Enclosure 3

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MITRE

Center for Advanced
Aviation System Development

Mexico Area Control Center Enroute and Mexico City Terminal Maneuvering Area Airspace Redesign

Baseline Metrics Sector Analysis

Prepared for

Aeropuertos y Servicios Auxiliares

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MITRE

Principal Acronyms and Abbreviations

ACC	Area Control Center
AICM	Aeropuerto Internacional de la Ciudad de México
CPL	Coordinated Flight Plan
DME	Distance Measuring Equipment
IAC	Instantaneous Aircraft Count
MITRE	The MITRE Corporation
MMAA	Acapulco International Airport
MMAS	Lic. Jesús Terán Peredo International Airport (Ciudad de Aguascalientes)
MMBT	Bahías de Huatulco International Airport (Ciudad de Huatulco)
MMCB	Cuernavaca Airport
MMGL	Guadalajara International Airport
MMIA	Colima Airport
MMLM	Los Mochis International Airport
MMLO	Del Bajío International Airport (Ciudad de Guanajuato)
MMOX	Xoxocotlán International Airport (Ciudad de Oaxaca)
MMPA	El Tajín National Airport (Ciudad de Poza Rica)
MMPB	Puebla International Airport
MMPN	Uruapan International Airport
MMPS	Puerto Escondido International Airport
MMQT	Querétaro International Airport
MMSP	Ponciano Arriaga International Airport (Ciudad de San Luis Potosí)
MMTM	Tampico International Airport
MMTN	Tamuín National Airport
MMTO	Toluca International Airport
MMVR	Veracruz International Airport
MMZH	Ixtapa-Zihuatanejo International Airport
MMZO	Playa de Oro International Airport (Ciudad de Manzanillo)
NAICM	Nuevo Aeropuerto Internacional de la Ciudad de México

NM	Nautical Mile
PBN	Performance-Based Navigation
QET	Querétaro VOR-DME
***s*E**	*sector*Evaluator
SENEAM	Servicios a la Navegación en el Espacio Aéreo Mexicano
SME	Subject Matter Expert
TMA	Terminal Maneuvering Area
TMN	Tamuín VOR-DME
U.S.	United States
VOR	Very High Frequency Omni-directional Range

1. Introduction

The MITRE Corporation (MITRE) is assisting Aeropuertos y Servicios Auxiliares (ASA) and the aviation authorities of Mexico with the implementation of a new airport, referred to in this document as Nuevo Aeropuerto Internacional de la Ciudad de México (NAICM), to replace the current Aeropuerto Internacional de la Ciudad de México (AICM). 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 Area (TMA) to support NAICM. As a result of modifying the current Mexico City TMA procedures to support NAICM, the current enroute airspace for the Mexico Area Control Center (ACC) will also need to be modified.

There is an initiative within SENEAM to incorporate Performance-Based Navigation (PBN) routes for all of Mexico's enroute airspace, which affects the Mexico ACC enroute airspace as well as the entry and exit points on the periphery of the Mexico City TMA. SENEAM and MITRE have been working closely together over the last several months to ensure that the proposed PBN routes for the Mexico ACC enroute airspace also accommodate the modifications of the routes and procedures within the new Mexico City TMA in support of NAICM.

As part of MITRE's support to the aviation authorities of Mexico, MITRE will assist SENEAM in its performance of an analysis of the enroute airspace structure that relates to the Mexico ACC in support of NAICM. This will help to identify and mitigate any factors that could limit the capacity of traffic flows arriving to or departing from a new Mexico City TMA. Therefore, MITRE's overall support on Mexico ACC enroute airspace matters includes the following:

- Providing guidance in the analysis of the existing enroute structure to assess its ability to accommodate increased traffic levels that conceivably could be required on opening day at NAICM to determine if there are any capacity-limiting issues
- Assisting in the determination of short-term changes required by the enroute structure to overcome any issues identified
- Assisting in the development of a long-term enroute route structure to support the ultimate runway configuration and projected traffic levels at NAICM
- Assisting in the assessment of airspace sectorization driven by any airspace redesigns performed under the above-mentioned items

The objective of this document is to present the baseline analyses that were done for the Mexico City TMA and the Mexico ACC enroute airspace. These analyses will be used as a baseline for the Mexico ACC enroute airspace and as a guideline for the examination of sectors within the new Mexico City TMA. The Mexico ACC sectors used for the analysis are based on data contained in the Aeronautical Information Publication (AIP) of Mexico, dated August 2016, and are shown in Appendix A to this document (see Figure A-1). The Mexico City TMA sectors used for the analysis are based on information provided by SENEAM in June 2016.

This document is divided into five sections.

- Section 1 introduces the project, structure, and scope of the work
- Section 2 describes the methodology used for the analysis of both the Mexico City TMA and the Mexico ACC enroute airspace, as well as the data that was used for the analyses
- Section 3 describes the analysis and results of the Mexico ACC enroute sectors
- Section 4 describes the analysis and results of the Mexico City TMA sectors
- Section 5 provides a summary as well as next steps

2. Methodology

The methodology MITRE will use to assess the Mexico ACC enroute structure and sectorization is described in MITRE's previously provided report, entitled *Mexico City Enroute Airspace Redesign, Methodology and Key Considerations* (see Enclosure 2 referenced in MITRE Technical Letter F500-L16-028, dated 18 March 2016). The methodology uses an iterative process where the airspace is evaluated, issues are addressed through redesign, if necessary, and then re-evaluated. This methodology is also being used to evaluate the Mexico City TMA structure and sectorization to support the NAICM airspace design. Therefore, this document also includes the results of MITRE's initial analysis of the current Mexico City TMA, which provides helpful information to assist in follow-on analyses.

