



Center for Advanced  
Aviation System Development

## Cancún Airport Terminal Maneuvering Area Redesign

*Procedural Separation, Sectorization, and  
Human-In-The-Loop Workshop in Cancún*

*Summary of Key Activities*

Prepared for

Servicios a la Navegación en el Espacio Aéreo Mexicano

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## Principal Acronyms and Abbreviations

<b>ACC</b>	Area Control Center
<b>APP</b>	Approach Control
<b>ATC</b>	Air Traffic Control
<b>CDO</b>	Continuous Descent Operation
<b>FAA</b>	(United States) Federal Aviation Administration
<b>GACM</b>	Grupo Aeroportuario de la Ciudad de México (GACM)
<b>HITL</b>	Human-In-The-Loop
<b>ICAO</b>	International Civil Aviation Organization
<b>MITRE</b>	The MITRE Corporation
<b>MMCZ</b>	Aeropuerto Internacional de Cozumel
<b>MMUN</b>	Aeropuerto Internacional de Cancún
<b>NAICM</b>	Nuevo Aeropuerto Internacional de la Ciudad de México
<b>NM</b>	Nautical Mile
<b>SENEAM</b>	Servicios a la Navegación en el Espacio Aéreo Mexicano
<b>SID</b>	Standard Instrument Departure
<b>STAR</b>	Standard Terminal Arrival Route
<b>TMA</b>	Terminal Maneuvering Area

## 1. Introduction

The MITRE Corporation (MITRE) is assisting, through Grupo Aeroportuario de la Ciudad de México (GACM), the aviation authorities of Mexico with the development of a new airport to serve Mexico City, 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. The proposed runway layout of NAICM will allow for dual- and triple-independent arrival and departure operations. In connection with that, MITRE is assisting the aviation authorities in implementing dual independent arrival and departure operations at Aeropuerto Internacional de Cancún (hereinafter referred to by its 4-letter International Civil Aviation Organization [ICAO] code of MMUN) to and from its two existing parallel runways. This would provide an increase in capacity for MMUN. Moreover, it would also allow MMUN to serve as a test-bed location where Mexican air traffic controllers could obtain an understanding of the issues associated with independent operations, and gain valuable experience for the future implementation of such procedures at NAICM.

MITRE has been working closely with Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM) on important matters regarding the transition to independent operations in Mexico, including the implementation of dual independent test-bed operations at MMUN. For example, MITRE provided information on the principal requirements for surveillance, display, and communications for conducting dual- and triple-independent operations, as well as important airspace and Air Traffic Control (ATC) elements to be considered in preparing NAICM and MMUN for conducting these complex operations. Assistance regarding the key elements for consideration during SENEAM's MMUN airspace redesign work, including MITRE-developed airspace concepts intended to facilitate the airspace redesign process with SENEAM, as well as instrument approach and departure procedures, were also provided.

To support the MMUN project, a large team of MITRE engineers conducted an intense 5-day workshop in Cancún from 12 through 16 December 2016 to assist SENEAM in the redesign of the MMUN airspace to support dual independent test-bed operations. The objectives of the visit were as follows:

- To solidify the MMUN and Aeropuerto Internacional de Cozumel (hereinafter referred to by its 4-letter ICAO code of MMCZ) Terminal Maneuvering Area (TMA) routes considering procedural separation and ATC sectorization
- To develop scenarios to be used to evaluate the MMUN/MMCZ TMA airspace design during the Human-In-The-Loop (HITL) dry-run simulations to be conducted at MITRE's Air Traffic Management Laboratory in Mclean, Virginia from 30 January 2017 through 3 February 2017.

This document is intended to describe the key activities that occurred during the above-mentioned 12 through 16 December 2016 workshop, and to highlight key decisions that were made by the SENEAM and MITRE teams. It is also intended to allow the SENEAM team to review the MMUN/MMCZ TMA routes considering procedural separation and ATC sectorization, as well as the HITL scenarios that were developed during the workshop prior to the upcoming HITL dry-run simulations.

The rest of this document is structured as follows:

- Section 2 summarizes the activities conducted during the workshop, including procedural separation and sectorization matters as well as the development of HITL scenarios
- Section 3 provides a summary of the key decisions that were made during the visit
- Section 4 provides some closing remarks and next steps

## 2. Summary of Key Workshop Activities and Discussions

This section provides a general description of the key activities that took place during the workshop. First, an intense airspace design workshop was held with the SENEAM airspace design team to solidify the airspace concept to support dual independent test-bed operations at MMUN. In order to complete the airspace concept, the SENEAM and MITRE teams focused on the procedural separation of the MMUN Standard Terminal Arrival Routes (STARs) and Standard Instrument Departures (SIDs), as well as the sectorization of the Approach, Arrival and Departure airspace of the MMUN Approach Control (APP) facility.

It was decided by SENEAM and MITRE that procedural separation would not be applied to the MMCZ routes because in doing so the MMUN routes would be forced into less than standard climb and descent rates that could possibly result in additional altitude level-offs. Applying procedural separation to MMCZ routes would also likely increase fuel burn rates and reduce efficiencies of MMUN arrivals and departures.

The rest of this section is divided into subsections that cover the topics that were discussed during MITRE's visit in more detail.

### 2.1 Technical Presentations and Discussions

Several technical presentations and discussions were conducted during the workshop. The purpose of the presentations and discussions was as follows:

- To inform the airspace design team of the work that both SENEAM and MITRE have accomplished since the last airspace design workshop held in August 2016
- To facilitate discussions regarding procedural separation and sectorization matters, and further evaluate the MMUN/MMCZ TMA airspace design concept
- To explain the need and use of HITL scenarios, and to develop HITL scenarios to be evaluated
- To discuss upcoming key next steps and milestones

The following lists the main presentations and discussions that were conducted:

- Project Update and Recent Activities
- MMUN/MMCZ Procedural Separation: Collaborative Discussion
- MMUN/MMCZ Sectorization: Collaborative Discussion

- Mérida Area Control Center (ACC) Considerations in Relation to MMUN/MMCZ STAR and SID Procedural Separation and Sectorization: Collaborative Discussion
- Overview of HITL Scenario Design and Development
- MMUN/MMCZ HITL Scenario Development: Collaborative Discussion
- Next Steps

## 2.2 MMUN/MMCZ TMA Procedural Separation

The airspace design workshop provided an opportunity for SENEAM and MITRE to solidify the airspace design concept for dual independent test-bed operations at MMUN. In order to solidify the design, it was decided by SENEAM and MITRE to procedurally separate the MMUN STARs and SIDs. The procedural separation will provide lateral and/or vertical separation between the MMUN STARs and SIDs while aircraft fly the published procedures. The procedural separation will also provide an additional level of safety by not requiring the MMUN controllers to verbally communicate all altitude and heading instructions to aircraft. This reduction in controller verbal communication is designed to minimize controller workload and allow a more efficient flow of air traffic inside of the MMUN/MMCZ TMA

In order to facilitate the review and discussion of MMUN procedural separation, MITRE utilized its Terminal Area Route Generation Evaluation and Traffic Simulation (TARGETS) airspace design tool, which contained the overall MMUN/MMCZ TMA airspace design and MMUN procedural separations for presentation to the workshop participants. It is important to note that prior to conducting the workshop, MITRE spent a significant amount of time procedurally separating routes within the MMUN/MMCZ TMA for consideration by SENEAM (refer to MITRE documents F500-L17-001 and F500 L17-006).

