

Enclosure 2

(Ref. Technical Letter F500-L14-004)



**Center for Advanced
Aviation System Development**

Alternative Runway Configuration for the Nuevo Aeropuerto Internacional de la Ciudad de México

***Feasibility Analysis of Independent
Approach Procedures***

Prepared for

Aeropuertos y Servicios Auxiliares

November 2013

1. Introduction

As part of MITRE's support to Aeropuertos y Servicios Auxiliares (ASA), an analysis was performed to examine the feasibility of conducting Category (CAT) I Instrument Landing System (ILS) approach procedures in both directions to three parallel runways. The runways would eventually be located in the proximity of the town of Texcoco, referred to in this document as the Nuevo Aeropuerto Internacional de la Ciudad de México (NAICM) site.

The analysis presented here took a substantial amount of effort and manpower. Therefore, additional runway configuration changes should only take place after careful consideration by ASA, as any runway location change necessarily leads to additional analyses as those presented. It is also important to note that these are not the approach procedures that MITRE delivered in July 2012 to the Dirección General de Aeronáutica Civil (DGAC), which are based on a MITRE-recommended runway configuration. See Section 2 for more background.

This document is organized into several sections. Section 2 provides background on both MITRE's previously examined runway configuration [referred to in this document as the *MITRE-Recommended Runway Configuration (July 2012)*] and a new runway configuration requested by ASA (referred to in this document as the *NAICM Alternative Runway Configuration*). Information on terrain and airspace issues is also included. Section 3 discusses MITRE's procedure development methodology used and lists key assumptions considered in this analysis. Section 4 provides procedure design results for the *NAICM Alternative Runway Configuration*. Finally, Section 5 provides a summary of MITRE's work and discusses next steps.

2. Background

Throughout the course of MITRE's overall support to Mexico's Secretariat of Communications and Transportation [Secretaría de Comunicaciones y Transportes (SCT)] over the past several years, MITRE has developed instrument procedures associated with various potential runway configurations pertaining to the NAICM project. That work was accomplished in coordination with officials from SCT dependencias such as ASA, the DGAC, and Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM).

The *MITRE-Recommended Runway Configuration (July 2012)*, shown in Figure 1, has a 002° True Orientation and runway lengths as given in Table 1. It is the preferred runway configuration due to procedures, airspace, and many other runway siting matters. This configuration was created after MITRE was informed by government officials in 2011 that additional land parcels had been acquired (or were in the process of being acquired) along the northeastern federal boundary line originally provided to MITRE by SCT. The additional land acquisition allowed for the possibility of shifting the easternmost pair of runways farther to the north, across the federal boundary line. However, for this runway configuration to be viable, a small land parcel, considered to be

politically sensitive, must be acquired. This small land parcel is shown as the red triangular shaped area in Figure 1.

With the eastern set of runways shifted further north, the southern ends of all proposed runways are now at least 3 km from Lago Nabor Carrillo, which is a natural bird attractant site that can present a hazardous situation for arriving and departing aircraft operations. The 3 km minimum distance meets the United States (U.S.) Federal Aviation Administration (FAA) recommendation for separation between runways and wildlife attractants.

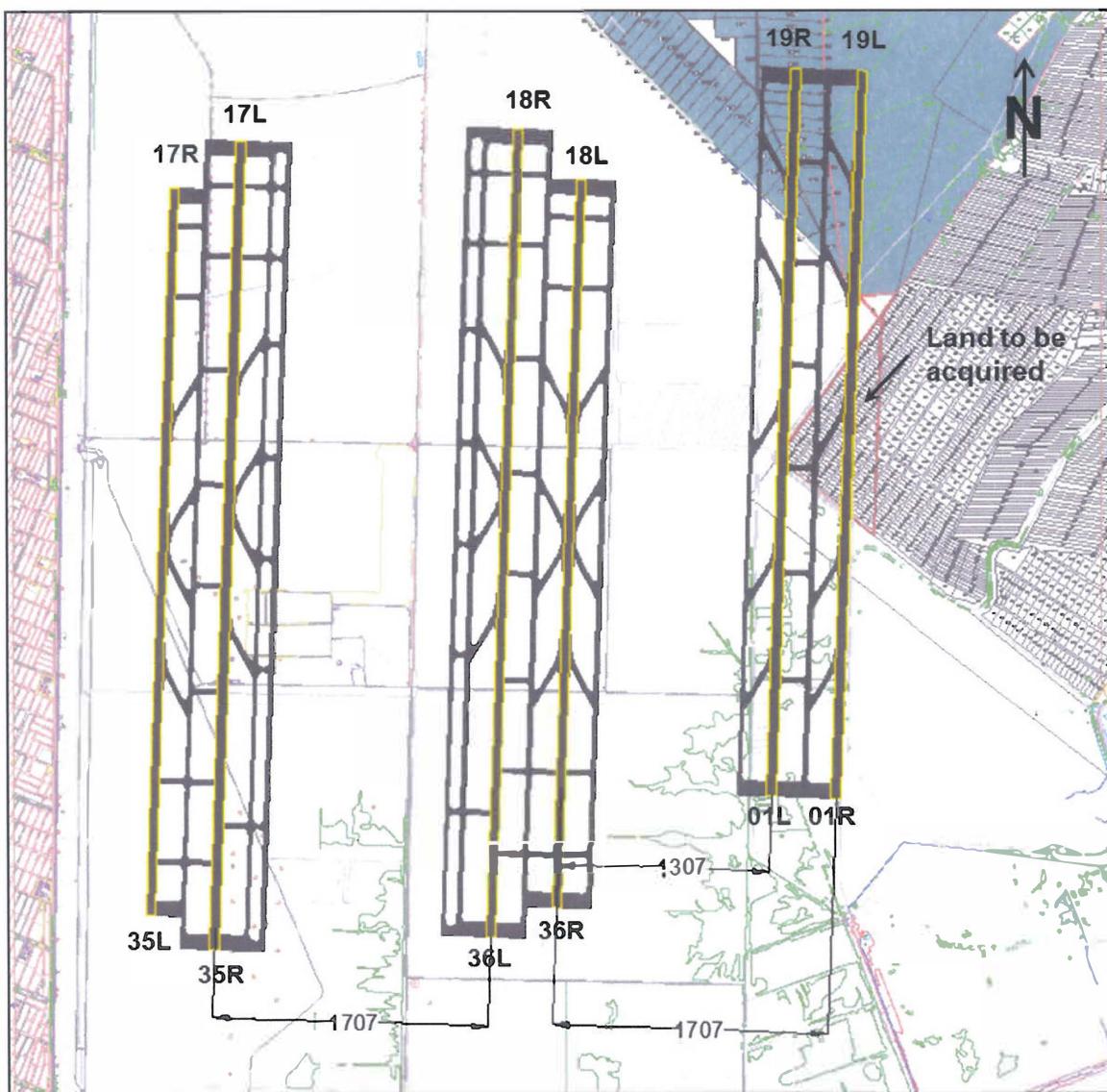


Figure 1. MITRE-Recommended Runway Configuration (July 2012)

Table 1. Runway Lengths

Runway	Length (m)
35L/17R	4500
35R/17L	5000
36L/18R	5000
36R/18L	4500
01L/19R	4500
01R/19L	4500

The recommended runway configuration shown in Figure 1 was developed under the assumption that additional land to the north and east of the boundary of federally-owned land would be acquired. Federal officials were confident at the time that the land required for this runway configuration would be purchased by the federal government. Nonetheless, ASA requested that MITRE examine an alternative runway configuration under the assumption that the triangular area of land to the east (and impinging on Runway 01R and Runway 01L) may not be acquired.

