Enclosure 6

(Ref. Technical Letter F500-L15-007)

MITRE

Center for Advanced
Aviation System Development

Review of the Pre-Master Plan for Nuevo Aeropuerto Internacional de la Ciudad de México

An Overview

Prepared for

Aeropuertos y Servicios Auxiliares

January 2015

Principal Acronyms and Abbreviations

ACC	Area Control Center
ADS-B	Automatic Dependent Surveillance-Broadcast
AICM	Aeropuerto Internacional de la Ciudad de México
ASA	Aeropuertos y Servicios Auxiliares
ATC	Air Traffic Control
ATCT	Air Traffic Control Tower
CAT	Category
DME	Distance Measuring Equipment
EAT	End-Around Taxiway
ELS	Equivalent-Level-of-Safety
FAA	U.S. Federal Aviation Administration
GBAS	Ground-Based Augmentation System
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
MITRE	The MITRE Corporation
MLAT	Multilateration
MSL	Mean Sea Level
NAICM	Nuevo Aeropuerto Internacional de la Ciudad de México
NAVAID	navigational aid
PANS-OPS	Procedures for Air Navigation Services-Aircraft Operations
PRM	Precision Runway Monitor
SSR	Secondary Surveillance Radar
TERPS	Standards for Terminal Instrument Procedures
U.S.	United States
UTM	Universal Transverse Mercator
VOR	VHF Omnidirectional Range

1. Introduction

As part of its support to Aeropuertos y Servicios Auxiliares (ASA), The MITRE Corporation (MITRE) works as an independent advisor within its areas of expertise as technical matters pertaining to Nuevo Aeropuerto Internacional de la Ciudad de México (NAICM) arise among the wide range of project stakeholders. Accordingly, per ASA's request, MITRE reviewed the Anteproyecto Ejecutivo, dated 1 September 2014 (hereafter referred to as the Pre-Master Plan), as submitted to ASA by Arup. The objective of MITRE's review was to identify differences between MITRE's and Arup's work and to highlight potential aeronautical issues for consideration by Mexican aviation authorities. Non-aeronautical matters were, in general terms, not reviewed.

It is important to note that MITRE first received Volume I of Arup's Pre-Master Plan in late October 2014. During an initial review of Volume I, MITRE realized that the Pre-Master Plan consisted of additional volumes and content, so, subsequently, requested this information from ASA to conduct a comprehensive review. The remaining volumes were received by MITRE in late November 2014.

MITRE assembled a large team with many diverse areas of expertise to conduct a comprehensive and detailed review of the Pre-Master Plan. Given that the Pre-Master Plan consists of a large amount of information that was received in over 136 files, a significant amount of effort and time was required to conduct the review. The MITRE team worked extremely hard to complete its review of the material as soon as possible in order to provide appropriate and helpful feedback for consideration by Arup in completing its on-going Master Plan development work.

2. Assumptions and Limitations

Many of the concepts developed within the Pre-Master Plan fall outside the expertise of MITRE. While it is not a complete list, the following illustrates some of the topics in which MITRE does not normally engage:

- Airport surface traffic flow, including taxiway and apron design
- Analysis, siting, and installation of airfield equipment, navigational aids (NAVAIDs), visual aids, lighting systems, and Air Traffic Control Towers (ATCTs)
- Layouts for Area Control Centers (ACC), Approach Control facilities, ATCT cabs, etc., as well as matters of communication and coordination among them
- Aeronautical communications, except for research purposes within the United States (U.S.)
- Terminal building design and, in general, airport landside matters
- Master planning, construction, civil engineering, airport development management, etc.

Thus, MITRE's review focused on matters that pertain to the aeronautical work it conducted to determine the feasibility of NAICM, such as runway siting, obstacles, development of instrument procedures, terminal area airspace design, etc.

MITRE did not conduct any analyses based on the information contained within Arup's Pre-Master Plan. Thus, the objective was to report key differences.

As mentioned above, the MITRE team worked extremely hard to complete its review of the material as soon as possible in order to provide appropriate and helpful feedback for consideration by Arup in completing its Master Plan document. It is possible that MITRE may identify additional items later.