MITRE's methodology starts with performing a baseline analysis that consists of the existing enroute and terminal structure and sectors at current traffic demand levels. The baseline analysis has two goals:

1. Identify any existing issues that can be uncovered with data analysis
2. Provide a baseline for the later comparative analysis with the new airspace design.

The airspace design team attempts to resolve the issues identified with the baseline analysis by preliminarily redesigning some aspects of the airspace. Even though both the enroute and the terminal route structures have already been redesigned, it is still important to conduct a baseline analysis to ensure that any identified issues can be resolved, as well as to measure improvements provided by the proposed airspace design. The proposed airspace design is also evaluated using the same methodology and any identified issues would then need to be resolved, if possible.

In future analyses, modifications to the airspace design for both the enroute and the terminal route structures and sectorizations will be evaluated first using the new routes and then again with the new sectorizations. MITRE will also evaluate the enroute and terminal designs with increased traffic levels, first considering the projected opening-day levels for NAICM, and then with the traffic levels expected for the ultimate six-runway configuration for NAICM.

MITRE's methodology utilizes two important elements: analytical tools and domain expertise that includes Air Traffic Control Subject Matter Experts (SMEs), specialized analysts and, based on the scope of the project, various other experts related to the airspace being studied. For this project, MITRE's airspace design team supports the domain expertise of SENEAM personnel who have specific knowledge of operating procedures, as well as an understanding of specific problems and issues being experienced with the current airspace structure.

For enroute analyses, MITRE has developed tools to measure the complexity and workload in a sector that, when used in conjunction with the airspace design SMEs, provide a data driven approach to airspace redesign. This approach consists of steps that assess the current airspace for issues, creates a baseline for evaluation, mitigates the identified issues, and then re-evaluates the proposed airspace. The results from these MITRE-developed tools, along with observations of recorded traffic, allow the airspace design team to identify issues and create a baseline for the evaluation. The list of identified issues and the baseline metrics are used as starting points for issue mitigation, where MITRE's airspace design team can assist the SENEAM airspace design team to modify the airspace design to mitigate the issues. The results from the MITRE-developed tools also provide indications of the severity and frequency of occurrence of an issue (e.g., number of flows merging at the same location).

For terminal analyses, MITRE relies on individual metrics, similar to those metrics used in the enroute suite of MITRE-developed tools, along with airspace design SMEs to measure the complexity and workload in a sector. The approach consists of the same steps used for the enroute analysis: assess the current airspace, create a baseline for evaluation, mitigate the identified issues, and re-evaluate the proposed design. The process relies on the airspace design team for their expertise and metrics that characterize a particular sector design.

The analysis of the Mexico ACC enroute airspace and the Mexico City TMA began with the MITRE airspace design team examining SENEAM-provided documents and operational data to develop an understanding of the current operational environment. The documents included the Aeronautical Information Publication of Mexico and facility documents (Letters of Agreement and Standard Operating Procedures). SENEAM also provided operational data in the form of Coordinated Flight Plan (CPL) data for March and April of 2016. This data allowed the MITRE team to model or "fly" the flights and observe the traffic during two specific days, as described below. By viewing the traffic as it went through the airspace, the MITRE SMEs were able to identify issues that would not be evident from analyzing the data alone. Additionally, the CPL data served as inputs into MITRE's analytical tools. From the visualization and analysis of the CPL data used to evaluate the Mexico ACC and Mexico City TMA sectors, MITRE was able to create a baseline for future comparative analyses and compile a list of identified potential issues.

The analysis was conducted for both the Mexico ACC enroute and the Mexico City TMA sectors using two days of CPL data that had at least 90 percent of the traffic on the busiest day during March and April 2016. This was done by calculating the total flight count for each single day and then choosing the maximum count of the all of the days. The maximum flight count is then multiplied by 0.90 (90 percent) to get the threshold for determining the candidate pool. If the total flight count for each day is either equal to the threshold or higher than that day is a considered to be in the candidate pool for use in the analysis. From this candidate pool, two days were selected that had a large gap of days between them, to capture different operating conditions. The days selected for the analysis were 4 March 2016 and 22 April 2016.

3. Mexico ACC Enroute Analysis Results

The Mexico ACC enroute sectors were evaluated using a collection of MITRE-developed tools that can be used alone or in concert with each other. One of those tools is *sector*Evaluator (*s*E*)*, which has received a United States (U.S.) patent, and analyzes the volume (amount of traffic a controller can work), complexity (amount of information a controller must consider in making a decision), and functionality (actions necessary to implement the decisions) of a sector design, through the application of a comprehensive set of factors that contribute to airspace design quality. This tool uses a series of factors to measure events that occur inside the sector being analyzed, and generates a workload or complexity metric for the controller.

Examples of the factors are:

- Traffic volume counts for each sector for 1-minute, 15-minute, and 60-minute intervals
- Count of and angle of flows of flights merging and crossing in the sector
- Number of flows either uni-directional or bi-directional in a sector and the amount of traffic on each flow

These factor values are then multiplied by a weighting schema corresponding to the difficulty in handling the event. These weighted factor values are then summed to define a score for that sector. The sector score is compared against a threshold (a value based on SME experience in using this tool on many previous analyses) to gauge sector workability. The *s*E sector scores are based on the most difficult conditions a sector would experience for the day, for each of the traffic days studied.