In response to the request mentioned above, a new runway configuration was investigated by MITRE, and that configuration, referred to as the *NAICM Alternative Runway Configuration*, is described in Enclosure No. 1 to MITRE Technical Letter F500-L14-004, November 2013, entitled *Alternative Runway Configuration for the Nuevo Aeropuerto Internacional de la Ciudad de México – Initial Assessment*. That enclosure, which is being delivered to ASA at the same time as this document, also presents the results of MITRE's assessment of selected International Civil Aviation Organization (ICAO) Obstacle Limitation Surfaces (OLSSs).

The subject of this report is the approach procedure design work performed for the *NAICM Alternative Runway Configuration*, shown in Figure 2. The specific runways for which approaches were designed for are highlighted in red. Runway lengths are unchanged from those given in Table 1.

Mountainous terrain surrounding the NAICM area (see Figure 3) complicates the development of instrument procedures, especially when considering independent parallel approaches. For example, the divergence requirement (i.e., a combined 45°) between missed approach courses can limit routing options. If terrain cannot be avoided, a minimum Climb Gradient (CG) for the missed approach segment may be specified¹.

During MITRE's previous project work it became apparent that the Santa Lucía Military Base and the Special Use Airspace (SUA) MMR-100 and MMR-112 would need

¹ U.S. and ICAO criteria require that in addition to a specified CG, published procedures also include separate missed approach points and minima utilizing a standard CG (i.e., 200 ft/NM) to be utilized by aircraft that cannot comply with a CG requirement. The preferred method is to publish both lines of minima on the same approach chart; however separate charts may be published.

to be relocated before the new airport opens. See Figure 4 (SUAs shown in green). Leaving the base and its SUAs in place would create a difficult and highly complex airspace environment (e.g., intermingling and crossing of routes, increased traffic density on those routes, and varying aircraft performance characteristics). Additionally, accommodating operations at Santa Lucía Military Base would adversely impact runway capacity at the new airport. Therefore, MITRE, in joint collaboration with SENEAM, mutually agreed that Santa Lucía Military Base and all of its associated SUAs should be relocated.

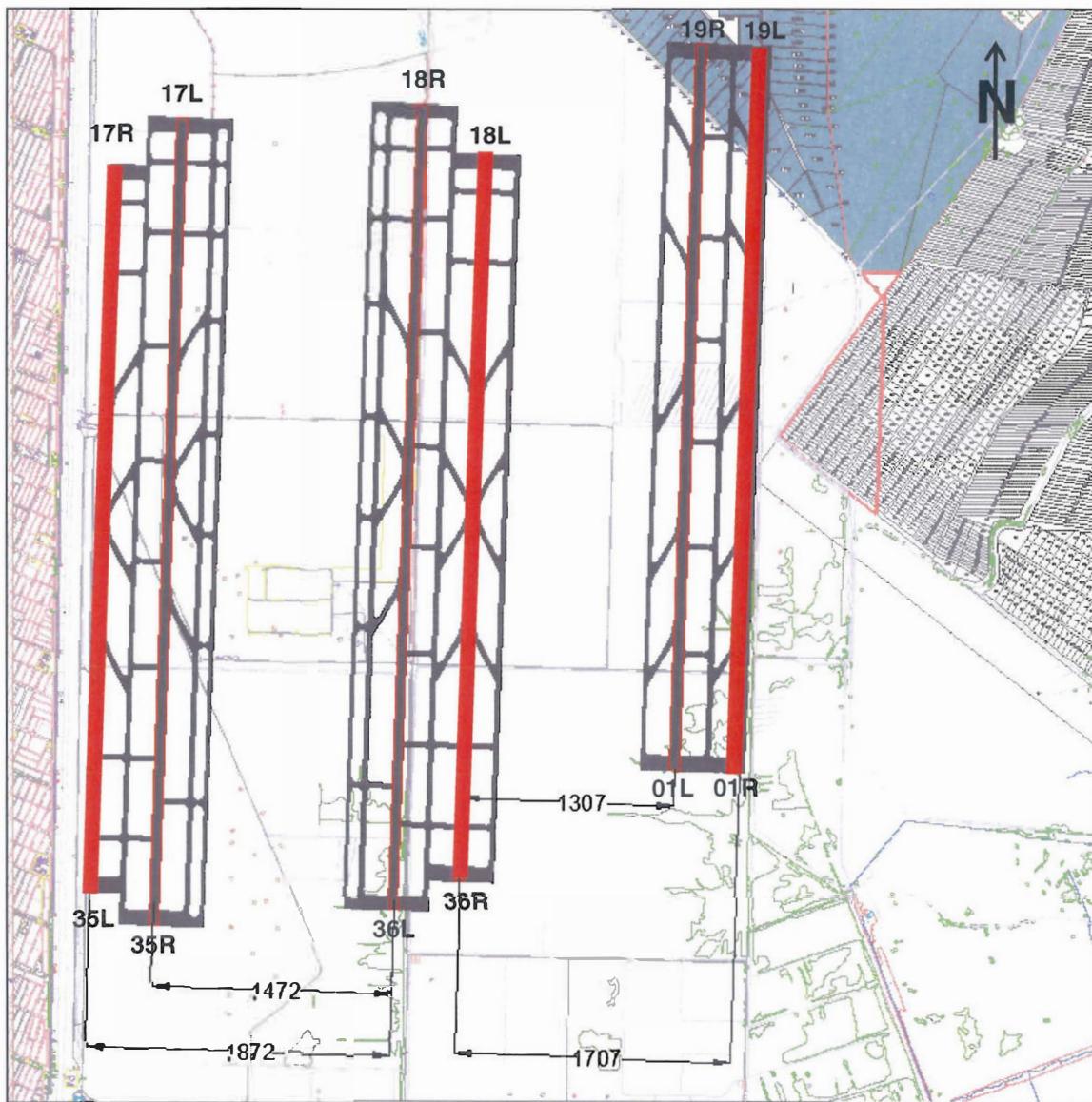
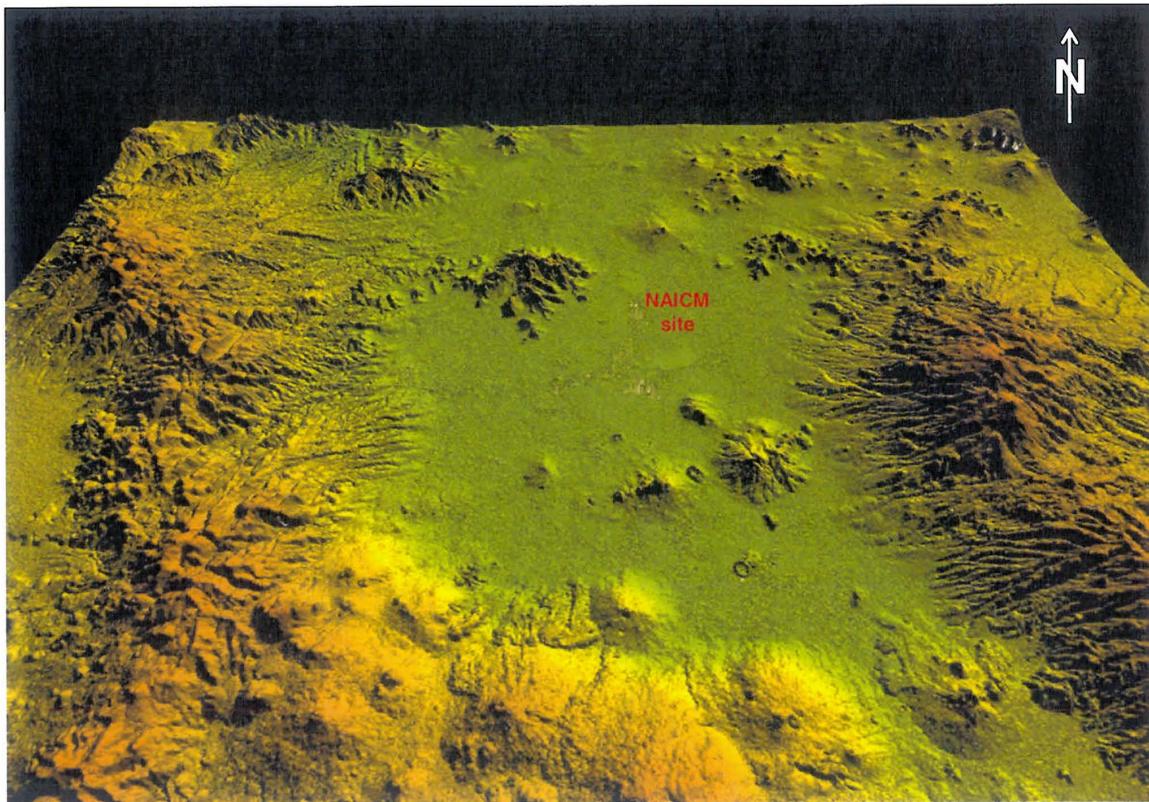


