

# **Enclosure 2**

(Ref. Technical Letter H560-L18-024)



**Center for Advanced  
Aviation System Development**

## **Human-In-The-Loop Simulation Evaluations to Support the Nuevo Aeropuerto Internacional de la Ciudad de México**

*Laboratory Configuration*

**Prepared for**

**Grupo Aeroportuario de la Ciudad de México**

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## Principal Acronyms and Abbreviations

<b>ACC</b>	Area Control Center
<b>ADS-B</b>	Automatic Dependent Surveillance-Broadcast
<b>AFTN</b>	Aeronautical Fixed Telecommunication Network
<b>AICM</b>	Aeropuerto Internacional de la Ciudad de México
<b>ARTCC</b>	Air Route Traffic Control Center
<b>ASDE-X</b>	Airport Surface Detection Equipment, Model X
<b>ATC</b>	Air Traffic Control
<b>ATM</b>	Air Traffic Management
<b>COTS</b>	Commercial-Off-The-Shelf
<b>CPL</b>	Current Flight Plan
<b>DSI</b>	Display System Integration
<b>DSS</b>	Decision Support System
<b>FAA</b>	U.S. Federal Aviation Administration
<b>FMA</b>	Final Monitor Aid
<b>HD</b>	High Definition
<b>HITL</b>	Human-In-The-Loop
<b>ICAO</b>	International Civil Aviation Organization
<b>JEDI</b>	Joint Enroute DSS Infrastructure
<b>MITRE</b>	The MITRE Corporation
<b>NAICM</b>	Nuevo Aeropuerto Internacional de la Ciudad de México
<b>NAS</b>	National Airspace System
<b>NTZ</b>	No Transgression Zone
<b>PTT</b>	Push-To-Talk
<b>SENEAM</b>	Servicios a la Navegación en el Espacio Aéreo Mexicano
<b>SSR</b>	Secondary Surveillance Radar
<b>TRACON</b>	Terminal Radar Approach Control
<b>UFM</b>	Unified Flight Modeler

<b>U.S.</b>	United States
<b>USB</b>	Universal Serial Bus
<b>VSCS</b>	Voice Switching and Control System

## 1. Introduction

The MITRE Corporation (MITRE) is assisting through the Grupo Aeroportuario de la Ciudad de México (GACM), the aviation authorities of Mexico in the development of a new airport, referred to in this document as Nuevo Aeropuerto Internacional de la Ciudad de México (NAICM), to replace the current Aeropuerto Internacional de la Ciudad de México (AICM). The proposed runway layout of NAICM will allow for both dual- and triple-independent instrument approach and departure operations. MITRE has been working closely with a team from Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM) to assist them with their development of new airspace and procedures to support NAICM, including modifications to the Mexico Area Control Center (ACC) enroute airspace. This work has been conducted through meetings, workshops, and teleconferences.

As part of the transition to the new airspace and procedures to support NAICM, MITRE and SENEAM will jointly conduct a series of Human-In-The-Loop (HITL) simulations to evaluate the routes, procedures, and sectorization for the new Mexico City Terminal Manuevering (Control) Area (TMA), which includes the new Toluca TMA, and the Mexico ACC. The goal of the HITL simulations is to refine and verify the appropriateness of the airspace design with SENEAM Air Traffic Control (ATC) participants managing simulated traffic. The scope and specific research goals of the HITL simulations will be determined as part of upcoming airspace design workshops. The HITL simulations will be conducted in MITRE's Air Traffic Management (ATM) Laboratory in McLean, Virginia over the next few years.

Two MITRE engineers visited *Centro México* on 7 September 2017 to observe operations and conduct discussions with controllers in preparation for the upcoming NAICM-related HITL simulations. The goal of the visit was for MITRE's HITL laboratory and simulation experts to obtain a better understanding of ATC equipment and system functionality in use at *Centro México* to support upcoming new Mexico City TMA and Mexico ACC HITL simulations. The MITRE engineers spent several hours observing operations, which allowed them to obtain a better understanding of ATC system functions that are typically used, as well as working position configurations and settings, peripheral hardware in use, common tasks, and communications and coordination matters.

This document provides MITRE's description of the technical capabilities and equipment that MITRE plans to customize and adapt to use during upcoming HITL simulations to support dual- and triple-independent operations at NAICM, as well as the modifications to the Mexico ACC enroute airspace. The intent of this document is to provide SENEAM with an understanding of the laboratory operational environment in which the HITL simulations will be conducted. With the information provided in this document, SENEAM officials should be able to provide feedback to MITRE on the laboratory environment and on modifications that may be needed, as appropriate.