In addition to performing an evaluation using the *s*E tool, the airspace design team also reviewed total daily traffic counts to determine if the counts were consistent with the complexity identified by *s*E. A daily traffic count guideline of 600 flights or less per day in a sector was used to represent an acceptable traffic count. A guideline of 300 was used as an acceptable *s*E complexity value in a sector. The use of two different scores and threshold values results in four possible combinations of threshold values and the possible actions to be taken. These are shown in Table 1.

Table 1. Threshold Combinations and Resulting Actions

		*s*E Sector Score	
		300 or less	**over 300**
Daily Traffic Count	**600 or less**	No Further Analysis	Analyzed and Potential Further Action Required
	over 600	Analyzed Further, but No Action Required	Analyzed and Potential Further Action Required

If the daily traffic counts were 600 or less and the *s*E sector scores were 300 or less, then no further analysis was required. If the daily traffic counts for a sector were over 600, then the sector was further analyzed to better understand the complexity and workload that exists within the sector and determine if mitigation was necessary. Any time the *s*E sector was above 300, the sector was analyzed further for potential mitigation to reduce the complexity and workload within the sector. The potential mitigation takes the form of modification of the enroute structure or modification of the sector boundaries. Both the *s*E sector score threshold value of 300 and the daily traffic count threshold value of 600 are intended to be used as guidelines.

The results of the baseline analysis for each sector are shown below in Tables 2 through 8 along with a description of the sector. The information presented is the range of *s*E sector scores and the daily traffic counts for each of the enroute sectors considering the two days of CPL data. The thresholds for each of the measures are 300 and 600, respectively, and if the *s*E sector score or daily traffic count are over the thresholds values it is indicated by a red box.

3.1 Mexico ACC Enroute Sector 1

Sector 1 is located to the northeast of the Mexico City TMA, bounded by the Mérida and Monterrey ACC facilities in the east and north, respectively, the Mexico ACC enroute sector 2 to the south, and the Mexico ACC enroute sector 6 to the west. Sector 1 owns airspace from the surface to unlimited excluding the airspace delegated to the Tampico TMA and Tampico International Airport (MMTM). There is also a non-towered airport, Tamuín National Airport (MMTN), and a towered airport, El Tajín National Airport (MMPA) for which the sector 1 controller provides air traffic control services.

The sector primarily manages arrivals and departures for AICM, MMTN, and MMPA as well as overflights. The controller working sector 1 is responsible for issuing speed restrictions and interim altitudes to provide the required arrival spacing for arrivals, and integrating departures into the traffic flow to and from AICM, MMTM, and MMPA. The major flows in the sector consists of AICM arrival and departure traffic from/to airports in the north or northeast. In addition, there are three locations where holding of aircraft can occur: at the waypoint DATUL, at the Very High Frequency Omni-directional Range (VOR)-Distance Measuring Equipment (DME) Poza Rica (PAZ), and at the Tamuín (TMN) VOR-DME.

Table 2 below presents the results of the baseline analysis for 4 March 2016 and 22 April 2016.

Table 2. Mexico ACC Enroute Sector 1 *s*E Sector Score and Daily Traffic Count

	***s*E Sector Score**		**Daily Traffic Count**	
Sector	**4-Mar-16**	**22-Apr-16**	**4-Mar-16**	**22-Apr-16**
Sector 1	226	263	499	518

For sector 1, there were no *s*E sector scores or daily traffic counts that exceeded either of the thresholds. Therefore, at the present traffic levels, there are no issues with the sector.

3.2 Mexico ACC Enroute Sector 2

Sector 2 is located to the east of the Mexico City TMA, bounded by the Mérida ACC in the east, and Mexico ACC sectors 1 (north and west) and 3 (south). The sector owns airspace from the surface to unlimited excluding the Veracruz TMA and Veracruz International Airport (MMVR), as well as a portion of the Puebla TMA and the Puebla International Airport (MMPB).

The sector primarily manages arrivals and departures for AICM, Toluca International Airport (MMTO), MMVR, and MMPB as well as overflights. The controller working sector 2 is responsible for issuing speed restrictions and interim altitudes to provide the required spacing for arrivals, and integrating departures into the traffic flow to and from AICM, MMVR, and MMPB. The major flows in the sector are AICM arrivals and departures and traffic from/to airports east of AICM. In addition, there is one location where holding of aircraft can occur, the Puebla (PBC) VOR-DME.

Table 3 below presents the results of the baseline analysis for 4 March 2016 and 22 April 2016.

Table 3. Mexico ACC Enroute Sector 2 *s*E Sector Score and Daily Traffic Count

	***s*E Sector Score**		**Daily Traffic Count**	
Sector	**4-Mar-16**	**22-Apr-16**	**4-Mar-16**	**22-Apr-16**
Sector 2	201	142	430	512

For sector 2, there were no *s*E sector scores or daily traffic counts that exceeded either of the thresholds. Therefore, at the present traffic levels, there are no issues with the sector.

