The in-pavement lighted X was also effective but would be expensive to implement. In addition, the airports should continue their efforts of using the Automated Terminal Information System message, training, and aeronautical chart publications. It was also concluded that airport geometry is a major causal factor in all these incidents and should be eliminated in early design phases of the airport.

It was recommended that Lincoln Airport remove the boxed A painted designation, since it looks too much like a displaced threshold chevron. Also, the word ONLY in the TAXI ONLY paint marking could be removed, since the word TAXI is sufficient for the intended task. Another recommendation was to have the hold line for runway 32 at the south end of taxiway Alpha changed from being perpendicular to the centerline of taxiway Alpha to an angle that more closely parallels runway 32. The serpentine taxiway centerline marking provides some enhancement of the taxiway surface, but was not significantly visible from the air.

INTRODUCTION

PURPOSE.

This research was conducted in an effort to identify visual aid enhancement solutions that may reduce or eliminate inadvertent landings on taxiways. Two components were considered during this research effort: (1) prevent the pilot from inadvertently lining up with the taxiway during the approach, and (2) prevent the pilot from landing on the taxiway if the first effort fails. This report will provide airports guidance on proven techniques that can be implemented to reduce or eliminate this problem.

OBJECTIVES.

The objectives of this research effort were to:

1. Find a solution for the Seattle-Tacoma International Airport (SEA-TAC) problem by identifying possible visual aid enhancements to prevent pilots from mistakenly identifying taxiway Tango as the adjacent runway 16R as a landing surface.

2. Find a solution for the Palm Beach International Airport (PBI) problem by identifying possible visual aid enhancements to prevent pilots from mistakenly identifying taxiway Lima as the adjacent runway 9L/27R as a landing surface.

3. Evaluate the nonstandard paint markings installed at Lincoln Airport (LNK) for a request for modification to standard.

4. Identify general solutions that can work for other airports experiencing the same problem.

BACKGROUND.

According to recent findings from the National Transportation Safety Board (NTSB) accident/incident database and the Aviation Safety Reporting System, some airports have been experiencing problems with pilots mistakenly identifying taxiways, which run parallel to adjacent runways, as runways, resulting in pilots landing on the taxiway instead of the runway. These events have occurred 267 times at 110 airports in the United States, current as of August 23, 2007 (including General Aviation and Air Carrier Airports) (appendix B). The search criteria for these findings did not include pilots who made emergency landings on the taxiway or landed on the wrong runway. Of the 110 airports reporting these incidents, 66 were random (single incidents) and 44 were trends (multiple incidents). For example, PBI in Palm Beach, FL, had 36 incidents that occurred between 1995 and 2007; LNK in Lincoln, NE, had 13 incidents that occurred between 1995 and 2006; and SEA-TAC in Seattle, WA, had 7 incidents that occurred between 1999 and 2005.

On December 22, 2005, members of the Federal Aviation Administration (FAA) Airport Technology Research and Development (R&D) Branch and Hi-Tec Systems (collectively called the Visual Guidance Team or the Team) conducted a preliminary flight evaluation at Atlantic City International Airport (ACY) to view multiple visual guidance aids for the upcoming work at SEA-TAC. The visual aids evaluated were an elevated lighted X, an omnidirectional runway

end identifier light (REIL), and an in-pavement lighted X. The Team, using a Cessna 172 aircraft, performed several straight-in approaches to runway 4, where each visual aid was arranged. Results of this evaluation determined what visual aids were to be tested at SEA-TAC.

The incidents at SEA-TAC were unique because only commercial airline pilots were making the error, as opposed to general aviation pilots at other airports. The frequency of these occurrences at SEA-TAC prompted the NTSB to investigate the situation and make recommendations to resolve the issue. Some of their recommendations involved having nonstandard markings, such as painting the word TAXIWAY on the pavement and/or a serpentine line over the standard taxiway centerline, which they believed would provide a quick solution to the problem. These recommendations were based upon anecdotal information regarding their effectiveness received from operators of two other airports that had experienced landings on taxiways, mainly involving general aviation pilots and aircraft. Las Vegas International Airport and Palm Spring International Airport applied these techniques to their taxiways for the same issue. After application, the problem ceased to occur.

Consequently, Mitre Corporation was tasked to conduct a human factors study that discussed the decision process by which pilots selected the active runway. The report, entitled "Recommendations for Treatments of Taxiway Tango at Seattle-Tacoma Airport for the Mitigation of Taxiway Landings," published in February 2005, gives an analysis of known human perceptual and cognitive capabilities; the visual environment under which pilots must select the landing runway, and the role of prior experience in the selection process. A pilot will generally associate an air traffic control (ATC) instruction such as "cleared to land runway 16R," with their visual presentation of the runway configuration. The research report provided several recommendations designed to maximize the likelihood that pilots will select the correct runway for landing. One of the more favorable solutions provided as a result of this study was the concept of placing triangle-shaped pavement treatment areas along the entire border of the taxiway as a way to visually differentiate the taxiway from the parallel runway.

Although a one-size fits all approach would be ideal, the complexity of the situation at some airports may require one or more solutions, which vary from location to location because the cause of these events may range from airport geometry, pilot experience, visual cues, and environmental conditions.

Accordingly, the FAA Airport Technology R&D Branch was tasked to conduct research on these incidents and provide various visual aid enhancement solutions that may be applicable to airports that have similar situations.

RELATED DOCUMENTATION.

- Mitre Corporation, "Recommendations for Treatments of Taxiway Tango at Seattle-Tacoma Airport for the Mitigation of Taxiway Landings," 2005.

- Cyrus, H., "Paint and Bead Durability Study," FAA report DOT/FAA/AR-02/128, March 2003.

- Cyrus, H., "Development of Methods for Determining Airport Pavement Marking Effectiveness," FAA report DOT/FAA/AR-TN03/22, March 2003.

- FAA Advisory Circular (AC) 150/5340-1J, "Standards for Airport Markings," April 29, 2005 with changes.

- Marinelli, R., "Development of a Visual Aid to Indicate Temporary Runway Closure," FAA report DOT/FAA/CT-TN87/3, January 1987.

- FAA AC 150/5340-30, "Design and Installation Details of Airport Visual Aids," April 11, 2005.

- FAA AC 150/5345-55, "Lighted Visual Aid to Indicate Temporary Runway Closure," July 14, 2003.

AIRPORT RESEARCH

Flight evaluations were conducted to test possible solutions that would prevent pilots from performing straight-in or circling approaches to a runway from landing on a taxiway. After initial observation flights at ACY, a list of solutions was considered. These solutions were based on subject matter experts, as well as already existing visual aids that may be of benefit in situations such as this. When considering these solutions, two goals were to be accomplished; the first was to prevent the pilot from initially lining up with the taxiway on final approach, and the second was to change the pilots' judgment, which still is on course with landing on the taxiway. These visual aid enhancements were tested at PBI and SEA-TAC. The following is the list of solutions that were tested.

- Elevated lighted X. This concept places the elevated lighted X just beyond the taxiway end in an effort to inform the pilot that this is not a landing surface. Each individual lamp was angled 3° toward the approach and flashed at a rate of 3 seconds on and 1 second off, as the FAA AC 150/5345-55, "Lighted Visual Aid to Indicate Temporary Runway Closure."

- Omnidirectional REILs. This concept was proposed in lieu of the typical unidirectional REIL, as it would allow both fixtures to be visible from approaching aircraft, regardless of which runway or taxiway they are aligned with. Each set of omnidirectional REILs was temporarily installed next to the airport's existing unidirectional REIL.

- Artificial turf (green, yellow, white, and orange). This concept would use material of contrasting color to either narrow the taxiway surfaces (green) or enhance the runway surface (yellow, white, and orange) to make it more visible to approaching pilots. Both PBI and SEA-TAC have rectangular-shaped taxiway ends that resemble runways. Since curving the taxiway edge would require major reconstruction of the pavement, it was not a feasible option for the airports. To create the effect of a curved taxiway or minimize its size, the Team considered using green artificial turf material to cover the pavement

within this square area and/or the shoulders of the taxiway, making it blend in with the surrounding grass, thus giving it a narrow taxiway appearance.

- In-pavement lighted X located on the taxiway. This concept incorporates a series of bright, in-pavement lighting fixtures (FAA-E-2968) configured such that they resemble an X to aircraft on approach. The in-pavement lighted X configuration measured 120 by 48 ft. The lights, however, due to their layout, would not form a recognizable signal to any aircraft operating on the taxiway. In addition, it eliminates any problem with obstruction clearances. The in-pavement lighted X flashed at a rate of 3 seconds on and 1 second off, as per the FAA AC 150/5345-55 "Lighted Visual Aid to Indicate Temporary Runway Closure."

The following is a brief description of the equipment used during the evaluations:

- One strip each of green, yellow, orange, and white artificial turf measuring 50 ft long by 15 ft wide and held in place by sand bags.

- Five incandescent in-pavement medium-intensity approach lighting systems with runway alignment indicators (MALSR) fixtures (FAA-E-2968); four in-pavement prototype light-emitting diode (LED) MALSR fixtures.

- Two sets of FAA-approved L-849 style F omnidirectional REILs.

- A 20- by 20-ft elevated lighted X with 13 par 38 120 watt incandescent spot lamps spaced at 3 ft 6 in.

SEATTLE-TACOMA INTERNATIONAL AIRPORT.

SEATTLE-TACOMA INTERNATIONAL AIRPORT DISCUSSION. SEA-TAC has two parallel runways, 16L/34R and 16R/34L, which are spaced 800 ft apart (centerline to centerline). Runway 16L/34R is an asphalt pavement that is 150 ft wide and 11,901 ft long, with shoulders 50 ft wide. Runway 16R/34L is a concrete pavement that is 150 ft wide and 9426 ft long, with shoulders 25 ft wide. On the south end, the thresholds for both runways are staggered, and on the north end the thresholds are even, as shown in figure 1. Both runway 16L and 16R are equipped with approach lighting systems (ALS), instrument landing systems, and have precision runway markings. The approach end of runway 16R is equipped with an ALS and a blast pad on its north end, 200 ft wide by 200 ft long, marked with chevrons.

