Enclosure 2

(Ref. Technical Letter H560-L18-027)

MITRE

Center for Advanced
Aviation System Development

Development of Instrument Approach and Departure Procedures at Toluca Airport

Prepared for

Grupo Aeroportuario de la Ciudad de México

March 2018

Principal Acronyms and Abbreviations

AIP	Aeronautical Information Publication
AR	Authorization Required
ATC	Air Traffic Control
Baro	Barometric
CAT	Category
CG	Climb Gradient
CL	Centerline
DA	Decision Altitude
DER	Departure End of Runway
DME	Distance Measuring Equipment
EGM96	Earth Gravitational Model 1996
ESV	Expanded Service Volume
FAA	U.S. Federal Aviation Administration
FPNM	foot (feet) per nautical mile
ft	foot (feet)
GACM	Grupo Aeroportuario de la Ciudad de México
GPD	Global Procedure Designer
GPS	Global Positioning System
GS	Glide Slope
HAT	Height Above Touchdown
HITL	Human-in-the-Loop
ICAO	International Civil Aviation Organization
IF	Intermediate Fix
IFP	Instrument Flight Procedure
ILS	Instrument Landing System
INT	Intersection
LNAV	Lateral Navigation
LOC	Localizer
LT	Left

m	meter(s)
MITRE	The MITRE Corporation
MSL	Mean Sea Level
MVAC	Minimum Vectoring Altitude Chart
NA	Not Applicable
NAICM	Nuevo Aeropuerto Internacional de la Ciudad de México
NAVAID	Navigational Aid
NM	Nautical mile(s)
OCS	Obstacle Clearance Surface
OEA	Obstacle Evaluation Area
PFAF	Precise Final Approach Fix
POFZ	Precision Obstacle Free Zone
PSA	Photogrammetric Survey Area
RA	Radar/Radio Altimeter
RNAV	Area Navigation
RNP	Required Navigation Performance
RT	Right
RVR	Runway Visual Range
S	Straight-In
SENEAM	Servicios a la Navegación en el Espacio Aéreo Mexicano
SID	Standard Instrument Departure
SM	Statute mile(s)
SRTM	Shuttle Radar Topography Mission
SSV	Standard Service Volume
TARGETS	Terminal Area Route Generation Evaluation and Traffic Simulation
TCH	Threshold Crossing Height
TERPS	Standard for Terminal Instrument Procedures
TMA	Terminal Maneuvering (Control) Area
U.S.	United States
VHF	Very High Frequency
VNAV	Vertical Navigation

VOR	Very High Frequency (VHF) Omni Directional Radio Range
WGS84	World Geodetic System 1984

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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 the existing Toluca Airport (hereinafter referred to as Toluca). Therefore, the future TMA is being designed to support traffic flows and Instrument Flight Procedures (IFPs) not only for NAICM, but also for Toluca, as well as other nearby satellite airports. For example, arrival, departure, and overflight routes to, from, and within the future TMA are being designed to eliminate, or at least reduce, interactions that could impact capacity at NAICM.

The IFPs presented in this document are based on both conventional and space-based means of navigation and incorporate the outcome of discussions during a recently conducted SENEAM/MITRE NAICM-Toluca airspace design workshop that took place in Mexico City from 15 through 19 January 2018. The following IFPs were examined by MITRE for both Runway 15 and Runway 33 at Toluca:

- Instrument Landing System (ILS) Category (CAT) I, II, and III approaches
- Required Navigation Performance (RNP) Authorization Required (AR) approaches
- Standard Instrument Departures (SIDs), both conventional and Area Navigation (RNAV)

All IFPs were developed by MITRE using the United States (U.S.) Federal Aviation Administration (FAA) Standard for Terminal Instrument Procedures (TERPS) criteria. Note that MITRE did not re-accomplish or examine any currently published IFPs for Toluca.

It is important to mention that the IFPs examined by MITRE were presented to SENEAM during the above-mentioned January 2018 airspace design workshop. Additionally, the MITRE procedure design team reviewed the procedures with SENEAM's procedure design specialists during the visit. Important matters, such as special interest concerns, obstacle penetrations, the development of ILS CAT I and II/III approaches, the need for Expanded Service Volume (ESV) checks for ILS equipment, and SIDs, were discussed and reviewed.

Since the January 2018 workshop, the NAICM-Toluca airspace design, as well as any IFP development for NAICM and Toluca, have been "frozen" in preparation for the upcoming Human-in-the-Loop (HITL) simulations to take place at MITRE's Air Traffic Management Laboratory. The IFPs presented in this document are the ones to be used in the HITL simulations, which are intended to examine the airspace design and the IFPs to identify any issues that need to be addressed. At the completion of the HITL simulations, the airspace and the IFP assessment results will be carefully analyzed, and modifications recommended, if necessary. Therefore, based on the outcome of the HITL simulations, future changes to the airspace and IFPs are possible.

This document is organized as follows: Section 2 provides an overview of MITRE's IFP design methodology and the data used in its work; Section 3 discusses important considerations; Section 4 and Section 5 provide information pertaining to the development of instrument approach and departure procedures, respectively; Section 6 provides a summary of MITRE's work.

2. Methodology and Data Used

The first step in the development of IFPs is the collection and verification of relevant data (e.g., aeronautical, terrain, and obstacle information). MITRE used Mexico's Aeronautical Information Publication (AIP) as the primary source of aeronautical data. The AIP contains pertinent information, such as airspace classification, obstacle information, and aeronautical charts.

In September 2016, a satellite-based photogrammetric survey of Toluca was completed (described in Section 2.2). The survey collected information on obstacles (buildings, towers, antennas, trees, etc.) and terrain at Toluca and its surrounding areas, as well as special interest areas identified by MITRE. These data were used to evaluate all IFPs presented in this document.

After the data were collected and verified, MITRE experts developed and assessed various IFP design options. The work was completed using sophisticated specialized procedure design software. MITRE uses the Global Procedure Designer (GPD) software for all IFP development, except for RNP AR procedures. The RNP AR procedures were developed using the Terminal Area Route Generation Evaluation and Traffic Simulation (TARGETS) software, which is a MITRE-developed tool.

Once these steps were completed, all procedure design work and associated input parameters were peer-reviewed to ensure the data used in the development of IFPs were entered correctly into the system.

Although properly designed and evaluated, the results presented in this document are neither intended nor authorized for publication. This is because the aviation authorities of Mexico are responsible for the final design, Flight Inspection/Flight Validation, and publication of procedures.

Information that relates to procedure design (i.e., instrument approaches and departures) is shown using the English unit system (e.g., foot/feet [ft] and Nautical mile(s) [NM]). Climb Gradients (CGs) are expressed in feet per nautical mile (FPNM). All headings and radials are magnetic, latitude and longitude coordinates are based on World Geodetic System 1984 (WGS84), and all vertical heights/elevations are based on the Earth Gravitational Model 1996 (EGM96). In general, measurements and dimensions on the ground, as well as obstacle elevations/heights are in meters (m). Elevations are based on Mean Sea Level (MSL), unless otherwise noted.

2.1 Assumptions

The following general assumptions were considered in the development of the IFPs:

- Radio, radar, and Navigational Aid (NAVAID) coverage will exist to support the proposed IFPs
- When any of the IFPs transition through Special Use Airspace, the airspace will be modified or relocated, as necessary
  - Some of the RNAV and conventional SIDs from both Runway 33 and Runway 15 overfly Restricted Air Space MMR103 (TACAMBARO)
- Obstacles/terrain that impact ILS CAT I/II/III approaches will be removed or adjusted, as necessary
- Appropriate equipment for an ILS (e.g., Localizer [LOC] and Glide Slope [GS] antenna, approach/runway lighting system, etc.) will be installed for Runway 33[1] to meet Flight Inspection and installation requirements for operational use (including beyond the Standard Service Volume [SSV]). For this study, key equipment was assumed to be located as follows:
  - A pseudo LOC located approximately 300 m (1000 ft) past the departure end of the runway on the extended runway centerline
  - A pseudo GS facility located approximately 320 m (1049 ft) past the approach end of the runway and approximately 120 m (400 ft) offset from centerline on the right side
  - Distance Measuring Equipment (DME) collocated with the LOC
- RNP AR procedures will be authorized by the aviation authorities of Mexico

2.2 Toluca Photogrammetric Survey

As mentioned above, the 2016 Toluca satellite-based photogrammetric survey was used as the primary source for terrain and obstacle data.[2] In areas where surveyed terrain data were not available, MITRE used post-processed Shuttle Radar Topography Mission (SRTM) Level 1 data formatted as a grid with terrain postings every 3 arc-second (~ 90 m postings).

The survey data were collected from the following MITRE-defined areas (see Figure 1):

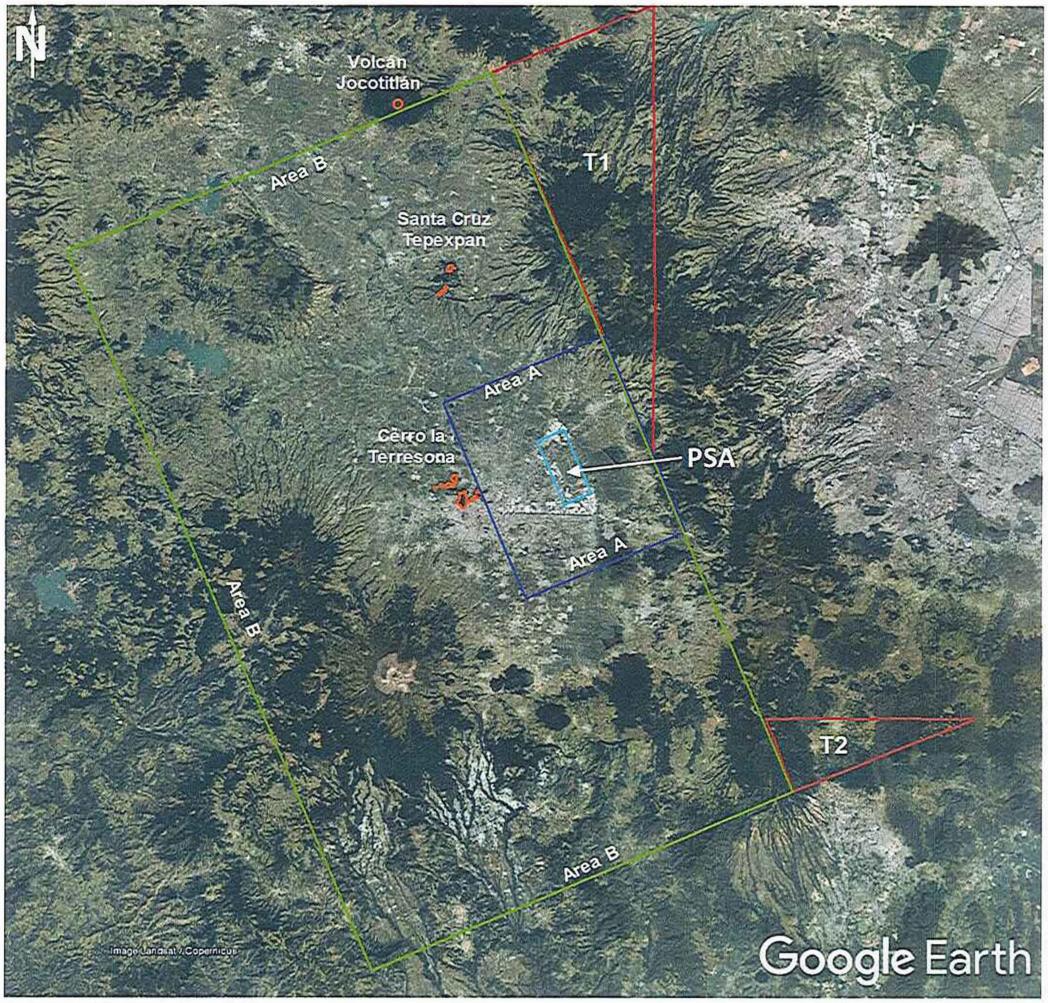
- Photogrammetric Survey Area (PSA)
- Area A
- Area B
- Two triangular areas referred to as "T1" and "T2"

[1] Note that Runway 33 currently does not have an ILS approach.

