Enclosure 1
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MITRE

Center for Advanced
Aviation System Development

Updated* Runway Spacing Analysis of the Texcoco Area

**** Final SIAM Modeling Results Subject to Review Before the Definitive Runway Configuration is Determined***

Prepared for

Dirección General de Aeronáutica Civil
Secretaría de Comunicaciones y Transportes

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1.0 Introduction

In early June 2008, MITRE delivered a *preliminary* analysis of the minimum spacing required between parallel runways in the Texcoco area in support of Mexico's Dirección General de Aeronáutica Civil (DGAC) [MITRE, 2008]. The runway spacing minimums were established for various scenarios, namely dual- and triple-independent approaches and for various types of surveillance equipment.

The purpose of this report is to provide an *update* to the preliminary minimum runway spacings mentioned above taking into account airspace and procedural work performed since the June 2008 results were issued. It is worth noting that when the updated results are compared to the preliminary results the variation is small. However, runway spacing is an essential safety factor that cannot be left unreported, even if the change is small. The updated results are still subject to review before the definitive runway configuration for Texcoco is determined. This is due to various elements in the analysis that may change before a final runway configuration is determined (e.g., ongoing changes in advanced surveillance technology and airspace factors that could impact procedure design). This update also provides important information relating to surveillance equipment that has recently been discontinued and will probably be replaced by new concepts. Finally, for the sake of completeness, concepts reported in 2008 that have not changed have been integrated to this update.

This updated analysis uses, like the preliminary work, the MITRE-developed Simultaneous Instrument Approach Model (SIAM), a fast-time simulation model that allows investigation of potential collision rates between aircraft on independent parallel approaches on the basis of runway spacing, site elevation, and other factors. Among other things, this model has been used to support the United States (U.S.) Federal Aviation Administration (FAA) in the development of requirements for independent approaches to two and three parallel runways. MITRE also uses SIAM to investigate and evaluate runway spacings at airports throughout the world in support of safety assessments.

2.0 Overview

This section describes the principal factors that play a role in the assessment of runway spacing when independent approach procedures are being evaluated. A general description of equipment, procedures, and resources used for independent approaches (such as monitor controllers, displays, and radars) is provided, and current standards are shown. However, these standards are not applicable to Texcoco primarily due to the site's elevation and, therefore, SIAM is utilized.

Sufficient runway spacing, as well as appropriate procedures and equipment are necessary to conduct independent approaches to two or three runways. During independent approaches, radar-equipped controllers monitor 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 final approach path. Should the controllers observe an aircraft entering or about to enter the NTZ, then the controllers for adjacent approach paths instruct aircraft under their responsibility to discontinue their approaches and turn to avoid the deviating aircraft.

For independent approaches to two parallel runways, 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 runways separated by 1035 m when using a Precision Runway Monitor (PRM) for surveillance. For runways spaced 1525 m or more apart, independent approaches may be conducted using a standard radar and display. 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." Criteria for independent approaches to three parallel runways are not published by ICAO.

The FAA authorizes independent approaches to two and three parallel runways [FAA, 2008]. Over 30 U.S. airports currently take advantage of this authorization. Among these, six airports operate triple independent approaches: Denver International Airport (KDEN), Dallas/Fort Worth International Airport (KDFW), George Bush Intercontinental/Houston Airport (KIAH), Cincinnati/Northern Kentucky International Airport (KCVG), Hartsfield-Jackson Atlanta International Airport (KATL), and Chicago O'Hare International Airport (KORD). Two other U.S. airports will likely start independent approaches to three runways: Washington Dulles International Airport (KIAD) and Detroit Metropolitan Wayne County Airport (KDTW). MITRE has been involved in making a safety case and assisting in the implementation of independent approach procedures at many of the U.S. airports.

Outside of the U.S., only a few airports (approximately six) conduct independent approaches to two runways and a few are considering independent approaches to three.