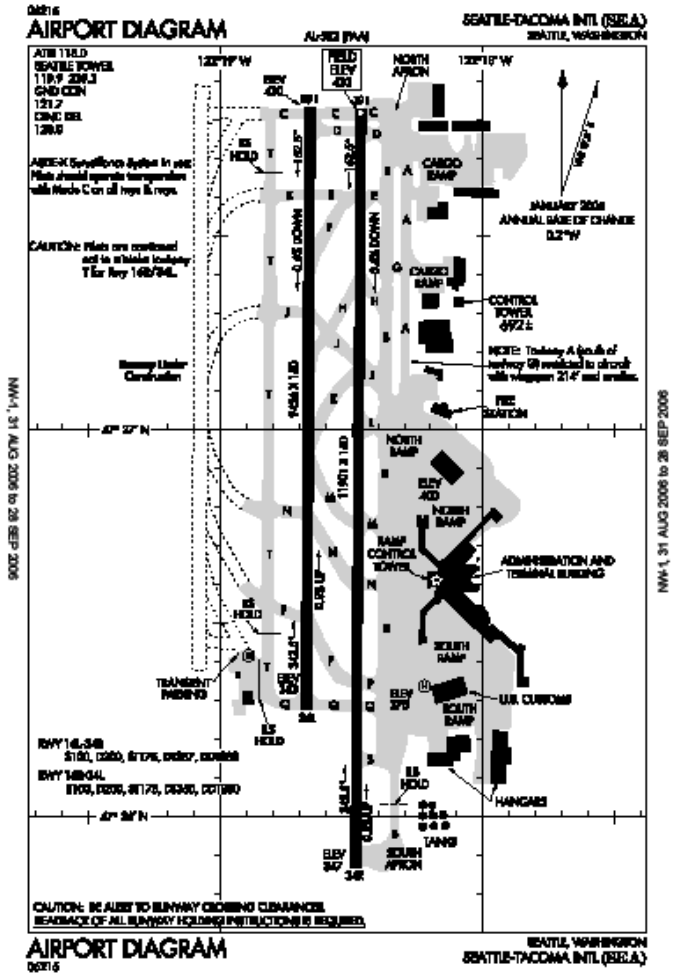


Figure 1. Airport Diagram of SEA-TAC

Taxiway Tango is located 600 ft to the west of runway 16R. It has asphalt shoulders that are 40 ft wide and are gray in appearance. The light-gray color of the shoulders blends with the concrete center, which is 100 ft wide, to produce a relatively uniform surface when viewed at a distance from the north. Taxiway Tango is unique because it appears to be physically larger than the parallel runways 16R and 16L, and it is made of new light-gray concrete, which makes it more prominent than the darker asphalt and concrete of runways 16L and 16R. The dimensions of the two runways and taxiway Tango are shown in table 1. In anticipation of future expansions that will include the construction of a third parallel runway to the west of the airport taxiway Tango (on the approach end of 16R) was constructed such that it has a rectangular shape, which gives it more of a runway appearance than a taxiway appearance.

Table 1. Runway and Taxiway Measurements at SEA-TAC

Runway/Taxiway	Runway/Taxiway Width	Shoulder Width	Total Pavement Width
16L	150 feet	100 feet	250 feet
16R	150 feet	50 feet	200 feet
Tango	100 feet	80 feet	180 feet

Since December 1999, SEA-TAC has experienced multiple incidences of commercial airline pilots performing approaches to, and actual landings on, taxiway Tango mistakenly identifying it as the parallel runway 16R. These incidents have occurred during the day in visual flight rule (VFR) weather conditions, during the period of mid-November to March, when low sun angle and frequent rain showers prevailed. Upon approach to the airport from the north, taxiway Tango is the most visible of all the airport's surfaces (figure A-1 in appendix A).

Taxiway Tango was constructed in October 1999 in preparation for future expansion of a third parallel runway to the west of the airport. Approximately 2 months after completion of taxiway Tango, one pilot made an approach to the taxiway thinking it was runway 16R. The pilot stated that, because of intense sun glare, he lined up to the taxiway since it was clearly more visible than the other landing surfaces. Similar instances have happened where pilots were cleared to land on runway 16R, but because of the glare from the sun, made approaches or landed on taxiway Tango. In another incident, which resulted in a landing, the pilots had been actively tracking the Instrument Landing System localizer for runway 16R until breaking out of the overcast. However, once visual acquisition of the airport was in sight, taxiway Tango was a more appealing landing surface than the surrounding pavements. Taxiway Tango faces north/south, which leads to problems when the sun, during the winter months, is very low on the horizon. This causes paint markings on the pavement surface to wash out, making it difficult to differentiate between surfaces (figures A-2 and A-3 in appendix A).

SEA-TAC personnel have been very proactive in trying to reduce the problem, including the installation of an unlit, nonreflective elevated lighted X at the threshold of taxiway Tango; broadcasting a notice on the Automatic Terminal Information Service (ATIS) not to mistake the parallel taxiway for the adjacent runway; posting warnings on aeronautical charts not to mistake the taxiway for runway 16R; and the development of numerous training aids and brochures that explain the problem to transient pilots traveling through SEA-TAC.

Mitre Corporation was tasked to research various surface treatments, which are thicker than paint that can be used in an effort to overcome the sun's glare so that the pilot can see the marking material from the air. The surface treatments are thicker than paint, much like pavement seal-coating material. The goal was to create a zig-zag pattern on the taxiway using the surface treatments, in an effort to deter the pilot from landing on the taxiway. These surface treatments were evaluated in February 2005 at SEA-TAC, where various types of material were placed on the shoulder of taxiway Tango, as shown in figure A-4 in appendix A. The results of that research showed that some type of unique surface treatment was required to enhance the color and/or shape of the taxiway, which would in turn make the taxiway less visible to approaching pilots. Unfortunately, using these surface treatments did not overcome the sun's glare, as shown in figures A-1 and A-2 in appendix A, and were just as invisible as normal airport paint.

SEATTLE-TACOMA INTERNATIONAL AIRPORT EVALUATION. The Visual Guidance Team traveled to SEA-TAC onboard the FAA's Boeing 727 on February 13, 2006, with numerous visual aid devices to be evaluated on taxiway Tango. On February 14, 2006, the Team met with SEA-TAC personnel to coordinate the events for the upcoming couple of days, which included installation of the equipment on taxiway Tango and the two parallel runways, and actual flight evaluations to view the visual aid devices. It was discussed that escorts would be

needed for access to taxiway Tango, and that the taxiway would be partially closed for the duration of the installation and evaluation.

One of the visual aid devices brought to SEA-TAC was a temporary elevated lighted X intended to be set up at the end of taxiway Tango on the approach end of runway 16R. The elevated lighted X was attached to the already existing metal X that the airport had installed. In addition, a prototype in-pavement red LED fixture was placed next to the elevated lighted X during the evaluation (figure A-17 in appendix A).

Other equipment that was set up were two sets of FAA-approved omnidirectional REILs. The omnidirectional REILs were installed at the end of runways 16R and 16L, next to the airport's existing unidirectional REILs (figure A-18 in appendix A).

Another visual aid that was installed on the shoulder of the taxiway included four strips of artificial turf in yellow, green, orange, and white. The purpose of the brighter colors was to determine which color was most conspicuous from the air. It was discussed that the creation of a large X or other shape with the bright artificial turf could be used in the prethreshold area of a taxiway or a runway. Each artificial turf strip measured 15 ft wide by 50 ft long and was held in place using sand bags (figure A-19 in appendix A).

The final visual aid to be evaluated was the in-pavement lighted X. The in-pavement lighted X was located on the taxiway centerline of taxiway Tango, parallel to the touchdown zone markings on runway 16R, facing the approach of runway 16R (figure A-20 in appendix A).

On February 15, 2006, the Visual Guidance Team, along with personnel from the Port of Seattle, Flight Standards, Runway Safety Office, and the FAA West Pacific Regional Airports Office, conducted 10 approaches to taxiway Tango in the FAA's B-727. Nine approaches were flown to taxiway Tango in the southerly direction, and one nondata approach was made in the northerly direction. Table 2 describes the various approaches made during the evaluation and which visual devices were being evaluated. The weather conditions for Seattle during the evaluation were 10+ mile visibility with clear skies. All final approaches started at least 10 miles out and were aligned with taxiway Tango.

Table 2. Visual Aids Viewed During Evaluation at SEA-TAC

Approach No.	Visual Aids Viewed
1	Unidirectional REILs, elevated lighted X, artificial turf
2	Omnidirectional REILs, elevated lighted X, artificial turf
3	Omnidirectional REILs, in-pavement lighted X, artificial turf
4	Unidirectional REILs, elevated lighted X, artificial turf
5	Omnidirectional REILs, elevated lighted X, artificial turf
6	Omnidirectional REILs, in-pavement lighted X, artificial turf

Table 2. Visual Aids Viewed During Evaluation at SEA-TAC (Continued)

Approach No.	Visual Aids Viewed
7	Unidirectional REILs, elevated lighted X, artificial turf
8	Omnidirectional REILs, elevated lighted X, artificial turf
9	Omnidirectional REILs, in-pavement lighted X, artificial turf
10	Opposite direction approach, no data collected.

Having completed the 10 approaches, the aircraft returned to Boeing Field in Seattle, WA, where those onboard the aircraft met to discuss the approaches.

SEATTLE-TACOMA INTERNATIONAL AIRPORT RESULTS. During the evaluation, it was noted that the in-pavement lighted X looked more like a line of white lights than an X (figure A-21 in appendix A). It was determined that placing the LED and incandescent fixtures together caused this visual appearance, and because the incandescent fixtures were brighter than the LED fixtures, the X looked off balance or like a line. Although the X configuration could not be interpreted by many of those onboard, the pilots reported that they liked having lights flashing on the taxiway pavement, because it made them think twice before landing there. Because the sun glare is so prominent at SEA-TAC; there was concern that the white light could disappear into the pavement during this condition. The possibility of using a different color, such as yellow, was discussed but was not tested. The in-pavement lighted X was visible at approximately 4.5 nautical miles (nm) from the end of the taxiway.

The elevated lighted X performed well, although a few of the incandescent fixtures were not aimed properly towards the final approach path (figure A-22 in appendix A). Consequently, this caused the X to lose some of its configuration. In addition, the prototype in-pavement red LED fixture that was positioned near the X was not visible at all during any of the approaches. This is likely due to its small size. Even though some of the incandescent fixtures on the X were not aimed properly, it was still one of the first visual aid devices to be seen on approach. The possibility of using a faster and crisper flash rate was discussed to enhance the X. The elevated lighted X was visible at 4.5 nm from the threshold.

The colored artificial turf strips were very visible, especially the orange and white, with yellow being the least visible. The brighter artificial turf colors were reported to be visible from almost 5.0 nm from the threshold, but an exact application for the brighter colors was not determined. The green artificial turf blended perfectly with its surroundings (figures A-21 and A-22 in appendix A) and could be used on the shoulder of the taxiway to visually narrow its appearance.

The omnidirectional REILs were found to be more visible than the unidirectional REILs during the approaches. This was because only one unidirectional REIL fixture was visible to the pilot approaching taxiway Tango due to its canted alignment in the opposite direction. The omnidirectional fixtures, however, were always visible during the approach from about 4.5 nm out. Some participants reported that the omnidirectional REILs caught the eye better than the unidirectional REILs, while others stated they did not notice them unless they were looking for them. This was attributed to the large space between the two parallel runways and the parallel

taxiway, where a pilot would have to look significantly to the left to acquire the REILs on runway 16L. After the evaluation was completed, the equipment was removed.

PALM BEACH INTERNATIONAL AIRPORT.

PALM BEACH INTERNATIONAL AIRPORT DISCUSSION. PBI has two parallel runways, 9L/27R and 9R/27L, and a cross runway, 13/31. Runways 9L/27R and 9R/27L have asphalt pavements and are staggered. Runway 9L/27R is primarily used for commercial aircraft, and 9R/27L is only used for general aviation aircraft. The length and width of 9R/27L is 3213 by 75 ft and 9L/27R is 10,008 by 150 ft. A few years ago, the airport installed taxiway Lima, which is parallel to runway 9R/27L and 9L/27R, positioned between the two runways. Taxiway Lima is an asphalt pavement and is wider and longer than 9R/27L, as shown in figure 2.