During the workshop, each individual STAR and SID was evaluated for altitudes based on aircraft climb and descent rate profiles, flyability of routes based on United States Federal Aviation Administration (FAA) approved criteria, and interactions between other MMUN STARs and SIDs. As the design became more solidified, the SENEAM and MITRE teams identified a need to establish holding patterns at tactical locations inside of the MMUN/MMCZ TMA.

Following the procedural separation discussion, MITRE and SENEAM reviewed the sectorization of the airspace to determine if the individual sectors, as designed, provided the necessary separation from other MMUN STARs and SIDs. The MMCZ SIDs and STARs were then reviewed, taking into consideration the procedural separation and sectorization of the MMUN procedures. These results were also presented to the Mérida ACC representative that participated in the workshop to ensure that enroute matters were being considered in the overall MMUN/MMCZ TMA design.

The results of the airspace design workshop procedural separation sessions are shown in Figures 1 and 2 below. These designs will be further evaluated during the upcoming HITL simulations.



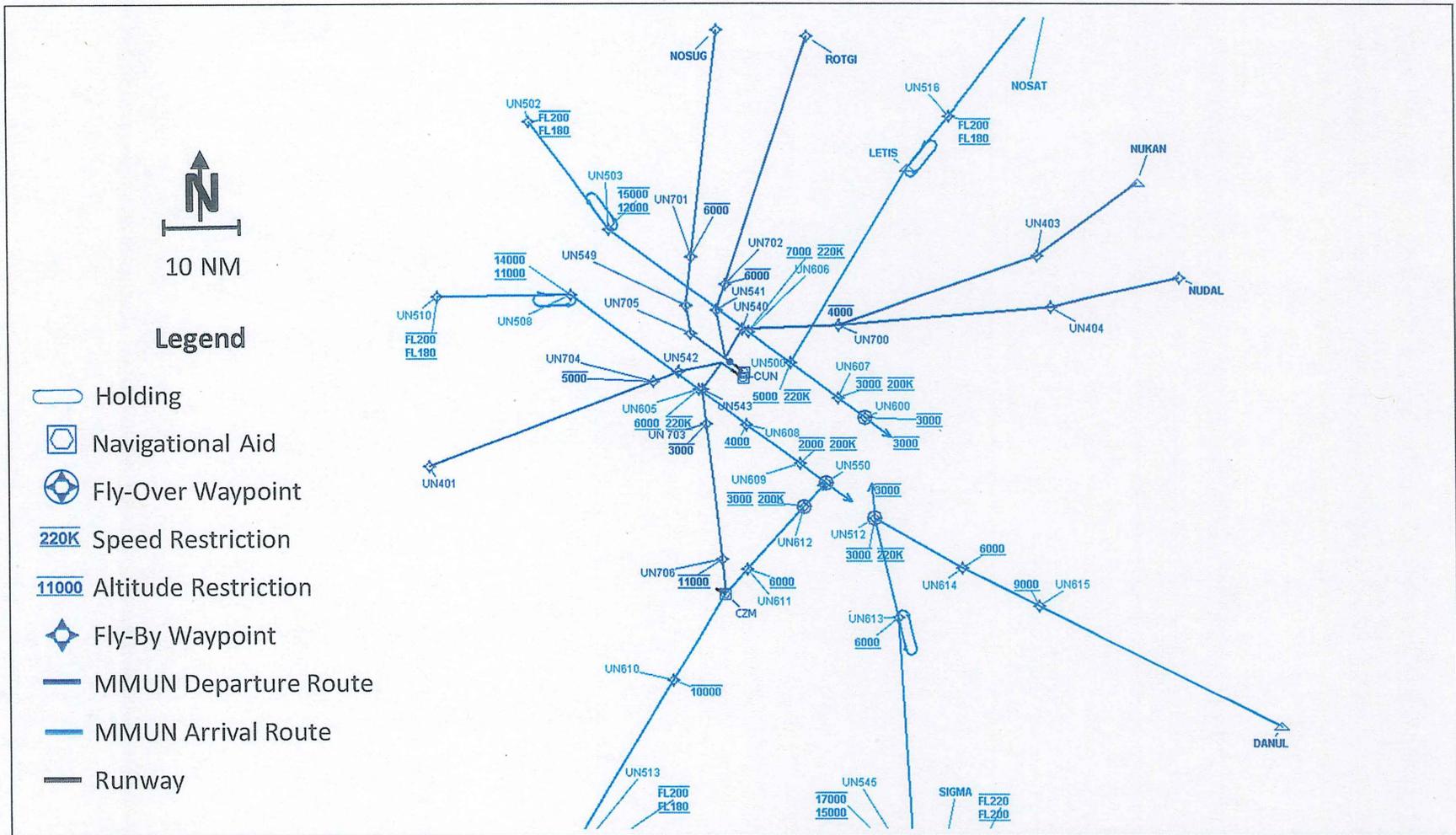


Figure 2. Airspace Concept with Procedural Separation for MMUN Runway 30 Direction  
(Not to be Considered Final)

### 2.3 MMUN/MMCZ TMA Sectorization

An integral part of the airspace design for the MMUN dual independent test-bed operation was the development of sectors for the overall MMUN/MMCZ TMA airspace design. Currently MMUN APP consists of four controller operating positions: two departure, one approach and one arrival sector. As dual independent test-bed operations will provide increased capacity, it is necessary to distribute controller workload and responsibilities in a more segmented and orderly manner by re-sectoring airspace. For example, current operations allow for one arrival controller to deliver all aircraft arriving to MMUN to the approach controller. In contrast, the re-sectorized airspace design for dual independent test-bed operations requires two arrival controllers (north and south) to deliver to two approach (north and south) controllers. During dual independent test-bed operations, two Final Monitor controllers (north and south) will also be required. This division of workload by additional controller operating positions will provide improved efficiency and capacity for MMUN.

The results of the airspace design workshop regarding sectorization are shown in Figures 3 through 12 below. These sector designs will be further evaluated during the upcoming HITL simulations.