This document is structured as follows:

- Section 2 provides detailed information on MITRE's HITL laboratory configuration that will be used for the new Mexico City TMA and Mexico ACC HITL simulations,

including: hardware and software, the connection and/or interrelationship between these elements, and how these elements support the different roles of the simulation.

- Section 3 are a few closing remarks.

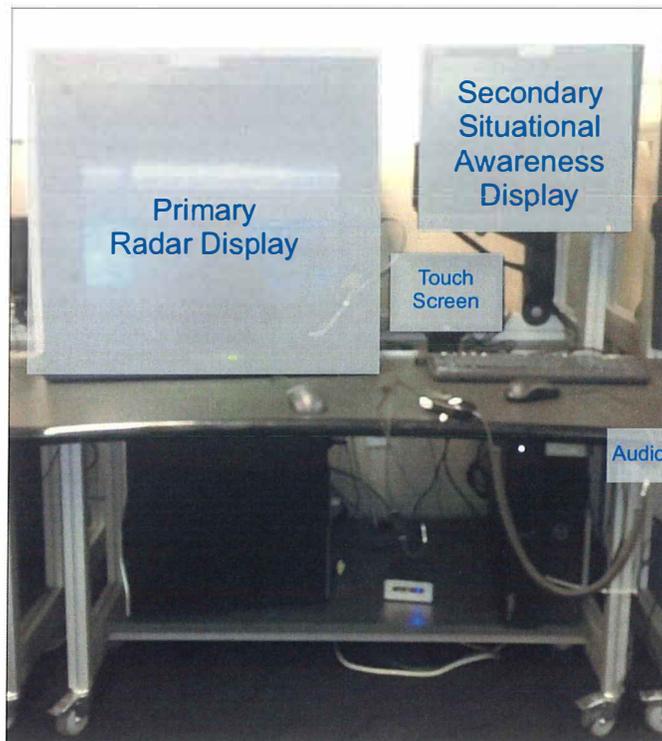
## **2. Simulation Environment**

This section includes details on displays, computers, peripherals, audio and communications equipment, software and applications, and their relationship within the context of the MITRE HITL laboratory system architecture. Each element contains a description of physical characteristics. Adapted capabilities, or capabilities that differ from existing MITRE HITL laboratory capabilities are also described.

### **2.1 Workstations and Laboratory Physical Layout**

The MITRE HITL laboratory provides a medium fidelity simulation of various ATC systems, capabilities, and functions. The laboratory can emulate a variety of different manufacturers of ATC software from both the United States (U.S.) and abroad. These capabilities are provided to users of the laboratory via different types of workstations, each designed to support different tasks. For the new Mexico City TMA and Mexico ACC HITL simulations, the laboratory will be utilizing three different workstation configurations. The first configuration (see Figure 1) is the ATC controller workstation that will be used during the new Mexico City TMA and Mexico ACC HITL simulations. This configuration simulates a medium fidelity ATC interface. It contains a primary radar display, secondary situational awareness display, touch panel for operating a generic Voice Switching and Control System (VSCS) control, and an audio jack. Controllers staffing these positions will be able to perform all the tasks required to control simulated traffic in the HITL simulations.

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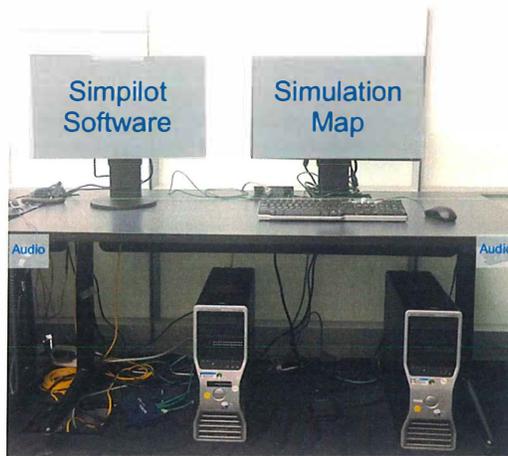


Source: MITRE

**Figure 1. ATC Controller Workstation**

The pilot workstations (see Figure 2) are also medium fidelity workstations that allow pseudo-pilots to control multiple simulated aircraft within designated airspace for the purpose of responding to ATC-issued commands and clearances. The pseudo-pilot responses to ATC commands and clearances cause changes to corresponding targets being generated by the Unified Flight Modeler (UFM). For the purpose of the new Mexico City TMA and Mexico ACC HITL simulations, the two adjoining pilot workstations will be used with one providing the software interface for aircraft control (simpilot software), and the other displaying a map with simulated traffic that the controller is seeing (simulation map).