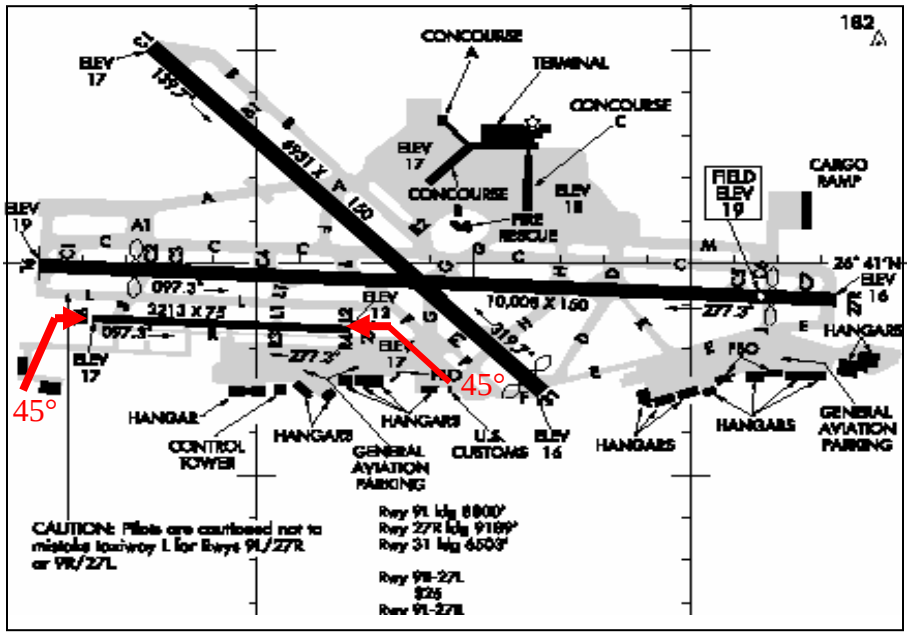


Figure 2. Airport Diagram of PBI

Of the 110 airports cited as having this particular problem, PBI is number one on the list, with approximately 36 reported incidents to date. The incidents occur in both directions on taxiway Lima, typically by general aviation pilots. ATC personnel will request that aircraft operating on 9R/27L approach or depart on a 45-degree-angle base leg or crosswind leg to increase the separation between the smaller general aviation aircraft and the air carrier jets (figure 2). This is done for two reasons: it creates an operational safety buffer, and it reduces the likelihood of potential wake turbulence encounters. The airport authority and ATC manager indicated that they did not believe that this practice contributed in any way to the inadvertent taxiway landings.

Since the construction of taxiway Lima in 1995, pilots have been mistakenly identifying the taxiway for runway 9R/27L. The pilots causing these incidents are PBI-based pilots that are fairly familiar with the airport's geometry. However, pilots have landed on taxiway Lima even when there is equipment on the taxiway.

The airport authority has been very proactive in trying different techniques to mitigate the problem, but has had minimal results. Some solutions that have been tried include posting warnings on aeronautical charts, special text entries in the airport facility directory, and a verbal warning to pilots posted on the airport's ATIS. The airport has also given several briefings to local pilots to heighten their awareness of the situation. On the airport itself, the airport authority installed unidirectional REILs on each end of runway 9R/27L, which are operated 24 hours a day.

On March 2 and 3, 2006, the Visual Guidance Team traveled to PBI to obtain information about the airport's geometry and incidents that have occurred. During this visit, the airport was installing paint markings on taxiway Lima with the word TAXIWAY placed in three different locations along the surface. One marking was positioned at the midpoint of the taxiway facing downwind/south side of the airport (figure A-5 in appendix A), with the other two positioned on each end of taxiway Lima, facing final approach (figures A-6 through A-10 in appendix A). The Team flew an aircraft to get a better understanding of the situation from the pilot's point of view and to see what methods should be tried, since every airport configuration is different (figures A-11 and A-12 in appendix A).

PALM BEACH INTERNATIONAL AIRPORT EVALUATION. On June 6, 2006, the Visual Guidance Team traveled to PBI to temporarily setup and evaluate various visual aids. The Team met with airport personnel to discuss the setup and evaluation activities, this included coordinating runway and taxiway closures, ATC coordination, and escorts onto the airfield. One visual aid device, a temporary elevated lighted X, was intended to be set up at the end of taxiway Lima on the approach end of runway 9R. The airport informed the Team that even though it was a good idea, a water retention ditch was located at the end of taxiway Lima. In the long term, it would not be feasible to put any electrical equipment in that area because the ditch is frequently filled with water. The Team proceeded to test the elevated lighted X at the desired location, with the understanding that this would not be a feasible solution at this location (figure A-23 in appendix A).

Other equipment that was set up were two sets of FAA-approved omnidirectional REILs at both approach ends of runway 9R/27L.

Four strips of artificial turf (green, yellow, white, and orange) were placed on taxiway Lima. In anticipation of future expansions, taxiway Lima (on the approach end of 9R) was constructed in a rectangular shape, which the Team believes makes the taxiway look more like a runway. Since curving the taxiway edge would require major reconstruction of the pavement, it was not a feasible option for the airport. To create the effect of a curved taxiway, the Team decided to use the green artificial turf to cover the pavement within this square area, which would blend in with the surrounding grass and give the appearance of a curved surface. In the event the surface was ever required for runway operation, the artificial turf could be peeled off, revealing the unaltered pavement surface. The remaining three colors of artificial turf were placed at the end of taxiway Lima on the bank of the water retention ditch next to the elevated lighted X for evaluation from the air. The purpose of setting up the remaining three strips of artificial turf was to determine which color was most conspicuous from the air. It was discussed that the creation of a large X or

other shape with this bright material might be used in the prethreshold area of a taxiway or a runway (figures A-24 and A-25 in appendix A).

The final visual aid to be evaluated was the in-pavement lighted X. It was located on the taxiway centerline of taxiway Lima, centered on the word TAXIWAY facing the approach of runway 9R (figure A-26 in appendix A).

As the Team was setting up the equipment on the taxiway, it was learned that the airport's unidirectional REILs were set to operate exclusively on medium intensity. At the time of the evaluation, the Team requested that the airport increase the intensity to high.

The flight evaluation activity started on June 7, 2006, at approximately 10:00 am. Seven approaches were made to runway 9R/27L, six to runway 9R, and one to runway 27L. Due to the structure of the airfield, all the Teams' equipment was positioned west of the Lima/Foxtrot intersection, with the only other equipment being the omnidirectional REILs at the approach end of 27L. Table 3 lists the visual aids that were viewed during each approach.

Table 3. Evaluation of Visual Aids Viewed at PBI

Approach No.	Runway	Visual Aids Viewed
1	9R	Unidirectional REILs (high intensity), artificial turf
2	9R	Omnidirectional REILs, elevated lighted X, artificial turf
3	9R	Omnidirectional REILs, in-pavement lighted X, artificial turf
4, 5, and 6	9R	Viewed the various visual aids to acquire photos and verify acquisition distances
7	27L	Omnidirectional REILs

PALM BEACH INTERNATIONAL AIRPORT RESULTS. PBI's unidirectional REILs were on high intensity and were visible from a distance of about 2.5 nm. Since the Team was approaching the runway at a 45-degree angle, only one REIL fixture was seen at 2.5 nm, and the other fixture was observed while on a close one-half-mile turn to final approach. The artificial turf samples were visible throughout the approach. The green artificial turf blended in with the surrounding grass, creating the illusion that the pavement was not there. The orange and white artificial turf was easily seen at about 4.5 nm, and the yellow artificial turf was not visible until within 1 nm.

PBI's unidirectional REILs were turned off after the first approach and remained off throughout the duration of the evaluation. On approach to 9R, all four omnidirectional REILs were visible from 4.6 nm. The REILs probably could have been seen at a greater distance; however, visibility of the runway is blocked by a string of hangars and buildings constructed along the perimeter of the airport. The Team was able to see all four omnidirectional REILs, giving good presentation of both runway thresholds. The elevated lighted X was visible at 3.2 nm, but it was not until approximately 2.6 nm when the Team determined that the X configuration could be interpreted.

The in-pavement lighted X was visible at 2.6 nm. The light fixtures' narrow beam width limited the acquisition distance of the X configuration, because approaches were being flown at approximately 45 degrees to the taxiway centerline. If the project aircraft had been aligned with the in-pavement lighted X at a greater distance, it is very likely that distances up to 4.8 nm may have been recorded (based on research at SEA-TAC and ACY).

The omnidirectional REILs at runway 27L were seen at approximately 2.0 nm and were harder to locate than when viewed from the runway 9R direction. This was attributed to the more complex background visible from the 27L direction.

LINCOLN AIRPORT.

LINCOLN AIRPORT DISCUSSION. LNK has two parallel runways, 18/36 and 17/35, and a cross runway 14/32 (figure 3). Runway 18/36 has asphalt/concrete-grooved pavement that is 12,901 by 200 ft. Runway 17/35 has asphalt/concrete aggregate friction seal-coated pavement that is 5400 by 100 ft. These two runways are staggered and placed more than 2560 feet apart from each other. Taxiway Alpha is an asphalt pavement surface that is parallel to runway 17/35.

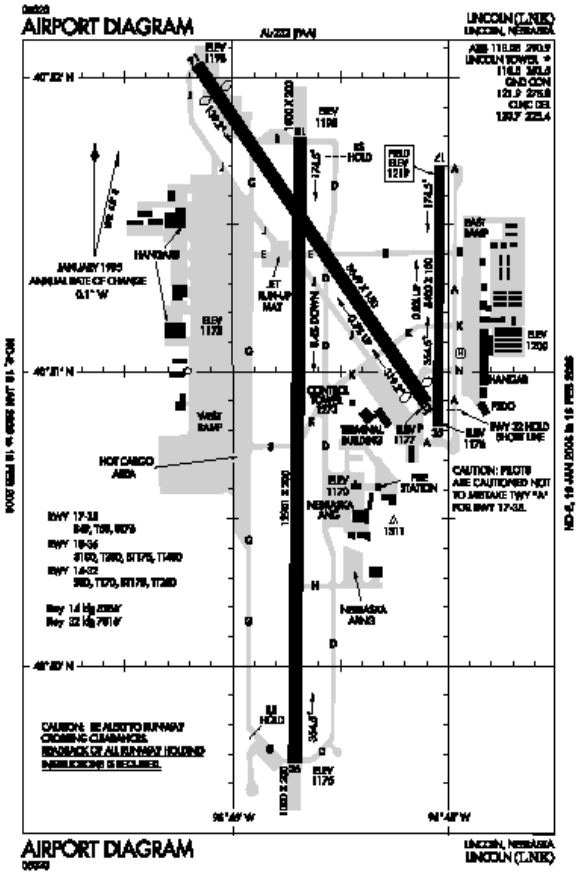


Figure 3. Airport Diagram of LNK

LNK has had 13 incidents to date since taxiway Alpha was constructed. One occurred in January 2004 when an aircraft that was cleared to land on runway 35 lined up with taxiway Alpha and made a touch-and-go on taxiway Alpha at a point abeam to taxiway November. At that same time, another aircraft was in the run-up area at the approach end of runway 35 and was overflown by the aircraft that conducted the touch-and-go. The vertical separation of the two aircraft was approximately 300 ft. A third aircraft was taxiing southbound on taxiway Alpha abeam taxiway Kilo and observed the first aircraft execute the touch-and-go 1000 feet in front of them. This incident was the closest near collision reported in the history of inadvertent taxiway landing events.

