Enclosure 1

(Ref. Technical Letter H560-L18-027)

MITRE

Center for Advanced
Aviation System Development

Toluca Airport

Assessment of International Civil Aviation Organization Annex 14 Obstacle Limitation Surfaces

Prepared for

Grupo Aeroportuario de la Ciudad de México

March 2018

Principal Acronyms and Abbreviations

AIP	Aeronautical Information Publication
ARP	Aerodrome Reference Point
CAT	Category
CFR	Code of Federal Regulations
FAA	U.S. Federal Aviation Administration
GACM	Grupo Aeroportuario de la Ciudad de México
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
MITRE	The MITRE Corporation
MSL	Mean Sea Level
NAICM	Nuevo Aeropuerto Internacional de la Ciudad de México
OFZ	Obstacle Free Zone
OLS	Obstacle Limitation Surfaces
RNAV	Area Navigation
SARPs	Standards and Recommended Practices
SENEAM	Servicios a la Navegación en el Espacio Aéreo Mexicano
TMA	Terminal Maneuvering (Control) Area
U.S.	United States
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

1. Introduction

The MITRE Corporation (MITRE) is assisting Grupo Aeroportuario de la Ciudad de México (GACM) and the aviation authorities of Mexico with the design of a new airport to serve Mexico City, the Nuevo Aeropuerto Internacional de la Ciudad de México (NAICM). The proposed runway layout of NAICM will allow for dual- and triple-independent arrival and departure operations. MITRE has been working closely with Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM) in developing an airspace design for the new Mexico City Terminal Maneuvering (Control) Area (TMA) to support NAICM.

The airspace design of NAICM is connected very closely to the airspace surrounding existing Toluca Airport (hereinafter referred to as Toluca). Therefore, an overall design of the airspace of the entire Toluca-Mexico City area needs to be developed in tandem. This is important to ensure that operations at Toluca do not create significant capacity-limiting effects on operations at NAICM due to airspace conflicts.

MITRE's Toluca-related work has been focusing on the examination of matters concerning existing single-runway (i.e., Runway 15/33) operations that take into account the above-mentioned airspace design for the new Mexico City TMA to support NAICM, including associated NAICM instrument procedures. During the airspace design process, it became apparent that many of the procedures at Toluca would need to change, as necessary, to avoid causing conflicts and/or complications with operations at NAICM. Therefore, MITRE examined the development of modified instrument approach and departure procedures for the existing single-runway at Toluca. Refer to Enclosure 2 to MITRE Technical Letter H560-L18-027: *Development of Instrument Approach and Departure Procedures at Toluca Airport*, dated 15 March 2018.

In support of the development of instrument approach and departure procedures for Toluca, MITRE also analyzed relevant International Civil Aviation Organization (ICAO) Annex 14 Obstacle Limitation Surfaces (OLSs). The analysis of ICAO Annex 14 OLSs is important in order to identify potential obstacles to air navigation. That analysis is the subject of this document. MITRE presented the key results of its ICAO Annex 14 OLS analysis of Toluca to SENEAM officials during an NAICM-Toluca airspace design workshop conducted in Mexico City from 15 through 19 January 2018.

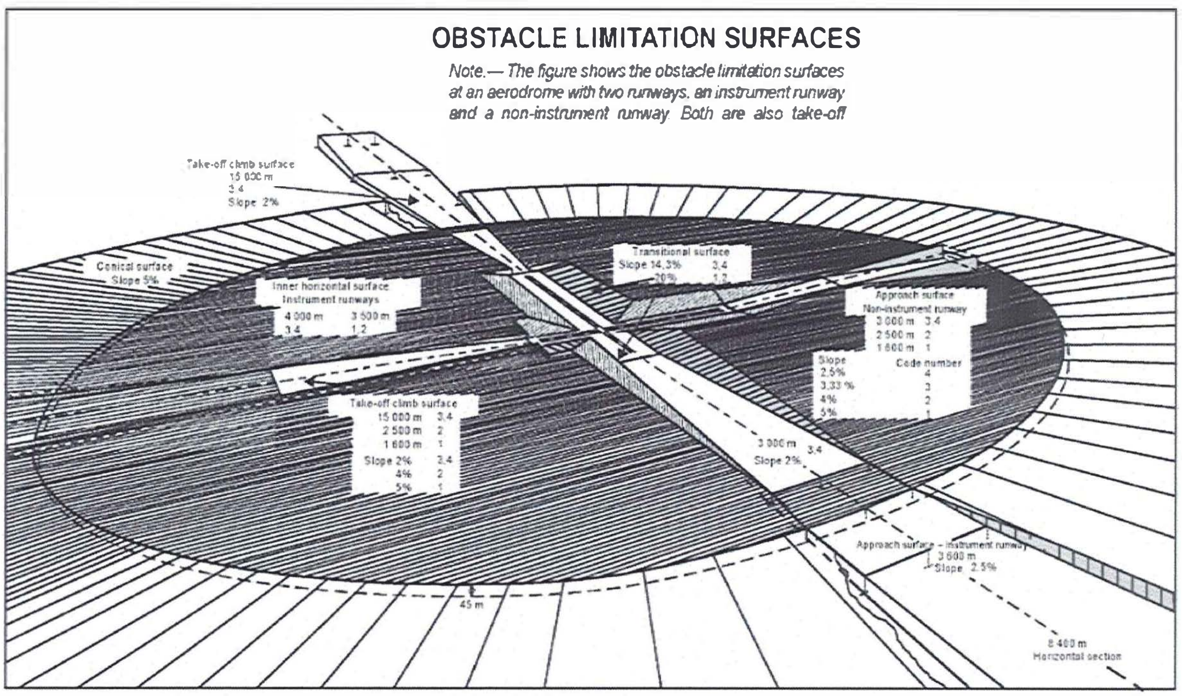
This document is organized as follows: Section 2 describes the ICAO Annex 14 OLSs that must be evaluated to ensure that critical areas at and near airports are kept free of obstacles that could adversely affect safety. Section 3 describes the methodology used in this analysis. Section 4 gives the results of the analysis. Section 5 provides closing remarks. Appendix A provides some information regarding the United States (U.S.) Federal Aviation Administration (FAA) process for conducting aeronautical studies.

2. ICAO Obstacle Limitation Surfaces

A key element of the consideration of safety is the application of Standards and Recommended Practices (SARPs) contained in ICAO Annex 14, *Volume I - Aerodromes*, Seventh Edition, dated 2016 (hereinafter referred to as ICAO Annex 14) in particular, the evaluation of the ICAO Annex 14 OLSs, described in this section.

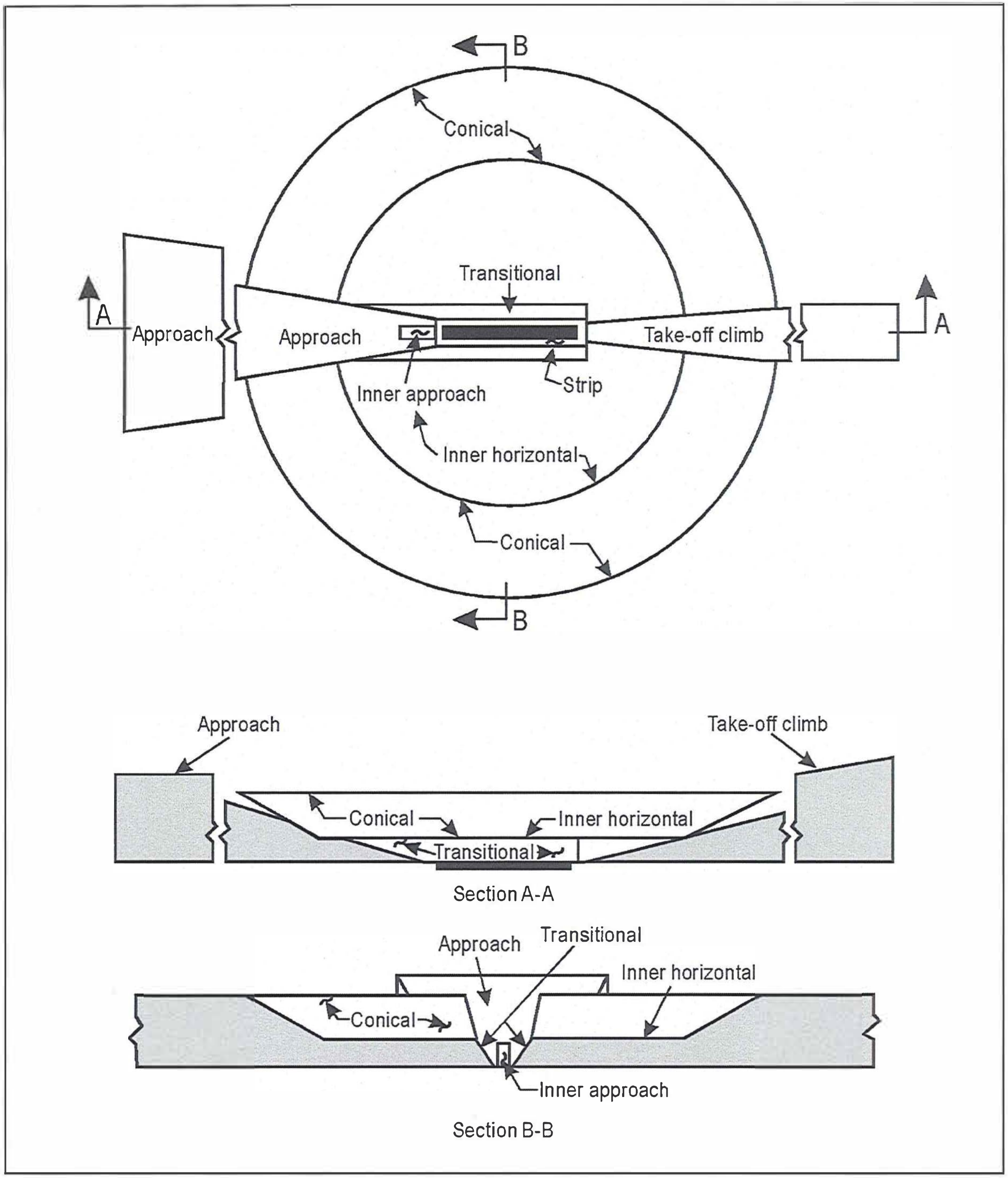
ICAO Annex 14 establishes OLSs around and over airports to be used for identifying obstacles to air navigation and preventing the development of obstacles that could adversely impact aircraft operations (see Figures 1 and 2). These surfaces define the limits of obstacle heights on and around an airport. Ideally, obstacles should not be allowed to penetrate these surfaces to minimize dangers to aircraft either during a visual approach or during the visual segment of an instrument approach. Obstacles that do penetrate these surfaces should, as far as practicable, be removed. If an object cannot be removed, an aeronautical study should be conducted, to determine if the object would impact air navigation or significantly affect the regularity of operations. Examples of potential measures to alleviate the impact of an obstacle penetration (depending on the outcome of an aeronautical study) include removing the obstacle, marking and lighting it, publishing its location in the Aeronautical Information Publication (AIP), displacing the threshold, limiting the use of the runway to certain types of approaches (e.g., instrument approaches), and restricting the type of traffic that may use the runway. Displacing the threshold, however, will result in a reduction of available landing distance. Therefore, consideration should be given to the operational impact of any threshold displacement on aircraft operations.

