Enclosure 3

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MITRE

Center for Advanced
Aviation System Development

Independent Approaches to Two Runways at Cancún

Preliminary Runway Spacing Analysis and Air Traffic Control-Related Equipment Requirements

Prepared for

Aeropuertos y Servicios Auxiliares (ASA)

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1. Introduction

MITRE is assisting Aeropuertos y Servicios Auxiliares (ASA) to turn into reality the project of a new airport for Mexico City. In connection to that, MITRE has been informed that the Aeropuerto Internacional de Cancún (Cancún) is considering the implementation of independent approaches to its two existing parallel runways in the mid-term. This would provide a significant increase in capacity for Cancún. Moreover, it would also allow Cancún to serve as a test location so that air traffic controllers could obtain an understanding of issues associated with independent operations, and gain experience for the future implementation of such procedures at the Nuevo Aeropuerto Internacional de la Ciudad de México (NAICM).

The International Civil Aviation Organization (ICAO), in both the *Manual on Simultaneous Operations on Parallel or Near-Parallel Instrument Runways (SOIR)* [ICAO, 2004] and *Procedures for Air Navigation Services – Air Traffic Management (PANS-ATM)* [ICAO, 2007], allows independent parallel approaches to two runways. This document provides a preliminary collision risk analysis for Cancún, as well as information on surveillance, display, and communications-override equipment required to manage the runway separation standards in [ICAO, 2004] and [ICAO, 2007].

Section 2 contains background information on dual independent approaches and presents the results of MITRE's preliminary collision risk analysis for Cancún. Section 3 provides suggestions on the required radar and surveillance display capability for Cancún based on the preliminary collision risk analysis. Section 4 provides information on communications-override requirements, and Section 5 provides comments on additional training, design, and procedures that will be required for the implementation of independent approach procedures. Finally, Section 6 presents a summary of the document.

2. Independent Parallel Approaches at Cancún

This section describes the principal factors that play a role in the assessment of safety versus runway spacing when independent approach procedures are being considered. A general description of equipment, procedures, and resources used for independent approaches (such as monitor controllers, displays, and radars) is provided.

Since Cancún's runway separation (1448 m[1]) is within the range of 1310 m to 1525 m for which [ICAO, 2007] indicates that surveillance equipment should be analyzed to determine "that the safety of aircraft operation would not be adversely affected…", a collision risk analysis is presented below to verify the safety of the surveillance and display equipment recommended in Section 3.

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[1] The spacing between the existing runways at Cancún was derived from runway end coordinates obtained from Mexico's Aeronautical Information Publication (AIP).

Sufficient runway spacing, as well as appropriate procedures and equipment, are necessary to conduct independent approaches to two runways in instrument conditions. During independent approaches, radar-equipped "monitor controllers" monitor approaching aircraft on each approach path using dedicated radar displays to ensure that the aircraft do not deviate from their respective approach paths. A No Transgression Zone (NTZ) at least 2000 ft (610 m) wide separates the parallel approach paths and is depicted on the radar display (see Figure 1). Should 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 approach path. Should the controllers observe an aircraft entering or about to enter the NTZ, then the controller for the adjacent approach path should instruct aircraft on his or her approach path to discontinue their approach and turn to avoid the deviating aircraft.

For approaches to two parallel runways, ICAO, in both the *Manual on Simultaneous Operations on Parallel or Near-Parallel Instrument Runways (SOIR)* [ICAO, 2004] and *Procedures for Air Navigation Services – Air Traffic Management (PANS-ATM)* [ICAO, 2007], allows independent parallel approaches to runways separated between 1035 m and 1310 m when using a Precision Runway Monitor (PRM) for surveillance. The PRM is a monopulse Secondary Surveillance Radar (SSR) capable of update rates as fast as one-half second. However, the PRM is no longer being manufactured and is not required for Cancún and therefore will not be further discussed in this document.

For runway separations between 1310 m and 1525 m, independent approaches are allowed "when it is determined that the safety of aircraft operations would not be adversely affected." In other words, an aeronautical analysis is required for runway spacing in this range. For runways spaced over 1525 m, independent approaches may be conducted using a standard radar and display without the need of a special study. Since Cancún's runway separation (1448 m) is between 1310 m and 1525 m, the collision risk analysis in this section will focus on demonstrating that the recommended surveillance equipment meets safety standards.

The United States (U.S.) Federal Aviation Administration (FAA) has authorized independent approaches to two parallel runways at about 30 airports, including approaches to three parallel runways at a number of them. MITRE has been involved in safety analyses and has assisted in the implementation of independent approach procedures at many of the U.S. airports. Outside of the U.S., only a few airports (approximately eight) conduct independent approaches to two runways.