Figure 2. NAICM Alternative Runway Configuration



Source: Global Mapper

Figure 3. High Terrain Surrounding the NAICM Area



Source: Includes material that is protected under the copyright of DigitalGlobe, Inc. All rights reserved.

Figure 4. Santa Lucía Military Base and SUAs in Relation to the NAICM Site

3. Methodology, Data Used, and Assumptions

In general, instrument procedures are not only developed for a specific runway configuration, but also for specific modes of operation. In the case of NAICM, MITRE examined the feasibility of triple independent instrument approach procedures, which will maximize ultimate runway capacity.

Many factors must be considered in the development of instrument procedures, especially when considering triple independent operations to parallel runways. All instrument approach procedures were developed in accordance with the U.S. Standard for Terminal Instrument Procedures (TERPS) criteria, which Mexico has used for many years. Moreover, ICAO does not publish standards for independent approaches to three runways.

A key U.S. Air Traffic Control (ATC) requirement for triple independent approaches (as well as dual independent approaches) is to provide a minimum of 1000 ft vertical separation between aircraft assigned to different runways during turn on to parallel final approach. Communications transfer to the control tower must be completed prior to losing vertical separation between aircraft.

Wherever possible, MITRE attempted to work within the existing airspace structure by using existing Navigational Aids (NAVAIDs), airways, fixes, etc. However, as a part of the design, MITRE defined a future Very High Frequency Omnidirectional Range (VOR)/Distance Measuring Equipment (DME) to be located at the NAICM site to assist in navigating. Additionally, the procedures described in this report were designed under the assumption that the existing VOR/DMEs at both Mexico City International Airport (AICM) and the Santa Lucía Military Base, along with several other existing NAVAIDs (as indicated in the procedures described below), would remain operational.

During MITRE's previous study, MITRE discovered that the Minimum Vectoring Altitude Chart (MVAC), which depicts the lowest altitudes at which air traffic controllers can radar vector aircraft, would not adequately support the anticipated future instrument procedures at the new airport. Moreover, plans for expansion of Toluca Airport (e.g., the addition of a parallel runway to conduct independent operations) located west of Mexico City could result in difficulties in the vectoring of traffic to that airport as well. Therefore, in close coordination with SENEAM, MITRE developed a new MVAC for a combined NAICM/Toluca Terminal Maneuvering Area (TMA) to support future operations.

The development of instrument procedures is a complex process. Increased levels of required accuracy and electronic databases (e.g., obstacle data) make automation a necessity. MITRE uses a variety of software tools when designing procedures, such as AutoCAD and PDTToolKit. The former is a well-known tool, while the latter is a specialized tool that is used to develop and evaluate instrument procedures and conduct obstacle assessments.

An up-to-date, robust, and accurate database of both aeronautical and obstacle information is essential in the development of instrument procedures. In 2010, a satellite-based survey of the area was conducted². Information from this survey and other sources, such as the Aeronautical Information Publication (AIP) of Mexico, were used to develop a highly detailed basemap within AutoCAD. MITRE uses the basemap to formulate, test, and analyze various procedure design options in order to determine feasibility. A new satellite-based survey is going to be commissioned by MITRE to be used by SENEAM and MITRE to verify that no problematic man-made obstacles have been erected since the 2010 survey.

To determine the feasibility of instrument procedures at NAICM, certain assumptions regarding important aeronautical factors were made:

- Existing AICM will close once NAICM opens
- Santa Lucía Military Base and the associated SUAs will be relocated before NAICM opens

² The survey is composed of 3 areas: 1) the Photogrammetric Survey Area (PSA), which approximates the NAICM boundary, 2) an Area A and 3) an Area B. Within the PSA is a rectangular box that encompasses all potential runway configurations. Area A extends from the boundary of the rectangular area to 10 km. Area B extends from the boundary of Area A an additional 35 km. As part of the satellite survey, site visits were conducted to collect and confirm additional information.

- The existing VOR/DMEs located at existing AICM and at Santa Lucía Military Base will remain in their current locations and continue to operate (even after existing AICM closes and Santa Lucía Military Base is relocated). MITRE must be informed as soon as possible if this assumption is not correct as the absence of these VOR/DMEs will affect MITRE's procedure design work.
- Air traffic controllers will use radar vectors as the primary means of navigation to the final approach courses
- All appropriate equipment for a CAT I ILS (e.g., localizer, glideslope, Approach Lighting System) will be installed as necessary and meet operational requirements. Where appropriate, equipment would be flight-inspected and certified for use beyond normal operating distances (i.e., Expanded Service Volume) to accommodate procedure design.
 - Note that the final approaches for NAICM are very long and exceed normal operating distances of localizer and glideslope equipment. MITRE was informed by an ILS manufacturer that appropriate equipment does exist that can support such long finals. Nevertheless, MITRE recommends that ASA consider conducting flight inspections as soon as possible using temporary ILS equipment to ensure that appropriate signal reception can be achieved. Early testing will help identify any potential issues that will need to be addressed.
- Information collected from the 2010 satellite-based survey took precedence over all other obstacle data sources. Note that the previously mentioned Enclosure No. 1 to MITRE Technical Letter F500-L14-004, November 2013, also considered obstacles from an earlier dataset provided to MITRE by the DGAC in 2008. Many of those obstacles are either not reflected in the detailed satellite-based survey conducted in 2010 or are included, but with a lower elevation that does not penetrate the ICAO Annex 14 surfaces described in that report.
- MITRE assumed an Adverse Assumption Obstacle (AAO) to account for any unidentified man-made obstacles. A 60 m Above Ground Level (AGL) AAO was applied from the outer boundary of Area A outward to a distance of 5 NM beyond the MVAC boundary.
- Future airport facilities (e.g., terminal buildings, aircraft parking stands, aprons, and other airfield components) were not considered. MITRE assumed that future airport facilities would not impact any airport ICAO OLS or ILS Obstacle Clearance Surfaces (OCSs) or impede ILS equipment signals.
- The new combined NAICM/Toluca MVAC (jointly developed by SENEAM and MITRE) will be implemented

- Missed approach CGs will be authorized by the Mexican aeronautical authorities

4. Instrument Procedure Development

MITRE developed triple independent CAT I ILS instrument approach procedures in both directions for the first three runways of the *NAICM Alternative Runway Configuration* (i.e., Runways 35L/17R, 36R/18L, and 01R/19L). See Figure 5. Note that there is some flexibility about which center pair of runways should be constructed first.

