Enclosure

(Ref. Technical Letter F500-L15-015)

MITRE

Center for Advanced Aviation System Development

Cancún Airport Terminal Maneuvering Area Redesign

Airspace Methodology, Initial Data Analysis and Notional Airspace Concepts

Prepared for

Aeropuertos y Servicios Auxiliares

March 2015

Principal Acronyms and Abbreviations

ACC	Area Control Center
ANSP	Air Navigation Service Provider
APP	Approach Control
ASUR	Aeropuertos del Sureste
ATC	Air Traffic Control
ATCT	Airport Traffic Control Tower
CCO	Continuous Climb Operations
CDO	Continuous Descent Operations
CTM	Chetumal VOR/DME
CZA	Chichen Itza VOR/DME
CZM	Cozumel VOR/DME
DGAC	Dirección General de Aeronaútica Civil
DME	Distance Measuring Equipment
FAA	Federal Aviation Administration
FAC	Final Approach Course
ft	feet
GA	General Aviation
IAP	Instrument Approach Procedure
ICAO	International Civil Aviation Organization
LOA	Letter of Agreement
MITRE	The MITRE Corporation
MMCZ	Cozumel International Airport
MMUN	Cancún International Airport
NAICM	Nuevo Aeropuerto de la Ciudad de México
NM	nautical miles
NTZ	No Transgression Zone
PMT	Project Management Team
POC	Point of Contact

SENEAM	Servicios a la Navegación en el Espacio Aéreo Mexicano
SID	Standard Instrument Departure
SMS	Safety Management System
STAR	Standard Terminal Arrival Route
TFM	Traffic Flow Management
TMA	Terminal Maneuvering Area
U.S.	United States
VFR	Visual Flight Rules
VHF	Very High Frequency
VOR	VHF Omnidirectional Range

1. Introduction

The MITRE Corporation (MITRE) is assisting the government of Mexico to turn into reality the construction of a new airport for Mexico City, hereinafter referred to as the Nuevo Aeropuerto Internacional de la Ciudad de México (NAICM). In connection with that, MITRE has been informed that the Aeropuerto Internacional de Cancún (hereinafter referred to by its 4-letter International Civil Aviation Organization [ICAO] code of MMUN) is considering the implementation of independent approach and departure operations to/from its two existing parallel runways. This would provide a significant increase in capacity for MMUN. Moreover, it would also allow MMUN to serve as a test 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.

1.1 Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM) and MITRE Coordination Activities

As part of the assistance being provided to SENEAM to plan the necessary changes that will permit the introduction of independent approach and departure operations at MMUN, SENEAM and MITRE have conducted several senior-level meetings and telephone conference calls over the last three months to help ensure that SENEAM is made fully aware of the many aspects and tasks that must be completed to transition smoothly to these complex arrival and departure operations. Most recently, on 25 February 2015, a meeting was held in Mexico City with CTA Bruce Magallón (Deputy Director General, Air Traffic Services) that sought to set up over the coming weeks a SENEAM Project Management Team (PMT) dedicated to preparing for the implementation of independent approach and departure operations at MMUN. In addition, it was agreed that a draft project plan would be prepared by SENEAM (with an estimated completion goal by the end of March 2015) that would be reviewed jointly with MITRE afterwards. This SENEAM-prepared project plan will form the basis of determining the individual tasks and timescales to achieve the implementation of the procedures at MMUN.

In addition, MITRE prepared a data request document that was submitted to SENEAM in January 2015 (see enclosure 4 of MITRE Technical Letter F500-L15-007, dated 12 January 2015 for additional details). In the last several weeks SENEAM has provided MITRE with some, but not all of the required data. SENEAM is still in the process of collecting appropriate data for use by MITRE to conduct its aeronautical work.

1.2 Purpose and Structure of this Document

The purpose of this document is to describe the airspace design methodology that MITRE typically uses in its airspace redesign projects. This process will be used as the basis for the redesign of MMUN airspace as well as assisting in identifying key elements for consideration during the redesign work. In addition, this document also shows the results of some of the initial analyses that MITRE has conducted considering the operational data that has been provided by SENEAM so far. Finally, this document provides a description of two initial notional airspace concepts developed by MITRE for the MMUN airspace that are intended to assist in starting the airspace design process with SENEAM.

This document is structured as follows:

- Section 2 contains a description of the generic airspace design methodology MITRE typically follows in its airspace design projects for both the United States (U.S.) Federal Aviation Administration (FAA) and other countries.
- Section 3 provides an outline of MITRE's operational concept for handling independent arrival and departure operations at MMUN.
- Section 4 presents results from MITRE's initial analyses using the operational data provided so far by SENEAM.
- Section 5 contains two initial notional airspace concepts for MMUN considering independent arrival and departure operations.
- Section 6 provides a summary and discusses next steps.

2. MITRE's Generic Airspace Design Methodology

MITRE has been involved in the analysis and redesign of airspace within the U.S. as well as many other countries around the world. MITRE uses the methodology described in this section as a basis for airspace redesign projects and adapts it as necessary to the particular project needs and conditions within each country and location. Section 2.1 describes how MITRE's airspace design methodology has been adapted for the MMUN project.

MITRE's generic airspace methodology has three phases:

1. Screening
2. Study
3. Implementation

Key points between each of the phases allows decision-makers to make appropriate strategic decisions regarding the continuation of the project to the next phase. Figure 1 depicts graphically MITRE's airspace redesign process.

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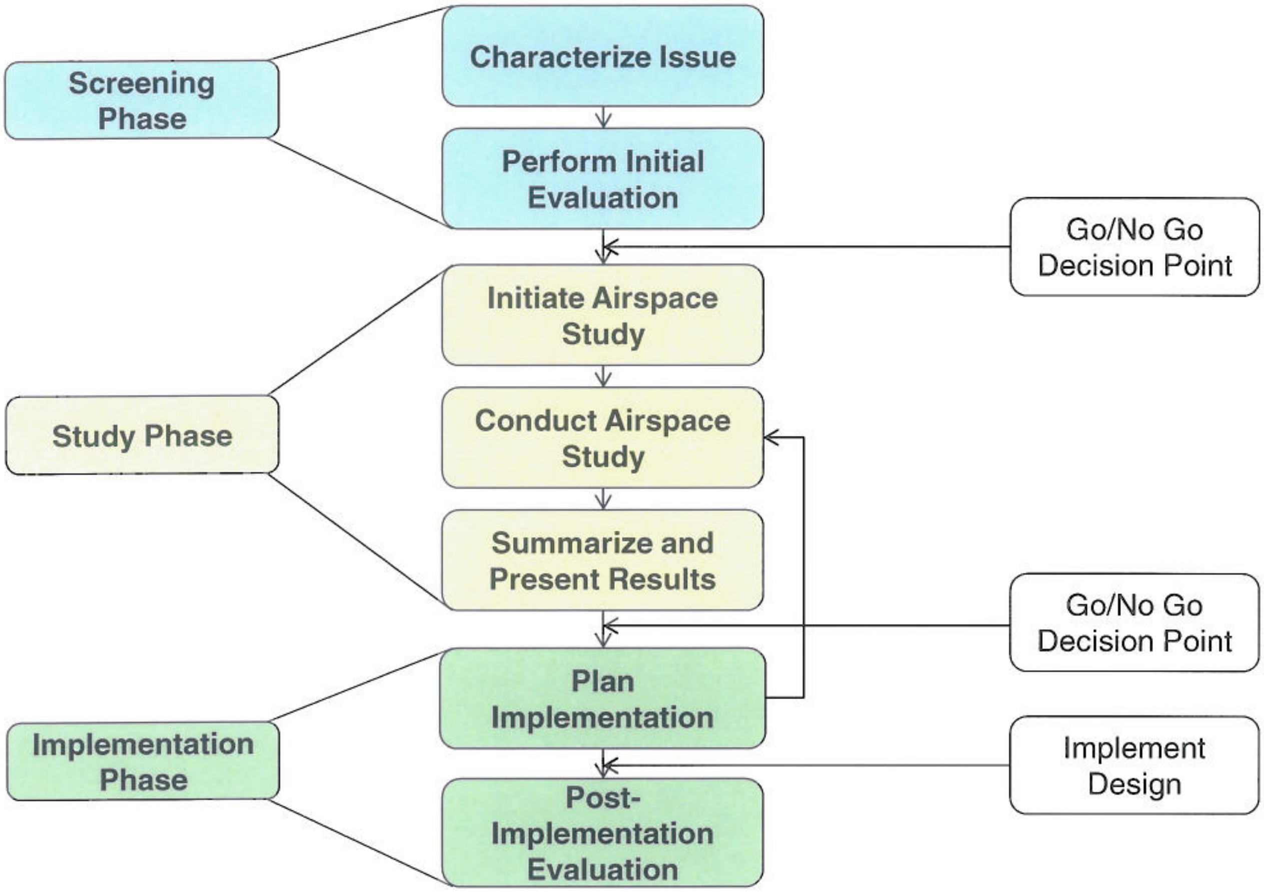

Figure 1. MITRE's Generic Airspace Redesign Methodology

During the screening phase, any airport- or Air Traffic Control (ATC)-related operational issues adversely affecting the safety and efficiency of the current operation are identified through discussions with controllers and analyses of operational data. The conversations and analyses help inform the airspace designers which operational areas are in most need of improvement, and thus where they need to concentrate their redesign efforts. During the screening phase, airport layout, aircraft ground movement flows, Standard Instrument Departures (SIDs), Standard Terminal Arrival Routes (STARs), radar vector patterns and other procedures are studied to help familiarize the airspace designers with the local operation. This is typically done by interviewing ATC personnel, including air traffic controllers and other airport and ATC operational and technical staff, and gathering a considerable quantity of airport and ATC operational data. If necessary, depending on each country's regulations, a decision regarding the need for environmental assessments and Safety Management System (SMS) requirements (outside the scope of MITRE's work) would be made at this stage and the length of time to complete these important aspects should be taken into account when developing the project plan. Once this phase is complete, decision-makers are typically allowed the opportunity to examine the findings of the evaluations and determine if the airspace redesign project should continue into the study phase.

In the study phase, an airspace study is initiated and the development and evaluation of an airspace redesign is conducted. Initiating the airspace study starts with establishing the project structure and support teams that will be responsible for overseeing the redesign and evaluation of the airspace, as well as the implementation of the design and post-implementation analysis. To assist the project team an overall project plan is developed with target dates for each of the major milestones of the airspace study. The milestones should be established at a level that allows the project team to track and determine the progress of each part of the project. These milestones will also help identify any delays in the completion of critical tasks and its impact on the overall project schedule. Responsibility for different aspects of the project should be assigned to a team manager, who in turn has teams of people working to accomplish their specified project task. For instance, one aspect of the project plan is determining the ATC equipage requirements to support the proposed airspace design. This task must also include the planning for acquiring, installing and testing of this equipment while also ensuring that any necessary equipment will be ready for operational use at the time when it is needed. This would be just one team with a team manager, working on this particular aspect of the project. Other teams would be working in parallel on other essential aspects. Once the project structure is developed and put in place the rest of the study phase, primarily consisting of the development and evaluation of the airspace design can begin.

The development of an airspace design requires an airspace redesign team. This team should consist of ATC personnel with local knowledge of the airport(s) and airspace that will be effected by any proposed changes, industry stakeholders (e.g., airlines, military and General Aviation [GA]), ATC support personnel (i.e., procedure designers, automation specialists), environmental analysts, airport authority personnel, aviation regulators, and other local offices/personnel deemed necessary by project managers. This team will attempt to address the issues identified in the screening phase, and redesign the routes, procedures, airspace structures and sectors as necessary to accomplish the project goals. Operational evaluations of the resulting airspace design are accomplished in a joint effort between the Air Navigation Service Provider (ANSP) and industry (e.g., airlines) to ensure that the airspace design meets design criteria and will be flyable by the types of aircraft that will be using these procedures. The evaluation tools available include spreadsheet analysis tools, fast-time simulations, aircraft flight simulators and real-time interactive simulations involving controllers and pilots.

It is also during the study phase that any environmental and SMS studies are conducted, depending on the regulatory requirements of the country. The length of time for these studies can be considerable, and should be considered when developing the overall project plan.

At the end of the study phase, the goal is to have a single airspace design that has been assessed as suitable for implementation.

After the study phase, there is another decision point for decision-makers to determine if the design should continue into the implementation phase. If the decision is made to implement, an implementation team is established that will be charged with the responsibility of ensuring the successful implementation of the design. The members of the implementation team should consist of ATC personnel, ATC support personnel such as technical staff associated with ATC equipment hardware and software, automation, procedures designers, and controller training. In addition, other important staff include public outreach officials, airport authority personnel, and industry stakeholders.