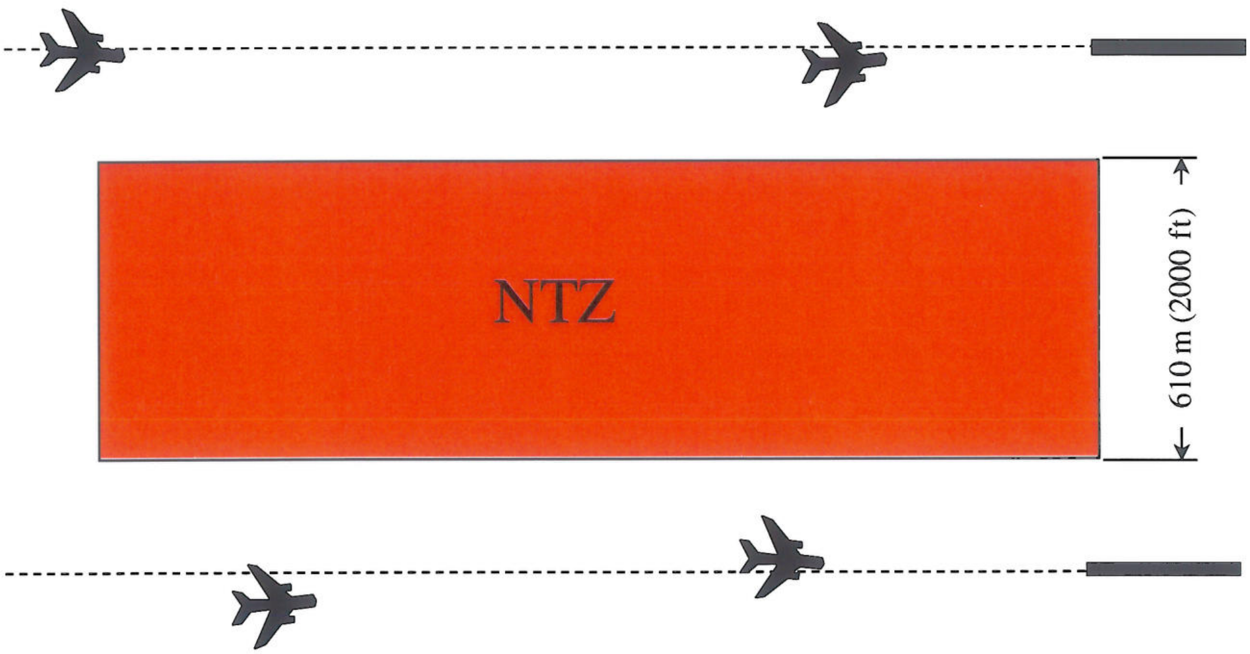
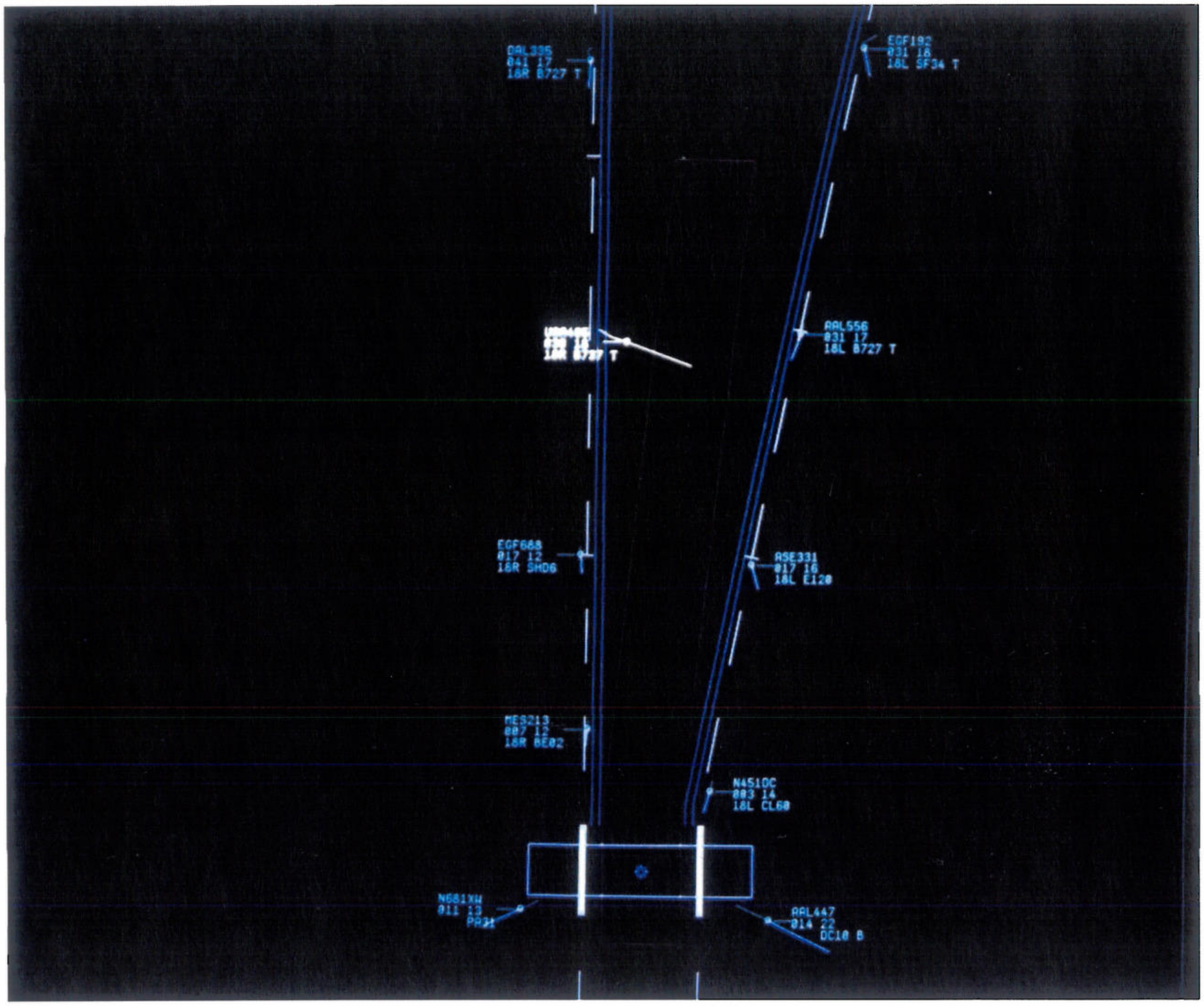


Figure 1. Independent Approaches to Two Parallel Runways

Standards for the evaluation of runway spacing for independent approaches to parallel runways depend on many factors, of which the following are key:

- Type of display used by the controllers monitoring the approach
- Update interval of the radar/surveillance system
- ATC and aircrew procedures (e.g., reaction times)
- Training of controllers and aircrews
- Environmental conditions

In general, displays used by the monitor controllers consist of a standard display, usually a monochromatic analog or digital display, or the Final Monitor Aid (FMA) display. The FMA is a color digital display with an expanded scale orthogonal to the runways. The FMA also includes visual or aural alerts to warn the controller that an aircraft is projected to enter the NTZ between the runways or has entered the NTZ. See Figure 2.



Source: William J. Hughes Technical Center

Figure 2. Prototype FMA Display (With Offset Localizer on Left Runway)[2]

Radars consist of standard Airport Surveillance Radars (ASRs) with monopulse SSRs that have an update interval of 5.0 seconds or faster.

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2 Independent approaches are authorized in the U.S. with an offset localizer. The offset is not necessary or applicable at Cancún.

In the U.S., ATC and pilot procedures have been established for independent approaches, and training is required for both controllers and aircrews. For example, the U.S. conducts training using simulation as a part of controller qualification for monitoring independent approaches. Table 1 shows the principal U.S. and ICAO standards for independent approaches to parallel runways.

Environmental factors should also be considered. In general, consideration for airport elevation and temperature is prudent for approaches to two runways, since high-elevation/density altitudes generally require aircraft to fly at faster true airspeed (TAS), which reduces time available for controllers to separate aircraft in case of a deviation.

The FAA performed extensive testing during the development of independent approach procedures over a multi-year period. This testing was a combination of human-in-the-loop (HITL) testing and fast-time simulation testing. For a general description of this work see [Massimini, 2006].

