Airspace Design technical feasibility of simultaneous operations between Mexico City International Airport (MMMX) and Santa Lucia military base (MMSM)

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List of figures

1. Executive summary

CHAPTER 01

As per contract A200558, NAVBLUE, conducted a pre-study assessing the technical feasibility of simultaneous operations between Benito Juárez international airport (MMMX) and Santa Lucia military base (MMSM).

The conclusion of the study reveals that it is technically feasible to operate Santa Lucia airport as a civil international airport, in parallel of keeping current Mexico City airport in place.

This document provides several options of conceptual design, ranked by simplicity of implementation.

Benito Juárez international airport being a very dense platform, local users and operators (Air Traffic controller, Pilot…) have acquired over the years habits and methods that allow a very efficient traffic management around the airport, leading to a 97.3% use of the two runways maximum capacity.

From this perspective, the first proposed conceptual design (Stage 1) caters extremely reduced changes to the current Air Traffic Management to and from MMMX, while providing new ICAO compliant arrivals and departures from/to Santa Lucia airport. Stage 1 is easily implementable and requires reduced ATC familiarization and implementation costs. However, because the MMMX traffic management remains unchaged, the dual system MMMX-MMSM would not reach the maximum achievable efficiency.

The second proposed conceptual design (Stage 2) provides an enhancement of Stage 1 by implementating minimum changes to the current ATM system and relocating SLM VOR. Stage 2 would provide increased separation between MMMX and MMSM traffic, providing a larger buffer and enabling a higher traffic density.

Finally, Stage 3 considers a completely remodeled airspace with fully seprated traffic between MMMX and MMSM for a maximum level of safety and efficiency. Stage 3 would require heavy changes in the Airspace structure as well as complete training of ATC.

Overall, the expected capacity would reach a maximum of 130 (140) aircraft per hour depending on the modus operandi of MMSM runways (non-independent or independent runways), using 72 aircraft an hour to MMMX as a baseline.

2. Project introduction

CHAPTER 02

2.1. Introduction and purpose

Mexico City International airport (Benito Juárez, MMMX) was declared in overcapacity in September 2014. In order to sustain the heavy and increasing traffic, Mexican major actors in the commercial aviation industry are today considering two main options:

- Building of a new airport located North East of current Benito Juárez airport: Texcoco project
- Converting Santa Lucia military airbase (MMSM) into a mixed civil / military airport and operate MMMX and MMSM simultaneously to increase global traffic throughput.

The present document addresses the technical feasibility of the second option, which consists in operating Benito Juárez and Santa Lucia airports simultaneously. It is meant to provide a high-level procedure conceptual design, focusing on safety and inter-operability, as well as preliminary traffic figures.

2.2. Study team cooperation

The Study Team was composed of the following individuals and organizations

Name	Organization	Role
Doug Marek	NAVBLUE	ATC/ATM/PBN/SID/STAR/CDM SME
Jorge BLANCO MONGE	NAVBLUE	Chief Procedure Designer
Mario PAVON HIDALGO	NAVBLUE	Procedure Designer
Maxime CAILLE	NAVBLUE	NAVBLUE Project Manager

2.3. Background and general overview

Located at the neighborhood of Peñón de los Baños within Venustiano Carranza, one of the sixteen boroughs into which Mexico's Federal District is divided, *Benito Juárez International Airport* is 5 k (3.1 nm) east from downtown Mexico City and is surrounded by the built-up areas of Gustavo A. Madero to the north and Venustiano Carranza to the west, south and east. As the airport is located on the east side of Mexico City and its runways run southwest-northeast, an airliner's landing approach is usually directly over the conurbation of Mexico City when the wind is from the northeast.

Mexico City currently unique commercial airport has suffered from a lack of capacity due to restrictions on expansion since it is located in a densely populated area. In 2014, Mexican authorities established and declared a maximum capacity of 61 operations per hour with a total of 16 peak hours (7:00 –22:59). Another issue with the airport is the limitation that its two runways provide, since they are used at 97.3% of their maximum capacity, leaving very little room for new operations into the airport. Only government, military, commercial, and specially authorized aircraft are allowed to land at the airport. Private aircraft must use alternate airports.

Figure 1, MEXICO CITY (MMMX) LOCATION

In order to face this challenge, the construction of a new Mexico City international airport was announced on September 2, 2014. However, because of the strong economic and environmental impact of such project, another alternative is currently being studied, which consists in remodeling the Santa Lucia military airbase (located 30km North of MMMX) into a mixed civil/military international airport.

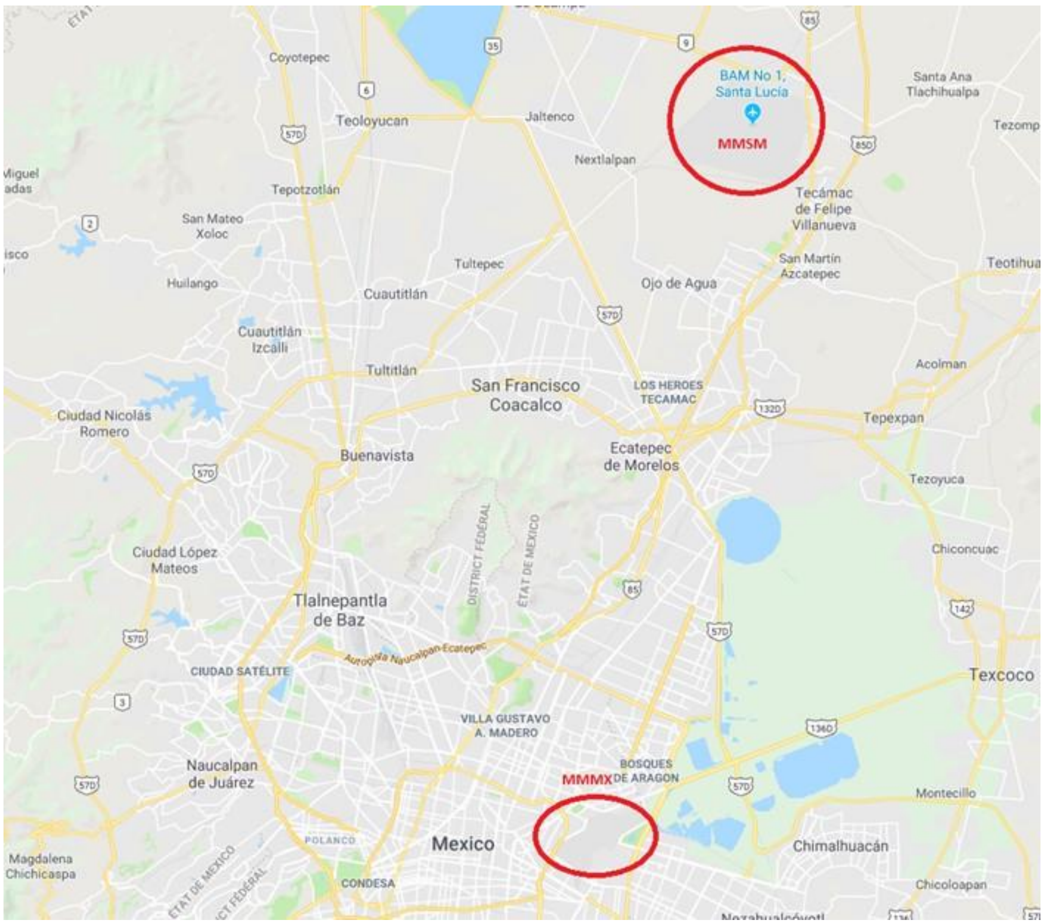

Figure 2, MEXICO CITY INTERNATIONAL AIRPORT (MMMX) and Santa Lucia military airbase (MMSM)

3. Project assumptions and strategy

CHAPTER 03

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3.1. Project assumptions

This study provides propositions of high level conceptual designs for future simultaneous operations between MMMX and MMSM. The project assumptions are based on the documentation provided by *Grupo Riobóo S.A.* as well as additional sources such as MMMX AIP or flight track from FlightRadar24™ platform.

3.1.1. Runway and airport data

For MMMX, the data published in the AIP were used for the conceptual design.

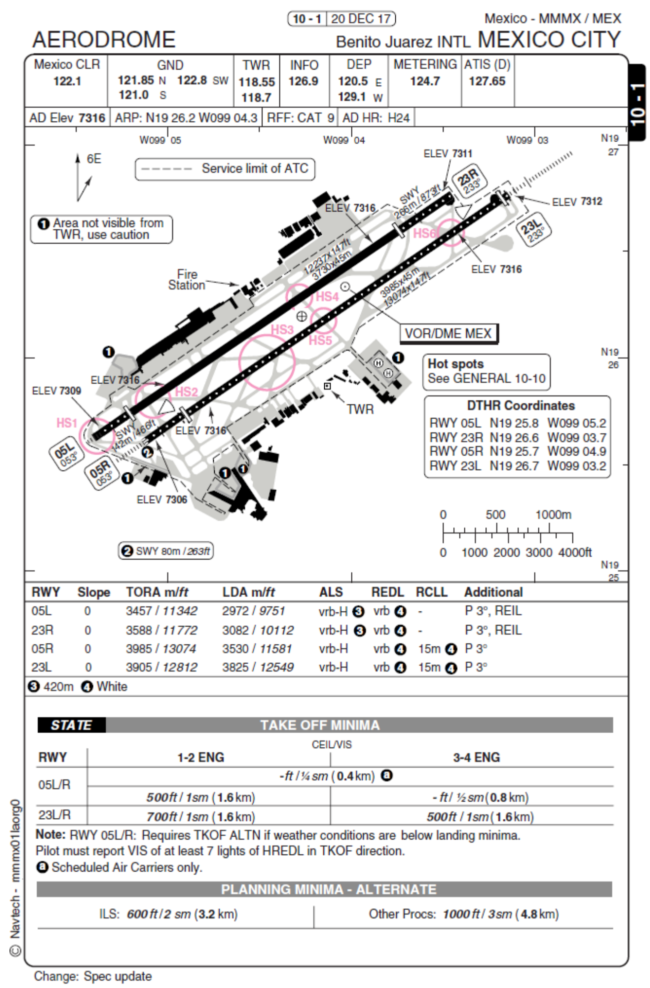

Figure 3, MMMX runway chart

For MMSM, the following data were used as a basis for the design of the procedures.

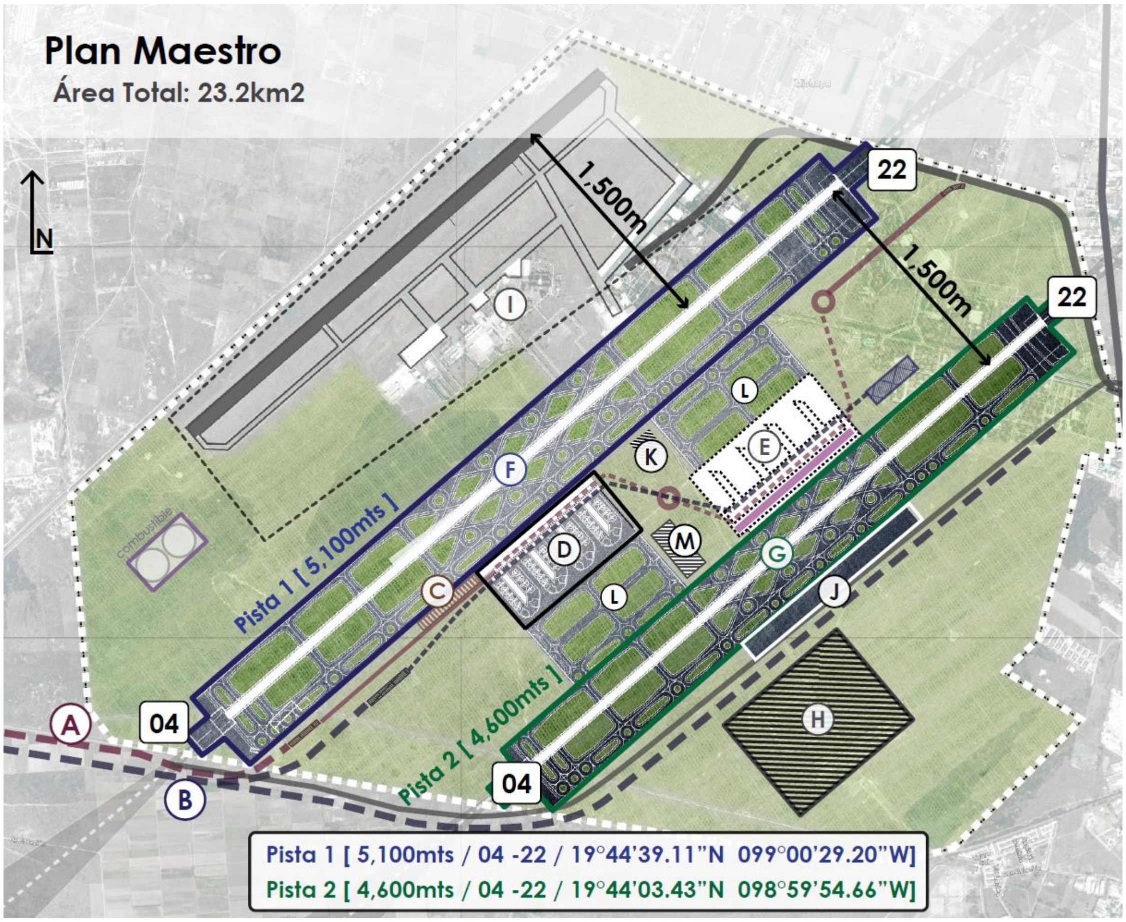

Figure 4, Santa Lucia runway master plan

Given the configuration of the surrounding terrain, the pre-study will assume two runways operating in simultaneous segregated operations, with the left runway (04L) preferred for landing and the right runway (04R) preferred for takeoff.

3.1.2. Traffic data

It was agreed that the new concept of operation (CONOPS) should concentrate most of the domestic flights to *Benito Juárez International Airport*, when Santa Lucia airport would be mostly used for international flights.

In order to acquire a comprehensive picture of the existing traffic in Mexico City, the overall traffic from and to *Benito Juárez International Airport* was captured through Flight Radar24™ (24 hours window the 1st of June 2018). The tracks are displayed below.