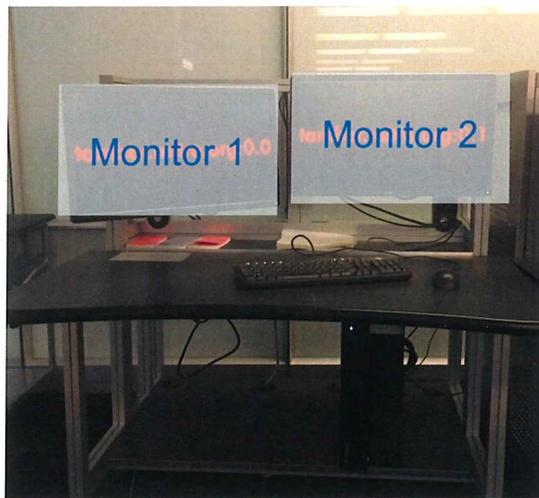
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Source: MITRE

**Figure 2. Pilot Workstation**

Lastly, the laboratory will employ two simulation control workstations, Monitor 1 and Monitor 2, as shown in Figure 3. These workstations are used to control (i.e., start and stop) the HITL simulations as well as perform other simulation related maintenance tasks. Although the physical locations of the workstations within the laboratory will be determined at a later date, the pilot workstations will be segregated in a separate area of the laboratory from the ATC controller workstations.



Source: MITRE

**Figure 3. Simulation Control Workstation**

## 2.2 Hardware

Hardware used in the HITL simulations will include the following:

1. Each ATC controller workstation will be comprised of one, high-resolution display (for the primary control interface), one computer to run the simulation software and interface elements being displayed on the primary control interface, one touch screen

for the communications interface, and peripherals (i.e., a Thales-style keyboard, a standard mouse, a standard headset with microphone and a Push-To-Talk [PTT] hand-held device). An additional High Definition (HD) flat screen monitor may be used at some workstations to display additional information.

2. Each pilot workstation will be comprised of two computer monitors for the primary pseudo-pilot control interface with one computer to run the simulation software and interface elements being displayed on the pilot workstation, and peripherals (i.e., a QWERTY keyboard, a standard mouse, a standard headset with microphone, and a PTT hand-held device and an audio foot pedal).
3. Each simulation control workstation will be comprised of up to two computer monitors for the primary simulation control interface, with one computer to run the simulation software and interface elements being displayed at the simulation control workstation and peripherals (i.e., a QWERTY keyboard and a standard mouse).

### 2.2.1 Displays

The primary displays being used at the ATC controller workstations are high resolution monitors (referred to as 2Ks). See the *Primary Radar Display* in Figure 1. These monitors emulate ATC displays used in the U.S. National Airspace System (NAS), such as the Federal Aviation Administration's (FAA's) Display System Integration (DSI) at Air Route Traffic Control Center (ARTCC) enroute facilities and the FAA's Standard Terminal Automation Replacement System (STARS) at Terminal Radar Approach Control (TRACON) terminal facilities. For the new Mexico City TMA and Mexico ACC HITL simulations, the 2K displays will display Thales Eurocat X (i.e., the ATC system currently in use at AICM) emulation at both the enroute and the terminal workstations.

Additional HD resolution monitors (either 19-inch monitors with 1280 x 1024 resolution, as seen in Figure 1 as a *Secondary Situational Awareness Display*, or 24-inch monitors with 1920 x 1080 resolution, as seen in Figure 3), are available at each ATC controller workstation, as well as at all pilot and simulation control workstations. These monitors will be used to display other flight data and/or functionality, including the simulation management interface, the SimPilot interface, planner position data, and/or background processes (e.g., flight modeling, etc.).

For the audio/communications systems interface, a 10-inch touchscreen display (shown in Figure 1 as *Touch Screen*) will be used to display the interactive VSCS emulation, which allows air traffic controllers to communicate with other sectors and positions both intra- and, if necessary, inter-facility.

