Definition, Testing, and Application of Instrument Landing System Critical Areas

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ABSTRACT

Instrument Landing System (ILS) Critical Areas are areas near the radiating antenna system that must be protected from moving or temporarily stationary objects that may affect the quality of the radiated guidance signals. These areas and their protection requirements have been defined in the International Civil Aviation Organization's Annex 10 document for many years. However, there is a continuing need for additional definition and validation of critical area sizes and more detailed operations policy for application of ILS critical areas.

Some issues necessitating additional assessment of ILS critical areas include new ILS antenna systems, larger aircraft, continual pressure for increased airport capacity resulting in changes in runway and taxiway layout, airline requests for lower visibility operations on existing ILS installations, and increasingly challenging multipath environments. Any proposed changes to critical area definitions and operational policies require modeling, validation by flight inspection, or both.

This paper discusses recent (late 2003) ILS critical area activities, studies, and policies in the United States National Airspace System. It presents simulation and flight inspection results of various critical area applications, and highlights the need for an update to the existing criteria and operational policies.

INTRODUCTION

ILS Critical Areas are areas near the Localizer (LOC, azimuth guidance) and Glide Path (GP, elevation guidance, also known as Glide Slope) radiating antenna system that must be protected from moving or temporarily stationary objects that may affect the quality of the radiated guidance signals. The objects act as reflectors of the navigation guidance information in unwanted directions. The effect of the reflections is a contamination of the guidance, generally in the form of bends in the electronic course.

On most airfields, signs are placed along critical area boundaries. Where a boundary crosses a taxiway or runway, it is marked by special paint symbols on the surface and by lighted signs near the edge of the surface. Air Traffic Control (ATC) personnel protect the critical areas during periods of low visibility.

The International Civil Aviation Organization (ICAO)[1] publishes typical examples of critical area sizes for varying conditions. However, their sizes and shapes vary with the type of antenna system radiating the landing guidance, the size and position of the reflecting object, and the extent to which aircraft rely on the ILS guidance, i.e., Category of Operation – Cat I, II or III, with III being most demanding. As a result, formal definition of size to accommodate these variables is left to individual member countries. In the U.S., ILS critical areas are defined in Federal Aviation Administration (FAA) Order 6750.16, Siting Criteria for Instrument Landing Systems.[2]

The FAA is currently revising Order 6750.16, and critical area definitions and their application are being updated. There are many reasons for the update, including new and larger aircraft, more antenna systems used for ILS guidance, increasingly challenging taxiway and runway geometries, routine reliance on ILS signals even in good weather, and increased demand for low-visibility ILS usage based on advanced aircraft equipage, on runways originally intended for higher visibility operations.

This paper reviews the U.S. critical area issue, and concludes a need exists to redefine critical area sizes, aircraft classification methods, and implementation procedures.

BACKGROUND & DEFINITIONS

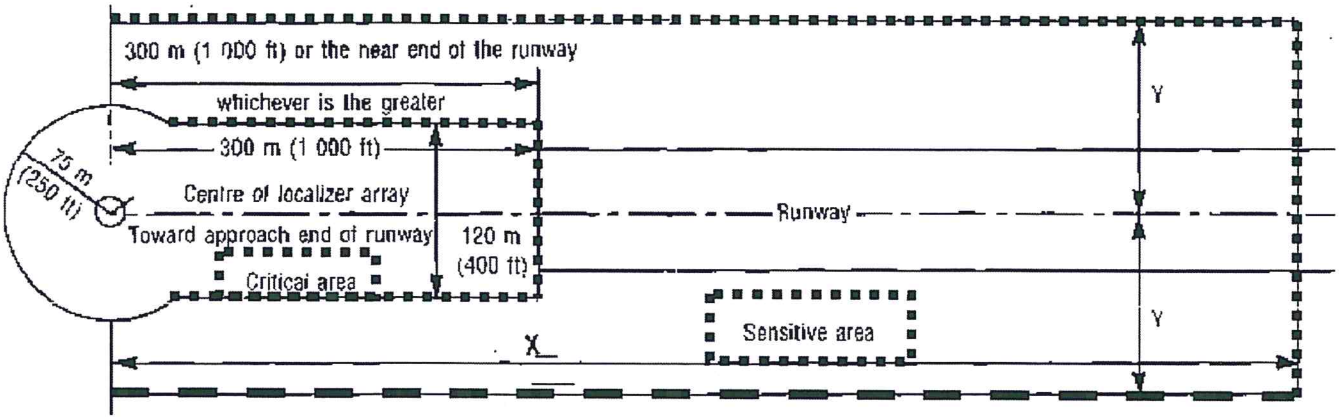
The need for protected areas around ILS antenna systems is discussed in ICAO Annex 10, Attachment C, paragraph 2.1.10. ICAO defines two classes of protected areas as follows:

1. *The ILS critical area is an area of defined dimensions about the localizer and glide path antennas where vehicles, including aircraft, are excluded during all ILS operations. The critical area is protected because the presence of vehicles and/or aircraft inside its boundaries will cause unacceptable disturbance to the ILS signal-in-space.*

2. *The ILS sensitive area is an area extending beyond the critical area where the parking and/or movement of vehicles, including aircraft, is controlled to prevent the possibility of unacceptable interference to the ILS signal during ILS operations. The sensitive area is protected against interference caused by large moving objects outside the critical area but still normally within the airfield boundary.*

The ICAO typical critical and sensitive area sizes for Boeing 747 and 727 aircraft on a runway using typical LOC antenna systems are shown in Figure 1.

In some countries, including the U.S., the term "critical area" refers to both of the ICAO areas. Figure 2 shows the U.S. LOC critical area (roughly analogous to ICAO's critical and sensitive area) for the B-747 in Category II and III operating conditions.



		Example 1	*Example 2*	*Example 3*
Aircraft type		B-747	B-747	B-727
Localizer antenna aperture		Typically 27 m (90 ft) (Directional dual freq., 14 elements)	Typically 16 m (50 ft) (Semidirectional, 8 elements)	Typically 16 m (50 ft) (Semidirectional, 8 elements)
Sensitive area (X, Y)				
Category I	X	600 m (2 000 ft)	600 m (2 000 ft)	300 m (1 000 ft)
	Y	60 m (200 ft)	110 m (350 ft)	60 m (200 ft)
Category II	X	1 220 m (4 000 ft)	2 750 m (9 000 ft)	300 m (1 000 ft)
	Y	90 m (300 ft)	210 m (700 ft)	60 m (200 ft)
Category III	X	2 750 m (9 000 ft)	2 750 m (9 000 ft)	300 m (1 000 ft)
	Y	90 m (300 ft)	210 m (700 ft)	60 m (200 ft)

Figure 1. Example ICAO Critical and Sensitive Areas

Since vehicles other than aircraft can be well controlled during low visibility periods, the predominant candidate reflectors used to determine critical area sizes are aircraft in normal operations on the airfield. In general, both ICAO and the U.S. define ILS critical/sensitive areas in terms of the size of the offending aircraft, e.g., "small, medium", which in turn is characterized by length and height of the aircraft. The ICAO and U.S. shapes of the critical/sensitive areas are defined almost completely by a rectangular coordinate system, although ILS service volumes and antenna patterns are angular in nature. Category of Operation and antenna system type are the remaining variables used to define critical area sizes.