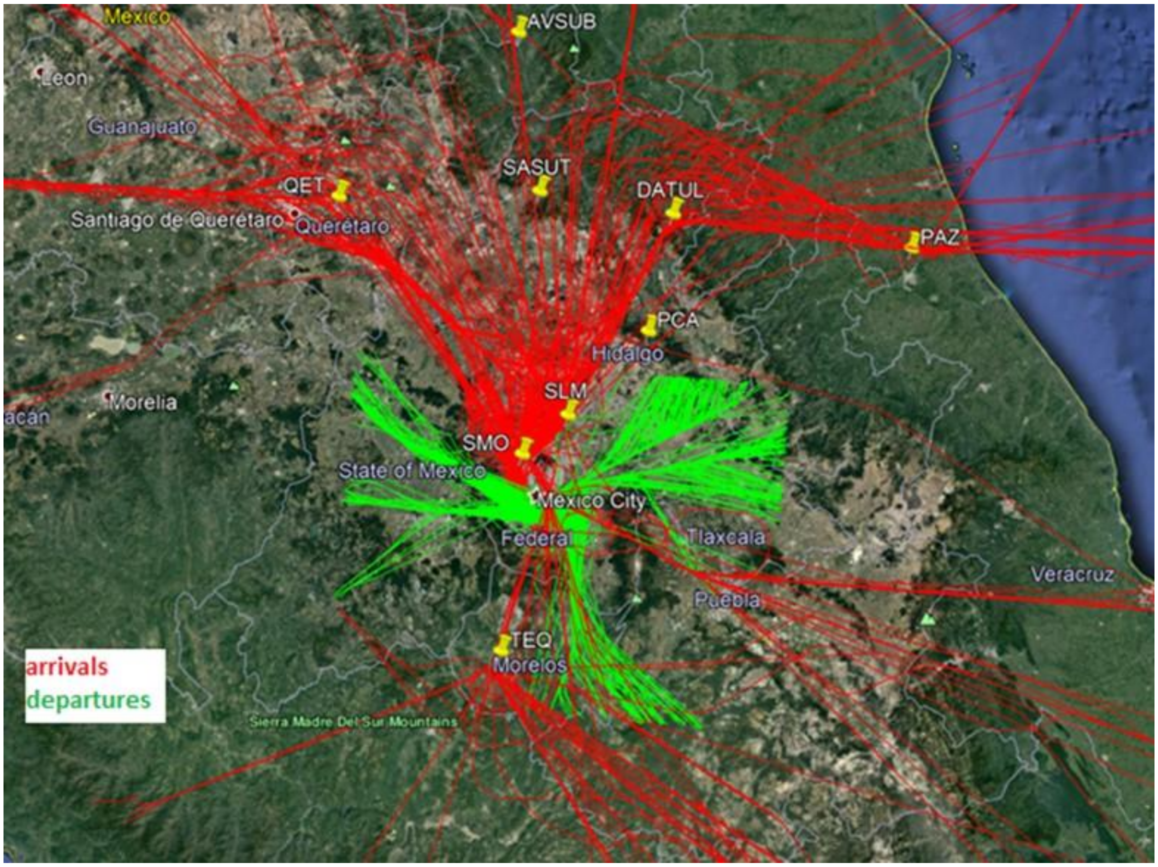

Figure 5, MEXICO CITY AIRPORT

In addition to providing detailed information about the traffic flow management in Mexico City, the previous data allows to geographically sectorize domestic and international flight. For the reference day of 1st of June 2018, the distribution of domestic and international traffic was as displayed in figure 6 Next page.

The analysis of the radar tracks shows the following strong city pairs:

<u>For domestic flights:</u>

Cancun/Merida – Mexico City (North East sector)
Guadalajara/Tijuana – Mexico City (North West sector)

<u>For international flights:</u>

USA East cost / Europe – Mexico City (North East)
California – Mexico City (North West)

Lima / Bogota / Medellin / Quito – Mexico City (South East)

The proposed design will be developed in order to provide the best efficiency on the heavy sectors of Mexico City Airspace.

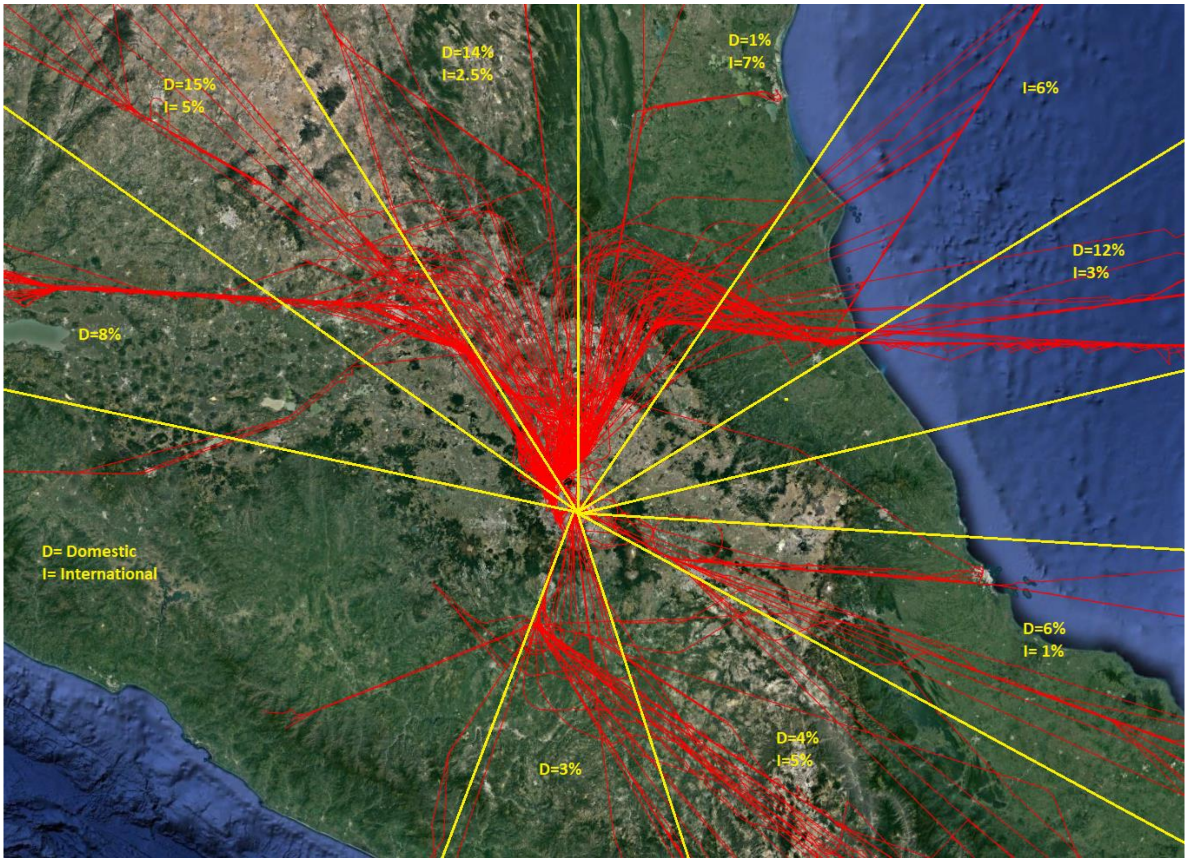

Figure 6, Geographical distribution of domestic and international flights

Note: The above distribution considers destinations with at least 3 flights a day

Finally, because of the limited information available and the absence of a defined plan regarding the future military activity in Santa Lucia, the study focuses only on inter-operability between commercial traffic operating in MMMX and MMSM. The military activity on Santa Lucia Airbase was excluded from the scope of the analysis.

3.1.3. Design assumptions

It is important to highlight that the pre-study conclusion in terms of IFP design feasibility is derived from numerous assumptions and subjected to several uncertainties in terms of input data and local regulations. In addition, it has not been tackled a formal obstacle assessment.

In case of deciding to implement the proposed concept, it will be needed to launch the IFP process taking this ConOPS as the operational input.

The flight procedures design criteria used for the pre-study are stated in the ICAO Doc. 8168 Volume II (Amdt. 7). In addition, the ICAO Doc. 9643 provides complementary criteria to be considered for simultaneous operations in MMSM airport.

The main assumptions considered in the pre-study:

- SID / STAR / IAP initial and MAP RNAV-1: Based on GNSS sensor (in case of need to consider DME/DME, no major impact in the design is expected).

- ISA variation: The MMMX reference temperature in the AIP is 27ºC and the mean temperature in the Distrito Federal 18ºC (source Conagua). The ISA temperature at MMMX altitude is around 1.1ºC. For the pre-study was considered ISA+15ºC.

ENTIDAD	ENE	FEB	MAR	ABR	MAY	JUN	JUL	AGO	SEP	OCT	NOV	DIC	ANUAL
AGUASCALIENTES	13.8	14.7	17.9	18.8	21.8	23.5	20.3	21.3	20.0	17.8	16.3	13.5	18.3
BAJA CALIFORNIA	13.7	15.5	19.2	20.4	22.7	26.4	29.3	29.0	25.5	23.2	19.2	15.8	21.7
BAJA CALIFORNIA SUR	17.8	19.3	21.8	23.1	23.7	26.6	29.8	30.8	28.3	28.0	24.3	20.7	24.5
CAMPECHE	25.5	26.7	27.4	29.5	30.8	29.3	29.0	29.4	29.0	27.2	25.0	24.4	27.8
COAHUILA	16.3	18.6	20.7	23.3	26.1	28.4	28.6	28.2	26.2	21.3	18.7	13.7	22.5
COLIMA	25.0	24.9	26.2	24.7	26.5	28.5	28.8	28.5	27.7	28.2	27.7	25.8	26.9
CHIAPAS	23.3	25.0	25.4	26.3	27.3	26.0	25.9	26.1	26.0	25.1	23.8	22.8	25.3
CHIHUAHUA	11.7	13.9	17.6	20.4	22.5	26.9	24.6	23.6	22.9	20.5	16.9	11.3	19.4
DISTRITO FEDERAL	15.5	16.9	17.3	19.3	21.3	20.3	18.7	19.6	18.5	17.6	16.2	14.6	18.0
DURANGO	13.4	14.9	17.6	20.2	22.5	25.0	23.0	22.4	21.0	19.5	16.5	12.5	19.0
GUANAJUATO	15.5	17.0	19.0	20.7	23.5	22.9	20.5	21.1	20.1	18.8	17.1	15.1	19.3
GUERRERO	23.9	24.3	25.6	26.1	27.1	26.3	25.8	25.9	25.2	25.2	24.5	22.8	25.2
HIDALGO	15.7	17.4	18.4	19.6	23.0	22.1	20.3	21.2	19.8	18.2	16.5	14.6	18.9
JALISCO	17.5	18.2	21.0	22.2	24.7	25.5	23.3	23.6	22.7	21.8	20.0	17.7	21.5
ESTADO DE MÉXICO	11.7	12.8	14.2	15.7	17.8	17.3	15.8	16.5	15.7	14.6	12.7	12.0	14.7

Figure 7, "Temperatura media a nivel nacional y por entidad federativa 2017" (CONAGUA)

<u>Protection areas and Obstacle/terrain assessment:</u>

For the pre-study, a high-level terrain interference assessment has been performed. The protection areas shall be fine-tuned in the further stages if applicable. Terrain data have been obtained processing the SRTM DTM model from the USGS (US Geological Survey). SRTM (Shuttle Radar Topography Mission) elevation data were processed from raw C-band radar signals spaced at intervals of 1 arc-second (approximately 30 meters) at NASA's Jet Propulsion Laboratory (JPL).

The input data and sources used in the pre-study have been taken from Mexico AIP (Amdt. AIRAC 10/18)

- Aeronautical data, local procedures and instrument flight procedures of MMMX.
- CTA Mexico structure and MVA chart.
- En route structure.

3.2. Project strategy

The implementation of flight operations in a new international airport in a relatively confined area (Mexico City being surrounded by high terrain) requires a thorough study and major changes at many levels (infrastructure, operations, safety, finance…). Such project usually being completed over several years, this document provides 3 conceptual designs which represent three stages with various level of complexity and expected implantation time. Each stage will be thoroughly detailed in chapter 4.

Stage 1: Short term implementation (6-18 months, increase in capacity of 49%)

The objective of stage one is to provide a conceptual design that allows operating commercial traffic in MMSM with minimal impact on today's concept to manage traffic from/to MMMX and therefore limited investment on infrastructure, Air Traffic Controller training, as well as pilot habits and experience in the area. The approach sequence (from IAF to the runways) will be identical from stage 1 to stage 3. Stage 1 assumes a single runway at MMSM.

Stage 2: Medium term implementation (18-24 months, increase in capacity of 89%-104%)

The objective of stage 2 is to enhance efficiency of stage 1 by slightly modifying navigation infrastructures. Stage 2 requires minor to medium change in the ATM system. Stage 2 assumes two runways at MMSM.

Stage 3: Long term implementation (24-48 months)

Stage 3 provides a preliminary conceptual design that requires a global modification of Mexico City TMA. It is meant to provide optimized traffic flows to/from both Benito Juarez and Santa Lucia international airports with the highest level of efficiency.

4. MMMX – MMSM conceptual design

CHAPTER 04

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4.1. Current traffic from/to MMMX

The current traffic at MMMX airport has been used as a “baseline” for stage 1 conceptual design.

4.1.1. Arrivals RWY05

According to the FlightRadar24™ tracks, the low altitude traffic is mostly managed using SLM (Santa Lucia), SMO (San Mateo) and MEX (Benito Juarez airport) VORs.