### 2.2.2 Computers

Computers used at all workstations are Linux platform, Centos 7 machines using 64-bit architecture. These machines run all simulation platforms, including background and display software.

### 2.2.3 Peripherals

Each ATC controller workstation is going to be equipped with:

- A custom-designed, Universal Serial Bus (USB) Thales-style keyboard, which is a specialized keyboard similar to those utilized for ATC applications in Mexico (see Figure 4)
- A Commercial-Off-The-Shelf (COTS) standard USB mouse (see Figure 5)
- A standard headset with microphone and a PTT hand-held device (see Figure 6)

Pilot and simulation control workstations will utilize:

- A standard, COTS USB QWERTY keyboard (see Figure 7)
- A standard USB mouse
- A standard headset with microphone and a PTT hand-held device



Source: MITRE

**Figure 4. Thales-style Keyboard**



Source: MITRE

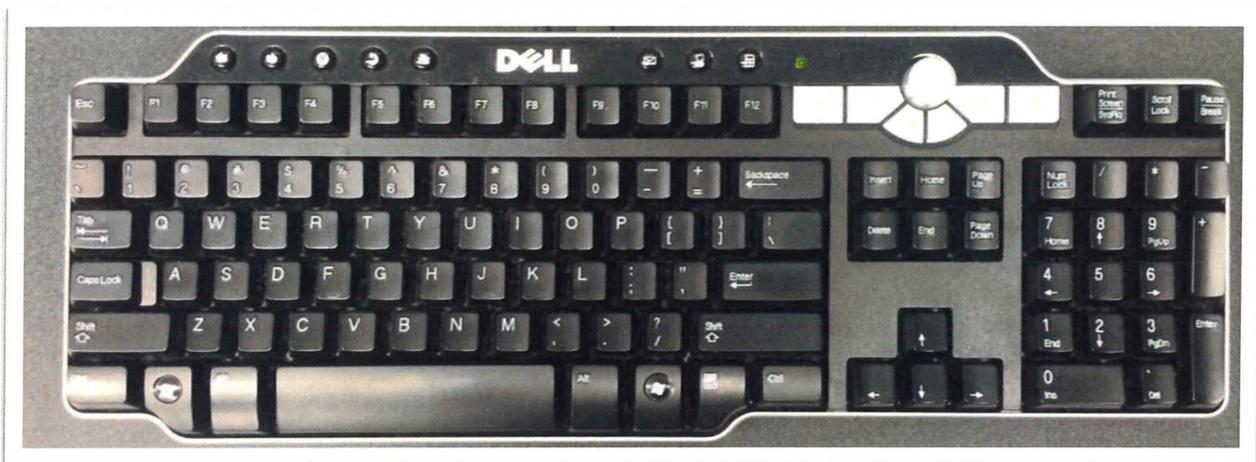
**Figure 5. Standard USB Mouse**

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Source: MITRE

**Figure 6. Standard Headset with Microphone and Handheld PTT**



Source: MITRE

**Figure 7. Standard QWERTY Keyboard**

## 2.3 Software

Within the laboratory, MITRE uses a variety of specially designed software tools to provide a realistic simulation environment. This section will discuss some of the software assets that pertain specifically to the new Mexico City TMA and Mexico ACC HITL simulations.

### 2.3.1 Simulation Control and Data Distribution

MITRE's laboratory contains a specialized simulation infrastructure for both simulation control as well as simulation data distribution. Together, these capabilities make up the core infrastructure for conducting HITL simulation research. The Simulation Data Distribution Framework is a technology that allows different applications within a HITL simulation to communicate and exchange data. SimBuilder is an application that manages and controls a HITL simulation itself. During the HITL simulation development process, an experimenter will use SimBuilder at one of the simulation control workstations (see Section 2.1) to setup and configure the various software components of a HITL simulation. During data collection, SimBuilder is used to control the start and stop of a HITL simulation and all its associated assets.

### 2.3.2 Target Generation (GRAIL/UFM)

GRAIL is an interactive, real-time environment that provides an integration capability that allows various systems, emulations, and prototypes to be used/tested in a realistic operational context in MITRE's laboratory. GRAIL will provide the ability to test existing ATC functionality under varied conditions (e.g., differing airspace designs or operational configurations).