The dimensions and slopes of the ICAO Annex 14 OLSs are shown in Table 1 (approach runways) and Table 2 (take-off runways).



Source: ICAO Annex 14

Figure 1. ICAO Annex 14 OLSs (3-Dimensional View)



Source: ICAO Annex 14

Figure 2. ICAO Annex 14 OLSs (Plan and Profile View)

Table 1. Dimensions and Slopes of ICAO Annex 14 OLSs: Approach Runways

APPROACH RUNWAYS

	RUNWAY CLASSIFICATION									
	Non-instrument Code number				Non-precision approach Code number			Precision approach category I Code number		Precision approach category II or III Code number
Surface and dimensions[a]	1	2	3	4	1,2	3	4	1,2	3,4	3,4
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
CONICAL										
Slope	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Height	35 m	55 m	75 m	100 m	60 m	75 m	100 m	60 m	100 m	100 m
INNER HORIZONTAL										
Height	45 m	45 m	45 m	45 m	45 m	45 m	45 m	45 m	45 m	45 m
Radius	2 000 m	2 500 m	4 000 m	4 000 m	3 500 m	4 000 m	4 000 m	3 500 m	4 000 m	4 000 m
INNER APPROACH										
Width	—	—	—	—	—	—	—	90 m	120 m[e]	120 m[e]
Distance from threshold	—	—	—	—	—	—	—	60 m	60 m	60 m
Length	—	—	—	—	—	—	—	900 m	900 m	900 m
Slope								2.5%	2%	2%
APPROACH										
Length of inner edge	60 m	80 m	150 m	150 m	150 m	300 m	300 m	150 m	300 m	300 m
Distance from threshold	30 m	60 m	60 m	60 m	60 m	60 m	60 m	60 m	60 m	60 m
Divergence (each side)	10%	10%	10%	10%	15%	15%	15%	15%	15%	15%
First section										
Length	1 600 m	2 500 m	3 000 m	3 000 m	2 500 m	3 000 m	3 000 m	3 000 m	3 000 m	3 000 m
Slope	5%	4%	3.33%	2.5%	3.33%	2%	2%	2.5%	2%	2%
Second section										
Length	—	—	—	—	—	3 600 m[b]	3 600 m[b]	12 000 m	3 600 m[b]	3 600 m[b]
Slope	—	—	—	—	—	2.5%	2.5%	3%	2.5%	2.5%
Horizontal section										
Length	—	—	—	—	—	8 400 m[b]	8 400 m[b]	—	8 400 m[b]	8 400 m[b]
Total length	—	—	—	—	—	15 000 m	15 000 m	15 000 m	15 000 m	15 000 m
TRANSITIONAL										
Slope	20%	20%	14.3%	14.3%	20%	14.3%	14. 3%	14.3%	14.3%	14.3%
INNER TRANSITIONAL										
Slope	—	—	—	—	—	—	—	40%	33.3%	33.3%
BALKED LANDING SURFACE										
Length of inner edge	—	—	—	—	—	—	—	90 m	120 m[e]	120 m[e]
Distance from threshold	—	—	—	—	—	—	—	c	1 800 m[d]	1 800 m[d]
Divergence (each side)	—	—	—	—	—	—	—	10%	10%	10%
Slope	—	—	—	—	—	—	—	4%	3.33%	3.33%

a. All dimensions are measured horizontally unless specified otherwise.
b. Variable length (see 4.2.9 or 4.2.17).
c. Distance to the end of strip.
d. Or end of runway whichever is less.
e. Where the code letter is F (Column (3) of Table 1-1), the width is increased to 155 m. For information on code letter F aeroplanes equipped with digital avionics that provide steering commands to maintain an established track during the go-around manoeuvre, see Circular 301 — *New Larger Aeroplanes — Infringement of the Obstacle Free Zone: Operational Measures and Aeronautical Study*.

Source: ICAO Annex 14

Table 2. Dimensions and Slopes of ICAO Annex 14 OLSs: Take-off Runways

RUNWAYS MEANT FOR TAKE-OFF

Surface and dimensions[a] (1)	Code number 1 (2)	2 (3)	3 or 4 (4)
TAKE-OFF CLIMB			
Length of inner edge	60 m	80 m	180 m
Distance from runway end[b]	30 m	60 m	60 m
Divergence (each side)	10%	10%	12.5%
Final width	380 m	580 m	1 200 m 1 800 m[c]
Length	1 600 m	2 500 m	15 000 m
Slope	5%	4%	2%[d]

a. All dimensions are measured horizontally unless specified otherwise.
b. The take-off climb surface starts at the end of the clearway if the clearway length exceeds the specified distance.
c. 1 800 m when the intended track includes changes of heading greater than 15° for operations conducted in IMC, VMC by night.
d. See 4.2.24 and 4.2.26.

Source: ICAO Annex 14

Note that the ICAO Annex 14 OLSs for Toluca have been evaluated consistent with the ICAO aerodrome reference code 4, per the definition given in ICAO Annex 14, which is based on the highest value of the aerodrome reference field length of the aircraft for which the runway is intended[1]. Examples of aerodrome reference code 4 aircraft regularly operating at Toluca are the Airbus 319 and Airbus 320. Furthermore, the ICAO Annex 14 OLSs associated with Category (CAT) II/III precision approaches were evaluated.

2.1 Conical Surface

The Conical Surface (along with the Inner Horizontal Surface) protects airspace for visual circling prior to landing. Visual circling is a maneuver used to align the aircraft with the runway for landing when a straight-in landing from an instrument approach is not feasible. The Conical Surface slopes upwards and outwards from the periphery of the Inner Horizontal Surface (defined below). The slope of the Conical Surface is measured in a vertical plane perpendicular to the periphery of the Inner Horizontal Surface. For Toluca, a slope of 5% (20:1) was applied.

The limits of the Conical Surface are the following:

[1] The minimum field length required for take-off at maximum certificated take-off mass, sea level, standard atmospheric conditions, still air and zero runway slope, as shown in the appropriate aeroplane flight manual prescribed by the certificating authority or equivalent data from the aeroplane manufacturer. Field length means balanced field length for aeroplanes, if applicable, or take-off distance in other cases.

- A lower edge coincident with the periphery of the Inner Horizontal Surface; and
- An upper edge located at a specified height above the Inner Horizontal Surface. For Toluca, a height of 100 m was used.

2.2 Inner Horizontal Surface

The purpose of the Inner Horizontal Surface (along with the Conical Surface) is to protect airspace for visual circling prior to landing. The Inner Horizontal Surface is a horizontal plane above an aerodrome and its environs. The height of the Inner Horizontal Surface is measured above an elevation datum established for such purpose. The radius or outer limits of the Inner Horizontal Surface is measured from a reference point or points established for such purpose. Guidance on determining the elevation datum and the extent of the Inner Horizontal Surface is contained in the ICAO Airport Services Manual (Doc 9137), Part 6, *Control of Obstacles*, 2nd edition, dated 1983.

For establishing the Inner Horizontal Surface at Toluca, a height of 45 m above the Aerodrome Reference Point (ARP) elevation of 2580 m above Mean Sea Level (MSL), resulting in an Inner Horizontal Surface elevation of 2625 m MSL, and a radius of 4000 m from the runway thresholds, were used.

2.3 Approach Surface

The Approach Surface defines the volume of airspace that should be kept free of obstacles in order to protect an aircraft in the final phase of landing. The Approach Surface is an inclined plane or combination of planes preceding the threshold, and composed of the following:

- An inner edge of specified length, horizontal and perpendicular to the extended centerline of the runway and located at a specified distance before the threshold;
- Two sides originating at the ends of the inner edge and diverging uniformly at a specified rate from the extended centerline of the runway;
- An outer edge parallel to the inner edge.

The above surfaces are varied when lateral offset, offset, or curved approaches are utilized, specifically, when two sides originating at the ends of the inner edge diverge uniformly at a specified rate from the extended centerline of the lateral offset, offset, or curved ground track. The elevation of the inner edge is equal to the elevation of the midpoint of the threshold. The slope of the Approach Surface is measured in the vertical plane containing the centerline of the runway (and continues to contain the centerline of any lateral offset or curved ground track).

For Toluca, each ICAO Annex 14 Approach Surface has a slope of 2% (50:1) for the first section (3000 m). The slope increases to 2.5% (40:1) in the second section until it intersects the horizontal plane of the third section at 150 m above the threshold elevation. Since no obstacle penetrations were observed in the third section of the Approach Surface, the horizontal plane was not raised, as prescribed by ICAO Annex 14[2]. The total length of the Approach Surface is 15,000 m. The Approach Surface has an inner edge of 300 m starting 60 m from the threshold and extending at a 15% divergence rate on both sides to 4800 m at the outer edge. A notional diagram of the ICAO Annex 14 Approach Surface is depicted in Figure 3, below.

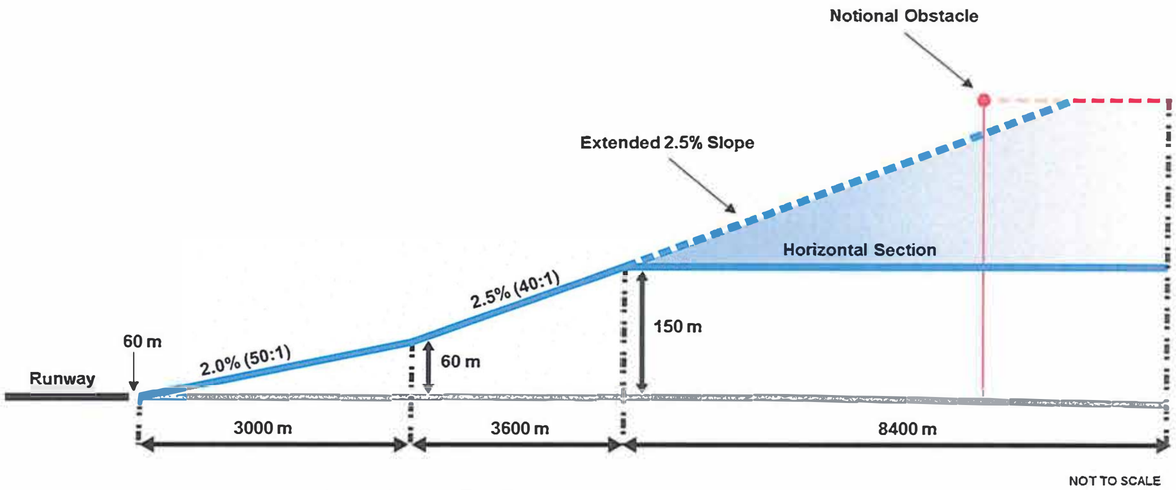


Figure 3. ICAO Annex 14 Approach Surface

2.4 Transitional Surface

The Transitional Surface (along with the Approach Surface) defines the volume of airspace that should be kept free of obstacles in order to protect an aircraft in the final phase of landing. The Transitional Surface is a complex surface along the side of the runway strip and part of the side of the Approach Surface, sloping upwards and outwards to the Inner Horizontal Surface, and composed of the following:

- A lower edge beginning at the intersection of the side of the Approach Surface with the Inner Horizontal Surface and extending down the side of the Approach Surface to the inner edge of the Approach Surface and from there along the length of the runway strip parallel to the runway centerline; and
- An upper edge located in the plane of the Inner Horizontal Surface.