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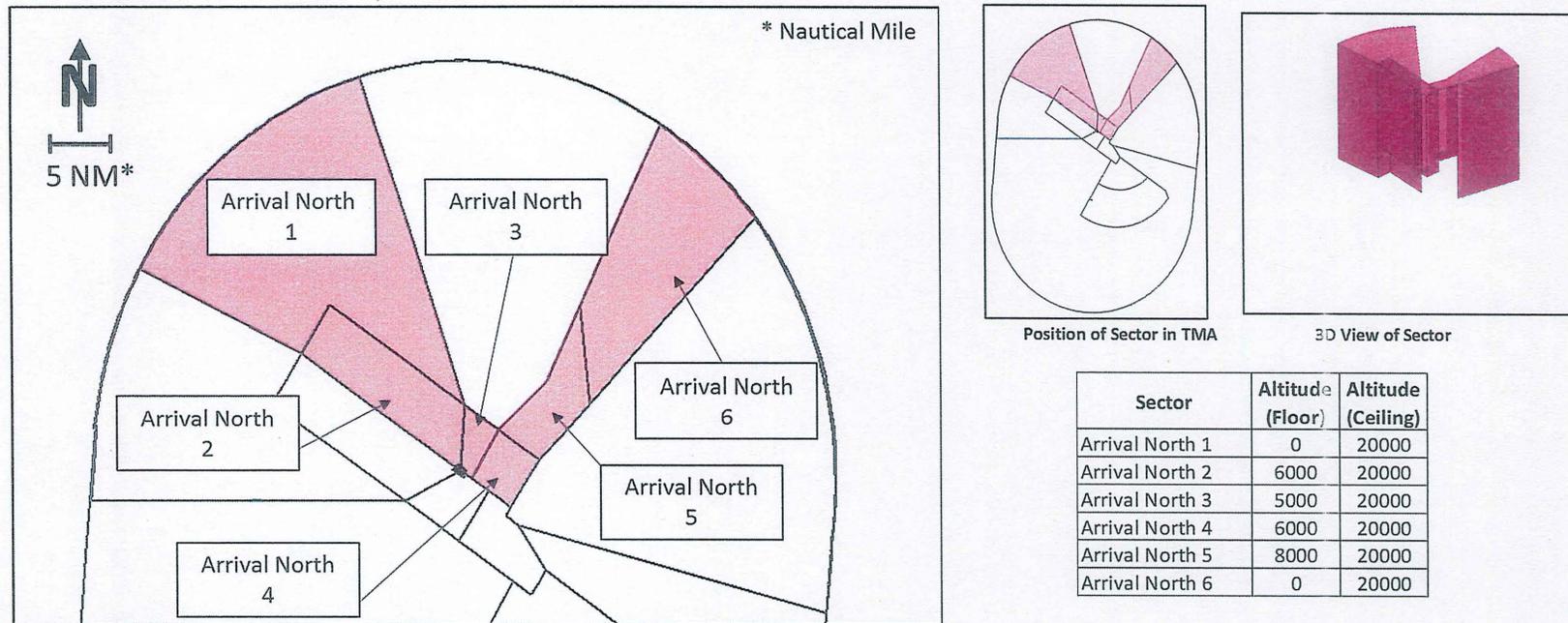


Figure 3. Airspace Concept with Arrival North Sectorization for MMUN Runway 12 Direction  
(Not to be Considered Final)

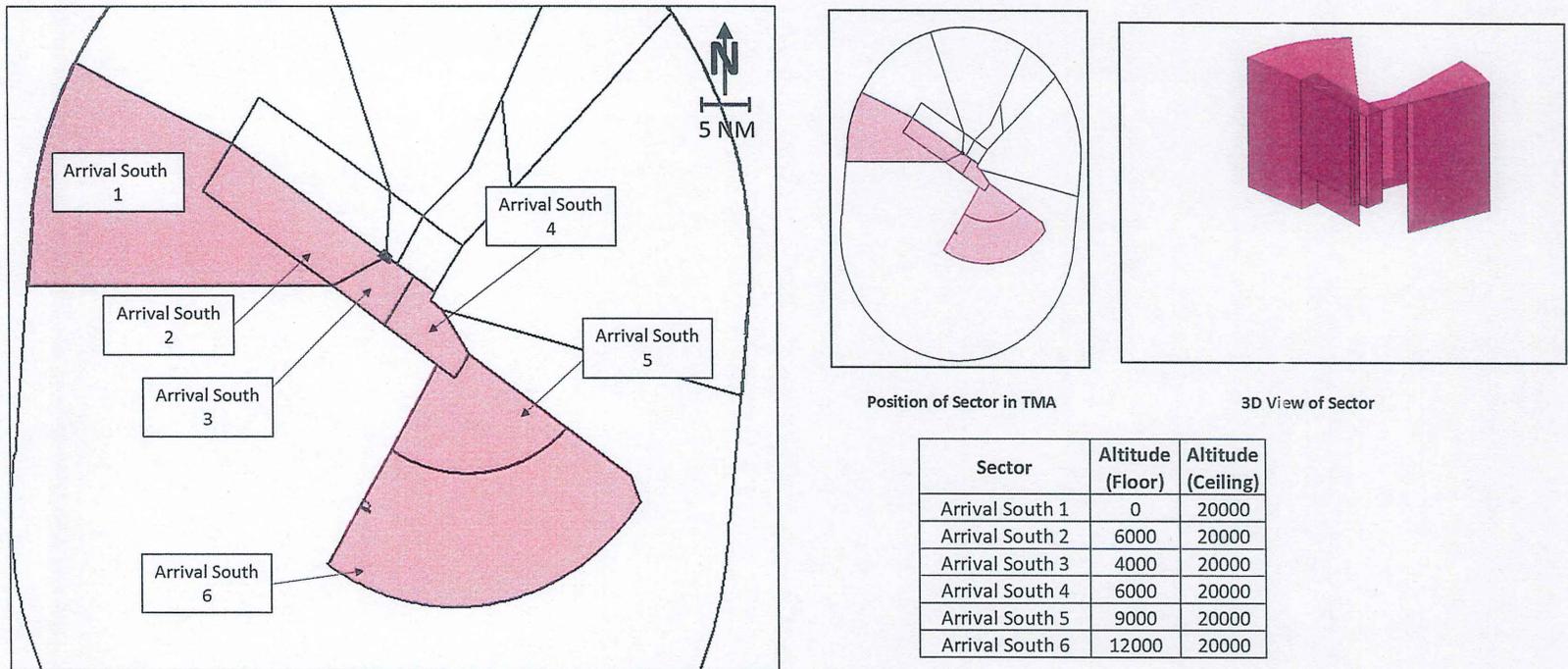
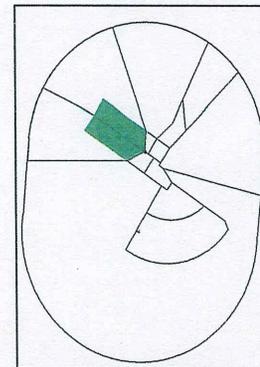
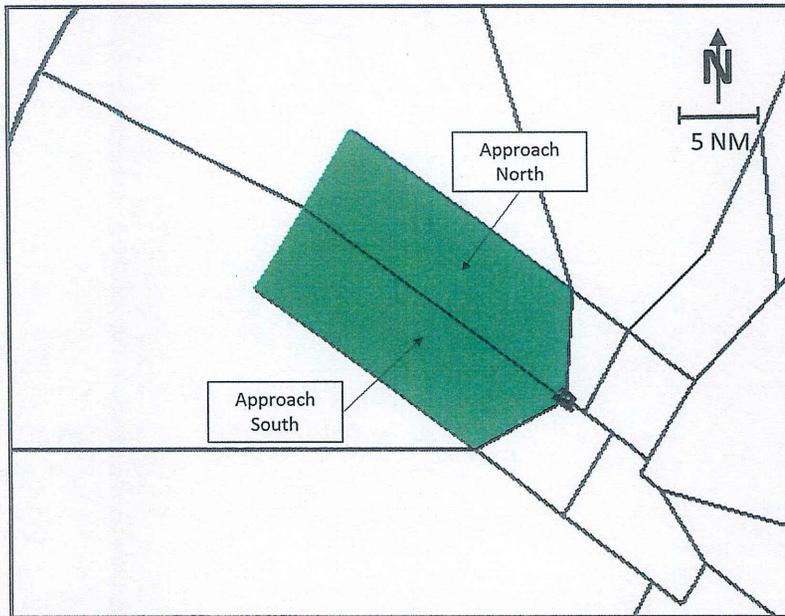
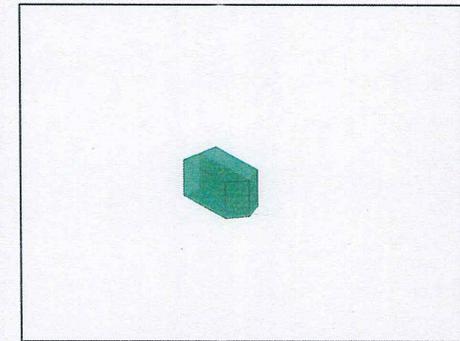