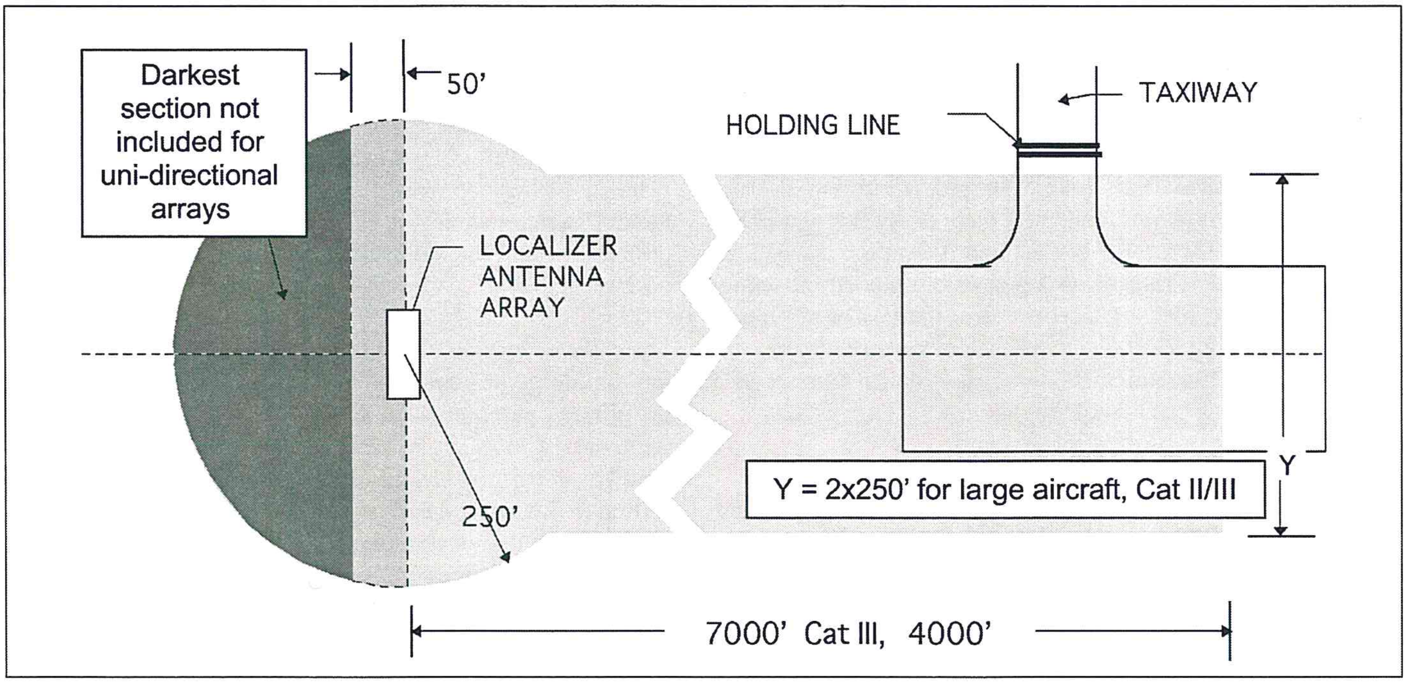


Figure 2. Example US Localizer Critical Area for Large Aircraft

Operationally, ICAO's guidance material expects that critical area sizes will be ILS-specific, based on the static beam quality of the ILS – *"If the course structure is already marginal due to static multipath effects, less additional interference will cause an unacceptable signal. In such cases a larger-size sensitive area may have to be recognized."* Examples are given using a root-sum-square technique to define the "*...allowance for moving objects to define [the] localizer [or glide path] sensitive area....*" In the U.S., critical area sizes are defined by assuming an offending aircraft at the boundary of the critical area is the only multipath source. The resulting size based on the most demanding aircraft expected at that airport/runway is then applied to all operations on that runway.

The ICAO definitions provide that non-stationary objects must be prevented access to critical areas, and their movement must be controlled in sensitive areas, during ILS operations. In the U.S., where only a single area is defined, the critical area is normally protected "when an arriving aircraft is inside the ILS . . . when conditions are less than reported ceiling 800 feet and/or visibility less than 2 miles."[3] However, there are exceptions that will be addressed in a later section of this paper. Aircraft hold lines are placed based on the most demanding aircraft type or critical area size at that airport.

Table 1 summarizes the key characteristics for ILS critical/sensitive areas, as defined by ICAO and the U.S.

Characteristic	ICAO		U.S.	
Area & protection conditions	Critical Area	Protected during ALL (e.g., good weather) ILS Usage	Critical Area	Normally protected, with exceptions, when weather worse than 800' ceiling and/or 2 miles visibility
	Sensitive Area	Movement controlled during ILS Operations		
Hold Lines	Can vary with aircraft type		Placed for most demanding aircraft size and 3.00 degree LOC course width	
Area sizes defined for...	Small, medium, large aircraft Category of Operation ILS Antenna system type		Small, medium, large aircraft Category of Operation ILS Antenna system type	
Size considers static multipath?	Yes		No	

Table 1: ILS Protected Area Characteristics

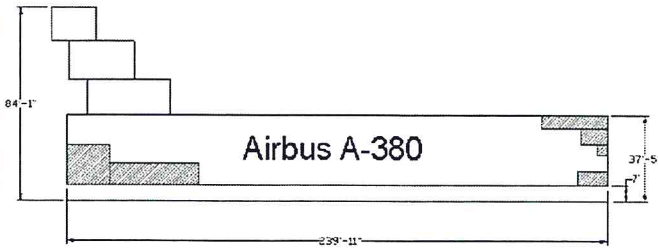
DEFINING CRITICAL/SENSITIVE AREA SIZES

Critical/Sensitive area sizes can be readily defined by computer modeling. For the purposes of this paper and past FAA efforts to establish ILS siting criteria, the Ohio University Physical Optics model is used.[4] Common aircraft are defined as reflectors, using a variety of rectangular plates to approximate the profile of the aircraft fuselage and tail. While this is not a technically rigorous or detailed modeling technique, it provides a fast, convenient method of placing aircraft at varying locations with respect to a simulated runway and an associated ILS antenna system. As a result, it produces a worst-case prediction for comparison against published flight inspection tolerances.[5,6]

During the past two decades, Ohio University developed and validated the mathematical models used for predicting the effects of parked aircraft on the ILS signal quality. The B-727 and B-747 were the predominant in-service aircraft at that time. They were used for definition of the existing U.S. critical areas and for aircraft size classes of small, medium, and large, which are functions of aircraft fuselage length and/or tail height. Table 2 documents the existing aircraft classification criteria.