The slope of the Transitional Surface is measured in a vertical plane at right angles to the centerline of the runway. For Toluca, a slope of 14.3% (7:1) was used. The elevation of a point on the lower edge is:

- Along the side of the Approach Surface—equal to the elevation of the Approach Surface at that point; and

[2] As per ICAO Annex 14 Section 4.2.17, the Annex 14 Approach Surface should be horizontal beyond the point at which the 2.5% slope intersects a horizontal plane 150 m above the threshold elevation or the horizontal plane passing through the top of any object that governs the obstacle clearance limit, whichever is higher.

- Along the runway strip — equal to the elevation of the nearest point on the centerline of the runway or its extension.

2.5 Take-off Climb Surface

The Take-off Climb Surface provides protection for an aircraft on take-off by indicating which obstacles should be removed, if possible, and marked and/or lighted if removal is impossible.

The Take-off Climb Surface is an inclined plane or other specified surface beyond the end of a runway or clearway composed of the following:

- An inner edge, horizontal and perpendicular to the centerline of the runway and located either at a specified distance beyond the end of the runway or at the end of the clearway when such is provided and its length exceeds the specified distance;
- Two sides originating at the ends of the inner edge, diverging uniformly at a specified rate from the take-off track to a specified final width and continuing thereafter at that width for the remainder of the length of the Take-off Climb Surface; and
- An outer edge horizontal and perpendicular to the specified take-off track.

The elevation of the inner edge is equal to the highest point on the extended runway centerline between the end of the runway and the inner edge, except that when a clearway is provided the elevation will be equal to the highest point on the ground on the centerline of the clearway.

For Toluca, a distance of 60 m from the runway end and a slope of 2% (50:1) were used. (Clearways are not established for the existing runway at Toluca.) Each Take-off Climb Surface has an inner edge of 180 m and diverges on each side at a rate of 12.5%. It is important to note that the final width for a straight-out take-off path is 1200 m, and the final width is 1800 m if the intended flight track includes changes of heading greater than 15° or greater in Instrument Meteorological Conditions (IMC) or Visual Meteorological Conditions (VMC) at night. Both types of take-off paths were assumed to exist at Toluca. A notional diagram of the ICAO Annex 14 Take-off Climb Surface is depicted in Figure 4, below.

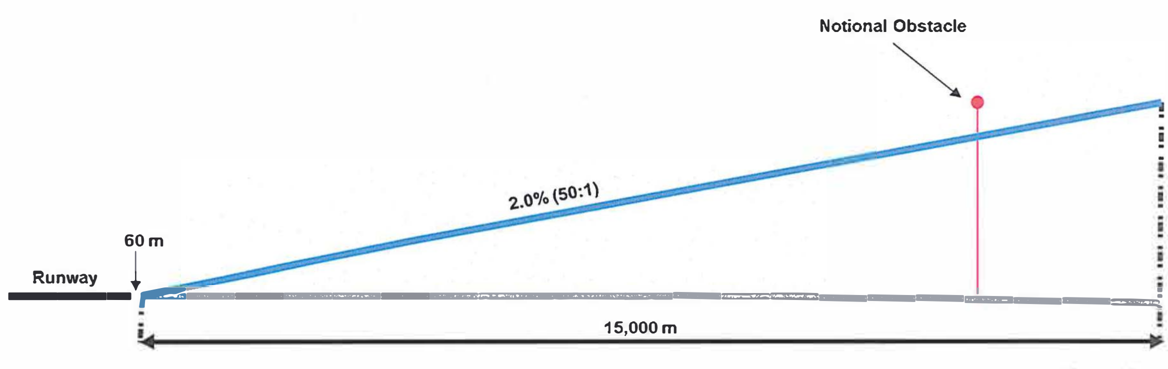


Figure 4. ICAO Annex 14 Take-off Climb Surface

2.6 Outer Horizontal Surface

The erection of tall structures in the vicinity of airports beyond the areas currently recognized in Annex 14 may cause problems for aircraft operations. Therefore, aviation authorities may establish an Outer Horizontal Surface to obtain advance notice of any proposal to erect tall structures that may penetrate this surface. This will enable them to study the aeronautical implications of such structures and take actions to protect aviation interests, if needed. The Outer Horizontal Surface, however, is not required to be established for precision approaches. Therefore, the Outer Horizontal Surface was not evaluated by MITRE. The previously-mentioned Airport Services Manual (Doc 9137), Part 6, *Control of Obstacles,* provides guidance for the establishment of an Outer Horizontal Surface to assist authorities in controlling the development of obstacles beyond the ICAO Annex 14 OLSs mentioned above.

2.7 Obstacle Free Zone

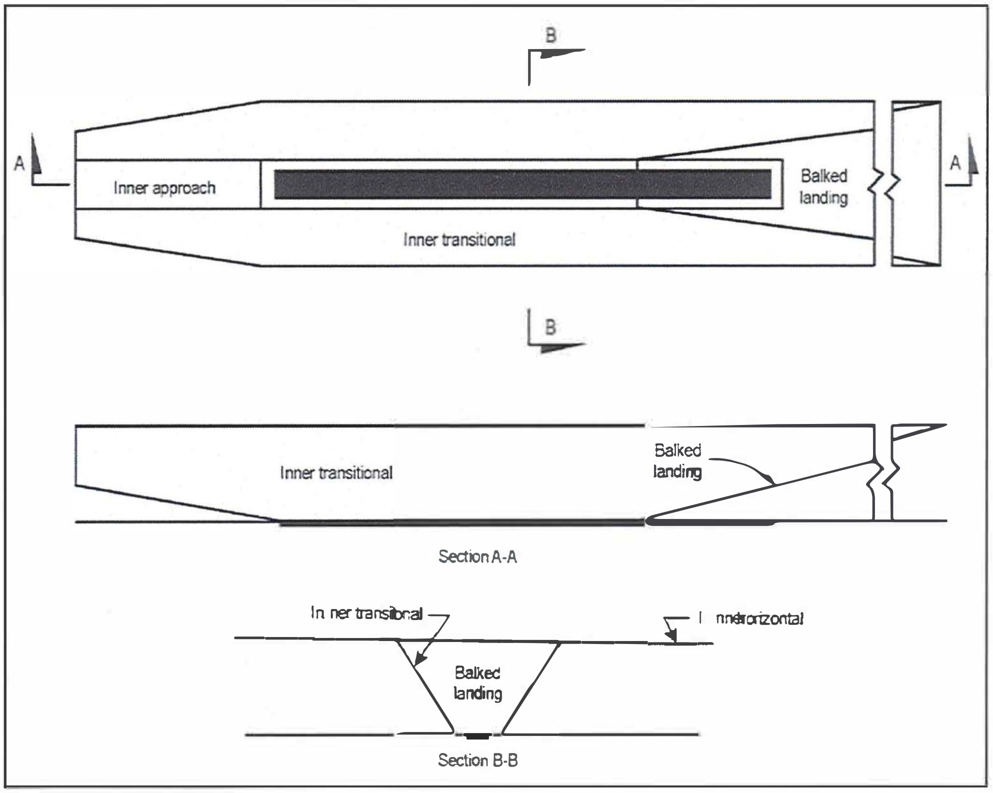
For CAT II/III precision approach runways, like Runway 15 at Toluca, ICAO requires (recommended for CAT I precision approach runways) that an Inner Approach Surface, Inner Transitional Surface, and Balked Landing Surface be established. These surfaces, described below, are in the immediate vicinity of the runway and are collectively known as the Obstacle Free Zone (OFZ).

2.7.1 Inner Approach Surface

The Inner Approach Surface (see Figure 5) is a rectangular portion of the Approach Surface immediately preceding the threshold, and composed of the following:

- An inner edge coincident with the location of the inner edge of the Approach Surface, but of its own specified length;
- Two sides originating at the ends of the inner edge and extending parallel to the vertical plane containing the centerline of the runway; and
- An outer edge parallel to the inner edge.

Intentionally Left Blank



Source: ICAO Annex 14

Figure 5. Inner Approach, Inner Transitional, and Balked Landing Surfaces

For Toluca, a distance of 60 m from the runway end, a length of 900 m, and a slope of 2% (50:1) were used to establish the Inner Approach Surface.

2.7.2 Inner Transitional Surface

The Inner Transitional Surface (see Figure 5) is similar to the Transitional Surface, but closer to the runway. It is intended that the Inner Transitional Surface be the controlling OLS for navigation aids, aircraft, and other vehicles that must be near the runway and not be penetrated except for frangible objects. In contrast, the Transitional Surface described above is intended to remain as the controlling OLS for buildings, etc. The Inner Transitional Surface is composed of the following:

- A lower edge beginning at the end of the Inner Approach Surface and extending down the side of the Inner Approach Surface to the inner edge of that surface, from there along the strip parallel to the runway centerline to the inner edge of the Balked Landing Surface (defined below) and from there up the side of the Balked Landing Surface to the point where the side intersects the Inner Horizontal Surface; and
- An upper edge located in the plane of the Inner Horizontal Surface.

The slope of the Inner Transitional Surface is measured in a vertical plane at right angles to the centerline of the runway. For Toluca, a slope of 33.3% (3:1) was used.

The elevation of a point on the lower edge is:

- Along the side of the Inner Approach Surface and Balked Landing Surface — equal to the elevation of the particular surface at that point; and
- Along the runway strip — equal to the elevation of the nearest point on the centerline of the runway or its extension.

2.7.3 Balked Landing Surface

The Balked Landing Surface (see Figure 5) is an inclined plane located at a specified distance after the threshold, extending between the Inner Transitional Surfaces, and composed of the following:

- An inner edge, horizontal and perpendicular to the centerline of the runway and located at a specified distance after the threshold;
- Two sides originating at the ends of the inner edge and diverging uniformly at 10% from the vertical plane containing the centerline of the runway; and
- An outer edge parallel to the inner edge and located in the plane of the Inner Horizontal Surface.

The elevation of the inner edge is equal to the elevation of the runway centerline at the location of the inner edge. The slope of the Balked Landing Surface is measured in the vertical plane containing the centerline of the runway.

For Toluca, a distance of 1800 m from the threshold and a slope of 3.33% (30:1) were used.

2.8 Key ICAO Annex 14 OLS SARPs

Fixed objects should not be permitted above the Inner Approach, Inner Transitional or the Balked Landing Surfaces, except for frangible objects which, because of their function, must be located on the strip. Mobile objects should not be permitted above these surfaces during the use of the runway for landing.

New objects or extensions of existing objects should not be permitted above an Approach Surface, Transitional Surface, or Take-off Climb Surface except when, in the opinion of the appropriate authority, the new object or extension would be shielded by an existing immovable object.

ICAO Annex 14 also recommends that new objects or extensions of existing objects should not be permitted above the Conical Surface and the Inner Horizontal Surface except when, in the opinion of the appropriate authority, an object would be shielded by an existing immovable object, or after aeronautical study it is determined that the object would not adversely affect the safety or significantly affect the regularity of aircraft operations.