Following the implementation of the airspace design, a post-implementation team should be formed to conduct post-implementation monitoring and evaluations. This team determines if the original issues were resolved and project goals achieved by the changes to the airspace and procedures that were just implemented, or if any adjustments to the implemented airspace design are necessary.

2.1 Application to MMUN

The MMUN project methodology differs in some respects from the generic airspace methodology discussed in the previous section because the decision to implement independent arrival and departure operations has already been made. As previously mentioned, the goal is to create an airspace design that will allow for independent arrival and departure operations at MMUN and to serve as an environment where air traffic controllers can gain experience with independent operations before NAICM becomes operational. As a result, the decision point to move from the screening to study phase has already occurred and the MMUN project is now at the start of the study phase.

The PMT and supporting teams need to start the many tasks necessary for designing and implementing independent operations at MMUN, so the PMT and support team should now be established. An overall project plan should now be developed for which the PMT is responsible. As mentioned earlier, MITRE has had initial meetings and telephone conversations with SENEAM to provide guidance on the necessary tasks and milestones that should be included in the project plan. The goal is for SENEAM to develop an initial project plan for discussion with MITRE in the April 2015 timeframe.

Shortly after establishing the MMUN project plan, an airspace team should be established with representatives from the ATC facilities, i.e., Mérida Area Control Center (ACC), MMUN Approach Control (APP), MMUN Air Traffic Control Tower (ATCT), Cozumel International Airport (hereinafter referred to by its four-letter ICAO code MMCZ) ATCT, and Traffic Flow Management (TFM) in charge of operations over eastern Mexico. These representatives should include operational air traffic controllers, airspace and ATC procedures experts, ATC system automation personnel, and any other local facility representatives deemed necessary by local management. In addition to the local ATC facility representatives, team members could include representatives from the main airlines that fly into MMUN (e.g., Aeroméxico, Volaris, Interjet), an environmental specialist, regional and/or national procedure design specialist(s), an airport authority representative and possibly a representative from the GA community. This will be the core group that will be responsible for designing the routes, procedures and ATC sectors to support independent operations.

3. MITRE's Operational Concept for Independent Arrival and Departure Operations at MMUN

This section discusses the various aspects of operational concepts that support independent arrival and departure operations, key ATC procedure criteria, airspace design aspects and controller operational techniques.

3.1 MMUN Operational Concept

Similar to the current operation, arrival traffic will enter the MMUN Terminal Maneuvering Area (TMA) at pre-determined entry points located on the boundary shared with the enroute airspace. A revised Letter of Agreement (LOA) will cover how these aircraft must be delivered from the enroute airspace to the TMA. The enroute air traffic controllers will clear arrivals to enter the TMA via the appropriate STAR. Transfer of control and communications to the MMUN TMA will take place prior to aircraft entering the TMA. Enroute controllers will be required to deliver arrival aircraft over the same entry point at pre-determined spacing (e.g., Miles-in-trail spacing) that will be determined by the terminal controllers or TFM. The required amount of spacing will be determined according to such factors as weather, runway conditions and work-in-progress on the airport that can all affect how quickly arriving aircraft can exit a runway.

Once inside the TMA, aircraft flying on a STAR will generally remain on the STAR unless operational conditions (e.g., other aircraft, weather, sequencing requirements, etc.) require air traffic controllers to vector the aircraft off the STAR. Once vectored off the STAR, aircraft can either be re-cleared to rejoin the STAR or continue to be vectored to the Final Approach Course (FAC). The STAR can either end at a point-in-space, not on the Instrument Approach Procedure (IAP), otherwise known as an open transition, or continue to join the IAP, known as a closed transition. Aircraft on open transitions will be vectored from the STAR termination point to the FAC. Typically, in the U.S. and elsewhere open transitions are used most often, primarily because they offer the most flexibility for terminal controllers to provide the appropriate longitudinal spacing on final approach.

Arrival traffic coming from the different entry points on the TMA boundary will be merged and sequenced by terminal controllers into the appropriate landing sequence. Merging of the multiple streams of aircraft arriving to the designated arrival runway is generally done away from the airport so that a landing sequence is already established, with appropriate spacing, prior to aircraft being turned on to the FAC. Dual independent arrivals permit aircraft to be sequenced to two different runways independently of the arrival flow to the adjacent runway. When conducting independent operations, a maximum angle of 30 degrees is permitted when turning aircraft onto the FAC. Aircraft must be vertically separated by a minimum of 1000 feet (ft) and/or 3 nautical miles (NM) laterally until they are established on the FAC[1] and transfer of control and communications of the aircraft has been accomplished to a "final monitor"

[1] Generally, 1000 ft vertical separation is used in lieu of 3 NM radar separation once aircraft are on base leg, or the intercept heading for the FAC.

controller.[2] Once that has been successfully accomplished the 1000 ft vertical separation or 3 NM lateral separation is no longer required between aircraft on adjacent FACs. The final monitor controller monitors the aircraft as it proceeds along the FAC. The responsibility of the final monitor is to ensure the appropriate longitudinal separation is maintained between aircraft on the same FAC and to take appropriate action in the event an aircraft deviates away from the FAC and penetrates the No Transgression Zone (NTZ)[3]. If the monitor controllers observe an aircraft deviating from its approach path toward the NTZ, the controller for that approach path will issue instructions to the aircraft to turn back to its correct approach path. Should monitor controllers observe an aircraft entering or about to enter the NTZ, then the controller for the adjacent approach path should instruct the affected aircraft to discontinue its approach and turn and climb to avoid the deviating aircraft.

A point at a predetermined distance from the arrival runway(s) will be used as the location which aircraft must be established on the FAC and the transfer of control and communication is switched to the joint tower/final monitor frequency. This predetermined distance is typically known as the "aiming point" (see Figure 2). The aiming point line extends across both FACs at a distance approximately 2 NM from the point on the FAC at which the highest aircraft will begin its descent. This is typically known as the "dual line". The transfer of control and communications to the joint tower/final monitor frequency at or before the dual line allows enough time for the flight crew to change frequencies and establish communications with the joint tower/final monitor controller prior to vertical separation being lost between aircraft on the adjacent parallel FAC. Intercepting the FAC at or outside the dual line should be accomplished via vectoring or with an approach transition from the STAR. The dual line will be determined by instrument procedure designers when designing the instrument approach procedures. At this point in time, the dual line or the aiming point for MMUN has not yet been determined since no procedure design work has been started.

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[2] Generally, the final monitor controller is monitoring the tower frequency for the runway to which the approach is being conducted. The approach controller changes the aircraft to the tower frequency prior to the aircraft losing separation with the aircraft on the adjacent FAC. The final monitor controller monitors this tower frequency and has override capability of the tower communications position in the event communications with a deviating aircraft are necessary.

[3] A NTZ is a 2000 ft wide zone located equidistant between the parallel-runway FACs in which flights are not allowed.

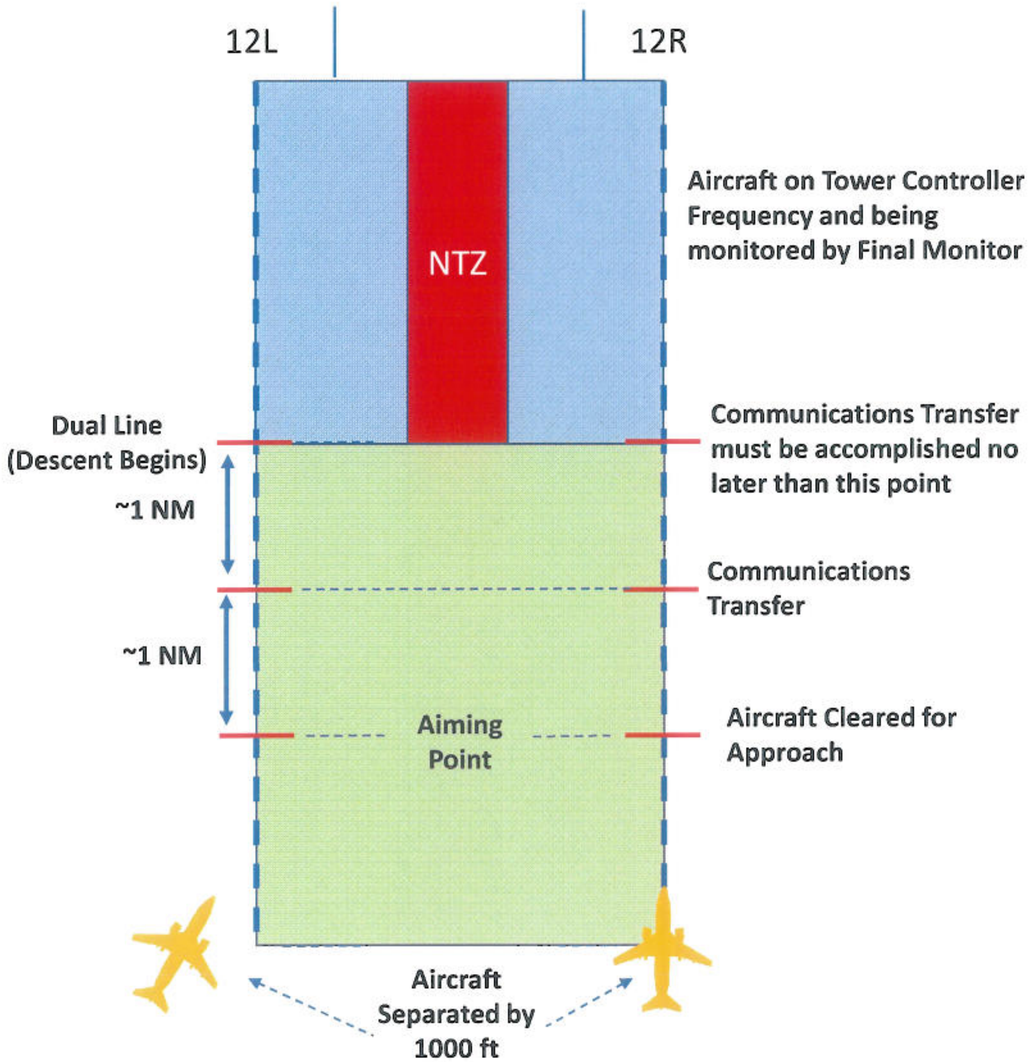


Figure 2. Dual Line and Transfer of Control and Communications

For independent departure operations, the departing traffic can depart on either of the two runways but are restricted in the direction the aircraft can turn due to other aircraft departing on the adjacent runway possibly at the same time. As a result, during independent departure operations, the allocation of the departure runway for a particular flight is done prior to taxi for takeoff. Typically, to avoid airspace conflicts, departure runways are allocated according to the exit fix and SID that a departing aircraft will fly. For instance, a potential departure runway allocation strategy at MMUN could be that aircraft departing to the east and north would depart using Runway 12L and aircraft departing to the south and west would depart using Runway 12R. Since, during independent departure operations two aircraft can depart the parallel runways at the same time, the departure procedures from the two runways must diverge as quickly as possible instead of continuing to fly a parallel course to ensure lateral radar separation is achieved within the first few miles of flight. In addition, it is recommended that divergence of at least 45 degrees or more is also built into different departure procedures that start from the same runway, so that one-minute departure separation can be used between consecutive departures, thus maximizing departure capacity at the airport. If this is not possible the following aircraft (assuming similar performance) will have to wait a minimum of an additional minute until the lead aircraft has attained adequate distance to ensure adequate vertical or lateral radar separation can be maintained once both aircraft are airborne.

3.2 Airspace Design Techniques

The design of the airspace routes and procedures has an impact on the workload experienced by controllers. It is typically the airspace designer's goal to reduce the overall controller workload as much as possible while balancing user requirements. The following items are examples of techniques that have been used by MITRE in many airspace redesign projects to help reduce the controller workload and airspace complexity.