[2] 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.

- Three Special Areas: Cerro la Teresona, Santa Cruz Tepexpan, and Volcán de Jocotitlán

Satellite-based photogrammetric surveys are very useful for collecting data over large areas in an efficient and cost-effective manner. However, in some cases it can be difficult for the photogrammetrist to determine exactly what an object is when analyzing the satellite imagery (e.g., a utility pole versus a light stanchion). So, while every reasonable attempt has been made to properly identify each object type, there may be some differences regarding the description of the obstacle.



Source: Google Earth Pro

Figure 1. Toluca 2016 Photogrammetric Survey Areas

Table 1 below shows the vertical and horizontal accuracy requirements of the terrain and obstacle data defined by MITRE. All the listed requirements were met by the surveyor.

Table 1. Photogrammetric Survey Accuracy

	PSA and Area A		Area B and Areas T1 and T2	Three Special Areas: Cerro la Teresona, Santa Cruz Tepexpan, Volcán de Jocotitlán	
	Terrain	Obstacles	Obstacles	Terrain	Obstacles
Vertical accuracy (m)	3.00	3.00	30.00	3.00	3.00
Vertical resolution (m)	1.00	1.00	1.00	1.00	1.00
Horizontal accuracy (m)	2.00	2.00	50.00	2.00	2.00

Note: the vertical resolution refers to the value which the vertical component of the obstacle is reported.

In its IFP design work, MITRE applied the photogrammetric survey's vertical accuracy tolerances shown in Table 1 above. However, for the PSA, Area A, and the three Special Areas, MITRE applied a larger horizontal accuracy tolerance (15 m instead of 2 m) to all obstacles to account for those that may have large footprints. In the case of Area B, as well as Areas T1 and T2, the horizontal accuracy shown in Table 1 above was applied.[3]

All the approach, missed approach, and departure controlling obstacles, as well as the obstacles penetrating the surfaces related to the IFPs are listed in this document. The aviation authorities of Mexico should investigate the obstacle information contained in this document in more detail and develop mitigation solutions, as appropriate.

3. Important Considerations

While the design of the IFPs for Toluca has been completed, there are three considerations that require attention: radar and radio coverage, ILS CAT II/III approach development, and NAVAID SSV.

3.1 Radar and Radio Coverage

The Toluca operational concept relies on the air traffic controllers' ability to radar vector aircraft to the ILS final approach course. MITRE, in collaboration with SENEAM, has been working on the development of new Minimum Vectoring Altitude Charts (MVACs) for Toluca and NAICM. In Mexico, sector altitudes must be within radio and radar coverage. As radio and radar coverage matters are not within MITRE's area of expertise, MITRE has been coordinating with SENEAM to ascertain where coverage, both radio and radar, does or does not exist. This is important, as changes to MVAC sector altitudes can affect the overall airspace design for the future Mexico City TMA to support operations at NAICM and Toluca.

In August 2017, MITRE received radio coverage results from SENEAM, based on six radio repeater sites. In December 2017, MITRE received radar coverage results, based on five radar sites. Of the five radar sites, only three exist currently: the other two are planned to be located at or near NAICM. MITRE completed its examination of the data in mid-December 2017, identifying areas where radar and/or radio coverage was lacking at altitudes that were needed to support the proposed SENEAM-MITRE developed MVACs for both Toluca and NAICM.

[3] Note that accuracy tolerances can be added or subtracted. However, for conservative planning purposes, MITRE added accuracy tolerances.

In January 2018, MITRE visited SENEAM's office in Mexico City and presented a briefing describing areas where there was a lack of primary radar or radio coverage based on the proposed sector altitudes of each MVAC. Throughout the visit several meetings with SENEAM engineers were held to review MITRE's findings and discuss practical options to mitigate the lack of coverage.

During those meetings, MITRE was asked to define in more detail those areas lacking radar and radio coverage, and to confirm the minimum altitudes necessary to maintain the appropriate amount of obstacle clearance and support the overall airspace design. This work is on-going, and MITRE expects to provide the information to SENEAM in the April/May 2018 timeframe. This will assist SENEAM in conducting additional examinations to determine what is required (e.g., additional radars and radio receptors may need to be acquired) to provide the appropriate coverage to support the MVAC sector altitudes and overall NAICM-Toluca airspace design.

3.2 ILS CAT II/III Approach Procedure Development

When discussing ILS approach procedures, a review of some common terminology is in order. A Decision Altitude (DA) is a specified minimum altitude (in ft MSL) on a precision approach at which a decision is made to either continue the approach or to initiate a missed approach. The height of the DA above the touchdown zone elevation is known as the Height Above Touchdown (HAT). A Radar/Radio Altimeter (RA) is the elevation of the terrain directly beneath the DA point along the final approach course.

There are three general classifications of ILS approaches: CAT I, CAT II, and CAT III.[4] The basic ILS approach, CAT I, only requires that pilots be instrument-rated, and that aircraft be appropriately equipped. ILS CAT II and CAT III approaches have lower minima than ILS CAT I approaches and require special certification for operators, pilots, aircraft, and airborne/ground equipment.

When all basic requirements are met, the lowest standard approach minima for each ILS category are as follows:

- CAT I: 200 ft HAT and Runway Visual Range (RVR) 2400 ft
- CAT II: 100 ft HAT and RVR 1200 ft
- CAT III: RVR 700 ft[5]

Lower minima may be possible if additional category-specific requirements (on-board and ground-based) are met (e.g. CAT I RVR can be 1800 ft with centerline and touchdown zone lighting).

Under FAA criteria, the ILS CAT I approach final segment obstacle evaluation affects the ILS CAT II/III approach authorization. Specifically, for an ILS CAT II approach to be developed to the same runway supporting an ILS CAT I approach, the CAT I procedure must be

[4] In 2012, the FAA discontinued CAT IIIa, CAT IIIb, and CAT IIIc terminology, although some published procedures still reference these categories. However, these terms are still used by the International Civil Aviation Organization (ICAO).

[5] ILS CAT III approach minima consist of just an RVR with no published ceiling.

able to support a 200-ft HAT and lowest possible visibility (no restrictions incurred by lack of infrastructure or Obstacle Clearance Surface [OCS] penetrations). In other words, there can be no penetrations to the ILS CAT I approach final segment, other surfaces located on final (e.g., light surfaces), and the missed approach segment.[6] When these surfaces are clear, the ILS CAT I approach is considered unrestricted. Note that use of a CG to mitigate a missed approach surface penetration to achieve a 200-ft HAT does not meet the intent of an unrestricted ILS CAT I approach.

Similarly, to publish the lowest authorized ILS CAT III RVR, which is 700 ft, the runway must be able to support unrestricted ILS CAT II approaches (100-ft HAT and RVR 1200 ft).

MITRE determined that obstacle penetrations in the final approach segment of the ILS CAT I approaches to both Runway 33 and Runway 15 result in HATs greater than 200 ft and RVRs greater than 2400 ft. For example, a portion of a perimeter fence located west and north of the approach end of Runway 15 (see Figure 2) penetrates the ILS Obstacle Evaluation Area (OEA) surface by 6.4 m (21 ft), resulting in a HAT greater than 200 ft (see Section 4.1). There are similar penetrations to the Runway 33 ILS CAT I approach surfaces.

Source: Google Earth Pro

Figure 2. Example of a Runway 15 Approach Obstacle Penetration

[6] Certain equipment essential to flight operations may penetrate the precision final approach and missed approach segments without impacting the procedure.

As mentioned above, there are other surfaces, in addition to the ILS final approach segment surfaces, that must be evaluated. If penetrated, each of the surfaces will carry its own set of consequences.

3.2.1 Visual Area Surfaces

There are two visual area surfaces located within the final approach segment: the 34:1 and 20:1 surfaces. When either of the surfaces is penetrated, visibility restrictions must be applied. More specifically, when the 34:1 surface is penetrated, visibility is limited to no lower than 4000 ft RVR or ¾ Statute mile (SM); when the 20:1 surface is penetrated, visibility is limited to no lower than 5000 ft RVR or 1 SM, and the IFP can only be used during daylight hours. See Section 4.1 (and Table 3 within that section) for the 34:1 surface penetrations for Runway 33. Note that there are no 20:1 surface penetrations for Runway 33. See Section 4.1 (and Table 5 within that section) for both 34:1 and 20:1 surface penetrations for Runway 15.

3.2.2 Precision Obstacle Free Zone

The Precision Obstacle Free Zone (POFZ) is defined as a volume of airspace above an area beginning at the threshold, at the threshold elevation, and centered on the extended runway centerline, measuring 60.96 m (200 ft) long and 243.84 m (800 ft) wide. This area is designed to protect aircraft from ground vehicles and aircraft when the following operational conditions are in place:

- An aircraft is flying an approach with vertical guidance
- The reported ceiling[7] is below 250 ft or visibility is less than 3/4 SM (or RVR is below 4000 ft)
- An aircraft is on final approach within 2 NM of the runway threshold

Note that Runway 15 has penetrations to the POFZ (see Table 5 in Section 4.1).

3.2.3 Missed Approach Segment

The missed approach segment is a mandatory component of any instrument approach. When there is a penetration to the ILS CAT I missed approach surface, and the route cannot be changed, or the obstacle mitigated (e.g., removed or lowered), then a CG should be considered. However, the use of a CG to achieve a 200-ft HAT for the purposes of developing ILS CAT II approaches does meet the intent of an unrestricted ILS CAT I approach.

The standard CG is 200 FPNM and is never charted, as the assumption is that all aircraft can maintain a 200 FPNM CG. However, when a CG greater than 200 FPNM is required due to penetrations to either a missed approach or departure surface, the FAA requires that the CG be charted. The charted CG is maintained until a specified altitude (e.g., 265 FPNM to 9800 ft), after which a rate of climb no less than standard can be resumed.

Based on FAA criteria, any ILS CAT I approach obstacle penetrations must be mitigated (e.g., removed or lowered) to allow development of an ILS CAT II approach. If all ILS CAT I

[7] Ceiling, when used in aviation weather reports and forecasts, is the height above ground (or water) level of the lowest layer of clouds or obscuring phenomenon.

approach obstacle penetrations are mitigated, an ILS CAT II approach to Runway 15 can be developed. If the ILS CAT II approach is determined to be unrestricted (i.e., there are no penetrations to any surface), then the lowest ILS CAT III RVR can be published.

3.3 NAVAID SSV

The ILS consists of a LOC, GS, marker beacons (or suitable substitute), inner marker for CAT II approaches (if RA minima are not authorized), and an approach lighting system. Both the LOC and GS have SSVs, and where operational necessity dictates, NAVAIDs—if properly certified—may be used beyond their SSV limits. A Flight Inspection is required to confirm and certify a reliable signal reception at the distances necessary to support IFPs.

Because of the high terrain and the need to harmonize the Toluca Runway 33 ILS approach altitudes with MVAC sector altitudes for turn onto the ILS final approach course, both the LOC and GS will need to be certified for use beyond their normal SSV. As stated in Section 2.1, MITRE assumed that appropriate ILS equipment will be installed for Runway 33 to meet Flight Inspection and installation requirements for operational use.

4. Instrument Approach Procedures

This section contains information on the design of the ILS CAT I/II/III and RNP AR approaches.

