Enclosure 2
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MITRE
Center for Advanced
Aviation System Development

Mexico City Enroute Airspace Redesign

Methodology and Key Considerations

Prepared for
Aeropuertos y Servicios Auxiliares

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# Acronyms and Abbreviations

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<th>Acronym</th>
<th>Definition</th>
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<tr>
<td>ACC</td>
<td>Area Control Center</td>
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<td>AFD</td>
<td>Automated Flow Detection</td>
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<td>AICM</td>
<td>Aeropuerto Internacional de la Ciudad de México</td>
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<td>AIP</td>
<td>Aeronautical Information Publication</td>
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<td>ATC</td>
<td>Air Traffic Control</td>
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<td>FAA</td>
<td>Federal Aviation Administration</td>
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<td>FAM</td>
<td>Fuerza Aérea Mexicana</td>
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<td>FL</td>
<td>Flight Level</td>
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<td>ICAO</td>
<td>International Civil Aviation Organization</td>
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<td>LOA</td>
<td>Letters of Agreement</td>
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<td>MITRE</td>
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<td>NAICM</td>
<td>Nuevo Aeropuerto Internacional de la Ciudad de México</td>
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<td>NAVAID</td>
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<td>RNAV</td>
<td>Area Navigation</td>
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<td>RNP</td>
<td>Required Navigation Performance</td>
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<td>SENEAM</td>
<td>Servicios a la Navegación en el Espacio Aéreo Mexicano</td>
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<td>SID</td>
<td>Standard Instrument Departure</td>
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<td>SME</td>
<td>Subject Matter Expert</td>
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<td>SOP</td>
<td>Standard Operating Procedures</td>
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<td>STAR</td>
<td>Standard Terminal Arrival Route</td>
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<td>SUA</td>
<td>Special Use Airspace</td>
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<td>TARGETS</td>
<td>Terminal Area Route Generation Evaluation and Traffic Simulation</td>
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<td>TMA</td>
<td>Terminal Maneuvering Area</td>
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<td>U.S.</td>
<td>United States</td>
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1. Introduction

The MITRE Corporation (MITRE) is assisting Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM) with the airspace design of the new Mexico City Terminal Maneuvering Area (TMA) to support Nuevo Aeropuerto Internacional de la Ciudad de México (NAICM). The Mexico City Area Control Center (ACC) enroute airspace must also be analyzed in relation to the new Mexico City TMA to support NAICM. This analysis will help to identify and mitigate factors that could limit the capacity of traffic flows arriving to or departing from a new Mexico City TMA. In doing all of the above, MITRE will assist SENEAM in its analysis of the enroute airspace and provide backing in determining modifications to accommodate NAICM. Other airports in the vicinity of the Mexico City area will also be considered.

1.1 Purpose and Structure of this Document

The purpose of this document is to describe the approach that MITRE intends to use for the short-term redesign of the Mexico ACC enroute airspace in support of the opening of NAICM, as well as for future long-term design strategies.

This document is structured as follows:

- Section 2 contains a description of the approach MITRE intends to use for the enroute analysis and how the approach fits into the overall airspace design methodology for the project
- Section 3 describes the tools that will be used to support the analysis
- Section 4 presents some of the key considerations necessary to perform the enroute analysis
- Section 5 summarizes this document

2. MITRE’s Airspace Design Methodology

MITRE has been involved in the analysis and redesign of airspace for many years and has conducted many airspace redesign projects for the United States (U.S.) Federal Aviation Administration (FAA) and countries around the world. In support of these projects, MITRE has established an analytical methodology for airspace analysis and design, and has developed specialized analytical tools that facilitate this process. This airspace design methodology has been used with great success and MITRE intends to leverage this methodology for the analysis and redesign of the airspace around Mexico City.

The MITRE methodology utilizes two important elements: analytical tools and domain expertise, which includes Air Traffic Control (ATC) Subject Matter Experts (SMEs). Specialized analysts and, based on the scope of the project, various other experts related to the airspace being studied will also be used as necessary. For this project, MITRE’s team also depends on the domain expertise of SENEAM personnel who have a specific understanding of operating procedures and knowledge of problems and issues particular to the Mexico City area.
MITRE’s airspace design methodology has three phases:

- Screening
- Study
- Implementation

Key decision points between each of the phases allow decision-makers to make appropriate strategic decisions regarding the continuation of the project into the next phase. Figure 1 depicts graphically MITRE’s airspace design methodology.

![Diagram of MITRE’s Airspace Design Methodology]

**Figure 1. MITRE’s Airspace Design Methodology**

The analysis of the enroute airspace fits into the “Conduct Airspace Study” portion of MITRE’s airspace design methodology, in which the airspace design is developed for implementation. The enroute airspace design team will evaluate the current Mexico ACC enroute airspace to determine the airways and sectors that need to be modified as a result of the changes in the new Mexico City TMA being developed. Enroute airspace designs being proposed by SENEAM, if applicable, will also be considered.