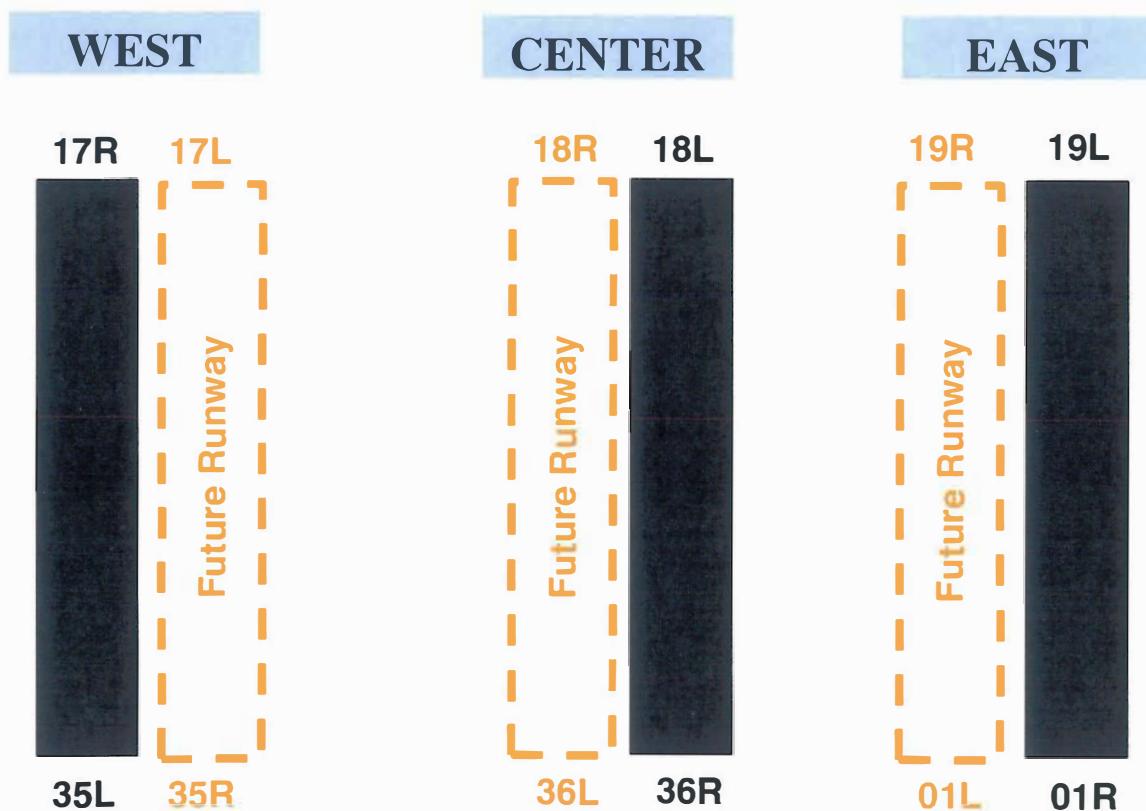


Figure 5. Potential Opening-Day Runways (Shown in Black) at NAICM

The objective of MITRE's procedure design work is to demonstrate the feasibility of instrument procedures required to support triple independent approach operations. As previously mentioned, all CAT I ILS approach procedures were designed based on U.S. TERPS criteria. MITRE attempted to design all procedures to achieve the best possible CAT I ILS minima.³

³ A CAT I ILS is a precision instrument approach and landing with a decision height not lower than 60 m (200 ft) and with either a visibility not less than 800 m ($\frac{1}{2}$ statute mile) or a runway visual range not less than 550 m.

Whenever possible, missed approach procedures should be developed that do not incur CGs above standard⁴. However, due to high terrain and other constraints (e.g., ATC missed approach divergence requirements), most of the ILS approach procedures will require a CG for the missed approach segment. ICAO has long permitted CGs to be published, and the U.S. has also adopted this practice. The Mexican government must adopt the practice of allowing CGs on a missed approach before implementation of MITRE's recommendations. As mentioned earlier, approach minima without a CG must also be published for those aircraft unable to meet the higher CG.

It is important to mention that the location of displaced runway thresholds has not been finalized. This is due to decisions that will need to be made by federal authorities about how much two hills [Chiconautla (hereinafter referred to as *Colina Norte*)⁵ and Chimalhuacán (hereinafter referred to as *Colina Sur*)] should be reduced.

Most noteworthy is Colina Norte and the antennas on top of the hill, which penetrate the U.S. TERPS final approach OCS for Runway 19L. Colina Norte also penetrates the ICAO Annex 14 Approach Surfaces for Runways 18L and 19L, and the ICAO Annex 14 Takeoff Climb Surfaces for Runways 36R and 01R. Colina Sur, on the other hand, only penetrates the horizontal section of the ICAO Annex 14 Approach Surface to Runway 01R. However, in accordance with ICAO guidance, it is possible to modify the Approach Surface to Runway 01R to avoid a penetration by Colina Sur by extending the 2.5% sloping surface (Approach Surfaces are composed of three components; the 2.5% surface is the middle component). Other penetrations to the ICAO Annex 14 Inner Horizontal and Conical Surfaces also exist but are less of a concern as these surfaces are intended to protect aircraft during visual circling maneuvers prior to landing, an unlikely event at a large, international airport such as the one envisioned at NAICM. Nevertheless, these obstacles should be marked, lighted, and published in the AIP of Mexico. Please note that all of the information provided in this paragraph is still subject to an internal peer review at MITRE.

When one or more obstacles penetrate an ICAO Annex 14 surface, an aeronautical study should be undertaken to assess the impact of the penetration, if any, on flight operations. An important part of an aeronautical study is the analysis of instrument procedures, such as those presented in Sections 4.1 and 4.2, to determine if any obstacles would impact air navigation and significantly affect the regularity of operations.

In the case of TERPS, however, penetrations to certain surfaces are not allowed. In such cases the procedure must be modified to avoid the penetration (e.g., by raising the glidepath of an approach) or the obstacle must be modified/removed until it is no longer an issue. Colina Norte penetrates the Runway 19L ILS final OCS by 56 ft (17 m). Considering the antennas on top of the hill, the amount of penetration increases to 200 ft (61 m) based on a 3° glideslope angle.

⁴ A standard CG is considered to be 200 ft/NM

⁵ There are also a number of tall antennas located on Colina Norte that figure prominently in assessing both Annex 14 and U.S. TERPS surfaces; these will need to be relocated.