Class	Tail Height (ft)	Conditional	Fuselage Length (ft)
Small	<20	OR*	<60
Medium	<38	OR*	<160
Large	>38	OR	>160
*Proposed to become "AND" [2]			

Table 2: Existing Aircraft Classification Criteria



Note: Shaded plates' effect subtracted from scattered field.

Figure 3: Example Aircraft Model, Side View

The methodology for modeling the localizer and glide path critical areas is based on previous work.[7,8] The aircraft of interest for this study include the Boeing 737, 747, 757, 767, 777, and the Airbus A-320, A-330, and A380. The aircraft models consist of various scattering plates which when placed together approximate the size and shape of the aircraft profile (see Figure 3). Table 3 contains the aircraft dimensions and the corresponding size classification based on Table 2.

Localizer and Glide Path antenna systems were modeled for common configurations and locations. Table 4 contains the primary parameters used for the modeling. For localizers, a setback of 1000' from the stop end of the runway was used for all existing U.S. antenna types. To simulate aircraft taxiing to the runway, each aircraft type was placed in varying locations and two orientations in front of the antenna system. Table 5 lists the parameters defining the grid of modeled aircraft locations. Offset is the aircraft distance from runway centerline. Setback or longitudinal distances from threshold are for the center of the aircraft fuselage.

Aircraft	Tail Height (ft)	Fuselage Length (ft)	Class
B-737	36.5	109.6	Medium
B-747	63.7	231.8	Large
B-757	44.5	155.3	Large
B-767	52.0	159.2	Large
B-777	60.8	209.8	Large
A-320	38.7	123.3	Large
A-330	58.7	193.8	Large
A-380	84.0	239.9	Large

Table 3: Aircraft Dimensions Used in Modeling

Parameter	LOC	GP
Ant. Setback (ft)	13,000	1,054
Ant. Offset (ft)	0	400
Path Angle (_, deg)	3.00	3.00
Frequency (MHz)	109.7	332.15
Threshold Crossing		
Height (TCH, ft)	55	55
Antenna Type	LPD	FA-8976
Antenna Configuration	1) 8 & 14 element 1-freq	1) Capture Effect
	2) 14/10 & 20/10 2-freq	2) Null Reference
		3) Sideband Reference

Table 4: Summary of ILS Modeling DataTable 4.

Aircraft Alignment	**Offset**		**Setback**	
	LOC	**GP**	**LOC**	**GP**
Perpendicular to Runway, Tail away from runway				
Start Point (ft)	75	75	+4000	+1000
Increment (ft)	50	50	500	100
End Point (ft)	2475	1375	-11000	-1050
Parallel to Runway, Tail toward Glide Path mast				
Start Point (ft)	75	75	+4000	+1000
Increment (ft)	50	50	500	-100
End Point (ft)	2475	1375	-11000	-1050

Table 5: Aircraft Modeling Locations for Glide Path

SOME MODELING RESULTS

In this paper, modeling results are expressed as a percentage of the allowed tolerance for ILS beam errors, based on the category of operation. The errors include *alignment* (static and low-frequency errors that can misposition an aircraft) and *structure* (high-frequency errors). Aircraft are placed parallel and perpendicular to the runway at various distances from runway centerline and from runway threshold. Hundreds of runs were performed to define the approximate boundaries of these areas for each ILS antenna system, aircraft type, and category of operation.

Some Modeling Results -- Localizer

An example modeling result for an A380 aircraft, positioned parallel to a very long runway with a 20-element, two-frequency, Log Periodic Dipole Localizer antenna system, is shown in Figure 4. For this modeled aircraft on a parallel taxiway, offset the typical 400' distance from the runway centerline, the predicted results are out-of-tolerance for aircraft locations between +1000' and -9000' from the approach threshold.

With one exception, current U.S. critical area sizes do not take into account the Localizer course width. Localizer width is an angular measure of the guidance sensitivity, and is inversely proportional to runway length. Wider courses defined for shorter runways do not require as much protection, as illustrated in Figure 5, which contrasts LOC course widths of 3.00 and 6.00 degrees on the same runway. This illustrates that the existing U.S. practice is overly conservative for shorter runways.