3. Findings for Consideration

This section reports MITRE's findings worth consideration on the basis of Volumes I through IV of the Pre-Master Plan and supplemental files (e.g., appendices, AutoCAD drawings, figures, etc.). References to the Pre-Master Plan, such as volume, section, and page number, or the name of a file are provided in parentheses after each of MITRE's section titles below.

3.1. Runway Differences

The following are key differences between the runways provided by MITRE and those discussed in the Pre-Master Plan.

3.1.1. Runway Coordinates (Volume I, Section 6.2.2, Page 22)

Figure 10 in Volume I, Section 6.2.2, Page 22 provides the geodetic coordinates of the runway ends contained in the Pre-Master Plan. The footnote to that figure indicates that Arup used MITRE-recommended runway geodetic coordinates contained in a MITRE document dated September 2012, and converted the geodetic coordinates to Universal Transverse Mercator (UTM) for the planning and design work of the Pre-Master Plan. Arup then *refined* those coordinates to the extent necessary to ensure the intended parallel runway centerlines.

Based on the above-mentioned footnote, it appears that both MITRE and Arup use UTM for planning and design work. The MITRE UTM coordinates have a precision of 1/10,000th of a meter (0.0001 m). MITRE then uses a software tool to convert UTM Northing (Y) and Easting (X) to geodetic latitude and longitude for reporting purposes only. In general, the accuracy of the geodetic coordinate output by the software tool has only been tested to a level of approximately 1 m (0.1 second). In order to avoid a loss of precision through the coordinate conversion from UTM to geodetic, MITRE can provide ASA with the UTM coordinates of the MITRE-recommended runway configuration.

This is important because the use of the geodetic coordinates and Arup's subsequent conversion back to UTM may have introduced slight discrepancies in the coordinates and consequently, measurements derived from those coordinates, such as runway spacing (e.g., 1708 m and 1308 m vs. 1707 m and 1307 m). It is also important to note that the UTM coordinates for the MITRE-recommended runway configuration are located such that the runway centerlines are exactly parallel. It is critical that when the NAICM runways are constructed that they be perfectly parallel and be separated by the distances recommended by MITRE.

3.1.2. Runway Phasing (Volume I, Section 2.2.1, Page 7)

Arup is recommending that the opening-day runway configuration should consist of runways 2, 3, and 6, (as counted from west to east) while MITRE strongly recommends runways 1, 3, and 6. Constructing the outer runways (1 and 6) will ensure and protect the ability of the airport to achieve its ultimate six-runway layout configuration.

On the basis of many years of experience, MITRE is convinced that if runway 1 is not built initially it may never be built, primarily due to unjustified noise complaints that may prove to be politically impossible to overcome. Thus, the envisioned six-runway airport would be curtailed to five runways and a reduced longevity. In addition, the impact of not being able to construct runway 1 could lead to an inefficient and unbalanced runway configuration that would have only one runway adjacent west of its main terminal building, instead of two runways.

The assertion that constructing runway 2 after runway 1 is more complicated needs to be balanced against a strong possibility of NAICM ending up with one fewer runway and with a less efficient runway configuration. It is worth recalling that Arup presented the same concern when the terminal building was going to be built on the airport's eastern side and there was no assurance that runway 6 would ever be built.

3.1.3. Runway Widths (Volume I, Section 6.2.2, Page 23)

Arup recommends that runways 1, 2, 4, and 5 have a width of 45 m. MITRE recommends that all runways be constructed with a width of 60 m. This would allow operational flexibility for all aircraft and ultimately permit airlines to avoid having to deal with what may amount to substantial restrictions, which is not recommended for a brand new airport that may still be there in one hundred years. Additionally, while aircraft requiring a 60 m wide runway may be a proportionally small part of the airport's fleet, within a few years their absolute number will be sizeable as the airport's operational volume increases. Apart from all of the above, MITRE has been informed by Grupo Aeroportuario de la Ciudad de México (GACM) that it requested that all runways be 60 m wide in the Master Plan.