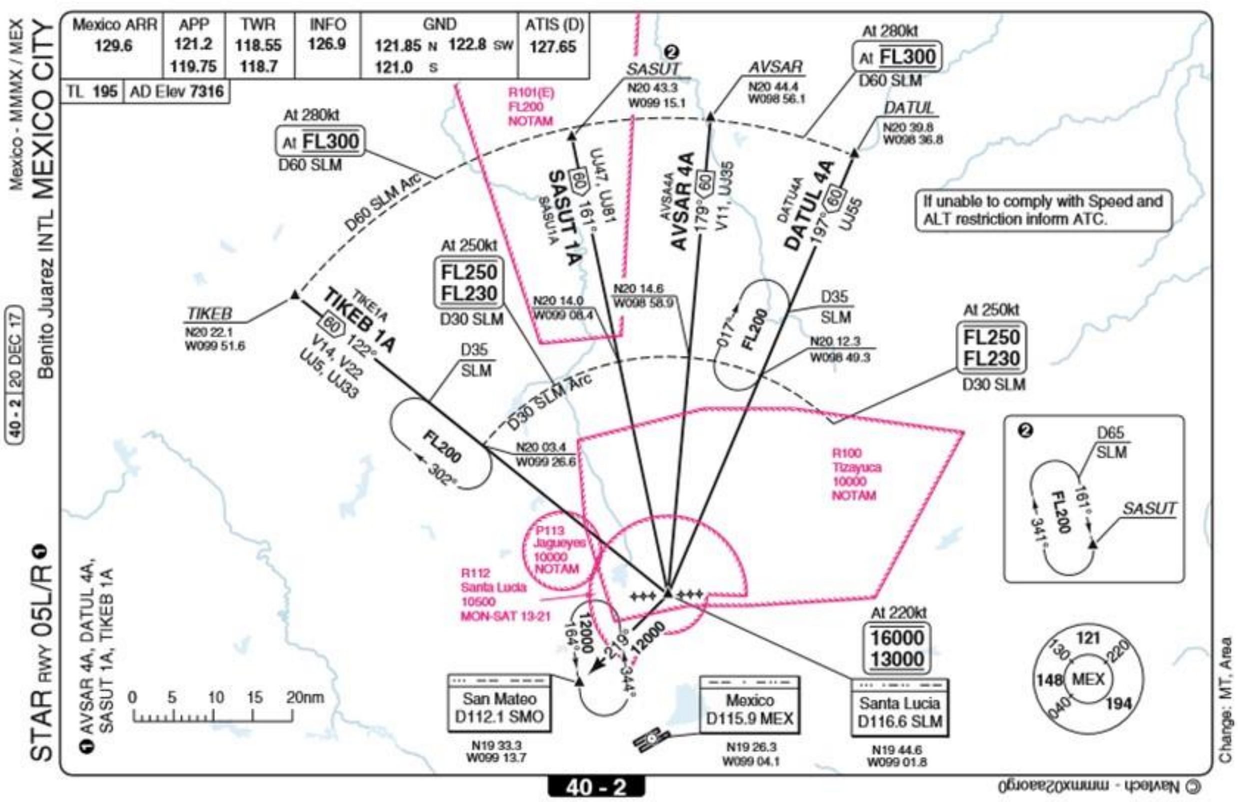

Figure 8, Arrivals from the North to SLM VOR

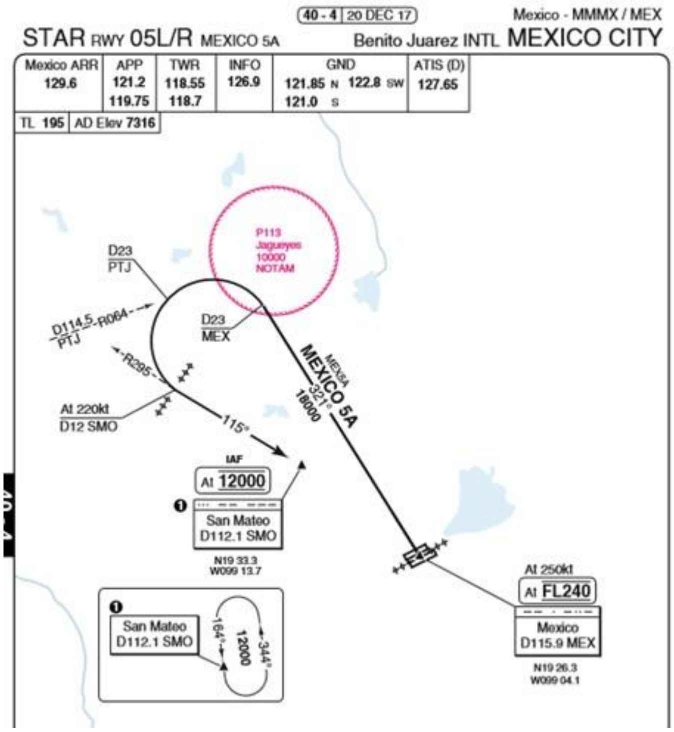

Figure 9, Arrivals from the South to SMO VOR

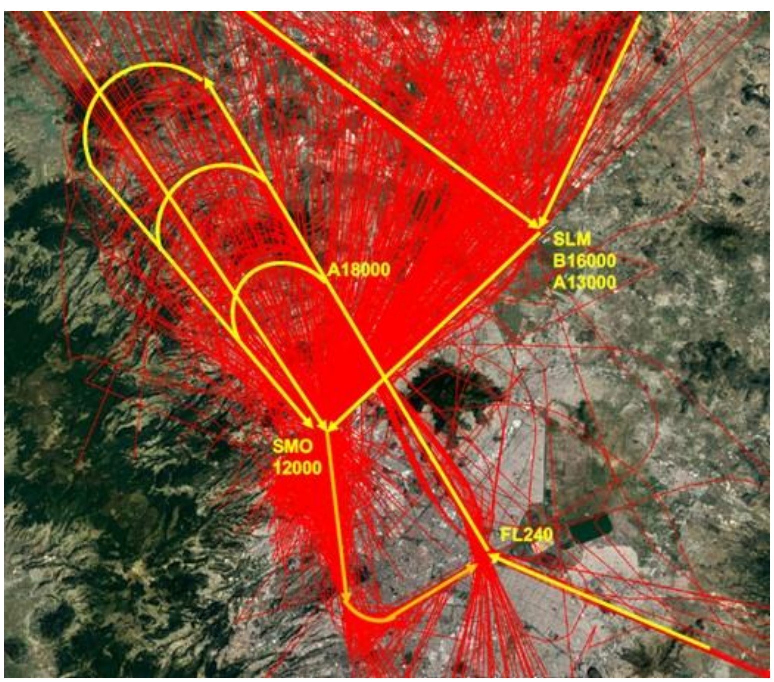

Figure 10, Overlay of traffic and current STARs

From the North, flight to MMMX are vectored to either SLM or SMO VOR, followed by a base leg from SMO VOR that intercepts MMMX RWY05R ILS with an intercept angle greater than 90° at 5Nm from the runway threshold.

The Procedures are limited in altitude with the following constraints:

- Above 13000ft and below 16000ft over SLM VOR
- Above FL240 over MEX VOR
- Above 18000ft in the “trombone” downwind
- At 12000ft over SMO VOR.

4.1.2. Departures RWY05

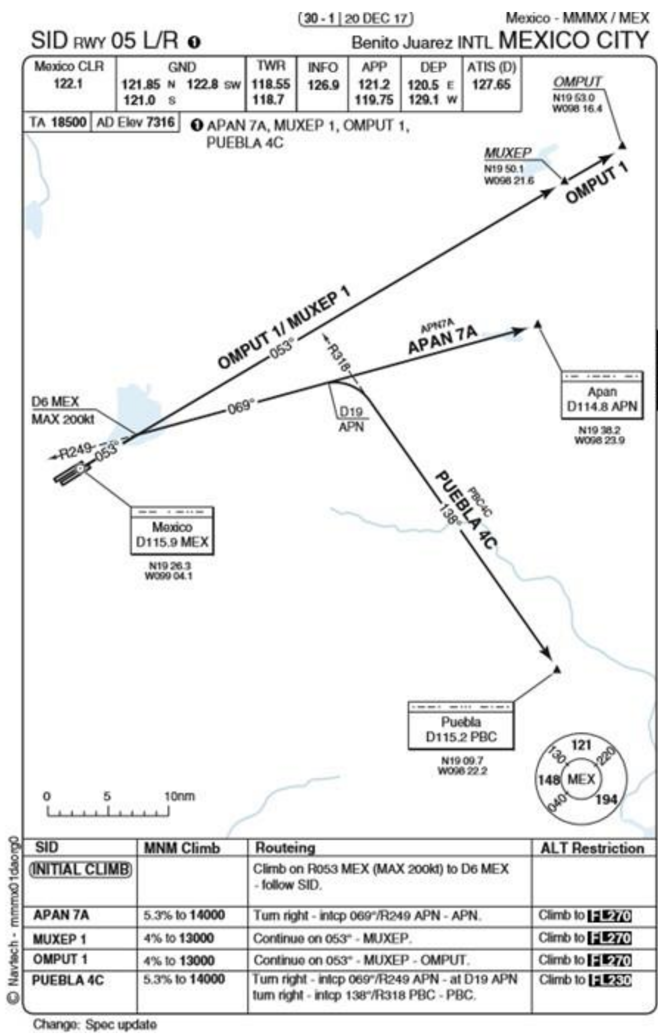

Figure 11, MMMX RWY05 Departures East

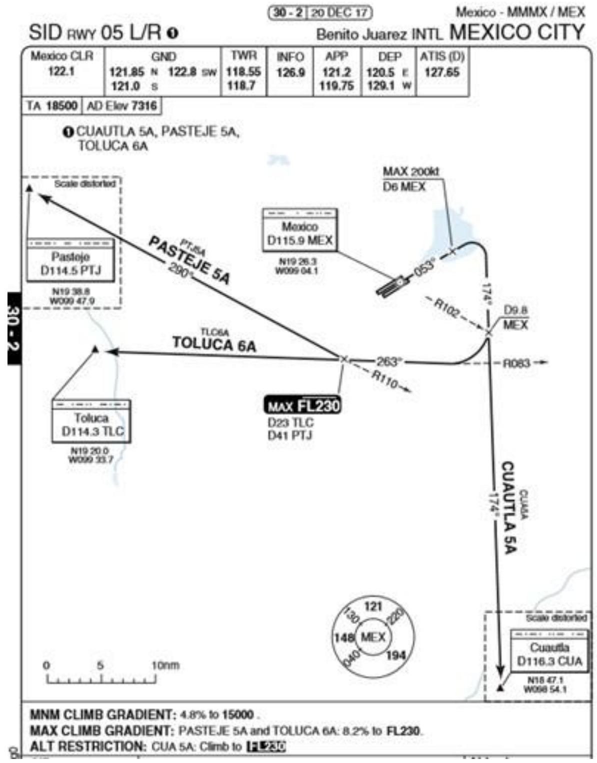

Figure 12, MMMX RWY05 Departures South/West

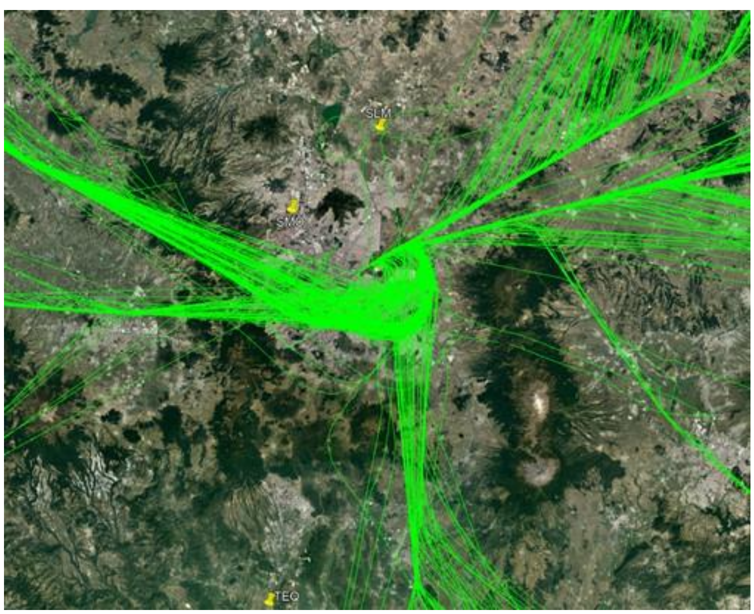

Figure 13, Actual traffic departing from MMMX

4.2. Conceptual design stage 1

4.2.1. Principles and assumptions

Stage 1 proposal is based on a short-term implementation scenario and can be done in parallel of infrastructure construction on Santa Lucia airport (6 to 18 months). The new structure enables to operate safely and simultaneously the two airports, with minimum changes brought on current MMMX traffic management.

The following assumptions and hypothesis have been taken into consideration:

- **Airport configuration**:
    - East configuration in both airports, RWYs 05 and 04 in operation.
    - MMMX Rwy 05 for approaches / Rwy 05R for departures.
    - MMSM single civilian runway operation (i.e. one military runway and one civilian runway) with one departure for every arrival. The compatibility with military operations on the current MMSM runway is out of the scope of this study.

- **Airspace structure**: Minor adjustments on vertical restrictions in the current SID/STARs routes. New procedures for MMSM.

- **Navigation infrastructure**. No expected changes.

- **En Route connection**: Traffic will enter and exit to the TMA using the current ATS routes.

- **Navigation specification**: Assuming that proposed concept will be applied in a radar environment, it is proposed the implementation of:
    - SID/STAR RNAV-1 in MMSM. Departure and approaches trajectories will not be changed for MMMX
    - Instrument Approach procedures RNAV-1 to ILS or RNP APCH to MMSM
    - MMSM missed approach based on RNAV-1.

4.2.2. Benefits

The potential benefits to be obtained from the implementation of this scenario are:

- Simplicity: The changes brought to the existing airspace will require minimum ATC training. The new CONOPS uses existing Navigation aids and SID/STAR system for MMMX.

- Procedural vertical separation will be provided in the arrival/departure or departure/missed approach crossing points.

- The sequencing of international aircraft to MMSM would be accomplished on the same high altitude point merge system at a procedurally separated lower flight level than MMMX.

- The MMSM RNAV-1 to ILS would resemble the current ILS approach to MMMX, giving ATC a similarity in already familiar sequencing, spacing, and speed control.

- Flight crews would have minimal changes to MMMX and a very familiar STAR and approach to MMSM.

- Cost for procedural design and ATC training would be kept to a minimum.

4.2.3. Description

4.2.3.1 MMMX Closed STAR structure

The incoming domestic traffic will be guided to the Mexico City airport proceeding from the same ATS routes and entry points as today:

- North and Northwest
    - UJ5-33 (QET VOR/DME)
    - UJ47-81 (SASUT)
- East
    - UJ55 (DATUL)
    - UJ12/UJ5/UM787/UJ33/UL308/-81 (PBC VOR/DME)
- South
    - UJ24S/UJ21W/UJ71/UL423 (TEQ VOR/DME)

The proposed design modifications on the MMMX STAR system consists in creating and modifying some altitudes constraints to provide vertical separation with the traffic going to Santa Lucia airport.

The detail of the proposed changes is described in the table and graph next page:

Controlling waypoint	Previous altitude constraints	Proposed altitude constraint
SLM	B16000/A13000	B17000/A15000
New waypoint midway between SLM and SMO	N/A	B15000/A13000

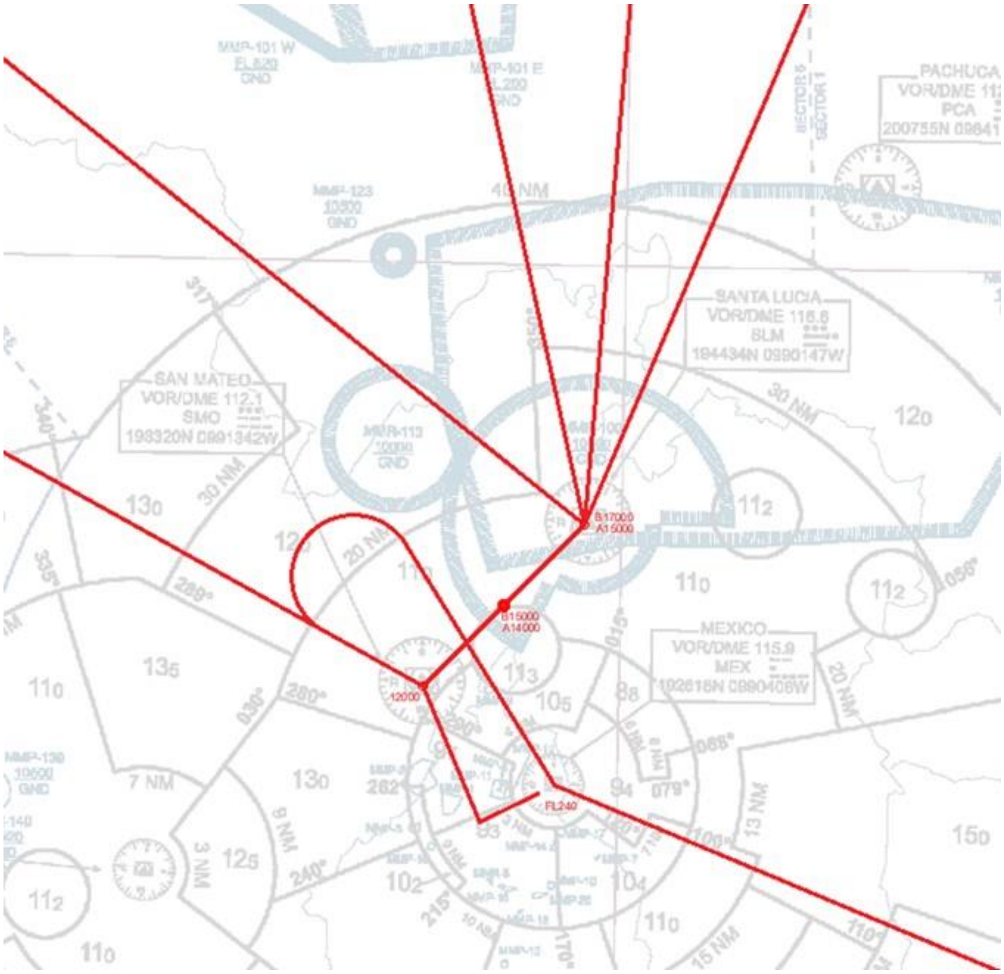

Figure 14, Stage 1 STARs MMMX

4.2.3.2 MMSM Closed STAR structure

The new runways of Santa Lucia airport will accommodate the international flights proceeding from the same ATS routes and entry points than for Mexico City Airport.

- North and Northwest
  - UJ5-33 (QET VOR/DME)
  - UJ47-81 (SASUT)
- East
  - UJ55 (DATUL)
  - UJ12/UJ5/UM787/UJ33/UL308/-81 (PBC VOR/DME)
- South
  - UJ24S/UJ21W/UJ71/UL423 (TEQ VOR/DME)

From the North, the traffic to Santa Lucia airport will evolve underneath the traffic to Benito Juárez (Santa Lucia being Northern than Benito Juarez, the aircraft will naturally be lower). The feeding remains from DATUL and QET VOR/DME, merging in a long base leg heading south bringing to the new Santa Lucia ILS for approach description, refer to section 4.2.3.5).

From the South, the traffic will be sent on a trombone using SLM VOR. The altitude constraint on SLM VOR will be set below 14000ft and above 12000ft to remain under the traffic going to MMMX. On the leg towards SLM, altitude constraints will be set (above 15000ft) in order to keep departing traffic from Santa Lucia and Benito Juarez below arriving traffic.