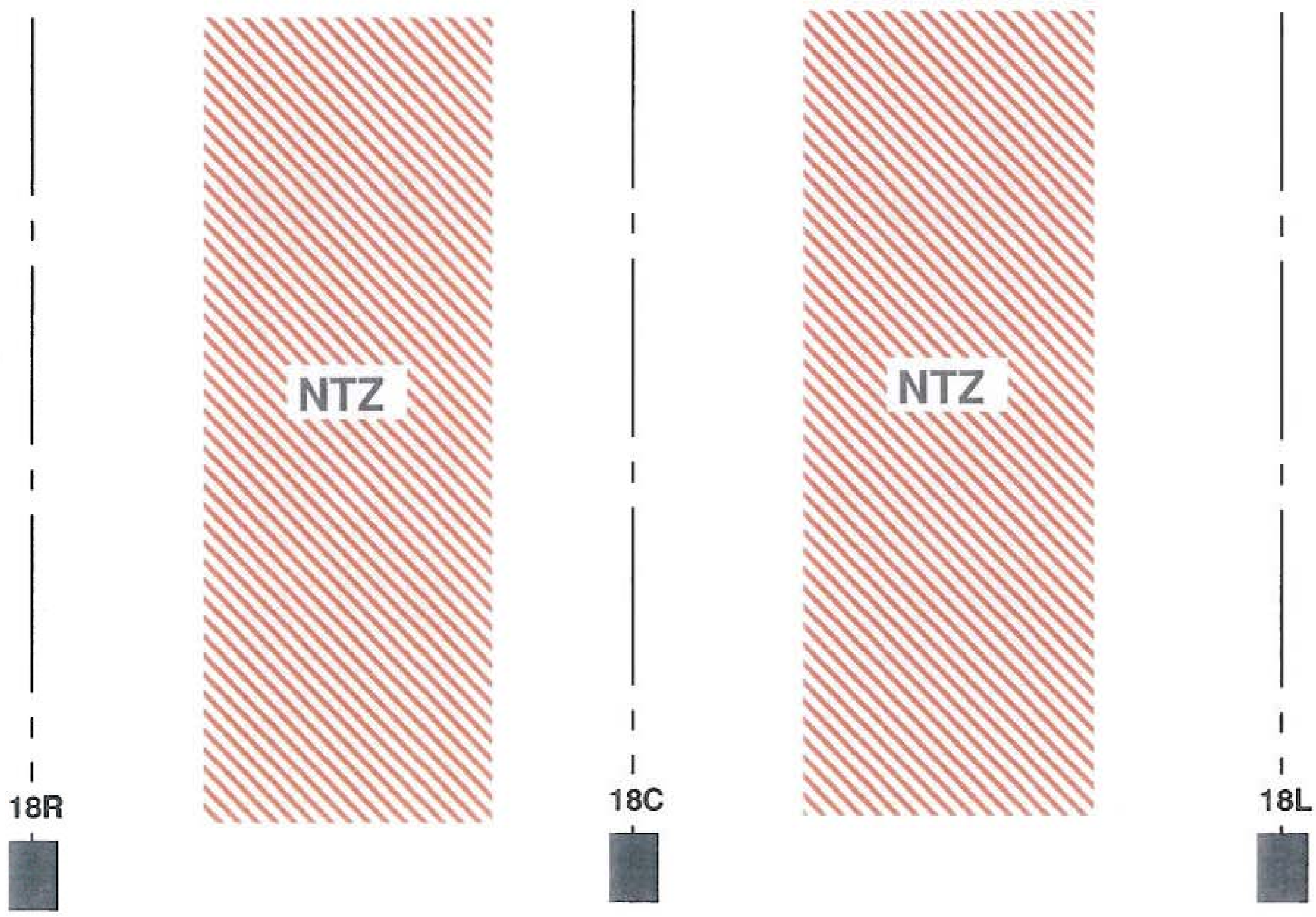

Figure 1. Independent Approaches to Three Parallel Runways

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
- Air Traffic Control (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.

Radars consist of standard Airport Surveillance Radars (ASRs) with monopulse Secondary Surveillance Radars (SSRs) that have an update interval of 5.0 seconds or less. For closely-spaced runways, a high-update-rate sensor, such as the PRM may be used.

