Enclosures 1 and 2

(Ref. Technical Letter F063-L09-001)

MITRE

Center for Advanced
Aviation System Development

Independent Parallel Approach Requirements and Display Features

Prepared for

Dirección General de Aeronáutica Civil
Secretaría de Comunicaciones y Transportes

24 October 2008

Enclosure 1

(Ref. Technical Letter F063-L09-001)

MITRE

Center for Advanced
Aviation System Development

Independent Approaches to Parallel Runways in the Texcoco Area

Prepared for

Dirección General de Aeronáutica Civil
Secretaría de Comunicaciones y Transportes

24 October 2008

1.0 Introduction

This document provides information on considerations for independent approaches, including both general requirements and requirements relating to equipment. It is intended to complement the results of MITRE's preliminary runway spacing analysis for the Texcoco area which were submitted to Mexico's Dirección General de Aeronáutica Civil (DGAC) in early June 2008 (see Enclosure No. 1 Ref. F063-L08-40). Refer to that document for information on runway spacing requirements and considerations.

2.0 General Requirements for Independent Approaches

The general requirements for independent approaches under the International Civil Aviation Organization (ICAO) are contained in [ICAO, 2007] and the [ICAO, 2004]. Requirements for independent approaches under the United States (U.S.) Federal Aviation Administration (FAA) are similar, and are contained in [FAA, 2008] and [FAA 2007]. The following is a summary of the procedures and general requirements for conducting independent approaches (with differences between ICAO and FAA annotated). Feet and nautical miles are used in this document; ICAO specifications have equivalent metric values.

- Airspace design must provide at least 1000 ft vertical separation between approach paths until the aircraft are established on their respective localizer courses. Minimum distance criteria for turn onto final must also be met. For independent approaches to three runways, each runway must be separated from the other two runways by at least 1000 ft.

- A No Transgression Zone (NTZ) at least 2000 ft wide must be established midway between the approach paths, starting at the point where the aircraft lose 1000 ft of altitude separation, and continuing until the nearest landing threshold.

- A dedicated monitor controller must be assigned for each approach path. The controller must monitor aircraft during the entire final approach. Monitoring usually stops when the aircraft is 1.0 NM from the runway threshold, but monitoring can be required to or past the threshold in some procedures. If an aircraft deviates towards the other approach course, the monitor controller should instruct the aircraft to return to its course. The monitor controller for the adjacent course should break out the aircraft approaching the adjacent runway if endangered by the deviation of the aircraft on the other approach.

- An analysis of parallel approach obstacle assessment surfaces (PAOAS) should be conducted to ensure that aircraft broken off from an approach do not collide with any obstacles. This is necessary since aircraft being broken off an approach will no longer be protected by the obstacle surfaces for that approach and may not be following the missed approach course. A detailed description of the off-centerline evaluation can be found in [ICAO, 2006 or FAA, 2007].

- MITRE's parallel runway spacing analysis for the Texcoco area assumes that a Final Monitor Aid (FMA) will be used for monitoring unless a Precision Runway Monitor (PRM) radar is in use.[1] The FMA is described in greater detail below. Additional information regarding the FMA is contained in Enclosure No. 2 Ref. F063-L09-001.

- For independent approaches not requiring a PRM, a surveillance radar associated with the display must have an update rate of 5.0 seconds or faster and an accuracy of equal or better than 0.06 degrees (one sigma), which is typical of monopulse Secondary Surveillance Radars (SSRs). A PRM, if used, must have similar accuracy requirements, but must have an update rate of one second or less.

- Each monitor controller must have a dedicated radio frequency. If the monitor controller shares the frequency with another controller (such as the local tower controller), then the monitor controller must have override capability on the frequency. Additional discussion of the override is presented below.

- Each approach path must have a functioning Instrument Landing System (ILS)[2], including a glide slope.

- Missed approach paths must diverge by at least 30 degrees (ICAO) or 45 degrees (FAA).

- Controller and pilot training information must be conducted and promulgated to promote awareness of the procedures necessary to conduct simultaneous approaches.

- Weather and other factors should be considered prior to the conduct of independent approaches. For example, excessive crosswinds and turbulence may make the tracking of ILS courses difficult, increasing path-following errors and causing higher workload for monitor controllers. Similarly, thunderstorms near the airport could interfere with the path following of the aircraft. Air Traffic Control (ATC) should evaluate adverse conditions and consider suspending independent approaches if deemed necessary.