The HITL testing consisted of simulations using trained controllers monitoring parallel approach paths using realistic surveillance displays and communications equipment. Position and altitude data from approved flight simulators flown by trained airline pilots were presented on the controller displays in a realistic manner, along with position and altitude information from computer-generated aircraft. During the simulation, certain aircraft were directed by the Test Director to "blunder," or deviate from one final approach path towards another (without the controller or other pilots' knowledge). The simulation measured how fast controllers and pilots reacted to avoid a collision and how close aircraft came to each other during the blunder event. Other measures were also recorded, such as the number of penetrations or near-penetrations of the NTZ during normal (i.e., non-blunder) approaches. These penetrations often necessitated that the controller instruct the aircraft to break off the approach and be re-sequenced into the traffic flow to the airport. These breakouts were referred to as nuisance breakouts.

Although the HITL testing lasted several weeks for each test conducted, enough results could not be collected to assure a sufficient level of safety with statistically-significant results. Therefore, fast-time simulation models were created that used input and human performance data from the HITL testing. These fast-time models could simulate hundreds of thousands of blunder events and refine the statistical estimate of projected performance of equipment, procedures, pilots, and controllers during independent approaches.

Table 1. U.S. and ICAO Standards for Independent Parallel Instrument Approaches to Two Runways

Number of Runways	Minimum Runway Spacing	Display	Radar (Maximum Update Interval)	Aircrew Training	Remarks
2 (U.S.)	915 m (3000 ft)	FMA	PRM (1.0 sec)	Required	≥ 2.5° offset
2 (U.S./ICAO)	1035 m (3400 ft)	FMA	PRM (2.4/2.5 sec)	Required	Not Applicable
2 (U.S)	1098 m (3600 ft)	FMA	ASR (4.8 sec)	Required	Note 1
2 (U.S.)	1310 m (4300 ft)	Standard	ASR (4.8 sec)	Not Required	Note 1
2 (ICAO)	1310 m (4300 ft)	FMA	ASR (5.0 sec)	Not Required	Notes 1,2
2 (ICAO)	1525 m (5000 ft)	Standard	ASR (5.0 sec)	Not Required	Note 1

Note 1: The U.S. standard for monitor-controller radar is 4.8 seconds, while the ICAO standard is 5.0 seconds. This analysis assumed that a monopulse SSR with a 5.0-second update rate is used for monitoring.

Note 2: U.S. standards permit independent approaches to be conducted at 1310–1525 m spacing with standard displays and a standard SSR. ICAO requires an aeronautical study to use displays and radar for 1310–1525 m spacing. To demonstrate that the procedure meets safety standards, MITRE assumed for Cancún that a monopulse SSR with a 5.0-second update rate and an FMA display would be used by monitor controllers.

The FAA used a combination of results from the HITL and fast-time simulation testing to approve standards. The considerations for approval of standards included:

- The nuisance breakout rate observed in the simulation.

  This is the percentage of approaches where a non-blundering aircraft had to be broken out from an approach because of path-following errors that cause the aircraft to stray too-close-to or into the NTZ. Nuisance breakouts are not normally a safety consideration. However, since each breakout must be re-sequenced into the arrival flow, nuisance breakouts can lead to capacity issues. A high rate of nuisance breakouts, however, could be a safety issue since controller workload generally increases with a high rate of nuisance breakouts.

- The results of a collision risk analysis showing if a predetermined Target Level of Safety (TLS) was achieved.

  This collision risk analysis was generally a combination of the HITL and fast-time simulation results.

- An operational evaluation by the members of the Technical Working Group that conducted the simulations.

  The Technical Working Group consisted of FAA representatives from several areas, such as flight standards, air traffic, and air traffic controllers experienced in the conduct of independent approaches.

Most of the standards contained in Table 1 were developed using the above-mentioned methodology.[3] While standards for runway spacing, surveillance equipment, and procedures are important, the published standards do not always encompass all requirements. For example, analysis of operations at Denver International Airport indicated that the higher approach speeds that result at higher airport elevations/density altitudes lead to a need for enhanced surveillance display equipment [Ozmore and DiMeo, 1994]. Thus, MITRE is particularly careful when analyzing airports located significantly above Mean Sea Level (MSL), such as NAICM.

2.1 Description of Independent Parallel Approach Modeling

MITRE's analytical work of runway spacing at Cancún regarding independent approaches consisted of two parts:

- An analysis of path-following errors of aircraft on final approach.

[3] Independent approaches to two runways spaced 1310 m (4300 ft) using a standard surveillance display were developed prior to the use of this methodology.

The analysis of path-following errors estimated the rate at which aircraft on a normal approach would penetrate or nearly penetrate the NTZ. A high rate of NTZ penetrations could result in an excess of nuisance breakouts, reducing the airport capacity. Additionally, a high rate of nuisance breakouts could increase controller workload, which could be a safety issue.

- An analysis of collision risk in case one aircraft deviates from its assigned approach path.

  The collision risk analysis used the MITRE-developed Simultaneous[4] Instrument Approach Model (SIAM) [Gladstone and Friedman, 1995]. SIAM is a fast-time computer model that uses human performance data gathered during the FAA's HITL testing.

Since the procedures, equipment, and general practice of independent approaches at Cancún will be similar to those tested by the FAA, the application of fast-time modeling should be sufficient to validate runway spacing, equipment, and procedural requirements for Cancún. Appropriate adjustments were included in the analysis to account for airport elevation, ambient temperature, and fleet mix based on data from the following sources:

- Airport elevation as per the Mexico AIP
- Airport surface temperature based on data obtained from the U.S. National Oceanic and Atmospheric Administration (NOAA) for Cancún for the period 1 January 2012 through 31 December 2013
- Traffic mix of heavy, large, and turboprop aircraft from publically available operational statistics during the period 1 January 2013 through 31 December 2013. These data include information on scheduled commercial operations that operate at Cancún.

2.1.1 Path-Following-Error Analysis

For independent approach paths to parallel runways, there is some concern that normal path-following errors of aircraft about the final approach path centerline, due to flight technical or other errors, could cause aircraft to stray close to or into the NTZ (see Figure 3). If this were to happen, the controller would be required to correct the heading of the wandering aircraft. Also, the controller may be required to break out the wandering aircraft and possibly the aircraft on the adjacent approach path. Controller workload could become excessive, and subsequent breakouts of aircraft could negate some of the capacity-enhancing effects of independent approaches.