The PRM is a monopulse SSR capable of update rates as fast as one-half second (although a one-second update rate is most commonly used). MITRE has recently confirmed through the PRM program manager of Raytheon Corporation (the sole manufacturer of the PRM) that the company has terminated the manufacture of the PRM.[1]

Other types of high-update-rate sensors (like the PRM) are under consideration, such as multilateration. Although not currently authorized for operational use, the U.S. is developing the "PRM-Alternative" (PRM-A) for Detroit. The PRM-A is a multilateration-based surveillance system that has been shown to provide equivalent performance to a standard PRM. It is anticipated that the PRM-A should be approved for use at Detroit in the near future. If that occurs, one can expect that a PRM-A will be acceptable for Texcoco if a high-update-rate sensor is required. While testing so far has shown that the PRM and the PRM-A provide equivalent surveillance, it would be prudent to wait for the outcome of the PRM-A installation and operation at Detroit. Additional information on the PRM-A will be provided as appropriate in future MITRE deliverables.

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. Pilot training, consisting of viewing videos, is required before pilots can execute independent approaches when a PRM is in use. Information is also published in pilot flight publications and is required to be read before independent approaches are conducted. It is anticipated that these requirements would also be required if a PRM-A were used in the future. Table 1 shows current ICAO and U.S. standards for independent approaches to parallel runways.

Environmental factors should also be considered. The FAA [FAA, 2008] requires additional analysis for independent approaches to three runways at airports with elevations above 1000 ft Mean Sea Level (MSL). In general, consideration for airport elevation and temperature is prudent for approaches to both two and three runways, since high-elevation/density altitudes generally require aircraft to fly at a faster true air speed (TAS), which reduces time available for controllers to separate aircraft in case of a deviation. Also, some airspace configurations can increase the difficulty of separating aircraft in case of a deviation on final approach, and this can affect runway spacing. This analysis accounts for these factors.

1 Raytheon will continue to support existing U.S. and international installations of the PRM.

Table 1. ICAO and U.S. Standards for Independent Parallel Approaches

Number of Runways	Runway Spacing	Display	Radar (Maximum Update Interval)	Aircrew Training	Remarks
2 (U.S. only)	915 m (3000 ft)	FMA	PRM (1.0 sec)	Required	≥ 2.5° offset Note 1
2 (U.S./ICAO)	1035 m (3400 ft)	FMA	PRM (2.4/2.5 sec)	Required	Notes 1,2
2 (U.S./ICAO) or 3 (U.S. only)	1310 m (4300 ft)	FMA	ASR (4.8/5.0 sec)	Not Required	Notes 2,3
2 (U.S./ICAO) or 3 (U.S. only)	1525 m (5000 ft)	Standard	ASR (4.8/5.0 sec)	Not Required	Notes 2,3

Note 1: U.S. and ICAO standards still specify the use of the now discontinued PRM; the PRM-A has not yet been formally approved.

Note 2: The U.S. standard for an ASR is 4.8 seconds, while the ICAO standard is 5.0 seconds. This analysis assumed that ASRs with a 5.0-second update rate are used. The U.S. standard for a PRM is 2.4 seconds or less, while the ICAO standard is 2.5 seconds or less. This analysis assumed that a PRM with a 1.0–second-update rate is used. ICAO requires an aeronautical study for dual runways spaced 1310 m – 1525 m; the FAA authorizes dual independent approaches to runways spaced 1310 m apart with a standard radar and an FMA.

Note 3: Airports with 1000 ft or higher elevation require an aeronautical analysis for independent approaches to three runways (U.S. standards).

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 pilot's 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 are 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. Therefore, fast-time simulation models were created that use input and human performance data from the HITL testing. These fast-time models could simulate hundreds of thousands of blunder events and refine the estimate of projected performance of equipment, procedures, pilots, and controllers during independent approaches. MITRE developed SIAM for use during this phase of the program [Gladstone and Friedman, 1995].

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

- 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, it is normally considered to be a capacity issue. 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 the target level of safety was met for the simulation.

  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 methodology.[2] 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 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]. Since the Texcoco elevation is even higher than Denver, standard runway spacing requirements do not apply.

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

3.0 Runway Spacing Analysis of the Texcoco Area

MITRE's analysis of runway spacing at Texcoco consisted of two parts:

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

  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 aircraft deviate from its assigned approach path.

  The collision risk analysis used the SIAM fast-time computer model combined with human performance data gathered during the FAA's HITL testing.

Since the procedures, equipment, and general practice of independent approaches at Texcoco 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 Texcoco. Appropriate adjustments were included in the analysis to account for airport elevation, ambient temperature, and the percentage of different types of traffic. MITRE analyzed weather data (for temperature) and recent operational statistics from a relatively high-volume peak week in 2007 (12-18 August) for the Mexico City International Airport (AICM) for percentages of different types of aircraft. The weather and traffic data were provided by Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM).