Figure 4. Airspace Concept with Arrival South Sectorization for MMUN Runway 12 Direction  
(Not to be Considered Final)



Position of Sectors in TMA



3D View of Sector

Sector	Altitude (Floor)	Altitude (Ceiling)
Approach South	0	5000
Approach North	0	5000

Figure 5. Airspace Concept with Approach North and South Sectorization for MMUN Runway 12 Direction  
(Not to be Considered Final)

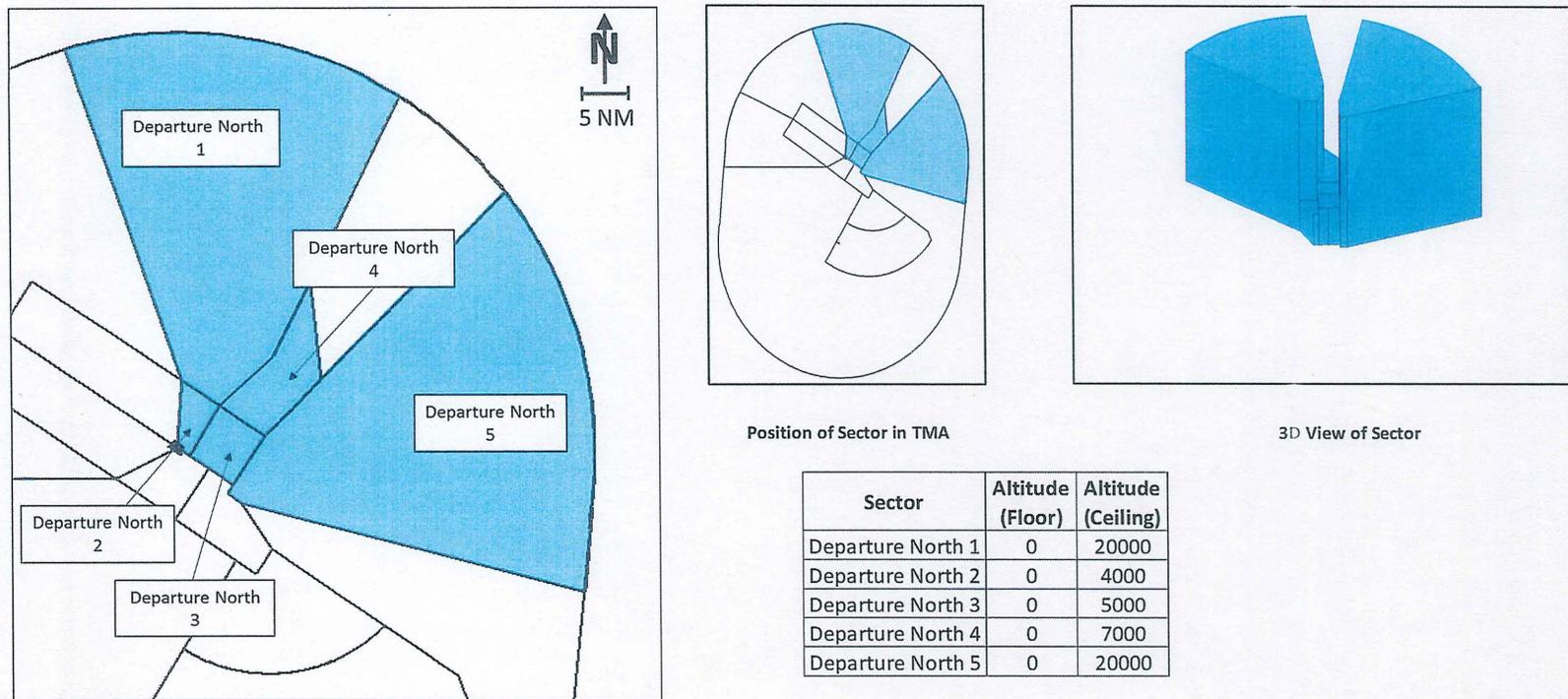


Figure 6. Airspace Concept with Departure North Sectorization for MMUN Runway 12 Direction  
(Not to be Considered Final)

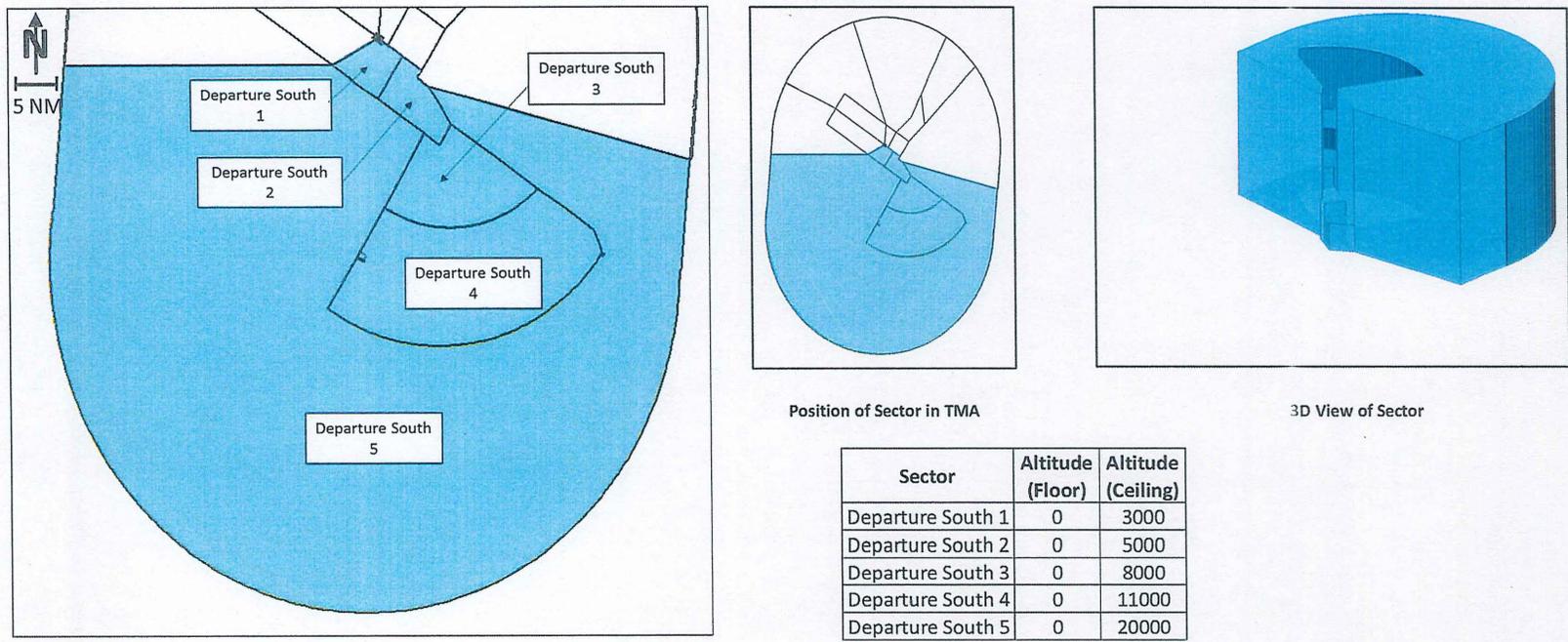
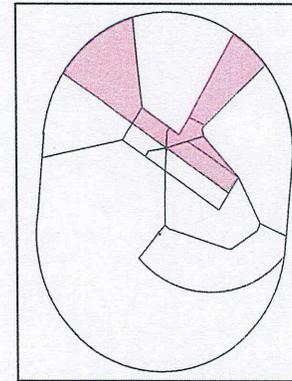
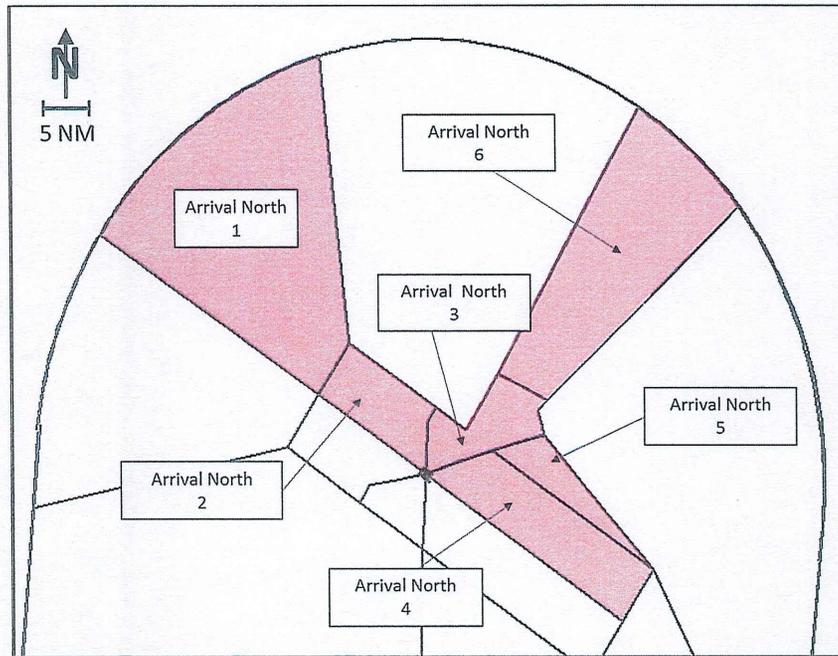
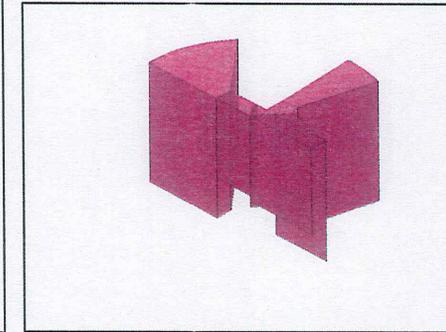