LNK personnel have been very proactive in trying different techniques to mitigate the problem. Some of the solutions have included renumbering the parallel runways from 17L/35R and 17R/35L to runways 17/35 and 18/36, respectively; installing a daytime-visible approach lighting system; the application of several different paint markings; the issuance of various verbal warnings (such as broadcasting a notice on ATIS not to mistake the parallel taxiway for the adjacent runway); and written information documents to pilots operating at the airport. In addition, the airport has installed an omnidirectional approach lighting system (ODALS), which they operate during the day. Their most recent effort involved the painting of a serpentine taxiway centerline, the words TAXI ONLY, and a surface-painted taxiway location sign on taxiway Alpha (figures A-13 through A-16 in appendix A). Since these paint markings are nonstandard, LNK personnel requested a modification to standard to markings. Consequently, the Team was tasked to evaluate the paint markings at LNK to determine if the markings were a safety enhancement, or if they should be removed.

LINCOLN AIRPORT EVALUATION. From June 26 to June 28, 2006, the Visual Guidance Team traveled to LNK to perform a thorough review of the taxiway markings installed on taxiway Alpha. The Team made recommendations on whether or not the existing markings should remain in place and determined if anything else could be done to improve the situation. Upon arrival, the Team met with airport personnel to review the history of the inadvertent taxiway-landing project, specifically highlighting the problems at SEA-TAC and PBI and the different visual aid treatments/techniques that had been tested at those airports. Following preliminary discussions, LNK personnel gave a brief synopsis of the past incidents that had occurred and the actions that had been taken in an effort to resolve the situation. In the fall of 2006, LNK personnel was planning to apply the same seal coat material used on runway 35 and taxiway Alpha that would alter the appearance of taxiway Alpha, making both runway 35 and taxiway Alpha appear the same.

After the meeting concluded, the Team returned to the aircraft to fly approaches to runway 35. Approximately 15 approaches were flown over a 2-hour period to observe the runway and taxiway layout and to determine the visual aspects that might be contributing to the inadvertent landings on the taxiway. Photographs and a video were taken from the air to document the findings of the Team. Several approaches were offset from the runway, in alignment with taxiway Alpha, to observe the effects of the paint markings from the air. While most approaches were flown from typical overhead rectangular patterns, several approaches were flown as 6-mile, straight-in approaches to ascertain acquisition distances of the paint markings on the taxiway,

and to compare the runway/taxiway visual cues over a longer distance. Acquisition of the taxiway markings consistently began to occur about 3 miles from the runway.

LINCOLN AIRPORT RESULTS. The TAXI ONLY marking was seen at 2 nm. The Team concluded that the two lines of text were difficult to read on an approach greater than 2 miles out. Removal of the word ONLY would make it easier to read.

The surface-painted taxiway location sign for taxiway Alpha was seen at 3.1 nm. The Team discovered that, on approach, the A designation sign resembled a displaced threshold chevron.

The serpentine taxiway centerline marking was seen at a distance of 1.6 nm. The Team observed that the serpentine centerline provided some enhancement but was not clearly visible from the air.

FINDINGS AND RECOMMENDATIONS

Table 4 shows a summary of the results from this research effort.

Table 4. Acquisition Distance Measurements of the Visual Aids and Markings

Visual Aids	SEA-TAC	PBI	LNK
Elevated lighted X	4.5 nm	3.2 nm /2.6 nm *	N/A
In-pavement lighted X	4.5 nm	2.6 nm	N/A
Omnidirectional REILs	4.5 nm	4.6 nm /2.0 nm ***	N/A
Artificial turf**(orange and white)	5.0 nm	4.5 nm	N/A
TAXI ONLY	N/A	N/A	2.0 nm
Serpentine centerline	N/A	N/A	1.6 nm
“A” taxiway surface location	N/A	N/A	3.1 nm

*The distance that the X configuration was interpreted.
**The purpose of the green artificial turf was to blend in with surroundings. The yellow artificial turf was visible at 1.0 nm.
***The omnidirectional REILs at runway 27L.

Considering the data collected during this research effort, the following conclusions were made.

SEATTLE-TACOMA INTERNATIONAL AIRPORT FINDINGS AND RECOMMENDATIONS.

- The elevated lighted X appears to be a simple, quick tool that could be easily fitted to the airport’s existing elevated metal X with minimal effort. The major requirement would be the trenching of electrical service to the location of the X.

- The Team learned that any surface treatment, such as paint or seal coating, did not overcome the excessive sun glare at SEA-TAC, because the green artificial turf is a viable way to visually limit the size of taxiway Tango, without using paint or removing

concrete. The artificial turf can accomplish this task by altering the surface of the pavement, without losing the weight-bearing capacity of the taxiway shoulder.

- The Team concluded that the continued use of ATIS messages, chart publications, and training should be the first line of defense in preventing the problem.

- Installing omnidirectional REILs would be an additional enhancement for locating the runways.

PALM BEACH INTERNATIONAL AIRPORT FINDINGS AND RECOMMENDATIONS.

- The airport's existing REILs were far more effective at high intensity than at medium intensity.

- The omnidirectional REILs, while operated at high intensity, far outperformed the unidirectional REILs on an equal intensity, because each fixture was visible regardless of the 45-degree offset approach angle made to runway 9R or taxiway Lima.

- The green artificial turf was very effective at masking the squared pavement surface of taxiway Lima. This would be an easy way to visually remove the excessive pavement from view of the pilot, making it look less like a runway.

- Of the artificial turf colors evaluated, the orange and white were the most favored colors for catching the pilot's attention.

- The elevated lighted X performed well and offered a significant warning (from more than 2 nm out) of a closed section of pavement that was not intended for landing. Due to terrain limitations at PBI, the elevated lighted X was not appropriate for this situation.

- The in-pavement lighted X performed well and offered a distinct symbol that showed the area is not for landing. Even at PBI, where pilots may not be approaching from long, straight-in final approaches, it offered at least 2 nm of warning that the pavement they are approaching is closed for landing. The benefit of this item is that, in situations such as those found on runway 27L where there is no room for an elevated lighted X or a prethreshold warning device to be constructed, the in-pavement lighted X can be imbedded in the pavement.

- The airports TAXIWAY paintings were visible when very close (within 2 nm) to approaching the airport or while on a close downwind leg approach to runway 9R/27L. While performing these approaches, however, the Team noticed several times that the paint markings of the word TAXIWAY were not visible, due to the sun fading the yellow-painted letters.

LINCOLN AIRPORT FINDINGS AND RECOMMENDATIONS.

- Removal of the boxed A painted designation is recommended, since it looks too much like a displaced threshold chevron. This paint marking may be making the situation worse, since the character A with its arrow-like resemblance, potentially draws the pilot's attention to the hold line that is just beyond it on the taxiway, creating a visual illusion that it is a runway.

- The word ONLY in the TAXI ONLY paint marking should be removed, since the word TAXI is sufficient for the intended task. The two lines of text make it very hard to read on approach from greater than 2 nm. A single line of text, perhaps in a larger character size, would be much more effective at further distances. In addition, larger black borders, or perhaps the seal coating of the surface area, would greatly enhance the yellow paint on the light concrete surface. Other airports experiencing similar problems (such as Palm Springs International Airport and McCarren International Airport) have had success by using the word TAXI or TAXIWAY.

- The hold line for runway 32 at the south end of taxiway Alpha should be changed from being perpendicular to the centerline of taxiway Alpha, to an angle that more closely parallels runway 32. Angling this hold line paint marking, at any distance, would distort the appearance that the line represents a possible runway threshold marking, especially with the large arrow-like A preceding it. Making any markings on the taxiway asymmetrical, or at least angling them, would create an abnormal visual for the approaching pilot, and likely cause them to question what they are looking at. Similarly, the word TAXI, which was discussed in the previous bullet, could be similarly angled with the new hold line.

- The serpentine taxiway centerline marking provides some enhancement of the taxiway surface, but was not significantly visible from the air. The marking was only visible within 1.6 nm of the taxiway. The problem lies in the fact that the marking passes across the taxiway perpendicular to the approach path, which makes the narrow stripe hard to see. To be visible, the width of the marking would have to be significantly increased, which is just not feasible to do.

- The ODALS installation on runway 35 was very beneficial in highlighting the runway 35 threshold and should remain in operation.

- The runway lights for runway 35 were on throughout the course of this evaluation, but were ineffective in identifying the runway during daylight conditions. They are not needed for runway identification, since the ODALS sufficient to highlight the runway.

- The geometrical design of taxiway Alpha at the southernmost end may be the single-most contributor to the inadvertent landing problem. The run-up pavement area ideally should be differentiated from the taxi area pavement, since it visually makes the taxiway look like a runway landing surface. As shown in figures 2 and 3, the large area of pavement, along with the way its edges slope in to join the edges of taxiway Alpha, make it look

almost identical to the way the taxiways lead into runway 35. Research has shown that the most common factor contributing to taxiway landings is the squared-off threshold (typically done in anticipation of future expansion and construction). One possible solution for this situation at LNK would be to seal coat the taxiway surface up to the curved taxiway edge line, and then possibly a year later, seal coat the run-up area. This would make the two pavement surfaces vary in color. The Team recommended that removing the run-up area would be ideal, but realized that this would not be acceptable to the airport authority.

GENERAL SOLUTIONS FOR ALL AIRPORTS.

The following solutions can be applied to any airport experiencing this problem:

- Airports should avoid constructing taxiways that may be confused as runways. It was found that the complex geometry of runways and taxiways was a major causal factor for inadvertent taxiway landings. The most common problem was located at airports where the approach side of a taxiway was constructed in a squared fashion to facilitate future expansion. This squared edge inadvertently made the taxiway look more like a runway with a squared threshold.

- Special notes or modifications to ATIS, aeronautical charts, and special training material are valuable solutions that are easy to apply and are of minimal cost to implement. For example, a recorded message stating: "Do not mistake taxiway Lima for runway 9R" on the ATIS system may make the pilot aware of the problem at the particular airport. This solution should be the first line of defense if an airport is experiencing this problem.

- Locating an elevated lighted X at the prethreshold area of the taxiway is a simple solution to implement and is readily available through airport lighting manufacturers. It provides a clear signal to pilots on approach that the area is closed and is not safe for landing. The cost to install is minimal to moderate; the only possible high-end cost would be if trenching of electrical service to the location of the X is needed.