4.1 ILS CAT I/II/III Instrument Approach Procedures

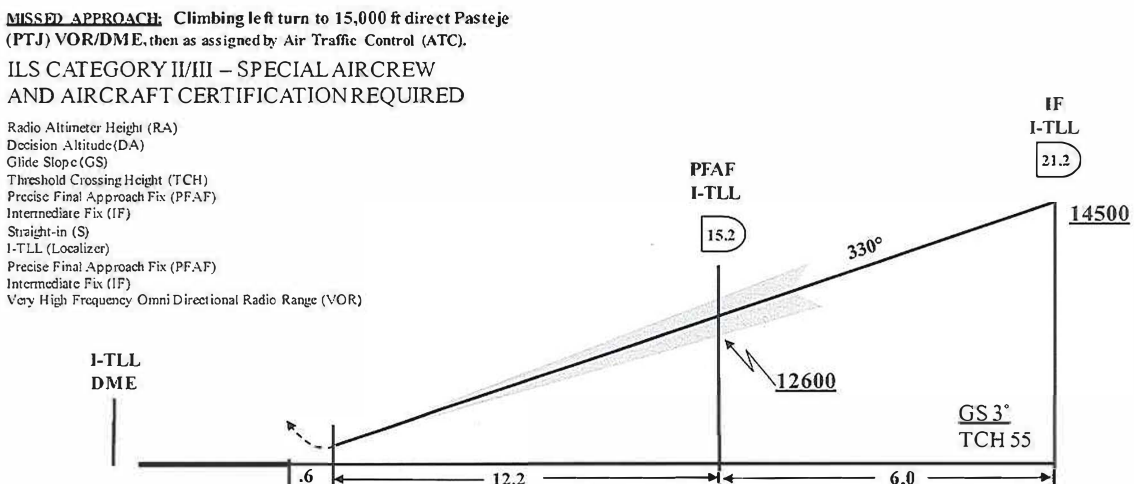
The ILS final segment OEA is composed of three OCS's: "W", "X", and "Y". The OEA originates 60.96 m (200 ft) from threshold and extends to the glidepath intercept point. The longitudinal (along-track) rising "W" OCS generally starts at the OEA origin; however, in certain cases, it may start at some distance from the OEA origin. The "W" surface is centered on the extended runway centerline and slopes up and away from the runway threshold. On either side of the "W" surface is the "X" surface, which slopes up and away from the edge of the "W" surface. On either side of the "X" surface is the "Y" surface, which slopes up and away from the edge of the "X" surface.

As previously mentioned, MITRE developed ILS CAT I/II/III approaches to Runway 33 and Runway 15 at Toluca. Figure 3 shows the approaches to Runway 33, with the information on the approach segment controlling obstacles listed in Table 2. Figure 4 shows the approaches to Runway 15, with the information on the approach segment controlling obstacles listed in Table 4. Table 3 and Table 5 list obstacles penetrating the ILS CAT I/II/III approach final segment, visual area surfaces (i.e., 20:1 and 34:1), and the POFZs of Runway 33 and Runway 15, respectively. Note for Tables 3 and 5: when investigating obstacle penetrations, be advised that specific vertical and horizontal accuracy tolerances were applied. See Section 2.2.

Note that the Runway 33 ILS CAT II/III approach visual area surfaces and the POFZ are clear. Obstacles penetrating the Runway 15 ILS CAT II/III approach visual area surfaces and the POFZ are part of the ILS CAT I approach obstacle list of those surfaces.

As mentioned above, the development of an ILS CAT II approach is dependent on whether the ILS CAT I approach can support a 200-ft HAT and ½-SM visibility (i.e., unrestricted). The ILS CAT II approach must be unrestricted to allow for the ILS CAT III approach minima to be published to the lowest RVR.

The ILS CAT I approach minima shown in Figure 3 (Runway 33) and Figure 4 (Runway 15) have been derived considering all obstacles. For the ILS CAT II approach, MITRE assumed that all ILS CAT I approach obstacle penetrations would be mitigated (e.g., removed or lowered). With the ILS CAT I approach obstacle penetrations mitigated, unrestricted ILS CAT II approaches are possible, and the ILS CAT III approach minima could be published to the lowest RVR.



CATEGORY	A	B	C	D
S-ILS 33	8722/40 259			
S-ILS 33	CAT II RA 108/12 100 DA 8563			
S-ILS 33	CAT III RVR 700			

Figure 3. Runway 33 ILS CAT I/II/III Approach: Profile View and Approach Minima
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Table 2. Controlling Obstacles for Runway 33 ILS CAT I/II/III Approach Segments

Segments	Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Final, CAT I	Light Stanchion	19° 18' 52.98" N	099° 33' 25.40" W	2597.00 (8520.34)
Final, CAT II/III	Pole Utility	19° 19' 07.60" N	099° 33' 23.40" W	2588.00 (8490.81)
Missed, CAT I	Pole Utility	19° 18' 51.61" N	099° 33' 24.49" W	2588.00 (8490.81)
	Light Stanchion	19° 18' 52.98" N	099° 33' 25.40" W	2597.00 (8520.34)
	Tower	19° 20' 10.31" N	099° 34' 13.23" W	2621.00 (8599.08)
Missed, CAT II/III	Terrain	19° 19' 42.12" N	099° 33' 45.67" W	2579.00 (8461.29)
	Hangar	19° 20' 36.04" N	099° 34' 24.93" W	2600.00 (8530.18)
Missed, All CATs	Tower	19° 20' 10.31" N	099° 34' 13.23" W	2621.00 (8599.08)
Intermediate	Terrain	19° 05' 12.00" N	099° 22' 09.00" W	3512.00 (11,522.31)
Initial	Terrain	19° 02' 30.00" N	099° 20' 55.00" W	3679.00 (12,070.21)

Table 3. Obstacles Penetrating Runway 33 ILS CAT I/II/III Final and Associated Surfaces

Obstacles Penetrating the Final Approach Surfaces

Description	Latitude	Longitude	Obstacle Height MSL in m (ft)	Vertical Accuracy in m (ft)	Penetration in m (ft)	Surface Penetrated
Antenna	19° 19' 07.63" N	099° 33' 25.02" W	2587.00 (8487.53)	3.00 (9.84)	3.96 (12.98)	W
Pole Utility	19° 19' 06.79" N	099° 33' 25.14" W	2588.00 (8490.81)	3.00 (9.84)	4.30 (14.1)	W
Pole Utility	19° 19' 07.60" N	099° 33' 23.40" W	2588.00 (8490.81)	3.00 (9.84)	4.37 (14.35)	W
Pole Utility	19° 19' 05.18" N	099° 33' 28.78" W	2588.00 (8490.81)	3.00 (9.84)	4.19 (13.74)	W
Pole Utility	19° 19' 06.07" N	099° 33' 22.20" W	2588.00 (8490.81)	3.00 (9.84)	2.69 (8.81)	W
Pole Utility	19° 19' 07.22" N	099° 33' 21.96" W	2588.00 (8490.81)	3.00 (9.84)	0.40 (1.31)	X
Pole Utility	19° 19' 04.38" N	099° 33' 30.55" W	2588.00 (8490.81)	3.00 (9.84)	4.13 (13.54)	W
Pole Utility	19° 19' 04.61" N	099° 33' 22.50" W	2588.00 (8490.81)	3.00 (9.84)	1.59 (5.22)	W
Pole Utility	19° 19' 05.95" N	099° 33' 26.99" W	2588.00 (8490.81)	3.00 (9.84)	4.23 (13.87)	W
Pole Utility	19° 19' 04.54" N	099° 33' 28.13" W	2588.00 (8490.81)	3.00 (9.84)	3.44 (11.28)	W
Building	19° 18' 56.51" N	099° 33' 24.66" W	2593.00 (8507.22)	3.00 (9.84)	0.59 (1.93)	W
Light Stanchion	19° 18' 52.98" N	099° 33' 25.40" W	2597.00 (8520.34)	3.00 (9.84)	1.91 (6.25)	W

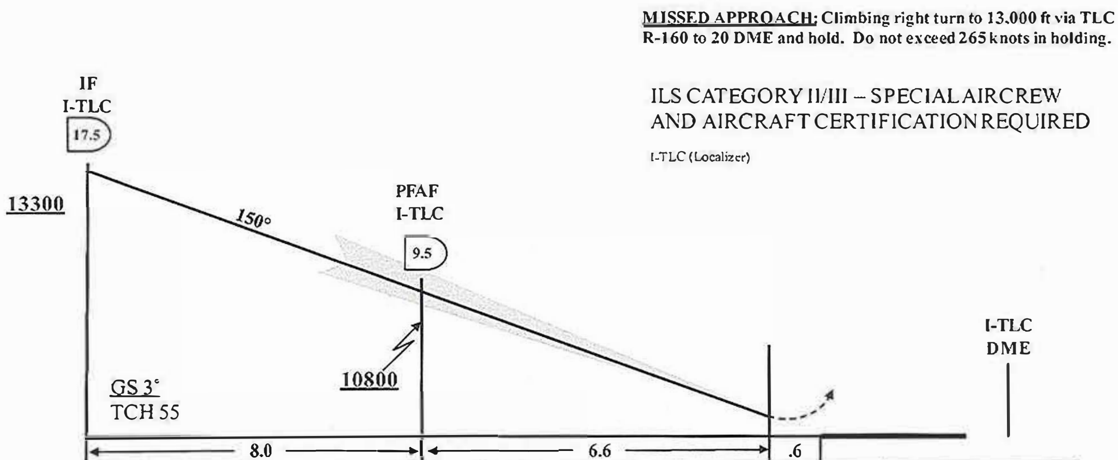
Obstacles Penetrating the 20:1 Surface

Description	Latitude	Longitude	Obstacle Height MSL in m (ft)	Vertical Accuracy in m (ft)	Penetration in m (ft)
Clear					

Obstacles Penetrating the 34:1 Surface

Description	Latitude	Longitude	Obstacle Height MSL in m (ft)	Vertical Accuracy in m (ft)	Penetration in m (ft)
Pole Utility	19° 19' 07.60" N	099° 33' 23.40" W	2588.00 (8490.81)	3.00 (9.84)	4.38 (14.36)
Pole Utility	19° 19' 06.79" N	099° 33' 25.14" W	2588.00 (8490.81)	3.00 (9.84)	4.30 (14.10)
Pole Utility	19° 19' 05.95" N	099° 33' 26.99" W	2588.00 (8490.81)	3.00 (9.84)	4.23 (13.87)
Pole Utility	19° 19' 05.18" N	099° 33' 28.78" W	2588.00 (8490.81)	3.00 (9.84)	4.19 (13.74)
Pole Utility	19° 19' 04.38" N	099° 33' 30.55" W	2588.00 (8490.81)	3.00 (9.84)	4.13 (13.54)
Antenna	19° 19' 07.63" N	099° 33' 25.02" W	2587.00 (8487.53)	3.00 (9.84)	3.96 (12.98)
Pole Utility	19° 19' 03.54" N	099° 33' 32.31" W	2588.00 (8490.81)	3.00 (9.84)	3.95 (12.95)
Pole Utility	19° 19' 07.22" N	099° 33' 21.96" W	2588.00 (8490.81)	3.00 (9.84)	3.57 (11.71)
Pole Utility	19° 19' 04.54" N	099° 33' 28.13" W	2588.00 (8490.81)	3.00 (9.84)	3.44 (11.28)
Pole Utility	19° 19' 06.07" N	099° 33' 22.20" W	2588.00 (8490.81)	3.00 (9.84)	2.70 (8.86)
Building	19° 19' 04.89" N	099° 33' 20.67" W	2589.00 (8494.09)	3.00 (9.84)	2.20 (7.22)
Building	19° 19' 05.21" N	099° 33' 20.07" W	2589.00 (8494.09)	3.00 (9.84)	2.08 (6.83)
Light Stanchion	19° 18' 52.98" N	099° 33' 25.40" W	2597.00 (8520.34)	3.00 (9.84)	1.91 (6.25)