UFM is a system capable of realistically representing the characteristics of most of the current worldwide airplane fleet. UFM models flights from takeoff, through all flight segments, to landing. Individual aircraft performance is dependent on many factors, including weather conditions such as wind, temperature, and pressure, and aircraft conditions such as airframe, fuel, and weight. UFM is a C++ application built using both standard libraries and MITRE's ATM Laboratory libraries of airplane performance. This construct is intended to be used by assets that do not have or need an internal flight modeling capability, such as an Airport Surface Detection Equipment, Model X (ASDE-X) display, or a visualization tool. UFM is also built as a library itself, allowing assets such as GRAIL to take advantage of the common flight modeling capability. UFM will provide target generation for the simulation.

### 2.3.3 Simulation Interface Software

A MITRE-developed emulation of the Thales Eurocat X controller display will be used for the new Mexico City TMA and Mexico ACC HITL simulations. This emulation includes the following capabilities:

- Display toggle of video maps
- Pan and zoom around the map

- Simulation of different types of targets, such as Automatic Dependent Surveillance-Broadcast (ADS-B) targets versus Secondary Surveillance Radar (SSR) targets
- Distance measurement between different targets
- Flight plan editing
- Display of data blocks

Each ATC and pilot workstation will be connected to the laboratory audio system, which will enable simulated ground-to-air/air-to-ground voice communications, as well as intra-facility and, if necessary, inter-facility position-to-position voice communications using a VSCS. The VSCS used for the new Mexico City TMA and Mexico ACC HITL simulations are based on a generic VSCS interface that will allow for controller-to-controller calls, as well as controller-to-pilot calls. When in a call, incoming pilot transmissions are played over a speaker while the controller-to-controller communications are heard in the headset. Similarly, when on call, the microphone (mic) is in “hot-mic” mode, where anything said by the controller is routed to the call; however, when the PTT is pressed audio is routed over the radio frequency to the pilots.

#### **2.3.4 Adaptation Details**

The adaptation and maps used within the simulation are based on the adaptation provided to MITRE by SENEAM, and modified, as needed, up through the dry run activities. These data are then converted to the internal format that MITRE uses for all GRAIL simulations. The video maps that will be used for the new Mexico City TMA and Mexico ACC HITL simulations also come from this dataset. Additionally, Jeppesen data will be used to augment the navigation data used by UFM as necessary.

#### **2.3.5 Automation (System Automated Options)**

Specific system functions, such as flash notification of handoffs from upstream adjacent sectors or modification to electronic flight data strips based on controller inputs, may be partially or fully automated for the simulation, depending upon the number of participants available and the configuration of specific scenarios.