- The departure procedures should be designed so that they cross under the arrival vector patterns or procedures (i.e., STARs) close to the airport. By having the arrival and departure procedures cross near the airport, vertical separation between these traffic flows can be more easily achieved without the need to require either or both traffic flows to level off. This helps to achieve Continuous Climb Operations (CCO) and Continuous Descent Operations (CDO).
- Departure and arrival traffic flows should be segregated as much as possible. This also helps to support unimpeded climbs and descents (CCO and CDO).
- The holding of aircraft (whether for traffic or weather) should be primarily done away from the airport in the enroute airspace. This increases available airspace within the TMA to allow the terminal controllers more flexibility to adequately sequence arrival traffic.
- Consideration should be given to provide separate arrival and departure routes for low performing aircraft (e.g., turboprop fixed-wing aircraft and/or helicopters). This helps to take these aircraft away from the routes/procedures that are used by the higher performing aircraft such as commercial jets, thus reducing airspace conflicts between traffic with significantly different performance. Where possible, it is very useful to have the low performing aircraft underneath the high preforming aircraft as quickly as possible to maintain vertical separation and thus minimize their effect on the higher-performing traffic flows.
- Offload arrival routes should be developed to assist in the balancing of traffic levels between the two runways. This is to minimize circumstances when one of the runways is overloaded, while the other is under-utilized.
- Airspace should be designed to allow arrival and departure operations for each runway to be operated independently. While air traffic controllers must be aware of the aircraft operating on the adjacent parallel runway and follow regulations for independent operations, operations on each runway should be conducted independently of the operations on the adjacent parallel runway to achieve the maximum overall runway capacity.

4. MMUN Initial Data Analysis

In order to appropriately examine airspace design matters it is important to analyze the current airspace operational environment. An analysis of operational data also creates a baseline to measure and demonstrate any improvements resulting from the proposed future operational environment. SENEAM provided MITRE with the following operational data:

- MMUN number of operations for 2013 and 2014 (except December 2014) as well as for each month of 2013 and 2014 (except December 2014). The annual operation totals for MMUN were 136,096 for 2013 and 133,134 for 2014 without the December monthly total.
- MMCZ number of operations for 2013, as well as for each month of 2013. The annual operation total for MMCZ was 13,911 for 2013.
- A typical peak traffic demand week (SENEAM selected 27 December 2014 through 2 January 2015 for a representative peak week operation) for all traffic operating inside the airspace controlled by Mérida ACC. Note that all hourly operational distributions in this document are shown in local time.
- A breakdown of the arrival operation percentages for European and Canadian flights, flights originating in Mexico and flights from other airports by month.
- Various other breakdowns of the annual operations for both MMUN and MMCZ that characterize the operations at annual and monthly levels.

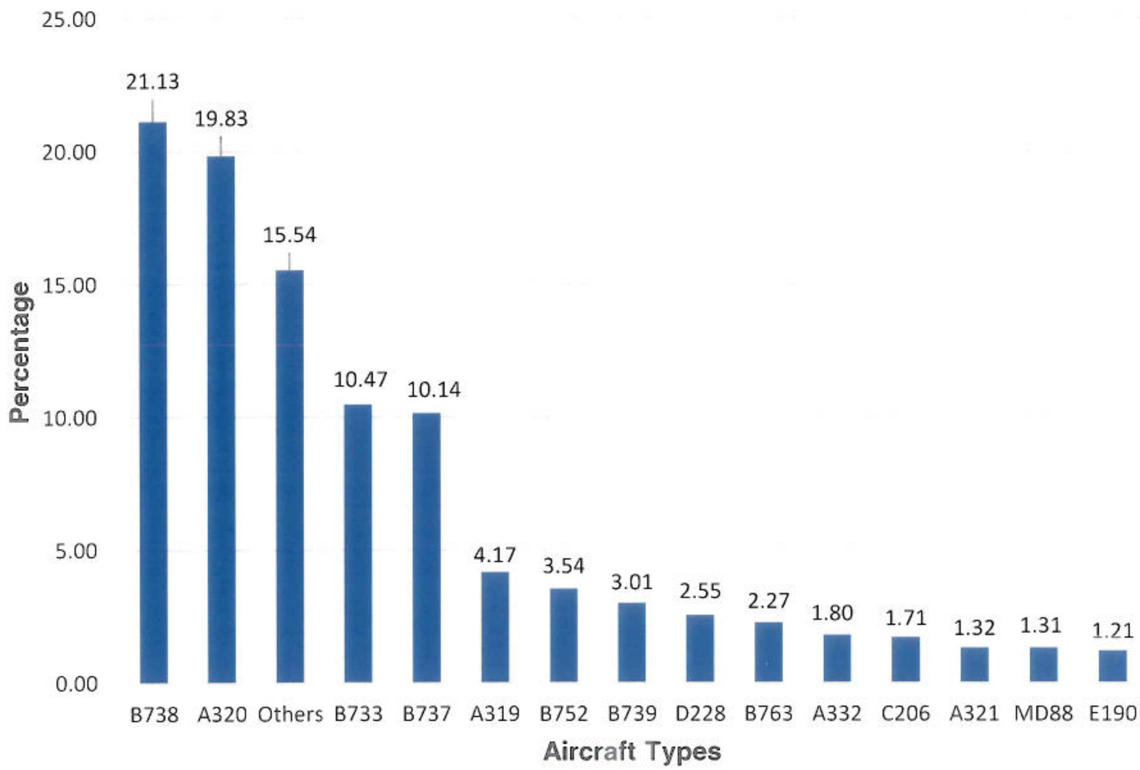
MITRE has begun analyzing the data provided by SENEAM to characterize the operations data both at the annual level and at the daily and hourly levels. At the annual level, MITRE analyzed the data to determine the types of aircraft (fleet mix) operating at MMUN and MMCZ. This information assists the airspace designers in understanding the performance of the aircraft the airport has to accommodate. In addition, the information will be used in evaluating the airspace design.

With the addition of the typical peak week operational data for the Mérida ACC traffic, MITRE examined the arrival and departure traffic distributions for each of the Mérida ACC airports (only MMUN and MMCZ are presented in this document). By concentrating on a typical peak week, it is possible to uncover issues that might not be evident during periods of the year with lighter traffic demand. MITRE also used the peak week data to determine the average hourly distribution of the Mérida enroute airspace entry and exit points. The entry and exit point analysis assists in determining which operations should be assigned to a specific runway.

4.1 Fleet Mix

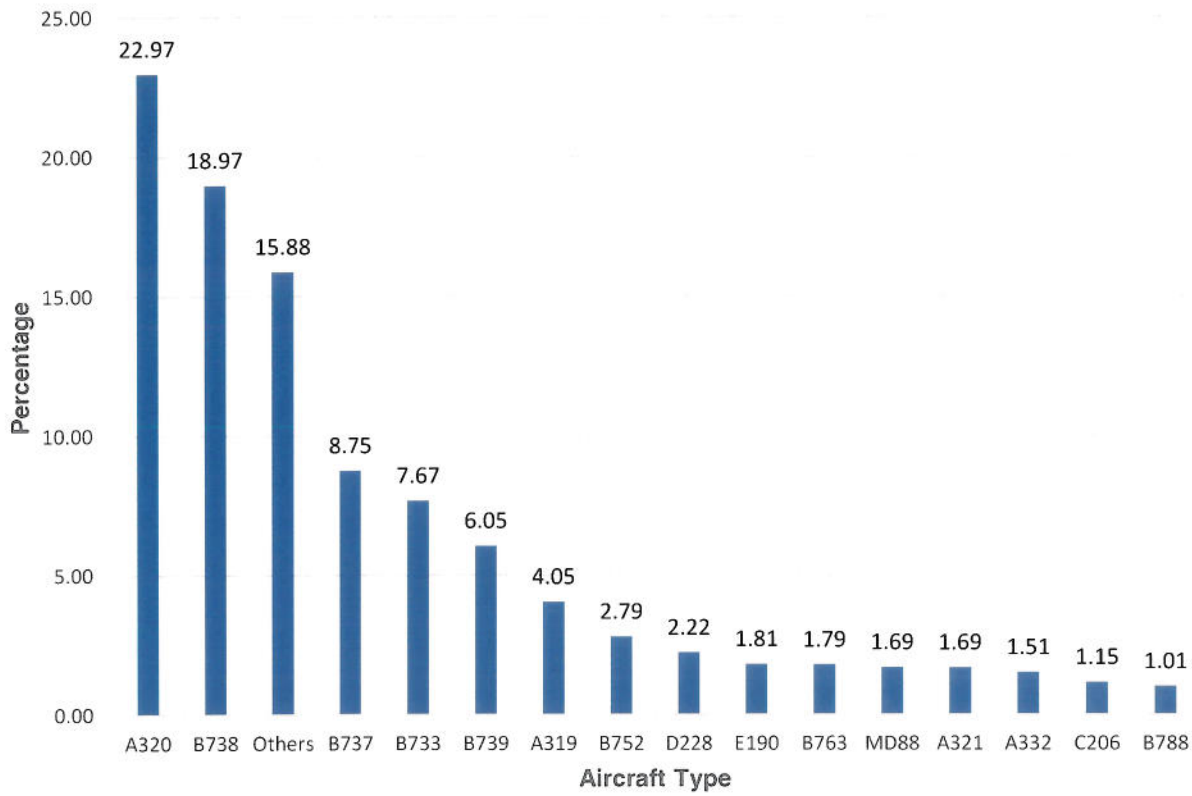
The yearly data for both MMUN and MMCZ were examined to obtain a representative sample of the types of aircraft that operate at these airports. This fleet mix information will be used to ensure that the routes in any proposed airspace design can be flown by a majority of the aircraft that operate at the relevant airport. It will also be used to help determine whether alternate routes designed for low performance aircraft could be useful.

In MITRE's analysis, the flights were grouped by aircraft type. The totals for each aircraft type were then divided by the total number of flights in that year to obtain the yearly percentage. Whether comparing the different years or individual airports, there were a large number of aircraft types that individually accounted for less than one percent of total operations. These types were grouped together into an "Others" category. These aircraft types varied dramatically from heavy commercial aircraft to business jets to light single-engine GA aircraft. It should be noted that this "Others" category totaled approximately 15 percent of total operations for both 2013 and 2014 at MMUN and approximately 17 percent of total operations for 2013 at MMCZ. While MITRE analyzed the fleet mix for other airports, only the fleet mix for MMUN is shown for both 2013 and 2014 (see Figures 3 and 4) and for MMCZ for 2013 (see Figure 5).



The "Others" category includes all aircraft types that individually had a frequency of occurrence of less than one percent

Figure 3. 2013 Fleet Mix for MMUN

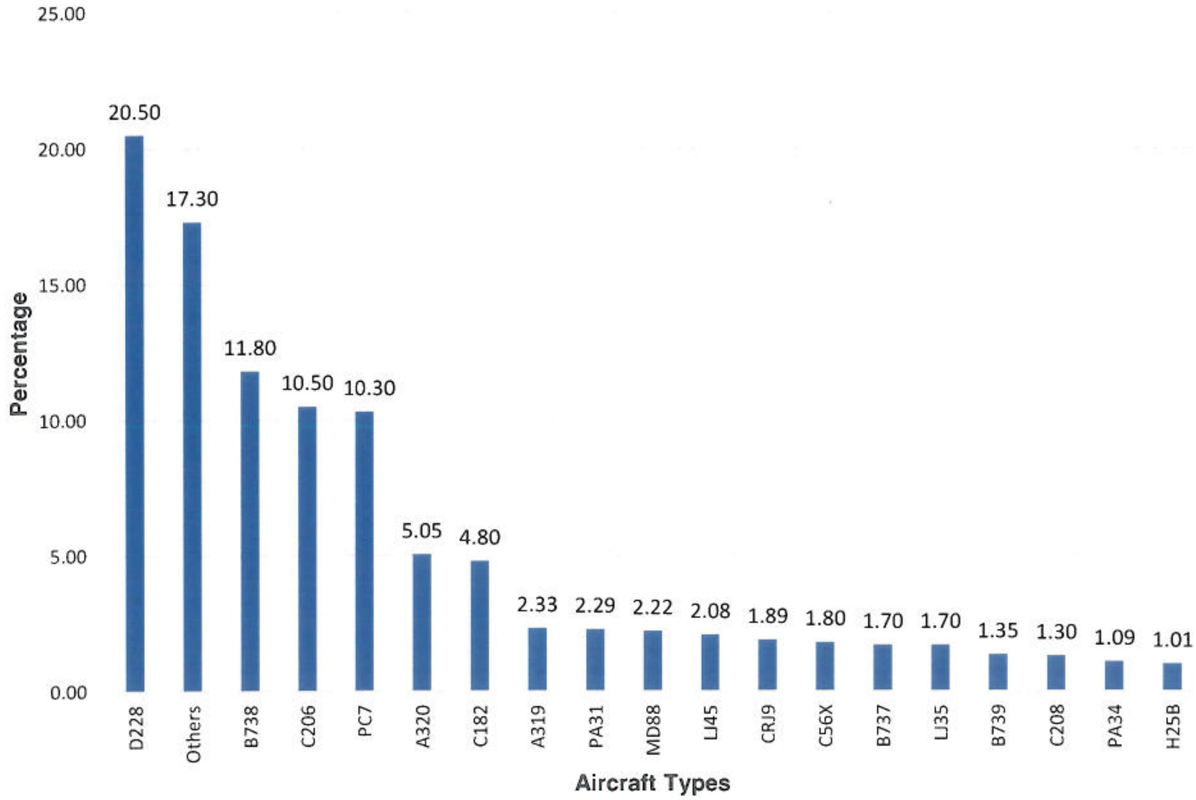


The "Others" category includes all aircraft types that individually had a frequency of occurrence of less than one percent

Figure 4. 2014 (through November) Fleet Mix for MMUN

The majority of the fleet mix at MMUN are medium size, narrow-body jets, with relatively few wide-body aircraft. In 2014, the largest categories of aircraft operating at MMUN are A320s and B738s, which together make up about 40 percent of the fleet mix. The aircraft type percentages drop significantly after that to approximately nine percent for the B737 and eight percent for the B733, and then to anywhere between six percent to around one percent.