- The installation or replacement of directional REILs with FAA-approved omnidirectional REILs would be an additional enhancement for the runway environment, as it would draw attention to the landing surfaces when the pilot first visually acquires the airport environment. It is readily available through lighting manufacturers and is easy to install.

- If an airport has a squared-off taxiway threshold or wide taxiway shoulders, a viable solution to either visually rounding or limiting the size of a taxiway, is to apply green artificial turf to the surface pavement. This can be accomplished without the use of paint or the removal of concrete. The artificial turf will blend in with the surrounding grass area; however, it can be a very expensive solution if it needs to cover a large area.

- The in-pavement lighted X offers a distinct symbol that the area is not for landing. The benefit of this visual aid is that, in situations where there is no room for an elevated lighted X or a prethreshold warning device to be constructed, the in-pavement lighted X

can be imbedded in the pavement. The fixtures are placed so far apart from each other that it will not give the pilot on the ground any mixed signal. This solution is very expensive to implement and would require pavement to be cut and wires to be installed.

The following list is an overall summary of the solutions and the cost to implement:

- ATIS, aeronautical charts, and training—$0 to $1,000
- Elevated lighted X—$0 to $5,000
- Omnidirectional REIL—$1,000 to $5,000
- Green artificial turf—$10,000 +
- In-pavement lighted X—$10,000 +

APPENDIX A—EVALUATION PHOTOGRAPHS

Figures A-1 through A-29 show evaluation photographs of Seattle-Tacoma International Airport (SEA-TAC), Palm Beach International Airport (PBI), and Lincoln Airport (LNK).

Figure A-1. View of SEA-TAC on Approach to Taxiway Tango (on the Right) and the MALSR System Illuminated on Runway 16L (on the Left)

Figure A-2. Distant View of SEA-TAC Showing Aircraft Aligned With Taxiway Tango on the Right

Figure A-3. Sun Glare on Black Surface Treatment (SEA-TAC)

(a)

(b)

(c)

(d)

Figure A-4. Mitre's Surface Treatment Solutions (SEA-TAC)

Figure A-5. View of PBI Taxiway Marking, Downwind

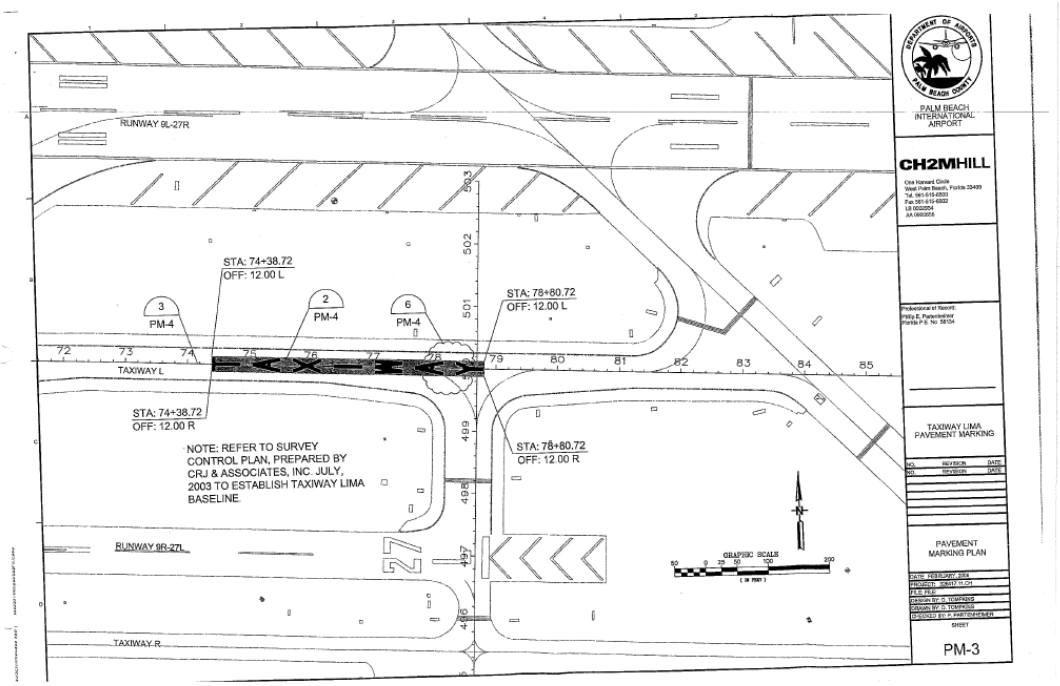


Figure A-6. Dimensions for Taxiway Lima Markings (PBI)

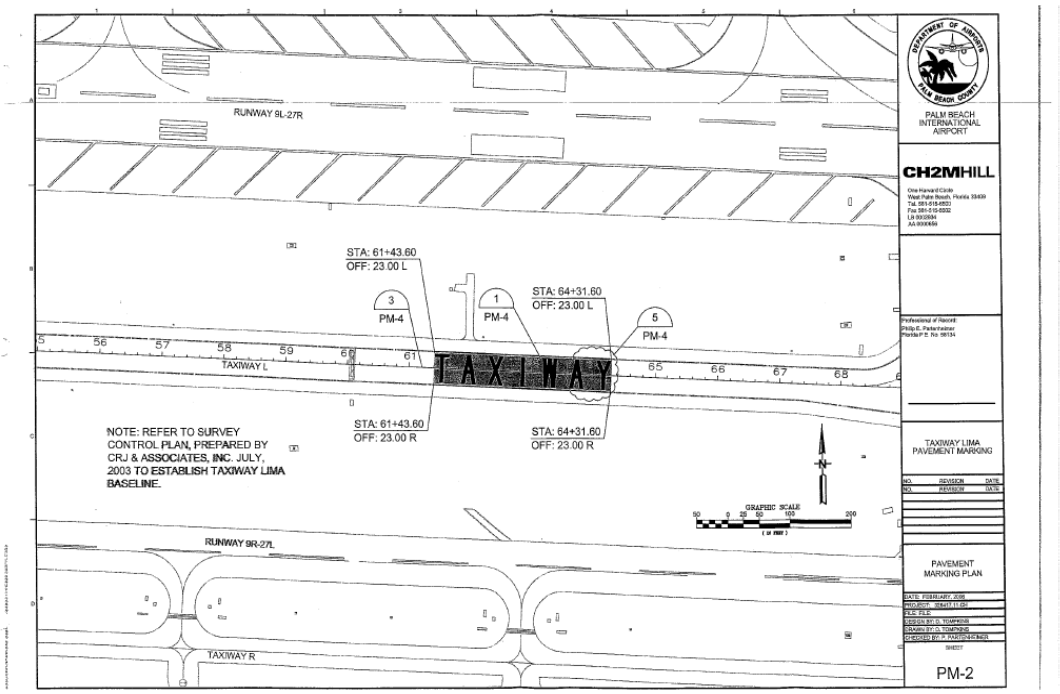


Figure A-7. Dimensions for Taxiway Lima Markings Facing Downwind (PBI)

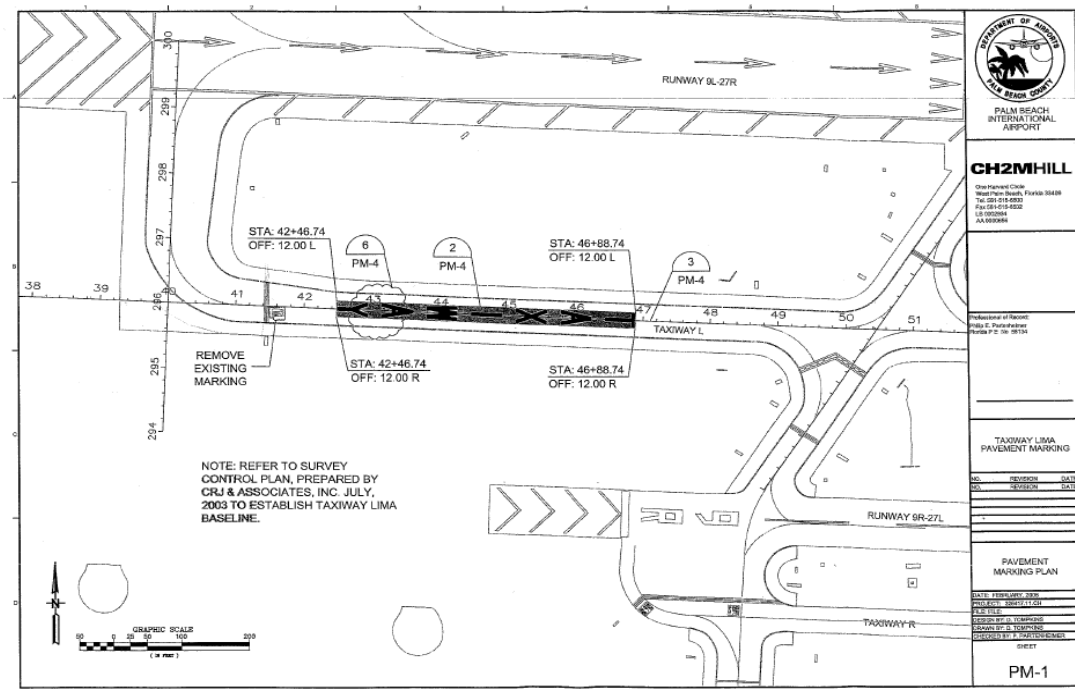


Figure A-8. Dimensions for Taxiway Lima Markings at the Approach End of Runway 9R (PBI)

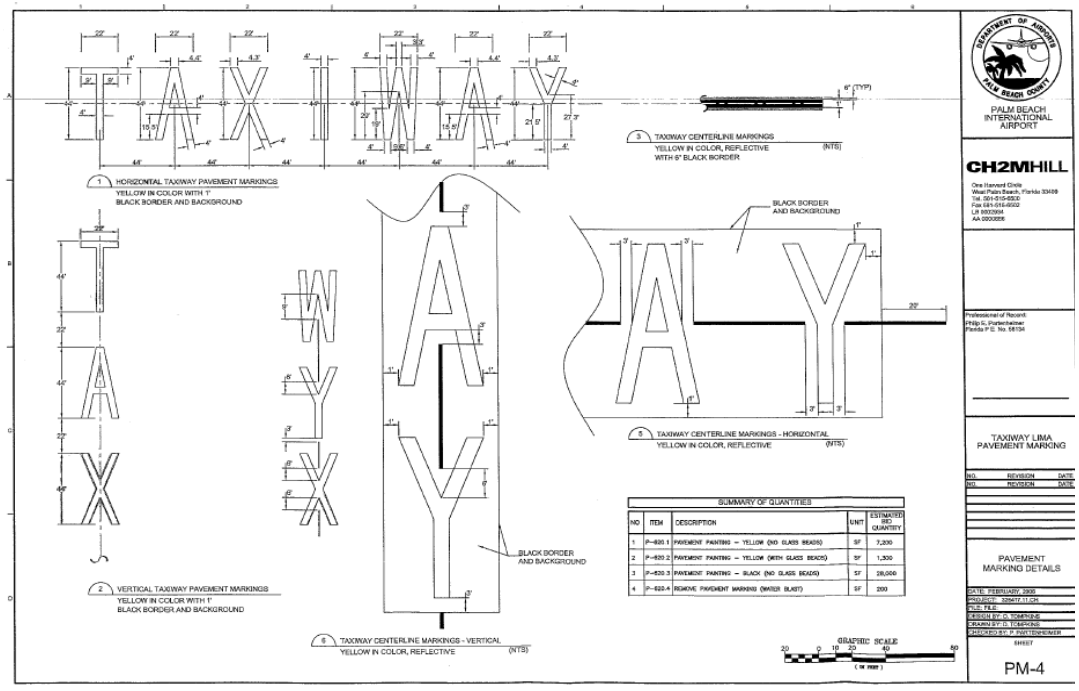


Figure A-9. Dimensions for the Word Taxiway (PBI)