An additional consideration is that under the current Pre-Master Plan, whenever runway 3 closes for any reason, the only alternative for aircraft requiring a 60 m wide runway would be to taxi to and from runway 6, which is very far from the terminal area. In addition, increasing the runway width by 15 m should not significantly increase construction costs if the runways are initially constructed at a width of 60 m. Widening runways to 60 m in the future would be way more expensive and complicated, requiring closure of the runways, relocation of runway lights, and other expensive modifications.

3.1.4. Runway Configuration (Volume I, Section 6.2.2, Page 22)

The Pre-Master Plan states that the runway configuration will be based on the MITRE-Recommended Runway Configuration (July 2012); however, there are differences between the two configurations. Most noticeably, Arup's runway 5 has been shifted 267 m to the south and has no displaced threshold. Also, Arup's runway 6, has a 500 m displaced threshold whereas MITRE's runway 6 has a tentative 427 m displaced threshold. It is important to note that MITRE has not analyzed the aeronautical feasibility of these runway-related differences.

3.1.5. Runway Operations (Volume I, Section 6.2.2.1, Pages 27-28)

It is not clear to MITRE if the opening-day runway configuration in the Pre-Master Plan limits the type of operation that can be conducted on runway 6 to non-commercial aircraft only (e.g., government, military, and general aviation). Triple independent operations may be needed at times (e.g., during approach and departure peak periods) when the airport opens (in 2021) and more frequently soon after. Therefore, it is essential that runway 6 be available for commercial operations.

3.1.6. Runway Elevations (Volume II, Several Runway Profile and Contour Drawings)

MITRE assumed 2223 m Mean Sea Level (MSL) for the runway threshold elevations for each runway at NAICM. Arup's runway threshold elevations differ at each runway end and are, on average, approximately 7 m higher. MITRE understands, however, that final runway elevations are yet to be determined.

3.2. Communication, Navigation, and Surveillance

The following considerations pertain to communications, navigation, and surveillance at NAICM; however, it is not clear which equipment described in the Pre-Master Plan is being suggested or how this equipment would be used for the eventual operation of the airport. MITRE recommends that a comprehensive Communications, Navigation, Surveillance/Air Traffic Management, and automation analysis be conducted for NAICM. This analysis should also include appropriate ACC elements.

3.2.1. Navigation (Volume I, Section 6.8, Page 59 and Volume II, Section 8.1.2-8.1.3, Pages 1-5)

The Pre-Master Plan indicates that each runway end should be equipped with a Category (CAT) IIIa Instrument Landing System (ILS) instrument approach procedure. MITRE's weather analysis (based on more than 5 years of detailed information at Texcoco), shows that CAT II/III weather is rare at the NAICM site, and when it occurs, would only be required for northerly operations. Also, if a CAT III instrument approach procedure is believed to be required, it is necessary to determine the level of CAT III to be supported (i.e., CAT IIIa or IIIb), which involves collecting data through a Runway Visual Range (RVR) system.

Accordingly, the Mexican aviation authorities should conduct a cost-benefit analysis regarding the establishment of CAT II/III instrument approach procedures at NAICM before making any final decisions. This is important because CAT II/III instrument approach procedures have very expensive infrastructure requirements, considerably more than CAT I instrument approach procedures (i.e., a more complex runway lighting system, redundant localizer and glideslope transmitters and power supplies, surface movement systems, etc.).

Arup also indicates that a Ground-Based Augmentation System (GBAS) should be installed. While a GBAS may have some benefits at NAICM, it would be appropriate to investigate how such an approach capability would be integrated into NAICM and when this should be accomplished, especially given the low rate of equipage of GBAS avionics currently observed.

MITRE recommends a comprehensive review of specific navigation requirements for NAICM. Similarly, the inclusion of appropriate lighting systems should be included along with the associated navigation and landing capabilities.