The results for MMCZ also show that a few number of aircraft types are very prevalent. Most of the aircraft operating at MMCZ are turboprops, with the most frequent aircraft type being the Fairchild Dornier D228. See Figure 5.



The "Others" category includes all aircraft types that individually had a frequency of occurrence of less than one percent

Figure 5. 2013 Fleet Mix for MMCZ

The most frequent jet aircraft operating at MMCZ are B738s, which are used mostly on flights between MMCZ and the U.S. along with a few Canadian and other Mexican destinations. The C206 and the PC7, which are GA aircraft, represent around 10 percent each of the MMCZ fleet and are mostly used to conduct flights operating under Visual Flight Rules (VFR) either transiting between MMUN and MMCZ or training flights at MMCZ. Similar to the fleet mix at MMUN, there is a large (17 percent) "Others" category, which consists of individual aircraft types that account for less than one percent each of operations. Most of the aircraft types in this category are small jets and turboprops with the occasional Airbus or Boeing aircraft.

4.2 MMUN and MMCZ Arrival and Departure Analysis

It is also important to analyze the number of operations (arrivals and departures) at an airport to determine the busiest hours of the day, the busiest day of the week, how traffic flows vary throughout the day, and traffic demographics. This information allows the airspace designer to characterize the traffic arriving and departing the airport and develop an understanding of the peak traffic demographics. Some initial results of MITRE's analysis of the operations data received from SENEAM so far are presented in this document. Further analysis is ongoing.

MITRE's initial analysis studied the total number of operations for the typical peak traffic demand week that SENEAM selected, i.e. 27 December 2014 to 2 January 2015 (Saturday through Friday) for MMUN and MMCZ. The results show individual arrival and departure totals for each day of the week, as well as the hourly distribution across each day. Figures 6 and 7 show the total arrival and departure traffic for each day of the peak week for both MMUN and MMCZ, respectively.

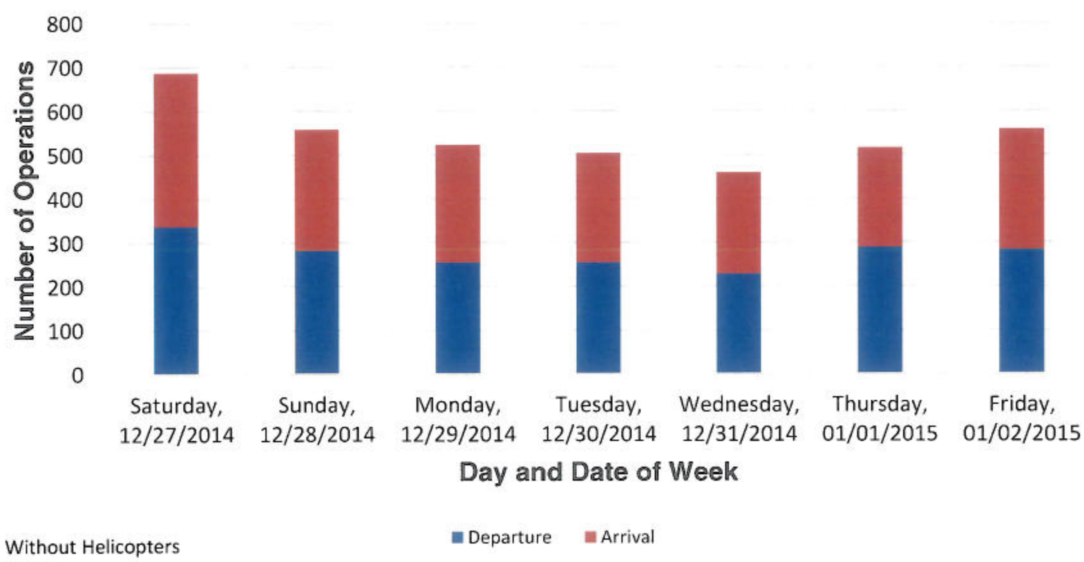


Figure 6. MMUN Daily Operations for a Typical Peak Week

Given that the MMUN and Riviera Maya areas are busy tourist destinations, the results of this analysis show, unsurprisingly, that the busiest days of the week for MMUN are Friday and Saturday, with Saturday 27 December 2014 being the busiest with a total of 688 operations that day, as well as the highest number of arrivals at 350 and departures at 338. The least busy day of the week is Wednesday with only 463 total operations.

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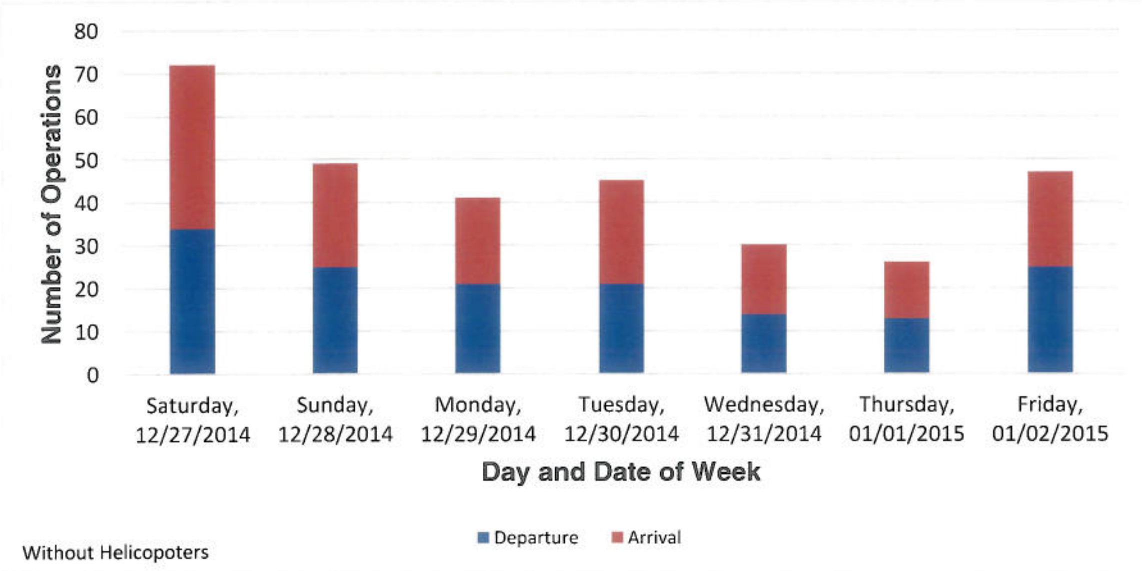

Figure 7. MMCZ Daily Operations for a Typical Peak Week

MMCZ, while considerably less busy that MMUN, follows a similar overall profile, with the busiest day of the seven-day period being Saturday 27 December 2014, with 72 total operations. That Saturday also happens to have individually the most arrivals (38) and the most departures (34). The least busy day of the week for MMCZ was Thursday, 1 January 2015, with a total of 26 operations, which breaks down into 13 arrivals and 13 departures for that day.

Typically, airspace designers want to use a representative peak traffic day on which to base their proposed airspace design. In the case of MMUN and MMCZ, MITRE proposes to use Saturday 27 December 2014 as a representative peak traffic day.

Continuing a more detailed analysis of the peak week, the days of the week were divided into hourly operations based on when the traffic arrived and departed each airport, see Figure 8 for MMUN and Figure 9 for MMCZ.

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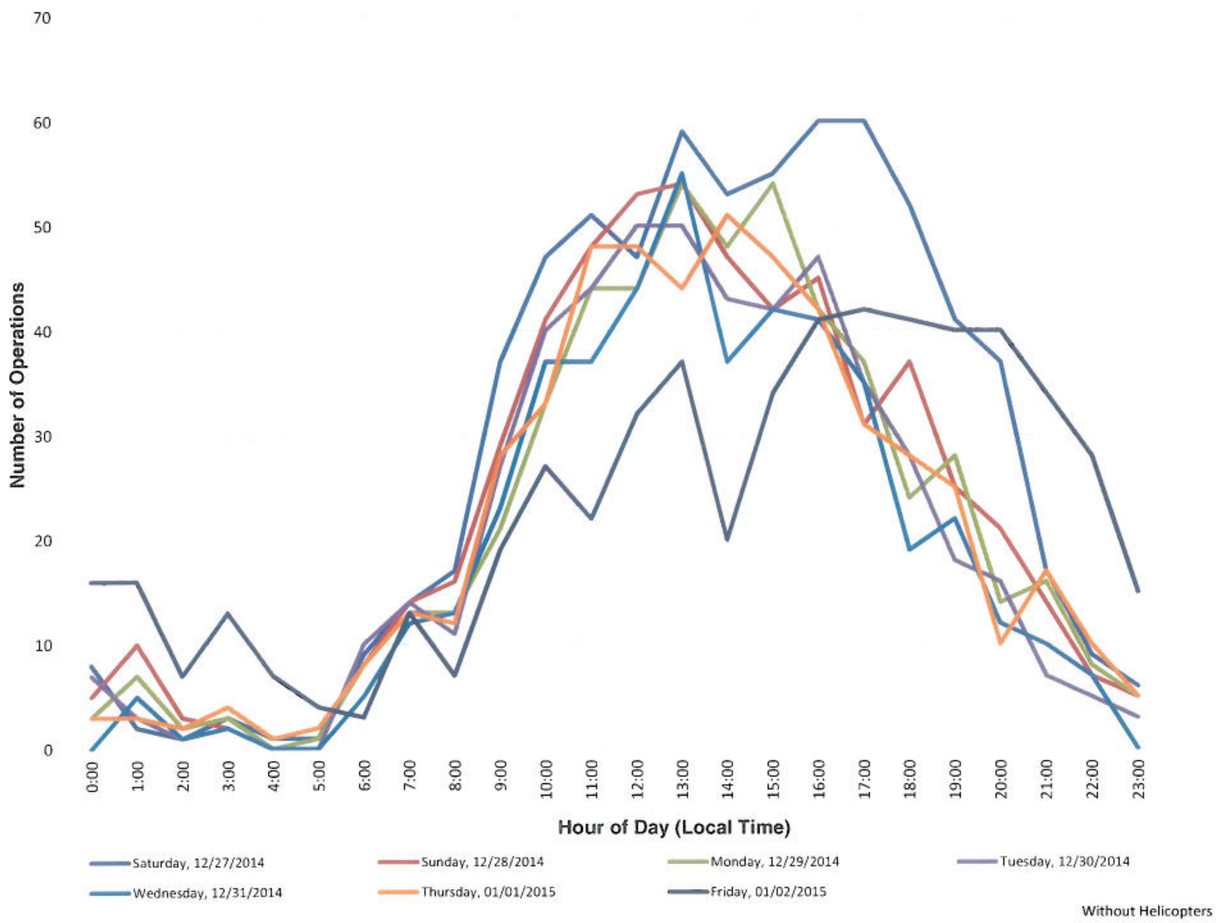

Figure 8. Hourly Operation Counts at MMUN (Typical Peak Week)

The busy period for the airport starts between 0800 and 0900 and lasts until between 2100 and 2200 hours. The busiest hour for most days occurs during the 1300 hour, except for Saturday 27 December 2014 where the highest hourly count occurred during the 1700 hour. The least amount of traffic occurred between the 2300 and 0500 hours. This is not surprising given the geographical location of the airport and the kind of passenger operations that the airlines serve (i.e., tourists).

MMCZ traffic was also examined for the hourly counts during each of the seven days of traffic data provided, and the results are shown in Figure 9.