3.0 Equipment Requirements for Independent Approaches

Some preliminary discussion of equipment requirements for independent approaches is contained in this section. These items may require a longer lead time for development and implementation.

3.1 FMA Display

The FMA was originally developed as the display for the PRM system. During the development of standards for independent approaches in the U.S., the display was adapted to function with a

[1] The PRM uses an FMA.

[2] Microwave Landing System (MLS) approaches are also permitted, but are not discussed in this analysis. It is anticipated that Area Navigation (RNAV) and Required Navigation Performance (RNP) approaches will be authorized in the near future, but these are not authorized at this time.

monopulse SSR. The FMA provides the following enhancements for monitoring of independent approaches. Figure 1 gives an example of an FMA display. Note that the approaches in Figure 1 are displayed with an offset localizer, which is unlikely to be required for Texcoco.

- The aspect ratio of the display is expanded 4 times orthogonal 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 aural 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 aural 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 aircraft deviations from the appropriate approach path much faster than when using a conventional display. FMA displays were installed at Denver International Airport in the mid-1990s in order to conduct independent approaches to three parallel runways and account for the high elevation of the airport. FMA displays are being incorporated into the U.S. FAA's new automation display system, the Standard Terminal Automation Replacement System (STARS). See Enclosure No. 2 Ref. F063-L09-001 for additional information on STARS.

The FMA functionality will have to be incorporated into the surveillance automation for Texcoco. **This will require a dedicated effort, including development of specifications, software modification, testing, and evaluation.**

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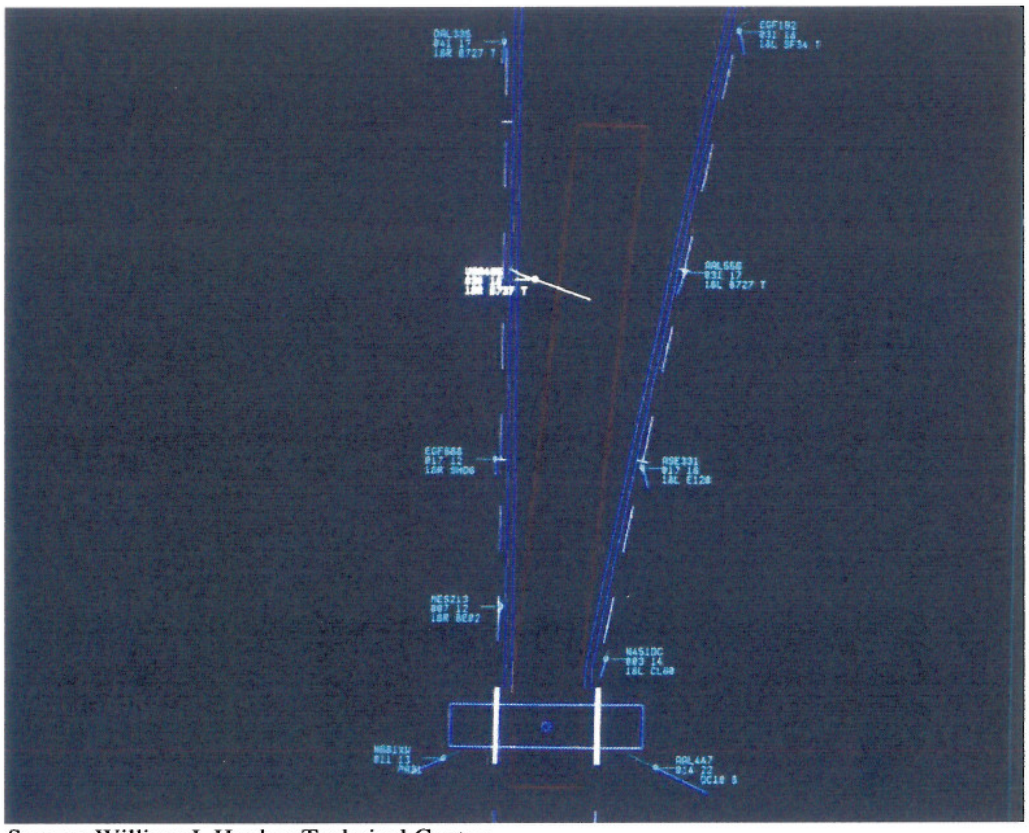

Source: William J. Hughes Technical Center

Figure 1. FMA Display (Shown with Offset Localizer on Left Runway)

3.2 PRM

The PRM was developed in the late 1980s, partially as a result of research performed by MITRE. Two different types of PRMs were originally developed, but only one type was actually produced. The production version is an electronically scanned monopulse SSR that uses an FMA display. The update rate of the PRM can be adjusted from one-half second to five seconds. Only one second update rates are normally used. PRMs are deployed at a number of airports in the U.S., and one is also deployed at Sydney's Kingsford-Smith Airport in Australia. See Figure 2 for a picture of the PRM antenna.