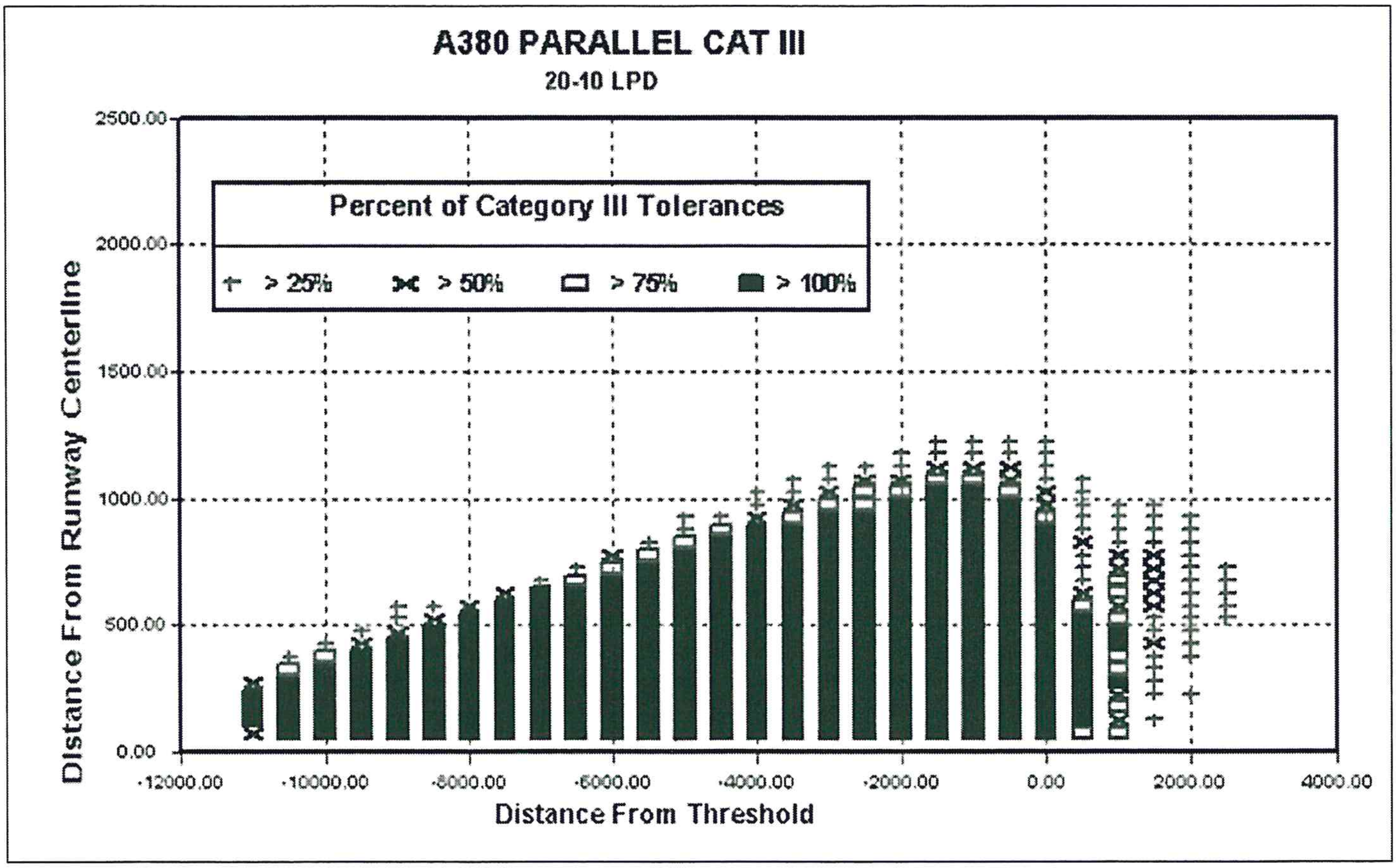


Figure 4: Example Localizer Results for A380 Aircraft Parallel to Runway

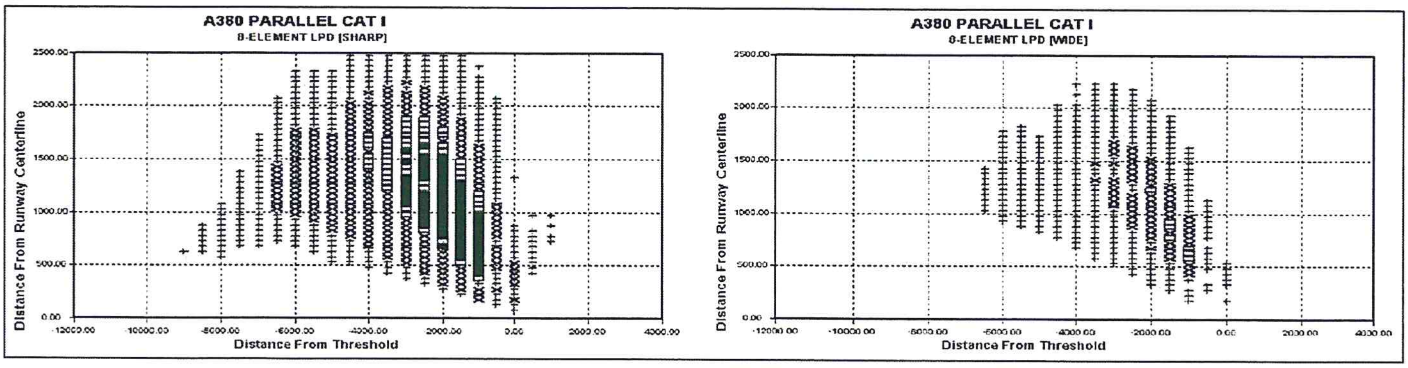


Figure 5: Effects of LOC Course Width on Cat I Reflection Magnitude. See Figure 4 for symbol legend. (Sharp = 3.00 deg, Wide = 6.00 deg, all other conditions equal)

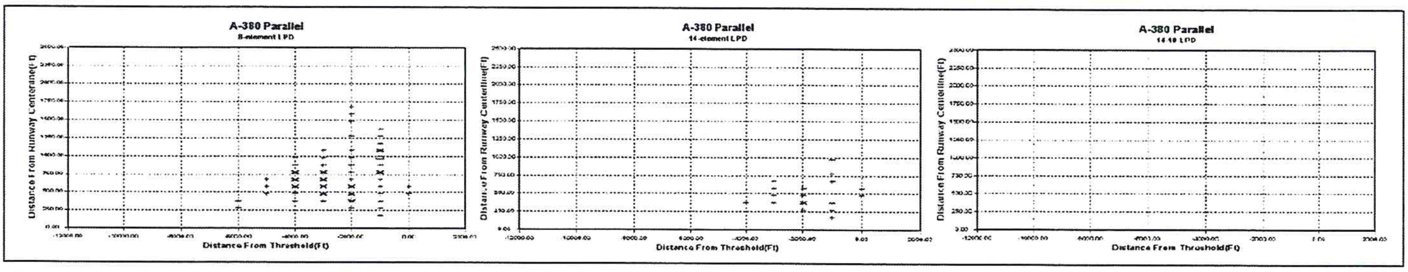


Figure 6: Comparison of Different Localizer Antenna Systems for A380, Category I. See Figure 4 for symbol legend.

As expected, the horizontal pattern of the Localizer antenna system has a dominant effect on the needed critical/sensitive area size. Arrays with greater directivity are the least affected by aircraft on taxiways, and two-frequency arrays are the most immune. Figure 6 illustrates this effect, showing the results in miniature for easy visual comparison. Three common antenna systems with increasingly narrower beamwidths are shown from left to right -- 8 element and 14 element single frequency, and 14/10 element dual frequency arrays.

Some Modeling Results -- Glide Path

An example result for a 3.00 degree sideband reference Glide Path antenna system, with an A-380 aircraft parallel with the runway and tail toward the GP mast, is shown in Figure 7. For the typical parallel taxiway geometry of 600' from runway centerline, the results exceed Category III tolerances for a taxiing outbound aircraft beginning at approximately 850' on the GP side of threshold and extending to the threshold area. However, recall that this is a worst-case prediction.