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[4] In the U.S., independent approaches are commonly referred to as simultaneous approaches. This is the principal reason for the word "simultaneous" in the model's name.

Instrument Landing System (ILS) path-following errors generally increase with distance from the runway threshold. This is primarily due to the angular beam width of the ILS, which is wider when the aircraft is further from the runway. As the aircraft flies on the ILS toward the runway, the variability is gradually reduced due to the reduced width of the ILS beam. Turning onto the ILS localizer closer to the runway generally results in fewer path-following errors.

The FAA has performed several data collections to characterize final approach path-following errors during independent approaches [PRM Program Office, 1991].

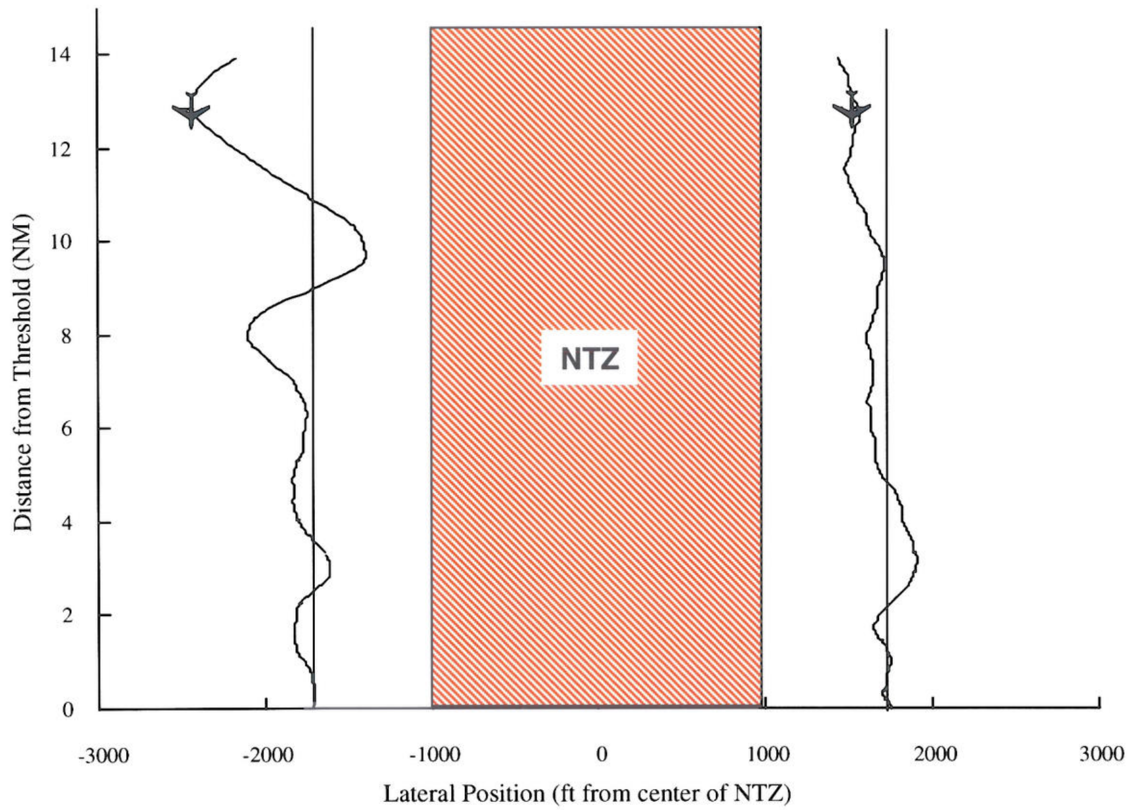

Figure 3. Example of Path-Following Errors during Independent Approaches

The path-following errors are stochastic, and are also affected by ILS beam bends and runway length (which affects the angular splay of the ILS). Note that path-following errors that occur before aircraft reach the glide slope do not result in a loss of separation, since aircraft maintain 1000 ft of altitude clearance until beginning to descend down the glide slope.

Table 2 gives the estimated probability of an aircraft entering the NTZ due to path-following errors on a normal approach (i.e., no blunder occurs) at Cancún, using the distribution of path-following errors of [PRM Program Office, 1991] mentioned above.

Note also that path-following-error frequency can also be affected by the width of the NTZ—a narrow NTZ would provide more lateral area for the aircraft to maneuver in, reducing the number of NTZ incursions. MITRE's analysis for Cancún assumed an NTZ width of 2000 ft (610 m), which is the width used for all independent approaches in the U.S.

Table 2. Estimated Probability* of an Aircraft Entering the NTZ Due to Path-Following Errors when Located 10 NM from the Runway Threshold

Runway Centerline Separation	P(Enter NTZ)*
1310 m	< 1%
1448 m	~ 0%

* Probability expressed as a percentage

There are no explicit standards established for the maximum probability of aircraft entering the NTZ, although a value of 5 percent was used informally for the FAA testing [Massimini, 2006]. Aircraft entering or getting close to the NTZ can increase controller workload, since these aircraft must usually have course corrections issued. Also, as mentioned before, arrival capacity can be affected.

The estimated probabilities in Table 2 indicate that there should be no difficulty with path-following errors for a runway spacing of 1448 m at Cancún.

2.1.2 Collision Risk Analysis

An area of serious concern during independent approaches is the occurrence of blunders. A blunder is a deviation of an aircraft from one approach path towards an adjacent approach path. While a path-following error is part of a normal approach, and will be corrected by the aircrew without controller intervention (although perhaps not before entering the NTZ), a blunder is a more severe deviation that probably would not be corrected by the aircrew without controller intervention.

Analysis has shown that blunders are rare events, but do occur. In the case of a blunder, intervention by the monitor controllers may be required to prevent a collision. A number of factors affect the chance of a collision in the case of a blunder. For example, the severity of the blunder (i.e., how quickly does the blundering aircraft proceed towards an adjacent runway) may affect how quickly the controller and pilot observe the deviation and correct it.

The speed of the controller reaction, either to correct the deviation by the blundering aircraft or to instruct the aircraft on another approach path to break out, is another critical factor as is the speed at which pilots react to controller instructions. Communication blockages, misunderstandings, and phraseology, as well as approach path separation, type of radar, display equipment, and controller/pilot training are also factors.