Figure 2. PRM

Although the PRM is already in use, other high-update-rate surveillance is being developed and will likely be approved in the future (in some form). For example, multilateration and Automatic Dependent Surveillance – Broadcast (ADS-B) have potential to provide high-update-rate surveillance service.

3.3 Communications Override Equipment

ICAO and U.S. standards, as well as the MITRE collision analysis, 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. 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, and all modern digital communications switches allow this capability. For example, a transmission by a controller to an aircraft typically overrides ground-to-ground hot microphone connections. This function should be able to be implemented without major difficulty (it is implemented at all independent-approach airports in the U.S.).

4.0 Closing Remarks

The transition from single and segregated runway operations (currently being used in Mexico) to dependent and independent operations of multiple parallel runways (being considered for the near-future in Mexico) is a complicated task that requires proper planning and coordination. Later on in the project, MITRE will assist the DGAC in the development of a transition plan that will address requirements for independent operations to parallel runways such as aircraft and ATC equipage, new controller positions, the incorporation of NTZs, and ATC coordination.

MITRE will also accompany SENEAM personnel to appropriate U.S. airports where dependent or independent parallel operations are conducted. This will allow SENEAM personnel to observe actual dependent and independent operations being conducted in order to obtain a better understanding of regulations, procedures, typical controller-techniques, equipment and other important factors. MITRE experts will be available during these observation visits to provide guidance and consultative support to ensure that the SENEAM personnel obtain information on appropriate elements of independent approach operations.

The requirements described in this document should provide the DGAC with appropriate high-level background information to assist in future planning and coordination efforts leading up to the eventual implementation of independent approaches in the Texcoco area and at other airports in Mexico, as necessary.

References

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Enclosure 2

(Ref. Technical Letter F063-L09-001)

MITRE

Center for Advanced Aviation System Development

Surveillance Displays for Independent Approaches

Prepared for

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1.0 Introduction

MITRE performed a preliminary analysis of the lateral separation required between parallel runways in the future Texcoco Airport area in support of Mexico's Dirección General de Aeronáutica Civil (DGAC). The results of this preliminary analysis were submitted to the DGAC in early June (see Enclosure No. 1 Ref. F063-L08-040). Minimum spacings were provided for combinations of independent approaches to both two and three runways, and considered the use of additional equipment, such as the Final Monitor Aid (FMA) display, to safely conduct independent approaches. See MITRE document Enclosure 1 Ref. Technical Letter F063-L09-001 for information on requirements for independent approaches to parallel runways.

The intent of this document is to provide a summary of the specifications used in FMA displays that are being incorporated into the United States (U.S.) Federal Aviation Administration's (FAA's) new terminal display and automation system [the Standard Terminal Automation Replacement System (STARS)]. As a result, the DGAC will have a much better understanding of the capabilities of an FMA for future planning purposes.

As mentioned above, MITRE recently conducted a preliminary analysis of runway spacing at Texcoco. One assumption of the analysis was that monitor controllers would use advanced surveillance displays. Displays of this type were originally developed by the U.S. FAA during the testing and development of U.S. independent approach standards using the high-update-rate Precision Runway Monitor (PRM). Subsequent testing revealed that the FMA display could be successfully coupled with a standard airport Secondary Surveillance Radar (SSR). In some cases, MITRE's preliminary runway spacing analysis assumed that controllers would use a display with the same functionality as the FMA display when using a standard SSR. The FMA display is also used with the high-update-rate PRM system.

Figure 1 gives an example of an FMA display. Note that the approaches in Figure 1 are displayed with an offset localizer, which is unlikely to be required for Texcoco.