3.1 Analysis of Path-Following Errors

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 2). 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.

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; Timoteo, 1993]. Of these data collections [Timoteo, 1993] is the most relevant to Texcoco, since data were collected for very long final approaches (30+ NM) at Los Angeles International Airport (KLAX). Consequently, this report should provide the most useful data considering that the planned final approach paths for Texcoco are also quite long. Additionally, The ICAO Collision Risk Model provides information on path-following performance during ILS approaches [ICAO, 1980].

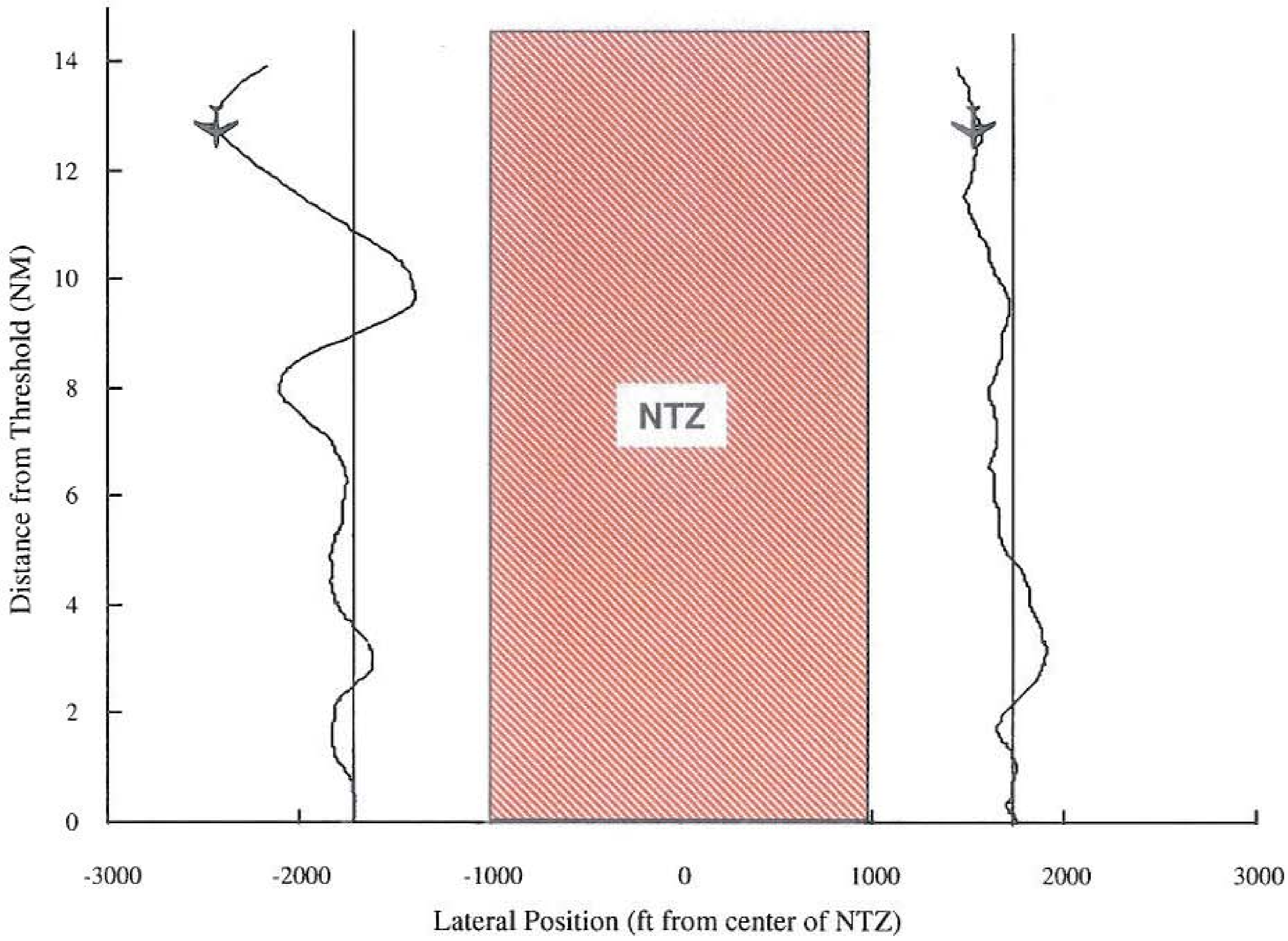

Figure 2. Example of Path-Following Errors during Independent Approaches

In general, the path-following errors are centered on the approach path and have magnitudes that increase with the distance from the runway threshold. However, the 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), using the distribution of path-following errors of [ICAO, 1980] mentioned above.[3] These calculations are consistent with observations at Los Angeles [Timoteo, 1993], although an exact comparison is not possible due to the stochastic nature of the path-following errors.

Note also that the path-following-error quantities 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. This analysis for Texcoco 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 at 20 NM and 25 NM from the Runway Threshold

Runway Spacing	P(Enter NTZ) 20 NM Dual Runways	P(Enter NTZ) 25 NM Dual Runways	P(Enter NTZ) 20 NM Triple Runways	P(Enter NTZ) 25 NM Triple Runways
1250 m (4100 ft)	3.1%	5.8%	4.7%	8.7%
1310 m (4300 ft)	2.3%	4.3%	3.5%	6.5%
1372 m (4500 ft)	1.8%	3.7%	2.7%	5.6%
1433 m (4700 ft)	1.3%	3.1%	1.9%	4.6%
1525 m (5000 ft)	0.7%	1.8%	1.0%	2.6%

* Probability expressed as a percentage

There are no explicit standards established for the maximum number or probability of aircraft entering the NTZ, although a value of 5 percent was informally used 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, some aircraft may have to be broken out from the approach due to NTZ entries, and this requires re-sequencing the broken-out aircraft back into the traffic flow, increasing workload and reducing arrival capacity.

The estimated probabilities in Table 2 indicate that there should be no difficulty with path-following errors for runway spacings of 1525 m or more considering potential long final approaches at Texcoco. For example, the P(Enter NTZ) for three runways at 1525 m spacing when the aircraft is 25 NM from the runway threshold is approximately 2.6 percent. This rate is likely to be satisfactory. Closer spacings, such as 1433 m, particularly for triple approaches, are marginal (probability of 4.6 percent at 25 NM). A spacing of 1372 m for triple approaches and 25 NM (the significance of 1372 m is described in Section 3.2.3) has a P(Enter NTZ) of about 5.6 percent. This level of NTZ