Figure 7. Airspace Concept with Departure South Sectorization for MMUN Runway 12 Direction  
(Not to be Considered Final)



Position of Sector in TMA



3D View of Sector

Sector	Altitude (Floor)	Altitude (Ceiling)
Arrival North 1	0	20000
Arrival North 2	7000	20000
Arrival North 3	5000	20000
Arrival North 4	6000	20000
Arrival North 5	0	20000
Arrival North 6	0	20000

Figure 8. Airspace Concept with Arrival North Sectorization for MMUN Runway 30 Direction  
(Not to be Considered Final)

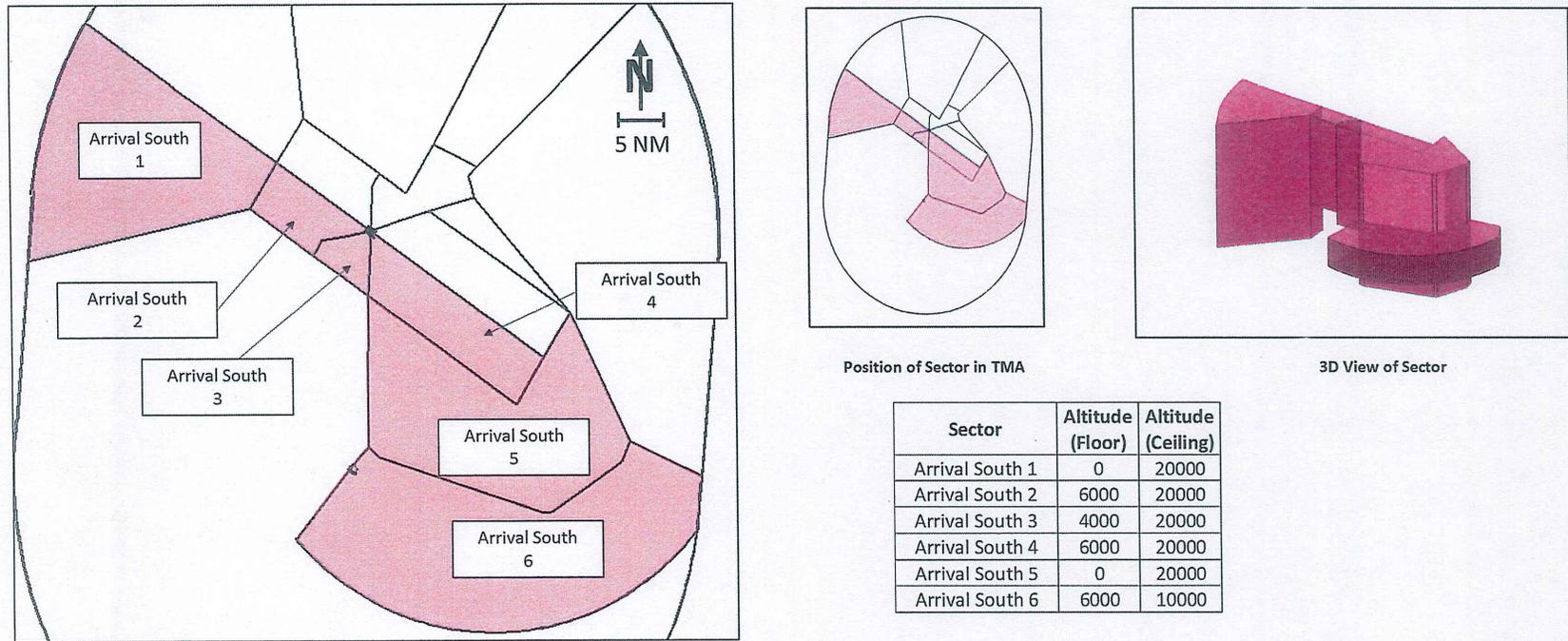


Figure 9. Airspace Concept with Arrival South Sectorization for MMUN Runway 30 Direction  
(Not to be Considered Final)

