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MITRE
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Cancún Airport Terminal Maneuvering Area Redesign

Procedural Separation, Sectorization, and Human-In-The-Loop Results of June 2017 Cancún Workshop

Summary of Key Activities

Prepared for

Servicios a la Navegación en el Espacio Aéreo Mexicano

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Principal Acronyms and Abbreviations

ACC	Area Control Center
APP	Approach Control
ATC	Air Traffic Control
FAA	(United States) Federal Aviation Administration
GACM	Grupo Aeroportuario de la Ciudad de México (GACM)
HITL	Human-In-The-Loop
ICAO	International Civil Aviation Organization
MITRE	The MITRE Corporation
MMCZ	Aeropuerto Internacional de Cozumel
MMUN	Aeropuerto Internacional de Cancún
NAICM	Nuevo Aeropuerto Internacional de la Ciudad de México
SENEAM	Servicios a la Navegación en el Espacio Aéreo Mexicano
SID	Standard Instrument Departure
STAR	Standard Terminal Arrival Route
TARGETS	Terminal Area Route Generation Evaluation and Traffic Simulation
TMA	Terminal Maneuvering (Control) 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 two-day workshop in Cancún from 8 through 9 June 2017 to assist SENEAM in the redesign of the MMUN airspace to support dual independent test-bed operations and to report results from the Cancún Human-In-The-Loop (HITL) 1 simulation evaluations that were conducted at MITRE's Air Traffic Management (ATM) Laboratory from 30 February 2017 through 3 March 2017. Matters pertaining to the upcoming Cancún HITL 2 dry-run simulation evaluation activities were also discussed. The objectives of the workshop 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 (Control) Area (TMA) routes considering procedural separation and ATC sectorization to allow the advancement of the Cancún test-bed timeline
- To review the results of the above-mentioned Cancún HITL 1 simulation evaluations
- To develop scenarios to be used to evaluate the MMUN/MMCZ TMA airspace design during the HITL 2 dry-run simulation evaluations to be conducted at MITRE's ATM Laboratory from 7 through 11 August 2017

This document is intended to describe the key activities that occurred during the above-mentioned June 2017 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

HITL 2 scenarios that were developed during the workshop prior to the above-mentioned HITL 2 dry-run simulation evaluations.

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 2 dry-run simulation evaluation scenarios
- Section 3 provides a summary of key decisions that were made during the workshop
- 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 June 2017 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 SENEAM-recommended changes to 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 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 Cancún airspace design team of the work that both SENEAM and MITRE have accomplished since the last airspace design workshop held in December 2016
- To facilitate discussions regarding procedural separation and sectorization matters, and further evaluate the MMUN/MMCZ TMA airspace design concept
- To present the results of the HITL 1 simulation evaluations
- To develop HITL 2 dry-run 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
- Cancún HITL 1 Simulation Evaluations: Results
- MMUN/MMCZ HITL 2 Dry-Run 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.

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.

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 STARs and SIDs were then reviewed, taking into consideration the procedural separation and sectorization of the MMUN procedures. These designs will be further evaluated during the upcoming HITL 2 simulation evaluations.

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 controllers (north and south). 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. These sector designs will be further evaluated during the upcoming HITL 2 simulation evaluations.

2.4 SENEAM-MITRE HITL 2 Dry-Run Scenario Development

The airspace design workshop provided an opportunity for SENEAM and MITRE to develop scenarios to be used during the upcoming HITL 2 dry-run simulation evaluations. 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 (e.g., Arrival, Approach, Final Monitor, and Departure, as appropriate).

The overall objective of the HITL simulation evaluations 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 2 simulation evaluations 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 observations during the simulation scenarios.