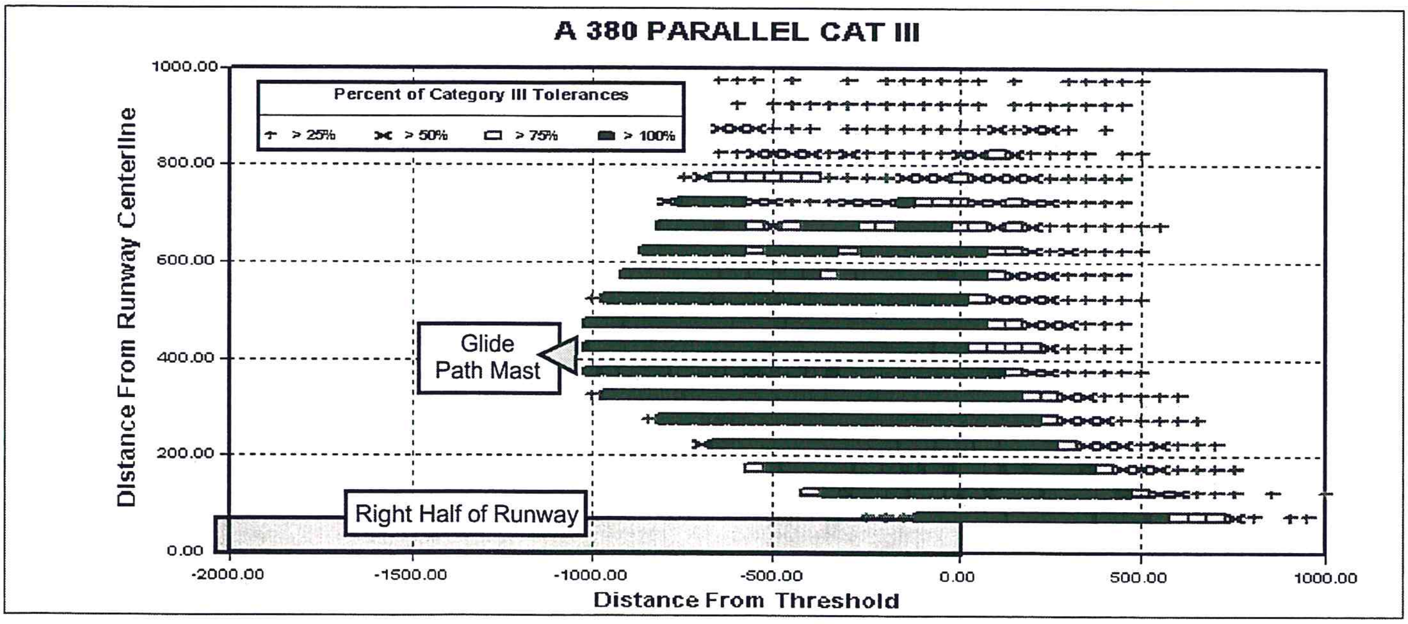


Figure 7: Example Sideband Reference Glide Path Results for A-380 Aircraft Parallel to Runway

To contrast the effects on a glide path of the two aircraft orientations and the effects of separate reflections from the tail and fuselage, a single aircraft location was modeled. These results are provided in Table 6, for approach zones 2 (from 4 nautical miles to 3500' prior to the runway threshold) and 3 (from 3500' prior to runway threshold to the threshold) in a normal descent. It is clear that the tall, flat tail surface is the predominant factor in the glide path guidance degradation. An aircraft orientation with fuselage parallel to the runway and the tail closest to the array (i.e., taxiing outbound aircraft) produces the worse case degradation. Orientations other than parallel and perpendicular were not considered for the balance of the modeling. However, there may be some airport configurations where additional orientations need to be modeled.

Aircraft Orientation & Section	**Roughness Structure (% of tolerance)**	
	Zone 2	Zone 3
Parallel		
Fuselage	35	161
Tail	27	480
Perpendicular		
Fuselage	100	155
Tail	203	238

Table 6: Aircraft Orientation Sensitivity for GP

Some Modeling Results -- General Observations

Some general antenna pattern-related effects are evident from the collective modeling results. In both Figures 4 and 7, an approximation of the horizontal antenna pattern of the ILS facility is visible. This suggests it may be possible and even beneficial to define critical and sensitive restricted areas using a polar coordinate system, rather than the traditional rectangular coordinate system.

The Localizer results show that the clearance signals from a two-frequency antenna system play a relatively minor role in the needed protected areas. For Category I applications, only those aircraft positions in the approach half of the runway are of potential concern. GP protected area lateral dimensions (offset away from the runway centerline) are highly dependent on the radiating antenna system's horizontal beamwidth and the bore site angle. The longitudinal dimensions away from the GP mast are primarily dependent on the radiating antenna system's vertical pattern. Figure 8 shows the vertical navigation guidance energy patterns of glide path configurations currently in operation in the National Airspace System (NAS). Existing criteria for protecting the distance in front of the mast are consistent with these patterns.

RESULTS SUMMARY

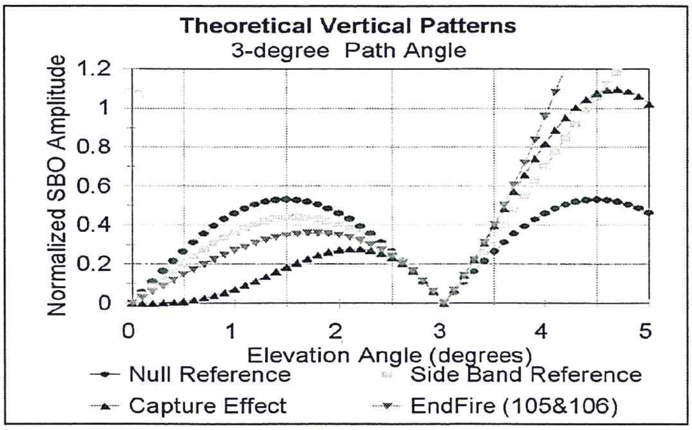


Figure 8: Vertical Glide Path Patterns

Modeling results similar to Figures 4 and 7 have been completed for various Localizer antenna systems, and for the three image type glide path antenna systems, for eight current aircraft types in widespread use. Considering the sideband reference (SBR) glide path as an example, key characteristics of a protected area are tabulated in Table 7.

For each aircraft type and for each orientation of the aircraft, two dimensions taken from results such as Figure 7 are shown. These are the maximum lateral (offset from runway centerline) and longitudinal (setback from threshold) dimensions necessary for the protected area to ensure the aircraft does not consume more than 100% of the allowed tolerances. Parallel setback and perpendicular offset distances include half the fuselage length, such that the nose of an aircraft at these distances would be at the boundary of the protected area. No allowance for static multipath on the GP guidance signals is included in the table.

Aircraft Type	**Cat**	**Aircraft Parallel**		**Aircraft Perpendicular**	
		Offset (ft)	**Setback (ft)**	**Offset (ft)**	**Setback (ft)**
B-737	I	475	-395	370	-400
	III	575	-445	370	-300
B-747	I	625	+165	360	+250
	III	675	+315	410	+465
B-757	I	625	-320	395	-150
	III	625	-270	395	-120
B-767	I	625	-270	395	+50
	III	725	-20	395	+100
B-777	I	625	+155	420	+200
	III	625	+155	420	+305
A-320	I	575	-440	365	-400
	III	575	+340	415	-250
A-330	I	625	+45	380	+100
	III	625	+45	380	+100
A-380	I	675	+220	405	+900
	III	725	+320	405	+900

Table 7: Protected Area Maximum Dimensions for 100% of SBR GP Tolerances

Similar tables are available for null reference and capture effect glide path antenna systems, and for various localizer antenna systems. However, before these results can serve as the basis of a revised critical area policy, several related operational issues which affect how the data are used must be considered.