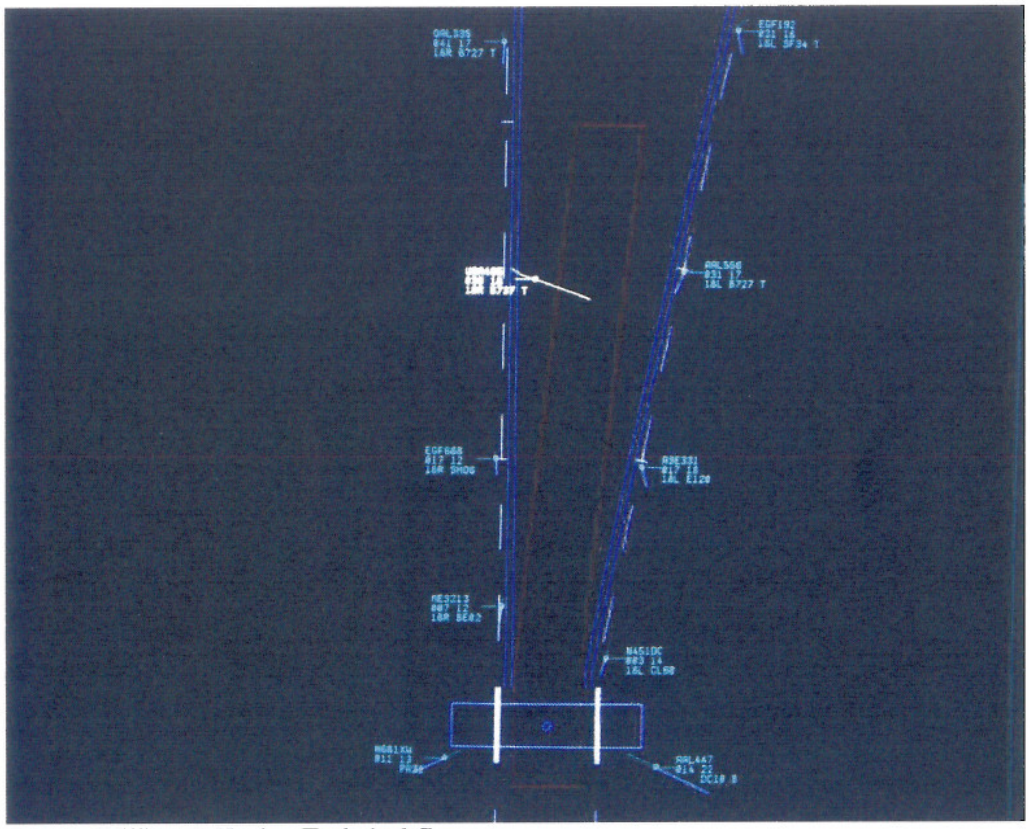
- The aspect ratio of the display is expanded 4 times orthogonal to the approach centerlines. This enhanced lateral display allows the controller to more easily identify deviations from centerline by aircraft flying independent approaches.

- Alerting algorithms provide a visual and aural alert to the controller when an aircraft is projected to enter the No Transgression Zone (NTZ) within 10 seconds. The FMA provides a second type of visual and aural 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. FMA displays were installed at Denver International Airport in the mid-1990s in order to conduct independent approaches to three parallel runways and account for the high elevation of the airport. MITRE used controller-reaction results from FAA testing when

analyzing the adequacy of the runway spacing at Texcoco for conducting independent approaches.

Therefore, the FMA functionally will have to be incorporated into the surveillance automation for Mexico. **This will require a dedicated effort, including development of specifications, software modification, testing, and evaluation.**



Source: William J. Hughes Technical Center

Figure 1. FMA Display (Shown with Offset Localizer on Left Runway)

Note that while the FMAs improve the ability of the monitor controllers to detect deviations from final approach, the 4:1 aspect ratio distorts the orientation of the screen, making the vectoring of aircraft more difficult, if not impossible. Procedures must be implemented to compensate for the reduced ability of the monitor controllers to vector aircraft.

As previously mentioned, FMA displays were installed in Denver International Airport in order to conduct independent approaches to three parallel runways. No other separate installations were performed, however, and the Denver FMAs were a "one-of-a-kind" manufacture. Therefore, there is no known vendor or source where an FMA display can be procured without a dedicated development activity.

General requirements for FMA displays are contained in FAA documents (FAA, 2008) and in several ICAO documents (ICAO, 2004 and ICAO, 2007). However, these documents lack sufficient detail to actually implement an FMA system.

Despite all of the above, FMA displays are being incorporated into the FAA's STARS as a type of display that may be called up by operators at specific times. Since it is unlikely that the DGAC will purchase the STARS system, the FMA functionality will have to be incorporated into the surveillance/display automation system at the Texcoco site in order to meet applicable safety standards for the conduct of independent approaches. This will require a dedicated effort by appropriate automation and display system vendors, including development of specifications, software modification, testing, and evaluation. This paper provides a high-level description of the requirements for an FMA display in order to assist in the eventual development of an "FMA Mode" for the surveillance displays at the Texcoco site.