3.3 Mexico ACC Enroute Sector 3

Sector 3 is located in the south and southeast of the Mexico ACC. It is also the sector that overlies the Mexico City TMA and portions of the Puebla TMA. It is bounded by the Mérida ACC in the south and east, the Mexico ACC enroute sectors 2, 5, and 6 in the north, and by sector 4 in the west. The sector owns airspace from the surface to unlimited excluding the Mexico City, Oaxaca, Acapulco, and Ixtapa-Zihuatanejo TMAs.

The sector primarily manages arrivals and departures for AICM, MMTO, Acapulco TMA and the Acapulco International Airport (MMAA), Xoxocotlán TMA and the Xoxocotlán International Airport (MMOX), Cuernavaca Airport (MMCB), Puerto Escondido International Airport (MMPS), Ixtapa-Zihuatanejo TMA and Ixtapa-Zihuatanejo International Airport (MMZH), and Bahías de Huatulco International Airport (MMBT) well as overflight traffic. The controller working sector 3 is responsible for issuing speed restrictions and interim altitudes to provide the required spacing for arrivals, and integrate departures into the traffic flow to and from AICM, MMAA, MMOX, MMCB, MMPS, and MMPB. The major flows in the sector are AICM arrivals and departures and traffic from/to airports south and southeast of AICM. In addition, there is one location where holding of aircraft can occur, the Tequesquitengo (TEQ) VOR-DME.

Table 4 below presents the results of the baseline analysis for 4 March 2016 and 22 April 2016.

Table 4. Mexico ACC Enroute Sector 3 *s*E Sector Score and Daily Traffic Count

	*s*E Sector Score		Daily Traffic Count	
Sector	**4-Mar-16**	**22-Apr-16**	**4-Mar-16**	**22-Apr-16**
Sector 3	221	159	526	470

For sector 3, there were no *s*E sector scores or daily traffic counts that exceeded either of the thresholds. Therefore, at the present traffic levels, there are no issues with the sector.

3.4 Mexico ACC Enroute Sector 4

Sector 4 is located to the southwest of the Mexico City TMA, bounded by the Mazatlán ACC in the west, Mexico ACC sectors 5 and 7 in the north, Mexico ACC sector 3 in the east, and the Mazatlán Oceanic sector in the south. The sector owns airspace from the surface to unlimited excluding portions of the Mexico City, Guadalajara, Playa de Oro, Morelia, and Ixtapa-Zihuatanejo TMAs.

The sector primarily manages arrival and departure traffic for AICM, MMTO, Guadalajara International Airport (MMGL), Playa de Oro International Airport (MMZO), Los Mochis International Airport (MMLM), MMZH, Del Bajío International Airport (MMLO), Uruapan International Airport (MMPN), and Colima Airport (MMIA) as well as overflights. The controller working sector 4 is responsible for issuing speed restrictions and interim altitudes to provide the required spacing for arrivals, and integrating departures into the traffic flow to and from AICM, MMLO, MMPN, and MMIA. The major flow in the sector is the AICM departures on UJ42W. In addition, there are two locations where holding of aircraft can occur, the Morelia (MLM) VOR-DME and the ANEVU waypoint.

Table 5 below presents the results of the baseline analysis for 4 March 2016 and 22 April 2016.

Table 5. Mexico ACC Enroute Sector 4 *s*E Sector Score and Daily Traffic Count

	*s*E Sector Score		Daily Traffic Count	
Sector	**4-Mar-16**	**22-Apr-16**	**4-Mar-16**	**22-Apr-16**
Sector 4	199	152	320	297

For sector 4, there were no *s*E sector scores or daily traffic counts that exceeded either of the thresholds. Therefore, at the present traffic levels, there are no issues with the sector.

3.5 Mexico ACC Enroute Sector 5

Sector 5 is located to the west of the Mexico City TMA, bounded by the Mexico ACC sectors 4, 6, 7, and 3 to the south, north, west, and east, respectively. The sector owns airspace from the surface to unlimited excluding portions of the Mexico City, Guadalajara, Morelia, Manzanillo, León-Aguascalientes and Ixtapa-Zihuatanejo TMAs.

The sector primarily manages arrival and departure traffic for AICM, MMTO, MMGL, MMZO, MMLM, MMZH, MMLO, MMPN, and MMIA as well as overflights. The controller working sector 5 is responsible for issuing speed restrictions and interim altitudes to provide the required spacing for arrivals, and integrating departures into the traffic flow to and from AICM, MMLO, and MMPN. The major flows in the sector are AICM departure traffic on J13 and AICM arrival traffic on UJ14 and UJ15. In addition, there is one location where holding of aircraft can occur, 40 nautical miles (NM) from the Querétaro (QET) VOR-DME on the 295 radial.

Table 6 below presents the results of the baseline analysis for 4 March 2016 and 22 April 2016.

Table 6. Mexico ACC Enroute Sector 5 *s*E Sector Score and Daily Traffic Count

	*s*E Sector Score		Daily Traffic Count	
Sector	**4-Mar-16**	**22-Apr-16**	**4-Mar-16**	**22-Apr-16**
Sector 5	219	203	522	524

For sector 5, there were no *s*E sector scores or daily traffic counts that exceeded either of the thresholds. Therefore, at the present traffic levels, there are no issues with the sector.

3.6 Mexico ACC Enroute Sector 6

Sector 6 is located to the north of the Mexico City TMA, bounded by the Mexico ACC sectors 5, 7, 1, and 3 to the southwest, west, east, and south, respectively, and Monterrey ACC to the north. The sector owns airspace from the surface to unlimited excluding portions of the Mexico City, Querétaro, León-Aguascalientes, and San Luis Potosí TMAs.