CRITICAL AREA OPERATIONAL ISSUES

As air traffic grows, increased demands for airport construction and runway capacity conflict with protection requirements for ILS critical areas. Recent U.S. experiences highlight several problems with existing critical area operational practices.

Operational Issue #1 – Insufficient Protection

The first problem is insufficient protection of the critical areas during ILS use. Critical area protection requirements are discussed for Airway Facilities personnel in Chapter 1 of the ILS Maintenance Handbook,[9] and protection procedures are defined for Air Traffic Control (ATC) personnel in Chapter 3 of the ATC Handbook.3 Appendix 1 of this paper contains those texts.

As described in paragraph 3-7-5a(1)a of the ATC Handbook, U.S. Localizer critical areas are not required to be protected for an aircraft inside the outer marker (or any substitute fix) when weather is reported to be better than 800' ceiling and/or 2 miles visibility. This is in contrast to the ICAO practice of excluding aircraft from critical areas during "all ILS operations", and controlling access to [ICAO] sensitive areas to "prevent the possibility" of unacceptable degradation of signals.

However, that same paragraph contains two additional exceptions to protecting the [U.S.] critical areas for aircraft that may transit through or over the critical area on the same or another runway. These exceptions are for a preceding arriving aircraft while landing or exiting the runway, and a preceding departing aircraft or missed approach.

Aircraft taking off or executing a missed approach are moving at flight speeds at generally high altitudes with respect to a landing aircraft, and the resulting ILS degradations will be transitory and high frequency in nature. However, a landing/exiting aircraft will be moving slowly through the Localizer critical area, and a departing taxiing aircraft will be moving slowly through the glide path critical area. These degradations can be at a low frequency, resulting in possible displacement of the using aircraft.

These three exceptions ("good weather", preceding landing and departing aircraft) to protecting U.S. critical areas result in numerous user complaints during ILS operations. The incidence of these complaints is rising due to increasing good-weather and advanced uses of the ILS signals. These uses include fully coupled and autoland approaches in clear weather, and Operations-Specification approvals for Category II and Lowest Standard Category I approach minima based on advanced avionics. [10]

Operational Issue #2 – Runway/Taxiway Design

The second problem arises from an increasingly common runway/taxiway design practice that places a second connecting taxiway between the approach end of a runway and the parallel taxiway. This second access to the runway allows departing aircraft to bypass a temporarily delayed aircraft on the first connector at the runway threshold. If this second connector is placed in front of the Glide Path antenna mast to maximize available runway length, an aircraft transiting through or stopped in the Glide Path critical area can be as little as 300' in front of the antennas. Figure 9 shows this taxiway geometry now commonly found at larger airports.

Years ago when the "good weather" and preceding aircraft exceptions to protecting critical areas were first implemented, the only connecting taxiway was approximately 1000' in front of the glide path antenna system. At that time, Category II and III operations were rare, autoland operations were not yet available, and a "large" aircraft might have been a B-707. For those conditions, a good weather exception was perhaps defensible. Today a "large" aircraft is much larger, and can be placed much closer to the glide path antenna due to the additional connector taxiway. A large aircraft such as a DC-10 can actually block the line of sight between a glide path antenna and an approaching aircraft, when stopped on a close connector taxiway. Even without the additional taxiway, today's autoland and much lower visibility operations suggest that these exceptions to protecting the critical area are unwise.

A recent operational experience illustrates this second problem. During the winter months, airline pilots filed numerous complaints of erratic Glide Path indications during approaches to Minneapolis Runway 12R. Investigation revealed that these approaches were cleared at times when weather conditions met the U.S. "good weather" exception for critical area protection, and aircraft waiting for departure clearances were in the Glide Path critical area. Pilots also complained that during periods of rapidly changing winter weather (e.g., snow squalls), even though they may have been cleared when the weather was better than 800' ceiling and/or 2 miles visibility (800/2), they were breaking out of the clouds in weather that had deteriorated, and they noted aircraft in the critical area. There is no requirement in the ATC procedures in Appendix 1 to monitor the weather after an approach clearance, to ensure it continues to meet the "good weather" exception throughout an ILS approach.

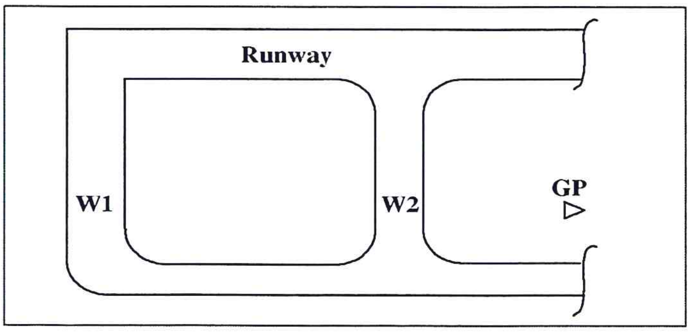


Figure 9: Two Taxiways in front of Glide Path

The Minneapolis critical area conditions were further aggravated by the fact that both ends of that runway have two connecting taxiways between the runway and the parallel taxiway, as shown in Figure 9. Because the taxiway connector at one threshold (e.g., W1) was closed for some months, departing aircraft were routinely entering and holding in the Glide Path critical area only 600' in front of the Glide Path mast on the second connector taxiway (e.g., W2). Even when the weather was considerably better than an 800' ceiling, pilots noted that their approaches were noticeably lower than usual.

FAA Flight Inspection aircraft made airborne measurements under these conditions.[ii] The results confirmed that an aircraft holding in the critical area at 600' in front of the Glide Path mast caused the Glide Path angle to be lowered throughout the approach by substantially more than one degree. Figure 10 shows one of the FAA flight measurements, where the baseline is the nominal 3.00 degree desired descent path. The error shown for a B-727 at that location in the critical area is more than 600% of the Glide Path alignment tolerance. Clearly the existing exception to critical area protection is unacceptable with this taxiway geometry.