The SENEAM/MITRE team identified six scenarios to be used to familiarize the SENEAM controllers that will participate in the HITL 2 dry-run simulation evaluations, 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 2 Dry-Run Simulation Evaluations: Practice Scenarios 1 through 6

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 Simulation
Practice Scenarios 1 and 2	MMUN Runway 12 Arrival and Approach	1. Refamiliarize controllers with airspace design and procedures 2. Introduce new arrival and departure airspace 3. Introduce new procedures	MMUN 12	Arrival North Approach North Arrival South Approach South	4
Practice Scenarios 3 and 4	**3A/4A:** MMUN Runway 12, MMCZ Runway 11 Departure **3B/4B:** MMUN Runway 30, MMCZ Runway 29 Departure	1. Refamiliarize controllers with airspace design and procedures 2. Introduce new arrival and departure airspace 3. Introduce new procedures	**A Scenarios:** MMUN 12, MMCZ 11 **B Scenarios:** MMUN 30, MMCZ 29	Departure North Departure South	2 for each scenario
Practice Scenarios 5 and 6	MMUN Runway 30 Arrival and Approach	1. Refamiliarize controllers with airspace design 2. Introduce new arrival and departure airspace 3. Introduce new procedures	MMUN 30	Arrival North Approach North Arrival South Approach South	4

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Table 2. HITL 2 Dry-Run Simulation Evaluations: Actual 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 Simulation
Actual Scenarios 1 and 2	Holding MMUN Runway 12 Arrival and Approach	1. Evaluate holding pattern locations in relation to departures and arrivals 2. Evaluate airspace boundaries when using holding patterns 3. Evaluate holding pattern altitudes 4. Evaluate holding complexity during dual independent operations	MMUN 12	Arrival North Approach North Arrival South Approach South	4
Actual Scenarios 3 and 4	Holding MMUN Runway 30 Arrival and Approach	1. Evaluate holding pattern locations in relation to departures and arrivals 2. Evaluate airspace boundaries when using holding patterns 3. Evaluate holding pattern altitudes 4. Evaluate holding complexity during dual independent operations	MMUN 30	Arrival North Approach North Arrival South Approach South	4
Actual Scenarios 5 and 6	Missed Approaches, Breakouts, Blunders MMUN Runway 12 Approach and Final Monitor	1. Evaluate missed approach procedures 2. Evaluate separation between aircraft on the missed approach procedures and departures on the ROTGI and VOBED SIDs 3. Introduce/evaluate breakout procedures when aircraft are outside the final approach fix 4. Introduce/evaluate breakout procedures when aircraft are inside the final approach fix 5. Perform/evaluate blunder procedures	MMUN 12	Arrival North Approach North Arrival South Approach South	4
Actual Scenarios 7 and 8	Missed Approaches, Breakouts, Blunders MMUN Runway 30 Approach and Final Monitor	1. Evaluate missed approach procedures 2. Evaluate separation between aircraft on the missed approach procedures and departures on the ROTGI and VOBED SIDs 3. Introduce/evaluate break out procedures when aircraft are inside the final approach fix 4. Introduce/evaluate break out procedures when aircraft are outside the final approach fix 5. Perform blunder procedures	MMUN 30	Arrival North Approach North Arrival South Approach South	4
Actual Scenarios 9 and 10	MMUN and MMCZ Landing Direction Change MMUN Runway 12 to Runway 30 MMCZ Runway 11 to Runway 29 Arrival and Departure	1. Evaluate procedures during runway landing direction change 2. Determine if airspace is adequate during landing direction change 3. Evaluate operating dual independent approaches immediately after a landing direction change 4. Evaluate MMCZ landing direction change	MMUN 12 changing to MMUN 30 MMCZ 11 changing to MMCZ 29	Arrival North Departure North Arrival South Departure South	4