The FAA has conducted extensive testing to quantify the chance of a collision during independent approaches [Massimini, 2006]. By agreement with diverse interested parties, for testing purposes a collision is considered to have occurred if aircraft pass within a 500-ft slant range of each other. That testing included pilot and controller reaction testing, HITL simulation, and fast-time simulation [PRM Program Office, 1991].[5]

The SIAM model is used to extend the results of the HITL simulations of independent approaches, and allows investigation of potential collision rates between aircraft on independent parallel approaches. MITRE has used this model to support the FAA in the development of requirements for independent approaches to two (and even three) parallel runways. MITRE also uses SIAM to investigate and evaluate runway spacing at airports throughout the world in support of safety assessments.

SIAM can accept a variety of parameters, including runway and approach path configuration, path-following information, and different types of aircraft on the independent approaches. For that reason, this type of analysis is performed on an airport-by-airport basis, since airport elevation, airspace design, and fleet mix can affect results. SIAM then simulates a large number of blunders to determine the chance of a collision given that a blunder occurs. Reaction times of pilots and controllers are usually modeled from statistical distributions of reaction times that were observed during the FAA HITL testing, which used qualified controllers and pilots.

SIAM, and other testing done by the FAA, gives a measure of the chance of a collision given that a blunder occurs—a "conditional" probability. However, the most important consideration is not how often a collision might occur given that a blunder occurs, but how often a collision might occur during independent approaches—an "unconditional" probability. In order to ensure that independent approaches do not contribute to an increased accident rate, the FAA determined a maximum allowable probability of a collision, given that a blunder occurs, in order for a procedure to be authorized. This maximum conditional probability is shown in Table 3. The conditional probability in Table 3 is equivalent to an

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[5] The FAA, based on data collection and analysis by MITRE, has revised the collision risk analysis for independent approaches to two runways. This revised methodology has not yet been accepted by ICAO, however. Accordingly, the analysis in this document is conservative, and is consistent with the currently published standards in [ICAO, 2004 and ICAO, 2007]. In any case, use of the revised FAA methodology would not change the equipment and procedures used for independent approaches to two runways spaced 1448 m apart at Cancún. Accordingly, MITRE did not use the revised FAA methodology for this report.

overall "unconditional" probability of one accident per 25 million approaches. See [PRM Program Office, 1991] and [Massimini, 2006].

Table 3. Maximum Acceptable Probability of a Collision Given that a Blunder Occurs

Independent Approaches to	Maximum P(Collision|Blunder)
Two Runways	.004

The ability of the monitor controllers to separate aircraft after a deviation is primarily dependent on the surveillance display, the update rate of the radar, and the procedures and communication requirements specified by ICAO and/or the FAA for independent approaches.

2.2 Summary of Results for the Independent Parallel Approach Analysis

Table 4 provides the results of the simulations of independent approaches to two runways at Cancún using SIAM.

The probability of collision given that a blunder occurs is less than specified in Table 3 for the runway spacing in Table 4, which implies that the overall level of accident rate from collisions is less than 1 in 25 million arrivals. This analysis is similar to those performed during the approval process for independent approaches in the U.S. and the subsequent adoption of standards by ICAO. The elevation and temperature at Cancún, potential changes in fleet mix, and stagger between runway thresholds were taken into account.

This runway spacing assumes that, in the event of a blunder by one aircraft that endangers another aircraft on an adjacent approach, the monitor controller can instruct the endangered aircraft to climb and turn away from the blundering aircraft. If airspace or other restrictions prevent the use of a climb-and-turn-away maneuver for the endangered aircraft, a climb-only maneuver can be used. However, the climb-only maneuver does not provide as much separation assurance as the climb-and-turn-away maneuver. Thus, additional separation may be required between the runways if a climb-only maneuver is anticipated during the planning process.

It is important to mention that certain aspects of independent approaches can be affected by the design of airspace and approach procedures. Since these factors have not yet been specified for Cancún, this analysis should be considered preliminary. MITRE believes, however, that these results are robust and should not change significantly unless major changes are made regarding airspace and procedural design, such as the inability for a controller to use a climb-and-turn-away maneuver from one or more approach paths or increased final approach length requirements, or other factors.

Table 4. Runway Spacing Analysis for Independent Approaches to Parallel Runways at Cancún (Collision Risk Analysis)

Number of Runways	Minimum Runway Spacing	Display	Radar (Maximum Update Interval)	P(Collision|Blunder) at Cancún	Maximum Allowable P(Collision|Blunder)	Pass/ Fail
2	1448 m	FMA	SSR (5.0 sec)	.0018	.004	Pass

Sections 3 and 4 will discuss surveillance, display, and communication requirements to meet the collision risk analysis above.

3. Surveillance and Display Equipment

This section discusses the equipment required to meet the surveillance and display requirements assumed in the collision risk analysis performed in Section 2.

3.1 Surveillance Equipment

As discussed in [ICAO, 2004] and [ICAO, 2007], an SSR capable of a five-second update rate and an accuracy of 0.06 degrees (1 milliradian and one sigma error) will be required to conduct independent approaches to two runways spaced between 1310 m and 1525 m. Associated display equipment will be discussed in Section 3.2.

Currently, most terminal class SSRs using monopulse processing are capable of meeting the above-mentioned accuracy requirements. Note that a Primary Surveillance Radar (PSR) is not required to conduct independent approaches. However, if a PSR is incorporated with the SSR, the primary target should be displayed on the ATC display equipment.

3.2 Display Equipment

Since [ICAO, 2004] and [ICAO, 2007] require monitoring of the approach paths by dedicated controllers, most ATC facilities have separate dedicated displays for each monitor controller. ATC facilities conducting independent approaches in the U.S. place the monitor-controller displays next to each other. This allows the monitor controller to quickly exchange verbal information in the event an aircraft deviates from its final approach or has some other difficulty. Most U.S. facilities permit the monitor controllers to share a display during a temporary outage of one monitor-controller display. However, one display is provided for a monitor controller for each runway involved in independent approaches (i.e., two displays for two runways).

As noted in Section 2, independent approaches at Cancún require, in addition to the specified sensor system (i.e., a 0.06 degrees/1 milliradian SSR noted above), an FMA display. The FMA provides the following enhancements for monitoring of independent approaches:

- The aspect ratio of the display is expanded 4 times orthogonally to the approach centerlines. This enhanced lateral display allows the controller to more easily identify deviations from centerline by aircraft flying independent approaches.
- Alerting algorithms provide a visual and voice alert to the controller when an aircraft is projected to enter the NTZ within 10 seconds. The FMA provides a second type of visual and voice alert if an aircraft actually enters the NTZ.