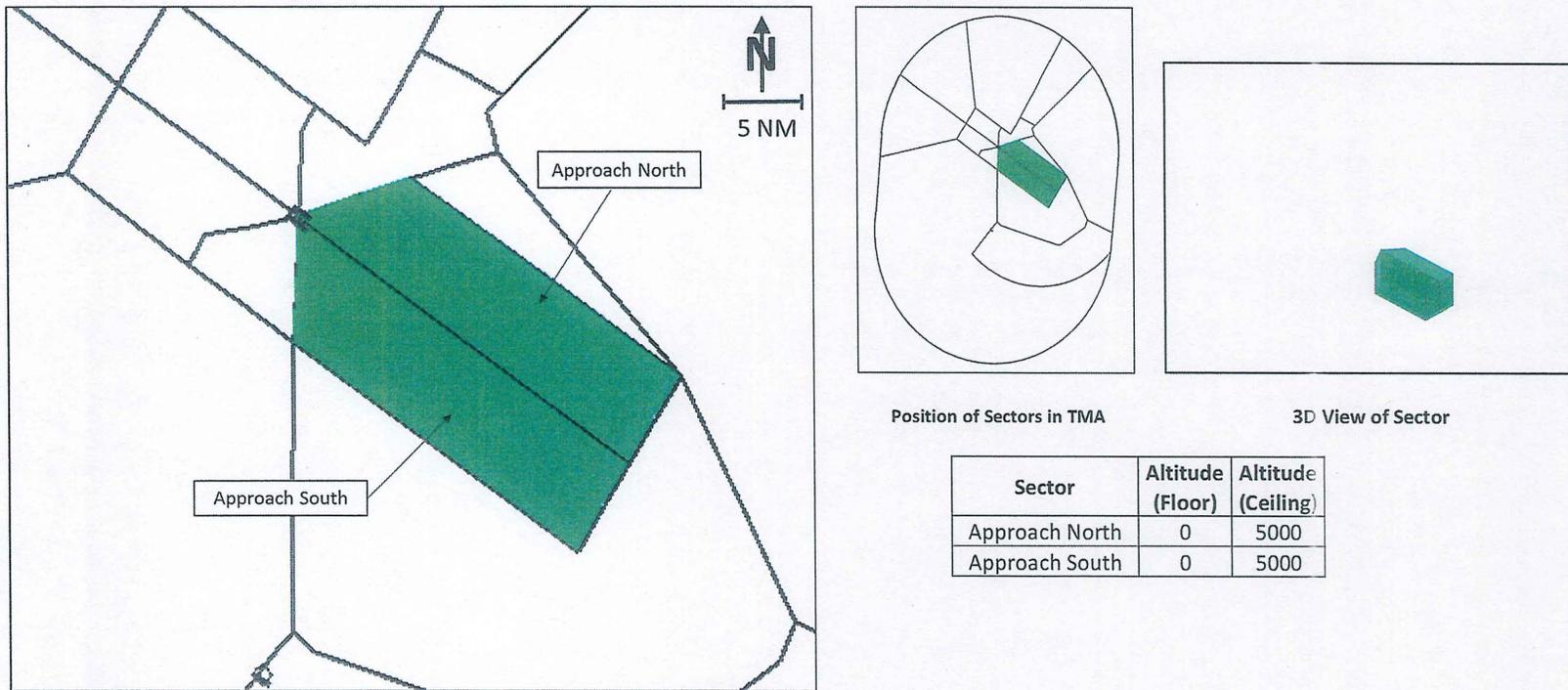


Figure 10. Airspace Concept with Approach North and South Sectorization for MMUN Runway 30 Direction  
(Not to be Considered Final)

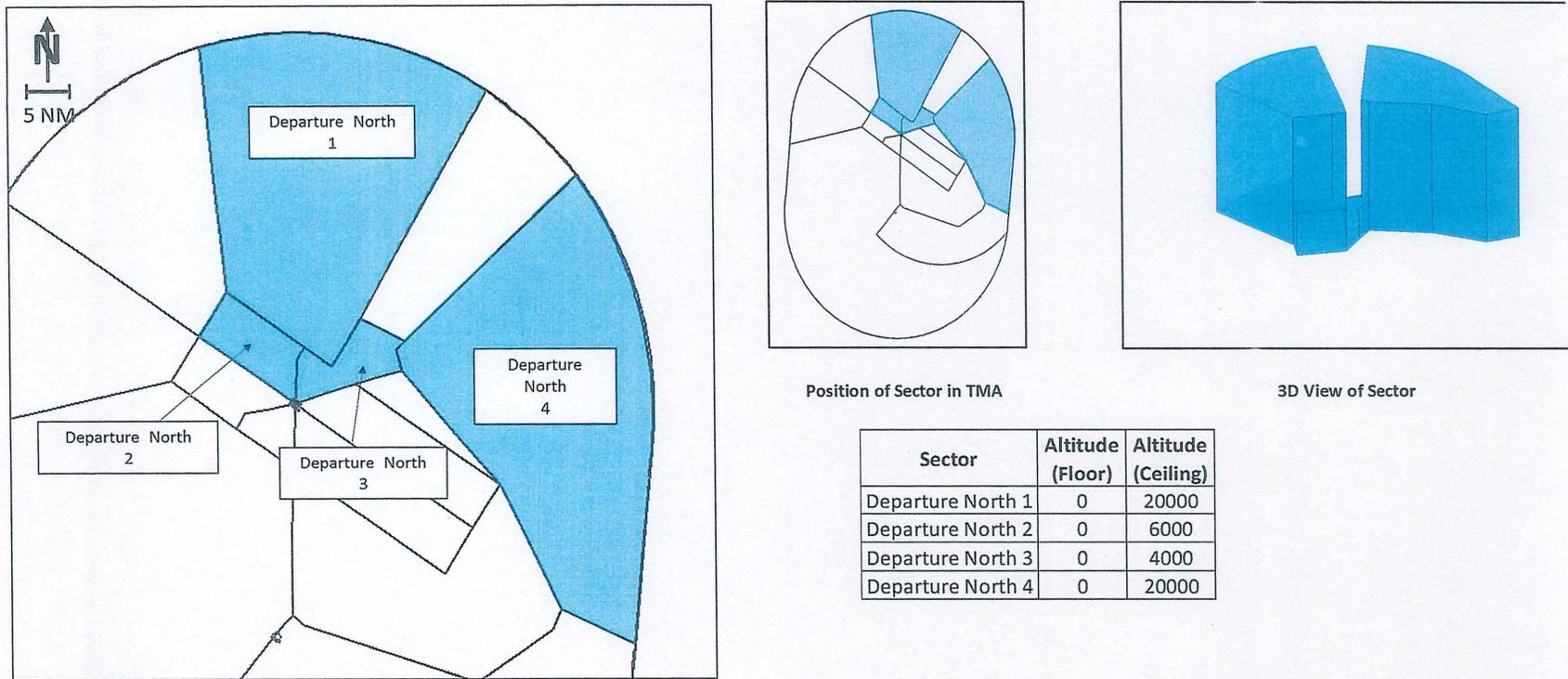


Figure 11. Airspace Concept with Departure North Sectorization for MMUN Runway 30 Direction  
(Not to be Considered Final)