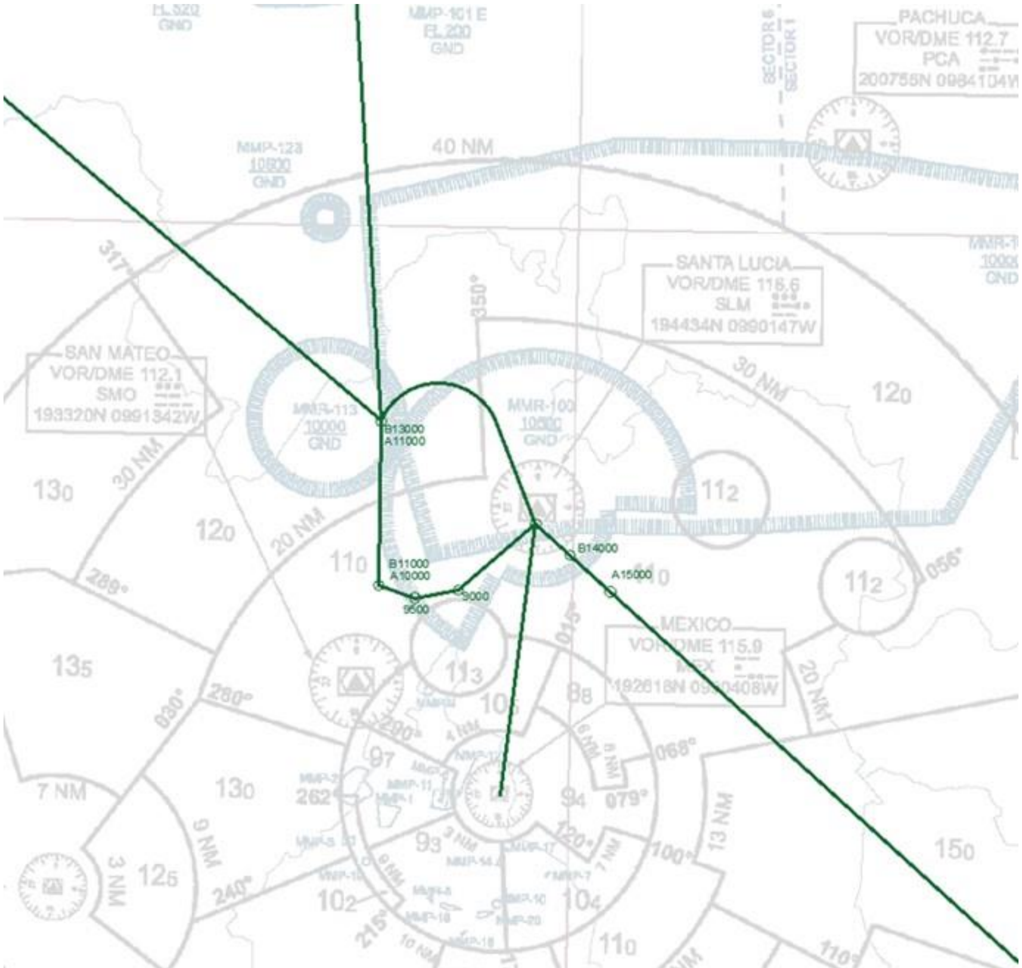

Figure 15, Stage 1 STARS MMSM

4.2.3.3 *MMMX SID*

In order to ease implementation, the proposed ConOPS provides very limited modifications to the current departures included in the AIP published SID1 chart.

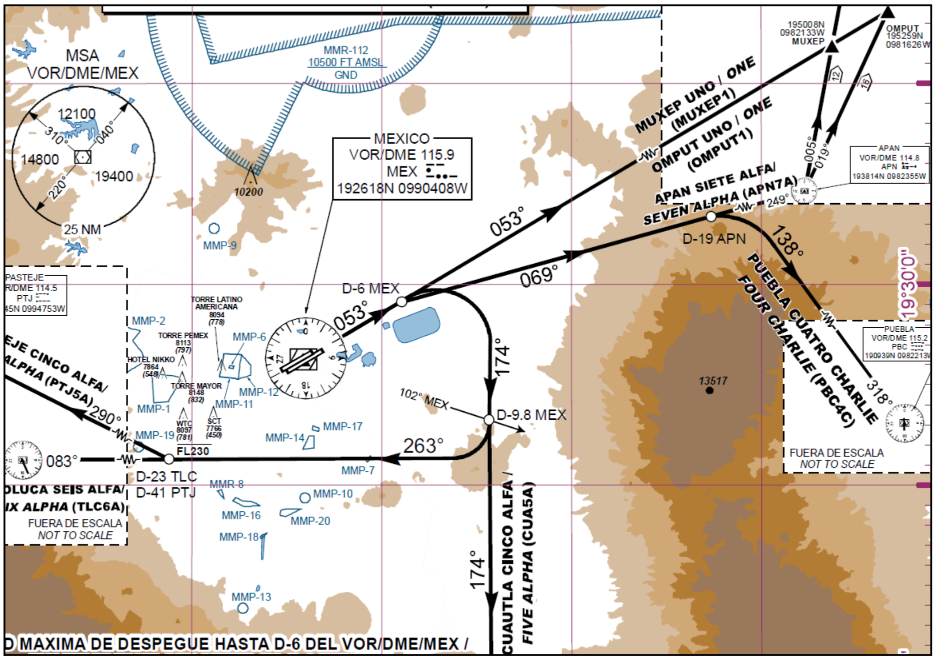

Figure 16, Current MMMX SIDs

As a reminder, the connection with enroute phase and current PDGs associated to these procedures are included in the table below:

SIDs	Route connection - Outbound flow	PDG
MUXEP1	UJ15-38 north/northeast	3.94%
OMPUT1	J177 north/northeast	3.94%
APAN7A	UJ28-30/UT19/UT42/UJ18 east	5.26%
PBC4C	UL318/UJ47 east/south-east	5.26%
CUA5A	UJ15/UJ39 south	4.77%
TLC6A	UJ18/UJ30 west/southwest	4.77%
PTJ5A	UJ45 northwest	4.77%

As it is stated in the SID1 remarks, the SIDs could be changed in accordance with ATC instructions by means of radar vectors and/or speed changes. The exit point of Benito Juarez will remain unchanged.

The only modification brought to the departures will be an altitude constraint (below 13000ft) placing departing aircraft below the flight arriving from the South to Santa Lucia (refer to 4.2.4 for visual reference).

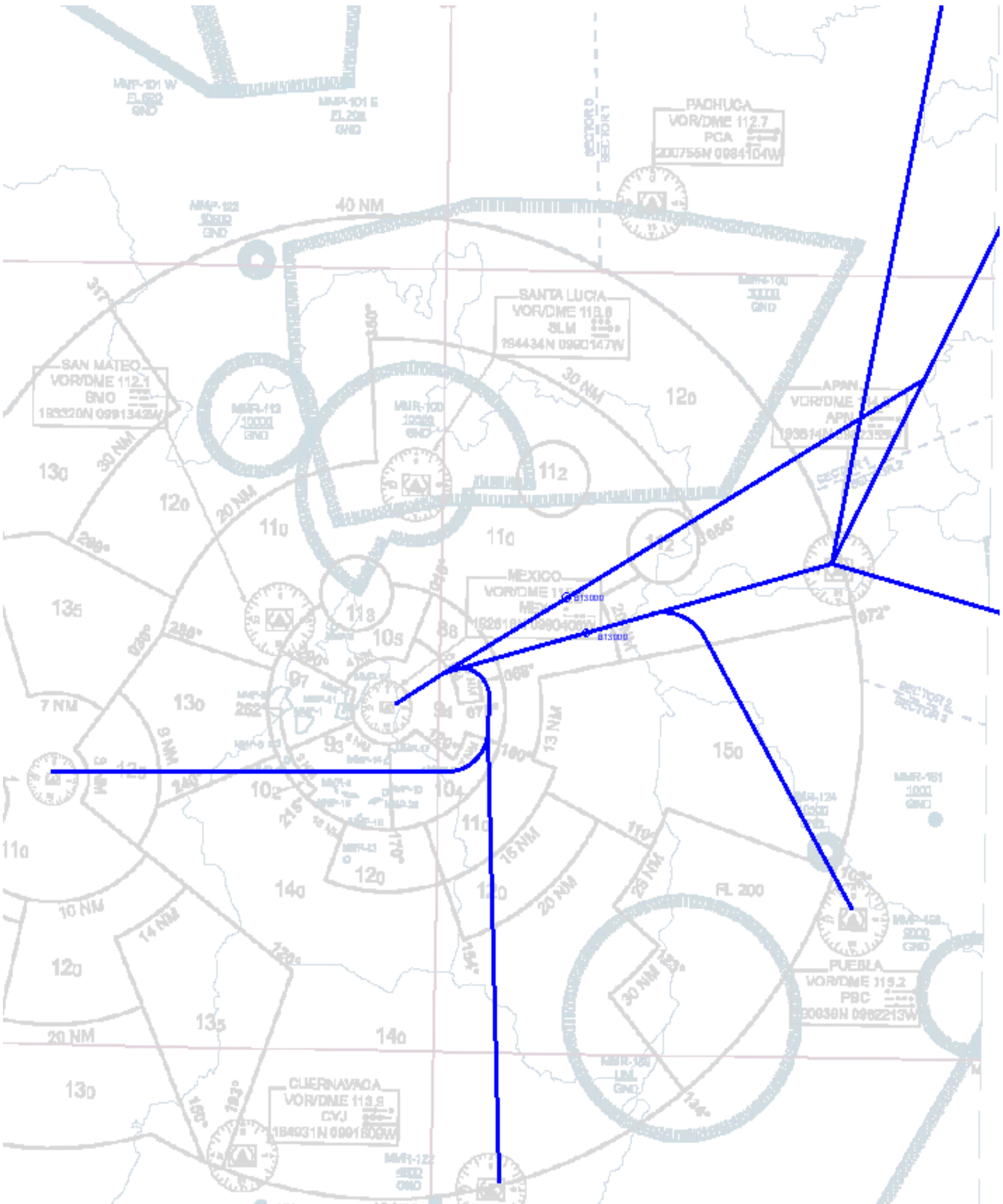

Figure 17, Stage 1 SID MMMX

4.2.3.4 *MMSM SID*

Santa Lucia airport will be fitted with departures to 5 exit points:

- TLC VOR for flights to the West
- MUXEP/OMPUT for flight to the North East
- APN VOR for flights to the South East
- CUA VOR for flight to the South

It should be highlighted that departures towards the West will overfly MEX VOR and Mexico City. However, initial computations show that once crossing MEX VOR, aircraft should have reached an altitude of at least 18000ft, which should limit noise disturbance along that trajectory.

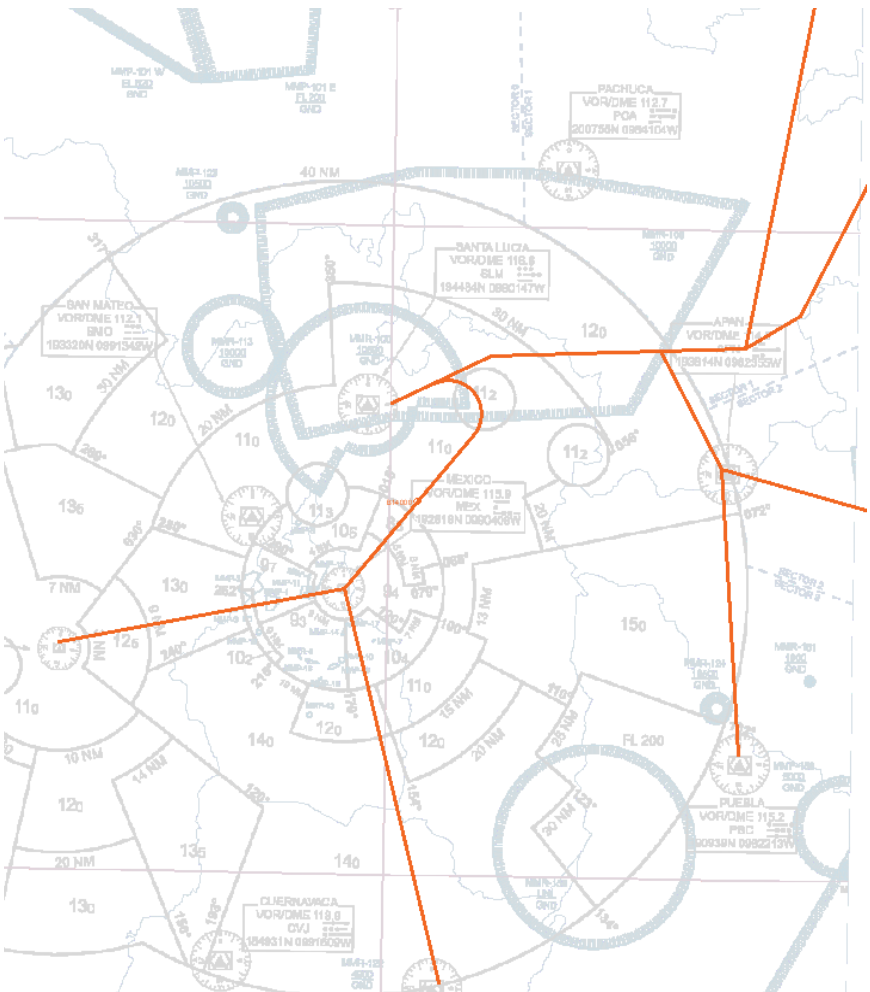

Figure 18, Stage 1 SID MMSM

4.2.3.5 MMSM Approach and missed approach

The approach proposal is a RNAV-1 to ILS procedure with the following characteristics:

The initial approach segment consists of three legs before the LOC course interception. The LOC angular interception is 30º at the IF established at 9000ft, 2NM before FAP. The final approach descend starts at 9000ft, 5.5NM from the displaced THR04L (*)

The approach Glide Path and Reference datum height (RDH) will be standard (3.0º and 50ft).

The project assumes that the preferred runway for landing and take-off is RWY04. The missed approach will turn to the north as soon as possible to diverge at least 30º with respect to the departure (i.e. once the terrain and obstacles were cleared). The missed approach will connect the procedure IAF at 12000ft.

(*) In order to beneficiate from sufficient obstacle clearance on the ILS final segment (San Mateo mountain), it is proposed to displace the landing threshold by 600m. According to the runway characteristics provided in section 3.1.1, the remaining runway length would be 4500m.

Figure 19, Proposed MMSM ILS approach and missed approach

4.2.4. Stage 1 CONOPS summary

- Single Runway assumed at MMSM
- Combined arrival/departure traffic increases considering both airports and using a declared MMMX capacity of 61 an hour as a base line;
  - MMSM one runway operation (1 DEP per 1 ARR): MMMX 61 + MMSM 32 = max rate 93 per hour. (49% increase over current traffic capacity)
  - MMSM capacity based on 16 arrivals = 3.75 minutes between arrivals which equals 8-9nm between arrivals to allow one departure for every arrival. The extra distance is due to higher speeds/distances required at altitude of MMSM.
- The CDO descents, to the extent possible are based on ICAO Doc 9931, Continuous Descent Operations (CDO).
- Concurrent CDO STARs are based on the lower STAR's altitude windows being at or below over a fix 5 NM before the higher STAR's at or above (example below).
- ATC Enroute sectors would keep the MMSM arrival aircraft below the MMMX arrivals before entering the high altitude point merge.
- Top of descent would be in accordance with "Descend Via or Descend On" altitude, speed and heading requirements programed into the FMS of the aircraft.
- Not having a holding pattern for traffic over SLM or the IAFs could be alleviated by ATC assigning the arrival to follow the approach path at 11,000ft back to the IAF via SLM and then the trombone.
- Two MMSM ATC sectors would be required to accommodate the increase in traffic.

Figure 20, Stage 1 CONOPS provides a global overview of Stage 1 proposal.