Table 3. HITL 2 Dry-Run Simulation Evaluations: Actual 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 Simulation
Actual Scenarios 11 and 12	MMUN and MMCZ Landing Direction Change MMUN Runway 30 to Runway 12 MMCZ Runway 29 to Runway 11 Arrival and Departure	1. Evaluate procedures during runway landing direction change 2. Determine if airspace is adequate during landing direction change 3. Evaluate operating dual independent approaches immediately after a landing direction change 4. Evaluate MMCZ landing direction change	MMUN 30 changing to MMUN 12 MMCZ 29 changing to MMCZ 11	Arrival North, Departure North Arrival South, Departure South	4
Actual Scenarios 13 and 14	Independent to Dependent Approaches, Offload STARs, Combining Sectors MMUN Runway 12 MMCZ Runway 11 Arrival, Approach, Departure	1. Examine combining Arrival North/South and Approach North/South sectors 2. Examine the timeframe for controllers to notice differing speeds on same SID aircraft 3. Introduce/evaluate offload routes for downwinds and baselegs 4. Evaluate runway balancing options for both Arrival positions 5. Introduce dependent approaches	MMUN 12 MMCZ 11	Arrival North, Approach North Arrival South, Approach South Combining to: Combined Arrival North/South Combined Approach North/South Departure North, Departure South	4; changing as configuration changes
Actual Scenarios 15 and 16	Independent to Dependent Approaches, Offload STARs, Combining Sectors MMUN Runway 30 MMCZ Runway 29 Arrival, Approach, Departure	1. Examine combining Arrival North/South and Approach North/South sectors 2. Examine the timeframe for controllers to notice differing speeds on same SID aircraft 3. Introduce/evaluate offload routes for downwinds and baselegs 4. Evaluate runway balancing options for both Arrival positions 5. Introduce dependent approaches	MMUN 30 MMCZ 29	Arrival North, Approach North Arrival South, Approach South Combining to: Combined Arrival North/South Combined Approach North/South Departure North, Departurte South	4; changing as configuration changes
Actual Scenarios 17 and 18	MMUN Landing Direction Change MMUN Runway 12 to Runway 30 MMCZ Runway 11 Arrival and Departure	1. Evaluate procedures during runway landing direction change 2. Determine if airspace is adequate during landing direction change 3. Evaluate operating dual independent approaches immediately after a landing direction change	MMUN 12 changing to MMUN 30 MMCZ 11 changing to MMCZ 29	Arrival North, Approach South Arrival South, Approach South Changing after runway change to: Arrival North, Departure North Arrival South, Departure South	4
Actual Scenarios 19 and 20	MMUN Landing Direction Change MMUN Runway 30 to Runway 12 MMCZ Runway 11 Arrival and Departure	1. Evaluate procedures during runway landing direction change 2. Determine if airspace is adequate during landing direction change 3. Evaluate operating dual independent approaches immediately after a landing direction change	MMUN 30 changing to MMUN 12 MMCZ 29 changing to MMCZ 11	Arrival North, Approach South Arrival South, Approach South Changing after runway change to: Arrival North, Departure North Arrival South, Departure South	4

3. Key Decisions

This section provides a summary list of the key decisions that were made during the June 2017 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 waypoints were added on the MMUN TMA boundary for coordination and handoffs to/from the Mérida Area Control Center (ACC)
- The MMCZ EMOSA STAR was moved east to provide additional lateral spacing with the MMUN NOSAT SID
- The MMUN DANUL STAR was moved so as to not have three STARs merge at the same point
- The MMUN Runway 12R TAKUX and DANUL SIDs were changed to straight-out departures. These are low use departure routes and even with this change, SENEAM can conduct independent departure operations through appropriate ground flow management of departure aircraft.
- The MMCZ Runway 11 and Runway 29 CZ500 SIDs were added
- The separation between the MMUN Runway 12 NOSUG and ROTGI SIDs was reduced and the design was amended
- The APP and Final Monitor airspace sectors were changed to allow for additional space for controller vectoring
- Runway change operations from Runway 12 to Runway 30 and from Runway 30 to Runway 12 operations at MMUN are to be included in the HITL 2 simulation evaluation scenarios
- Missed approach interactions with departures are to be included in the HITL 2 simulation evaluation scenarios
- Holding when ACC overloads the TMA and during weather situations when there are multiple go-arounds are to be included in the HITL 2 simulation evaluation scenarios

4. Closing Remarks

MITRE's June 2017 workshop 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 2 dry-run simulation evaluations.

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:

- MITRE to prepare for HITL 2 dry-run simulation evaluations
- SENEAM/MITRE to conduct dry-runs for the HITL 2 simulation evaluations at MITRE's ATM Laboratory from 7 through 11 August 2017
- SENEAM/MITRE to conduct HITL 2 simulation evaluations at MITRE's ATM Laboratory planned for 28 August 2017 through 1 September 2017
- MITRE to perform a post evaluation analysis of the HITL 2 simulation evaluation results