Building	19° 19' 04.39" N	099° 33' 20.59" W	2589.00 (8494.09)	3.00 (9.84)	1.76 (5.77)
Pole Utility	19° 19' 04.61" N	099° 33' 22.50" W	2588.00 (8490.81)	3.00 (9.84)	1.59 (5.22)
Building	19° 18' 56.51" N	099° 33' 24.66" W	2593.00 (8507.22)	3.00 (9.84)	0.59 (1.93)
Obstacles Penetrating the POFZ					
General Description	**Latitude**	**Longitude**	**Obstacle Height MSL in m (ft)**	**Vertical Accuracy in m (ft)**	**Penetration in m (ft)**
Clear					



CATEGORY	A	B	C	D
S-ILS 15	8712/50 250			
S-ILS 15	CAT II RA 104/12 100 DA 8562			
S-ILS 15	CAT III RVR 700			

Figure 4. Runway 15 ILS CAT I/II/III Approach: Profile View and Approach Minima (Not Intended for Navigation/Publication)

Table 4. Controlling Obstacles for Runway 15 ILS CAT I/II/III Approach Segments

Segments	Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Final, CAT I	Light Stanchion	19° 21' 26.05" N	099° 34' 35.80" W	2589.00 (8494.09)
Final, CAT II/III	Fence	19° 21' 16.83" N	099° 34' 31.63" W	2584.00 (8477.69)
Missed, CAT I	Pole Utility	19° 21' 35.70" N	099° 34' 38.65" W	2590.00 (8497.38)
	Pole Utility	19° 21' 34.01" N	099° 34' 39.53" W	2590.00 (8497.38)
	Treeline	19° 21' 38.09" N	099° 34' 29.55" W	2589.00 (8494.09)
	Terrain	19° 07' 13.00" N	099° 21' 37.00" W	3705.00 (12,155.51)
Missed, CAT II/III	Fence	19° 21' 16.91" N	099° 34' 29.99" W	2580.00 (8464.57)
	Terrain	19° 07' 15.00" N	099° 21' 40.00" W	3698.00 (12,132.55)
Intermediate	Antenna	19° 33' 29.92" N	099° 41' 50.75" W	3042.00 (9980.32)
Initial	Terrain	19° 44' 04.35" N	099° 44' 58.31" W	3582.93 (11,755.02)

Table 5. Obstacles Penetrating Runway 15 ILS CAT I/II/III Final and Associated Surfaces

Obstacles Penetrating the Final Approach Surfaces						
Description	**Latitude**	**Longitude**	**Obstacle Height MSL in m (ft)**	**Vertical Accuracy in m (ft)**	**Penetration in m (ft)**	**Surface Penetrated**
Light Stanchion	19° 21' 26.05" N	099° 34' 35.80" W	2589.00 (8494.09)	3.00 (9.84)	3.44 (11.29)	W
Fence	19° 21' 16.83" N	099° 34' 31.63" W	2584.00 (8477.69)	3.00 (9.84)	6.43 (21.09)	X
Pole Utility	19° 21' 28.75" N	099° 34' 35.02" W	2588.00 (8490.81)	3.00 (9.84)	0.50 (1.65)	W
Antenna	19° 21' 24.17" N	099° 34' 32.73" W	2587.00 (8487.53)	3.00 (9.84)	4.09 (13.41)	W
Fence	19° 21' 16.83" N	099° 34' 30.13" W	2580.00 (8464.57)	3.00 (9.84)	3.65 (11.97)	W
Fence	19° 21' 16.91" N	099° 34' 29.99" W	2580.00 (8464.57)	3.00 (9.84)	3.65 (11.97)	W
Treeline	19° 21' 17.72" N	099° 34' 32.41" W	2583.00 (8474.41)	3.00 (9.84)	2.22 (7.28)	X
Treeline	19° 21' 17.69" N	099° 34' 32.43" W	2583.00 (8474.41)	3.00 (9.84)	1.98 (6.48)	X
Light Stanchion	19° 21' 26.88" N	099° 34' 35.30" W	2588.00 (8490.81)	3.00 (9.84)	1.96 (6.44)	W
Light Stanchion	19° 21' 29.19" N	099° 34' 33.54" W	2589.00 (8494.09)	3.00 (9.84)	1.64 (5.37)	W
Fence	19° 21' 21.68" N	099° 34' 33.82" W	2583.00 (8474.41)	3.00 (9.84)	1.63 (5.35)	W
Light Stanchion	19° 21' 27.58" N	099° 34' 34.85" W	2588.00 (8490.81)	3.00 (9.84)	1.53 (5.02)	W
Pole Utility	19° 21' 27.29" N	099° 34' 35.87" W	2588.00 (8490.81)	3.00 (9.84)	1.42 (4.67)	W
Light Stanchion	19° 21' 29.95" N	099° 34' 32.53" W	2589.00 (8494.09)	3.00 (9.84)	1.35 (4.44)	W
Roof Feature	19° 21' 18.64" N	099° 34' 32.89" W	2583.00 (8474.41)	3.00 (9.84)	1.14 (3.75)	X
Light Stanchion	19° 21' 30.75" N	099° 34' 31.41" W	2589.00 (8494.09)	3.00 (9.84)	1.06 (3.49)	W
Light Stanchion	19° 21' 28.47" N	099° 34' 34.30" W	2588.00 (8490.81)	3.00 (9.84)	0.98 (3.21)	W
Tree	19° 21' 18.04" N	099° 34' 32.97" W	2584.00 (8477.69)	3.00 (9.84)	0.12 (0.38)	X

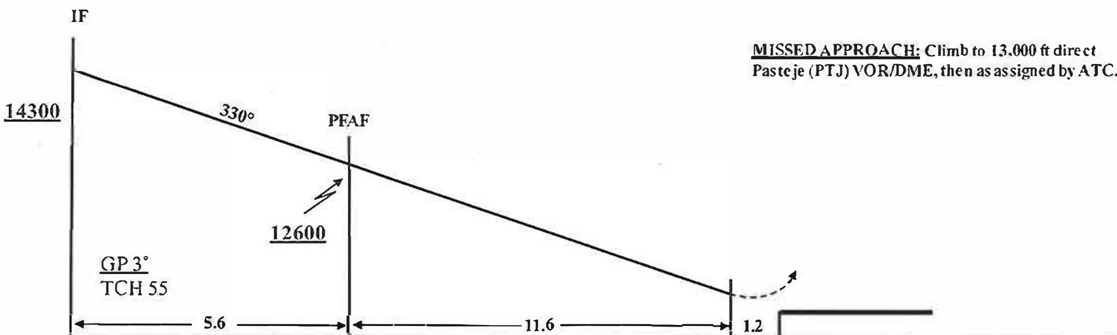
Obstacles Penetrating the 20:1 Visual Surface (* Denotes Penetration to CAT I and CAT II/II Visual Surfaces)					
Description	**Latitude**	**Longitude**	**Obstacle Height MSL in m (ft)**	**Vertical Accuracy in m (ft)**	**Penetration in m (ft)**
Fence*	19° 21' 16.83" N	099° 34' 30.13" W	2580.00 (8464.57)	3.00 (9.84)	3.65 (11.97)
Fence*	19° 21' 16.91" N	099° 34' 29.99" W	2580.00 (8464.57)	3.00 (9.84)	3.65 (11.97)

Obstacles Penetrating the 34:1 Visual Surface (* Denotes Penetration to CAT I and CAT II/II Visual Surfaces)					
Description	**Latitude**	**Longitude**	**Obstacle Height MSL in m (ft)**	**Vertical Accuracy in m (ft)**	**Penetration in m (ft)**
Tree	19° 21' 25.48" N	099° 34' 36.65" W	2590.00 (8497.38)	3.00 (9.84)	4.64 (15.21)
Antenna	19° 21' 24.17" N	099° 34' 32.73" W	2587.00 (8487.53)	3.00 (9.84)	4.09 (13.41)
Fence*	19° 21' 16.83" N	099° 34' 30.13" W	2580.00 (8464.57)	3.00 (9.84)	3.65 (11.97)
Fence*	19° 21' 16.91" N	099° 34' 29.99" W	2580.00 (8464.57)	3.00 (9.84)	3.65 (11.97)
Light Stanchion	19° 21' 26.05" N	099° 34' 35.80" W	2589.00 (8494.09)	3.00 (9.84)	3.48 (11.43)
Light Stanchion	19° 21' 26.88" N	099° 34' 35.30" W	2588.00 (8490.81)	3.00 (9.84)	1.96 (6.44)
Fence*	19° 21' 21.68" N	099° 34' 33.82" W	2583.00 (8474.41)	3.00 (9.84)	1.76 (5.78)
Light Stanchion	19° 21' 29.19" N	099° 34' 33.54" W	2589.00 (8494.09)	3.00 (9.84)	1.64 (5.37)
Light Stanchion	19° 21' 27.58" N	099° 34' 34.85" W	2588.00 (8490.81)	3.00 (9.84)	1.53 (5.02)
Pole Utility	19° 21' 27.29" N	099° 34' 35.87" W	2588.00 (8490.81)	3.00 (9.84)	1.43 (4.68)
Light Stanchion	19° 21' 29.95" N	099° 34' 32.53" W	2589.00 (8494.09)	3.00 (9.84)	1.35 (4.44)
Light Stanchion	19° 21' 30.75" N	099° 34' 31.41" W	2589.00 (8494.09)	3.00 (9.84)	1.06 (3.49)
Light Stanchion	19° 21' 28.47" N	099° 34' 34.30" W	2588.00 (8490.81)	3.00 (9.84)	0.98 (3.21)
Fence*	19° 21' 20.71" N	099° 34' 33.76" W	2581.00 (8467.85)	3.00 (9.84)	0.52 (1.69)
Pole Utility	19° 21' 28.75" N	099° 34' 35.02" W	2588.00 (8490.81)	3.00 (9.84)	0.50 (1.65)

Obstacles Penetrating the POFZ				
Description	**Latitude**	**Longitude**	**Obstacle Height MSL in m (ft)**	**Vertical Accuracy in m (ft)**
Fence	19° 21' 16.83" N	099° 34' 30.13" W	2580.00 (8464.57)	3.00 (9.84)
Fence	19° 21' 16.91" N	099° 34' 29.99" W	2580.00 (8464.57)	3.00 (9.84)

4.2 RNP AR Instrument Approach Procedures

MITRE also developed RNP AR procedures for Toluca. The relevant approach information for Runway 33 and Runway 15 are shown in Figure 5 and Figure 6, respectively. Table 6 and Table 7 list the controlling obstacles for each individual segment for Runway 33 and Runway 15, respectively.



CATEGORY	A	B	C	D
RNP 0.30 DA	8896/45 433			

Figure 5. Runway 33 RNP AR Approach: Profile View and Approach Minima
(Not Intended for Navigation/Publication)

Table 6. Controlling Obstacles for Runway 33 RNP AR Approach Segments

Segment	Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Final	Clear			
Missed Approach	Antenna	19° 18' 16.31" N	099° 33' 36.96" W	2618.84 (8592)
Intermediate	Terrain	19° 05' 19.00" N	099° 28' 59.00" W	3087.93 (10,131)
Initial	Terrain	19° 40' 13.00" N	099° 25' 11.00" W	3083.97 (10,118)

Notes:
1. Procedures are RNP 0.30.
2. Glidepath intercept altitude and distance from threshold assume International Standard Atmosphere day
3. Authorization Required. For uncompensated Barometric (Baro)-Vertical Navigation (VNAV) systems, procedure Not Applicable (NA) below -1° Celsius (30° Fahrenheit) or above 42° Celsius (107° Fahrenheit).
4. Missed approach requires RNP less than 1.0. Global Positioning System (GPS) required.