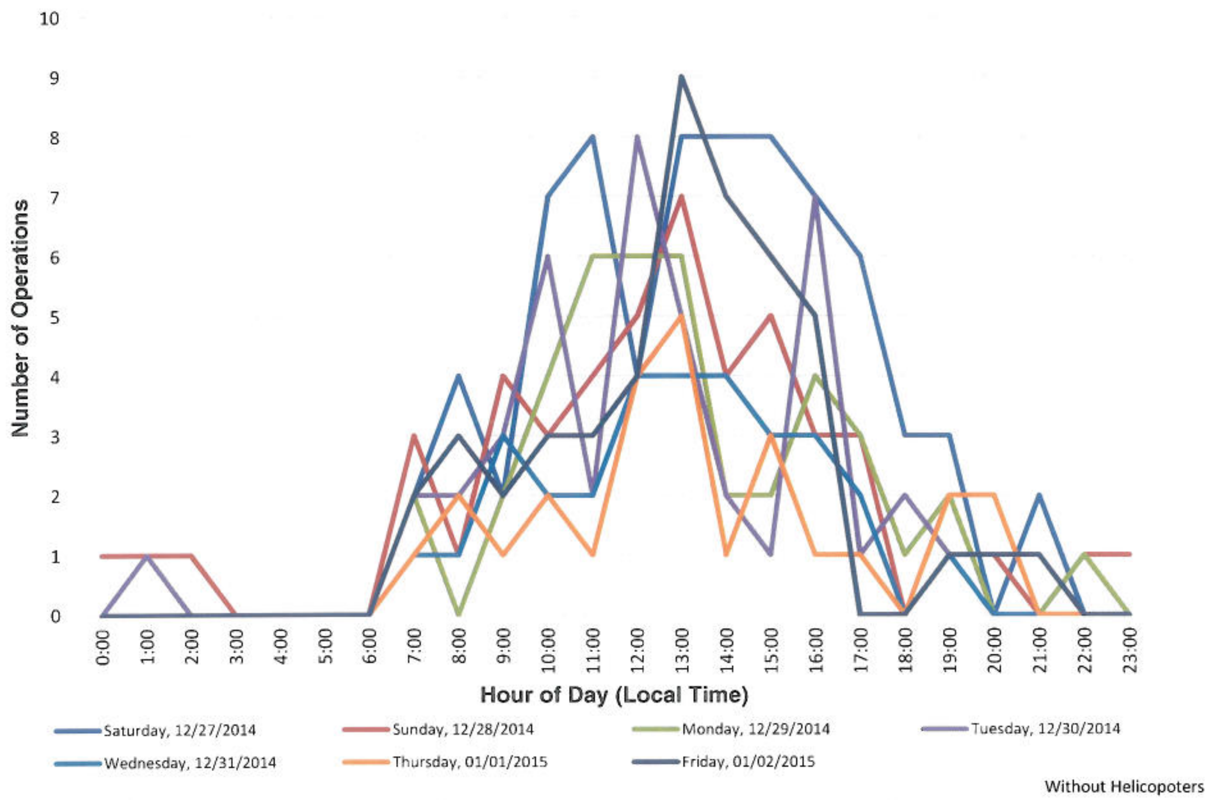

Figure 9. Hourly Operation Counts at MMCZ (Typical Peak Week)

At MMCZ, the busiest period of the day is between 0800 and about 1800, which likely corresponds to hotel and resort activity. MMCZ has more traffic variability, where one hour experiences a high number of aircraft and the next has only a few, when compared to MMUN where the traffic remains at a high level for a longer period of time. The most traffic in an hour is a total of nine operations that occurred during the 1300 hour on Friday, 2 January 2015. Compared with MMUN, MMCZ is a much smaller airport in terms of traffic volume. Also, it is important to mention that a significant portion of the MMCZ traffic flies back and forth to MMUN.

4.3 Analysis of Mérida's Enroute Airspace Entry/Exit Points

The Mérida ACC is responsible for the enroute airspace over the eastern part of Mexico, including over the Yucatán Peninsula. Neighboring ACCs are:

- Monterrey
- Houston
- Habana
- Mexico
- Central American

Analyzing the use of the various entry/exit points provides insight into the frequency of MMUN arrival and departure flights over enroute airspace boundary points throughout the day. The analysis was conducted using an average of the seven days from the peak week of operational data (27 December 2014 to 2 January 2015) provided by SENEAM. The hourly distribution of the seven days was totaled by hour and then averaged to provide a representative sample. As this analysis was done to determine the most frequently used enroute airspace entry and exit points, any point that did not have an average of five or more aircraft during the week was not considered.

Figure 10 shows the location of Mérida's enroute airspace boundary entry points associated with MMUN arrival traffic along with the average counts over the seven days for those points that had an average of five or more aircraft during the week. Note that even though the Cozumel (CZM) Very High Frequency (VHF) Omnidirectional Range (VOR)/Distance Measuring Equipment (DME) is not an entry point on the Mérida enroute airspace boundary it was included in the analysis due to the volume of traffic that flies between MMCZ and MMUN.

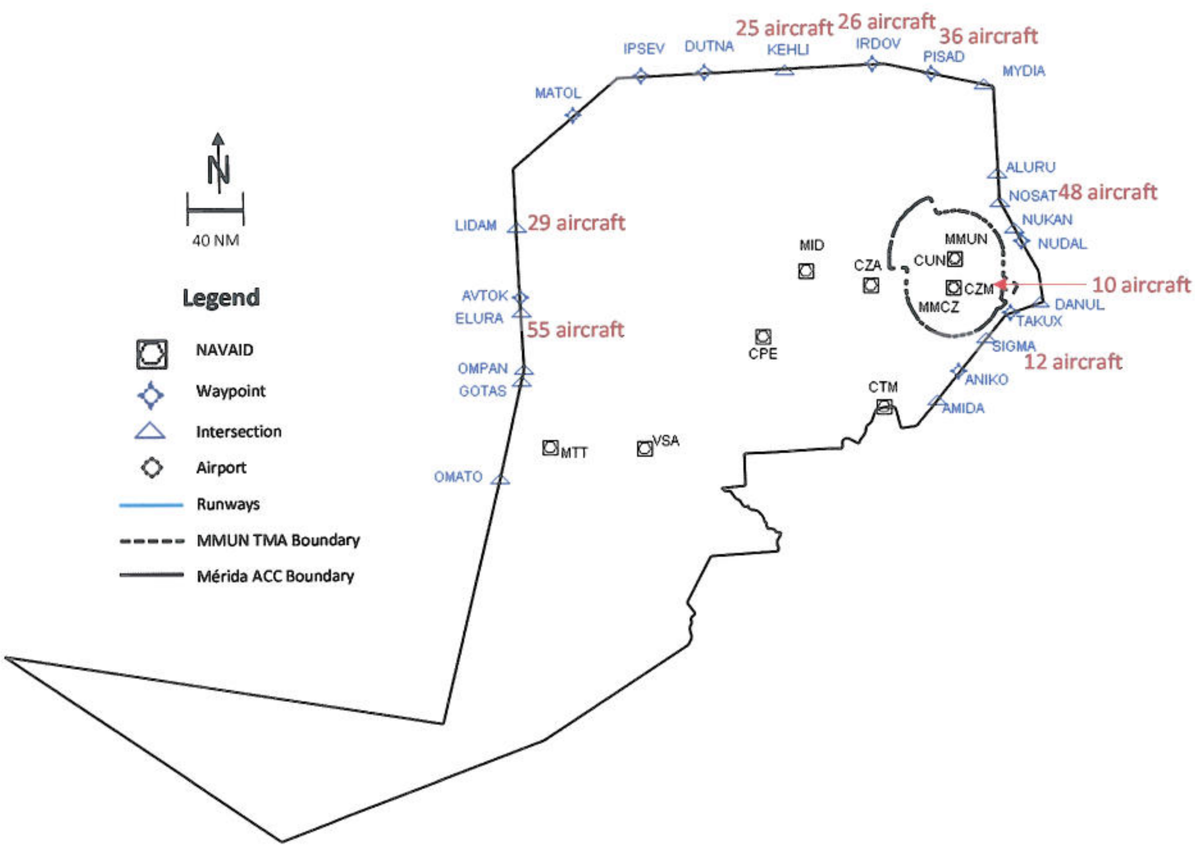

Figure 10. Mérida Enroute Airspace Entry Point Locations and Average Counts for MMUN Arrival Traffic

Distributing the average count for the entry points to their respective hours provides information regarding at what times of the day the entry points are used. Figure 11 below shows the hourly distribution of the most frequently used Mérida enroute airspace entry points associated with MMUN arrivals.

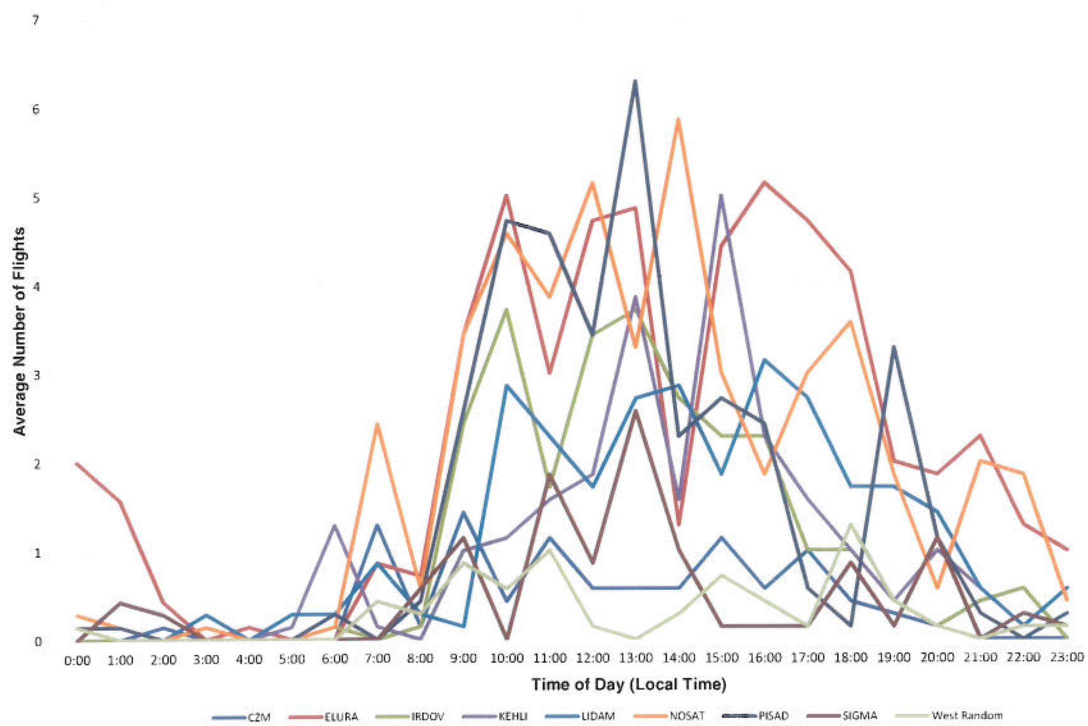

Figure 11. Mérida Enroute Airspace Entry Point Average Hourly Distribution for MMUN Arrival Traffic

The most frequently used entry point per hour is PISAD with an average of 6.3 flights in the 1300 hour. The entry point with the most flights over the entire average day was ELURA with 55 flights per day across the seven-day period. PISAD (located on the northern enroute airspace boundary) is used predominantly by flights from eastern Canada and the east coast of the U.S. ELURA (located on the western enroute airspace boundary) is the entry point into the Mérida's enroute airspace from many of the other airports within Mexico. As most of MMUN's arrival traffic comes from the west and the north and the fact that these two points show a high frequency of flights is not surprising.

There are also flights that did not fly over the named waypoints which were grouped together into categories based on directionality (i.e., West Random, South Random, etc.). For the most part these averages were below one flight for the week, but the random flights from the west averaged seven flights over the week and has been shown in Figure 11.

The times of day that show the least number of arrivals is between the 0200 and 0600 hours with the lowest number (0) of arrivals over all entry points occurring during the 0300 and 0400 hours. Whereas, the busiest times of day are between the 0900 and 1900 hours with the peak (30) number of arrivals over all of the entry points occurring during the 1300 hour.

The same analysis was done for the MMUN departure traffic with Mérida's enroute airspace boundary exit points. Figure 12 shows the location and average counts of departure traffic over the exit points.