3.2.2. VHF Omnidirectional Range/Distance Measuring Equipment (Volume II, Section 8.1.3, Page 5)

The Pre-Master Plan does not specify a location for the proposed VHF Omnidirectional Range/Distance Measuring Equipment (VOR/DME). MITRE's procedure design work for NAICM assumed an on-airport VOR/DME. Since the location of the VOR/DME affects procedure design work, the proposed location of the VOR/DME should be coordinated with MITRE. It is also important to note that MITRE's procedure design work assumed that the existing VOR/DME at Aeropuerto Internacional de la Ciudad de México (AICM) and the VOR/DME at Santa Lucía will remain. This, of course, may be changed.

3.2.3. Surveillance (Volume I, Section 6.8, Page 59 and Volume II, Section 8.1.2, Pages 1-3)

The Pre-Master Plan indicates that a Mode S radar, Precision Runway Monitor (PRM), Multilateration (MLAT), Automatic Dependent Surveillance-Broadcast (ADS-B), Airport Surface Movement Guidance System, and associated automation will be installed.

MITRE's analysis for independent approaches indicates that a monopulse Secondary Surveillance Radar (SSR) or equivalent would be necessary at NAICM on or near the airport, but there is no associated requirement for ADS-B, not at least immediately. PRM radar is not only not required, but it is not manufactured any longer, for many years. On the other hand, a Final Monitor Aid as the one that used to be associated with PRMs, must be incorporated into the surveillance system.

It might be advantageous for Mexico to implement an MLAT system, but it is not clear how this would interface with the SSR system. If ADS-B were implemented and/or required, it is not clear what the relationship would be to the SSR and MLAT. Accordingly, MITRE recommends that a comprehensive study be conducted to determine the appropriate ground surveillance to be provided for NAICM.

3.3. Procedure Development Matters

The following sections address matters that could affect procedure development at NAICM.

3.3.1. Differences in Criteria (Volume I, Section 6.7.1, Page 56)

The Pre-Master Plan mentions the application of International Civil Aviation Organization (ICAO) Procedures for Air Navigation Services-Aircraft Operations (PANS-OPS) criteria, while MITRE applied U.S. Federal Aviation Administration (FAA) Standards for Terminal Instrument Procedures (TERPS), which have been used in Mexico for many years. It is also important to note that ICAO <u>does not</u> have criteria for conducting triple independent operations.

3.3.2. Category II/III Procedure Design Considerations (Volume I, Section 6.2.2, Page 25)

The Pre-Master Plan mentions the establishment of CAT II/III procedures at NAICM. However, there are some issues that need to be addressed regarding the establishment of those procedures. MITRE's preliminary CAT II/III approach designs indicate that under U.S. FAA criteria, eleven out of the 12 runway ends (considering the ultimate development of the airport) would *not be eligible* for CAT II/III approach procedures due to issues with climb gradients on missed approaches and precipitous terrain. However, if CAT II/III approach procedures are determined to be necessary, then Mexican authorities may need to conduct an Equivalent-Level-of-Safety (ELS)[1] study to allow for the establishment of CAT II/III approach procedures at additional runway ends at NAICM.

3.3.3. Obstacle Penetrations to Runway 6 (Volume III, Section 2.5, Page 26)

The Pre-Master Plan states that there are no obstacle penetrations to either the ICAO PANS-OPS Obstacle Assessment Surfaces or U.S. TERPS Obstacle Clearance Surfaces for runway 6. However, based on the MITRE-Recommended Runway Configuration (July 2012), runway threshold locations and elevation (i.e., 2223 m MSL), terrain height and accuracies, and other procedure design considerations, MITRE determined that the north hill (Chiconautla) is a penetration to the U.S. TERPS approach surfaces for runways 5 and 6 (i.e., 19L/R). Once again, not ICAO PANS-OPS.

It is important to note that the displaced threshold of runway 6 in the Pre-Master Plan (MITRE's Runway 19L) is in a different location. Furthermore, the runway elevations also differ. These factors may contribute to the differences in results.