[3] The calculations in Table 2 are courtesy of Dr. James Yates.

entries could be problematic for conducing triple approaches at Texcoco. Additional discussion of path-following errors is contained in Section 4.

3.2 Analysis of Collision Risk

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.

3.2.1 Blunders and the SIAM Model

Analysis has shown [Higgins and Massimini, 1996] 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 other approach paths to break out, is important. Also, the speed at which pilots react to controller instructions is critical. Communication blockages, misunderstandings, and phraseology, as well as approach path separation, type of radar, display equipment, and controller/pilot training can also be factors.

The FAA has conducted extensive testing to quantify the chance of a collision during independent approaches [Massimini, 2006]. By agreement with industry, union, and government participants, for testing purposes a collision is considered to have occurred if aircraft pass within 500 ft slant range of each other. This testing has included pilot and controller reaction testing, HITL simulation, and fast-time simulation [PRM Program Office, 1991; Ozmore and Morrow, 1996].

As discussed earlier, the SIAM model is used to extend the results of the HITL simulations of independent approaches. 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. (This type of analysis is performed on an airport-by-airport basis, since elevation 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 observed in the FAA HITL testing using qualified controllers and qualified 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. These maximum probabilities are shown in Table 3. The probabilities in Table 3 are equivalent to an overall unconditional probability of one accident per 25 million approaches. See [PRM Program Office, 1991], [Ozmore and Morrow, 1996], and [Massimini, 2006] for a more complete discussion of how these probabilities were derived.

Table 3. Maximum Acceptable Probability of a Collision Given that a Blunder Occurs (as determined during FAA testing)

Independent Approaches to	Maximum P(Collision|Blunder)
Two Runways	.004
Three Runways	.003

Note that independent approaches to three runways require a lower conditional collision rate than approaches to two runways. This is due to the additional risk of blunders from the center runway. This reduced maximum conditional collision rate often results in larger runway spacing for three-runway systems than for two-runway systems. The unconditional collision rate is the same for both two- and three-runway systems (i.e., less than 1 accident per 25 million approaches).