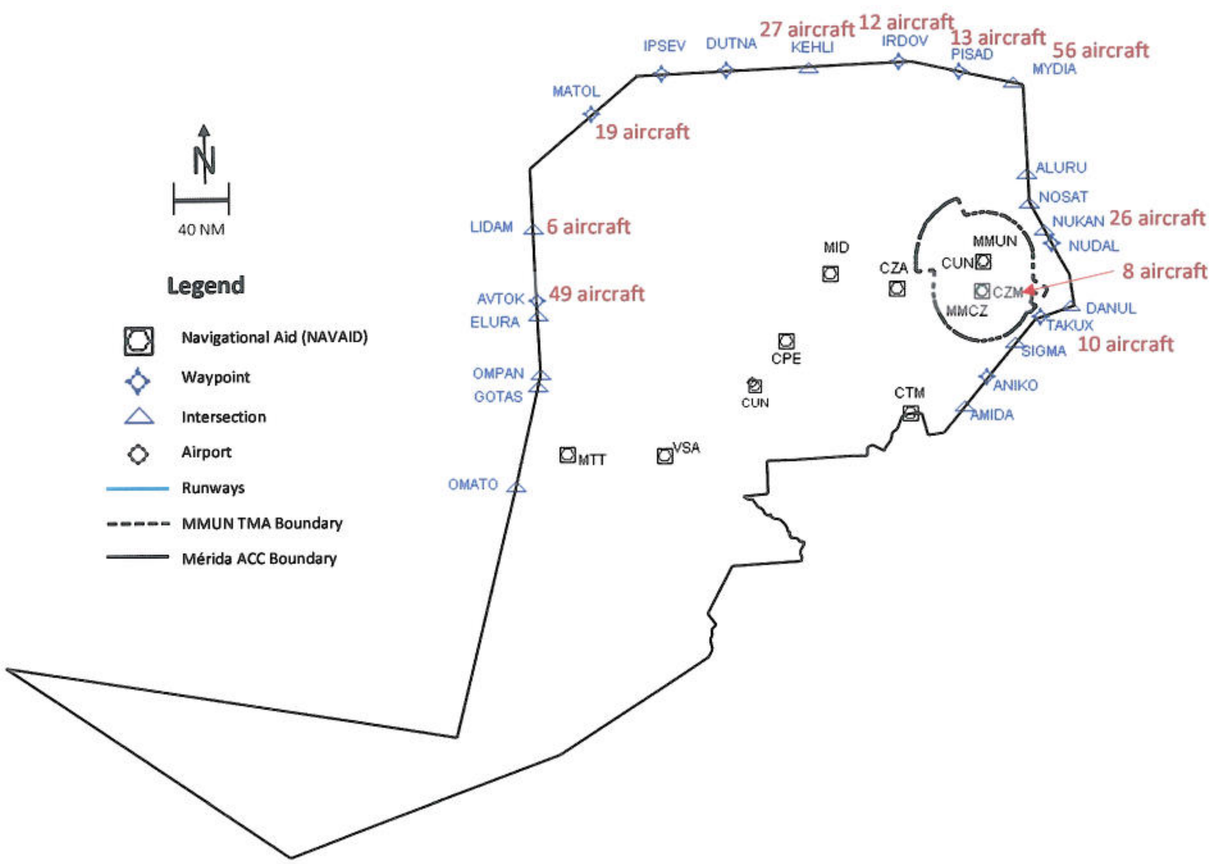

Figure 12. Mérida Enroute Airspace Exit Point Locations and Average Counts for MMUN Departure Traffic

The busiest exit points, on average, are also in the west, AVTOK, and the northeast, MYDIA which corresponds to the results of the entry point analysis. In addition, the hourly analysis was done for Mérida's enroute airspace exit points and is shown in Figure 13 below.

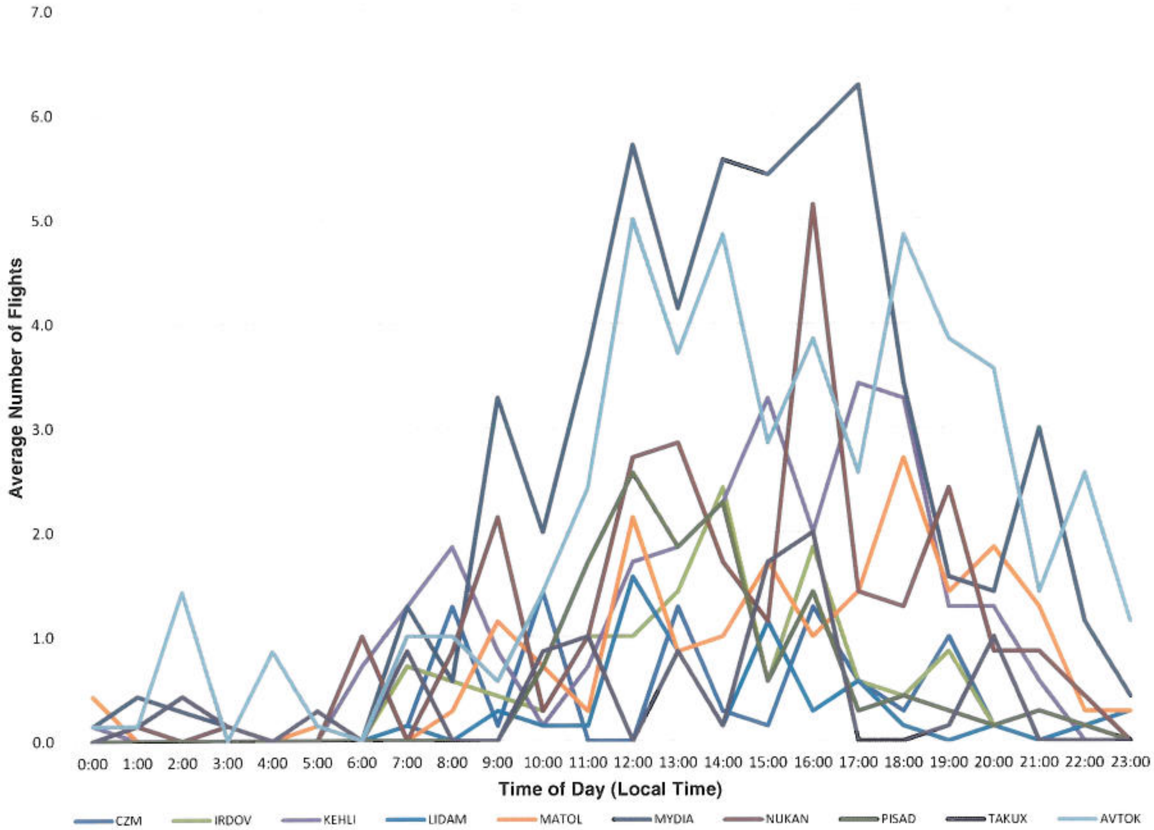

Figure 13. Mérida Enroute Airspace Exit Point Average Hourly Distribution for MMUN Departure Traffic

The busiest Mérida enroute airspace exit point for MMUN departure traffic is MYDIA, with an average of 56 flights per day. The most frequently used exit point per hour is also MYDIA, with an average of 6.3 flights in the 1700 hour. MYDIA (located on the northern enroute airspace boundary) is used by flights to eastern Canada, the east coast of the U.S. and to some European destinations. The busiest times of day are between the 0900 and 2000 hours with the peak (27) number of flights over all of the exit points occurring during the 1600 hour.

Overall, this analysis has shown that the most frequently used enroute airspace entry and exit points for Mérida ACC are located on the western enroute airspace boundary for traffic coming from and going to other parts of Mexico, and on the northeast corner of the enroute airspace for flights from and to eastern Canada, Europe and the east coast of the U.S. The enroute airspace entry and exit points to the south of MMUN are only used by a few flights towards parts of Central and South America although MITRE has been told that this traffic to and from these regions is growing. There are also a significant number of flights operating between MMCZ and MMUN that will also require consideration in any new airspace design.

5. Notional Airspace Concepts to Support Independent Operations at MMUN

MITRE has developed two initial notional airspace concepts that support the use of independent arrival and departure operations at MMUN. These notional concepts are meant to serve as starting points for the SENEAM airspace design team to consider. It is expected that various aspects of each concept might be used to develop a single concept that can then be further developed. Aspects of each concept may be discarded, or modified based on the knowledge of local conditions and operational experience that SENEAM will bring to this project.

Both of the notional concepts shown below consist of a downwind-base leg-final structure with downwinds that are parallel to the FAC and located on either side of the airport. As these are notional concepts, the downwind, base leg and FAC lengths and placement of these segments are approximate and will be adjusted as the airspace design process establishes the FAC intercept altitudes and distances from arrival runway thresholds.

MITRE kept the enroute airspace boundary entry and exit points for both notional concepts the same as in today's operations, to minimize change. These entry and exit points were divided into two sections to determine which arrival runway would normally be allocated. The dividing line was a line equidistant between the two runways and parallel to each of the extended runway centerlines. Those entry and exit points that were in the north and east section had routes drawn from them to Runway 12L/30R and those in the west and south section had routes drawn from them to Runway 12R/30L. Routes from the DUTNA waypoint, located on the northern enroute airspace boundary, were drawn to incur the least amount of mileage and change depending on the runway direction in use.

5.1 Notional Airspace Concept - Option 1

Option 1 attempts to keep the "cone" concept that is currently in use at MMUN with some modifications for the arrivals. The cone is a quadrant of airspace where only arriving flights are normally permitted to enter. This segregates arrival and departure flows and reduces airspace conflicts while also allowing the opportunity to create CDOs. Option 1 also maintains the current MMUN TMA boundary.

In this option, the merging of the arrival routes is the responsibility of the controllers working traffic in the terminal airspace.

A minimum of 15 degrees of divergence is provided between departure routes from adjacent runways to permit independent departure operations. A minimum of two departure routes in both flow directions diverge immediately at the end of same runway by 45 degrees or more to meet the one-minute separation criteria between departures from the same runway. Although this is not a requirement for independent departure procedures it is used to increase the departure capacity at an airport.

5.1.1 Runway 12 Operating Direction

Figure 14 shows MITRE's notional airspace concept – Option 1 for operations in the Runway 12 direction. The grey dashed lines represent the arrival routes while the dark blue dashed lines represent the departure routes. The green shaded area with the green border is the current "cone".

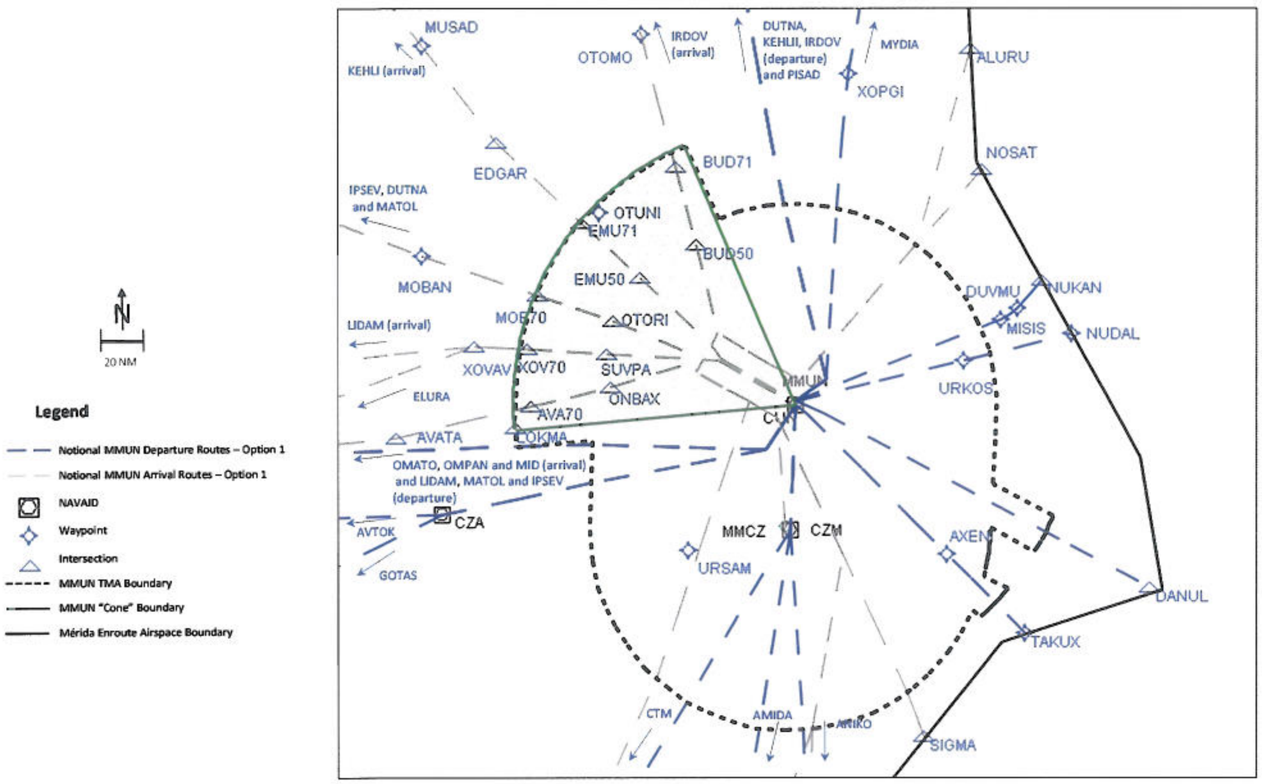

Figure 14. Option 1 Airspace Concept (Runway 12 Direction)

5.1.1.1 Runway 12 Arrival Routes

The arrival routes associated with MITRE's notional airspace concept – Option 1, Runway 12 direction, are described below.