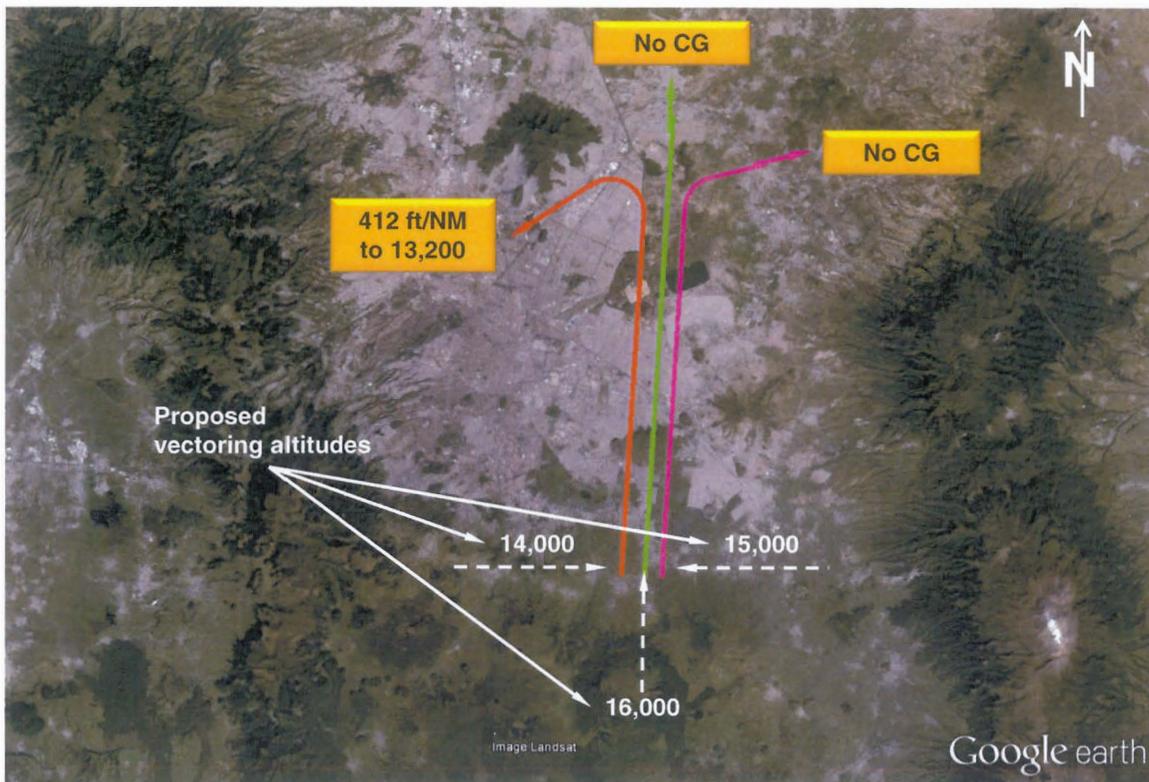
Naturally, the best outcome would be to remove all ICAO and TERPS penetrations. However, the extent of any excavation effort or antenna removal (to reduce the height of these two hills) is a decision that the Mexican government will need to address. The outcome of those decisions will affect many things, including the location of some runway thresholds, amount of runway displacement, and the feasibility of an ILS approach to Runway 19L and 19R when eventually constructed.

It is worthwhile mentioning that ASA reported to MITRE an intention by the Comisión Federal de Electricidad (CFE) of installing a power line in the proximity of the NAICM site. MITRE is waiting for coordinates and elevations of the power line to analyze its impact or possible relocation.

4.1 Instrument Approach Procedures to the North

Figure 6 shows the triple independent CAT I ILS approach and missed approach procedure paths to the north for the *NAICM Alternative Runway Configuration*. Figures 7 through 9 show a profile view of the instrument approach procedures to Runways 35L, 36R, and 01R, including minima and missed approach instructions. All headings and radials denoted on these figures are with respect to True North (rather than magnetic).

Note that all procedures have an Intermediate Fix (IF) at 16,000 ft. However, approaches to the three runways will be assigned turn-on altitudes that provide 1000 ft of vertical separation from approaches to adjacent runways, as previously described in Section 3. Specifically, approaches to Runway 35L will be assigned an altitude of 14,000 ft, approaches to Runway 36R will be assigned an altitude of 16,000 ft, and approaches to Runway 01R will be assigned an altitude of 15,000 ft. The approaches to the two outboard runways will intercept the procedures inside of the IF.



Source: Google Earth

Figure 6. NAICM Alternative Runway Configuration Approach and Missed Approach Paths: North Flow

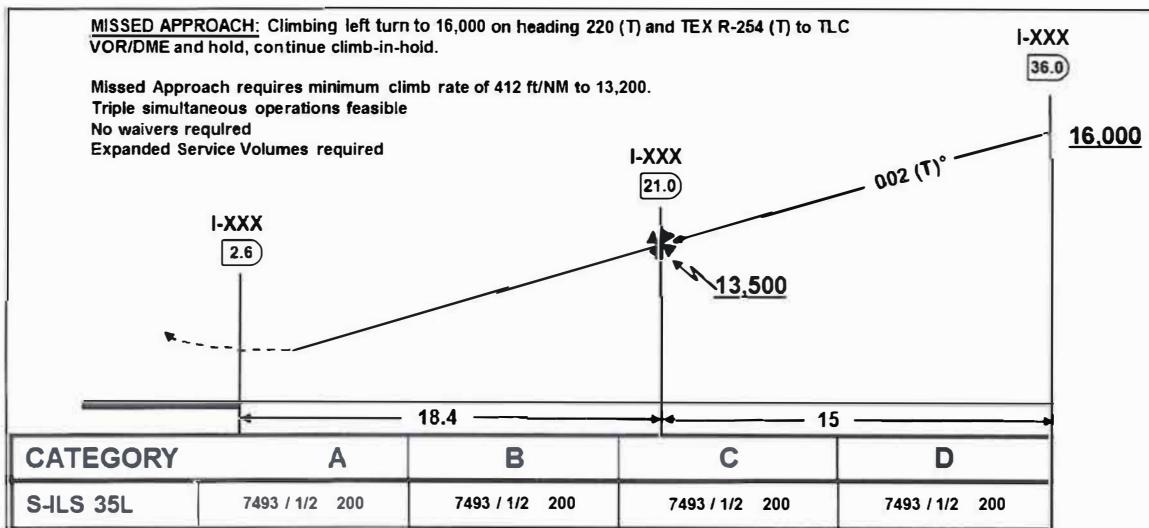


Figure 7. NAICM Alternative Runway Configuration: Runway 35L CAT I ILS Approach Profile (Not Intended for Navigation/Publication)

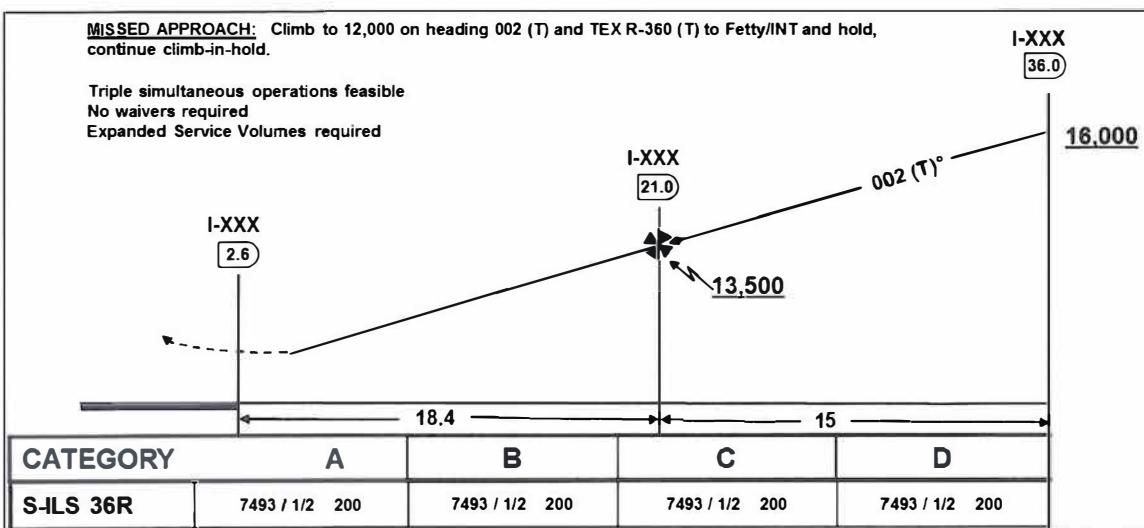


Figure 8. NAICM Alternative Runway Configuration: Runway 36R CAT I ILS Approach Profile (Not Intended for Navigation/Publication)