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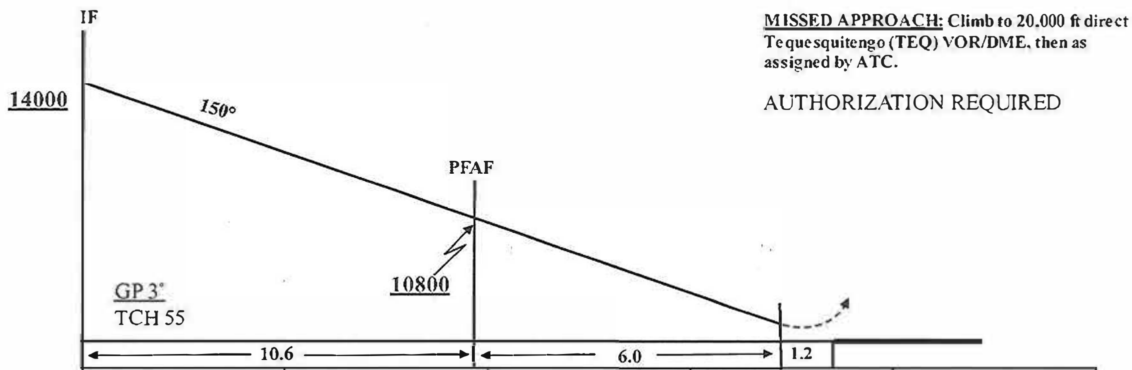


CATEGORY	A	B	C	D
RNP 0.30 DA	8888/40 425			

Figure 6. Runway 15 RNP AR Approach: Profile View and Approach Minima
(Not Intended for Navigation/Publication)

Table 7. Controlling Obstacles for Runway 15 RNP AR Approach Segments

Segment	Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Final	Clear			
Missed Approach	Antenna	19° 22' 13.30" N	099° 34' 3.02" W	2616.71 (8585.00)
Intermediate	Terrain	19° 33' 27.00" N	099° 41' 52.00" W	3090.98 (10,141.00)
Initial	Terrain	19° 40' 18.00" N	099° 45' 13.00" W	2631.95 (8635.00)

Notes:
1. Procedures are RNP 0.30.
2. Glidepath intercept altitude and distance from threshold assume International Standard Atmosphere day
3. Authorization Required. For uncompensated Baro-VNAV systems, procedure NA below 1° Celsius (30° Fahrenheit) or above 42° Celsius (107° Fahrenheit)
4. Missed approach requires RNP less than 1.0. GPS required.

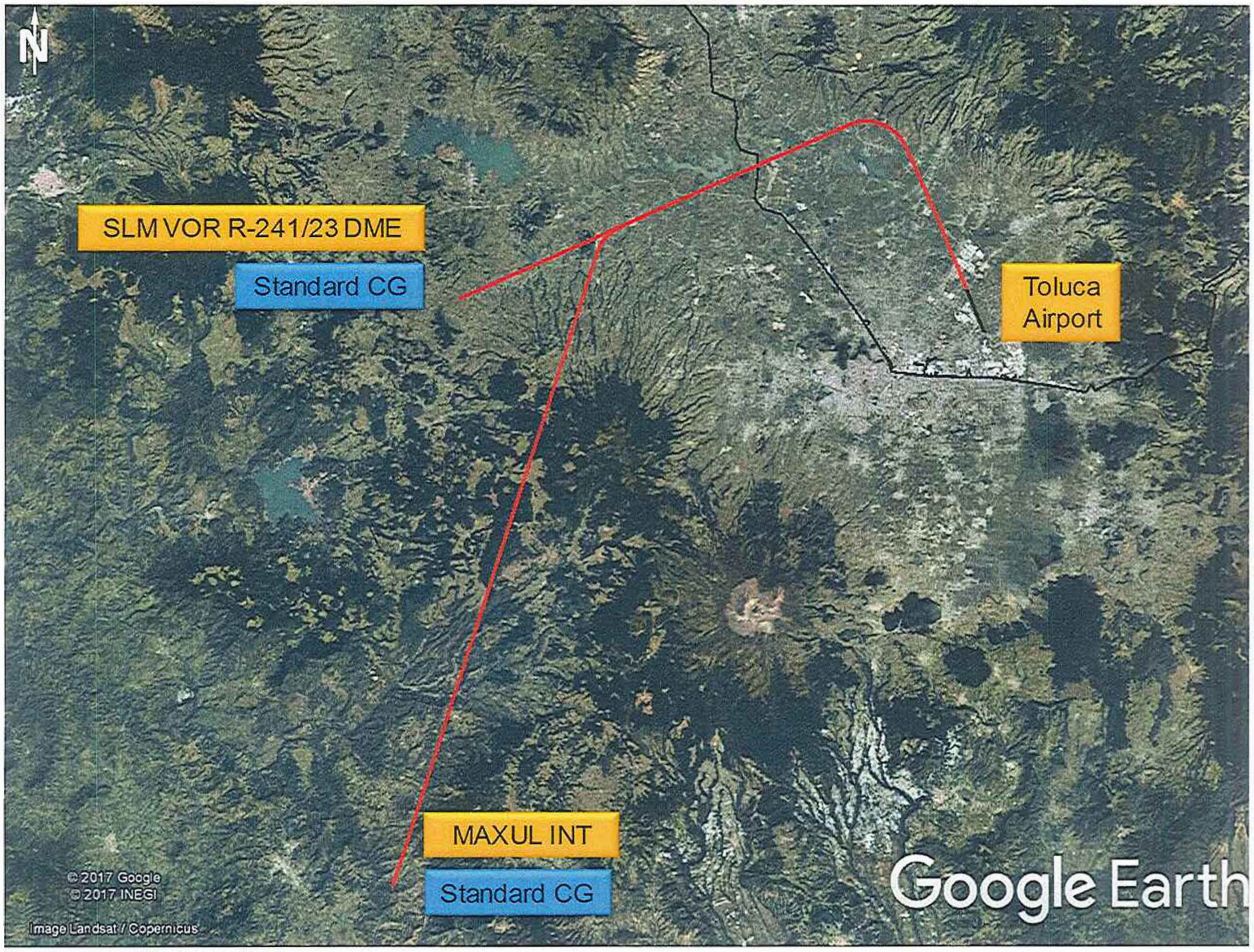
5. Instrument Departure Procedures

MITRE developed five conventional SIDs for Toluca: two for Runway 33 and three for Runway 15. These procedures will primarily be used as backup for those aircraft not equipped to fly RNAV SIDs. MITRE had also initially developed ten RNAV SIDs: five for Runway 33 and five for Runway 15. However, during the January 2018 SENEAM/MITRE NAICM-Toluca airspace design workshop, two new RNAV SIDs were developed, one previously developed SID was dropped, and minor changes were applied to others. This document reflects those recent changes.

Note that the use of the term "standard" in the context of SIDs refers to a 200 FPNM CG. When a CG greater than 200 FPNM is required, the FAA requires that these CGs be charted.

5.1 Conventional Departures

Figure 7 and Table 8 provide flight track and relevant information on the three conventional SIDs for Runway 33. Figure 8 and Table 9 provide flight track and relevant information for the two conventional SIDs for Runway 15.



Source: Google Earth Pro

Figure 7. Runway 33 Conventional SID Flight Tracks

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Table 8. Runway 33 Conventional SID Procedure Information

Take-off Obstacles (Applies to all the SIDs for Runway 33)	
Take-off Obstacles are obstacles that penetrate the 40:1 OCS and require a CG greater than 200 FPNM to an altitude of 200 ft or less above the Departure End of Runway (DER) elevation. This obstacle information should be published so the pilot can avoid the obstacle. Note: Centerline (CL), Left (LT), Right (RT).	
Antenna 299.31 m (982 ft) from DER 81.08 m (266 ft) LT of CL, 2587.14 m (8488 ft) MSL	Light Stanchion 289.86 m (951 ft) from DER 182.27 m (598 ft) LT of CL, 2588.06 m (8491 ft) MSL
Building 145.39 m (477 ft) from DER 154.53 m (507 ft) LT of CL, 2581.96 m (8471 ft) MSL	Pole Utility 331.62 m (1088 ft) from DER 241.71 m (793 ft) LT of CL, 2588.06 m (8491 ft) MSL
Building 180.44 m (592 ft) from DER 220.07 m (722 ft) LT of CL, 2581.96 m (8471 ft) MSL	Pole Utility 346.86 m (1138 ft) from DER 230.12 m (755 ft) LT of CL, 2588.97 m (8494 ft) MSL
Building 183.18 m (601 ft) from DER 188.67 m (619 ft) LT of CL, 2581.05 m (8468 ft) MSL	Pole Utility 423.98 m (1391 ft) from DER 127.41 m (418 ft) LT of CL, 2588.06 m (8491 ft) MSL
Building 190.20 m (624 ft) from DER 198.12 m (650 ft) LT of CL, 2582.88 m (8474 ft) MSL	Pole Utility 455.37 m (1494 ft) from DER 86.87 m (285 ft) LT of CL, 2588.06 m (8491 ft) MSL
Building 231.34 m (759 ft) from DER 185.32 m (608 ft) LT of CL, 2585.92 m (8484 ft) MSL	Pole Utility 183.18 m (601 ft) from DER 198.73 m (652 ft) LT of CL, 2588.06 m (8491 ft) MSL
Building 244.14 m (801 ft) from DER 239.88 m (787 ft) LT of CL, 2582.88 m (8474 ft) MSL	Rooftop Feature 145.08 m (476 ft) from DER 152.4 m (500 ft) LT of CL, 2582.88 m (8474 ft) MSL
Building 262.43 m (861 ft) from DER 238.66 m (783 ft) LT of CL, 2582.88 m (8474 ft) MSL	Tree 381.61 m (1252 ft) from DER 170.38 m (559 ft) LT of CL, 2589.89 m (8497 ft) MSL
Fence 62.18 m (204 ft) from DER 100.28 m (329 ft) LT of CL, 2580.13 m (8465 ft) MSL	Tree 597.41 m (1960 ft) from DER 213.97 m (702 ft) LT of CL, 2591.10 m (8501 ft) MSL
Fence 62.79 m (206 ft) from DER 95.71 m (314 ft) LT of CL, 2580.13 m (8465 ft) MSL	Tree 128.93 m (423 ft) from DER 161.85 m (531 ft) LT of CL, 2584.09 m (8478 ft) MSL
Fence 79.55 m (261 ft) from DER 140.51 m (461 ft) LT of CL, 2584.09 m (8478 ft) MSL	Tree 267.00 m (876 ft) from DER 245.36 m (805 ft) LT of CL, 2591.10 m (8501 ft) MSL
Fence 241.71 m (793 ft) from DER 140.51 m (461 ft) LT of CL, 2582.88 m (8474 ft) MSL	Tree 286.82 m (941 ft) from DER 178.61 m (586 ft) LT of CL, 2584.09 m (8478 ft) MSL
Light Stanchion 360.88 m (1184 ft) from DER 199.95 m (656 ft) LT of CL, 2588.97 m (8494 ft) MSL	Treeline 352.04 m (1155 ft) from DER 251.46 m (825 ft) LT of CL, 2588.97 m (8494 ft) MSL
Light Stanchion 361.49 m (1186 ft) from DER 246.58 m (809 ft) LT of CL, 2588.06 m (8491 ft) MSL	Treeline 358.14 m (1175 ft) from DER 263.65 m (865 ft) LT of CL, 2588.97 m (8494 ft) MSL
Light Stanchion 388.01 m (1273 ft) from DER 140.82 m (462 ft) LT of CL, 2588.97 m (8494 ft) MSL	Treeline 374.90 m (1230 ft) from DER 266.09 m (873 ft) LT of CL, 2588.97 m (8494 ft) MSL
Light Stanchion 391.97 m (1286 ft) from DER 259.69 m (852 ft) LT of CL, 2588.06 m (8491 ft) MSL	Treeline 393.80 m (1292 ft) from DER 192.33 m (631 ft) LT of CL, 2588.06 m (8491 ft) MSL
Light Stanchion 405.69 m (1331 ft) from DER 117.04 m (384 ft) LT of CL, 2588.06 m (8491 ft) MSL	Treeline 402.03 m (1319 ft) from DER 187.45 m (615 ft) LT of CL, 2588.06 m (8491 ft) MSL
Light Stanchion 413.92 m (1358 ft) from DER 282.55 m (927 ft) LT of CL, 2588.06 m (8491 ft) MSL	Treeline 410.87 m (1348 ft) from DER 205.74 m (675 ft) LT of CL, 2588.06 m (8491 ft) MSL
Light Stanchion 420.32 m (1379 ft) from DER 96.62 m (317 ft) LT of CL, 2588.06 m (8491 ft) MSL	Treeline 41.15 m (135 ft) from DER 163.07 m (535 ft) LT of CL, 2588.06 m (8491 ft) MSL
Light Stanchion 439.22 m (1441 ft) from DER 71.02 m (233 ft) LT of CL, 2588.06 m (8491 ft) MSL	Treeline 41.45 m (136 ft) from DER 170.69 m (560 ft) LT of CL, 2588.06 m (8491 ft) MSL
Light Stanchion 440.44 m (1445 ft) from DER 300.23 m (985 ft) LT of CL, 2588.06 m (8491 ft) MSL	Treeline 439.52 m (1442 ft) from DER 232.87 m (764 ft) LT of CL, 2588.97 m (8494 ft) MSL
Light Stanchion 450.80 m (1479 ft) from DER 41.76 m (137 ft) LT of CL, 2588.97 m (8494 ft) MSL	Treeline 445.01 m (1460 ft) from DER 222.81 m (731 ft) LT of CL, 2588.97 m (8494 ft) MSL
Light Stanchion 460.25 m (1510 ft) from DER 5.79 m (19 ft) LT of CL, 2588.97 m (8494 ft) MSL	Treeline 112.78 m (370 ft) from DER 151.79 m (498 ft) LT of CL, 2582.88 m (8474 ft) MSL
Light Stanchion 470.31 m (1543 ft) from DER 34.14 m (112 ft) LT of CL, 2588.97 m (8494 ft) MSL	Treeline 113.39 m (372 ft) from DER 150.88 m (495 ft) LT of CL, 2582.88 m (8474 ft) MSL
Light Stanchion 248.72 m (816 ft) from DER 181.66 m (596 ft) LT of CL, 2588.06 m (8491 ft) MSL	Treeline 24.69 m (81 ft) from DER 172.52 m (566 ft) LT of CL, 2588.06 m (8491 ft) MSL
Light Stanchion 283.16 m (929 ft) from DER 210.31 m (690 ft) LT of CL, 2588.06 m (8491 ft) MSL	