- Northeast MMUN arrival traffic from Europe, eastern Canada and the east coast of the U.S. enters the Mérida enroute airspace primarily over ALURU or NOSAT on routes that are merged into one route close to the TMA boundary. The single route then joins the downwind for Runway 12L and follows the standard arrival pattern merging with other routes from the northwest before landing on Runway 12L.
- MMUN arrival traffic from South and Central America enters the Mérida enroute airspace primarily from the south over AMIDA, ANIKO, Chetumal (CTM) VOR/DME and SIGMA. The routes from these entry points are merged together

primarily inside the TMA airspace boundary before joining the Runway 12R downwind.

- MMUN arrival traffic from the west (originating at Mexican airports) enters Mérida's enroute airspace on routes over OMPAN, OMATO, LIDAM and ELURA which are a part of the cone arrival concept at MMUN. These western routes are merged with the northwestern routes from IPSEV, DUTNA and MATOL to form a straight-in approach to Runway 12R.
- Northwest MMUN arrival traffic, generally from the west coast and the central part of the U.S, is divided between Runway 12R and Runway 12L to balance the operations on each of the runways. The routes from the northwest are part of the routes that make up MMUN's cone. The arrival routes from IPSEV, DUTNA and MATOL are merged together in the enroute airspace to create a single route over MOBAN. These arrival routes are then merged with the other routes from the south and west for a straight-in approach before landing on Runway 12R. The northwest arrival traffic destined for Runway 12L on a route over IRDOV is merged with the arrival routes from the northeast on the base leg. The base leg is then merged with the arrival route from over KEHLI, on a straight-in approach to land on Runway 12R.

5.1.1.2 Runway 12 Departure Routes

- The departure routes associated with MITRE's notional airspace concept – Option 1 Runway 12 direction are described below. Departure traffic to the north departs Runway 12L on departure routes that make an immediate left turn to pass under Runway 12L downwind. Once passed the downwind, the departure route makes another left turn heading north and divides into two routes, one exiting the enroute airspace over MYDIA and the other dividing into three routes (not shown in Figure 14) to exit the enroute airspace over DUTNA, KEHLI, IRDOV and PISAD. The traffic on the routes to the north are destined for airports in the U.S., eastern Canada and Europe.
- Departure traffic to the east also departs Runway 12L on routes that make an immediate left turn and then divides into two routes exiting the enroute airspace over NUKAN and NUDAL. This traffic is headed principally for airports in the Caribbean.
- Southeast departure traffic departs MMUN on routes from both Runway 12L and Runway 12R. After departing the respective runway, the departure routes diverge by the required 15 degrees and exit the enroute airspace over DANUL and TAKUX, respectively. This traffic is headed for South American airports.
- Departure traffic from Runway 12R to the south depart on a route that makes an immediate right turn proceeding over the CZM VOR/DME before dividing into three departure routes. These routes exit the enroute airspace over ANIKO, AMIDA and the CTM VOR/DME heading for Central American airports.

- Departure traffic to the west departs MMUN from Runway 12R on a route that makes an immediate right turn to pass under the Runway 12R downwind. Once passed the downwind, the departure route proceeds to the Chichen Itza (CZA) VOR/DME where the route further divides and exits the enroute airspace over AVTOK and GOTAS heading for other Mexican airports.

- Northwest departure traffic departs MMUN on Runway 12R on a route that passes under the downwind and then divides into two. The northern of these two departure routes exits the enroute airspace over LIDAM, MATOL and IPSEV destined for airports in the U.S.

5.1.2 Runway 30 Arrival Routes

Figure 15 shows MITRE's notional airspace concept – Option 1 for operations in the Runway 30 direction. The light green dashed lines show the arrival routes while the dark green dashed lines are for the departure routes. The green shaded area with the green border is the current "cone".

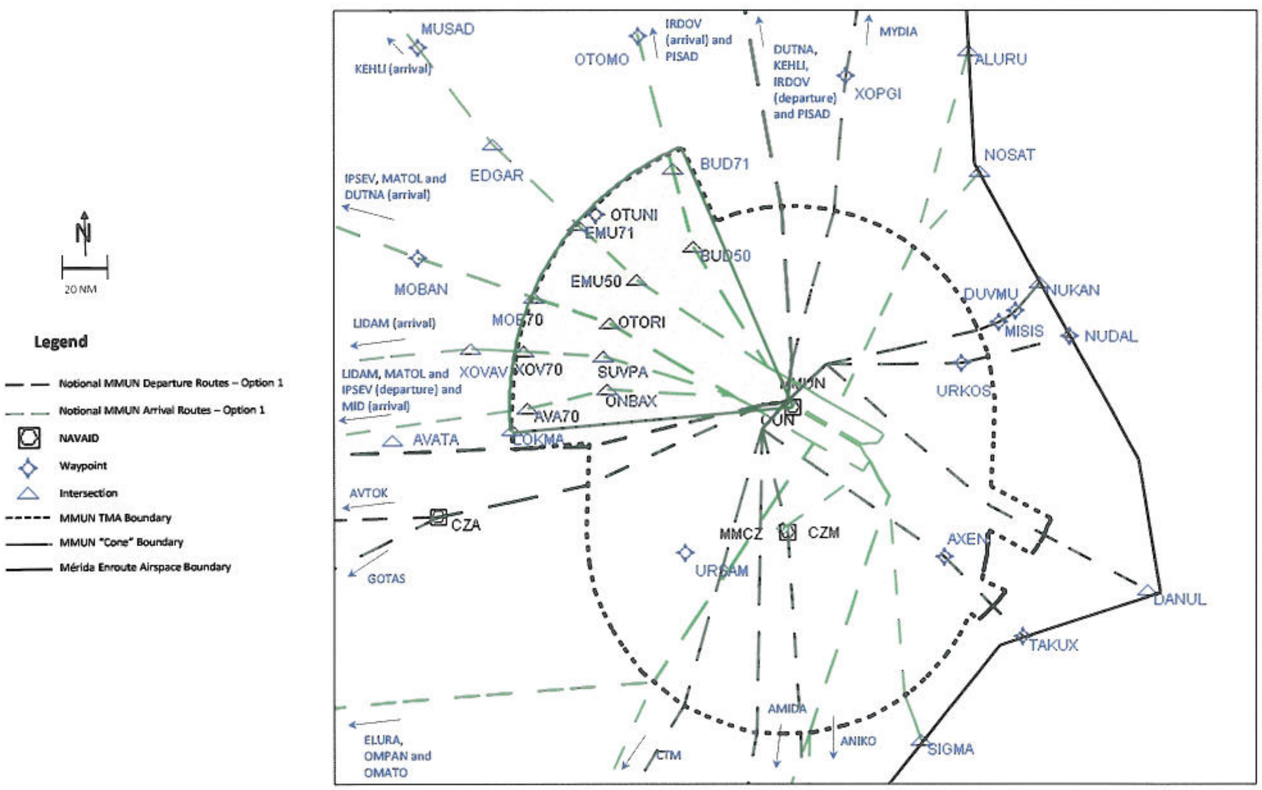

Figure 15. Option 1 Airspace Concept (Runway 30 Direction)

5.1.2.1 Runway 30 Arrival Routes

The arrival routes associated with MITRE's notion airspace concept – Option 1 in the Runway 30 direction are described below.

- Northeast MMUN arrival traffic from Europe, eastern Canada and the east coast of the U.S. enters the Mérida enroute airspace on routes over ALURU or NOSAT. These routes are merged with the arrival routes from the northwest and form the standard arrival pattern for Runway 30R.
- MMUN arrival traffic from South and Central America enters the Mérida enroute airspace primarily from the south on routes over AMIDA, ANIKO, SIGMA and the CTM VOR/DME. These routes are merged, like in Option 1, in the terminal airspace and then merged with routes from the west (described in the next bullet) to join the downwind for Runway 30L.
- MMUN arrival traffic from the west (other Mexican airports) enters Mérida's enroute airspace on routes over OMPAN, OMATO, ELURA and LIDAM and are merged prior to joining the left downwind leg for Runway 30L.
- Northwest MMUN arrival traffic is divided between Runway 30L and Runway 30R to balance the operations on each of the runways and is generally traffic from the central and west coast areas of the U.S. Arrivals entering the enroute airspace on routes over IPSEV, DUTNA and MATOL are merged with the arrival traffic from the south and west on base leg for Runway 30L using MMUN's cone. The northwest arrival traffic destined for Runway 30R over KEHLI is merged with the arrival traffic over IRDOV and PISAD prior to the right downwind leg and then merged with routes from ALURU or NOSAT to land on Runway 30R.

5.1.2.2 Runway 30 Departure Routes

The departure routes associated with MITRE's notional airspace concept – Option 1 Runway 30 direction are described below.

- Departure traffic to the north departs Runway 30R on a route that makes an immediate right turn to the north before dividing to exit the enroute airspace over DUTNA, KEHLI, IRDOV, PISAD and MYDIA. These routes to the north serve traffic that is destined for airports in the U.S., eastern Canada and Europe.
- Departure traffic to the east departs Runway 30R on routes that make an immediate right turn passing under the downwind for Runway 30R and exiting the enroute airspace over NUKAN and NUDAL for airports in the Caribbean.
- Southeast departure traffic departs MMUN on both Runway 30R and Runway 30L on routes that make immediate right and left turns, respectively, to pass under the downwinds. The traffic departing Runway 30R make an additional right turn and exits the enroute airspace over DANUL. The Runway 30L departure traffic makes a left turn and exits the enroute airspace over TAKUX. Both of these routes serve South American airports.
- Departure traffic to the south depart Runway 30L on routes that make an immediate left turn passing under the Runway 30L downwind and exiting the enroute airspace over the CTM VOR/DME, AMIDA and ANIKO serving Central American airports.

- West departure traffic departs MMUN on Runway 30L on routes that make an immediate left turn proceeding over the CZA VOR/DME and exiting the enroute airspace over AVTOK and GOTAS headed for other Mexico airports.
- Departure traffic to the northwest from Runway 30L make an immediate left turn heading in the westerly direction before dividing into three routes (not shown in Figure 15) and exiting the enroute airspace over LIDAM, MATOL and IPSEV headed for airports in the U.S.

5.2 Notional Airspace Concept - Option 2

For this option, the boundary of the TMA was changed so that the sequencing of the arrival traffic would be done primarily in the enroute airspace instead of inside the TMA. In this case, the TMA boundary is a racetrack shape with the northern half being a semi-circle 50 NM away from MMUN and the southern half being a semi-circle 50 NM away from MMCZ. Parallel lines join the two semicircles.

By changing the TMA boundary most of the merging and sequencing is now done in the enroute airspace. This provides the TMA with two flows of traffic destined for Runway 12L and three flows of traffic destined for Runway 12R. These flows of traffic will be merged by the terminal controllers into a single flow either on the base leg or FAC for each arrival runway. The initial departure routes, while diverging by the required 15 degrees to permit independent departures, do not turn further until passing a point 4 NM from the departure runway end. Option 2 makes more significant changes than in Option 1 to the departure routes that may affect the enroute airspace sectorization.

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5.2.1 Runway 12 Operating Direction

Figure 16 shows MITRE's notional airspace concept – Option 2 for operations in the Runway 12 direction. The arrival routes are in solid pink lines while the departure routes are in solid red lines.