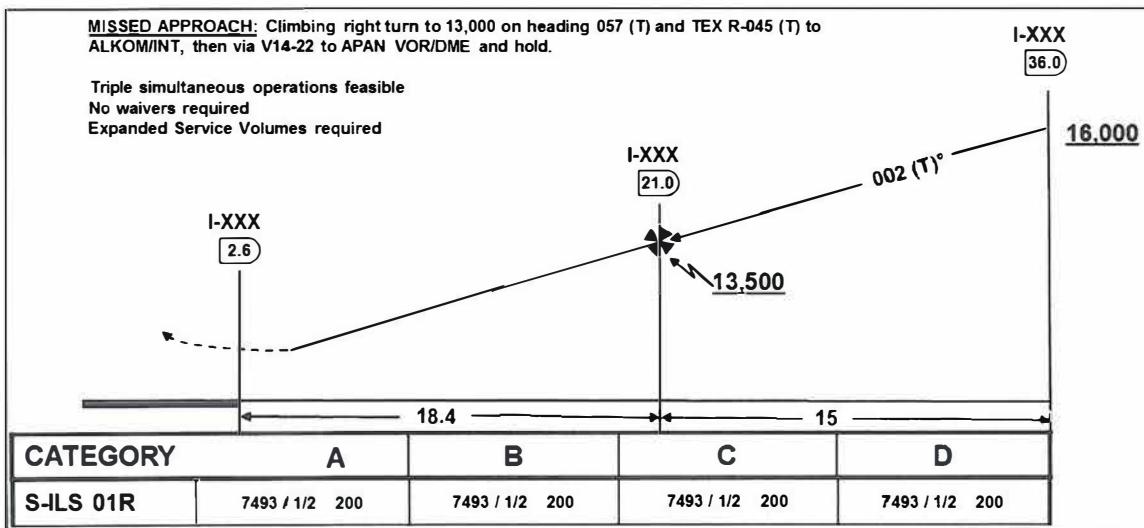


Figure 9. NAICM Alternative Runway Configuration: Runway 01R CAT I ILS Approach Profile (Not Intended for Navigation/Publication)

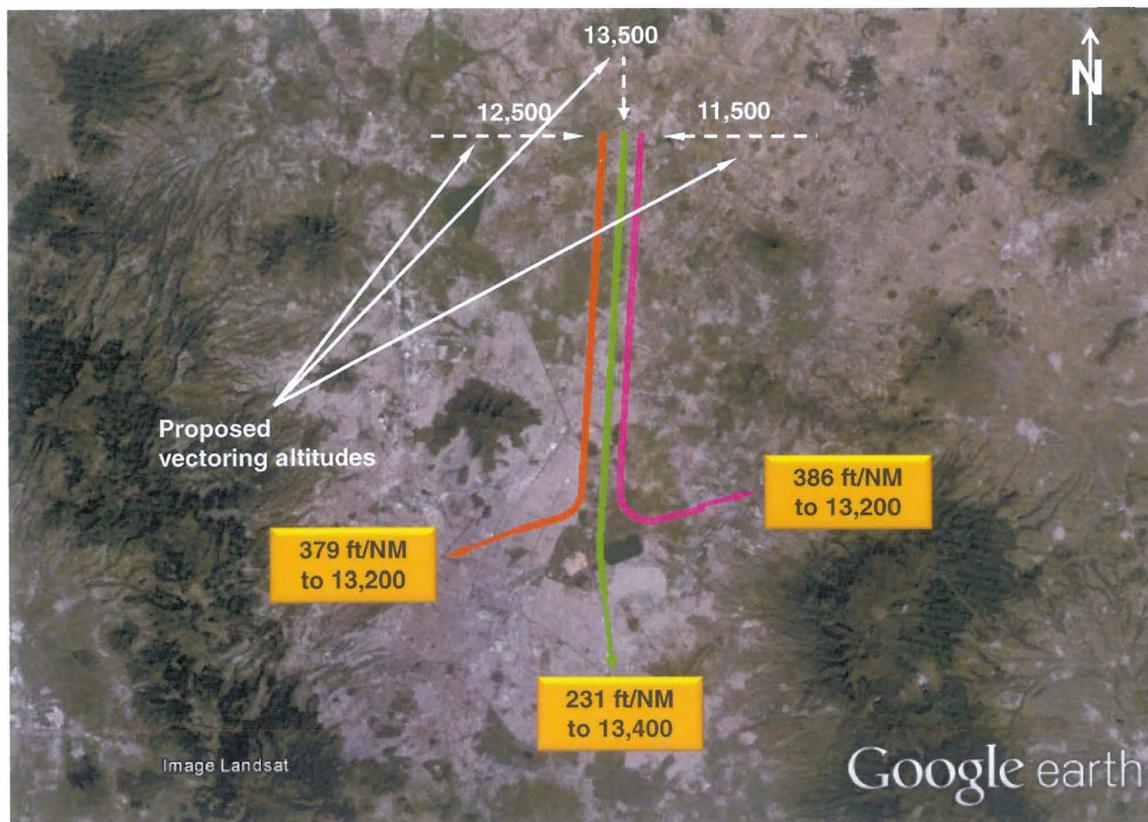
4.2 Instrument Approach Procedures to the South

Figure 10 shows the triple independent CAT I ILS approach and missed approach procedure paths to the south for the *NAICM Alternative Runway Configuration*. Figures 11 through 13 show a profile view of the instrument approach procedures to Runways 17R, 18L, and 19L, including minima and missed approach instructions.

Note that all procedures have an IF at 16,000 ft. However, approaches to the three runways will be assigned turn-on altitudes that provide 1000 ft of vertical separation from approaches to adjacent runways, as previously described in Section 3. Specifically,

approaches to Runway 17R will be assigned an altitude of 12,500 ft, approaches to Runway 18L will be assigned an altitude of 13,500 ft, and approaches to Runway 19L will be assigned an altitude of 11,500 ft. The approaches will intercept the procedures inside of the IF.

The 19L approach is designed to a 427 m displaced threshold and assumes no penetration to the final approach OCS. Displacing the threshold is one action that can be taken to help mitigate the impact of Colina Norte and antennas located on top of it (penetrations to the ILS final surfaces are not allowed). Depending on decisions made by the Mexican government, additional actions will be required for the ILS approach to Runway 19L to be feasible.