The sector primarily manages arrival traffic to AICM, arrival and departure traffic for Querétaro International Airport (MMQT), and Ponciano Arriaga International Airport (MMSP) as well as overflights. The controller working sector 6 is responsible for issuing speed restrictions and interim altitudes to provide the required arrival spacing for arrivals, and integrating departures into the traffic flow to and from AICM. There are two arrival flows from the north, one over TMN via UF35 and one over AVSUB via UJ81, and one arrival flow from the northwest over QET via UF5/UJ33. In addition, there is one location where holding of aircraft can occur, 60 NM from the Lucía (SLM) VOR-DME on the 320 radial.

Table 7 below presents the results of the baseline analysis for 4 March 2016 and 22 April 2016.

Table 7. Mexico ACC Enroute Sector 6 *s*E Sector Score and Daily Traffic Count

	*s*E Sector Score		Daily Traffic Count	
Sector	**4-Mar-16**	**22-Apr-16**	**4-Mar-16**	**22-Apr-16**
Sector 6	361	248	559	545

Over Threshold

For sector 6, the 4 March 2016 *s*E sector score is over the threshold of 300. The *s*E sector score for 22 April 2016 as well as the daily traffic counts for both days were not over the threshold value. The high *s*E sector score is due to managing multiple arrival flows for AICM and managing arrival and departure traffic into and from MMQT and departure traffic for MMSP. Two of the three AICM arrival flows (flow over TMN VOR-DME and flow over QET VOR-DME), are worked by sector 6 for only about 55 NM and 30 NM, respectively, which is a relatively short period of time. In addition, the sector 6 controller is responsible for providing air traffic services for the towered MMQT airport. On the days where there are numerous flights for MMQT, this becomes a distraction. As a result, this sector has the potential to require a redesign based on the current structure and sectorization.

3.7 Mexico ACC Enroute Sector 7

Sector 7 is located to the northwest of the Mexico City TMA, bounded by the Mexico ACC sectors 4, 5, and 6 to the south, southeast, and east, respectively, and Mazatlán and Monterrey ACCs to the west and north, respectively. The sector owns airspace from the surface to unlimited excluding portions of the San Luis Potosí, Guadalajara, and León-Aguascalientes TMAs.

The sector primarily manages arrival and departure traffic for MMGL, MMZC (a towered airport), MMSP, Lic. Jesús Terán Peredo International Airport (MMAS), and MMLO, as well as overflights. The major flows through the sector are aircraft departing MMGL to the north, arrival aircraft from the north to MMGL, and AICM arrivals from the northwest. There are two locations where holding of aircraft can occur, the Potosí (SLP) VOR-DME for AICM and the Aguascalientes (AGU) VOR-DME for MMGL.

Table 8 below presents the results of the baseline analysis for 4 March 2016 and 22 April 2016.

Table 8. Mexico ACC Enroute Sector 7 *s*E Sector Score and Daily Traffic Count

	*s*E Sector Score		Daily Traffic Count	
Sector	4-Mar-16	22-Apr-16	4-Mar-16	22-Apr-16
Sector 7	244	238	493	536

For sector 7, there were no *s*E sector scores or daily traffic counts that exceeded either of the thresholds. Therefore, at the present traffic levels, there are no issues with the sector.

3.8 Mexico ACC Enroute Sector Baseline Analysis Conclusions

Based on the *s*E sector scores for the baseline analysis, only enroute sector 6 has an *s*E sector score over the threshold, which occurs when MMQT has numerous flights and should be addressed in the redesign of the Mexico ACC enroute airspace. There are, however, no other enroute sectors that have a daily traffic count over the threshold.

Only one issue was identified in the baseline analysis, and it is that Sector 6 manages three arrival flows and arrival and departure traffic for MMQT as well as departure traffic for MMSP.

There are small changes that can be made in the Mexico ACC enroute sectors that would improve the controller workload, but they are not considered issues to warrant a redesign of the airspace at the current traffic levels.

4. Mexico City TMA Analysis Results

For the Mexico City TMA, any comparison analysis is not possible since the main airport, AICM, is closing and a new airport, NAICM, with a different operating mode and number of runways is opening. As a result, the baseline analysis of the Mexico City TMA serves to provide guidelines for the traffic counts and controller workload in a sector that is acceptable going forward with the airspace design to support NAICM. However, any issues that are identified in the baseline analysis should be addressed in the redesign of the airspace to support NAICM.

4.1 Analysis

As previously mentioned, historical CPL data was provided by SENEAM for the months of March and April 2016. From this data, two days were analyzed and were chosen in conjunction with the enroute analysis. The days chosen for the analysis were 4 March 2016 and 22 April 2016. For both of these days, the primary airport operating direction for AICM was to the northeast (i.e., Runway 05L/R). For the study, it was difficult to obtain traffic information for the opposite direction at AICM (i.e., Runway 23L/R). As a result, MITRE artificially created two days of traffic operating in the Runway 23 direction at AICM. The only portion of the CPL data that was altered was the arrival or departure procedure. For instance, if in the CPL data, the arrival procedure for a particular flight was Mexico 5A, then for the artificial Runway 23 direction traffic day, the arrival procedure assigned to the flight was Mexico 3B, which is the same STAR only for the other operating direction. The modification of the CPL data was necessary to allow MITRE to analyze the Runway 23 direction sectors and procedures for a complete analysis.