The following text is not intended to be a specification for an FMA display, but rather a summary of the specifications used in the STARS system that are essential to the monitoring of independent approaches. 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 likely can be accomplished in a manner consistent with the surveillance/display automation systems in place at Mexico City International Airport (AICM).

Portions of Section 2 of this paper are copied directly or paraphrased from [Raytheon, 2006][1].

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[1] The overall Raytheon document is export-controlled by U.S. authorities. Information provided in this MITRE report has been judged to not fall under the export-control restrictions.

2.0 Final Monitor Aid (FMA) Display Requirements

The FMA display is a 20 x 20 inch (51 x 51 cm) high-resolution color display. Although a separate display is required for the monitor controllers (usually each monitor controller has a separate display), the FMA does not have to be a standalone display. It can be a mode of a more general display system. The current FMAs used at Denver International Airport display only SSR information (i.e., no information from the primary radar is displayed). However, the display of primary data on the FMA can be implemented if desired—but SSR and data-block information should also be displayed.

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.

2.1 Overall Requirements

The FMA typically only displays the final approach courses for the independent arrival runways in use. 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 to a selected Active Monitored Zone (AMZ). See Figure 2 for a depiction of an AMZ.

The AMZ is typically characterized by the parameters listed below. The associated dimensions are nominal for the STARS system, but are not a de facto requirement for the FMA system.

a. Approach Course Orientation for each of up to four runways

b. Boundary vertex points

c. Vertical extent

d. Runway end points

e. No Transgression Zone(s) (NTZ)

f. Normal Operating Zones (NOZ)

g. Approach Course Line length for each of up to four runways (0 to 30 NM from approach threshold)

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 2 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 2 are not necessarily shown to scale nor with expected operational alignments or dimensions. Also note that the location and dimensions of the rectangular 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.

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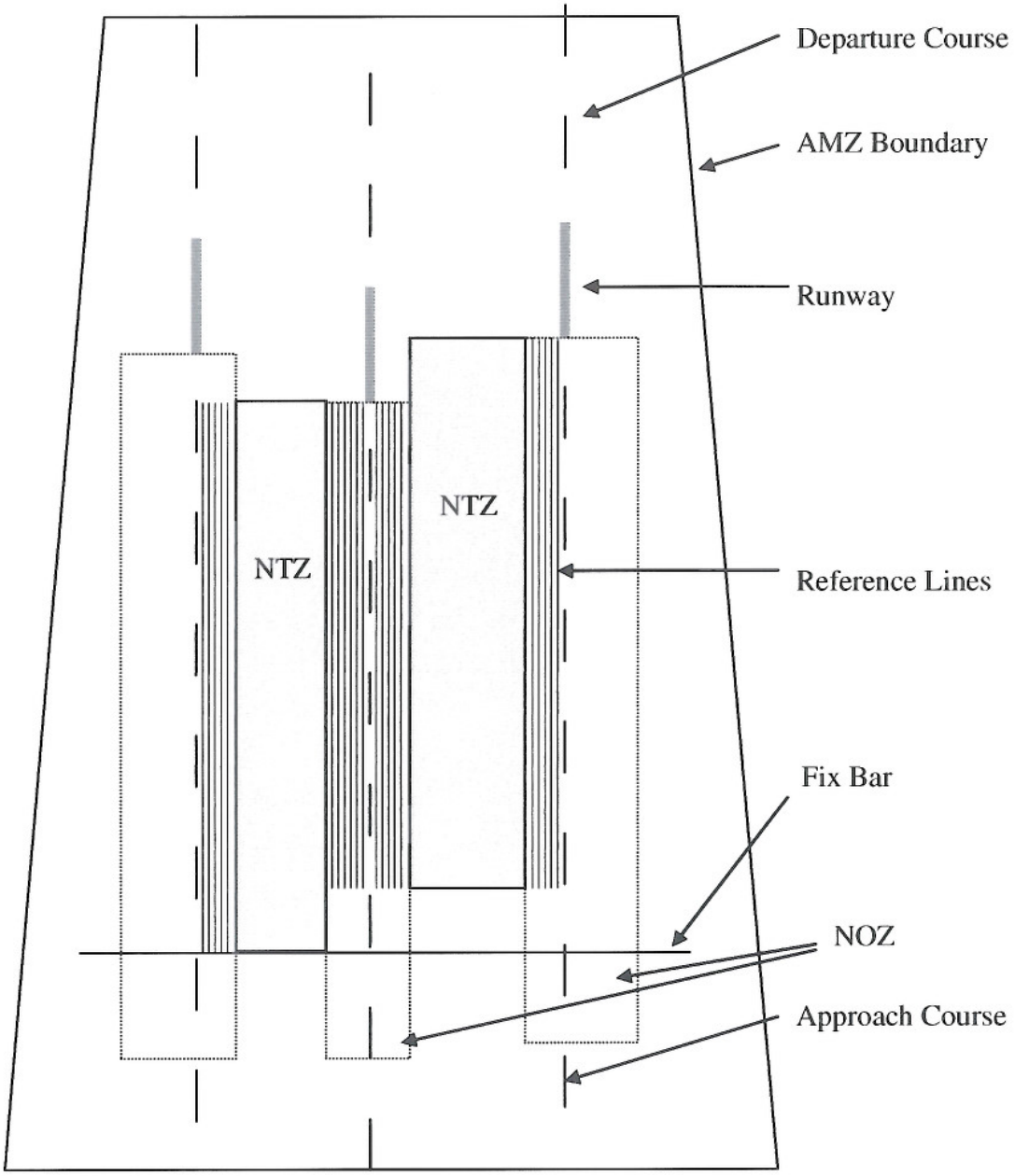