Source: Google Earth

Figure 10. NAICM Alternative Runway Configuration Approach and Missed Approach Paths: South Flow

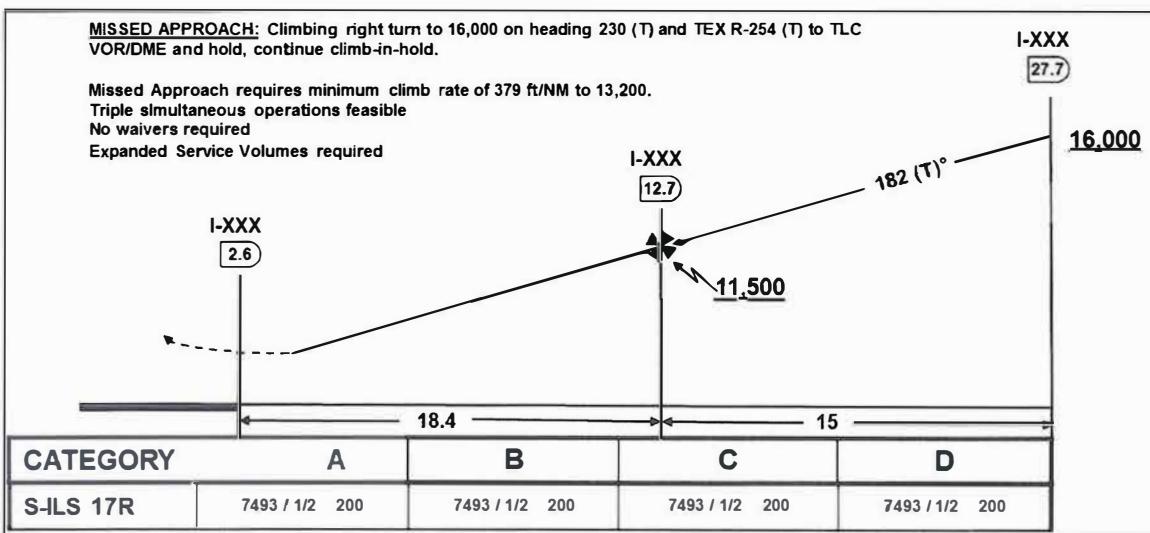


Figure 11. NAICM Alternative Runway Configuration: Runway 17R CAT I ILS Approach Profile (Not Intended for Navigation/Publication)

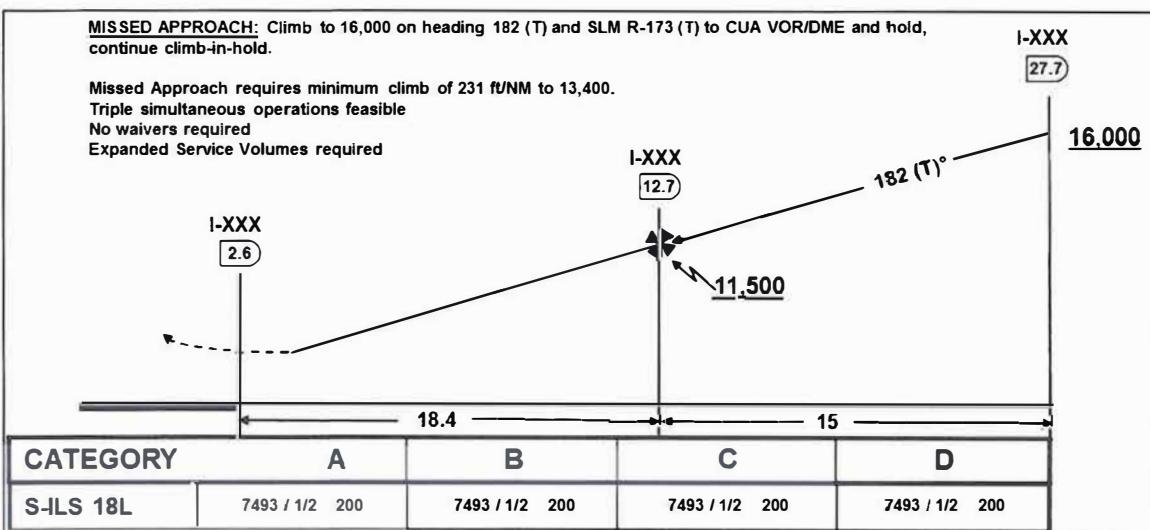


Figure 12. NAICM Alternative Runway Configuration: Runway 18L CAT I ILS Approach Profile (Not Intended for Navigation/Publication)

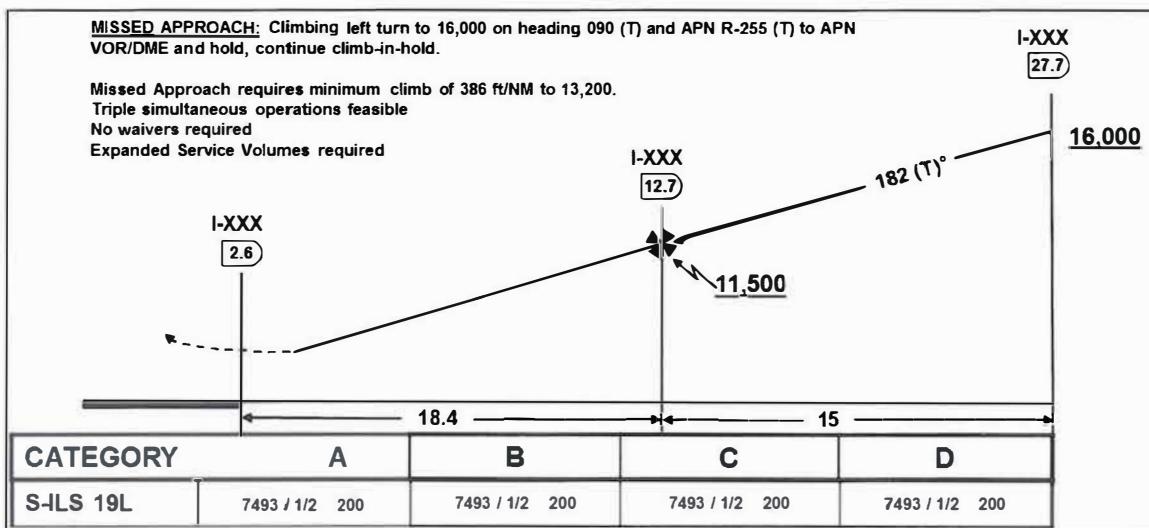


Figure 13. NAICM Alternative Runway Configuration: Runway 19L CAT I ILS Approach Profile (Not Intended for Navigation/Publication)