The metrics that were used in the analysis heuristically analyze the sector for complexity and/or the controller workload. As sector complexity and controller workload are difficult to measure directly, heuristics were used to approximate these measures. Complexity relates to the tasks or functions that a controller is required to perform within a sector where the tasks and functions are intertwined and usually dependent on each other. Controller workload is composed of the complexity and the volume of aircraft that is being handled in a sector. The metrics used for measuring sector complexity and controller workload within the Mexico City TMA include:

- **Sector Volume Count**, which measures the number of aircraft in or entering a sector for intervals of 1-minute, 15-minutes, and 60-minutes
- **Merge Count**, which measures the number of flows merging together during a 1-minute interval
- **Cross Count**, which measures the number of aircraft paths that intersect where the aircraft come within 1000 feet vertically of each other

Unlike the tool suite for the analysis of the enroute sectors, MITRE does not have a weighting schema that corresponds to the difficulty in handling the events in the TMA sectors. Therefore, the results of the analysis are reported by metric for each sector, which are then examined by MITRE SMEs and issues are identified.

The following sections describe the analysis of the baseline TMA design, using the metrics described above.

4.1.1 Sector Volume Counts

Sector volume counts measure the number of aircraft that are inside a sector or enter a sector for a given period of time, usually 1-minute, 15-minutes, or 60-minutes. The 1-minute counts are used as a surrogate for an instantaneous count of the number of aircraft that are on a controller's frequency at the same time. This measure is an indicator of frequency congestion and controller workload. The 15-minute count is used to measure sustained controller workload and is reported as the highest number of aircraft in the 15-minute period. A sustained high aircraft count generates more workload for the controller than a single high 1-minute peak. The 60-minute count is typically used when analyzing the airport capacity and controller workload.

The baseline results for the Runway 05 direction are shown in Table 9 and the baseline results for the Runway 23 direction are shown in Table 10. These tables show the average maximum aircraft count for each of the Mexico City TMA sectors, calculated by finding the maximum count for each of the days of traffic analyzed and then averaging those values. The range of these average maximum aircraft counts for each sector is also provided in order to show the variation among the days. The time periods used are the 1-minute, 15-minute, and the 60-minute time periods starting at midnight local time and going through midnight of the following day.

The CPL data used for the analysis is what the flight planned to fly without any controller intervention for loss of separation or sequencing, not the ground track of what the aircraft actually did for that day. The average sector volume counts are higher than what a controller would normally manage in the given time period. These results will be used as a guideline for the amount of flight plan traffic that is acceptable to be worked in a modified sector.

Table 9. Mexico City TMA Runway 05 Direction Sector Counts

Sector	1-Minute Instantaneous Aircraft Count (IAC)		15-Minute		60-Minute	
	Baseline Maximum Average	Baseline Range	Baseline Maximum Average	Baseline Range	Baseline Maximum Average	Baseline Range
Final	9	8-10	17	16-18	45	42-48
Approach	11	10-12	18	17-18	49	45-52
Arrival	11	11	21	19-22	50	47-52
Departure East	11	9-12	17	17	41	38-43
Departure West	7	6-8	13	12-14	28	24-31

Table 10. Mexico City TMA Runway 23 Direction Sector Counts

Sector	1-Minute IAC		15-Minute		60-Minute	
	Baseline Maximum Average	Baseline Range	Baseline Maximum Average	Baseline Range	Baseline Maximum Average	Baseline Range
Final	9	8-9	17	16-17	46	43-48
Approach	10	8-12	16	14-17	48	46-49
Arrival	11	10-12	21	19-22	52	50-54
Departure East	8	8	16	15-17	39	37-41
Departure West	9	9	14	13-14	31	28-34

The resulting values are similar to those observed in TMA sectors at busy airports in the U.S. The average maximum 1-minute aircraft counts range from 6 to 12 with the larger numbers observed in the arrival and departure sectors. The arrival sectors in the Mexico City TMA are similar to low enroute sectors in the U.S., which can handle more traffic than the lower TMA sectors. The larger 1-minute aircraft counts for the Departure East and Departure West sectors can be attributed to using flight plan data without any spacing mechanisms applied to separate aircraft departing from the runways. The arrival sector has the largest 15-minute and 60-minute sector volume counts for both analysis days. The ranges for the 1-minute, 15-minute, and 60-minute time intervals show the range of values over the two days of data.

4.1.2 Merge Count

A merge occurs where two or more aircraft flows come together to create a single flow, which can require controller intervention. Workload at these merge points is generated by the need for the controller to sequence the aircraft and maintain the minimum separation distance between the two aircraft. The identification of these merge points in the SENEAM-provided CPL data can aid the airspace design team in developing a redesigned route structure, by limiting the number of flows to be merged at any one time and by balancing the workload associated with merging aircraft.

The TMA airspace design team examined multiple days of data in identifying the merge points to obtain a more comprehensive view of merging within the Mexico City TMA. The team identified the number of merge instances and their locations, as well as the maximum count of aircraft that were merged for that occurrence. The count of merge instances shows how many times the controller would need to intervene in a sector. The merge instance maximum aircraft count shows how many aircraft are being merged. Both of these are indications of controller workload that is being done either by the sector where the merge is physically located or by the previous sector, depending on the location.