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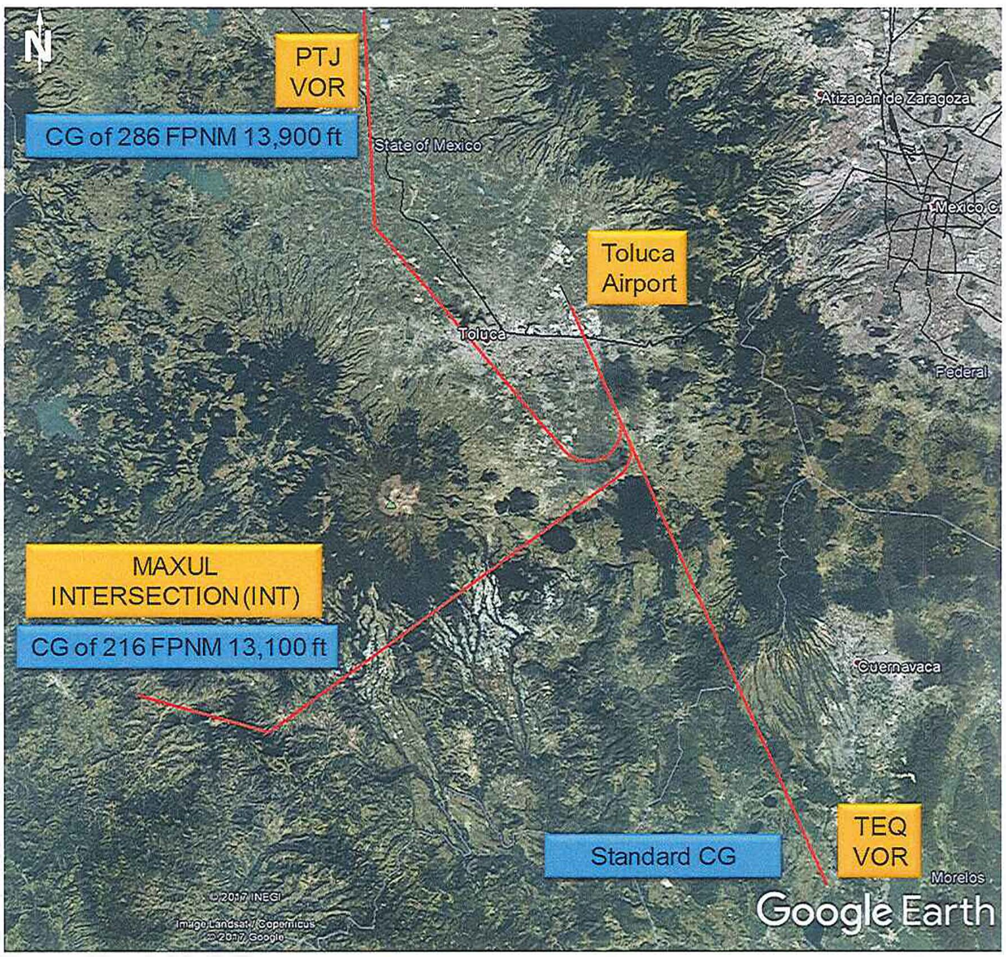
SLM SID			
Instructions	**Required CG**	**Termination Altitude MSL (ft)**	
Climb to 20,000 ft, intercept TLC VOR/DME R-328, intercept SLM VOR/DME R-241, intercept SLM VOR/DME, then as assigned by ATC.	Standard		
Controlling Obstacle			
Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Antenna	19°31'43.33" N	99°53'15.44" W	3356.00 (11,010.5)
Antenna	19°22'21.35" N	99°35'12.35" W	2628.00 (8622.05)
MAXUL SID			
Instructions	**Required CG**	**Termination Altitude MSL (ft)**	
Climb to 20,000 ft, intercept TLC VOR/DME R-328, intercept SLM VOR/DME R-241, intercept PTJ VOR/DME R-191, to MAXUL INT, then as assigned by ATC.	Standard		
Controlling Obstacle			
Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Terrain	19°15'04.00" N	99°52'46.00" W	3726.00 (12,224.41)
Antenna	19°22'21.35" N	99°35'12.35" W	2628.00 (8622.05)



Source: Google Earth Pro

Figure 8. Runway 15 Conventional SID Flight Tracks

Table 9. Runway 15 Conventional SID Procedure Information

Take-off Obstacles (Applies to all the SIDs for Runway 15)	
Take-off Obstacles are obstacles that penetrate the 40:1 OCS and require a CG greater than 200 FPNM to an altitude of 200 ft or less above the DER elevation. This obstacle information should be published so the pilot can avoid these obstacles. Note: Centerline (CL), Left (LT), Right (RT).	
Abandoned Aircraft 234.09 m (768 ft) from DER 207.26 m (680 ft) LT of CL, 2585.01 m (8481 ft) MSL	Light Stanchion 707.14 m (2320 ft) from DER 108.51 m (356 ft) LT of CL, 2596.90 m (8520 ft) MSL
Abandoned Aircraft 256.95 m (843 ft) from DER 202.69 m (665 ft) LT of CL, 2588.06 m (8491 ft) MSL	Pole Utility 316.99 m (1040 ft) from DER 122.53 m (402 ft) LT of CL, 2588.06 m (8491 ft) MSL
Abandoned Aircraft 263.96 m (866 ft) from DER 201.17 m (660 ft) LT of CL, 2587.14 m (8488 ft) MSL	Pole Utility 319.74 m (1049 ft) from DER 66.14 m (217 ft) LT of CL, 2588.06 m (8491 ft) MSL
Abandoned Aircraft 292.91 m (961 ft) from DER 204.22 m (670 ft) LT of CL, 2588.06 m (8491 ft) MSL	Pole Utility 322.17 m (1057 ft) from DER 6.10 m (20 ft) LT of CL, 2588.06 m (8491 ft) MSL
Abandoned Aircraft 295.35 m (969 ft) from DER 196.60 m (645 ft) LT of CL, 2588.06 m (8491 ft) MSL	Pole Utility 322.78 m (1059 ft) from DER 180.44 m (592 ft) LT of CL, 2588.06 m (8491 ft) MSL
Antenna 297.48 m (976 ft) from DER 79.55 m (261 ft) LT of CL, 2587.14 m (8488 ft) MSL	Pole Utility 323.39 m (1061 ft) from DER 51.21 m (168 ft) LT of CL, 2588.06 m (8491 ft) MSL
Building 357.84 m (1174 ft) from DER 188.67 m (619 ft) LT of CL, 2588.06 m (8491 ft) MSL	Pole Utility 325.53 m (1068 ft) from DER 108.20 m (355 ft) LT of CL, 2588.06 m (8491 ft) MSL
Building 369.42 m (1212 ft) from DER 205.13 m (673 ft) LT of CL, 2588.06 m (8491 ft) MSL	Pole Utility 326.75 m (1072 ft) from DER 210.31 m (690 ft) LT of CL, 2588.97 m (8494 ft) MSL
Building 422.76 m (1387 ft) from DER 183.18 m (601 ft) LT of CL, 2588.97 m (8494 ft) MSL	Pole Utility 328.88 m (1079 ft) from DER 165.81 m (544 ft) LT of CL, 2588.06 m (8491 ft) MSL
Building 424.89 m (1394 ft) from DER 163.07 m (535 ft) LT of CL, 2588.97 m (8494 ft) MSL	Pole Utility 334.06 m (1096 ft) from DER 229.51 m (753 ft) LT of CL, 2588.06 m (8491 ft) MSL
Building 429.46 m (1409 ft) from DER 241.40 m (792 ft) LT of CL, 2588.97 m (8494 ft) MSL	Pole Utility 337.11 m (1106 ft) from DER 267.92 m (879 ft) LT of CL, 2588.97 m (8494 ft) MSL
Building 433.12 m (1421 ft) from DER 274.93 m (902 ft) LT of CL, 2588.97 m (8494 ft) MSL	Pole Utility 339.24 m (1113 ft) from DER 215.49 m (707 ft) LT of CL, 2588.97 m (8494 ft) MSL
Building 440.13 m (1444 ft) from DER 158.80 m (521 ft) LT of CL, 2588.97 m (8494 ft) MSL	Pole Utility 344.42 m (1130 ft) from DER 156.67 m (514 ft) LT of CL, 2588.06 m (8491 ft) MSL
Building 615.70 m (2020 ft) from DER 45.72 m (150 ft) LT of CL, 2592.93 m (8507 ft) MSL	Pole Utility 349.00 m (1145 ft) from DER 41.45 m (136 ft) LT of CL, 2588.06 m (8491 ft) MSL
Fence 32.61 m (107 ft) from DER 166.42 m (546 ft) LT of CL, 2580.13 m (8465 ft) MSL	Pole Utility 359.05 m (1178 ft) from DER 240.79 m (790 ft) LT of CL, 2588.97 m (8494 ft) MSL
Fence 68.58 m (225 ft) from DER 182.88 m (600 ft) LT of CL, 2580.13 m (8465 ft) MSL	Pole Utility 373.99 m (1227 ft) from DER 136.25 m (447 ft) LT of CL, 2588.06 m (8491 ft) MSL
Fence 70.71 m (232 ft) from DER 184.10 m (604 ft) LT of CL, 2580.13 m (8465 ft) MSL	Pole Utility 411.78 m (1351 ft) from DER 110.64 m (363 ft) LT of CL, 2588.06 m (8491 ft) MSL
Fence 92.35 m (303 ft) from DER 155.45 m (510 ft) LT of CL, 2581.05 m (8468 ft) MSL	Tree 206.35 m (677 ft) from DER 196.60 m (645 ft) LT of CL, 2584.09 m (8478 ft) MSL
Fence 95.40 m (313 ft) from DER 186.54 m (612 ft) LT of CL, 2578.91 m (8461 ft) MSL	Tree 229.51 m (753 ft) from DER 178.00 m (584 ft) LT of CL, 2584.09 m (8478 ft) MSL
Fence 25.30 m (83 ft) from DER 155.14 m (509 ft) LT of CL, 2580.13 m (8465 ft) MSL	Tree 275.54 m (904 ft) from DER 191.11 m (627 ft) LT of CL, 2585.92 m (8484 ft) MSL
Fence 25.30 m (83 ft) from DER 155.14 m (509 ft) LT of CL, 2581.05 m (8468 ft) MSL	