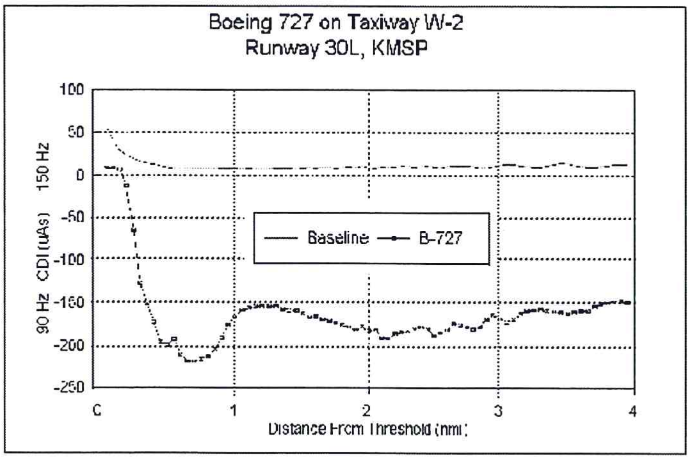


Figure 10: GP Error with B-727 in Critical Area

Operational Issue #3 – Aircraft Classification System

A third operational problem arises from the existing aircraft classification system shown previously in Table 2. Its combination of fuselage length and tail height overemphasizes the effects of the fuselage length, and causes some critical area sizes to be unduly large. For example, Figure 11 shows the modeling results for the A-320 and B-737 aircraft and a null reference glide path. The two aircraft are classified as large and medium sizes, respectively, due to the slightly larger tail height of the A-320. However, the modeling results are nearly identical. In the U.S., an airfield handling A-320 aircraft would have a large critical area protected for all smaller aircraft sizes. If the aircraft classification system were modified to focus primarily on tail height, the classes would better fit the modeling results and minimize critical area sizes.

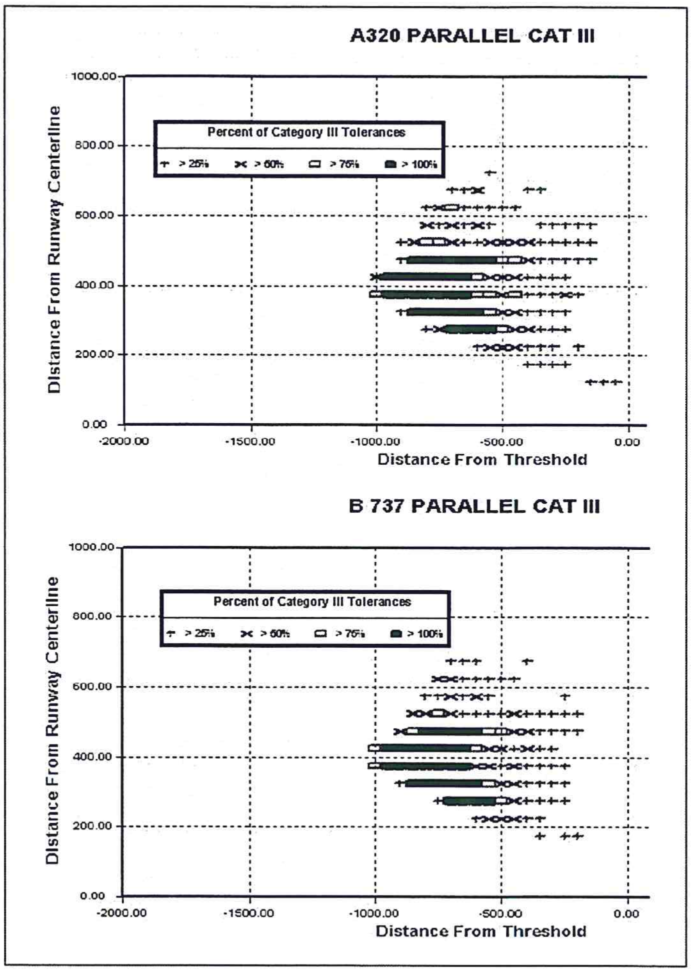


Figure 11: Dissimilar Class Aircraft

Operational Issue #4 – Static Multipath

A fourth operational problem arises from the U.S. practice when defining critical area sizes to ignore the effects of static multipath derogations to the guidance signal. Many other sources of multipath exist at an airport, primarily buildings near the runway. While the effects of these structures may consume only a small proportion of the allowed tolerances for many Localizers and Glide Paths, they routinely consume a much larger proportion, e.g., 60-80% of tolerances, at some runways.

The expected effects of proposed structures on airports are modeled and predicted by Airway Facilities engineering personnel. A common practice is to allow a new structure to consume up to approximately 50-60 per cent of tolerances. This in turn would reduce the allowance for aircraft in or near the critical areas by an appropriate amount, or increase the required critical area size, if the ICAO practice of combining static and transient effects together via a root-sum-squared procedure were used.

However, using such a combining procedure for static and dynamic multipath errors will result in runway-specific sizes for critical areas. In addition, the positions of hold lines that define the critical area boundary would necessarily change over time for a given runway as the multipath environment changes. A method is needed to account for most static multipath conditions without routine changes in the protected area dimensions.

Operational Issue #5 – New Applications

New or previously seldom-used applications of ILS facilities further challenge the critical area issue. One of these applications is Simultaneous Offset Instrument Approaches (SOIA), which provide ILS approaches to two closely-spaced parallel runways at major airports. Since the runways are too close to one another to support independent straight-in ILS approaches, one of the localizers is sited atypically to provide an offset approach. While offset localizers are somewhat common at smaller airports, their application on major airports, with large taxiing aircraft and many taxiways, often places the critical area over high-usage taxiways. If the weather conditions are better than 800/2, the critical area is usually not protected at all from the taxiing aircraft.

Operational Issue #6 – One CA Size for All Aircraft

A final operational problem occurs due to the U.S. practice of determining the critical area size based on the largest size aircraft expected to use the runway. This of course creates large critical areas. Since only a single set of hold lines is marked and signed on the taxiways to define the resulting boundary, the ILS signals are over protected for any smaller aircraft nearing the critical area boundary.

CONCLUSIONS

The following conclusions are drawn from the extensive modeling done for new aircraft and ILS antenna systems, and from the operational considerations previously discussed:

a. U.S. and ICAO critical [and sensitive] area policies different in several key respects.

b. U.S. critical area sizes are overly conservative for some applications.

c. U.S. critical area definitions rely on an inappropriate aircraft classification system.

d. Current U.S. critical areas are not adequately protected under some operational conditions.

e. Current U.S. critical area sizes are independent of individual ILS static beam quality.

f. New aircraft, additional ILS antenna system choices, and operational conditions require a revision to U.S. critical area policy and procedures.

g. New aircraft types and ILS antenna systems have been modeled for the purpose of defining new critical [and sensitive] area boundaries.

h. Before the new data can be used, several key policy decisions must be made.

i. Static ILS beam quality can be taken into account without adopting runway-specific protected area sizes, by defining appropriate critical and sensitive areas, and fully protecting the critical area during any ILS operations.

j. Critical and sensitive area sizes may be reduced by several readily available techniques.