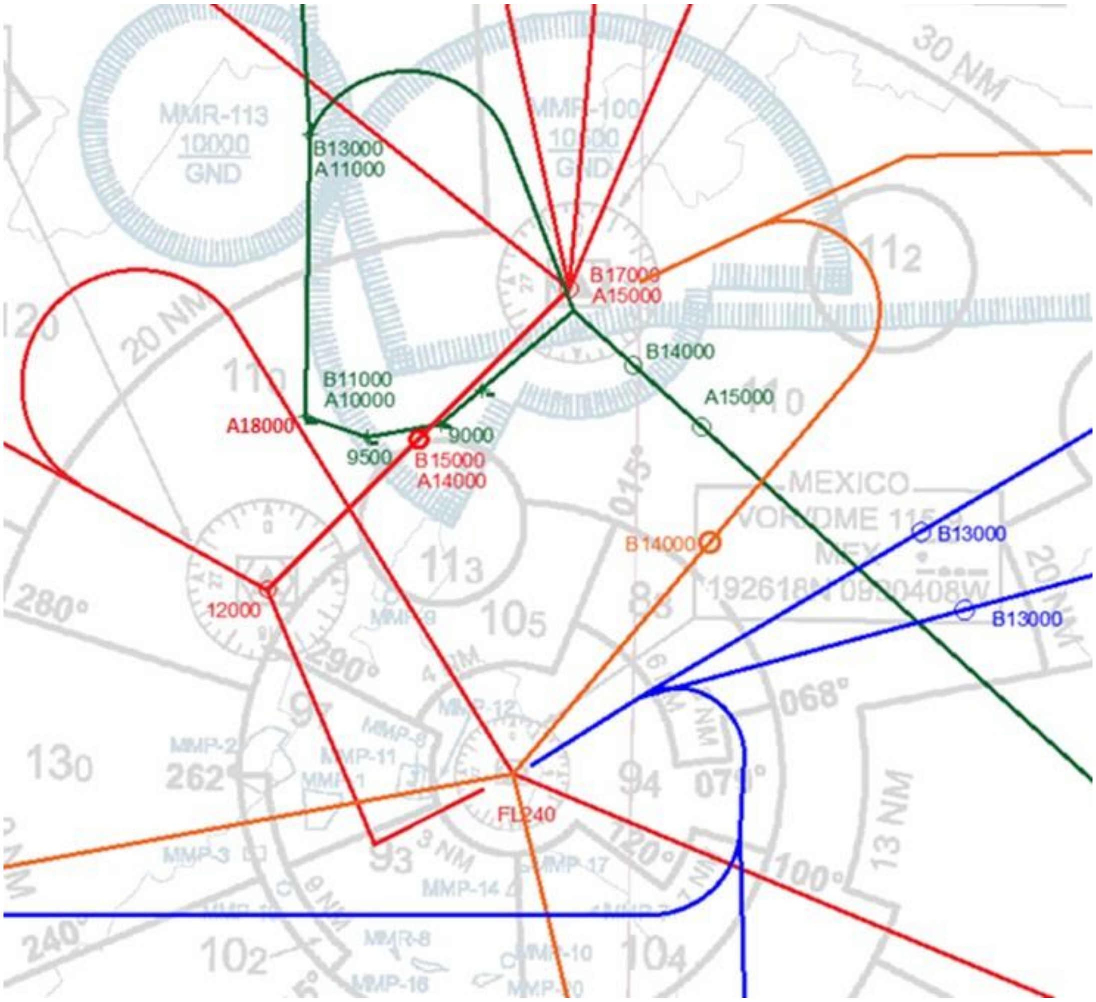

Figure 20, Stage 1 CONOPS

The CDO descents, to the extent possible are based on ICAO Doc 9931, Continuous Descent Operations (CDO).

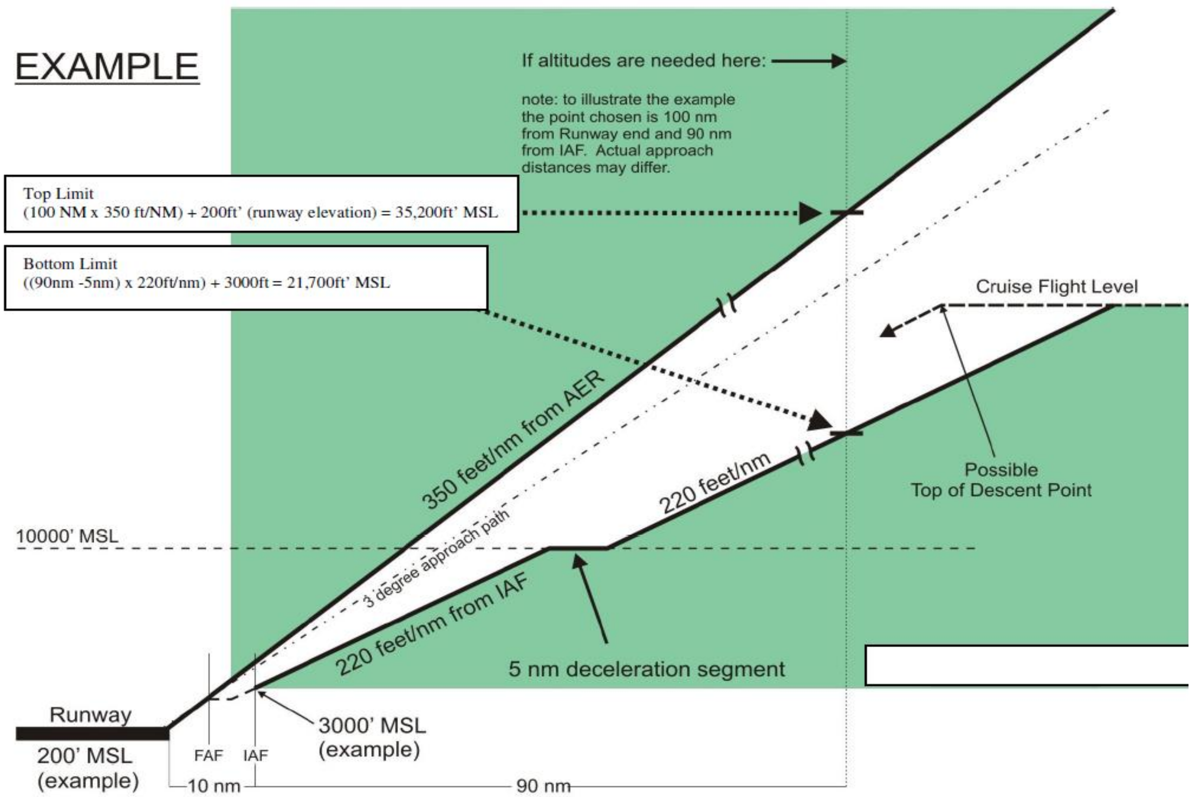

Figure 21, details of CDO

Concurrent CDO STARs are based on the lower STAR's altitude windows being at or below over a fix 5 NM before the higher STAR's at or above.

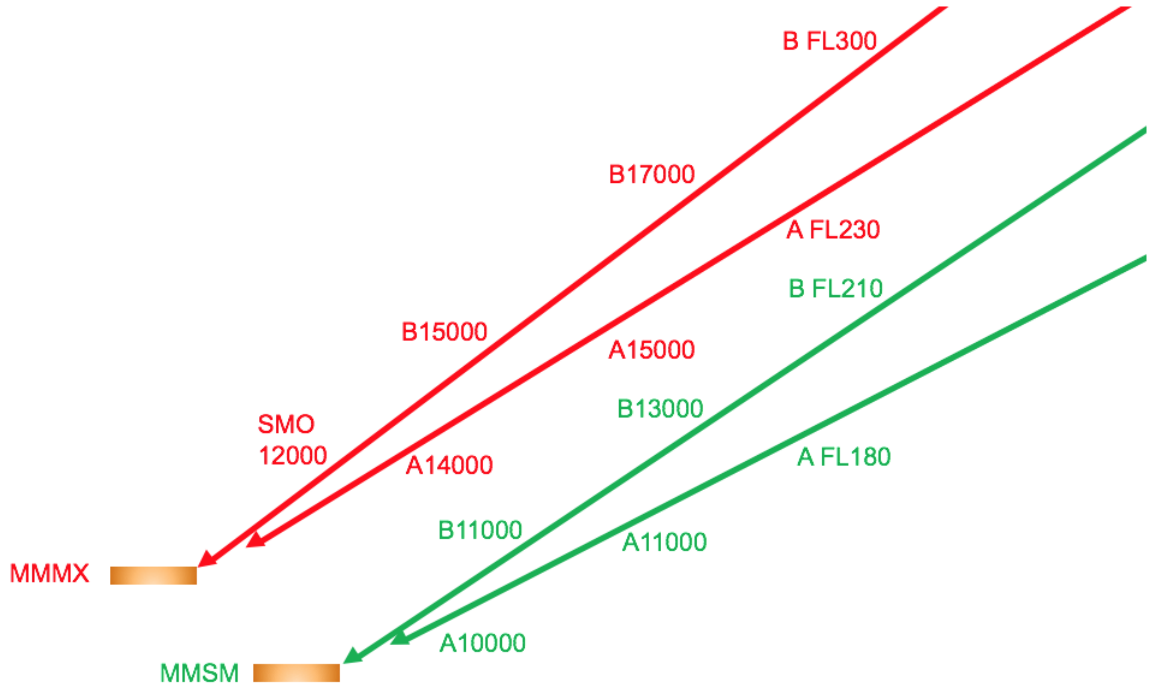

Figure 22, MMSM vs MMMX simultaneous approaches

4.3. Conceptual design stage 2

4.3.1. Principles and assumptions

Stage 2 proposal is based on a short to medium term implementation scenario (18 to 24 months) which requires the establishement of a waypoint ot take the place of the SLM VOR creating a new merge point approximately 6nm southwest of the current SLM merge point. It will not impact the current conventional approaches to Santa Lucia airport (currently the military approaches are based on the VOR only). The impact on mixing RNAV with the conventional approaches is not assessed on this pre-study since it is replaced by the RNAV to ILS approach.

The following assumptions and hypothesis have been taken into consideration:

- **Airport configuration**:
  - East configuration in both airports, RWYs 05 in operation.
  - MMMX Rwy 05L for approaches / Rwy 05R for departures.
  - MMSM Segregated parallel approaches/departures in a semi-mixed mode. It is assumed departures from RWY04L/R and approaches to RWY04L. The compatibility with military operations in the current MMSM runway is out of the scope of this study.

- **Airspace structure**: Minor adjustments on vertical restrictions in the current SID/STARs routes. New procedures for MMSM.

- **Navigation infrastructure**: Creation of new waypoints and slightly modified trajectories to MMMX.

- **En Route connection**: Traffic will enter and exit to the TMA using the current ATS routes.

- **Navigation specification**: Assuming that proposed concept will be applied in a radar environment, it is proposed the implementation of:
  - SID/STAR RNAV-1 in MMSM and MMMX
  - Instrument Approach procedures RNAV-1 to ILS or RNP APCH to MMSM
  - Missed approaches based on RNAV-1.

4.3.2. Benefits

The potential benefits to be obtained from the implementation of this scenario are:

- Simplicity: The changes brought to the existing airspace will require simplified ATC training.

- Procedural vertical separation will be provided in the arrival/departure or departure/missed approach crossing points.

- Horizontal separation will be more efficient than for stage 1 providing a more comfortable environment to ATC.

- The sequencing of international aircraft to MMSM would be accomplished on the same high altitude point merge system at a procedurally separated lower flight level then MMMX.

- The MMSM RNAV to ILS would resemble the current ILS approach to MMMX, giving ATC a similarity in already familiar sequencing, spacing, and speed control.

- Flight crews would have minimal changes to MMMX and a very familiar STAR and approach to MMSM.

- Cost for procedural design and ATC training would be kept to a minimum.

4.3.3. Description

4.3.3.1 MMMX Closed STAR structure

The incoming domestic traffic will be guided to the Mexico City airport proceeding from the same ATS routes and entry points as today:

- North and Northwest
  - UJ5-33 (QET VOR/DME)
  - UJ47-81 (SASUT)
- East
  - UJ55 (DATUL)
  - UJ12/UJ5/UM787/UJ33/UL308/-81 (PBC VOR/DME)
- South
  - UJ24S/UJ21W/UJ71/UL423 (TEQ VOR/DME)

The proposed design is very similar to stage 1, but provides better tools to ATC to ensure aircraft separation. The modifications on the MMMX STAR system consists in rerouting arriving aircraft coming from the North East to a slightly more westerly trajectory to provide more room for MMSM arrivals, as well as creating and modifying some altitudes constraints to provide vertical separation with the traffic going to Santa Lucia airport.

This STAR configuration can also be achieved by using waypoints instead of the SLM VOR. By doing so, the arrival from DATUL would become a full RNAV1 arrival.

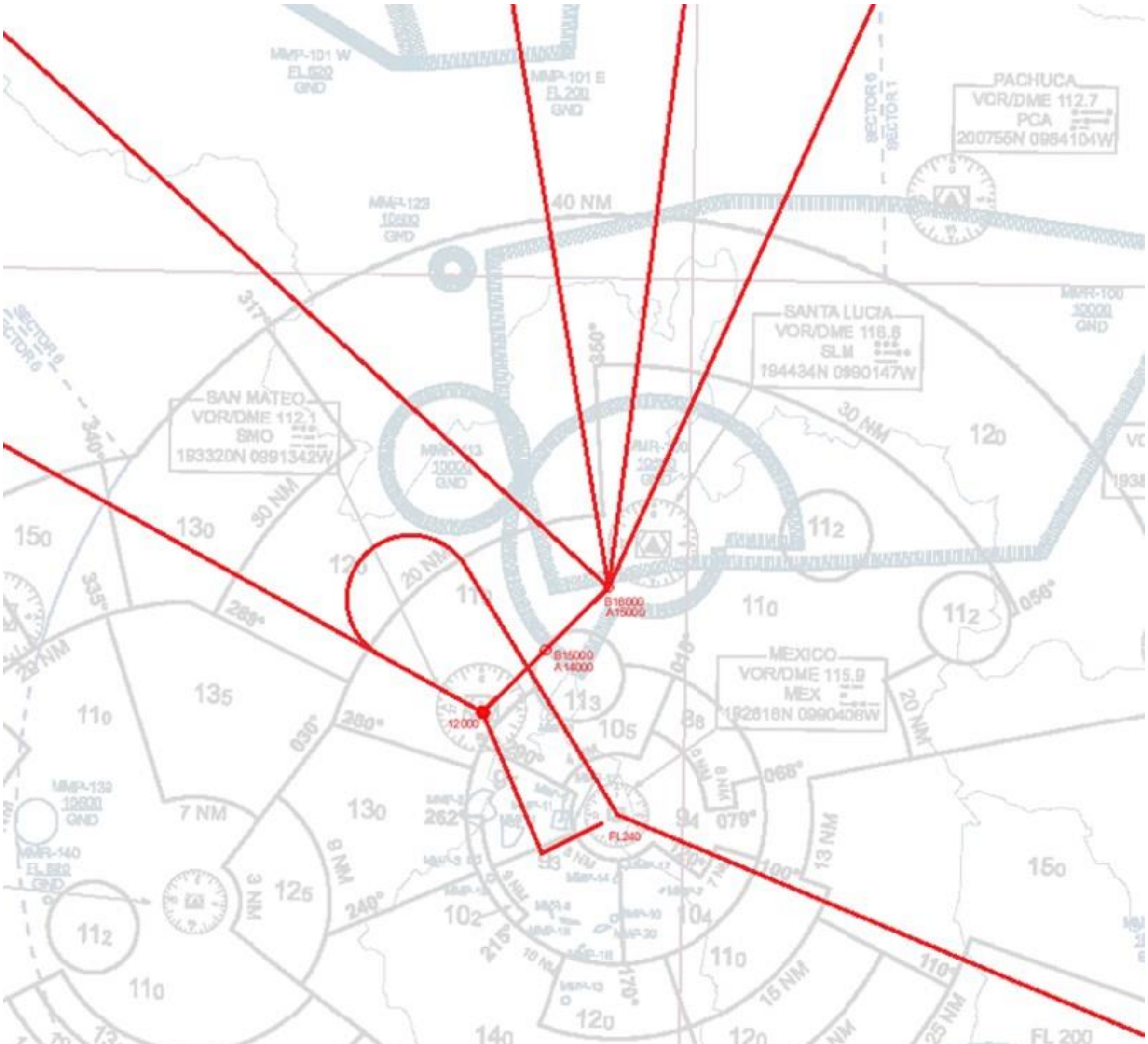

Figure 23, Stage 2 MMMX STARs

4.3.3.2 *MMSM Closed STAR structure*

The MMSM STAR structure remains would the almost the same than presented in stage (Refer to 4.2.3.2). The main difference is that aircraft arriving to current SLM position and landing at Santa Lucia would be laterally <u>and</u> vertically separated from aircraft on Benito

Juarez STAR. This would allow a better management of the descent profile for aircraft to Santa Lucia with limited level off over SLM and therefore increase of efficiency.