Additionally, ICAO recommends that existing objects above an Approach Surface, a Transitional Surface, the Conical Surface, the Inner Horizontal Surface, or the Take-off Climb Surface should as far as practicable be removed except when, in the opinion of the appropriate authority, an object is shielded by an existing immovable object, or after aeronautical study it is determined that the object would not adversely affect the safety or significantly affect the regularity of aircraft operations.

3. Methodology

This section describes the methodology used in the study, including the data analyzed, tools utilized, and assumptions made, as well as the limitations of the study.

3.1 Data

It is crucial to have a comprehensive, accurate, and current obstacle and terrain database with which to evaluate the various ICAO Annex 14 OLSs. Accordingly, MITRE commissioned a detailed satellite-based photogrammetric survey of Toluca and its surroundings. The photogrammetric survey, completed in September 2016, provided ground elevation as well as natural (e.g., trees and other vegetation) and man-made features such as buildings, towers, power line towers (including the power lines running between towers), trees, bridges, poles, posts, antennas, etc. Refer to Enclosure No. 4 to MITRE Technical Letter F500-L16-059: *Photogrammetric, Satellite-Based Survey of the Toluca Airport and Its Surroundings - Final Report*, dated 26 September 2016 for additional information. Additionally, where appropriate, MITRE used Shuttle Radar Topography Mission data, which was used to provide terrain information for areas beyond the extents of the photogrammetric survey. The above-mentioned data were used by MITRE for its ICAO Annex 14 OLSs assessment of Toluca.

3.2 Tools

MITRE used obstacle assessment analytical tools, such as PDToolkit, PHX, and other specialized software to evaluate the ICAO Annex 14 OLSs, including ArcMap, ArcScene, Global Mapper, Google Earth, and AutoCAD.

3.3 Assumptions and Limitations

As mentioned above, the photogrammetric survey of the Toluca site and its surroundings was completed in September 2016. Any structures or alterations completed after that date are not considered by MITRE's study.

MITRE evaluated only those ICAO Annex 14 OLSs prescribed by ICAO. However, some countries restrict new construction of tall structures beyond the areas currently recognized in ICAO Annex 14 to ensure the safety and efficiency of aerodrome operations. If tall structures are erected in or near areas suitable for instrument approach procedures, they may result in increased procedure heights with consequent adverse effects on aircraft operations and runway availability. Moreover, high masts or other structures in some areas beyond those mentioned in ICAO Annex 14 can become an impediment for departure or missed approach climb-paths. Therefore, the aviation authorities of Mexico should establish strict regulations to control construction in the vicinity of Toluca to prevent the development of obstacles to aircraft operations.

The Take-off Climb Surfaces evaluated by MITRE correspond to candidate departure procedures that were developed by MITRE to help in avoiding conflicts and/or complications with operations at NAICM. The actual future departure procedures that will be implemented may differ from these candidate procedures, and therefore the impact of specific obstacles (and penetration amounts) on those future departure procedures may be different than the results contained in this document.

Note that in its analysis, MITRE assumed that taxiing (or parked) aircraft or vehicles do not infringe the ICAO Annex 14 OLSs or interfere with the operation of radio navigation aids. For example, it is assumed that appropriate runway-holding positions are provided, in accordance with ICAO aerodrome reference code of 4 for runways having precision approaches, such that a holding aircraft or vehicle do not infringe the OFZ, Approach Surface, Take-off Climb Surface or Instrument Landing System (ILS) critical/sensitive area, or interfere with the operation of radio navigation aids.

3.4 Runway Information

Toluca Airport is located approximately 16 km northeast of the city of Toluca and approximately 40 km from the western portion of Mexico City. The Mexico AIP shows the airport to be located at an elevation of 2580 m above MSL. Toluca has one runway: Runway 15/33 (4200 m x 45 m).

Runway 15 (the more frequently used runway direction) provides CAT I, as well as CAT II/III ILS approaches to help deal with the very low visibility conditions that frequently occur during the critical morning hours during several winter months. Note that MITRE analyzed CAT II/III required surfaces for both runway directions (i.e., Runway 15 and Runway 33), for planning purposes if authorities ever consider CAT II/III ILS approaches for Runway 33.

4. Results

This section provides the results of MITRE's ICAO Annex 14 OLSs analysis of Toluca. Note that the results provided in the figures below do not take into consideration a vertical accuracy for terrain and man-made obstacles of 3 m. Therefore, there may be some differences in the number of penetrations identified, as well as the amount of penetration shown in the figures, if a vertical accuracy of 3 m is applied (added or subtracted).

4.1 Conical Surface and Inner Horizontal Surface

The Conical and Inner Horizontal Surfaces are shown in Figure 6. There are no penetrations to the Conical Surface. There are man-made penetrations to the Inner Horizontal Surface. More detailed views are shown in Figures 7 and 8.