Airways will be examined first for connectivity with the new Standard Instrument Departures (SIDs) and the new Standard Terminal Arrival Routes (STARs) for NAICM, but also with other
relevant airports within the new Mexico City TMA. Any places where the new procedures do not connect with the existing enroute airways will be resolved through either the modification of existing airways or the creation of new ones. Once the airways are examined for connectivity, the sectors containing these airways are examined to determine if modification is required due to additional complexity and workload. The additional complexity and workload may be due to additional or modified tasks that the controller is required to perform within the sector, or from increased traffic volume traversing the sector.

To measure the complexity and workload in a sector, MITRE has developed tools that, when used in conjunction with airspace design SMEs, provide a data-driven approach to airspace redesign. The 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. Figure 2 depicts this iterative approach along with the tools that are used for each step. The MITRE-developed tools that are used include the sectorEvaluator, Automated Flow Detector (AFD) Tool Suite, and Terminal Area Route Generation Evaluation and Traffic Simulation (TARGETS). Both TARGETS and AFD support sectorEvaluator, which is the evaluation tool that heuristically assesses sector complexity and, by extension, controller workload. The results from these tools along with traffic observations of live or recorded traffic in the Mexico ACC enroute airspace 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 the Issue Mitigation step, where the enroute airspace design team modifies the airspace design to mitigate the issues identified. The results from the tools provide indications of the severity and frequency of occurrence of an issue (e.g., two flows merging together too close to a sector boundary). The result of the Issue Mitigation step is a proposed route and sector design that then needs to be evaluated to determine if the identified issues have been sufficiently mitigated and to determine if any new issues arise from the redesigned routes or sectors.

The same metrics that were used for the baseline sector evaluation are used to evaluate the proposed route and sector design, which allows for a comparison of the baseline and redesign, and an assessment of the effectiveness of the design at resolving the identified issues. If the evaluation uncovers no remaining issues and the sector score\(^1\) (output from the sectorEvaluator tool) is within the acceptable range, the proposed sector configuration is then evaluated for future traffic demand levels before being finalized. If this second evaluation with increased traffic levels results in a new or unresolved issues or sector scores that are not within the acceptable range, then the proposed sector configuration goes back to the Issue Mitigation step for more adjustments. This mitigation-evaluation loop is repeated until there are no adjustments or only minimal adjustments that can be made to improve the sector configuration. In airspace analyses such as these, there can be cases where the sector score is not within the acceptable range, but the airspace design team determines that the sector is workable nonetheless. In such cases the sector would be deemed acceptable.

\(^1\) The sector score is a value that is the result of the combination of the airspace design factors used by the sectorEvaluator tool to evaluate of the sector and is used to compare different designs of the same sector.
3. **Airspace Analysis Tools**

This section describes the tools that MITRE uses in the assessment steps for evaluating the enroute airspace.

3.1 **sectorEvaluator**

The MITRE-developed *sectorEvaluator* tool, which has received a U.S. patent, measures the *traffic volume* (amount of traffic a controller is working), *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 of the sector being analyzed, and generates a workload or complexity metric for the controller. The more complex the airspace, the more information the controller has to process before making a decision. Once a decision is made, implementation of that decision may require one or more aircraft instructions, computer entries, and possibly additional controller functions (e.g., coordination with other sectors/facilities).
The tool uses over 70 quality factors of airspace design to evaluate an airspace and produce a sector score. These factors are based on generally accepted airspace design principles and include all altitude strata. Not all of the 70 possible factors apply to every sector; therefore, only those factors that apply are measured and calculated. For instance, a sector with altitude strata of Flight Level (FL) 350 and above does not handle traffic into or out of a small airport and therefore the factors associated with that workload would not be used. The factors can be divided into two groups: one group measures the volume within a sector (measurement is taken for the peak complexity hour) and the other measures the complexity within a sector. The peak complexity hour is determined by looking at the traffic volume and the number of flows, defined below, that are active during the hour. The most complex hour is used in the assessment to ensure that the controller’s workload is manageable.

Examples of the above-mentioned factors are:

- Traffic volume
  - Counts for each sector for one-minute, 15-minute, and 60-minute intervals

- Complexity
  - Count of and angle of flows of flights merging and crossing in a sector
  - Number of flows either uni-directional or bi-directional in a sector and the amount of traffic on each flow
  - Percentage of random flights in the sector
  - Distance between a flow and a sector boundary

Where traffic data are available in both filed flight plan and radar track format, both sets of data are evaluated. If filed flight plan data are used then the measurement would be on the designed routes and procedures of the sector and would establish how the traffic would be managed without controller action. If radar track data are used then the measurement would be on how traffic actually flew through the sector as it was managed by ATC. The radar track data allow the airspace design team to observe the types of control action taken by the controller and can lead to design changes to reduce required actions.

Sector traffic is divided into two categories: flows of traffic and random flights. A sector is considered to have a one way or “uni-directional” flow of aircraft through its airspace if there are six or more aircraft in a given hour that follow a similar flight path and within an altitude strata. If aircraft are flying in opposite directions and there are five or more aircraft in each direction then a bi-directional flow exists. A flow is only considered to exist during the hours of the day when the volume of traffic meets the criteria (e.g., five or six aircraft per hour) for a flow. Traffic on flows is considered to be more predictable than traffic that is not part of a flow (random flights) since flows often demonstrate repetitive control actions.