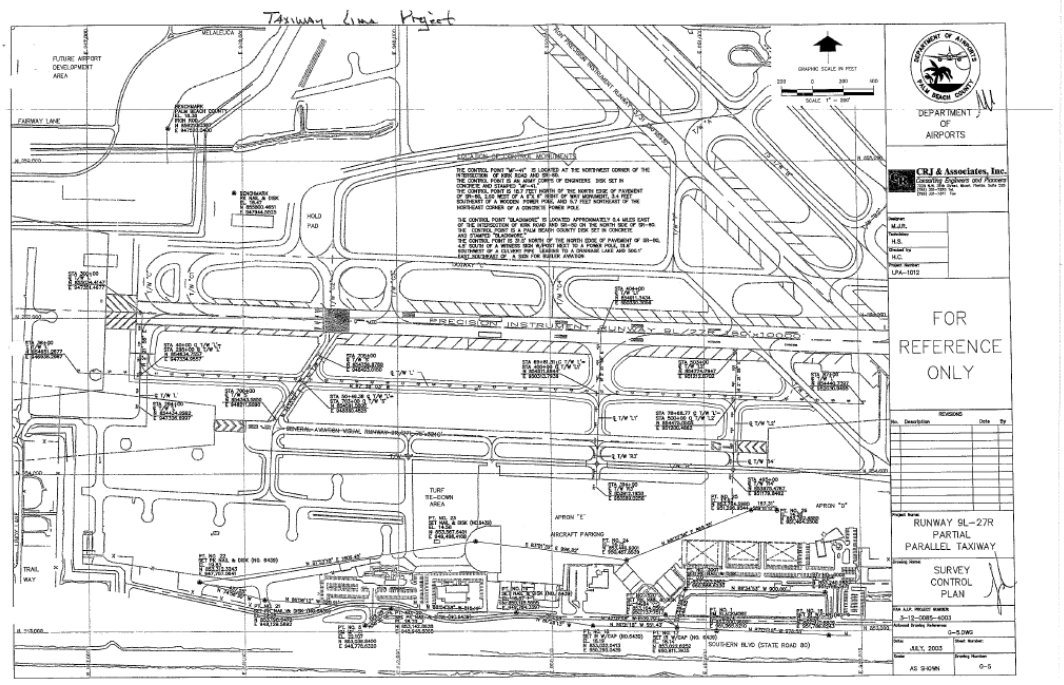


Figure A-10. Layout of Palm Beach Airport (PBI)

Figure A-11. Aircraft on a 45-Degree Approach Angle to Runway 9R (PBI)

Figure A-12. Aircraft on a 45-Degree Approach Angle to Runway 27L (PBI)

Figure A-13. Nonstandard Paint Markings on Taxiway Alpha at Lincoln Airport (LNK)

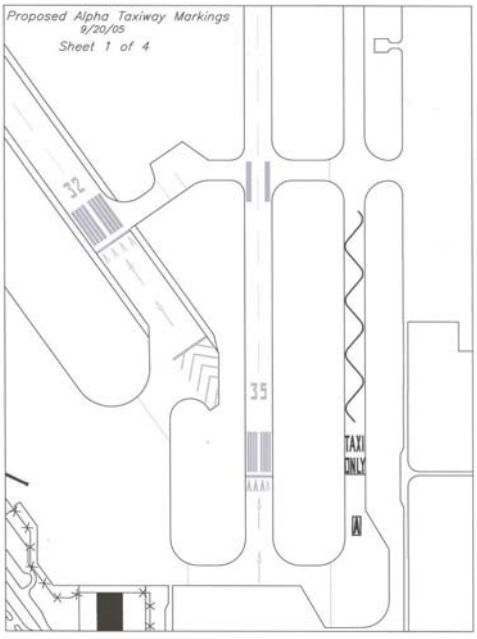


Figure A-14. Taxiway Alpha and Runway 35 With Nonstandard Taxiway Markings (LNK)

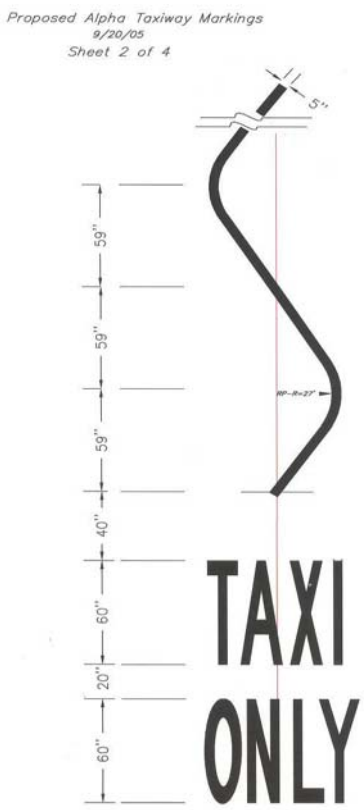


Figure A-15. Dimensions of Markings on Taxiway Alpha (LNK)

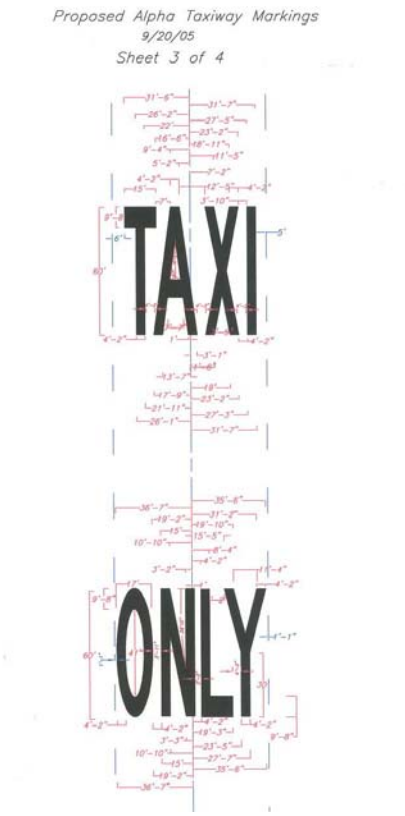


Figure A-16. Dimensions of Nonstandard Paint Markings on Taxiway Alpha (LNK)

(a) (b)

Figure A-17. (a) Elevated Lighted X on Ground and (b) High-Intensity Light-Emitting Diode Sample (LNK)

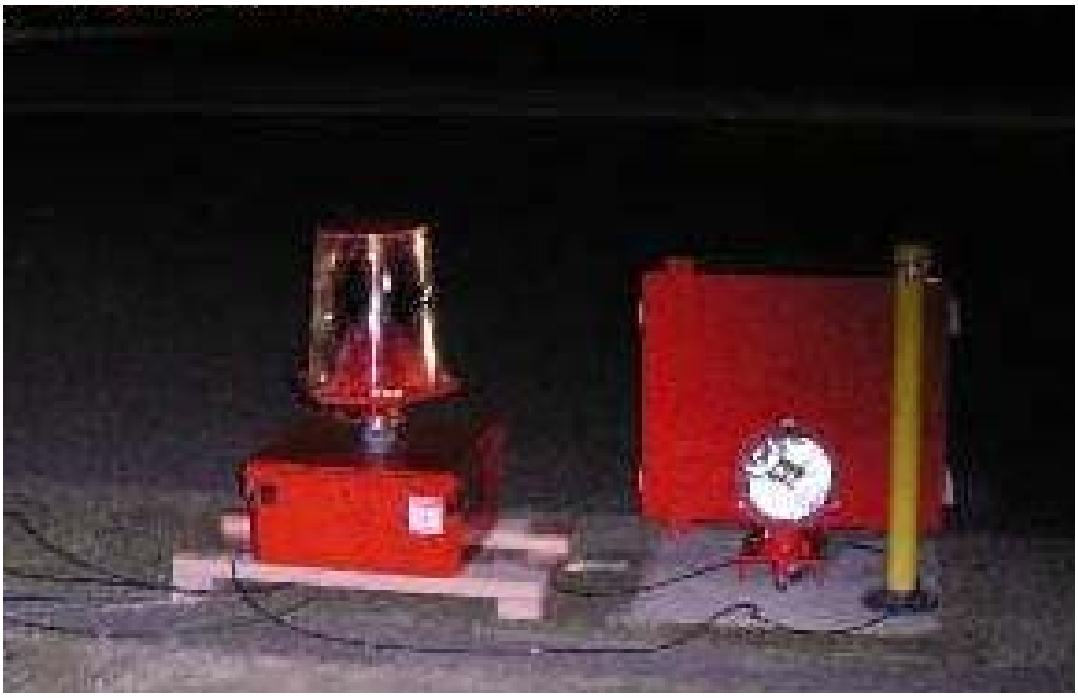
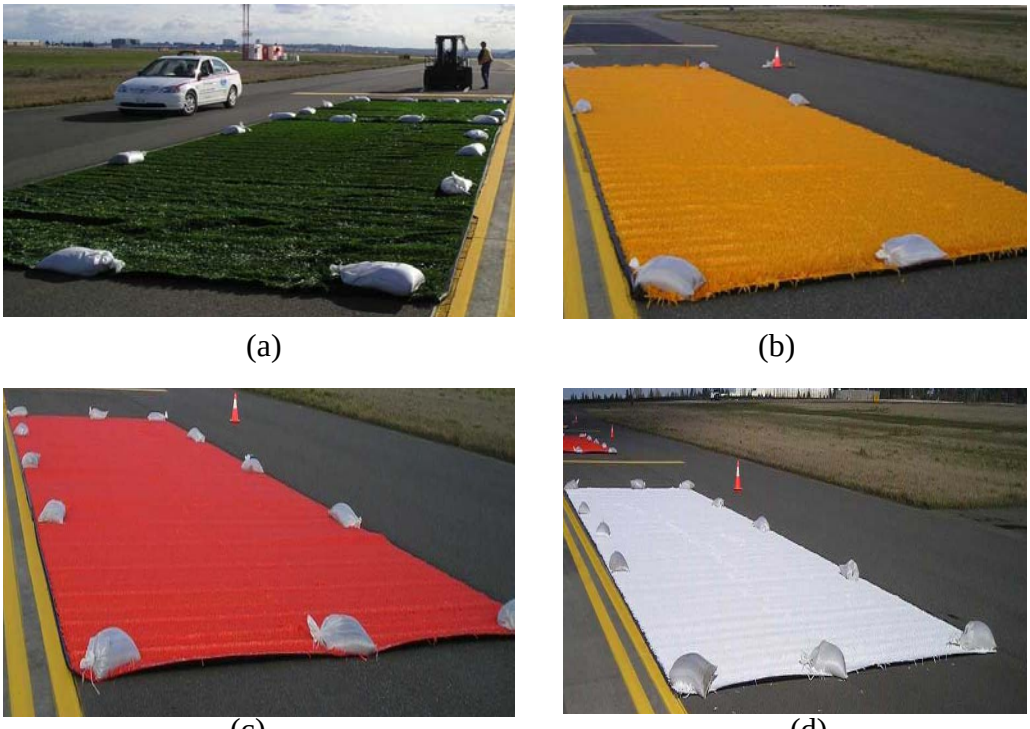