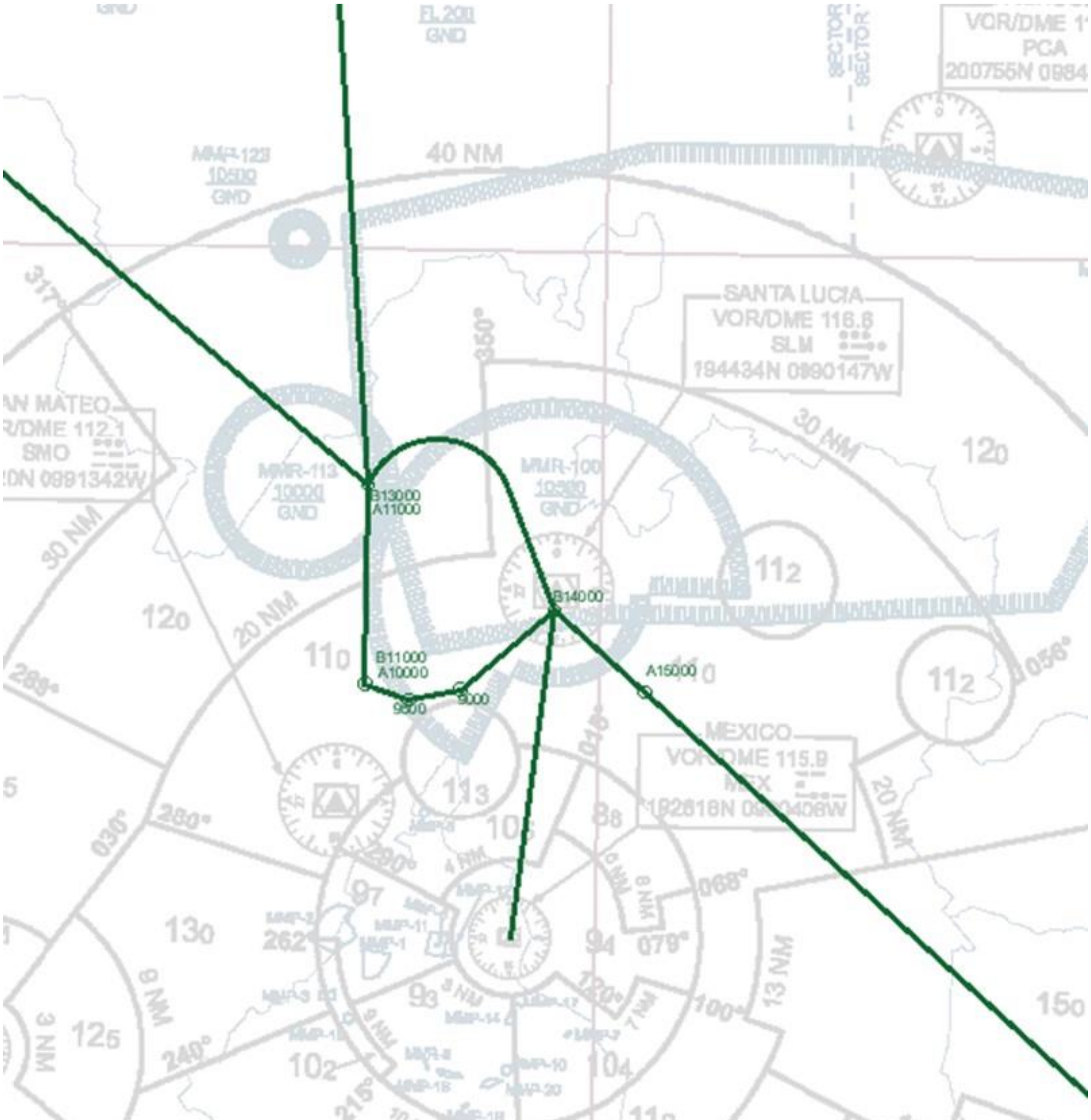

Figure 24, Stage 2 MMSM STARs

4.3.3.3 *MMMX SID*

The MMMX SID structure would remain the same as in Stage 1. Refer to 4.2.3.3.

4.3.3.4 MMSM SID

The MMSM SID structure would remain the same as in stage 1. Refer to 4.2.3.4.

4.3.3.5 MMSM Approach and missed approach

The MMSM approaches would remain the same as in stage 1. Refer to 4.2.3.5.

4.3.4. Stage 2 CONOPS summary

- Combined arrival/departure traffic increases considering both airports and using a declared MMMX capacity of 65 an hour as a base line;
  - MMSM two runway non independant operation (1 DEP, 1 ARR): MMMX 65(*) + MMSM 58(**) = max rate 123 per hour.

(*) Considering that most of the heavy aircraft would be dispatched to Santa Lucia and replaced by medium to large aircraft, the average separation on final and between departures would decrease, avoid A380/B747 having to taxi back and cross mid field, thus leaving room for more aircraft.

(**) MMSM 58 rate is lower based on international traffic mix including a higher number of heavies, requiring more ATC separation on final, and ATC use of new procedures/sectors that are not optimized for two airports.

  - MMSM two runway independent operation: MMMX 65 + MMSM 68(**) = max rate 133 per hour.

- New ATC sectors and a reorganization of some traffic flows would lead to increased safety and efficiencies.
- Moving MMMX merge point would increase separation between MMMX and MMSM traffic, providing a larger buffer and enabling a higher traffic density.
- The CDO descents, to the extent possible are based on ICAO Doc 9931, Continuous Descent Operations (CDO).
- Concurrent CDO STARs are based on the lower STAR's altitude windows being at or below over a fix 5 NM before the higher STAR's at or above. Example below.
- ATC Enroute sectors would keep the MMSM arrival aircraft below the MMMX arrivals before entering the high altitude point merge.

- Top of descent would be in accordance with “Descend Via or Descend On” altitude, speed and heading requirements programed into the FMS of the aircraft.

- Not having a holding pattern for traffic over SLM of the IAFs could be alleviated by ATC assigning the arrival follow the approach at 11,000ft back to the IAF via SLI and then the trombone.
- One additional (including the two in phase 1) MMSM ATC sectors would be required to accommodate the increase in traffic.

Figure 25 next page provides a global overview of Stage 2 proposal.

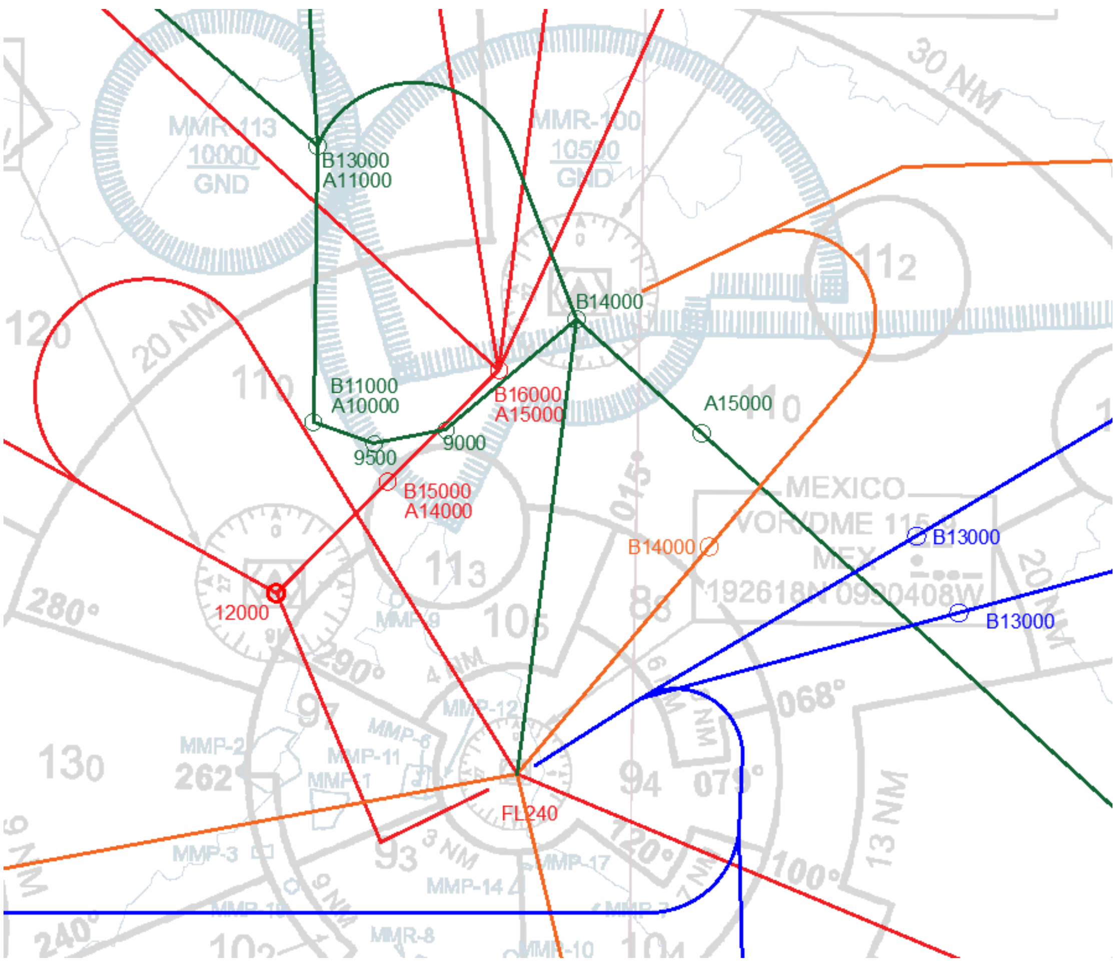

Figure 25, Stage 2 CONOPS overview

4.4. Conceptual design stage 3

4.4.1. Principles and assumptions

The Stage 3 is based on a medium to long term implementation scenario. It is acknowledged that, at least a couple of years will be needed to implement changes associated to this new Operational Concept. The new sector and route structure will enable to get the maximum benefit from the new airport system operation in Mexico TMA, while traffic count would only increase slightly, an increase in safety and CDO/CCO fuel savings and decreasing flight miles and CO2 emissions will be observed. This proposal is aligned with the global ICAO PBN implementation strategy as it is considers the PBN application in all flight phases. This proposal serves as as starting point upon which consultation with existing Air Ttaffic Controllers and system users should occur prior to settling upon a final design.

The following assumptions and hypothesis have been taken into consideration:

- **Airport configuration**:
    - East configuration in both airports, RWYs 05 and 04 in operation.
    - MMMX Rwy 05L for approaches / Rwy 05R for departures.
    - MMSM Segregated parallel approaches/departures in a semi-mixed mode. It is assumed departures from RWY04L/R and approaches to RWY04L. The compatibility with military operations in the current MMSM runway is out of the scope of this study.
- **Navigation infrastructure**: VOR infrastructure could be discontinued.
- **Airspace structure**: There are not expected major changes in the airspace structure, TOLUCA/PUEBLA/MEXICO TMAs. Some minor adjustments could be required in the ATC sectors limits to accommodate “concurrent CDO/CCO” procedures.
- **En Route connection**: Traffic will enter and exit the TMA using the current ATS routes. The option 3 design keeps the connection with the main flows through the same routes with the exception of the international traffic coming from the northwest. The incoming traffic from US west coast will be proceed from SASUT (UJ-47) or AVSAR (UJ-81) instead of QET (UJ-5 33).
- **Navigation specification**: Assuming that proposed concept will be applied in a radar environment, it is proposed the implementation of:
    - SID/STAR RNAV-1 in both airports. It is needed to replace the conventional MMMX SID/STAR. The new MMSM SID and STAR

  - Instrument Approach procedures RNAV-1 to ILS or RNP APCH.
  - Missed approaches based on RNAV-1.

4.4.2. Benefits

In addition to the already known benefits derived from the PBN implementation (ICAO Doc. 9613, Predictable trajectories, repeated tracks, cost savings based on removal of expensive ground navigations means…), there are additional benefits to be obtained from the implementation of this scenario:

- Lateral segregation of the inbound traffic to MMMX and MMSM and vectoring areas. Air traffic controllers could build the approach sequences to each airport independently.

- Terminal routes are merged progressively as they approach to the Initial Approach Fixes (IAFs). It simplifies the route structure within terminal airspace by ensuring that the complex task of traffic merging is done outside the Terminal core area.

4.4.3. Description

4.4.3.1 MMMX closed STAR structure

The incoming domestic traffic will be guided to the Mexico City airport proceeding from the following ATS routes and entry points:

- North and Northwest
  - UJ5-33 (QET VOR/DME)
  - UJ47-81 (SASUT)
  - J13/V52 (XOVAB)
- East
  - UJ55 (DATUL)
  - UJ12/UJ5/UM787/UJ33/UL308/-81 (PBC VOR/DME)
- South
  - UJ24S/UJ21W/UJ71/UL423 (TEQ VOR/DME)

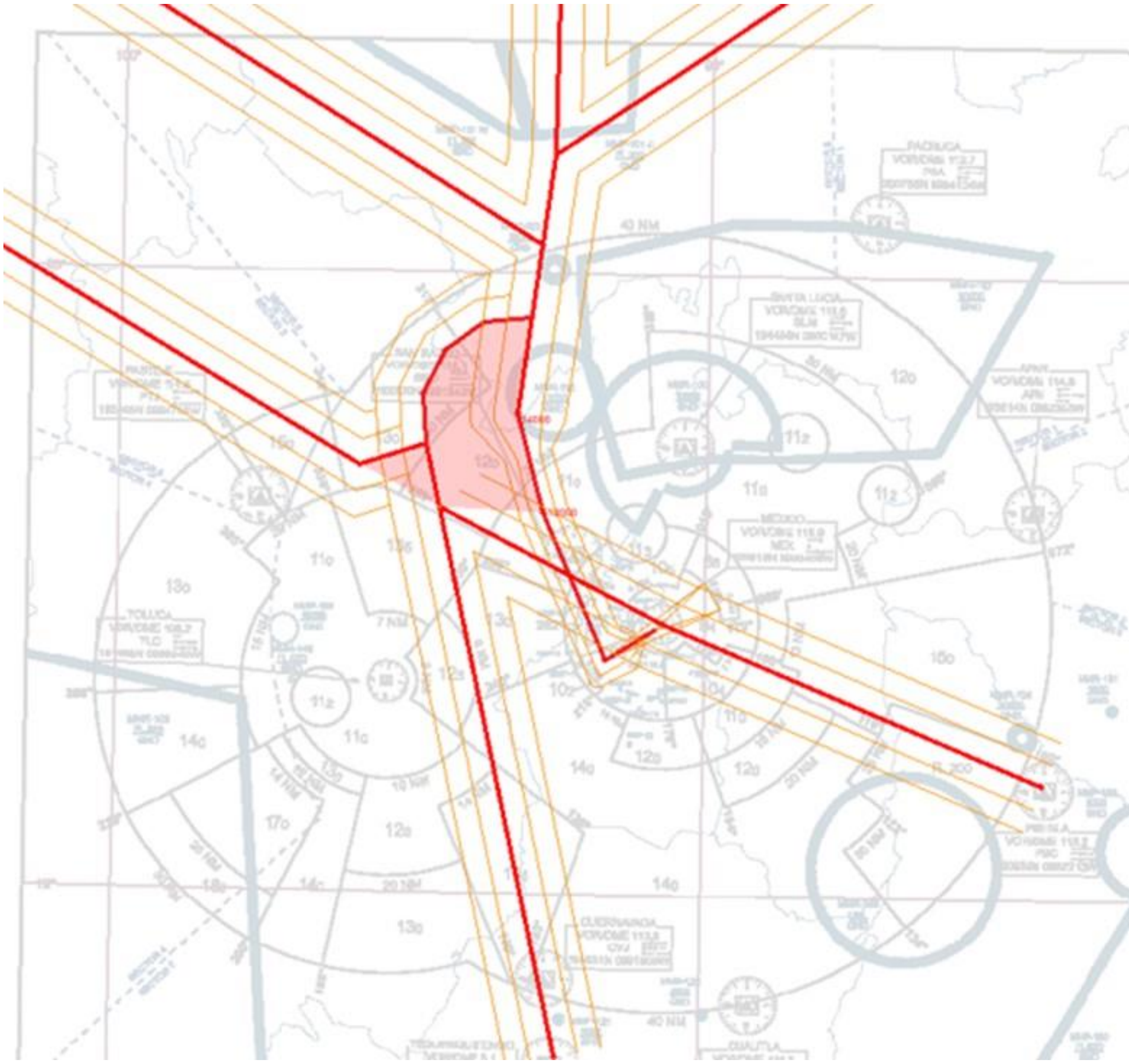

Figure 26, Stage 3 MMMX STARs

The proposed design establishes and RNAV-1 STAR structure leading traffic to two feeders, one at the north and other at the south, and merging the south flow in a unique sequence through a point merge structure. The merging would be designed at or above 14000ft. The traffic coming from the south could be directed at or above 12000ft to the southern waypoint to shortcut the transition.