PTJ SID			
Instructions	**Required CG**	**Termination Altitude MSL (ft)**	
Climb to 20,000 ft via TLC Very High Frequency (VHF) Omni Directional Radio Range (VOR)/DME R-152 to 9 DME, turn right heading 290° to intercept the CVJ VOR/DME R-314, intercept the PTJ VOR/DME R-170 to PTJ VOR/DME, then as assigned by ATC.	286 FPNM	13,900	
Controlling Obstacle			
Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Terrain	19°06'13.00" N	99°43'20.00" W	3905.00 (12,811.68)

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MAXUL SID			
Instructions	**Required CG**	**Termination Altitude MSL (ft)**	
Climb to 20,000 ft via TLC VOR/DME R-152 to 12 DME, intercept MEX VOR/DME R-228, intercept TEQ VOR/DME R-280 to MAXUL INT, then as assigned by ATC.	216 FPNM	13,100	
Controlling Obstacle			
Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Terrain	19°03'25.00" N	99°43'00.00" W	3682.00 (12.080.05)

TEQ SID			
Instructions	**Required CG**	**Termination Altitude MSL (ft)**	
Climb to 20,000 ft via TLC VOR/DME R-152 to 15 DME, intercept TEQ VOR/DME R-329 to TEQ VOR/DME, then as assigned by ATC.	Standard	NA	
Controlling Obstacle			
Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Terrain	19°05'18.00" N	99°28'57.00" W	3029.00 (9937.66)

5.2 RNAV Departures

RNAV SIDs provide much more procedure design flexibility than those based on conventional navigation. RNAV SIDs are not reliant on ground-based navigation and allow flight from any point or fix to another.

As mentioned above, MITRE had initially developed ten RNAV SIDs: five for Runway 15 and five for Runway 33. However, at the above-mentioned January 2018 airspace design workshop at SENEAM, two new RNAV SIDs were developed, one previously developed SID was dropped, and minor changes were applied to others.

FAA criteria permit up to two CGs to be published on a SID to support a Lateral Navigation (LNAV) engagement altitude[8] and for obstacle clearance purposes. The obstacle clearance CG is generally a lesser climb rate, but to a higher altitude.

All RNAV SIDs from Runway 33 have a 500 FPNM CG to 9000 ft MSL for LNAV engagement. All RNAV SIDs from Runway 15, except the FILOS SID, have a 500 FPNM CG to 9500 ft MSL for LNAV engagement and to reduce impact on the local traffic pattern. The FILOS SID has a standard CG for the entire route.[9] With the exception of the ICVOR SIDs from Runways 15/33, all other SIDs can resume a standard climb rate after reaching 9000 ft or 9500 ft, as appropriate.

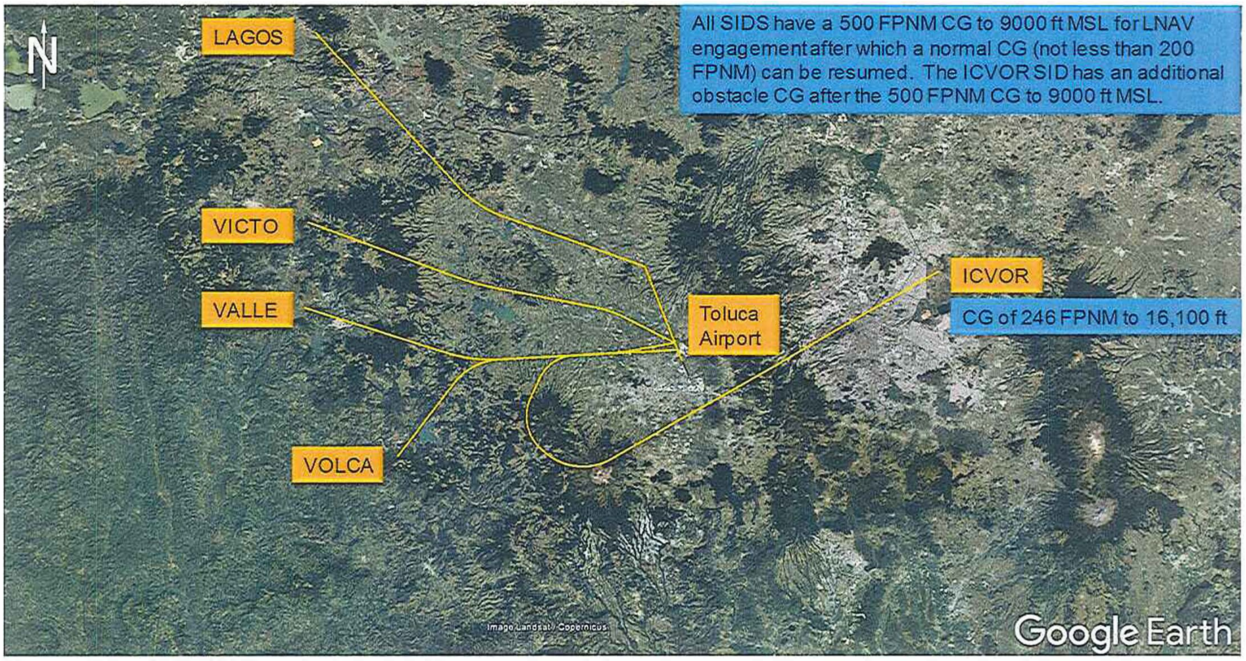
Some waypoints on the SIDs have crossing altitude restrictions. These restrictions are intended to provide vertical separation from other crossing routes. The CGs necessary to meet

[8] RNAV equipment must engage no later than 500 ft above airport elevation. A CG to an altitude is provided to ensure RNAV equipment engagement prior to any turns.

[9] LNAV engagement occurs at 500 ft above the airport. To prevent a turn prior to reaching that height, a CG of 500 FPNM is incorporated into the procedure. The FILOS SID departure track is straight ahead for 6 NM before turning. At 200 FPNM, the aircraft will reach 1200 ft above the airport before a turn is made. Additionally, the FILOS SID does not interfere with the local traffic pattern. Therefore, an LNAV engagement CG for the FILOS SID is not required.

these crossing restrictions are considered ATC CGs and are not published. However, these ATC CGs are being provided for informational purposes only.

Figure 9 shows the Runway 33 nominal flight tracks, and Table 10 provides the Runway 33 RNAV SID information. Figure 10 shows the Runway 15 nominal flight tracks, and Table 11 provides the Runway 15 RNAV SID information. Note that the take-off obstacles listed in Table 8 and Table 9 above are also applicable to the RNAV SIDs.



Source: Google Earth Pro

Figure 9. Runway 33 RNAV SID Flight Tracks

Table 10. Runway 33 RNAV SID Procedure Information

Runway 33 - RNAV LAGOS SID			
Instructions	**GG**	**Termination Altitude (ft)**	**CG Reason**
Climb heading 330° to 9000 ft, then direct TL12A, then climbing track 283° to cross TL080 at or below 16,000 ft, then track 283° to cross MAZAS at 18,000 ft, then track 310° to TL088, then track 310° to LAGOS, maintain 22,000 ft or higher as assigned by ATC.	500 FPNM	9000	LNAV Engagement
	281 FPNM	18,000	ATC (Not Published)
Controlling Obstacle			
Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Antenna	19°22'21.35" N	99°35'12.35" W	2628.00 (8622.05)
Treeline	19°21'34.11" N	99°34'23.21" W	2586.00 (8484.25)

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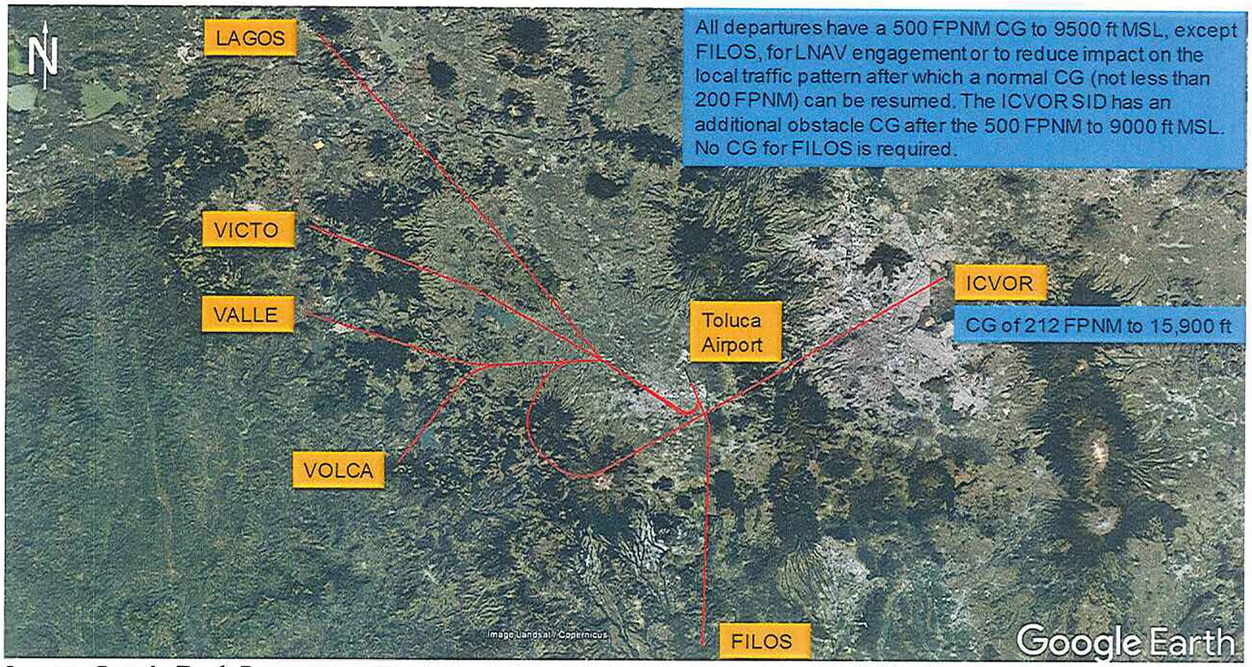
Runway 33 - RNAV VICTO SID			
Instructions	**GG**	**Termination Altitude (ft)**	**CG Reason**
Climb heading 330° intercept course 290° to cross TL081 between 13,000 ft and 16,000 ft, then track 274° to cross GUADA at or above 18,000 ft, then track 283° to TL089, then track 283° to VICTO, maintain 20,000 ft or higher as assigned by ATC.	500 FPNM	9000	LNAV Engagement
	405 FPNM	13,000	ATC (Not Published)
	333 FPNM	18,000	
Controlling Obstacle			
Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Antenna	19°22'21.35" N	99°35'12.35" W	2628.00 (8622.05)
Terrain	19°22'49.00" N	99°38'31.00" W	2626.00 (8615.49)