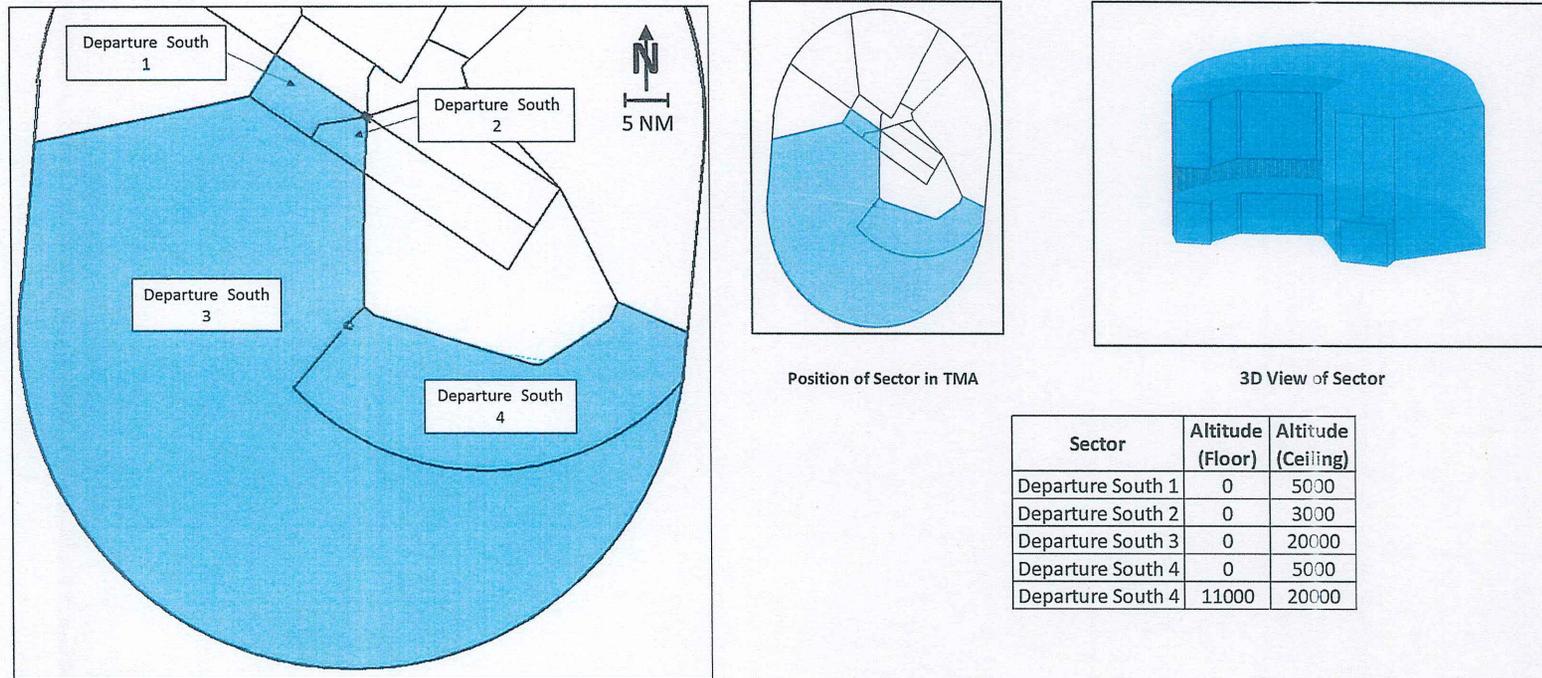


Figure 12. Airspace Concept with Departure South Sectorization for MMUN Runway 30 Direction  
(Not to be Considered Final)

## 2.4 SENEAM-MITRE HITL Scenario Development

The airspace design workshop provided an opportunity for SENEAM and MITRE to develop scenarios to be evaluated during the upcoming HITL simulations. The scenario development sessions focused on determining the objectives of each evaluation, the runway configuration to use, and which operating positions inside of the MMUN APP should be evaluated.

A scenario is a time-bound activity (usually 30-60 minutes) that provides the participant with a sequence of events on a system; it is a realistic exercise, but it is simulated. Scenarios typically contain specific objectives, airspace/sectors, procedures, airport configurations, traffic (partially controlled by simulation, subject to inputs from pseudo pilots based upon controller commands), and controller positions (Arrival, Approach, Final Monitor, Departure and Enroute, as appropriate).

The overall objective of the HITL simulations are to identify issues associated with the airspace design (sectorization, procedures, and altitude restrictions) and to assist in the resolution of those issues. The HITL simulations will allow MMUN controllers to evaluate the new airspace design interactively by controlling simulated traffic in specific operational situations or scenarios.

The airspace design will be evaluated using two sets of metrics:

- Observed (Objective) Measures - metrics (e.g., aircraft sector counts, aircraft time in a sector, aircraft time on frequency, number of radio transmissions per aircraft, aircraft maneuvers, system inputs) collected by automation while the controllers manage the simulated traffic. The objective metrics collected by the automation during the scenario runs are then analyzed for each scenario and the week as a whole.
- Perception (Subjective) Measures - metrics (e.g., workload or how hard the controller perceives to be working, acceptability of the airspace elements, preferences related to procedures, as well as the overall airspace design and operation) collected from participant inputs via questionnaires at the end of each scenario and observations during the scenario. Questionnaires gather subjective data based on participants' background, operational experience, and experiences during the simulation scenarios.

The SENEAM/MITRE team identified eight scenarios to be used to familiarize the SENEAM controllers that will participate in the HITL and an additional 20 scenarios that will be used to evaluate the proposed MMUN/MMCZ TMA airspace design. The scenarios are shown and described in Tables 1 through 3 below.

**Table 1. HITL Practice Scenarios 1 through 8**

Scenario #	Scenario Name	Objective: What is(are) the Question(s) to be Answered?	Main Airport's Runway Flow Direction	List of "Connected" Positions to be Run Simultaneously	Number of Sectors/Positions in HITL
Practice Scenarios 1 and 2	MMUN Runway 12 Arrival and Approach	<ol style="list-style-type: none"> <li>1. Familiarize TMA controllers with dual independent procedures including Duals Bar</li> <li>2. Familiarize TMA controllers with new arrival and approach airspace</li> <li>3. Introduce runway balancing options for arrival controllers</li> <li>4. Familiarize TMA controllers with Continuous Descent Operations (CDO) altitudes and procedures</li> </ol>	MMUN 12	Arrival North and South Approach North and South	4
Practice Scenarios 3 and 4	MMUN Runway 12 Arrivals and Departures; MMCZ Runway 11 Arrivals and Departures	<ol style="list-style-type: none"> <li>1. Familiarize TMA controllers with new approach and departure airspace</li> <li>2. Introduce interactions between MMUN and MMCZ procedures</li> </ol>	MMUN 12 and MMCZ 11	Arrival North and South Departure North and South	4
Practice Scenarios 5 and 6	MMUN Runway 30 Arrival and Approach	<ol style="list-style-type: none"> <li>1. Familiarize TMA controllers with dual independent procedures including Duals Bar</li> <li>2. Familiarize TMA controllers with new arrival and approach airspace</li> <li>3. Introduce runway balancing options for arrival controllers</li> <li>4. Familiarize TMA controllers with CDO altitudes and procedures</li> </ol>	MMUN 30	Arrival North and South Approach North and South	4
Practice Scenarios 7 and 8	MMUN Runway 30 Arrivals and Departures; MMCZ Runway 29 Arrivals and Departures	<ol style="list-style-type: none"> <li>1. Familiarize TMA controllers with new approach and departure airspace</li> <li>2. Introduce interactions between MMUN and MMCZ procedures</li> </ol>	MMUN 30 and MMCZ 29	Arrival North and South Departure North and South	4