3.2.2 Airport Elevation/Aircraft Speed

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 communications requirements specified by ICAO and/or the FAA for independent approaches. The controllers ability to separate aircraft is also affected by aircraft speed, as described below.

During testing, the FAA found that airport elevation could have a significant effect on the ability of monitor controllers to separate aircraft, primarily due to the higher aircraft TAS that results from the higher altitudes being flown during the approaches. For this reason, as previously mentioned, the FAA imposed a maximum elevation of 1000 ft MSL for independent approaches to three runways unless additional analyses are performed and appropriate measures taken. Although airport elevation applies equally to approaches to two runways, the FAA standards for two runways were never changed to incorporate elevation. ICAO also did not limit airport elevation for independent approaches to two runways. (Recall that ICAO has not published standards for independent approaches to three runways.)

As previously mentioned, notwithstanding the lack of FAA or ICAO standards, MITRE believes that elevation should be considered in the safety analysis of *all* independent approach procedures. Accordingly, the analysis conducted by MITRE for this report has adjusted speeds based on the elevation and temperature of Texcoco.

3.2.3 Results of the Collision Risk Analysis (SIAM Modeling)

Table 4 provides the results of the simulations of independent approaches to two and three runways in the Texcoco area using SIAM. To assist in the eventual design of the airport in Texcoco, minimum spacing is provided for combinations of independent approaches to both two and three runways. The results include the use of high-update-rate surveillance, such as the PRM or PRM-A.

The probability of collision given that a blunder occurs is less than specified in Table 3 for each of the runway spacings 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.

These runway spacings assume 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-maneuver. Thus, additional separation would be required between the runways if a climb-only maneuver must be performed by the endangered aircraft.

Note that these results are slightly different than those presented in the preliminary report [MITRE, 2008]. The differences are generally due to different assumptions regarding the length of the final approach and the placement of the final approach fixes for each approach.

Table 4. Minimum Runway Spacing for Approaches to Parallel Runways in Texcoco (SIAM Modeling)

Number of Runways	Minimum Runway Spacing	Display	Radar (Maximum Update Interval)	P(Collision|Blunder) at Texcoco	Maximum Allowable P(Collision|Blunder)	Pass/Fail
2	1250 m (4100 ft)	PRM	PRM (1.0 sec)	0.0037	.004	Pass
3	1372 m (4500 ft)	PRM	PRM (1.0 sec)	0.0029	.003	Pass
2	1585 m (5200 ft)	FMA	ASR (5.0 sec)	0.0037	.004	Pass
3	1707 m (5600 ft)	FMA	ASR (5.0 sec)	0.0028	.003	Pass

Notes: Runways are assumed to be evenly spaced in 3-runway configurations.

U.S. and ICAO standards still specify the use of the now discontinued PRM; the PRM-A has not yet been formally approved.

4.0 Observations

The runway spacings provided in Table 4 should provide appropriate safety levels for conducting independent approaches to two or three runways at Texcoco, although path-following errors can cause problems and therefore should be taken into consideration. Said differently, the results of Tables 2 and 4 should be considered simultaneously before a decision is made.

Specifically, path-following errors should provide no difficulties for spacings associated with the FMA display, since these spacings are more than 1525 m. However, spacings associated with the PRM or the PRM-A could be problematic due to potential high probability of NTZ penetration (see Table 2). A spacing of 1250 m for dual approaches using a PRM would likely be satisfactory if the distance where altitude separation is lost is restricted to 20 NM or less. If triple approaches require that the aircraft lose altitude separation at a distance of 25 NM, then the minimum 1372 m spacing shown in Table 4 could be problematic, as shown in Table 2. Asymmetric runway spacing may improve this situation and, if necessary, will be explored by MITRE.

This report provides an analysis of runway spacing at Texcoco that is necessary to meet U.S. or ICAO safety requirements for independent approaches. Prior to approving independent approaches, however, a large number of other items must be addressed. Examples of this are reviews of controller training, controller positions, communication links, and others.

MITRE considers the results of this report to be robust. However, modifications to runway placement, and airspace and procedural design could cause changes that would require a revision of this analysis.

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