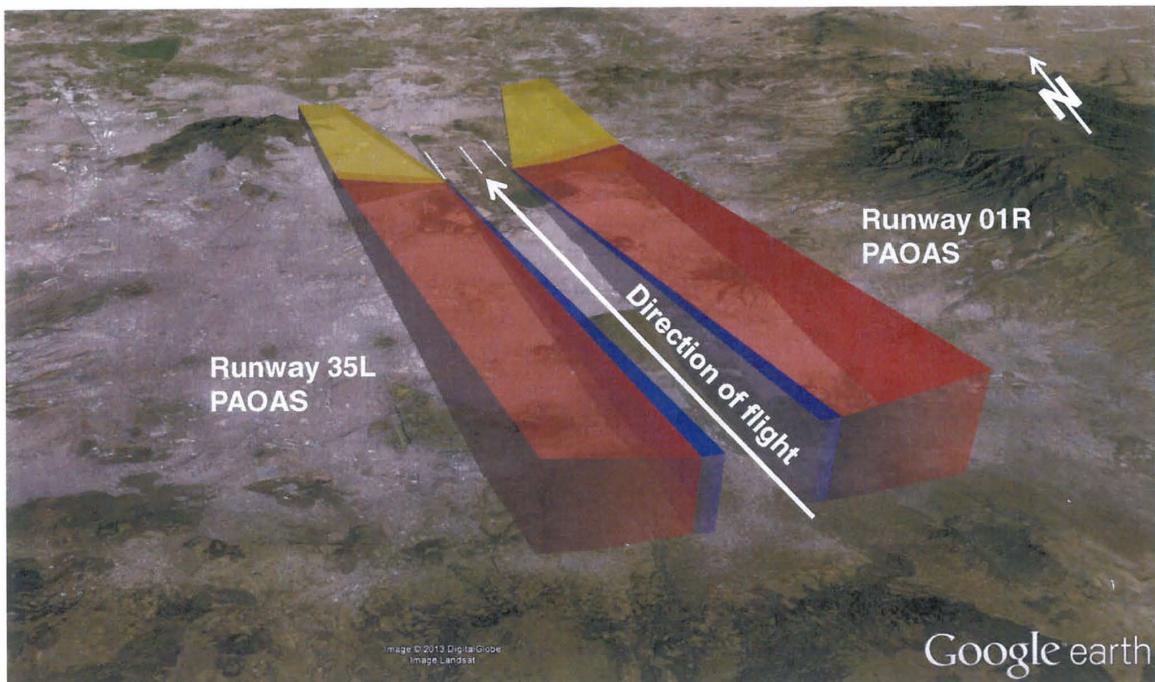
4.3 Parallel Approach Obstruction Assessment Surfaces

A Parallel Approach Obstruction Assessment (PAOA) must be accomplished before independent parallel operations can be conducted. The purpose of the PAOA is to ensure an obstacle-free path for an aircraft on final approach that needs to conduct an evasive maneuver (typically a command to turn and climb) to avoid another aircraft on final approach to an adjacent runway that blunders into its path. The Parallel Approach Obstruction Assessment Surfaces (PAOAS) are applied to the outboard runways, in this case, to the eastern and western runways⁶.

The Sierra de Guadalupe to the northwest of the site was of particular concern, especially for Runway 17R. However, as with the other runway PAOAS, MITRE determined that there were no penetrations.

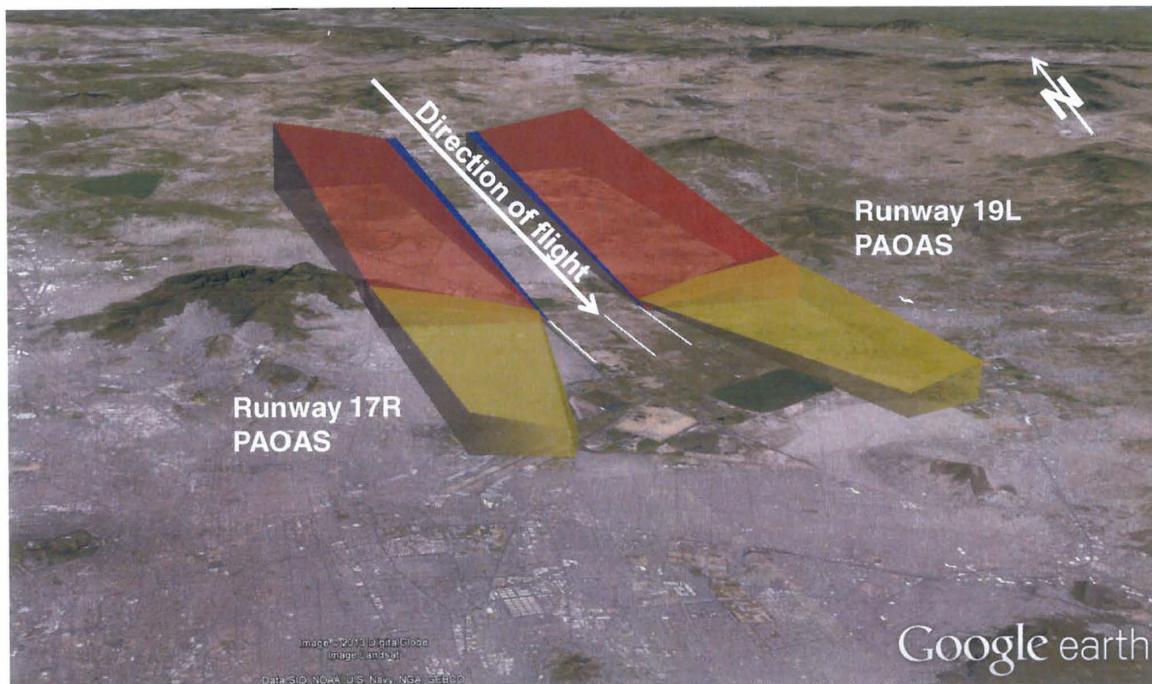
Figure 14 shows the PAOAS for Runways 35L and 01R. Figure 15 show the PAOAS for Runways 17R and 19L.

⁶ A PAOA is not normally performed for the center runway in a parallel 3-runway configuration, since the PAOAS for the center runway will be higher than those from the outboard runways. If there were no penetrations to the PAOAS of the outboard runways, there would not be any for the center runway.



Source: Google Earth

**Figure 14. NAICM Alternative Runway Configuration:
PAOAS for Runways 35L and 01R**



Source: Google Earth

**Figure 15. NAICM Alternative Runway Configuration:
PAOAS for Runways 17R and 19L**

5. Summary

Triple independent approaches are feasible in both directions for the *NAICM Alternative Runway Configuration*. Having said that, much work remains to be performed, examples of which are Required Navigation Performance (RNP) approach procedures to lower CGs, departure procedures, and more. Also, the feasibility being enunciated here is dependent on assumptions described in this document. Some of these assumptions are significant, such as the extent of the reduction, if any, of Colina Norte and Colina Sur. While these procedure designs may not reflect the final solution, they do demonstrate what is achievable.

Four of the six procedures presented in this document require CGs on the missed approach segments. However, it is fortunate that two of the three approach procedures to the north (likely to be the preferred operational direction) utilize standard CGs. On the other hand, all three approach procedures to the south require higher than standard CGs. MITRE considers it important that the DGAC and ASA discuss as soon as possible the application of CGs with appropriate airline representatives to obtain operational feedback. Additionally, CGs need to receive regulatory approval by the DGAC.

These procedures represent only a portion of the overall complex and integral set of actions needed to make these procedures feasible. Local operating and intra-facility coordination procedures will have to be developed. Controller training and additional staffing will have to be addressed as well. The final implementation and operation of this airport has a magnitude of complexity that is a first for Mexico. As the project matures, and when appropriate, MITRE will provide guidance and assistance to ASA and other relevant authorities regarding the many elements that need to be considered in preparing for independent approach and departure procedures.

Over the coming months, MITRE will be examining the feasibility of triple independent instrument departure procedures, CAT II/III ILS procedures, and RNP procedures to better manage climb gradients for the *NAICM Alternative Runway Configuration*.

Finally, SENEAM should thoroughly review MITRE's work and the DGAC should ultimately validate and approve it. Likewise, ASA should carefully consider whether MITRE should move on to complete the feasibility analysis that has been initiated and delivered through this report. MITRE strongly recommends that Mexico adopts either the *MITRE-Recommended Runway Configuration (July 2012)* solution or the *NAICM Alternative Runway Configuration* solution once the feasibility analyses are finalized, as working out another alternative would delay final decisions. MITRE understands, however, that this may necessitate the acquisition of a relatively small, problematic area; yet, acquisition of that area would not only accelerate decisions, but would also ensure that the new 6-runway airport meets capacity requirements for much of this century.