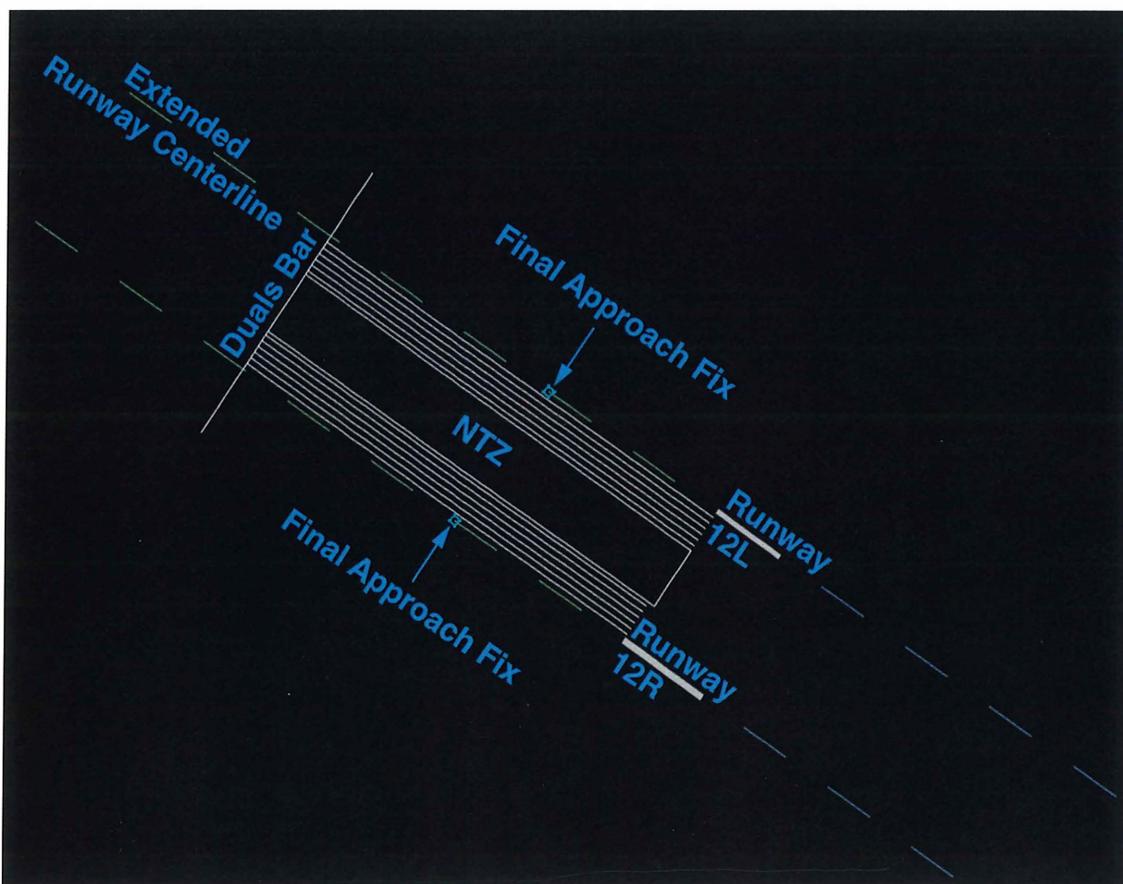
#### **2.3.6 Flight/Track Data**

The basic flight plan data that will be used as input to all of the scenarios will be based on Aeronautical Fixed Telecommunication Network (AFTN) Current Flight Plan (CPL) messages. SENEAM has provided MITRE with CPL data for March 2016 through April 2016. These message types provide the necessary fields and information that MITRE needs to model an aircraft when it is not under ATC control (outside of the evaluation sectors). These fields include the Call Sign, Aircraft Type, Aircraft Equipment, Departure Time, Filed Altitude, Filed Speed, and Route of Flight. These data will then be converted to MITRE’s internal formats and will provide a realistic baseline for traffic before it is edited (replicated, time shifted, deleted), as

needed, to generate the situations and traffic levels needed for the new Mexico City TMA and Mexico ACC HITL simulations.

## 2.4 Principal Design Elements

The HITL simulations conducted for the terminal area, will utilize a Final Monitor Aid (FMA) prototype, adapting custom software that was developed in support of the previously-conducted Cancún HITL simulations. The Cancún FMA was designed to emulate a generic FMA capability. The FMA is based on the existing Thales Emulation, but with a number of features removed or disabled and the aspect ratio stretched. The Cancún FMA display will be customized by MITRE to support the configuration of NAICM (i.e., dual- and triple-independent approaches). An example of this display is provided in Figure 8.