3.3.4. On-Airport Facilities and Development (Various Figures and Drawings)

MITRE is concerned about the location of some proposed facilities shown in the Pre-Master Plan. These facilities, which include parking lots, buildings, and other structures, depending on their height and location, could be obstacles and, as a result, impact conventional and/or satellite-based procedures. For example, MITRE is concerned about the proposed buildings located to the southeast of runway 6. MITRE requires a drawing showing the proposed heights of all facilities in order to appropriately evaluate the impact of facilities on instrument approach and departure procedures.

3.3.5. Navigational Aid Interference (Volume I, Section 5.6, Page 19 and Volume II, IM-01_Iluminación y Marcas Detalle A.pdf)

MITRE is also concerned that some proposed facilities could potentially cause signal interference with NAVAIDs, in particular the ILS localizer and glideslope. The final approaches at NAICM are <u>very long and exceed normal operating standards of ILS equipment</u>. As a result, specialized localizer and glideslope equipment are required. It is important to ensure that proposed buildings, roads, parking facilities, taxiing/holding aircraft, etc., are located in a manner that do not interfere/degrade signal quality of the localizer and/or glideslope.

All glideslope antenna critical areas appear to be clear of obstacles; however, based on the information in the Pre-Master Plan, it appears that there are objects within some of the glideslope antenna sensitive areas, such as a railway and an automated people mover. However, it is unclear from the drawings if the automated people mover is underground or above ground.

[1] An ELS study establishes that alternative actions may provide a level of safety equal to that provided by the airworthiness standards for which equivalency is being sought.

Furthermore, aircraft on some End-Around Taxiways (EATs) may penetrate the glideslope antenna sensitive area and localizer critical area. Therefore, the location of facilities and other airfield development should be closely coordinated with the companies responsible for installing NAVAIDs to ensure that facility locations do not cause issues (e.g., electromagnetic affects, reflections). This also involves conducting appropriate flight checks and other testing.

3.4. Airfield Considerations

The following sections pertain to airfield considerations of which some are not within MITRE's area of expertise. Therefore, it is recommended that Arup and the Mexican aviation authorities collaborate with the airlines and other stakeholders to address these areas in more detail.

3.4.1. Taxiway Separation (Volume I, Section 6.3.2, Page 35)

The Pre-Master Plan shows 190 m separation between some runways and parallel taxiways. It is important to note that the ICAO Aerodrome Design Manual, Part 2, Taxiways, Aprons and Holding Bays, preliminarily recommends that to accommodate future aircraft development (e.g., Very Large Aircraft) a runway to parallel taxiway separation of 192 m should be considered. Even though this is a seemingly small difference, MITRE recommends that the taxiway separations be further evaluated.

Furthermore, the Pre-Master Plan shows 210 m separation between some runways and parallel taxiways. It is not clear to MITRE why a runway to parallel taxiway separation of 210 m is used in some cases and 190 m in others.

3.4.2. End-Around Taxiways (Volume I, Section 5.6, Page 19 and Volume III, Section 2.4.1-2.4.2, Pages 23-24)

The Pre-Master Plan includes EATs located south of the thresholds of runways 2, 3, 4, and 5 (i.e., Runways 35R, 36L, 36R and 01L). MITRE agrees with the development and benefits of EATs, especially for runways adjacent to terminal areas. However, the EATs are not far enough away from the runway thresholds and, as a result, do not allow for the "free flow" of aircraft when the runway is being used for approach or departure operations that fly over the EATs. Aircraft will need to stop at a holding position that is properly located to ensure aircraft do not penetrate an obstacle limitation surface, and wait for Air Traffic Control (ATC) clearance to proceed on the EAT. Also, holding positions should be located so that aircraft do not penetrate TERPS procedure design surfaces. Once cleared to proceed by ATC, the time required to proceed around the EAT and clear the protected runway environment is considerably longer than a direct runway crossing.

Therefore, ATC may need to create appropriate gaps in the arrival stream and/or hold departures to allow sufficient time for aircraft to taxi around the EATs. Therefore, the movement of aircraft around the EATs has the potential to require increases in arrival and/or departure operation separations, thus reducing runway capacity. Periodic inability to create gaps in arrival and departure sequences and move aircraft across the EATs may produce queues of holding aircraft. These queues may create surface congestion and aircraft movement conflicts, particularly on taxiway segments near terminal areas and runway departure queues. MITRE recommends that consideration be given to the development of unrestricted "free-flow" EATs to avoid impacts on capacity.

