Enclosure 2
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MITRE

Center for Advanced
Aviation System Development

Cancún Airport Human-In-The-Loop Simulations

Initial Laboratory Configuration Technical Requirements

Prepared for

Aeropuertos y Servicios Auxiliares

September 2016

Principal Acronyms and Abbreviations

ADS-B	Automatic Dependent Surveillance - Broadcast
AFTN	Aeronautical Fixed Telecommunication Network
APP	Approach
ARR	Arrival
ARTCC	Air Route Traffic Control Center
ATC	Air Traffic Control
COTS	Commercial-Off-The-Shelf
CPL	Current Flight Plan
DEP	Departure
DSI	Display System Integration
E	East
FAA	Federal Aviation Administration
FMA	Final Monitor Aid
FPL	Filed Flight Plan
HD	High definition
HITL	Human-In-The-Loop
ICAO	International Civil Aviation Organization
MITRE	The MITRE Corporation
MMMX	Mexico City International Airport (ICAO code)
MMUN	Cancún International Airport (ICAO code)
NAICM	Nuevo Aeropuerto Internacional de la Ciudad de México
NAS	National Airspace System
NTZ	No Transgression Zone
PTT	Push-To-Talk
SDDF	Simulation Data Distribution Framework
SENEAM	Servicios a la Navegación en el Espacio Aéreo Mexicano
SSR	Secondary Surveillance Radar
STARS	Standard Terminal Automation Replacement System

TMA	Terminal Control (Maneuvering) Area
TRACON	Terminal Radar Approach Control
UFM	Unified Flight Modeler
URET	User Request Evaluation Tool
USB	Universal Serial Bus
VSCS	Voice Switching and Command System
W	West

1. Introduction

The MITRE Corporation (MITRE) is assisting Aeropuertos y Servicios Auxiliares and the aviation authorities of Mexico with the implementation of a new airport to serve Mexico City, 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 (International Civil Aviation Organization [ICAO] code MMMX). The proposed runway layout of NAICM will allow for both dual and triple-independent arrival and departure operations. In conjunction with this effort, MITRE is assisting the Mexican aviation authorities in implementing independent arrival and departure operations at Aeropuerto Internacional de Cancún (hereinafter referred to by its ICAO code MMUN) to and from its two existing parallel runways. The successful implementation of independent arrival and departure operations is expected to provide a significant increase in capacity for MMUN. In addition to this capacity gain, air traffic controllers will gain experience in conducting independent arrival and departure operations. Such operations would be a first within the Mexican Air Traffic Control (ATC) system and would allow MMUN to serve as a test-bed location where Mexican air traffic controllers can gain real-world experience with live traffic. This experience can then be leveraged to support the future implementation of independent operations at NAICM.

As part of the assistance being provided to Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM) to plan the necessary changes that will permit the introduction of independent approach and departure operations at MMUN, SENEAM and MITRE have conducted several meetings, workshops, and teleconferences to help ensure that SENEAM is aware of the many aspects and tasks that must be completed in order to transition smoothly to these complex arrival and departure operations. In early August 2016, SENEAM and MITRE conducted an intense airspace design workshop, where MITRE and SENEAM collaborated on a refined airspace design to support dual independent operations at MMUN, and also worked on planning matters in preparation for upcoming Human-In-The-Loop (HITL) simulations to evaluate the airspace design.

This document provides MITRE's description of the technical capabilities and equipment that MITRE plans to use during upcoming HITL simulations to support dual independent test-bed operations at MMUN. This document should 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 efficacy of the laboratory environment and on modifications that are needed, as appropriate.

This document is structured as follows:

- Section 2 provides detailed information on MITRE's HITL laboratory configuration that will be partially used for the 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 provides a summary and discusses next steps.

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 its physical characteristics. Any adapted capabilities or capabilities that differ from existing MITRE HITL laboratory capabilities are also described.

2.1 Simulation Architecture and Position Layout

A graphical representation of the overall Simulation Architecture is provided in **Figure *1***.