Source: Raytheon, 2006

Figure 2. Approach Monitor Zone (AMZ) with Three Runways Depicted

The colors of the FMA in the STARS system are noted in Table 1 below. Note that Figure 1 is a depiction of a prototype FMA display. As such, some colors in Figure 1 may be different than that specified in Table 1.

Table 1. 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

2.2 The No Transgression Zone (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 2,000 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 in FMA mode 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.

2.3 The Normal Operating Zone (NOZ)

An NOZ is associated with each runway approach course. The location and dimensions of the NOZ should be adaptable, with the default parameters such that it 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 Caution Alerts. The NOZ outline is not displayed.

2.4 FMA Alerts

The essential alerts for the FMA are the Caution Alert and the Warning Alert, as discussed in Sections 2.4.1 and 2.4.2 below. However, there are additional alerts that should be implemented, as summarized in Sections 2.4.3-2.4.5 below. Sections 2.4.6-2.4.8 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 FMA is one necessary condition for generation of all types of FMA alerts below.

2.4.1 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.

2.4.2 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 in one-second increments with a minimum value of zero, a maximum value of 20 seconds, and a default value of 10 seconds.

2.4.3 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 (minimum 6 seconds, default 15 seconds, maximum 20 seconds, increment of 1 second).

2.4.4 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.

2.4.5 FMA Runway Alert due to Invalid 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.

2.4.6 Simultaneous FMA Alerts

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

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

The STARS system 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.

2.4.8 Voice Alert Indications

Any newly-established FMA alert condition for a track should initiate a voice alert indication identifying the flight followed by the alert condition for the track as shown in Table 2.

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 2. The STARS system allows alerts to be silenced after acknowledgement by the controller.

Table 2. FMA Voice Alerts

Alert	Default Spoken Text
Warning	"WARNING"
Surveillance	"COAST"
Runway (wrong runway)	"WRONG RUNWAY"
Runway (missing or invalid runway)	"WRONG RUNWAY"
Caution (NTZ prediction)	"CAUTION"

2.5 Final Monitor Aid (FMA) Performance

2.5.1 Runways and Aircraft per Active AMZ

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

2.5.2 Tracked Target Deviations

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

2.5.3 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.

2.5.4 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.

2.6 Simulation Capability

Training for monitor controllers should be conducted on a display equivalent to the FMA displays used for independent approaches. The ability to conduct normal independent approaches should be available, including the activation and use of all display features.

Additionally, the simulation capability should accommodate simulation of deviations from the final approach course, requiring 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.

The simulation capability should be tailored to the normal training equipment used at AICM. If training today is normally accomplished on ATC equipment used for control of aircraft at AICM, then that equipment should incorporate a simulation capability. Otherwise, a dedicated FMA simulation capability should be developed for Texcoco.

3.0 Conclusions

The intent of this document was to provide parameters utilized in the development of FMA displays to assist the DGAC in the incorporation of FMA functionality into the surveillance/display/automation equipment at Texcoco. Not all of the specifications of the U.S. STARS system were included in this document. However, the relevant specifications for the display and performance of the specific FMA functions required for independent approaches were included.

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