3.4.3. Air Traffic Control Towers (Volume I, Section 6.9, Pages 60-69 and Volume III, Section 2.3.2-2.3.4, Pages 15-21)

The Pre-Master Plan considers the development of two ATCTs at NAICM. It is important to examine a two-tower operation very carefully. Having two towers controlling traffic separately is an uncommon and complex operation. Just as an example, Amsterdam Schiphol Airport experienced major operational and coordination problems with its two-tower operation, impacting procedures adversely.

Also note that MITRE has not conducted an analysis of the impact of the location and height of the ATCTs being proposed in the Pre-Master Plan on instrument procedures. This analysis needs to be conducted to determine if there are any impacts on instrument approach and departure procedures, and other aeronautical matters.

3.4.4. Additional Taxiways (Volume I, Section 5.2, Page 15)

The opening-day runway configuration in the Pre-Master Plan only includes one taxiway between runways 3 and 6. This has the potential to cause bottlenecks. Therefore, consideration should be given to providing additional taxiways between runways 3 and 6.

3.4.5. Taxiway Specifications (Volume I, Section 6.3.2, Page 36)

Arup is proposing that some taxiways be constructed to 4E specifications. Again, while this is not MITRE's area of expertise, it should be stated that the taxiway system should be designed to ensure the most efficient use of the airfield by <u>all</u> aircraft (including aircraft requiring 4F specifications). It is risky to plan taxiways on assumptions about traffic and fleets far in the future.

3.5. Projected Demand (Volume I, Section 4, Pages 10-12)

The projected total demand (total operations, including commercial, cargo and general aviation) stated in the Pre-Master Plan assumes an overall growth rate of approximately 2% from 2013 through 2062. MITRE used an average traffic growth rate of 4% starting from 2011 through 2042, which was agreed upon by the Mexican authorities (and was based on detailed analyses). Note that merely from 2011 through 2013 the operations at AICM have already grown at an annual average of 6%.

3.6. Projected Capacity (Volume III, Section 1.4.3.3.1, Pages 24-29)

Arup has presented a range of capacity estimates based on "actual" and "modernized" ATC scenarios. MITRE's capacity estimates are generally in agreement with the "actual" ATC capacity estimates, with the exception of differences in the peak departure capacities for future "actual" scenarios. However, MITRE has concerns with capacity estimates derived from Arup´s "modernized" scenarios, which may be extremely difficult to achieve. In addition, based solely on the information presented in the Pre-Master Plan, it is unclear how Arup concluded that these capacity estimates will meet projected demand.

3.7. Schedule Considerations

The following sections pertain to the commencement of operations and the general schedule.

3.7.1. Commencement of Operations (Volume IV, SAADMCR_Cronograma preliminar.pdf)

The Pre-Master Plan suggests an opening of the airport by 2018. However, it is MITRE's understanding, per GACM, that NAICM's operations are slated to begin towards 2020/2021, which coincides with MITRE's overall work plan. Given past experiences with major airport development projects, MITRE feels it is overly optimistic to assume the opening of a safe and efficient three-runway operation before 2021.

3.7.2. Planning Schedule (Volume IV, Apéndice B_SAADMCR Cronograma.pdf and SAADMCR_Cronograma preliminar.pdf)

The completion dates identified in the Pre-Master Plan do not coincide with MITRE's overall work plan. Arup's Gantt Chart, which assumes an airport opening of 2018, does not consider several key aeronautical steps that need to be conducted in order to commence operations at the airport (flight checks, final review, and approval of airspace and aeronautical procedures, to name but a few).

4. Closing Remarks

The above-mentioned considerations are to prepare and inform ASA about key concerns (before concerns become issues), regarding the development of NAICM. It is advised that these considerations be addressed and incorporated into Arup's Master Plan document, which is currently being developed, when there is sufficient time to do so.