Table 2. HITL Scenarios 1 through 10

Scenario #	Scenario Name	Objective: What is(are) the Question(s) to be Answered?	Main Airport's Runway Flow Direction	List of "Connected" Positions to be Run Simultaneously	Number of Sectors/Positions in HITL
Scenarios 1 and 2	MMUN Runway 12 Arrival and Approach	<ol style="list-style-type: none"> <li>1. Evaluate airspace design for each sector/position</li> <li>2. Evaluate the location, speeds, and altitudes of the base leg and downwind feeds</li> <li>3. Evaluate the complexity of three STARs merging at UN511</li> <li>4. Evaluate function/understanding of the Duals Bar</li> <li>5. Evaluate runway balancing options for both Arrival positions</li> <li>6. Evaluate CDO procedures for location, altitudes, and speeds</li> </ol>	MMUN 12	Arrival North and South Approach North and South	4
Scenarios 3 and 4	MMUN Runway 12 Approach and Final Monitor	<ol style="list-style-type: none"> <li>1. Introduce Final Monitor position, Final Monitor Aid functionality, 4-1 aspect ratio, and phraseology</li> <li>2. Evaluate the location, speeds, and altitudes of the base leg and downwind feeds</li> <li>3. Evaluate function/understanding of the Duals Bar</li> <li>4. Evaluate airspace design for each sector/position</li> <li>5. Evaluate CDO procedures for location, altitudes, and speeds</li> </ol>	MMUN 12	Approach North and South Final Monitor North and South	4
Scenarios 5 and 6	MMUN Runway 12 Arrivals and Departures; MMCZ Runway 11 Arrivals and Departures	<ol style="list-style-type: none"> <li>1. Evaluate the interactions between MMUN STARs and SIDs</li> <li>2. Evaluate the interaction between MMUN procedures and MMCZ procedures</li> <li>3. Evaluate airspace design for each sector/position</li> <li>4. Evaluate the interactions between MMCZ STARs and SIDs</li> <li>5. Evaluate CDO and Climb via procedures for location, altitudes, and speeds</li> </ol>	MMUN 12 and MMCZ 11	Arrival North and South Departure North and South	4
Scenarios 7 and 8	MMUN Runway 30 Approach and Arrival	<ol style="list-style-type: none"> <li>1. Evaluate airspace design for each sector/position</li> <li>2. Evaluate the location, speeds, and altitudes of the base leg and downwind feeds</li> <li>3. Evaluate function/understanding of the Duals Bar</li> <li>4. Evaluate runway balancing options for both Arrival positions</li> <li>5. Evaluate CDO procedures for location, altitudes, and speeds</li> </ol>	MMUN 30	Arrival North and South Approach North and South	4
Scenarios 9 and 10	MMUN Runway 30 Approach and Final Monitor	<ol style="list-style-type: none"> <li>1. Introduce Final Monitor position for Runway 30</li> <li>2. Evaluate the location, speeds, and altitudes of the base leg and downwind feeds</li> <li>3. Evaluate function/understanding of the Duals Bar</li> <li>4. Evaluate airspace design for each sector/position</li> <li>5. Evaluate CDO procedures for location, altitudes, and speeds</li> </ol>	MMUN 30	Approach North and South Final Monitor North and South	4

Table 3. HITL Scenarios 11 through 20

Scenario #	Scenario Name	Objective: What is(are) the Question(s) to be Answered?	Main Airport's Runway Flow Direction	List of "Connected" Positions to be Run Simultaneously	Number of Sectors/Positions in HITL
Scenarios 11 and 12	MMUN Runway 30 Arrival and Departure; MMCZ Runway 29 Arrival and Departure	<ol style="list-style-type: none"> <li>1. Evaluate the interactions between MMUN STARs and SIDs</li> <li>2. Evaluate the interaction between MMUN procedures and MMCZ procedures</li> <li>3. Evaluate airspace design for each sector/position</li> <li>4. Evaluate the interactions between MMCZ STARs and SIDs</li> <li>5. Evaluate CDO and Climb via procedures for location, altitudes, and speeds</li> </ol>	MMUN 30 and MMCZ 29	Arrival North and South Departure North and South	4
Scenarios 13 and 14	MMUN Runway 12 Arrival/Departures; MMCZ Runway 29 Arrivals/Departures	<ol style="list-style-type: none"> <li>1. Evaluate airspace design for each sector/position</li> <li>2. Evaluate MMUN and MMCZ traffic in opposite direction runway configurations</li> </ol>	MMUN 12 and MMCZ 29	Arrival North and South, Departure North and South	4
Scenarios 15 and 16	MMUN Runway 30 Arrivals/Departures; MMCZ Runway 11 Arrivals/Departures	<ol style="list-style-type: none"> <li>1. Evaluate airspace design for each sector/position</li> <li>2. Evaluate MMUN and MMCZ traffic in opposite direction runway configurations</li> </ol>	MMUN 30 and MMCZ 11	Arrival North and South, Departure North and South	4
Scenarios 17 and 18	MMUN Runway 12 Arrivals and Approaches with Increased Traffic	<ol style="list-style-type: none"> <li>1. Evaluate airspace design for each sector/position</li> <li>2. Evaluate the location, speeds, and altitudes of the base leg and downwind feeds</li> <li>3. Evaluate airspace design with increased traffic levels</li> <li>4. Evaluate runway balancing options for both Arrival positions</li> </ol>	MMUN 12	Arrival North and South Approach North and South	4
Scenarios 19 and 20	MMUN Runway 30 Arrival and Approaches with Increased traffic	<ol style="list-style-type: none"> <li>1. Evaluate airspace design for each sector/position</li> <li>2. Evaluate the location, speeds, and altitudes of the base leg and downwind feeds</li> <li>3. Evaluate airspace design with increased traffic levels</li> <li>4. Evaluate runway balancing options for both Arrival positions</li> </ol>	MMUN 30	Arrival North and South Approach North and South	4

### 3. Key Decisions

This section provides a summary list of the key decisions that were made during the workshop. These decisions were the result of discussions that were held between SENEAM and MITRE concerning the airspace design that is being developed, as well as the HITL scenarios to evaluate the airspace design.

#### 3.1 Key Decisions

- Procedural separation was not applied to the MMCZ SIDs and STARs. It was agreed that due to a limited amount of traffic at MMCZ, controllers would vector aircraft and provide altitude restrictions, as necessary
- Transfer of control points are needed on the MMUN TMA boundary for coordination and handoffs to/from the Mérida ACC
- The Approach Control and Final Monitor positions are new to the MMUN APP controllers and should be included in the HITL evaluation scenarios
- Holding locations were established inside the MMUN TMA on the NOSAT, UN502, UN510 and SIGMA STARs
- Low performing aircraft should be added to the HITL evaluation scenarios
- At least one scenario involving a two to three aircraft sequence at MMCZ with 12 nautical miles (NM) spacing between each arrival should be included in the HITL evaluation scenarios

### 4. Closing Remarks

MITRE's visit to Cancún to meet with the SENEAM team was extremely successful. The SENEAM and MITRE teams were able to advance with the airspace design, which has allowed MITRE to proceed with its preparations for the upcoming HITL dry-run simulations. The following next steps were highlighted at the closing of the workshop pertaining to airspace design matters for implementing dual-independent test-bed operations at MMUN.

- SENEAM/MITRE to conduct dry runs for HITL simulation 1 at MITRE's facilities from 30 January 2017 through 3 February 2017
- SENEAM/MITRE to conduct HITL simulation 1 at MITRE's facilities from 27 February 2017 through 3 March 2017
- MITRE to perform post evaluation analysis of HITL simulation 1 results
- SENEAM to examine and modify airspace design based on results from HITL simulation 1
- SENEAM/MITRE to conduct an airspace design workshop to discuss the overall results of the HITL simulation 1, discuss any airspace modifications, and develop scenarios for HITL simulation 2

- MITRE to prepare for HITL simulation 2
- SENEAM/MITRE to conduct dry runs for HITL simulation 2 at MITRE's facilities (tentatively planned for the July 2017 timeframe)
- SENEAM/MITRE to conduct HITL simulation 2 at MITRE's facilities (tentatively planned for the August 2017 timeframe)
- MITRE to perform post evaluation analysis of HITL simulation 2 results

Following the post evaluation analysis, SENEAM can make additional modifications to the airspace design, as necessary, for further discussion with MITRE.