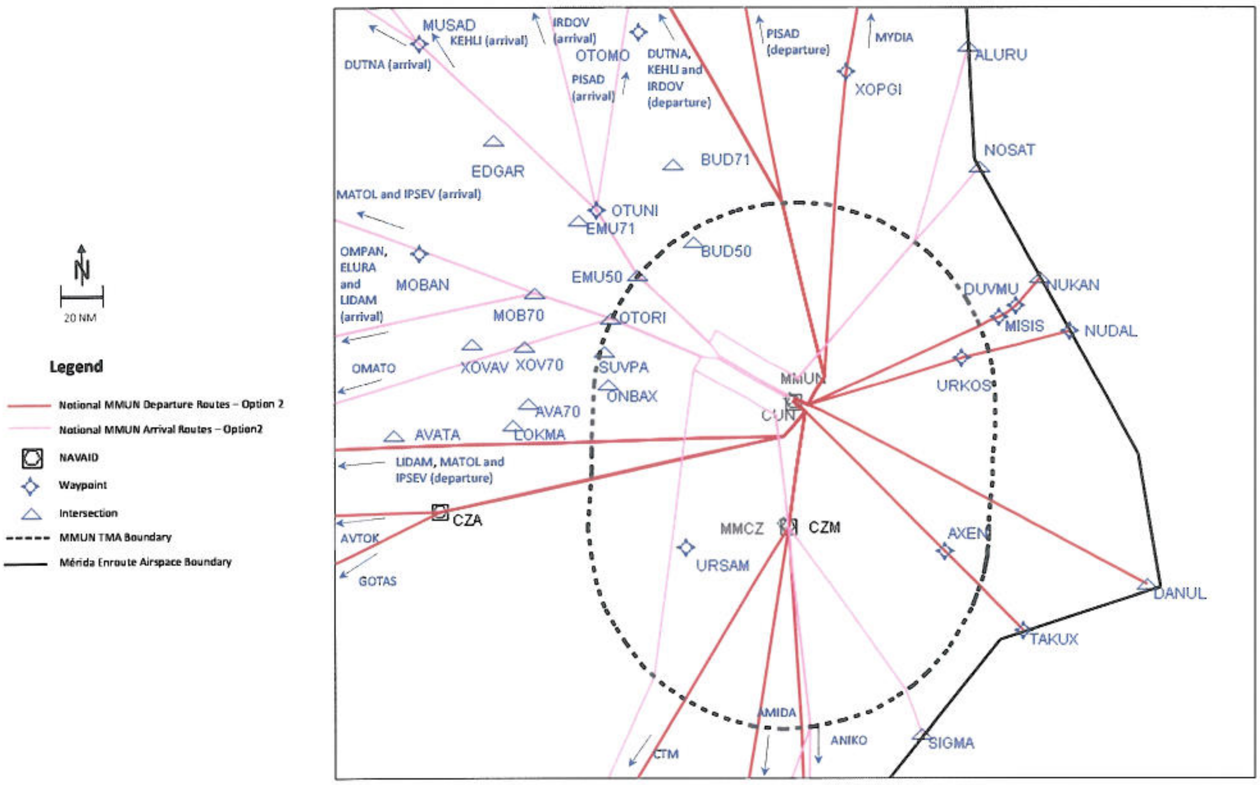

Figure 16. Option 2 Airspace Concept (Runway 12 Direction)

5.2.1.1 Runway 12 Arrival Routes

The arrival routes associated with MITRE's notional airspace concept – Option 2 Runway 12 direction are described below.

- Similar to Option 1, northeast MMUN arrival traffic from Europe, eastern Canada and the east coast of the U.S. enters the Mérida enroute airspace on routes over ALURU or NOSAT and are merged together close to the TMA boundary. Once merged the traffic joins the downwind for Runway 12L to be sequenced for landing.
- MMUN arrival traffic from South and Central America enters the Mérida enroute airspace on routes from the south over AMIDA, ANIKO, CTM VOR/DME and SIGMA. The routes from these entry points are merged together primarily inside the TMA airspace boundary before joining the Runway 12R downwind.
- MMUN arrival traffic from the west (other Mexican airports) enters Mérida's enroute airspace on routes over OMATO, OMPAN, LIDAM and ELURA, which are merged

with the other routes from the northwest over IPSEV and MATOL before landing on Runway 12R.

- Northwest MMUN arrival traffic is divided between Runway 12R and Runway 12L to balance the operations on each of the runways and is generally traffic from the west coast and central U.S. This traffic is merged in the enroute airspace with the other traffic for the respective runway.

5.2.1.2 Runway 12 Departure Routes

The initial departure routes associated with MITRE's notional airspace concept – Option 2 Runway 12 diverge by 15 degrees to maintain independence from the adjacent runway. They then continue on those courses for 4 NM before diverging to exit the enroute airspace. All additional turns listed below are made after this 4 NM point. These routes are described below:

- Departure traffic to the north departs Runway 12L on routes that make a left turn to pass under the downwind for Runway 12L. Once passed the downwind the route turns left and then divide into multiple routes (not shown in Figure 16) that proceed over DUTNA, KEHLI, IRDOV, PISAD and MYDIA headed for airports in the U.S and eastern Canada and Europe.
- Departure traffic to the east also depart Runway 12L on a route that makes a left turn and divides into two routes that exit the enroute airspace over NUKAN and NUDAL for airports in the Caribbean.
- Southeast departure traffic departs MMUN on both Runway 12L and Runway 12R diverge by the required 15 degrees to maintain independence from the adjacent runway and exit the enroute airspace over DANUL and TAKUX, respectively, for South American airports.
- Departure traffic on routes from Runway 12R to the south make a right turn to the CZM VOR/DME and divide into multiple routes proceeding over ANIKO, AMIDA and CTM VOR/DME headed for airports in Central America.
- Departure traffic on routes to the west make a right turn passing under the downwind for Runway 12R before heading to the CZA VOR/DME and exiting the enroute airspace at AVTOK and GOTAS headed for other Mexican airports.
- Northwest departure traffic departs MMUN on routes from Runway 12R passing under the downwind for Runway 12R before turning to the northwest and exiting the enroute airspace over LIDAM, MATOL and IPSEV headed for airports in the U.S.

5.2.2 Runway 30 Operating Direction

Figure 17 shows MITRE's notional airspace concept – Option 2 for operations in the Runway 30 direction. The arrival routes are shown in solid yellow lines while the departure routes are in solid brown lines.

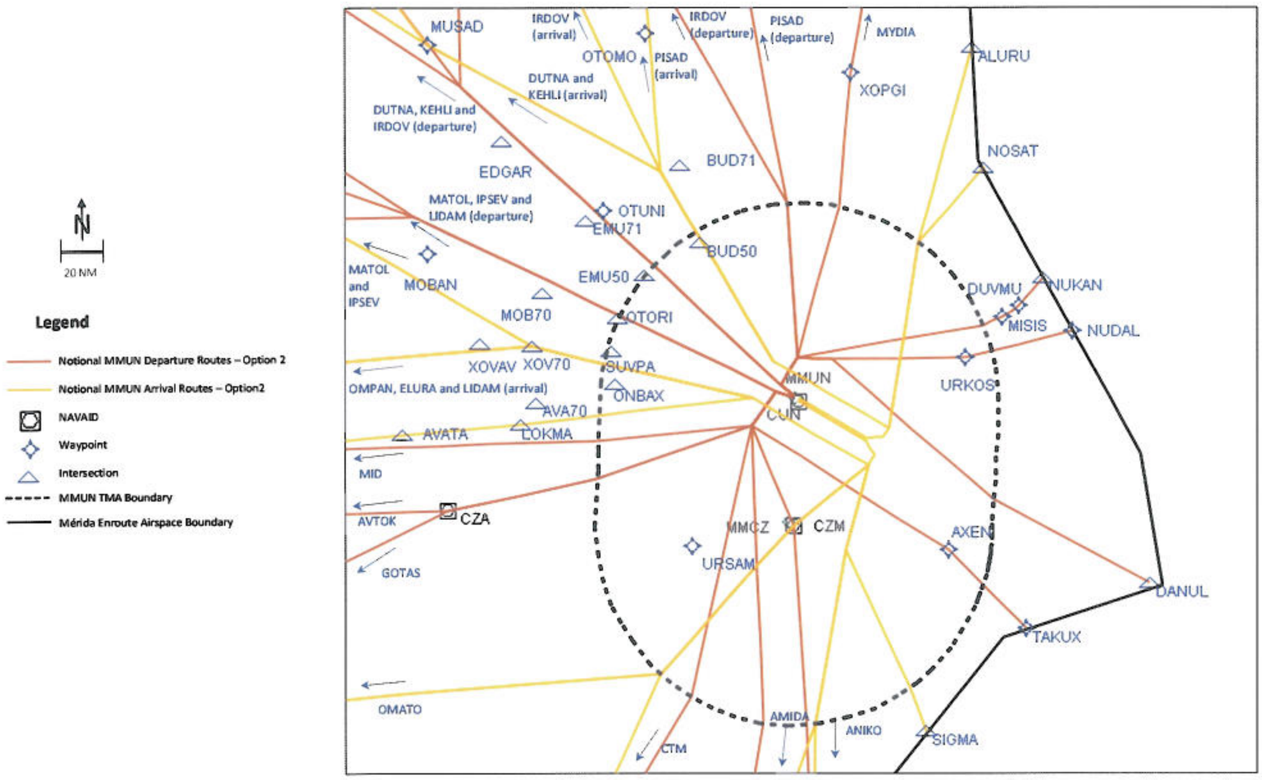

Figure 17. Option 2 Airspace Concept (Runway 30 Direction)

5.2.2.1 Runway 30 Arrival Routes

The arrival routes associated with MITRE's notion airspace concept – Option 2 for Runway 30 do not use the MMUN cone but instead are merged in the enroute airspace and are described below.

- Similar to Option 1, the northeast MMUN arrival traffic from Europe, eastern Canada and the east coast of the U.S. enters the Mérida enroute airspace on routes over ALURU or NOSAT and merged prior to entering the TMA airspace and join an extended right base leg for Runway 30R.
- MMUN arrival traffic from South and Central America enters the Mérida enroute airspace primarily on routes from the south over AMIDA, ANIKO, SIGMA and the CTM VOR/DME and land on Runway 30L.

- MMUN arrival traffic from the west (other Mexican airports) enters Mérida's enroute airspace over OMATO, LIDAM, ELURA and OMPAN and are merged together in the enroute airspace prior to using a straight-in approach to land on Runway 30L.
- Northwest MMUN arrival traffic is divided between Runway 30L and Runway 30R to balance the operations on each of the runways and is generally traffic from the west coast and central U.S. Arrival routes from over IPSEV and MATOL land on Runway 30L while the routes from DUTNA, KEHLI, IRDOV and PISAD land on Runway 30R.

5.2.2.2 Runway 30 Departure Routes

The initial departure routes associated with MITRE's notional airspace concept – Option 2 Runway 30 diverge by 15 degrees to maintain independence from the adjacent runway. They then continue on those courses for 4 NM before diverging to exit the enroute airspace. All additional turns listed below are made after this 4 NM point. These routes are described below:

- Departure traffic exiting the enroute airspace over IRDOV, PISAD and MYDIA to the north depart Runway 30R. This traffic is destined for airports in the U.S., eastern Canada and Europe.
- Departure traffic to the east departs Runway 30R on routes that make a right turn and exit the enroute airspace over NUKAN and NUDAL for airports in the Caribbean.
- Southeast departure traffic departs MMUN on routes from both Runway 30R and Runway 30L and make right and left turns, respectively, passing under the downwinds. The Runway 30R route exit the enroute airspace over DANUL, while the Runway 30L route exits over TAKUX.
- Departure traffic to the south depart on routes from Runway 30L that make a left turn passing under the downwind for Runway 30L. Once passed the downwind arrival traffic, the routes divide and exit the enroute airspace over the CTM VOR/DME, AMIDA and ANIKO serving Central American airports.
- West departure traffic departs MMUN on routes from Runway 30L and make a left turn exiting the enroute airspace over AVTOK and GOTAS headed for other Mexico airports.
- Departure traffic on routes to the northwest fly straight ahead diverging by the required 15 degrees to maintain independence from the adjacent runway and follow courses that take the traffic between the arrival traffic from the northwest. The traffic departing Runway 30L exits the enroute airspace over LIDAM, MATOL and IPSEV. The Runway 30R traffic exits the enroute airspace over DUTNA and KEHLI with an alternate route over IRDOV (this alternate route will aid in balancing the departure traffic demand between the two runways). The northwest traffic is destined for airports in the U.S.

6. Summary

This document presents the initial investigations that MITRE has done in preparation for the design work that will develop independent arrival and departure procedures at MMUN. In preparation for assisting SENEAM, MITRE created an operational concept based on independent operations in the U.S. and two notional airspace concepts that may support independent operations. The operational concept and notional airspace concepts were developed to serve as starting points for the airspace design work at MMUN and are based on typical airspace concepts used in the U.S. MITRE expects that various aspects of each of the notional airspace concepts might be used to develop a single concept that can be further refined. In addition, any part of the notional airspace concepts may be discarded, or modified based on the knowledge of the local conditions and operational experience that SENEAM brings to this project.

As the project moves forward, MITRE will continue to work closely with SENEAM as it makes important decisions towards the implementation of independent arrival and departure operations at MMUN. The next steps are for SENEAM to establish its PMT for the MMUN project and develop its project plan, which MITRE can review and provide feedback on. Following those steps, SENEAM and MITRE can continue to advance on the development of conceptual airspace designs to support independent operations at MMUN.