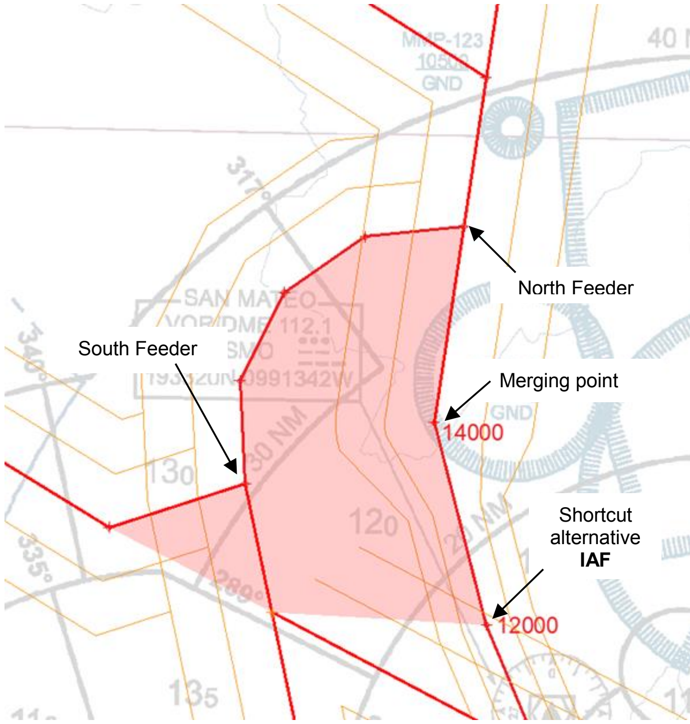

Figure 27, Stage 3 MMMX STARs (zoom merge point)

Taking into consideration that the main domestic flows come from Cancún and Guadalajara, and assuming that this traffic would proceed from En route structure to Mexico TMA as today, the north feeder would receive these flows (DATUL and QUET) producing a significant unbalance between north and south feeders. As an alternative to balance traffic, the design proposes to direct the Cancún traffic to the south feeder from PBC VOR/DME. The flow management service could take into consideration this alternative as a proposal to the operators to avoid congestion and regulations in the northern sectors during the peak hours.

4.4.3.2 MMSM closed STAR structure

The new runways of Santa Lucia airport will accommodate the international flights proceeding from the following ATS routes and entry points:

- North and Northwest
    - UJ47-81 (SASUT)
    - UJ35 (AVSAR)
- East
    - UJ55 (DATUL)
    - UJ12/UJ5/UM787/UJ33/UL308/-81 (PBC VOR/DME)
- South

- UJ24S/UJ21W/UJ71/UL423 (TEQ VOR/DME)

Similarly, to the Mexico City transition, the proposed design establishes the RNAV-1 standard arrivals routes to connect the en-route with two feeders, one for traffic coming from the north and northwest, and other for the traffic coming from the east and south. The east/south flow is integrated in a unique sequence with the north traffic through a point merge structure. The merging would be produced at or above 12000ft.

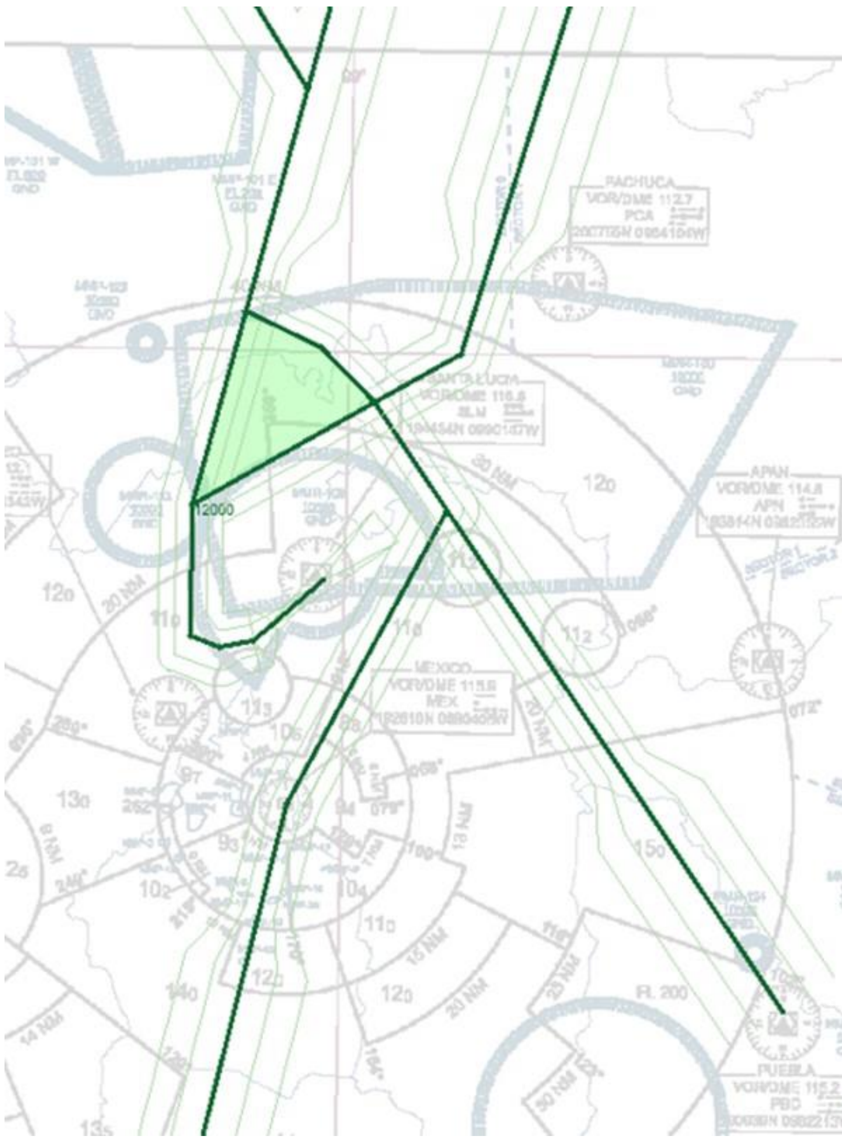

Figure 28, Stage 3 MMSM STARs

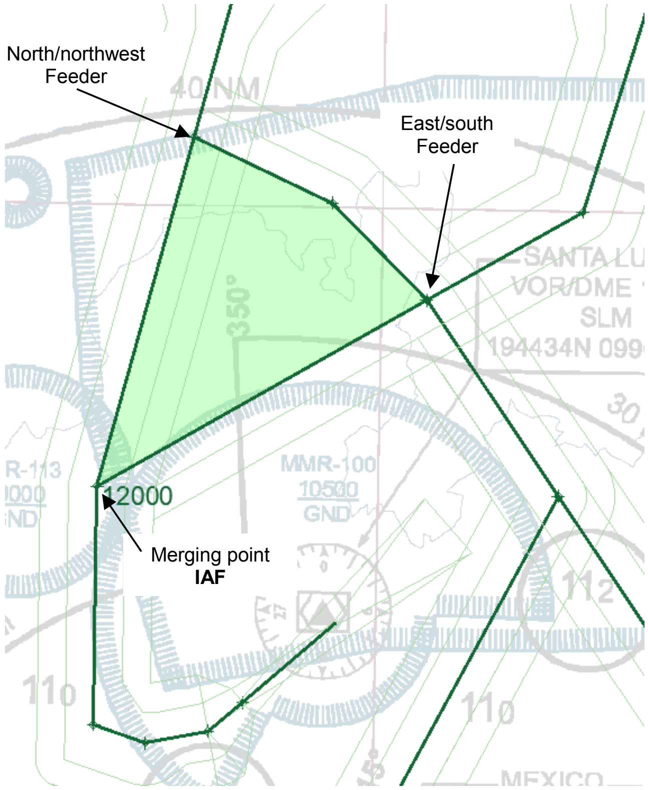

Figure 29, Stage 3 MMSM STARs (zoom merge point)

In terms of traffic flows balance, the arrival traffic to Santa Lucia airport would be much more balanced than the Mexico City ones. The main flow coming from the West coast of US would proceed through the North/northwest feeder, and traffic from Europe and South America would do it through the East/south.

4.4.3.3 MMMX SID

In general terms, the MMMX SID structure would remain the same than for Stage 1. Refer to 4.2.3.3.

A minor adjustment is required in the SID PBC4C which will be displacing to the east the turning fix published at 19 DME APN. The purpose is to avoid MMSM incoming traffic from the south.

4.4.3.4 MMSM SID

To guarantee an appropriate integration to the enroute phase of flight, the new departures from MMSM are connected to the same SID exit waypoints.

The initial departure track is deviated 15º to the south respect to the extended runway center line to enable the simultaneous segregated operations. From this initial track, the SIDs will diverge in different directions:

- PTJ, TLC and CUA: In the initial track, a turning waypoint is placed at 4.6NM away from DER. Aircraft will turn to the right (IAS max 185kt) proceeding direct to MEX VOR/DME. From MEX two tracks diverge one to CUA (CUA1B) and other to TLC (TLC1B and PTJ1B). Finally, a new track is defined from TLC to PTJ (PTJ1B).

- MUXEP, OMPUT, APAN and PBC: These departures keep the initial track up to a waypoint placed 11.0 NM away from DER. Then, aircraft shall turn to the right to continue on the track to MUXEP and OMPUT. At 16.9NM from the tuning point the SIDs to APAN and PBC diverge to the south from the track MUXEP/OMPUT.

SIDs	Route connection - Outbound flow	PDG approx.
MUXEP1B	UJ15-38 north/northeast	5.8%
OMPUT1B	J177 north/northeast	5.8%
APAN1B	UJ28-30/UT19/UT42/UJ18 east	5.8%
PBC1D	UL318/UJ47 east/south-east	5.8%
CUA1B	UJ15/UJ39 south	6.0%
TLC1B	UJ18/UJ30 west/southwest	6.0%
PTJ1B	UJ45 northwest	6.0%

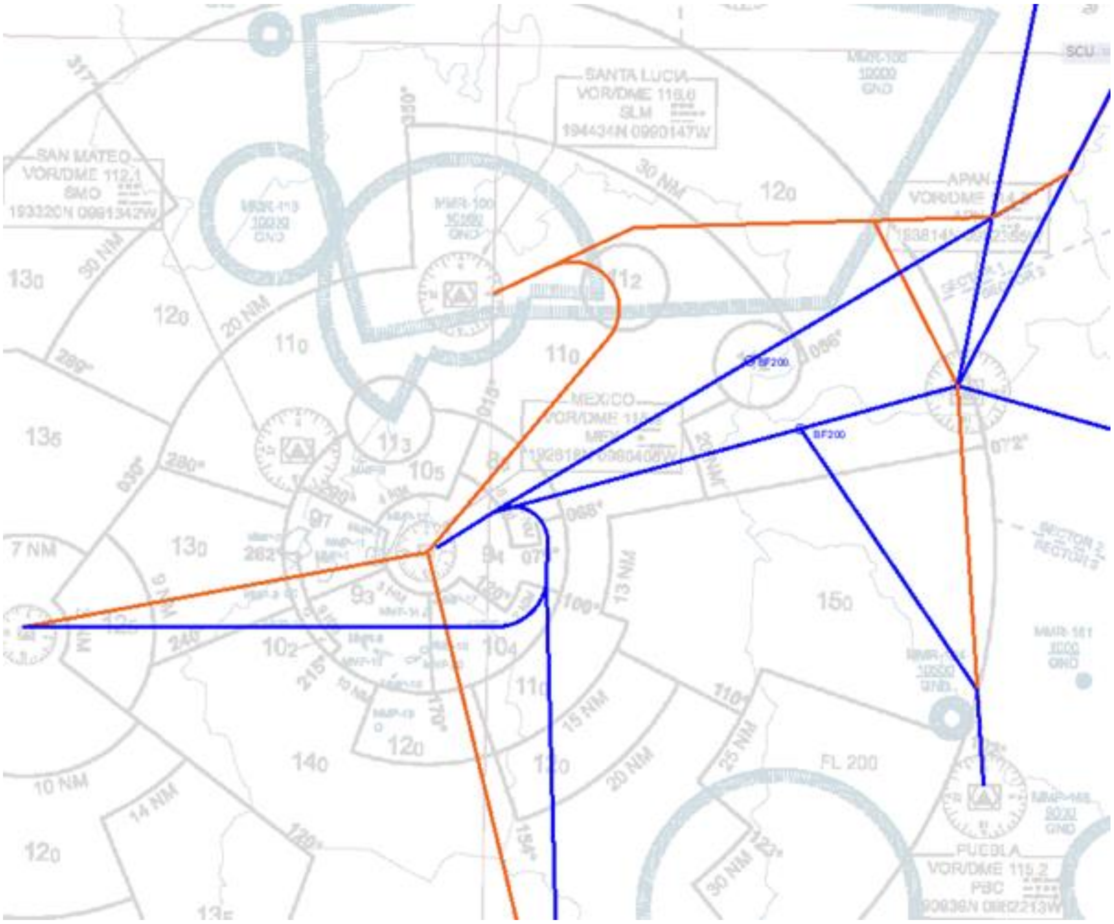

Figure 30, Stage 3 MMMX and MMSM SIDs

4.4.3.5 MMSM Approach and missed approach

The MMSM approaches would remain the same than for stage 1. Refer to 4.2.3.5.

4.4.3.6 MMMX Approach and missed approach

The new RNAV-1 STAR structure is compatible with the AIP instrument approach procedures published (IAC1 and IAC7). However, it would be needed to deal with some modifications to the already published approach procedures:

- Initial approach segment: It is needed to displace the IAF MAVEK or SMO 5.7NM to the northwest. It enables the suitable spacing respect to the MMSM new approach procedure.
- LOC interception: To prevent the LOC overshooting at CI05R, it is proposed to replace the current 90º turning for interception with a RF transition. It enables a

smooth final approach course interception providing 2NM distance before the GP capture.