RECOMMENDATIONS

The following recommendations are made for the current and future revisions of the U.S. ILS Siting Handbook and other relevant FAA documents:

a. For mathematical modeling activities used to define critical [and sensitive] area boundaries, consider aircraft orientations of parallel with the runway with tail toward the ILS facility being modeled, and perpendicular to the runway with tail away from the runway.

b. For all airports, position hold lines at or outside the boundary of critical [and sensitive] areas to minimize an aircraft turning to orientations other than parallel or perpendicular to the runway, unless additional orientations are modeled.

c. Modify the aircraft size classification system, for purposes of defining critical [and sensitive] areas, to focus primarily on tail height. Change the tail height break point from 38' to 40'.

d. Define critical [and sensitive areas] in a polar coordinate system, to the extent feasible, with origin at the relevant ILS antenna system.

e. Adopt the ICAO critical and sensitive area concept, to replace the current critical-area-only concept. Protect the two areas as follows:

  - Prohibit any vehicles or aircraft in the critical area, during ANY (e.g., to include good visibility) ILS operation.
  - Restrict aircraft from the sensitive area whenever reported weather conditions are worse than a defined threshold (currently 800' ceiling and/or two miles visibility) and a landing aircraft relying on the ILS is inside the final approach fix.
  - If an aircraft is using the ILS during weather conditions better than defined above, and an aircraft is in the sensitive area, notify the using aircraft of the sensitive area violation, and assure the weather

conditions do not deteriorate below the defined criteria during the approach without advising the aircraft on approach.

f. Define protected area boundaries for each aircraft classification size as follows:

- Define critical area boundaries equal to those defined by ICAO, or larger if required to protect 100 per cent of alignment tolerances.
- Define minimum sensitive area boundaries such that no more than 80% of tolerances (i.e., alignment, bends, and roughness) are consumed for each Category of Operation. This allows for static multipath of up to 60% of tolerances, using the root-sum-squared technique.

g. Promote construction of second connecting taxiways behind, rather than in front of, the GP mast.

h. Aggressively pursue methods to reduce critical and sensitive area sizes. At minimum, these methods include using advanced modeling techniques, considering Localizer course width and Glide Path antenna bore site angle, installing more directional antenna systems, and defining a more detailed classification system for aircraft sizes.

FUTURE WORK

The results presented here are the first efforts in a substantial task, and analysis continues. Additional orientations of aircraft should be considered for unusual taxiway geometries, especially for Category II and III operations. Before fully defined ILS protected area boundaries can be determined, major policy decisions must be made. Where the resulting critical and sensitive area boundaries are restrictively large, they likely can be reduced significantly. Techniques to achieve this include using more advanced ground antenna systems, applying more detailed modeling techniques which have been published internationally,[12] and taking advantage of the increased use of advanced avionics which offer additional signal processing of the received ILS signal.

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APPENDIX 1

Excerpts from FAA Order 7110.65, Air Traffic Control, and Order 6750.16C, Siting Criteria for Instrument Landing Systems

Order 7110.65:

3-7-5. Precision Approach Critical Area

a. ILS critical area dimensions are described in FAAO 6750.16, Siting Criteria for Instrument Landing Systems. Aircraft and vehicle access to the ILS/MLS critical area must be controlled to ensure the integrity of ILS/MLS course signals whenever conditions are less than reported ceiling 800 feet and/or visibility less than 2 miles. Do not authorize vehicles/aircraft to operate in or over the critical area, except as specified in subpara a1, whenever an arriving aircraft is inside the ILS outer marker (OM) or the fix used in lieu of the OM unless the arriving aircraft has reported the runway in sight or is circling to land on another runway.

PHRASEOLOGY-HOLD SHORT OF (runway) ILS/MLS CRITICAL AREA.

1. LOCALIZER CRITICAL AREA

(a) Do not authorize vehicle or aircraft operations in or over the area when an arriving aircraft is inside the ILS OM or the fix used in lieu of the OM when conditions are less than reported ceiling 800 feet and/or visibility less than 2 miles, except:

  (1) A preceding arriving aircraft on the same or another runway that passes over or through the area while landing or exiting the runway.

  (2) A preceding departing aircraft or missed approach on the same or another runway that passes through or over the area.

(b) In addition to subpara a1(a), do not authorize vehicles or aircraft operations in or over the area when an arriving aircraft is inside the middle marker when conditions are less than reported ceiling 200 feet and/or RVR 2,000 feet.

2. GLIDESLOPE CRITICAL AREA. Do not authorize vehicles or aircraft operations in or over the area when an arriving aircraft is inside the ILS OM or the fix used in lieu of the OM unless the arriving aircraft has reported the runway in sight or is circling to land on another runway when conditions are less than reported ceiling 800 feet and/or visibility less than 2 miles.

b. Air carriers commonly conduct "coupled" or "autoland" operations to satisfy maintenance, training, or reliability program requirements. Promptly issue an advisory if the critical area will not be protected when an arriving aircraft advises that a "coupled," "CATIII," "autoland," or similar type approach will be conducted and the weather is reported ceiling of 800 feet or more, and the visibility is 2 miles or more.

PHRASEOLOGY-ILS/MLS CRITICAL AREA NOT PROTECTED.

Order 6750.16:

1-24. ILS Critical Areas

a. **Definition**. The facility system specialist must be aware that disturbance to the localizer or glide slope signals may occur when other aircraft or surface vehicles operate near the localizer or glide slope antennas. These areas, which are to be protected from vehicular or aircraft traffic, are called the ILS critical areas. Airway facilities ILS specialists should consider conformance to critical area marking standards when certifying a facility. The critical areas and additional data concerning hold lines, signs, etc., are defined in the latest edition of Order 6750.16, Siting Criteria for Instrument Landing Systems, and the latest editions of Advisory Circular 150/5340-1, Marking of Paved Areas of Airports, and Advisory Circular 150/5340-18, Standards for Airport Sign Systems.

b. **Protection of Areas.** Air Traffic procedures require that the tower personnel control airport surface traffic so localizer and glide slope critical areas are protected when-ever reported weather is poorer than prescribed minima. When the weather conditions are better than the prescribed minima, or when no tower is in operation, ILS critical area protection is not provided other than by self-policing of air-port areas. For this reason, proper marking of the ILS critical areas is essential.

c. **Actions Required.**

(1) Airway facilities personnel are responsible for advising airport management authorities of critical area criteria, and for requesting that they provide and maintain the necessary signs, holding lines, and other markings delineating the restricted areas.

(2) Airway facilities personnel are responsible for unlighted critical area warning signs, to prevent un-authorized vehicular traffic in the localizer and glide slope critical areas. At a minimum, signs shall be installed where each road enters/leaves the critical area. The signs should be approximately 1 ft by 2 ft (30 by 60 cm) in size, and preferably constructed of nonmetallic material. Suggested wording is ILS CRITICAL AREA KEEP OUT. See figure 1-2 for typical placement.

(3) Vegetation in the critical areas shall be kept below 12 inches (30 cm). Except for cutting and removal of vegetation, all farming activities are forbidden in the ILS critical areas.

BIOGRAPHY

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Dave Quinet is the program manager for the Navigation and Landing Systems team at the Ohio University Avionics Engineering Center. He has performed numerous analyses to determine ILS performance in high multipath environments, and to determine ILS hold lines based on airport configuration and the aircraft types operating at an airport.