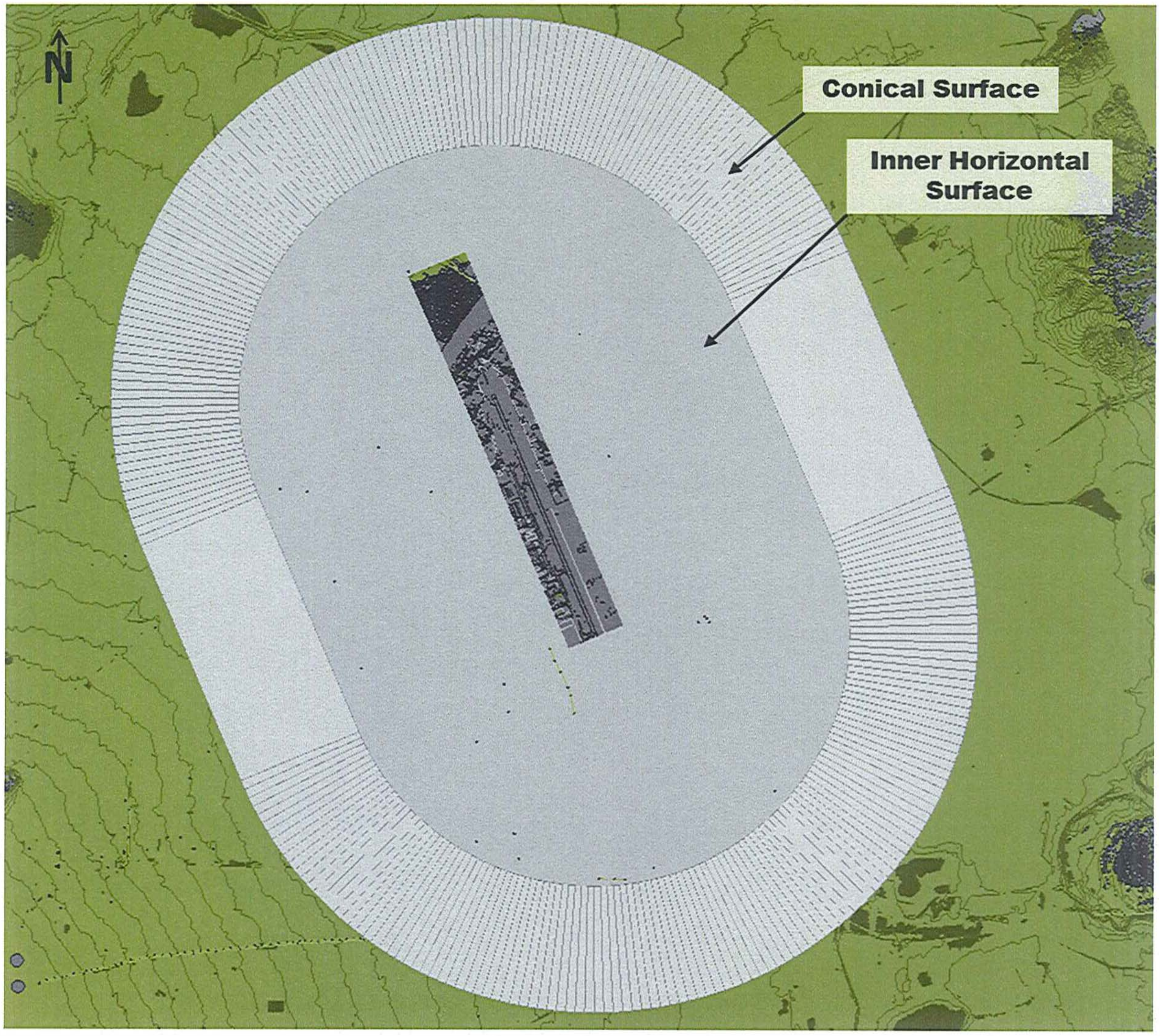


Figure 6. Conical and Inner Horizontal Surfaces

Intentionally Left Blank

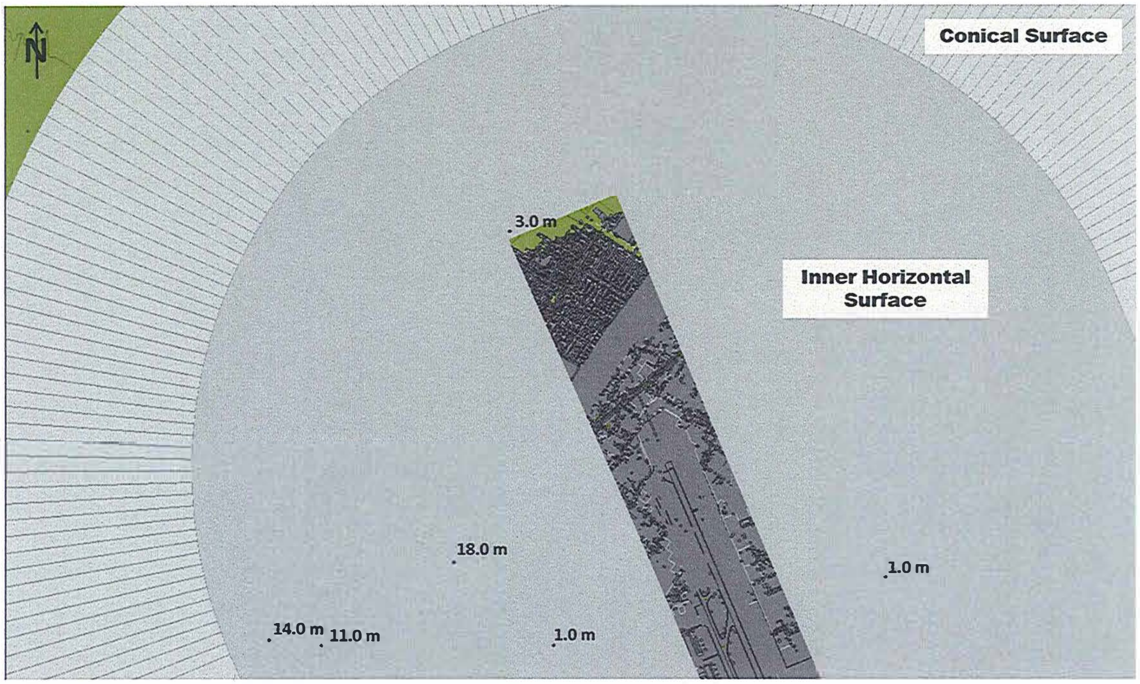


Figure 7. Penetrations to the Inner Horizontal Surface

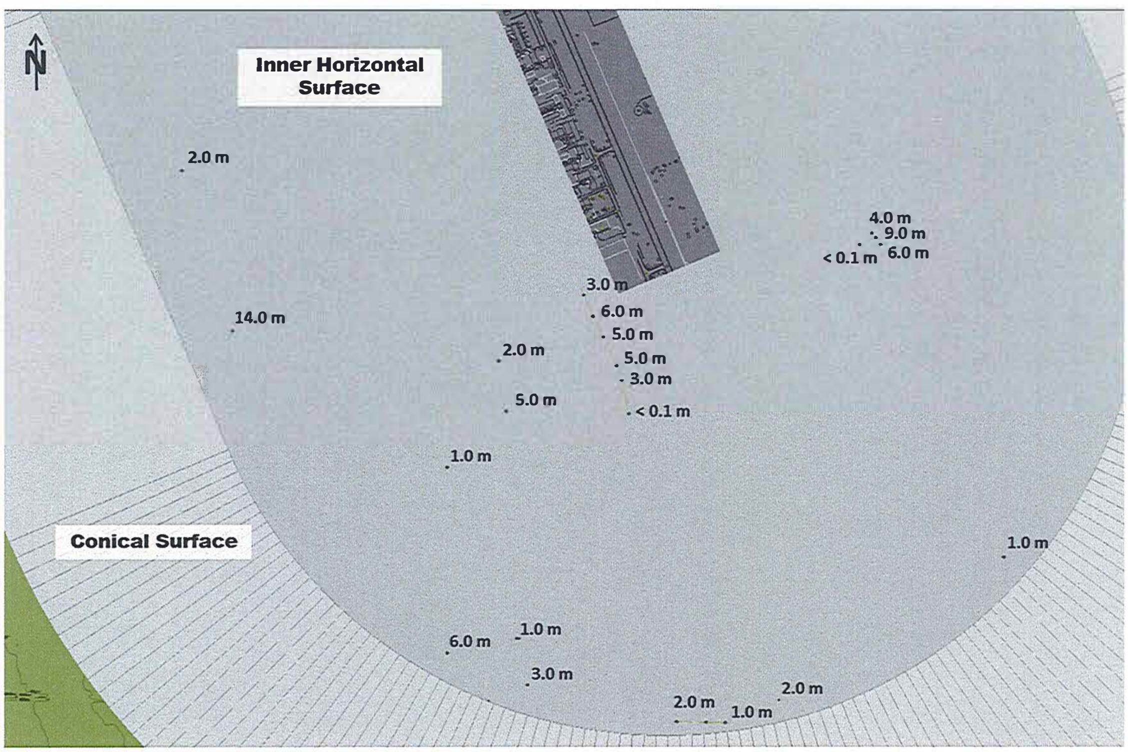


Figure 8. Additional Penetrations to the Inner Horizontal Surface

4.2 Approach Surfaces and Transitional Surfaces

The Approach and Transitional Surfaces are shown in Figures 9 through 12. As can be seen, there are some close-in penetrations to the Approach and Transitional Surfaces.

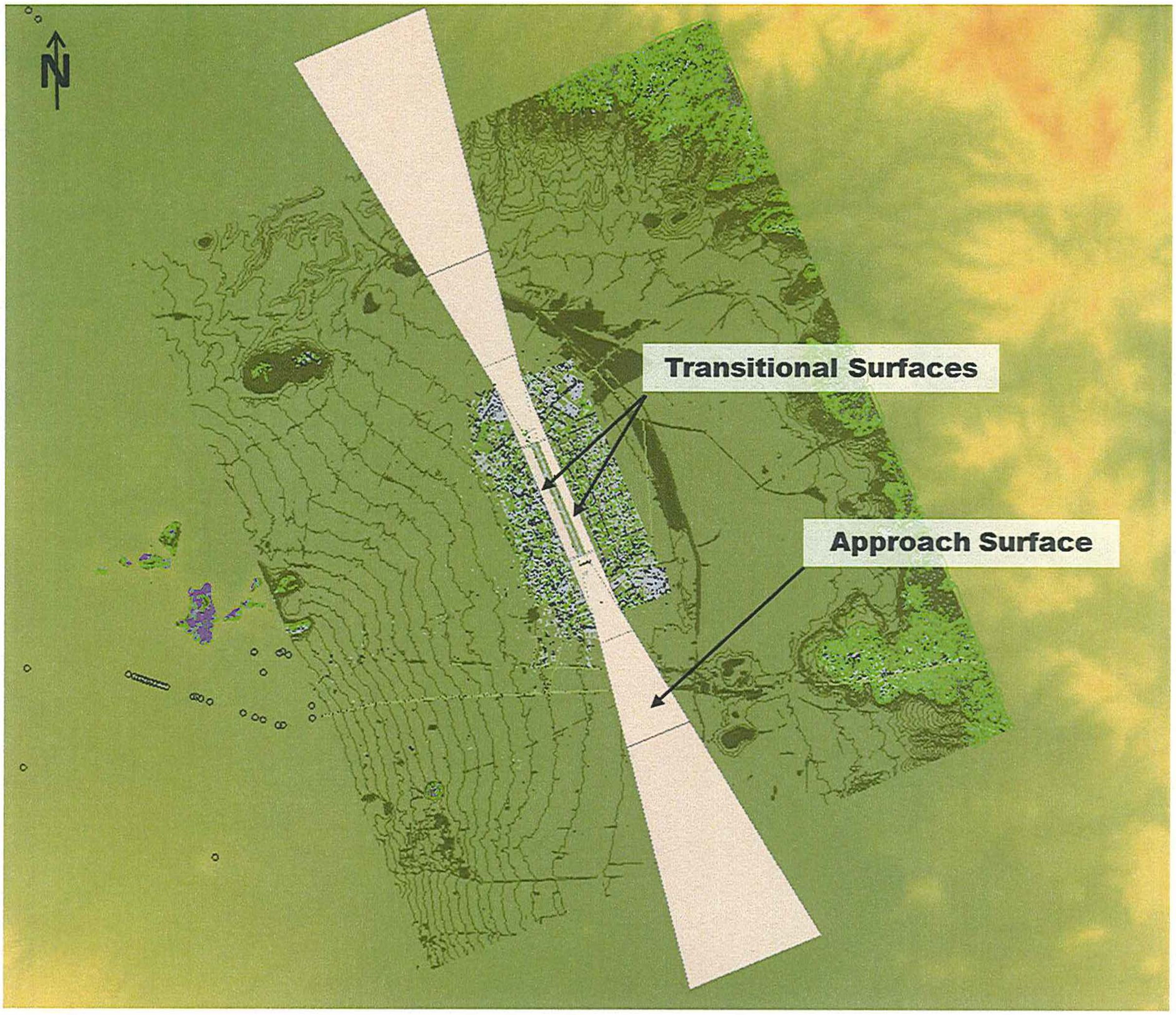


Figure 9. Approach and Transitional Surfaces

Intentionally Left Blank

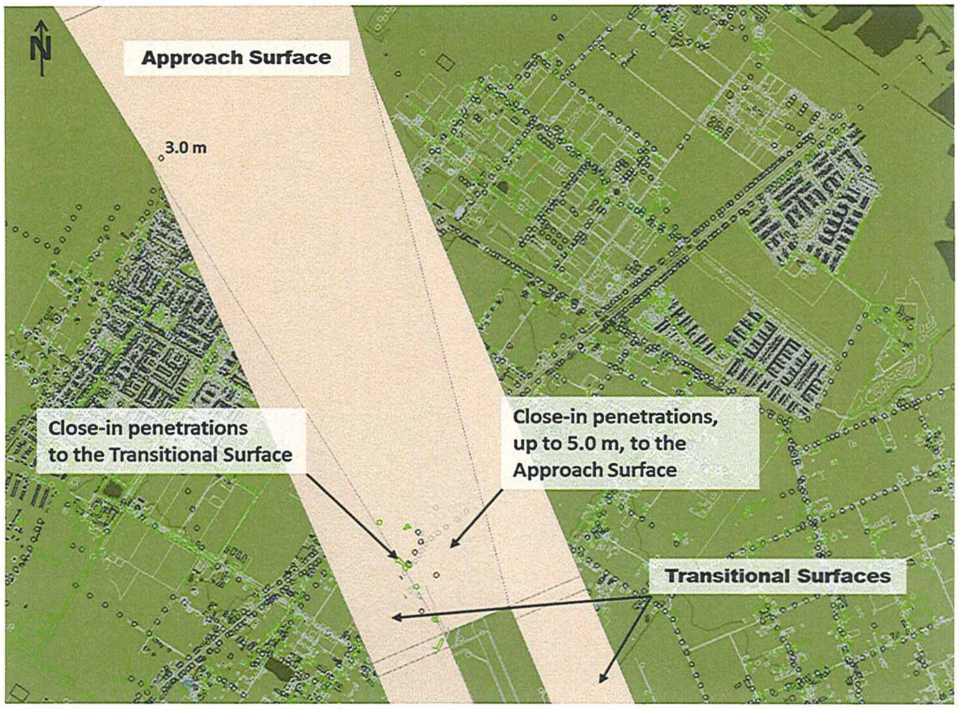


Figure 10. Approach and Transitional Surfaces (Runway 15 Detailed View)

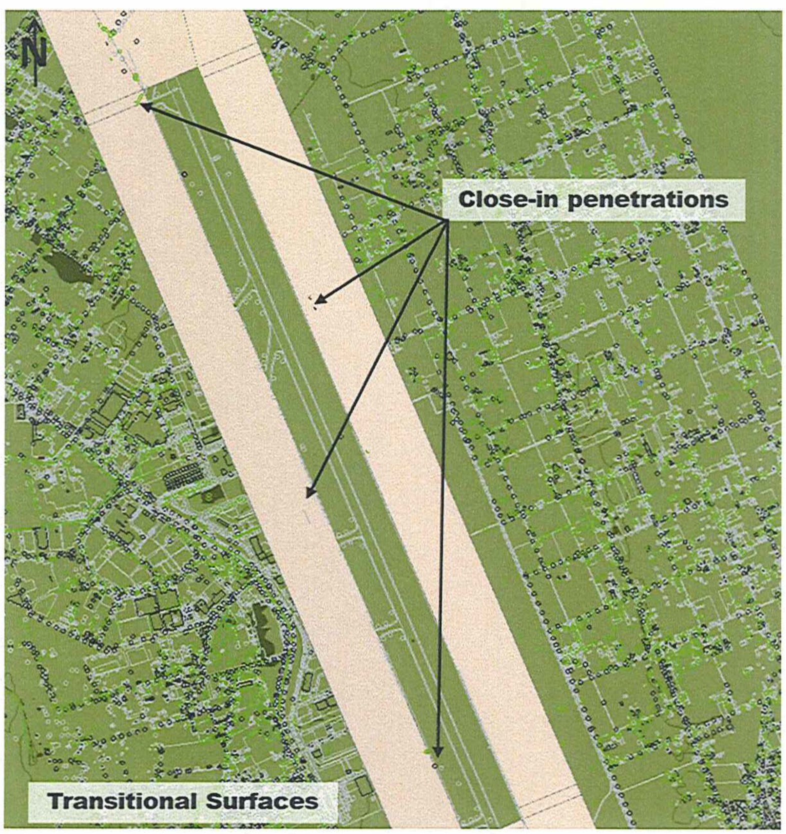


Figure 11. Transitional Surfaces (Detailed View)