Testing during the development of independent approach standards in the U.S. verified that the FMA allowed monitor controllers to identify and react to blunders much faster than when using a conventional display. MITRE used controller-reaction results from FAA testing when analyzing the adequacy of the runway spacing at Cancún for conducting independent approaches to two runways. In order to rigorously meet safety standards, monitor controllers should have displays with the functionality of the FMA.

The FMA improves the ability of the monitor controller to detect deviations from final approach. However, the 4:1 aspect ratio distorts the orientation of the screen, making the vectoring of aircraft more difficult, if not impossible. ATC procedures must be implemented to compensate for the reduced ability of the monitor controllers to vector aircraft. See Section 6.

3.2.1 The FMA and the Standard Terminal Automation Replacement System (STARS)

The FMA was developed by the FAA in the 1990s as part of the high-update-rate PRM system for closely-spaced independent approaches. The display was later combined with standard-update-rate radars and first used for triple independent approaches at Denver International Airport.

Subsequently, all FMA capability in the U.S. has been incorporated into the FAA's Standard Terminal Automation Replacement System (STARS). The FMA is a module in STARS that can be called up so that monitor controllers can use the display for independent approaches. No other implementation of the FMA is known to exist. However, some Air Navigation Service Providers outside the U.S. are planning to implement the system. Accordingly, either Mexico will have to purchase STARS or the FMA functionality will have to be incorporated into the automation system at Cancún.

The text in the remainder of this Section is not intended to be a specification for an FMA display, but rather a summary of the specifications used in STARS that are essential to the monitoring of independent approaches with an FMA.[6] This document does not discuss specific adaptations of the display to import flight plan data, transfer control to/from other controllers, display failed surveillance sensors, display warnings of unassociated/unknown traffic, etc., since these functions are not specific to independent approaches and can be accomplished in a manner consistent with the surveillance/display automation systems in place at Cancún.

3.2.2 Overall Requirements

The FMA display is a 20 x 20 inch (51 x 51 cm) high-resolution color display. Normally, a separate display is required for each monitor controllers. The FMA typically only displays the final approach courses for the independent arrival runways in use.

When an aircraft is not adhering to its assigned course, the FMA provides an alert to the monitor controller. A *Caution Alert* is issued when an aircraft is predicted to enter the NTZ and a *Warning Alert* is issued when an aircraft enters the NTZ. Other alerts are issued when an aircraft is approaching a different runway than the one assigned.

To conserve processing power, only a portion of the area around the airport is displayed. The FMA provides enhanced display monitoring and automated alert generation for flights on final approach that are contained in a selected Active Monitored Zone (AMZ). See Figure 4 for a depiction of an AMZ.

The AMZ is typically characterized by the parameters listed below.[7]

a. Approach course orientation for each of two to four runways
b. Boundary vertex points
c. Vertical extent
d. Runway end points
e. NTZ
f. Normal Operating Zones (NOZ)
g. Approach course line length for each of two to four runways (0 to 30 NM from approach threshold)

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6 Portions of the remainder of Section 3 of this paper are copied directly or paraphrased from [Raytheon, 2006], which is export-controlled by U.S. authorities. Information provided in this MITRE document has been judged to not fall under export-control restrictions and has been released.

7 The associated dimensions are nominal for STARS; they are not specific requirements for the FMA system.

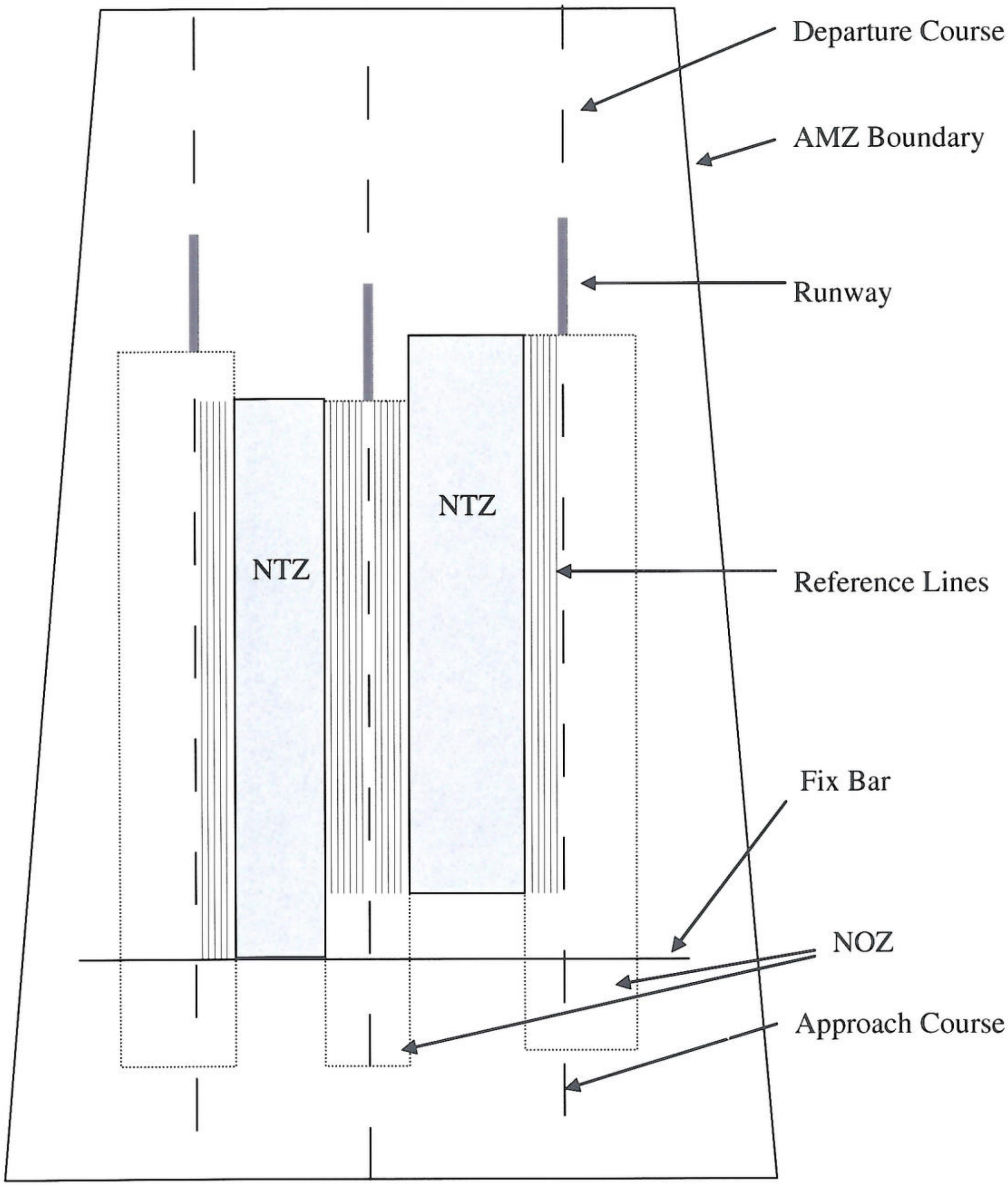
h. Departure course line length for each of up to four runways (0 to 5 NM from departure end of runway)
i. Lateral distance offset from approach course line to runway approach threshold for each of up to four runways (50,000 ft left to 50,000 ft right, default = 0, increment = 100 ft)
j. Longitudinal distance offset from approach course line end point to runway approach threshold for each of up to four runways (50,000 ft backward to 50,000 ft forward, default = 0, increment = 100 ft)
k. Visual elements
    1. AMZ outline (polygon)
    2. NTZ outline(s) (polygons)
    3. Runways (solid filled polygons depicting the position and size of each runway in the AMZ)
    4. Final approach course (broken line per runway)
    5. Departure runway course (broken line per runway)
    6. Reference lines parallel to the final approach course [a series of lines, nominally separated by 200 ft, beginning nominally 200 ft from the final approach course, in the region between each final approach course centerline and the edge of the adjacent NTZ(s)]
    7. A fix bar perpendicular to the final approach course marking the distance at which approach descent is to commence