- Missed approach: Current MAP turning to MIXEX would interfere with the departure traffic from MMSM (proceeding to MEX VOR/DME). To produce an optimal crossing in MEX, it is proposed to redefine the missed approach from MEX23 turning to the right direct to MEX (IAS shall be limited to avoid terrain interferences). From MEX, the aircraft could be integrated again in the approach sequence.

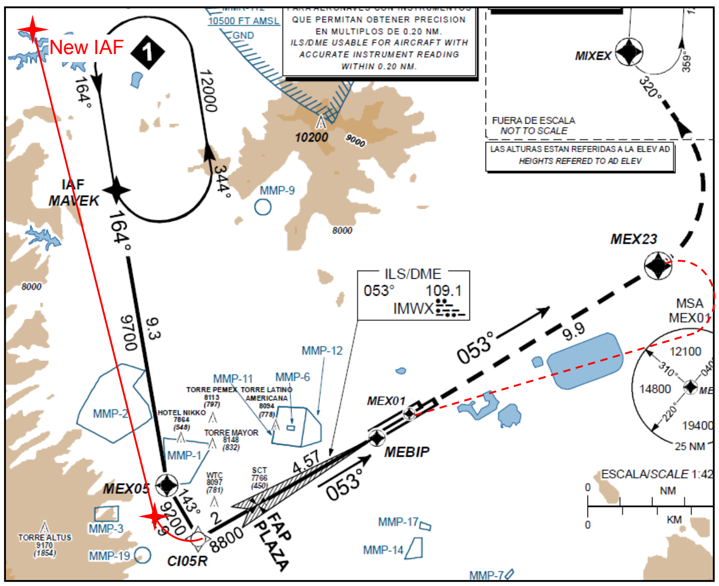

Figure 31, Stage 3 MMMX Missed Approach

4.4.3.7 Stage 3 - Strategic deconfliction at crossing points

In the Stage 3 ConOPS have been identified several crossing points that could be managed easily in a tactical way. As an alternative solution, these crossings could be solved adding some vertical restrictions to the proposed routes. Some potential solutions are detailed below:

MEX - MMSM SIDs (PTJ, TLC and CUA) and MMMX/MMSM STARs:

MMSM SIDs need a vertical restriction at or below FL220 after crossing MEX VOR/DME to be strategically deconflicted respect to the MMSM/MMMX arrival traffic at MEX. The arrivals will have a vertical restriction at or above FL230 at MEX (In addition, arrivals to MMSM and MMMX can be procedurally separated assigned altitude windows).

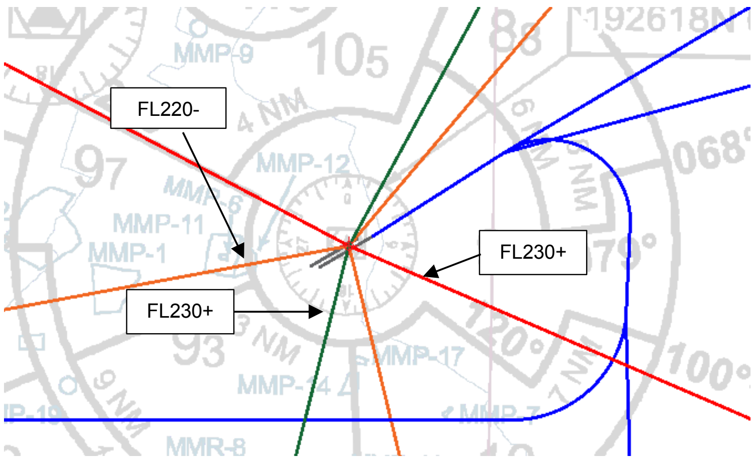

Figure 32, Stage 3 Crossing at MEX

MMSM SIDs (MUXEP, OMPUT, APAN and PBC) and MMSM STARs:

MMSM SIDs need an initial clearance at 16000ft to strategically deconflict departures and the MMSM arrival traffic (at or above 17000ft).

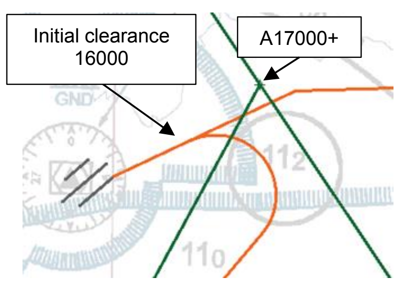

Figure 33, Stage 3 MMSM SIDs initial clearance

MMMX STAR (DATUL) and MMSM STARs (AVSAR and SOSUT):

It will be needed to add vertical restrictions to strategically deconflict traffic from these arrivals. One solution could be crossing MMMX arrival from DATUL above the MMSM STARs.

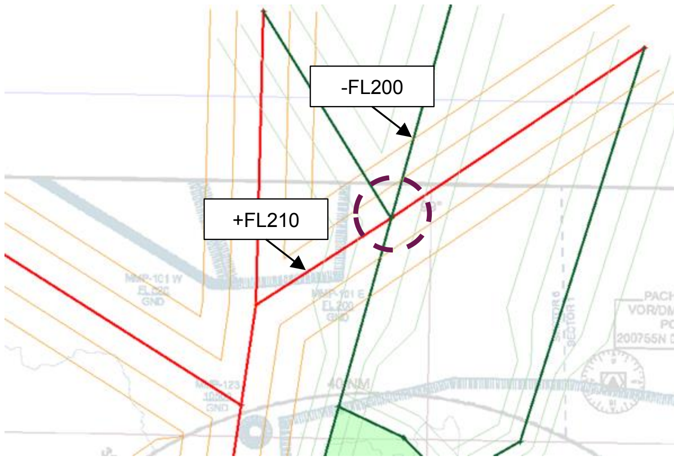

Figure 34, Stage 3 MMMX and MMSM north arrival flows crossing

MMSM STARs (South) and MMMX SIDs (MUXEP1/OMPUT1/APN7A/PBC4C):

It is needed to add vertical restrictions to strategically deconflict departure traffic from MMMX and arrivals to MMSM. A potential solution could be to add an “at or above FL210” constraint to the MMSM STAR and “at or below FL200” to the MMMX ones.

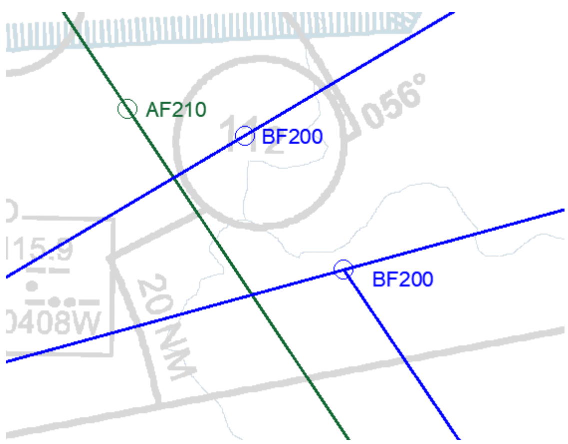

Figure 35, Stage 3 MMMX and MMSM departures crossing

4.4.4. Stage 3 CONOPS summary

- Combined arrival/departure traffic increases considering both airports and using the max MMMX airport rate of 72(*) and hour as a base line;

  (*) MMMX maximum capacity rate is currently stated as 61 per hour. This rate is more likely to be achieved or surpassed, with a rate as high as 72 using fully separated traffic and lower percentage of heavy traffic into MMMX airport

  - MMSM two runway non independant operation (1 DEP, 1 ARR): MMMX 72 + MMSM 58(**) = max rate 130 and hour.

  (**) MMSM 58 rate is lowered based on international traffic mix including a higher number of heavies, requiring more ATC separation on final.

  - MMSM two runway independant operation: MMMX 72 + MMSM 68(**) = max rate 140 per hour.

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- MMSM and MMMX traffic would be fully separated from high altitude (en-route), horizontally and vertically, to the threshold, increasing the level of safety and efficiency.

- New ATC sectors and a reorganization of some traffic flows would lead to increased safety and efficiencies.

- CDO and CCO would be easier to provide from the ATC perspective

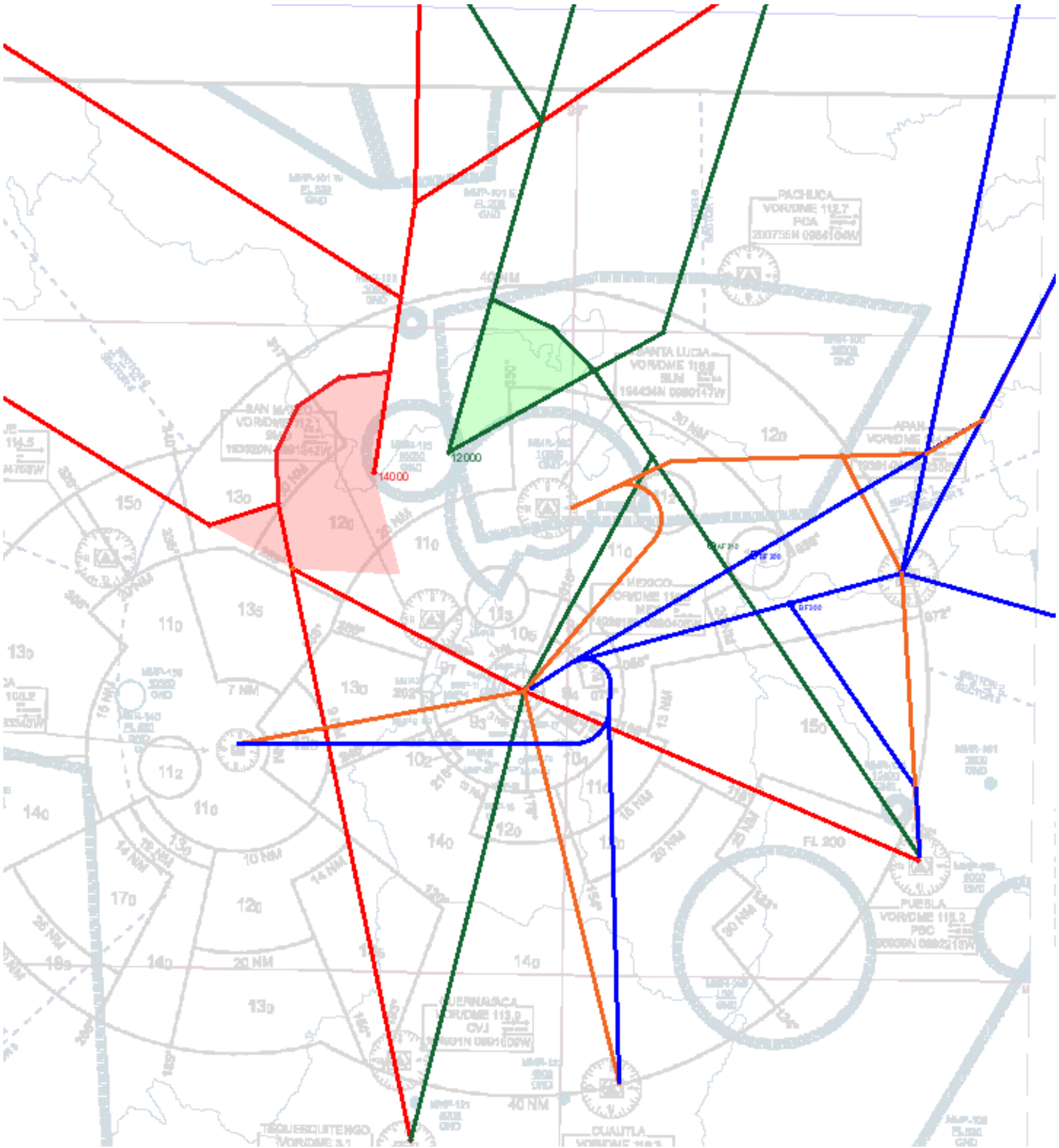

Figure 36, Stage 3 CONOPS

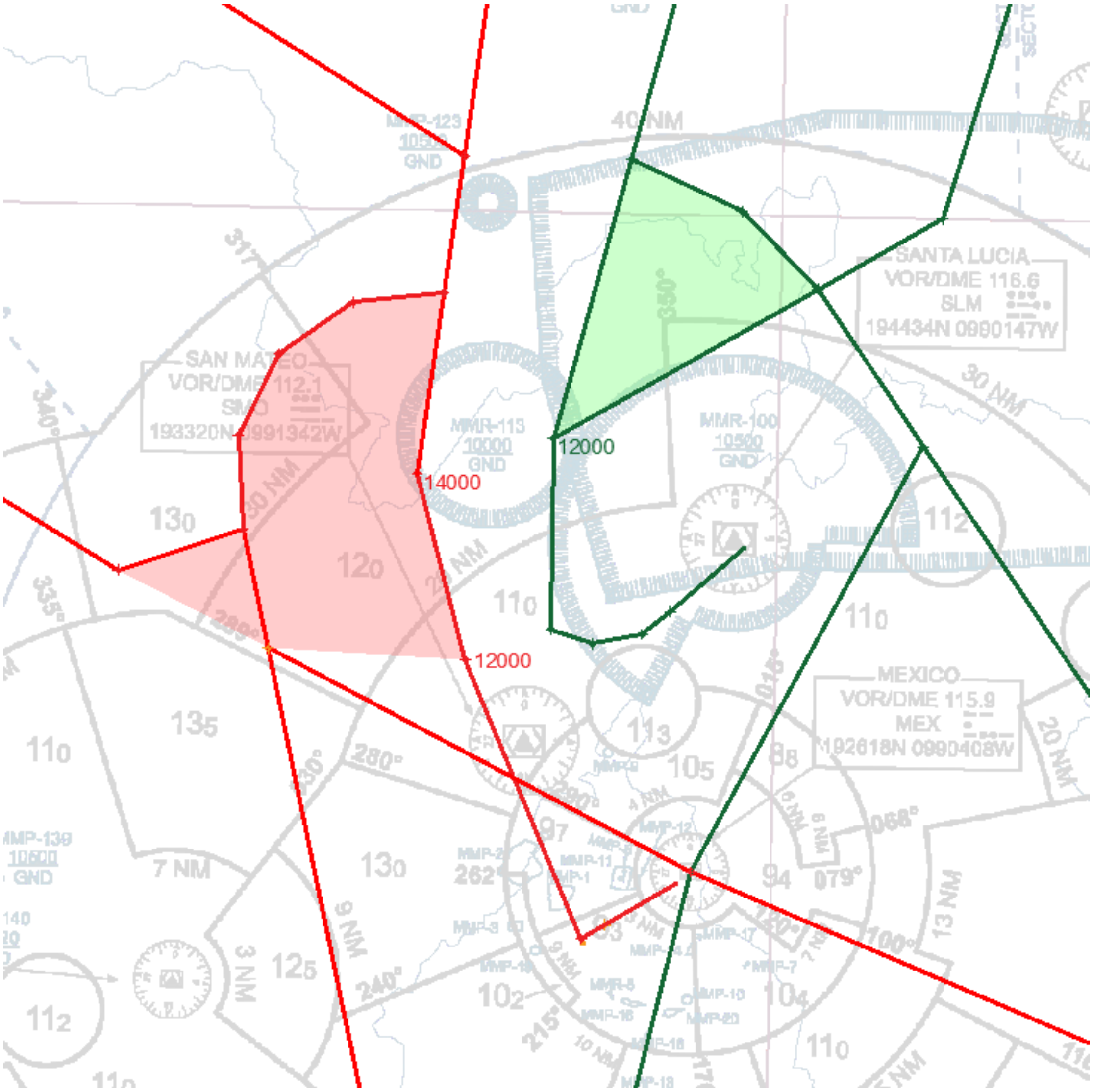

Figure 37, Stage 3 CONOPS (only arrivals)