Table 11 gives the count of the merge instances occurring in each of the Mexico City TMA sectors for both the Runway 05 and Runway 23 directions by analysis day. Table 12 gives the maximum count of aircraft that are being merged at a time for both the Runway 05 and Runway 23 direction by analysis day. Figure 1 shows the depiction of these merge point locations, identified with red circles for the Runway 05 direction. Figure 2 shows the merge point locations, identified with red circles for the Runway 23 direction.

Table 11. Merge Instance Count

Sector	4-Mar-16 Runway 05	22-Apr-16 Runway 05	4-Mar-16 Runway 23	22-Apr-16 Runway 23
Final	64	85	0	7
Approach	67	72	92	100
Arrival	5	6	4	5
Departure East				
Departure West				

As expected with the Approach and Final sectors, there are a high count of merge instances. These are the sectors that have the responsibility to merge all of the arrival aircraft into a single flow for landing.

Table 12. Merge Instance Maximum Aircraft Count

Sector	4-Mar-16 Runway 05	22-Apr-16 Runway 05	4-Mar-16 Runway 23	22-Apr-16 Runway 23
Final	4	4	0	4
Approach	4	4	4	5
Arrival	3	2	2	2
Departure East				
Departure West				

The maximum number of aircraft merging at a merge instance is 5, which occurs in the Approach sector. This is due to the cone configuration where the arrivals are funneled to a single merge point.

Ideally, the number of flows that are merged at any one time should be limited to two or three, in order to keep the workload involved at a reasonable level. For both the Runway 05 and the Runway 23 directions, there are four or five flows in the Approach sector that merge at the same location. All other sectors have two or less flows merging at a given point. Reducing the number of flows that merge at one point should be considered by the design team when redesigning the Mexico City TMA airspace to support NAICM.

4.1.3 Cross Count

A cross occurs where two flows may intersect within 1000 feet vertically within a 1-minute time period, which requires controller intervention. Workload at these cross points is generated by the need for the controller to separate the aircraft vertically to maintain the minimum separation requirements. The identification of these cross points in the SENEAM-provided CPL data can aid the airspace design team in developing a redesigned route structure by limiting the number of aircraft that cross at any one time and by balancing the workload associated with the crossing. Inside the TMA, it is unavoidable for the procedures not to cross, but ideally the aircraft flying on those procedures are separated by more than 1000 feet vertically.

The CPL data for the analysis days were examined in identifying the cross points, those locations where aircraft are less than 1000 feet vertically, to obtain a more comprehensive view of aircraft crossing within the Mexico City TMA. The MITRE team identified and counted the cross point locations by sector, which provided information on the current sector workload. Table 13, below, gives the count of the cross points for locations where aircraft are less than 1000 feet vertically for each of the Mexico City TMA sectors in the Runway 05 direction.

Table 13. Mexico City TMA Runway 05 Direction Crossing Points Less Than 1000 Feet Vertically

	Number of Crossing Points	
Sector	**4-Mar-16**	**22-Apr-16**
Final	0	0
Approach	0	0
Arrival	0	0
Departure East	0	0
Departure West	0	0

The same analysis was done for the Runway 23 direction. The results of that analysis are given in Table 14.

Table 14. Mexico City TMA Runway 23 Direction Crossing Points Less Than 1000 Feet Vertically

	Number of Crossing Points	
Sector	**4-Mar-16**	**22-Apr-16**
Final	0	0
Approach	0	0
Arrival	0	0
Departure East	0	0
Departure West	0	0

The analysis found no locations where the aircraft crossed within 1000 feet vertically. All of the crosses were separated by more than the 1000 feet for which the controller would not have to intervene.

4.2 Mexico City TMA Sector Baseline Analysis Conclusions

Based on the baseline metrics, presented in the previous TMA analysis sections, the airspace design team was able to identify one issue with the current TMA structure and airspace that could be mitigated with an airspace redesign. The issue identified was that more than three flows merge at a single point in a sector which occurs in the Arrival, Approach, and Final sectors.

5. Summary and Next Steps

As the airspace design teams redesign the Mexico ACC and the Mexico City TMA resulting from the closing of AICM and the opening of NAICM, the issues that were identified and the metric results will provide airspace designers with insight into the current operation. This information is useful in the redesign by ensuring that the airspace will operate as smoothly as possible. In addition, the list of identified issues and the baseline metric results from the enroute and the TMA analyses are going to be used as starting points for future comparative analyses for the redesign of the enroute and TMA structure and sectors.

For the enroute analysis, Table 15 summarizes the *s*E sector scores along with the identified sector that potentially requires further analysis.

Table 15. Summary of *s*E sector scores and Daily Traffic Counts

	*s*E Sector Score		Daily Traffic Count	
Sector	**4-Mar-16**	**22-Apr-16**	**4-Mar-16**	**22-Apr-16**
Sector 1	226	263	499	518
Sector 2	201	142	430	512
Sector 3	221	159	526	470
Sector 4	199	152	320	297
Sector 5	219	203	522	524
Sector 6	361	248	559	545
Sector 7	244	238	493	536

Over Threshold

Sector 6 is the only sector in the Mexico ACC enroute airspace that requires further examination. This sector manages heavy arrival flows from the northeast to AICM as well as the arrival and departure traffic to MMQT. MMQT is a towered airport, but is required to call for release whenever there is a departing aircraft. This creates an unwanted distraction for the controller if there are numerous MMQT departures. On days when MMQT does not have a lot of departure and arrival traffic, the situation is manageable but as traffic increases the issue will become significant. This issue should be kept in mind when designing the enroute sectors to support NAICM.