Note: Figure 4 is a schematic representation of an AMZ incorporating three parallel runways. An AMZ can accommodate two to four parallel runways together with associated parameters and visual elements. The components of Figure 4 are not necessarily shown to scale nor with expected operational alignments or dimensions. Also note that the location and dimensions of the AMZ volume must be adaptable, with a default location such that the AMZ longitudinal axis is co-linear with the runway axis; a default longitudinal range of 30 NM from the final approach end of the runway to 5 NM beyond the departure end of the runway; and a default vertical range from 50 ft to 11,000 ft above ground level.

The colors of the FMA in STARS are noted in Table 5. Note that Figure 2 is a depiction of a prototype FMA display. As such, some colors in Figure 2 may be slightly different than those specified in Table 5.

Table 5. FMA Colors

Data Item	Color
Radar Window Background	Black
Data Block Owned/Previously Owned	White
Position Symbol	White
Caution (FMA) – Unacknowledged	Blinking Yellow
Caution (FMA)	Yellow
Alert (FMA) – Unacknowledged	Blinking Red
Alert (FMA)	Red
FMA Runway	Gray
FMA NTZ	White
FMA Reference Lines	White
FMA AMZ	Light Blue
FMA Course Line	White
FMA Fix Bar	White



Source: [Raytheon, 2006]

Figure 4. AMZ with Three Runways Depicted

3.2.3 The NTZ

The location and dimensions of the NTZ should be adaptable, with an orientation such that it is aligned with the adapted approach course orientation and having an adapted location such that it may be centered between two adjacent runways being used for parallel approaches, with a typical width of 2000 ft.

The NTZ outline is represented on the FMA display as a white solid line unless an alert is active within that NTZ. The NTZ outline color represents the current NTZ alert state:

a. No Alert (Default White)

b. Caution Alert (Default Yellow)

c. Warning Alert (Default Red)

If FMA alert processing is inhibited for all tracks or for a specific NTZ, the NTZ outline will not be displayed. The lack of a displayed NTZ should cue the controller that FMA alerting is inhibited.

3.2.4 The NOZ

An NOZ is associated with each runway approach course. The location and dimensions of the NOZ should be adaptable. The default parameters should be such that the NOZ is a volume of airspace around the final approach course centerline and not a part of any enabled NTZ. Aircraft position relative to the NOZ is used as a condition for Warning Alerts and for Caution Alerts. The NOZ outline is not displayed.

3.2.5 FMA Alerts

The essential alerts for the FMA are the Warning Alert and the Caution Alert, as discussed in Sections 3.2.5.1 and 3.2.5.2 below. However, there are additional alerts that should be implemented, as summarized in Sections 3.2.5.3-3.2.5.5 below. Sections 3.2.5.6-3.2.5.8 cover additional features of alerts that can be implemented.

Regarding eligibility discussed below, a track should be eligible for monitoring by the FMA when its last reported position is within an AMZ, unless FMA processing has been inhibited for that track or for all tracks. Eligibility for monitoring by the FMA is one necessary condition for generation of all types of FMA alerts below.

3.2.5.1 FMA Warning Alert

For each eligible track, an FMA Warning Alert should be generated when the corresponding aircraft enters an NTZ from the NOZ associated with its assigned runway based on current track information.

3.2.5.2 FMA Caution Alert

For each eligible track, an FMA Caution Alert should be generated when the corresponding aircraft is predicted to enter an NTZ from the NOZ associated with its assigned runway, based on current track position and velocity information, and an adapted look-ahead time with a default of 10 seconds, a minimum value of zero, a maximum value of 20 seconds, and an increment of 1 second.

3.2.5.3 FMA Surveillance Alert

For each eligible track having an assigned runway corresponding to one of the AMZ parallel runways, an FMA Surveillance Alert should be generated when the track has not correlated for an adaptable period of time, i.e., the track is coasting. (Minimum 6 seconds, default 15 seconds, maximum 20 seconds, increment of 1 second).

3.2.5.4 FMA Runway Alert Due to Mismatch

For each eligible track, an FMA Runway Alert should be generated when a track has been determined to be stabilized on an approach and the assigned runway for the aircraft is different.

3.2.5.5 FMA Runway Alert Due to Invalid or Missing Assigned Runway

For each eligible track, an FMA Runway Alert should be generated when a track has been determined to be stabilized on an approach and the assigned runway for an aircraft is invalid (not one of the runways defined for the arrival airport) or the aircraft has no assigned runway.

3.2.5.6 Simultaneous FMA Alerts

Multiple simultaneous FMA alerts for an individual track will not be displayed. When a track condition is such that multiple alert conditions apply, the single highest priority FMA alert should be displayed. The priority ordering of FMA alerts from highest to lowest priority is as follows:

a. Warning Alert for NTZ zone penetration

b. Surveillance Alert for missing surveillance data condition

c. Runway Alert for

    1. FMA Runway Mismatch

    2. Missing or invalid FMA Runway Designator

d. Caution Alert for predicted NTZ zone violation

3.2.5.7 Visual Alert Indications

An FMA Warning Alert should be indicated by an adaptable text string (default: "NTZ") in the data block of the affected track. The data block text for an FMA Warning Alert should appear in the corresponding alert color (i.e., red).