Figure A-18. Omnidirectional REIL and Unidirectional REIL (LNK)



(a) (b)

(c) (d)

Figure A-19. Details of Artificial Turf Installation (LNK)

Figure A-20. In-Pavement Lighted X on Taxiway Tango (SEA-TAC)

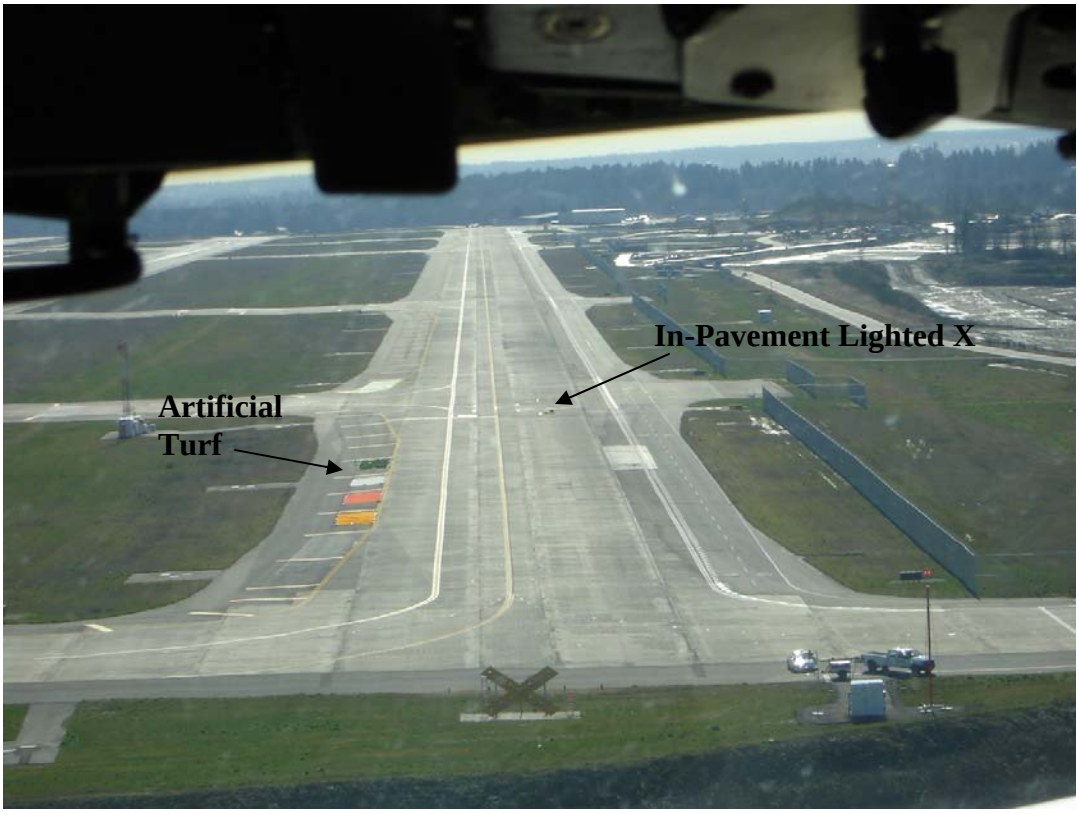


Figure A-21. In-Pavement Lighted X in Operation With Artificial Turf on the Left Shoulder of Taxiway Tango (SEA-TAC)

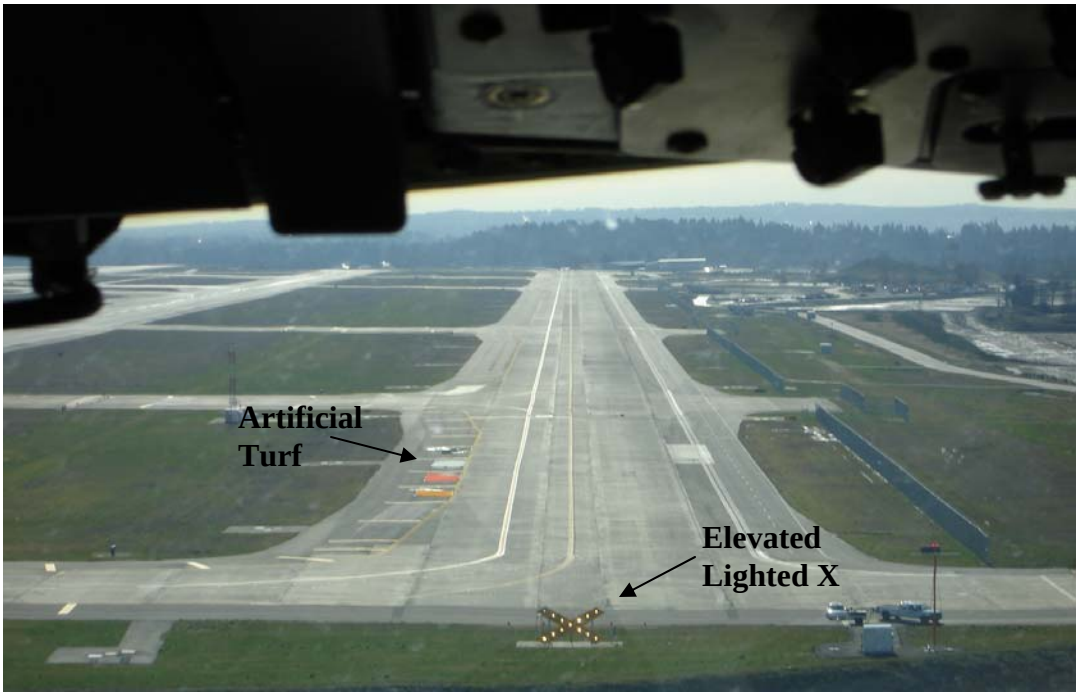


Figure A-22. Elevated Lighted X and Artificial Turf Material (SEA-TAC)

Figure A-23. Temporary Elevated Lighted X in Water Retention Ditch (PBI)

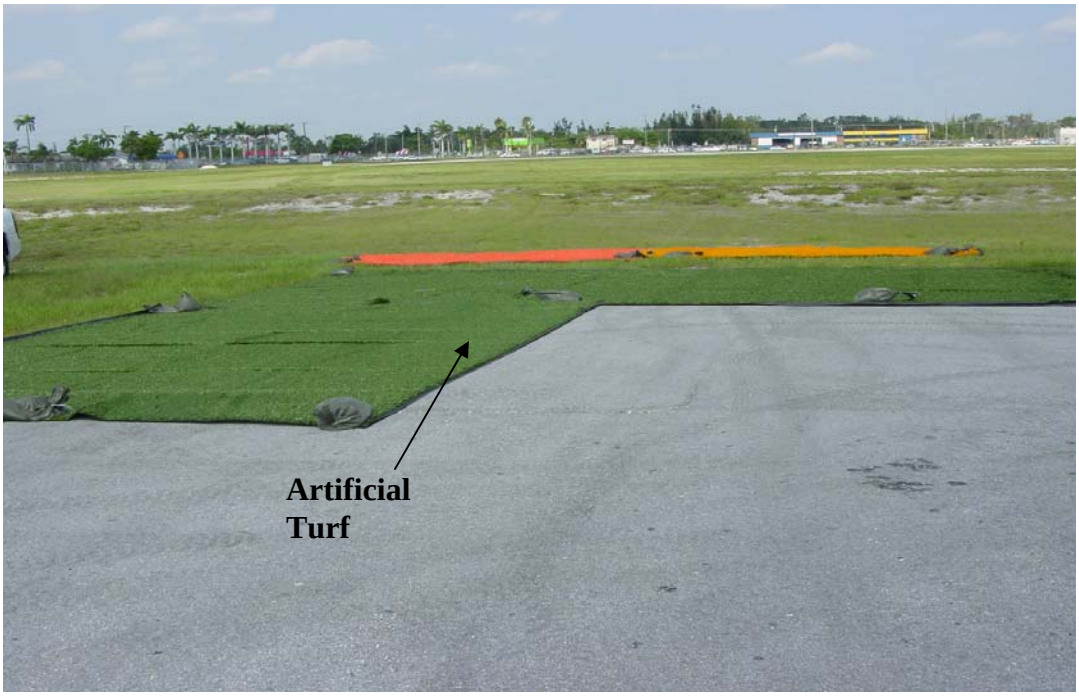


Figure A-24. Artificial Turf in Position on Taxiway Lima (PBI)

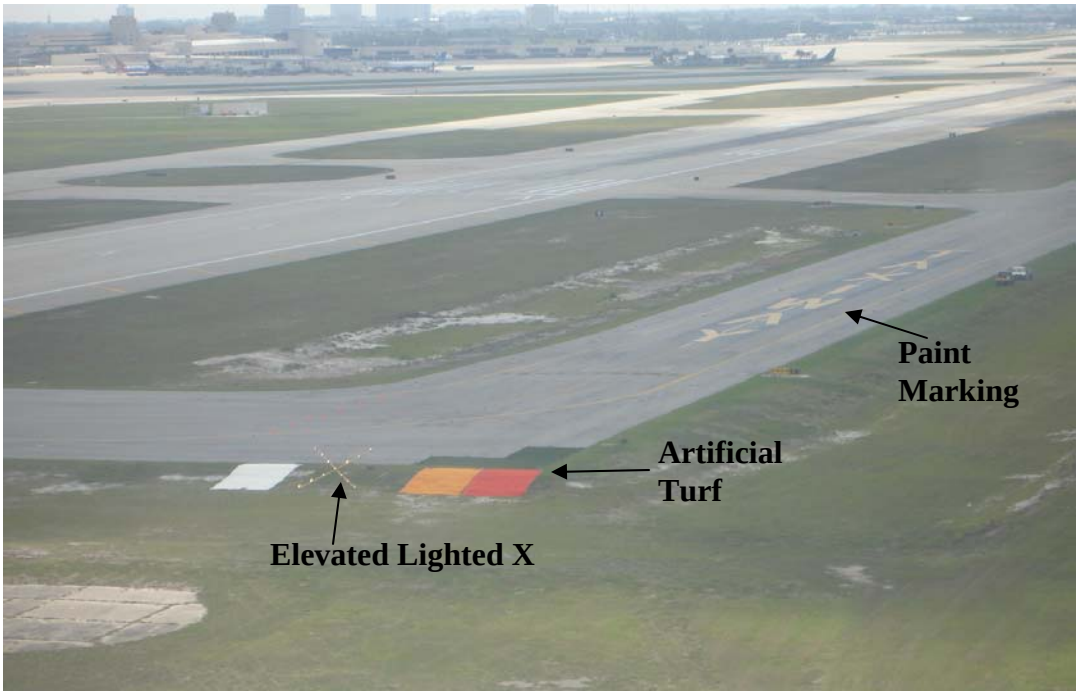


Figure A-25. Closer View of Artificial Turf, Elevated Lighted X, and Paint Marking (PBI)