Runway 33 - RNAV VALLE SID			
Instructions	**GG**	**Termination Altitude (ft)**	**CG Reason**
Climb heading 330° to intercept course 260° to cross TL082 at or below 14,000 ft, then track 260° to cross ZIHUA at 18,000 ft, then track 281° to TL090, then track 281° to VALLE, maintain 20,000 ft or higher as assigned by ATC.	500 FPNM	9000	LNAV Engagement
	352 FPNM	18,000	ATC (Not Published)
Controlling Obstacle			
Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Antenna	19°22'21.35" N	99°35'12.35" W	2628.00 (8622.05)
Building	19°21'11.59" N	99°34'35.47" W	2584.99 (8480.97)

Runway 33 - RNAV VOLCA SID			
Instructions	**GG**	**Termination Altitude (ft)**	**CG Reason**
Climb heading 330° to intercept course 260° to cross TL082 at or below 14,000 ft, then track 260° to cross ZIHUA at 17,000 ft, then track 211° to TL094, then track 211° to VOLCA, maintain 20,000 ft or higher as assigned by ATC.	500 FPNM	9000	LNAV Engagement
	315 FPNM	17,000	ATC (Not Published)
Controlling Obstacle			
Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Antenna	19°22'21.35" N	99°35'12.35" W	2628.00 (8622.05)
Building	19°21'11.59" N	99°34'35.47" W	2584.99 (8480.97)

Runway 33 - RNAV ICVOR SID			
Instructions	**GG**	**Termination Altitude (ft)**	**CG Reason**
Climb heading 330°, intercept course 260° to cross TL082 at or below 14,000 ft, then track 260° to cross TL063 at or above 14,600 ft, then track 198° to cross TL095 at or above 17,000 ft, then track 126° to cross TL096 at 18,000 ft, then track 054° to cross TL097 at or above 23,000 ft, then track 053° to cross ICVOR at 28,000 ft, maintain 28,000 ft or higher as assigned by ATC.	500 FPNM	9000	LNAV Engagement
	246 FPNM	16,100	Obstacle CG
	361 FPNM	14,600	ATC (Not Published)
	354 FPNM	17,000	
	318 FPNM	18,000	
	302 FPNM	23,000	
	247 FPNM	28,000	
Controlling Obstacle			
Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Antenna	19°22'21.35" N	99°35'12.35" W	2628.00 (8622.05)
Building	19°21'11.59" N	99°34'35.47" W	2584.99 (8480.97)



Source: Google Earth Pro

Figure 10. Runway 15 RNAV SID Flight Tracks

Table 11. Runway 15 RNAV SID Procedure Information

Runway 15 - RNAV LAGOS SID			
Instructions	**GG**	**Termination Altitude (ft)**	**CG Reason**
Climb heading 150° to 9500 ft, then right turn direct to cross TL065 at or below 13,000 ft, then track 313° to cross MAZAS at 18,000 ft, then track 310° to TL088, maintain 20,000 ft or higher as assigned by ATC.	500 FPNM	9500	LNAV Engagement; Local Traffic Pattern Avoidance
	264 FPNM	18,000	ATC (Not Published)
Controlling Obstacle			
Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Powerline	19°18'04.15" N	99°33'34.10" W	2617.00 (8585.96)
Runway 15 - RNAV VICTO SID			
Instructions	**GG**	**Termination Altitude (ft)**	**CG Reason**
Climb heading 150° to 9500 ft, then right turn direct to cross TL065 at or below 13,000 ft, then track 292° to cross GUADA at 18,000 ft, then track 283° to TL089, then track 283° to VICTO, maintain 20,000 ft or higher as assigned by ATC.	500 FPNM	9500	LNAV Engagement; Local Traffic Pattern Avoidance
	309 FPNM	18,000	ATC (Not Published)
Controlling Obstacle			
Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Powerline	19°18'04.15" N	99°33'34.10" W	2617.00 (8585.96)

Runway 15 - RNAV VALLE SID			
Instructions	**GG**	**Termination Altitude (ft)**	**CG Reason**
Climb heading 150° to 9500 ft, then right turn direct to cross TL065 at or below 13,000 ft, then track 260° to FR014 at or above 18,000 ft, then track 281° to TL090, then track 281° to VALLE, maintain 20,000 ft or higher as assigned by ATC.	500 FPNM	9500	LNAV Engagement; Local Traffic Pattern Avoidance
	325 FPNM	18,000	ATC (Not Published)
Controlling Obstacle			
Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Powerline	19°18'04.15" N	99°33'34.10" W	2617.00 (8585.96)

Runway 15 - RNAV VOLCA SID			
Instructions	**GG**	**Termination Altitude (ft)**	**CG Reason**
Climb heading 150° to 9500 ft, then right turn direct to cross TL065 at or below 13,000 ft, then track 260° to cross ZIHUA at 17,000 ft, then track 211° to TL094, then track 211° to VOLCA, maintain 20,000 ft or higher as assigned by ATC.	500 FPNM	9500	LNAV Engagement; Local Traffic Pattern Avoidance
	291 FPNM	17,000	ATC (Not Published)
Controlling Obstacle			
Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Powerline	19°18'04.15" N	99°33'34.10" W	2617.00 (8585.96)

Runway 15 - RNAV ICVOR SID			
Instructions	**GG**	**Termination Altitude (ft)**	**CG Reason**
Climb heading 150° to 9500 ft, then right turn direct to cross TL065 at or below 13,000 ft, then track 260° to TL063, then track 198° cross TL095 at 17,000 ft, then track 126° to cross TL096 at 18,000 ft, then track 054° to cross TL097 at or above 23,000 ft, then track 053° to cross ICVOR at 28,000 ft maintain 28,000 ft or higher as assigned by ATC.	500 FPNM	9500	LNAV Engagement; Local Traffic Pattern Avoidance
	212 FPNM	15,900	Obstacle CG
	324 FPNM	17,000	ATC (Not Published)
	296 FPNM	18,000	ATC (Not Published)
	288 FPNM	23,000	ATC (Not Published)
	240 FPNM	28,000	ATC (Not Published)
Controlling Obstacle			
Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Powerline	19°18'04.15" N	99°33'34.10" W	2617.00 (8585.96)

Runway 15 - RNAV FILOS SID			
Instructions	**GG**	**Termination Altitude (ft)**	**CG Reason**
Climb heading 150° to intercept course 174° to cross TL099 at 15,000 ft, then track 174° to FILOS, maintain 15,300 ft or higher as assigned by ATC.	218	15,000	ATC (Not Published)
	201	15,300	ATC (Not Published)
Controlling Obstacle			
Description	Latitude	Longitude	Obstacle Height MSL in m (ft)
Terrain	19°04'01.00" N	99°34'12.00" W	3318.00 (10,885.83)

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6. Summary

MITRE has presented a series of new approach and SID procedures at Toluca based on both conventional and space-based means of navigation. The procedures discussed in this document are based on the redesign of the Mexico City-Toluca airspace to support NAICM, which is connected very closely to the airspace of Toluca. This is an important consideration to ensure that operations at Toluca do not have a significant capacity-limiting impact on operations at NAICM.

All procedures were evaluated on the basis of obstacle data collected from the satellite-based photogrammetric survey of Toluca and its surroundings that was completed in 2016. It is important to note that MITRE applied vertical and horizontal accuracy tolerances, as described earlier in this document. All approach, missed approach, and SID controlling obstacles, as well as obstacles penetrating the surfaces related to instrument approaches are listed in this document. MITRE recommends that the aviation authorities of Mexico review this work and, in particular, investigate the obstacles in more detail and develop, if necessary, appropriate mitigating solutions.

The existing obstruction environment is continuously changing. Therefore, MITRE also recommends that a program be established to manage, monitor, and control both existing obstacles, as well as the potential construction of future obstacles. The ICAO Annex 14 Obstacle Limitation Surfaces examined by MITRE for Toluca can assist authorities in the control of obstacles. Refer to Enclosure 1 to MITRE Technical Letter (H560-L18-027): *Toluca Airport—Assessment of International Civil Aviation Organization Annex 14 Obstacle Limitation Surfaces*, dated 15 March 2018.

MITRE's findings on its Toluca procedure design work that require additional work by the Mexican aviation authorities are summarized as follows:

Approaches

MITRE identified numerous penetrations to important ILS OCS's to both Runway 15 and Runway 33. Because of these penetrations, the ILS CAT I approaches are not capable of supporting a 200-ft HAT and the lowest possible visibility. Therefore, FAA criteria would not allow development of ILS CAT II approaches. That, in turn, would also negate the development of ILS CAT III approaches.

As previously mentioned, all of the obstacle penetrations consider assigned accuracy tolerances. Therefore, some of the penetrations may be due in part to those assigned accuracy tolerances, which reinforces the need for the authorities to check and confirm all penetrations. If obstacle penetrations are confirmed, they should be removed or appropriately lowered. If that is not possible, the aviation authorities of Mexico could investigate the appropriateness of conducting a collision risk analysis, which may support an equivalent level of safety justification. However, this would need to be discussed in more detail among the aviation authorities of Mexico.

In this document, MITRE presented ILS CAT I approach minima considering the current obstacle situation (see Figure 3 and Figure 4). For ILS CAT II approaches, however, MITRE assumed that all ILS CAT I approach obstacle penetrations would be mitigated (e.g., removed or lowered). With the ILS CAT I approach obstacle penetrations mitigated, unrestricted ILS CAT II approaches are possible, and the ILS CAT III approach minima could be published to the lowest RVR.

The surrounding high terrain also requires the ILS approaches to Runway 33 to be developed beyond the SSVs of the ILS equipment. Therefore, ESVs will be required for Flight Inspection to confirm that the ILS equipment can support the ILS approach to Runway 33.

Finally, RNP AR approach procedures to both runway ends are feasible albeit with high, but reasonable, landing minima.

Departures

Both conventional and RNAV SIDs are feasible. Two of the three conventional SIDs from Runway 15 require CGs. The ICVOR RNAV SIDs from Runway 15 and Runway 33 also require CGs. However, the CGs are reasonable.

Except for the FILOS RNAV SID, all RNAV SIDs from Runway 15 include a 500 FPNM CG to 9500 ft for LNAV engagement, after which a normal rate of climb (i.e., not less than standard) can be resumed, unless otherwise annotated (i.e., the ICVOR RNAV SID requires a CG). No CG is required for the FILOS SID.

All RNAV departures from Runway 33 include a 500 FPNM CG to 9000 ft for LNAV engagement, after which a normal rate of climb (i.e., not less than standard) can be resumed, unless otherwise annotated (i.e., the ICVOR RNAV SID requires a CG).

Other Factors

The following are additional factors of relevance pertaining to instrument procedures described in this document:

- As with all of MITRE's analyses, a validation of instrument procedures and other associated work must be accomplished by the Mexican aviation authorities.
- Initiation of Flight Inspection/Flight Validation activities should start as soon as possible by the Mexican aviation authorities to ensure that undetected obstacles and other safety and operational factors do not affect procedural designs.