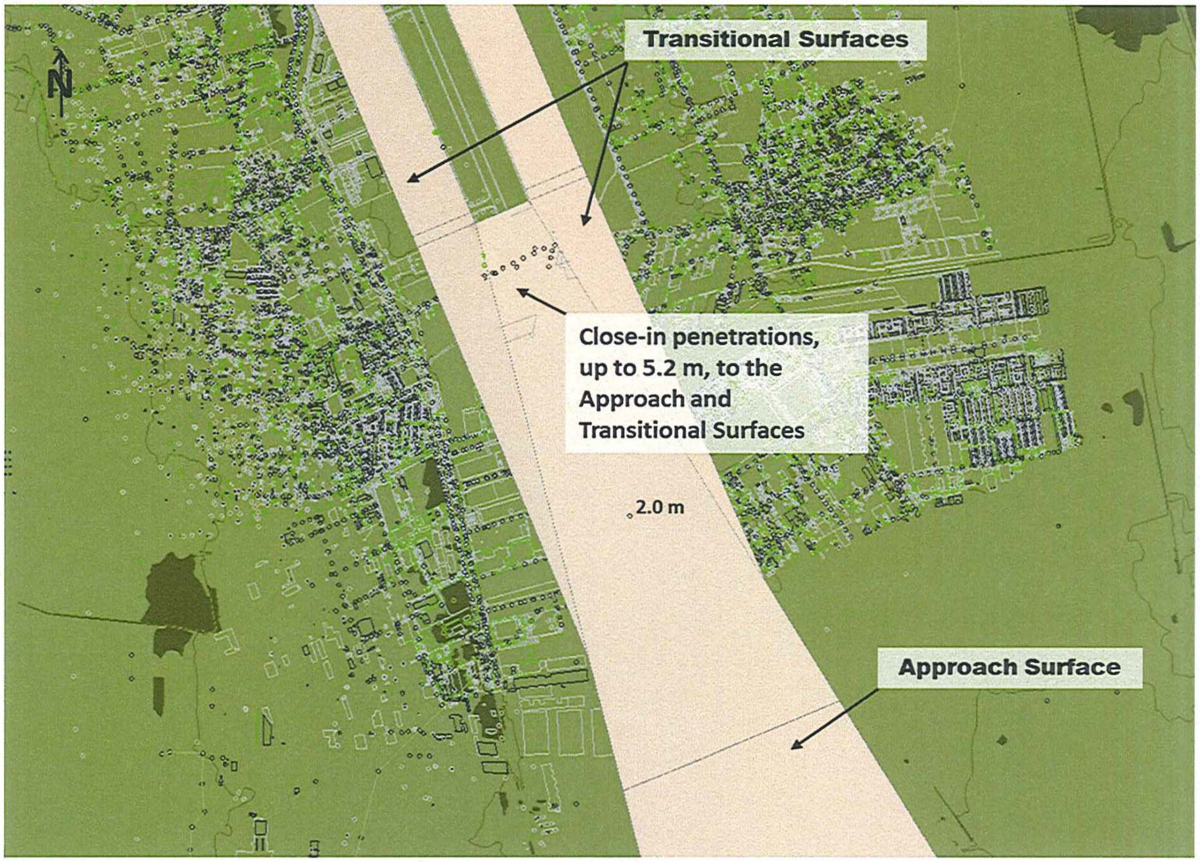


Figure 12. Approach and Transitional Surfaces (Runway 33 Detailed View)

4.3 Obstacle Free Zone Surfaces

There are some close-in penetrations to the OFZ surfaces, more specifically to the Inner Approach Surface, Inner Transitional Surface, and Balked Landing Surface. As per ICAO Annex 14, fixed objects should not be permitted above any of the OFZ surfaces, except for frangible objects which because of their function must be located on the strip. Mobile objects should not be permitted above these surfaces during the use of the runway for landing.

It is important to make sure that all obstacles penetrating the OFZ surfaces are low-mass and with frangible-mounted fixtures, and are required for air navigation purposes. If not, they should be removed. The OFZ surfaces and the identified penetrations are shown in Figures 13 through 16.

Figure 13. OFZ Surfaces

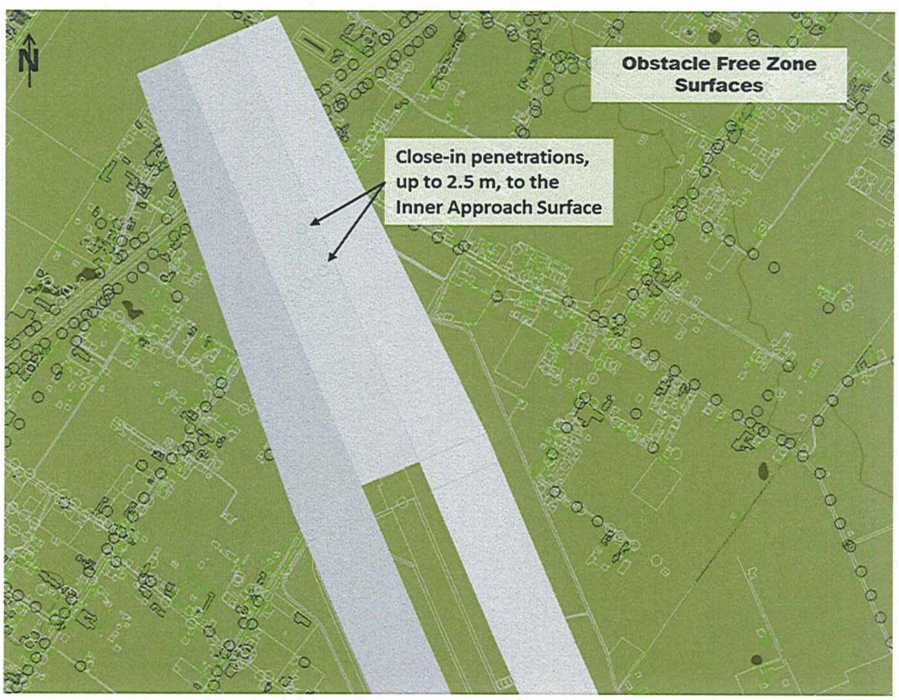


Figure 14. OFZ Surfaces (Runway 15 Detailed View)

Figure 15. OFZ Surfaces (Additional Detailed View)

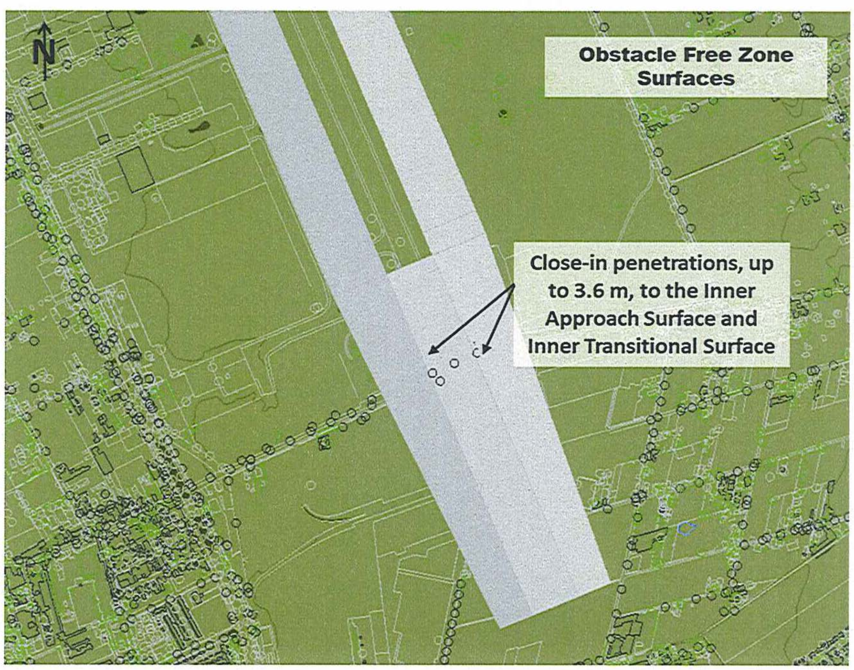


Figure 16. OFZ Surfaces (Runway 33 Detailed View)

4.4 Take-off Climb Surfaces

MITRE evaluated the Take-off Climb Surfaces corresponding to candidate departure procedures that were developed by its expert staff. These candidate procedures are described in detail in Enclosure 2 to MITRE Technical Letter H560-L18-027: *Development of Instrument Approach and Departure Procedures at Toluca Airport*, dated 15 March 2018.

MITRE developed 11 Area Navigation (RNAV) departure procedures for Toluca: five from Runway 33 and six from Runway 15. All departures were developed in accordance with the currently proposed airspace plan for NAICM and Toluca in collaboration with SENEAM. MITRE also developed five conventional departure procedures to accommodate the aircraft that are not RNAV equipped. All departure routes were designed to provide an efficient departure traffic flow and minimize interaction with in-bound Toluca and NAICM traffic. Figure 17 shows all the Take-off Climb Surfaces that were developed based on the nominal flight paths of the above-mentioned departure procedures.

Figure 17. Take-off Climb Surfaces

MITRE identified some penetrations close to the airport. Due to their proximity to the runway ends, all the identified penetrations were common for the 11 RNAV and five conventional departures. The Take-off Climb Surfaces with the identified penetrations are shown in Figures 18 and 19.