Figure A-26. In-Pavement Lighted X Illuminated on Taxiway Lima (PBI)

Figure A-27. Straight-In Approach to Runway 35 With Taxiway Alpha on the Right (LNK)

Figure A-28. Aircraft on 6-Mile Approach to Taxiway Alpha (LNK)

Figure A-29. Off-Set Alignment Approach to Taxiway Alpha (LNK)

APPENDIX B—AIRPORT LIST

No.	Airport	Airport ID	No. of Incidents	Date of Events
1	Palm Beach International Airport	PBI	36	4/25/95, 9/15/96, 9/1996, 5/21/97, 5/26/99, 7/8/99, 2/21/00, 9/7/04, 10/16/04, 1/11/05,7/7/05,7/7/05,8/21/05, 8/22/05, 1/5/06, 1/16/06, 2/5/06, 2/7/06, 2/11/06, 2/18/06, 2/25/06,4/17/06, 4/18/06, 10/15/06, 10/22/06, 10/26/06, 1/9/07, 3/2/07, 3/5/07,4/15/07, 4/18/07,4/27/07, 6/13/07, 6/18/07, 7/15/07, 7/28/07, 7/22/07
2	Lincoln Airport	LNK	13	5/24/95, 8/22/95, 4/13/97, 4/1998, 4/3/98, 10/2/99, 12/19/01, 4/2/02, 9/14/03,1/11/04, 2/14/04, 2/17/05,4/12/06, 12/23/06
3	San Antonio International Airport	SAT	11	9/92, 2/10/96, 5/30/96, 10/31/96, 9/17/97, 9/25/98, 7/7/99, 9/5/99, 1/5/00, 4/1/02, 6/14/02
4	Phoenix Deer Valley Airport	DVT	10	08/1990, 09/1990, 10/1991, 7/1992, 7/1992, 9/1992, 10/1/97, 10/8/99, 12/1999, 8/14/2005
5	Seattle-Tacoma International Airport	SEA-TAC	7	12/1999, 12/2/2000, 3/14/2003, 1/10/2004, 1/19/2004, 2/24/2004, 1/30/2005
6	Las Vegas International Airport	LAS	7	10/1993, 12/1993, 9/21/95, 4/26/97, 10/29/97, 10/30/97, 11/5/97
7	Memphis International Airport	MEM	6	10/1991, 1/31/1996, 3/2/1997, 9/14/99, 10/25/02, 10/4/04
8	Merrill Field Airport	MRI (AMR)	6	5/20/03, 10/18/03, 5/20/04, 6/3/05, 5/23/06, 7/10/06
9	Tucson International Airport	TUS	5	5/1992, 1/17/97, 12/2/02, 7/13/2005, 11/19/2005
10	Centennial Airport	APA	5	8/2/96, 1/16/97,1/1997, 1/6/05, 1/16/07

No.	Airport	Airport ID	No. of Incidents	Date of Events
11	Palm Springs International Airport	PSP	5	10/4/96, 12/21/99, 5/20/00, 1/15/00, 2/24/07
12	Dekalb-Peachtree Airport	PDK	4	2/18/1990, 10/17/98, 11/1/04, 1/11/05
13	Fort Worth Meacham International Airport	FTW	4	5/31/02, 10/9/02, 11/16/02, 12/4/02
14	Jeffco Airport	BJC	4	7/16/95, 2/4/96, 2/2000, 2/13/01
15	Fresno Yosemite International Airport	FAT	4	9/8/1988, 12/1991, 1/11/97, 5/12/01
16	Flying Cloud Airport	FCM	4	7/6/98, 8/20/99, 6/26/01, 7/6/06
17	Daytona Beach International Airport	DAB	4	03/1994, 6/9/1995, 02/1999,9/15/06
18	Anchorage International Airport	ANC	4	1/7/04, 3/6/05, 8/29/2006, 9/26/2006
19	Indianapolis International Airport	IND	4	6/16/98, 10/1/99, 5/3/01, 10/13/06
20	Portland International Airport	PDX	3	9/4/97, 7/22/03, 7/2003
21	Burke Lakefront Airport	BKL	3	03/1993, 02/1993, 11/1995
22	Spirit of St. Louis Airport	SUS	3	5/22/99, 5/11/00, 6/6/00
23	Lakeland Linder Regional Airport	LAL	3	4/1997, 2/14/00, 4/3/03
24	John Wayne Airport Orange County	SNA	3	7/1/97, 11/12/97, 7/17/2005
25	Newark Liberty International Airport	EWR	3	3/23/04, 3/2004, 4/18/2005, 4/16/2005
26	Orlando Sanford International Airport	SFB	3	1/11/02, 12/13/01, 3/25/06
27	Juneau International Airport	JNU (AJN)	3	12/19/02, 12/27/03, 12/2003
28	Capital City Airport Lansing	LAN	3	10/11/2005, 6/17/06, 7/20/2006
29	Essex County Airport	CDW	3	12/1991, 8/9/96, 12/10/06
30	Nashville International Airport	BNA	2	10/17/03, 10/28/03
31	Washington Dulles International Airport	IAD	2	6/13/95, 12/18/97
32	Reno-Tahoe International Airport	RNO	2	5/18/90, 7/23/93
33	Philadelphia International Airport	PHL	2	08/1990, 05/1991

No.	Airport	Airport ID	No. of Incidents	Date of Events
34	Dupage Airport	DPA	2	5/10/00, 5/15/01
35	Boise Air Terminal Airport	BOI	2	5/15/98, 2/16/01
36	North Las Vegas Airport	VGT	2	8/1991, 2/6/00
37	Dayton International Airport	DAY	2	2/7/01, 11/5/02
38	Ontario International Airport	ONT	2	4/2002, 5/3/02
39	Hartsfield Jackson Atlanta International Airport	ATL	2	7/4/02, 7/2002
40	Jackson Hole Airport	JAC	2	9/14/04, 4/19/05
41	Salt Lake City International	SLC	2	1/1990, 12/8/2005
42	Wiley Post Airport	PWA	2	11/26/98, 11/1998
43	Chicago Midway International Airport	MDW	2	11/16/97, 5/20/07
44	Eagle County Regional	EGE	1	5/23/2005
45	Denver International Airport	DEN	1	8/20/05
46	Chandler Municipal	CHD	1	3/30/96
47	Raleigh Durham International Airport	RDU	1	8/19/97
48	Martha's Vineyard Haven Airport	MVY	1	8/3/05
49	Greenville Spartanburg Airport	GSP	1	5/24/98
50	Dallas Love Field Airport	DAL	1	1/5/99
51	Phoenix Sky Harbor Airport	PHX	1	4/7/99
52	Tampa International Airport	TPA	1	5/10/00
53	Pittsburgh International Airport	PIT	1	7/23/99
54	Syracuse Hancock International	SYR	1	8/30/99
55	Chino Airport	CNO	1	10/25/99
56	Harrison Marion Regional Airport	CKB	1	9/2/00
57	Santa Barbara Municipal Airport	SBA	1	1/9/00
58	Bethel Airport	BET	1	10/23/00
59	Detroit Metro Wayne County Airport	DTW	1	1/22/01
60	Richard Lloyd Jones Jr. Airport	RVS	1	2/8/00
61	Fort Lauderdale Executive Airport	FXE	1	2/16/05
62	Newport News Williamsburg International Airport	PHF	1	8/23/01

No.	Airport	Airport ID	No. of Incidents	Date of Events
63	Natrona County International	CPR	1	12/28/02
64	Mc Clellan Palomar	CRQ	1	10/19/03
65	Bob Hope Airport	BUR	1	9/10/01
66	Gulfport Biloxi International	GPT	1	12/28/02
67	Baltimore-Washington International Airport	BWI	1	6/12/04
68	Long Island Mac Arthur Airport	ISP	1	4/25/02
69	Meadows Field Airport	BFL	1	5/11/03
70	Hector International Airport	FAR	1	12/22/04
71	San Francisco International	SFO	1	6/14/02
72	San Carlos Airport	SQL	1	6/9/00
73	Wittman Regional Airport	OSH	1	7/18/95
74	Lubbock Preston Smith International Airport	LBB	1	9/1/04
75	Eppley Air Field Airport	OMA	1	11/10/02
76	Willow Run Airport	YIP	1	8/10/01
77	Spokane International Airport	GEG	1	3/22/03
78	Napa County Airport	APC	1	9/1988
79	Johnson County Executive Airport	OJC	1	4/1994
80	Gerald R Ford International	GRR	1	9/1989
81	Grand Prairie Municipal Airport	GPM	1	7/1996
82	Fairbanks International Airport	FAI	1	8/1992
83	General Mitchell International Airport	MKE	1	3/14/96
84	Brown Field Municipal Airport	SDM	1	2/1998
85	Colorado Springs Muni Airport	COS	1	9/1992
86	Sarasota Bradenton Airport	SRQ	1	6/1990
87	Montgomery Field Airport	MYF	1	5/1999
88	Livermore Municipal Airport	LVK	1	9/1991
89	Hobby Airport	HOU	1	6/1990
90	Snohomish County Airport	PAE	1	10/1999
91	Barnstable Municipal Airport	HYA	1	3/12/1988
92	Sonoma County Airport	STS	1	8/1990
93	Chicago O'Hare Intl. Airport	ORD	1	10/1988
94	Manassas Regional Airport	HEF	1	2/23/95
95	Valdosta Regional Airport	VLD	1	10/2003

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96	San Jose International Airport	SJC	1	12/1993
97	Elizabeth City Regional Airport	ECG	1	5/4/1993
98	Cheyenne Regional Airport	CYS	1	7/18/95
99	Ellington Field Airport	EFD	1	3/2001
100	Lafayette Regional Airport	LFT	1	09/14/2005
101	Camarillo Airport	CMA	1	10/2005
102	Charlotte/Douglas International Airport	CLT	1	12/3/2005
103	Fort Lauderdale/Hollywood Airport	FLL	1	12/9/2005
104	Pueblo Memorial Airport	PUB	1	4/1/2006
105	Theodore Francis Green State Airport	PVD	1	5/5/06
106	Norwood Memorial Airport	OWD	1	5/25/2006
107	St. Cloud Regional Airport	STC	1	3/14/07
108	Outagamie Co. Airport	ATW	1	5/12/07
109	Port Columbus International Airport	CMH	1	5/17/07
110	Logan International Airport	BOS	1	6/22/07