An FMA Surveillance Alert should be indicated by an adaptable text string (default: "CST") in the data block of the affected track. A track displaying an FMA Surveillance Alert will not indicate CST elsewhere in the data block.

An FMA Runway Alert should be indicated by an adaptable text string (default: "RWY") in the data block of the affected track.

An FMA Caution Alert should be indicated by an adaptable text string (default: "NTZ") in the data block of the affected track. The data block text for an FMA Caution Alert should appear in the Caution color (i.e., yellow).

STARS allows for controller acknowledgement of an alert. The alert visual symbol is blinking until acknowledged, but steady afterward. The alert color remains constant during the alert.

3.2.5.8 Voice Alert Indications

Any newly-established FMA alert condition for a track should initiate a voice alert indication identifying the flight call sign followed by the alert condition for the track as shown in Table 6.

Each voice alert indication is spoken once after onset of the alert condition and is completed within one radar scan period. The alert condition should be identified by adaptable spoken text with default phrasing per Table 6. STARS allows alerts to be silenced after acknowledgement by the controller.

Table 6. FMA Voice Alerts

Alert	Default Spoken Text
Warning	"WARNING"
Surveillance	"COAST"
Runway	"WRONG RUNWAY"
Caution	"CAUTION"

3.2.6 FMA Performance

This section discusses various requirements concerning the performance of surveillance automation and the FMA system.

3.2.6.1 Runways and Aircraft per Active AMZ

STARS requires that the surveillance/display system have the capacity for two to four runways and support approach operations for up to 150 associated aircraft in the selected AMZ. The system implemented at Cancún should display the two runways active during independent approaches, and an appropriate maximum number of aircraft that could be operating in the AMZ at any one time. This number should be estimated separately.

3.2.6.2 Tracked Target Deviation

The FMA should support detection of target deviations of 100 ft in range or in azimuth within 10.7 NM of the selected radar.

3.2.6.3 Voice Alert Response Time

The audio signal associated with FMA Voice Alerts driving the speaker at the controller station should occur within 200 milliseconds after the alert becomes active.

3.2.6.4 Alert Activation Time

A visual Warning Alert resulting from a track entering an NTZ should be displayed within 100 milliseconds of the track display position update. A visual Caution Alert resulting from a track predicted to enter an NTZ will be processed and displayed with the same system timing as a visual Warning Alert.

3.2.7 Simulation Capability

Simulator training for monitor controllers should be conducted on actual display equipment or on dedicated training displays equivalent to the FMA displays used for independent approaches.

This capability should use simulated air traffic to accommodate simulation of deviations from the final approach course and other anomalies. This simulation should require the controller to become familiar with the various FMA alerts and to practice procedures to return deviating aircraft to course, break out endangered aircraft, coordinate with other monitor controllers, and make voice calls to affected aircraft.

This simulation capability should be tailored to other training equipment and facilities used at Cancún. If controller training is normally accomplished on actual ATC equipment, then that equipment should incorporate a simulation capability. Otherwise, a dedicated FMA simulation capability should be developed for Cancún.

4. Communications-Override Equipment

The *Manual on Simultaneous Operations on Parallel or Near-Parallel Instrument Runways (SOIR)* [ICAO, 2004], the *Procedures for Air Navigation Services – Air Traffic Management (PANS-ATM)* [ICAO, 2007], and the collision analysis conducted for Cancún in Section 2 require that each monitor controller have a separate dedicated communications frequency to talk to aircraft on their respective final approaches. There is no requirement, however, that the monitor controller be the only controller talking on that frequency. In the U.S., the monitor controllers commonly communicate on the local tower frequency. This allows ATC to switch the aircraft to the appropriate tower frequency when turning onto final approach. The local and monitor controllers can both then talk to the aircraft until touchdown on the same frequency.

If the monitor controller shares a frequency with another controller, then the monitor controller must be able to override the other controller in case a transmission is necessary [ICAO, 2004; ICAO, 2007]. Normally, this override is done through a digital communications switch. When the monitor controller begins to transmit, then any transmit functions from other controllers on that frequency are immediately interrupted.

Overrides of various types are common in digital communications switches. All modern ATC digital communications switches allow this capability. For example, a transmission by a controller to an aircraft typically overrides other controller transmissions and receptions, such as ground-to-ground microphone connections.

The specific method for the monitor controller to override transmissions of other controllers on the frequency is dependent on the specific type and configuration of the digital communications switch(es) in the ATC facility. Digital communication override switch matters are outside of MITRE's area of expertise. Therefore, the Mexican authorities should consult with appropriate system integrators on the specifics of this subject.

5. Additional Considerations and Requirements

This document has discussed the surveillance, display, and communications-override equipment necessary for independent approaches to two runways at Cancún. However, there are numerous other requirements that must be completed before conducting independent approaches. Some of these requirements are explicitly stated in [ICAO, 2004 and ICAO, 2007], but others must be derived from best practices. Some additional requirements are:

- Airspace design must allow arrivals and departures in a manner that allows independent approaches and departures to be conducted without congestion in the arrival and departure sectors
- Turns onto final approach must be accomplished with at least 1000 ft of vertical separation between the two adjacent approach paths

- Missed approach paths must diverge by at least 30 degrees under ICAO requirements and 45 degrees under FAA requirements
- Departure operations must allow for sufficient departures to balance arrival operations

6. Summary

This document provides a preliminary analysis of runway spacing at Cancún and broadly summarizes the additional equipment necessary to safely conduct independent instrument approach procedures. As the project progresses, additional details will arise.

Under current standards, a monopulse SSR with a 5.0 second update rate (or faster) will be required, as will an FMA display. Unless the U.S. STARS is purchased, Mexico will need to incorporate the FMA functionality into the terminal automation system for Cancún. To facilitate an understanding of the FMA that is incorporated in FAA automation (i.e., STARS), MITRE has provided in this document its basic requirements.

Although the surveillance, display, and communications systems are important for independent approaches, many other factors, such as procedure and airspace design, training, and more are also critically important. Those factors can affect independent approach procedures and require significant amounts of work to plan and execute successfully. These areas will be examined by MITRE along with Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM) at a later stage of this project, which will allow the preliminary results described in this document to be verified.

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