For certain functions of ATC, sectorEvaluator uses multiple factors to calculate the impacts of a control function (e.g., merging traffic). For example, in order to successfully merge traffic, controllers must consider aircraft route/heading, speed, flight distance to the merge point, convergence angle, etc. Measuring the individual factors of the merge provides airspace
designers information to establish the difficulty of the merge within the given airspace. Compiling results of the analytical data from the sectorEvaluator factor spreadsheet complements and supports airspace designer’s knowledge in the decision making process of airspace design, and allows for comparisons between a current sector design and one or more alternatives.

These factor values are then multiplied by a weighting scheme 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 subject matter experience in using this tool on many previous analyses) to gauge sector workability. The sectorEvaluator sector score can also be used for a relative comparison between different definitions of the same sector (e.g., baseline versus proposed). For the upcoming evaluation of the Mexico ACC, a relative comparison will be made, at varying traffic levels, between existing enroute sectors and the sectors that will be redesigned to connect to the redesigned Mexico City TMA. Where MITRE finds either a sectorEvaluator sector score above the acceptable threshold or a sizable difference between sector scores for the compared designs, further investigation is conducted into the cause and its potential mitigation.

3.2 AFD Tool Suite

The MITRE-developed AFD Tool Suite consists of various tools that analyze traffic data (simulated or radar tracks) to determine sector counts, time in sector, location of traffic flows, and the hours of the day in which those flows are active. In addition, these tools calculate a variety of flow characteristics, including flow directionality, climbing, descending, or level flight, as well as a variety of characteristics related to the sector in which identified flows are contained. This is a supporting tool suite to sectorEvaluator that reduces the amount of time necessary to determine the sector counts, time in sector, and flows of traffic through a sector of interest, compared to an analyst actually observing recorded traffic moving through a sector.

3.3 TARGETS

TARGETS, a MITRE-developed tool, offers a unique combination of capabilities for the design, analysis, and operational assessment of sectors and procedures. The tool incorporates data visualization capabilities with readily accessible design elements to enable designers to rapidly and easily develop airspace designs. The tool includes several modules that assist in the design of new sectors and the modification of existing sectors as well as the design of enroute and terminal procedures. Although initially developed for terminal airspace, it has been expanded to support enroute airspace redesign such as Mexico’s ACC enroute airspace.

Along with the airspace design capabilities, TARGETS offers a visualization playback capability of live or simulated traffic, flyability assessment of new or modified Area Navigation (RNAV) procedures, and the capability to assess the procedures for other measures, such as filed flight plan route distance. The visualization playback of traffic allows airspace designers to develop a better understanding of air traffic operations in the sectors. Once routes are designed, they need to be assessed to determine if they can be flown by RNAV equipped aircraft. The flyability assessment is used in the first step in determining if an RNAV procedure, as designed, can be flown by representative aircraft. TARGETS has grown over the years to include the
measurement of numerous other metrics for both proposed procedures and sectors. These metrics are used to support the analysis and redesign efforts.

3.4 Supporting Data

Various types of data are needed for airspace designers and analysts to use these tools. These types of data include, but are not limited to:

- Radar track data
- International Civil Aviation Organization (ICAO) flight plans
- Airspace elements not in the Aeronautical Information Publication (AIP), such as
  - Proposed or not published Special Use Airspace (SUAs)
  - Future navigational aids (NAVAIDs), waypoints, procedures, etc.
- Letters of Agreement (LOA)
- Standard Operating Procedures (SOPs)
- Future traffic volumes

4. Key Considerations

The airspace design team must consider issues that will impact the analysis and design process to provide solutions that will support the scope of the project, achieve goals, and ensure system connectivity with adjacent airspace sectors and ATC facilities. For the Mexico ACC, some of the key considerations are:

- The relocation of Fuerza Aérea Mexicana (FAM) SUAs
- TMA airspace modifications that would impact ACC enroute airspace
  - Changes to the lateral and/or vertical limits of the Mexico City TMA
  - Changes to transfer of control entry/exit points between the TMA and ACC
  - New/amended SIDs and STARs and associated impacts to ACC traffic flows
- Aircraft performance capability, such as RNAV, Required Navigation Performance (RNP), and types of aircraft expected at NAICM (e.g., jets, turboprops)
- Projected traffic volumes (e.g., NAICM opening day)
5. Summary

In support of the opening of NAICM, an assessment of the Mexico ACC enroute airspace and development of a short-term ACC enroute airspace redesign is needed. The MITRE airspace design methodology presented in this paper is a well-accepted approach to airspace design used by MITRE, both for U.S. FAA airspace design projects and internationally. The steps for assessing and assisting in the potential redesign of the Mexico ACC enroute airspace involve not only airspace design expertise, but also MITRE-developed tools that use data to make the assessment of a proposed redesign more objective.