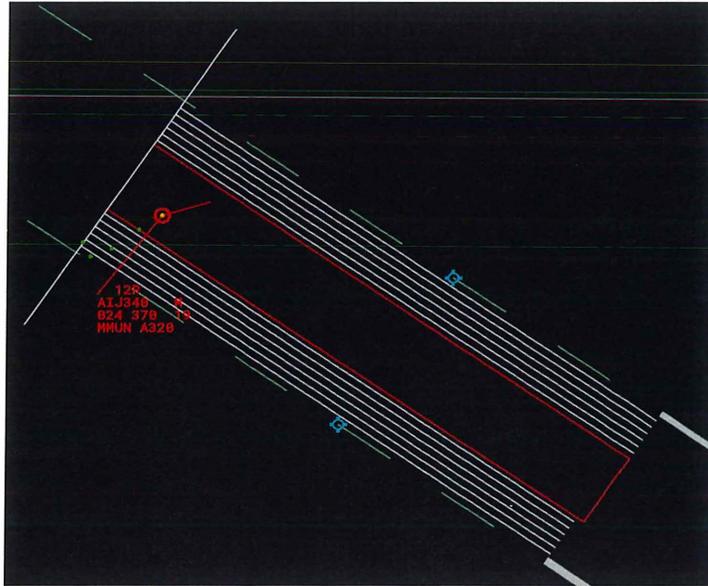
NTZ = No Transgression Zone

Source: MITRE

**Figure 8. Cancún Final Monitor Aid Prototype**

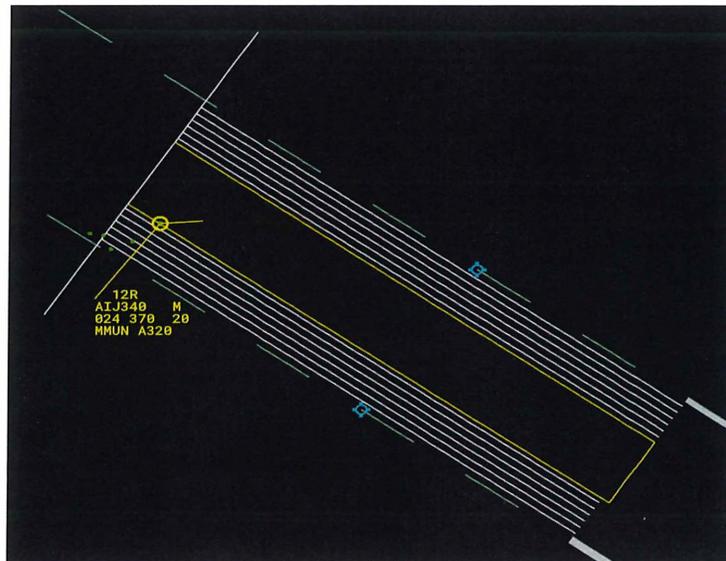
This FMA display contains a variety of elements. The display shows a vertical scene depicting the parallel runways. The view scale is an exaggerated 4:1 horizontal scale, which allows controllers to better detect deviations from runway centerlines. A red box depicting the NTZ is also depicted. If a target penetrates the NTZ it will be drawn in red (see Figure 9); if it is

predicted to penetrate, it is drawn in yellow (see Figure 10). All other targets will be drawn in white.



Source: MITRE

**Figure 9. FMA in Warning State**



Source: MITRE

**Figure 10. FMA in Caution State**

The Trial Planning/Conflict Probe capability will be modeled after the Conflict Probe and Trial Planning capabilities in Eurocat X. The MITRE-developed capabilities use algorithms

from the Joint Enroute Decision Support System (DSS) Infrastructure (JEDI), as well as input from SENEAM to simulate the Trial Planning and Conflict Probe algorithms built into Eurocat X. The interface of MITRE’s emulation will serve as a graphical way for controllers to interface with MITRE’s backend service while providing a look and feel similar to that of Eurocat X.

**2.5 Data Collection**

Two types of metrics will be collected during the new Mexico City TMA and Mexico ACC HITL simulations on each participant: subjective measures and objective measures. Subjective measures refer to metrics based on a participant’s experience or interpretation, such as a participant’s responses to survey questions (see Figure 11) or comments from a participant. Objective measures are metrics of direct performance, such as the number of communications between controller and aircraft within that controller’s sector, or the number of command inputs into the ATC controller workstation, such as reroutes or flight plan changes.

1. My overall workload was acceptable. (circle one)

1	2	3	4	5	6	7
Strongly Disagree						Strongly Agree

Comments: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

2. How would you rate the scenario overall traffic load? (circle one)

1	2	3	4	5	6	7
Very Low						Very High

Comments: \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

**Figure 11. Example of Subjective Survey Questions**

Three methods of data collection will be used in these simulation activities: electronic questionnaires, system-recorded data/voice, and observations. Questionnaires will be

administered electronically at the conclusion of scenario runs. The surveys will include questions that seek to gather subjective data on participants background, operational experience, and experiences during the simulation scenarios, including perceived workload, acceptability, preferences, perceived efficiency, interactions, and issues. System-recorded data/voice includes command and system inputs from participants, track and aircraft state data (such as speed, vector and altitude changes), pseudo-pilot control inputs, audio frequency loading, and individual channel recordings, including PTT logs from the various workstations. Simulation observers from MITRE and SENEAM (as available) will circulate among participants during data collection runs and will take general notes and capture any significant or unusual communications or actions visually or physically observed during the scenarios.

### 3. Closing Remarks

This document provides an initial description of technical capabilities and equipment (including specially customized equipment) that is going to be provided by MITRE to conduct upcoming new Mexico City TMA and Mexico ACC HITL simulations in support NAICM's eventual dual- and triple-independent operations. SENEAM officials should review the information contained in this document and provide feedback to MITRE, as necessary, so that appropriate discussions can take place and modifications made to MITRE's HITL laboratory, if required.

MITRE will continue to work closely with SENEAM to further define and/or refine scenarios and other aspects of the new Mexico City TMA and Mexico ACC HITL simulation in preparation for the implementation of dual- and triple-independent operations at NAICM.