The baseline analysis for the Mexico City TMA used three metrics to analyze the sectors and traffic inside the Mexico City TMA: sector volume counts, merge counts, and cross counts. Of these metrics, the counts of merges and crosses are the heuristic metrics examining the sectors for controller workload. The sector volume counts will be used as a guideline for a threshold for the future comparative analyses. The situation of merging multiple flows of aircraft together at a single point is not the best airspace design practice, especially when traffic increases on the flows. This issue should be kept in mind when designing the new routes inside of the Mexico City TMA to support NAICM.

The same metrics used for the baseline sector evaluation will be used for the future analyses of the proposed route and sector configuration, which allows for a comparison to be made regarding the effectiveness of the design at resolving the identified issues.

The next steps for the enroute analysis are to consider the following analyses:

- Analysis of SENEAM's PBN routes within the Mexico ACC with the current sectors
- Analysis of SENEAM's PBN routes and the redesigned enroute sectors to accommodate NAICM
- Analysis of the PBN routes and the redesigned enroute sectors with the projected NAICM opening-day traffic levels
- Analysis of the PBN routes and the redesigned enroute sectors with the projected NAICM ultimate traffic levels

For the TMA analysis, the next steps are:

- Analysis of the redesigned new Mexico City TMA procedures and sectors
- Analysis of the redesigned procedures and sectors with the NAICM projected opening-day traffic levels
- Analysis of the redesigned procedures and sectors with the NAICM projected opening-day traffic levels
- Analysis of the PBN routes and the redesigned enroute sectors with the projected NAICM ultimate traffic levels

Appendix A

Figure A-1 shows the Mexico ACC enroute sectors.

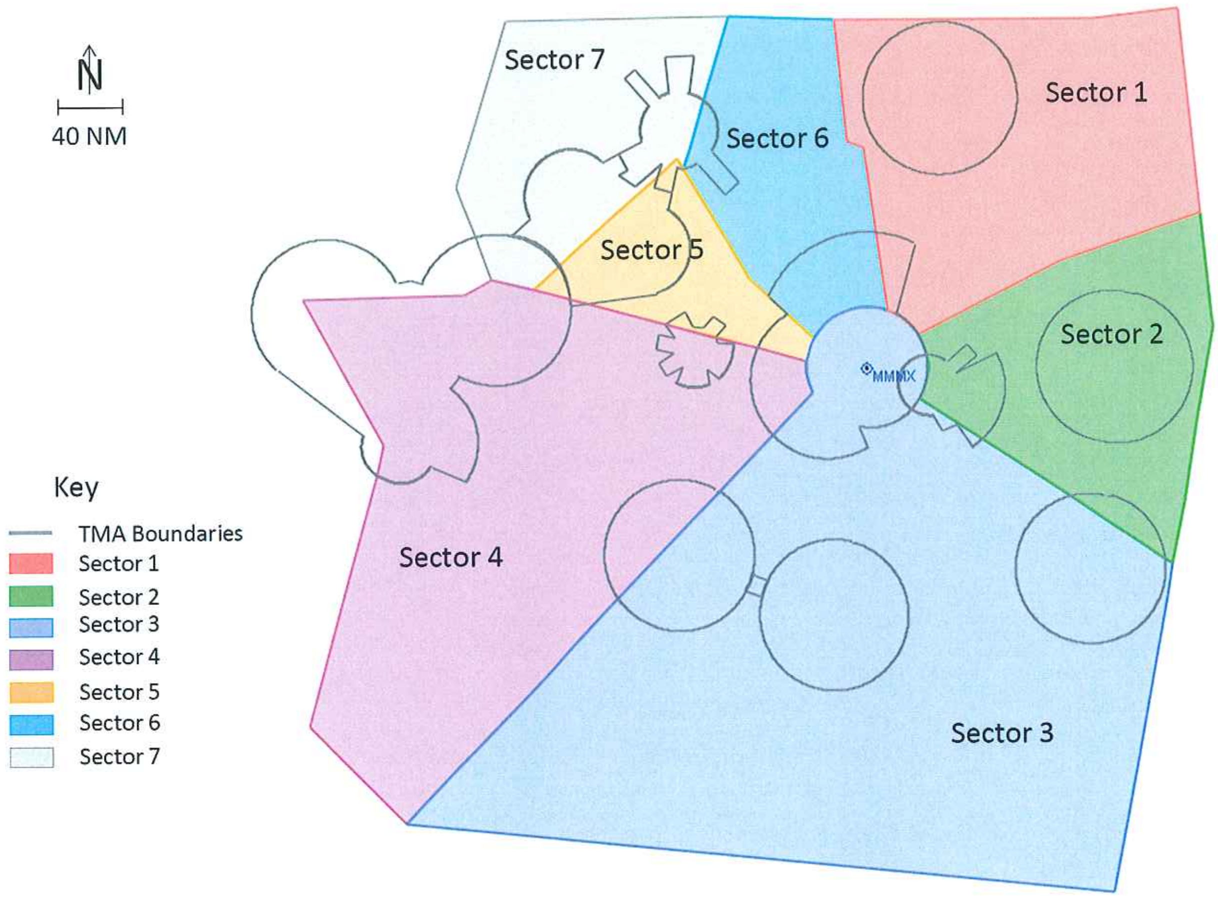

Figure A-1. Mexico ACC Enroute Sectors