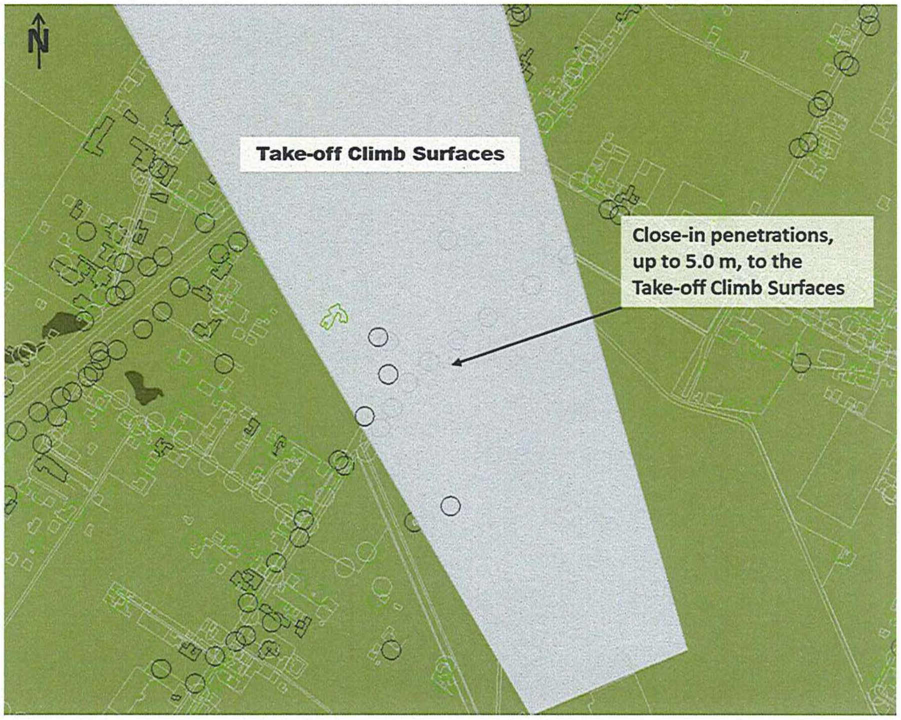
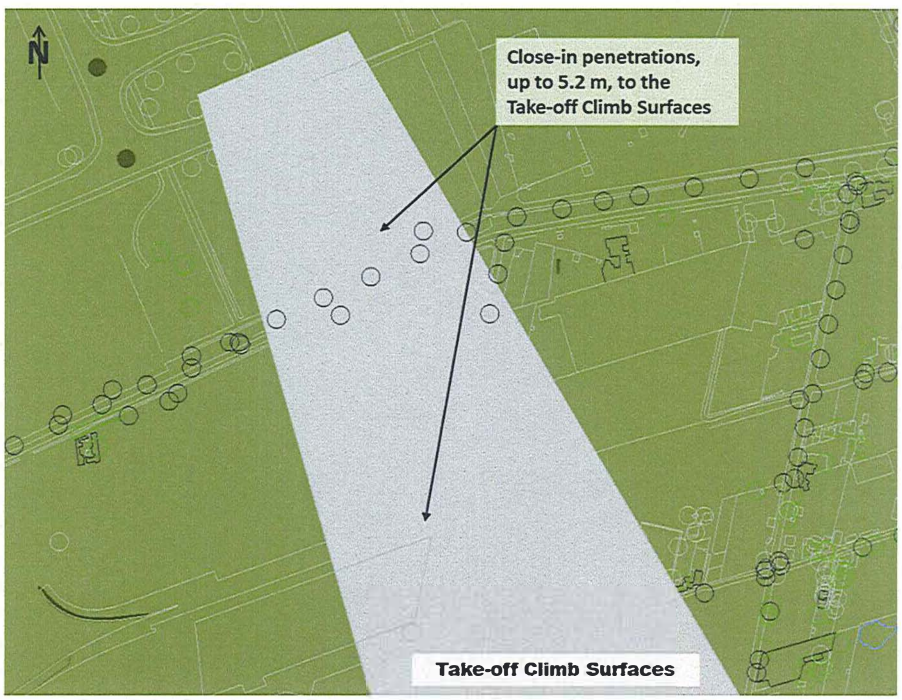


Figure 18. Take-off Climb Surface (Runway 33 Detailed View)



Note: this slide focuses on close-in obstacle penetrations. An additional obstacle penetration of 2.0 m is located farther to the south and can be seen on Figure 17.

Figure 19. Take-off Climb Surface (Runway 15 Detailed View)

5. Closing Remarks

MITRE developed relevant ICAO Annex 14 OLSs and identified obstacles that could impact aircraft operations. Multiple obstacles were identified penetrating the Inner Horizontal Surface. Some close-in penetrations to Approach, Transitional, and Take-off Climb Surfaces, in both directions, were also identified. Ideally, all penetrations to ICAO Annex 14 OLSs should be removed as far as practical. If removal is not practical or possible at all, the aviation authorities of Mexico should conduct a more detailed aeronautical study (outside the scope of MITRE's work) to determine that the penetrations would not affect the safety or regularity of aircraft operations and/or what actions should be taken to mitigate the impact of the obstacle(s). See Appendix A for FAA guidance on aeronautical studies in the U.S.

MITRE also identified some penetrations to the OFZs, more specifically to the Balked Landing, Inner Approach, and Inner Transitional Surfaces. ICAO Annex 14 states that fixed objects should not penetrate the Balked Landing, Inner Approach, and Inner Transitional Surfaces, except for frangible objects which because of their function must be located on the strip. MITRE was not able to verify if the penetrating obstacles are frangible. The penetrations identified to the OFZs should be reviewed as soon as possible by the appropriate aviation authorities of Mexico to determine what actions need to be taken.

It is important to note that the impact of ICAO Annex 14 OLS penetrations, as determined through a more detailed aeronautical study, in some cases may be mitigated and/or alleviated through measures such as marking and lighting the obstacle, or publishing it in the AIP and other navigational charts in accordance with Mexican regulations. Runway length modification, displacement of thresholds, conducting only vertically-guided approach procedures, and utilizing climb gradients on departure and missed approach procedures are other mitigation methods that can be considered. However, these measures need to be carefully examined with the airlines and various other stakeholders to ensure a safe and efficient operational environment for arriving and departing aircraft.

Note that the ICAO Annex 14 OLSs are also a very useful tool to assist authorities with the establishment of land-use regulations by defining obstacle height limits to prevent the development of man-made structures that could adversely impact current or future aircraft operations. MITRE recommends that the aviation authorities of Mexico establish strict regulations to control construction in the vicinity of Toluca to prevent the development of obstacles to aircraft operations.

Finally, MITRE recommends that this document be reviewed by the appropriate aviation authorities of Mexico, who have background in dealing with ICAO Annex 14 OLS penetrations, as well as in conducting aeronautical studies.

Appendix A. U.S. Regulations and FAA Procedures for Notification and Evaluation of Obstacles

General Overview

Much like ICAO, the U.S. Code of Federal Regulations (CFR) Title 14, Part 77, referred to simply as Part 77, establishes standards and notification requirements for objects affecting navigable airspace. Part 77 also provides for aeronautical studies of obstructions to air navigation in order to determine their effect on the safe and efficient use of airspace. It also allows for public hearings on the hazardous effect of proposed construction or alteration on air navigation.

FAA Part 77 Surfaces/Civil. Part 77.25 establishes the imaginary surfaces associated with civil airports and their individual runways. The shape of each imaginary surface is based on the category of its associated runway, according to the type of approach the runway is able to support. A complete explanation and description of the Part 77 imaginary surfaces is given below.

Aeronautical Studies. FAA regulations also establish the requirements for conducting aeronautical studies in order to determine the effect of proposed construction on the use of navigable airspace. Once the aeronautical study has been completed, a determination is made regarding the impact to air navigation. The determination concludes whether the object has no foreseeable effect on air navigation; is acceptable after necessary mitigation measures are implemented; or the object is considered to be a hazard and therefore objectionable.

An object is considered to have an adverse effect when it:

- Exceeds the obstruction standards outlined in Part 77 and/or may have a physical and/or electromagnetic effect on air navigational facilities
- Prompts a change to an instrument procedure or minimum flight altitude
- Restricts Control Tower line-of-sight
- Reduces airport capacity and efficiency
- Affects useable runway length

The result of an aeronautical study will determine whether an object has an adverse effect on aviation safety and/or a significant volume of aeronautical operations will be affected.

An aeronautical study is an important tool that can be used in determining the impact of an object on air navigation or aircraft operations at an airport. Unfortunately, detailed guidance on how to conduct an aeronautical study is not clearly provided by ICAO. Thus, an FAA guidance is hereby provided.

FAA Regulations for Objects Affecting Navigable Airspace

As mentioned above, Part 77 establishes standards for determining obstructions in navigable airspace, sets the requirements for notice to the Administrator and provides for aeronautical studies of obstructions to air navigation to determine their effect on the safe and efficient use of airspace. It applies to any object of natural growth, terrain, permanent or temporary construction or alteration, including equipment or materials used therein and apparatus of a permanent or temporary character. Notification allows the FAA to identify potential aeronautical hazards in advance, thus preventing or minimizing the adverse impacts to the safe and efficient use of navigable airspace. The regulation establishes the standard heights for determining if an existing object or a future object would be an obstruction to air navigation.

Construction or alteration of objects on or around airports can have an adverse impact to operations at an airport, such as the following:

- An increase to approach minimums
- Impacts on runway protection zones, safety areas, object free areas and obstacle free zones
- Impacts on the proper operation of navigational aid facilities, such as those that could be caused by the transmitting frequency of a proposed communications facility

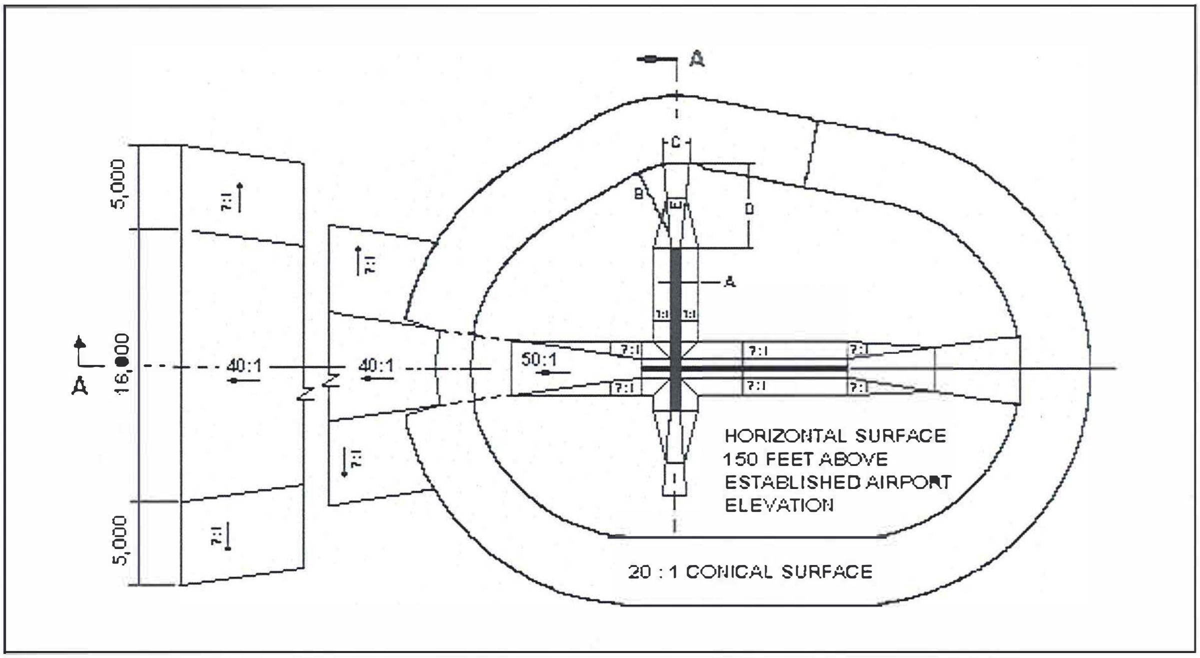
It is prudent for airport owners to protect the airspace around their airport to prevent loss of existing approaches or other negative impacts affecting utilization of their airport.

Civil Airport Imaginary Surfaces. Part 77.25 establishes imaginary surfaces with relation to the airport and to each runway. The size of each imaginary surface is based on the category of each runway according to the type of approach available or planned for that runway. The slope and dimensions of the Approach Surface applied to each end of a runway are determined by the most precise approach existing or planned for that runway end. Of significance are the following surfaces (see Figures A-1 and A-2):

- The **Primary Surface** is a surface longitudinally centered on a runway. When the runway has a specially prepared hard surface, the Primary Surface extends 200 ft beyond each end of that runway; the elevation of any point on the Primary Surface is the same as the elevation of the nearest point on the runway centerline. The width of a Primary Surface is 1000 ft for precision instrument runways.
- The **Approach Surface** is a surface longitudinally centered on the extended runway centerline and extending outward and upward from each end of the Primary Surface. An Approach Surface is applied to each end of each runway based upon the type of approach available or planned for that runway end.
- The **Transitional Surface** extends outward and upward at right angles to the runway centerline and the runway centerline extended, at a slope of 7:1 from the sides of the Primary Surface and from the sides of the Approach Surfaces.
- The **Horizontal Surface** consists of a horizontal plane 150 ft above the established airport elevation, the perimeter of which is constructed by swinging arcs of a specified radius from the center of each end of the Primary Surface of

each runway of each airport and connecting the adjacent arcs by lines tangent to those arcs.

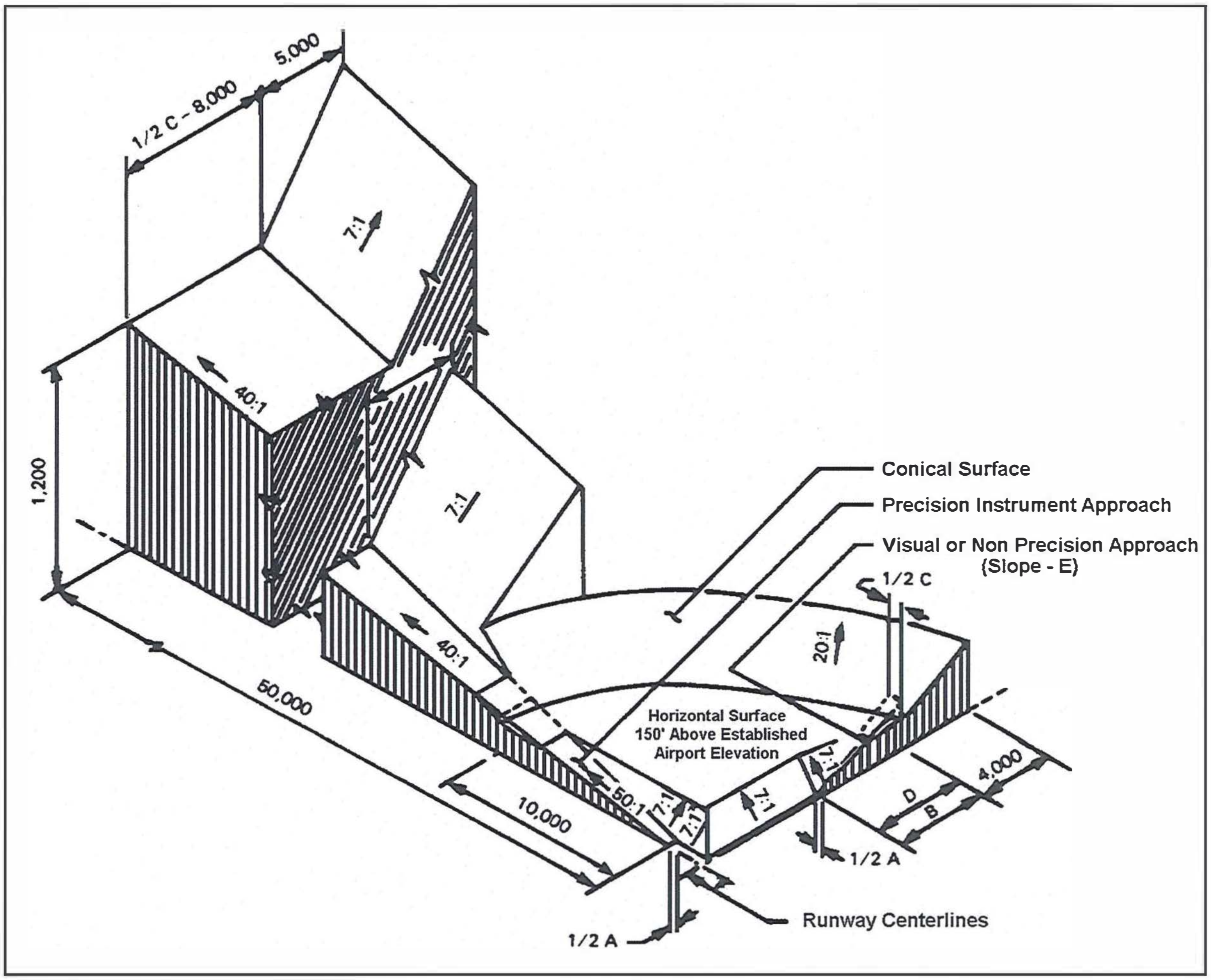
- The **Conical Surface** extends outward and upward from the periphery of the Horizontal Surface at a slope of 20:1 for a horizontal distance of 4000 ft.



Source: U.S. FAA

Figure A-1. Plan View of FAA Civil Airport Imaginary Surfaces

Intentionally Left Blank



Source: U.S. FAA

Figure A-2. Three-Dimensional View of FAA Civil Airport Imaginary Surfaces

FAA's Notification Procedure for Objects Affecting Navigable Airspace

Part 77, Subpart B: Notice of Construction or Alteration, establishes standards and notification requirements for objects affecting navigable airspace. This notification serves as the basis for evaluating the effect of the construction or alteration on operating procedures, determining the potential hazardous effect of the proposed construction on air navigation, identifying mitigation measures to enhance safe air navigation, and determining other appropriate measures to be applied for continued safety of air navigation and the charting of new objects.

Any person or organization who intends to sponsor any of the following construction or alterations must notify the Administrator of the FAA.

- Any construction or alteration exceeding 200 ft above ground level
- Any construction or alteration:

- Within 20,000 ft of a public-use or military airport which exceeds a 100:1 surface from the nearest point of the nearest runway of each airport with at least one runway more than 3200 ft
- Within 10,000 ft of a public-use or military airport which exceeds a 50:1 surface from the nearest point of the nearest runway of each airport with its longest runway no more than 3200 ft
- Within 5000 ft from the nearest landing and take-off area of a public-use heliport which exceeds a 25:1 surface

- Any highway, railroad, or other traverse way with prescribed adjusted height that would exceed the above noted standards
- When requested by the FAA, any construction or alteration that would be in an instrument approach area, and available information indicates it might exceed an appropriate obstacle clearance standard
- Any construction or alteration located on a public-use airport or heliport regardless of height or location

Once the FAA has completed an aeronautical study, a determination is made regarding the impact to air navigation. One of three responses is typically issued:

- **No Objection** - the subject construction did not exceed obstruction standards and marking/lighting is not required
- **Conditional Determination** - the proposed construction/alteration would be acceptable contingent upon implementing mitigation measures (e.g., marking and lighting, etc.)
- **Objectionable** - the proposed construction/alteration is determined to be a hazard and is thus objectionable. The reasons for this determination are outlined to the proponent.

FAA's Procedure for Conducting Aeronautical Studies of Effect of Proposed Construction on Navigable Airspace

Part 77, Subpart D: Aeronautical Studies of Effect of Proposed Construction on Navigable Airspace, also establishes the requirements for the conduct of aeronautical studies to determine the effect of proposed construction on the use of navigable airspace by aircraft. At the conclusion of an aeronautical study, a determination is made as to whether or not the proposed construction would be a hazard to air navigation.

An aeronautical study is normally initiated when requested by the sponsor of any construction or alteration or whenever the FAA determines it appropriate. The FAA is responsible for conducting aeronautical studies. Typically, this process begins at the regional level within the FAA, and involves all operational and regulatory divisions of the FAA, such as Airports, Airway Facilities, Flight Standards, Flight Procedures, and Air Traffic. The FAA's philosophy in evaluating objects that may impact navigable airspace is that each is presumed to be a hazard until proven otherwise. This posture clearly favors the aeronautical community, and is consistent with the FAA's overall mission of promoting aviation safety.

If a tower or other object is found to have a significant adverse impact, a "hazard" determination will be issued. However, in most cases, the FAA typically negotiates with the proponent until conditions are met for a "no-hazard" determination. It is important to note that by congressional mandate, the FAA cannot prohibit any construction activities. Instead, as described above, the FAA evaluates the proposed construction, and, as necessary, works with the proponent to mitigate any impact that may result. These efforts are a key benefit of the FAA's participation at this level.

There are four steps in the FAA's aeronautical study process, as follows:

- **Notice to the FAA:** Part 77 outlines the type of construction or alteration requiring notice to the FAA. In many cases, the proponents will submit their information for study to the FAA despite the fact their activities do not meet notice criteria because the issuance of a no-hazard determination from the FAA will all but ensure no federal entanglements will halt construction efforts.
- **Obstruction Evaluation:** If a proposed structure exceeds any Part 77 obstruction standard, an aeronautical study must be conducted to identify the effects of the proposal on the use of navigable airspace. In this case, the different offices within the FAA (Air Traffic, Airports, Flight Procedures and Flight Standards, Airways Facilities, and the military representative, if appropriate) determine the possible impact as it relates to their area of responsibility.
- **Circulation of Evaluation Results for Public Comment:** Notification and public circulation is required for the following types of proposals:
    a. Those that would affect a public-use airport
    b. Those requiring a change in aeronautical operations or procedures
    c. When a structure exceeds obstruction standards
    d. When a structure would have a possible impact on Visual Flight Rules (VFR) operations

  There are limited, specific situations where notification is not required, as follows:

    a. Any object that would be shielded by existing structures of a permanent and substantial character or by natural terrain or topographic features of equal or greater height, and would be located in the congested area of a city, town, or settlement where it is evident beyond all reasonable doubt that the structure will not adversely affect safety in air navigation
    b. Any antenna structure of 20 feet or less in height except for one that would increase the height of another antenna structure

c. Any air navigation facility, airport visual approach or landing aid, aircraft arresting device, or meteorological device of a type approved by the Administrator, or an appropriate military service on military airports, the location and height of which is fixed by its functional purpose

d. Any construction or alteration for which notice is required by any other FAA regulation

- **Evaluating Aeronautical Effect and Issuing a Determination:** After an appropriate period of time for comment by the aeronautical community, the FAA makes a final determination if an object is a hazard to air navigation. Not all obstructions are necessarily a hazard. For an object to be considered for adverse effect, one or more of the following conditions must be met:

  a. The object must exceed the obstruction standards outlined in Part 77, and/or

  b. The object must have a physical and/or electromagnetic effect on air navigational facilities

Hazards and Mitigations

Typically, a determination will have to be made as to whether or not a proposal for new construction or an alteration to an existing structure has an adverse effect on navigable airspace, as described above, or will have an effect on a significant volume of operations. Such determination is made through a detailed aeronautical study, also described above.

There are many demands on uses of airspace, both aviation and non-aviation. A responsible agency is designated with the responsibility of managing navigable airspace to ensure equitable and maximum utilization. To help accomplish this, there are a number of obstacle mitigation methods that may be employed:

- Removal
- Marking and lighting
- Publishing the location of the obstacle in the AIP
- Limiting the use of the runway to certain types of approaches (e.g., instrument approaches)
- Restricting the type of traffic
- Establishment of appropriate operational procedures to ensure that the obstacle and/or area is avoided