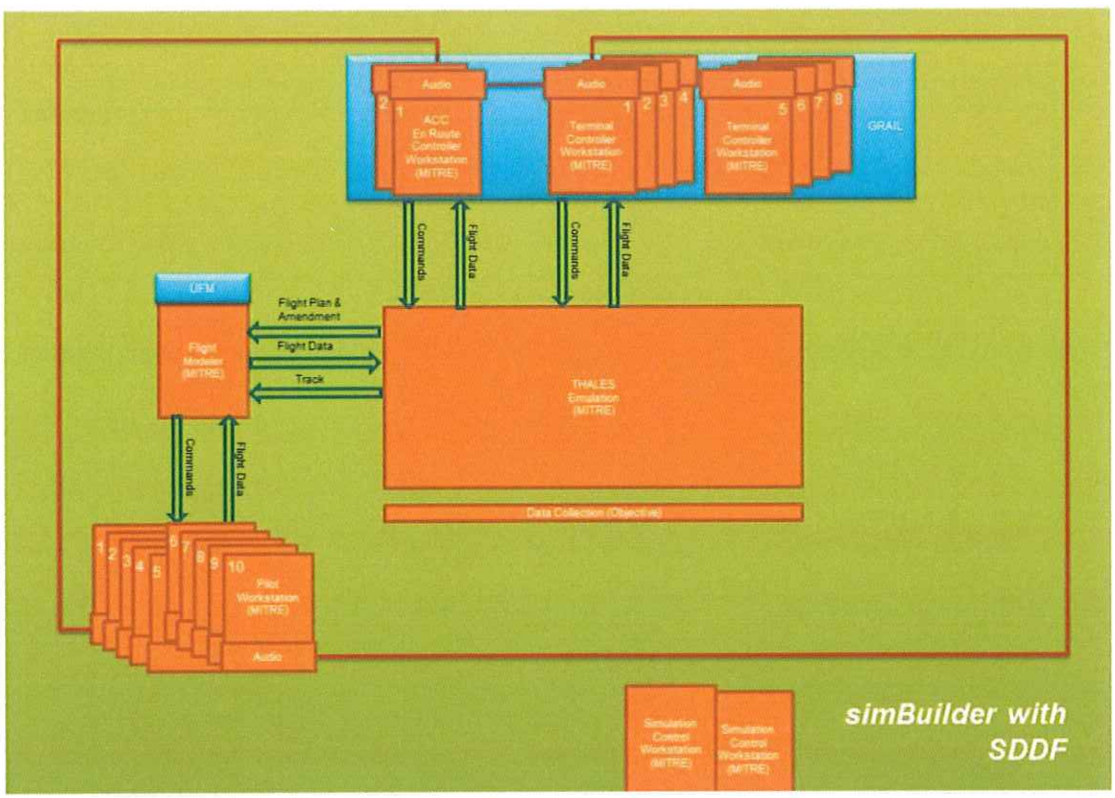

Figure 1. MITRE HITL Laboratory: Simulation Architecture

As shown in Figure 1, the following capabilities exist within MITRE's HITL laboratory:

- Up to ten ATC workstations (eight terminal controller workstations and two Area Control Center/en route controller workstations)
- Up to ten pilot workstations

- Up to two simulation control workstations, which will be used to launch and manage the simulation

The ATC workstations are medium-fidelity workstations that provide an interface and functionality consistent with capabilities and functionality currently observed in operational use at MMUN. The pilot workstations are also medium-fidelity workstations that allow persons serving as pseudo-pilots in the simulation to control multiple simulated aircraft within designated airspace for the purpose of responding to ATC-issued commands, clearances, and directions, which will, in turn, effect changes to corresponding aircraft targets being generated by the Unified Flight Modeler (UFM).

The terminal ATC workstations will be co-located within one area of the laboratory, with the en route ATC workstations, if needed, being in an adjacent area. The Approach (APP) East (E) and West (W) positions are adjacent to each other in order to facilitate immediate coordination between the positions; the Arrival (ARR) E and W positions are adjacent to the corresponding APP positions; the Departure (DEP) E and W positions are adjacent to each other for immediate coordination purposes; and the Final Monitor Aid (FMA) E and W positions are adjacent to each other for immediate coordination purposes.

Figure 2 provides a graphical representation of the layout for the ATC and simulation control workstations being considered within MITRE's HITL laboratory. The en route ATC workstations, if needed, will be located next to one another in an adjacent (but separate) area of the laboratory. Simulation control workstations will also be located in this area. Note that the positions can be rotated or changed, as deemed necessary by the participants.

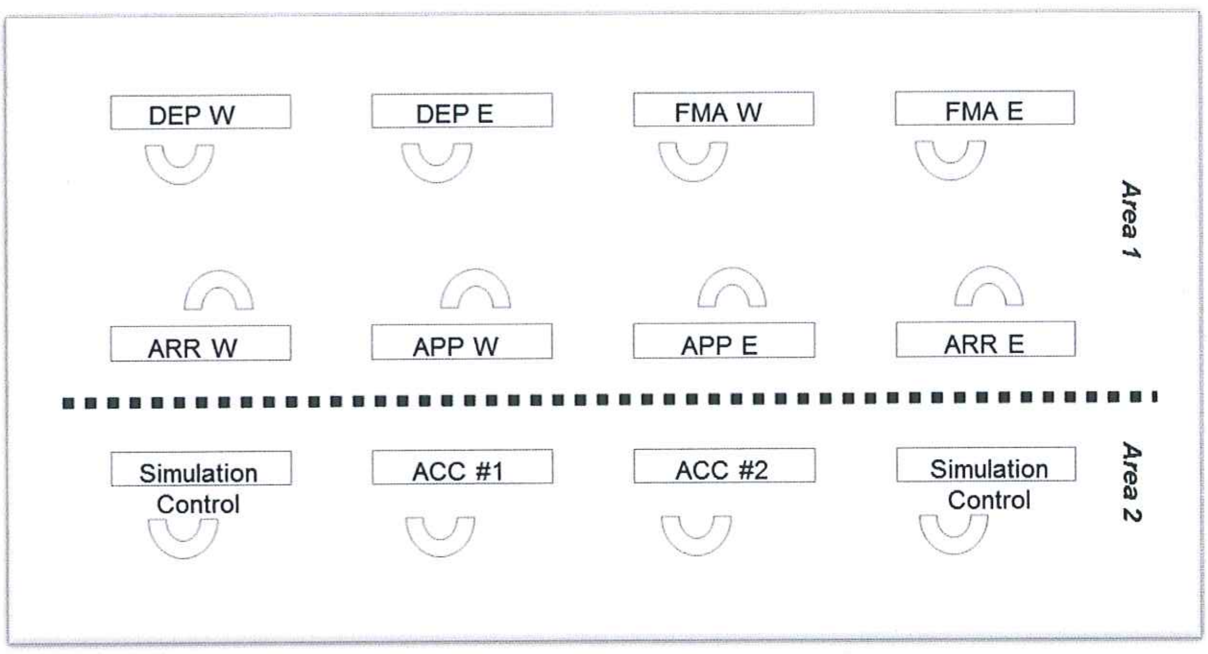

Figure 2. MITRE HITL Laboratory: MMUN ATC and Simulation Control Workstation Layout

The pilot workstations will be located in a separate area of the laboratory (see Figure 3).

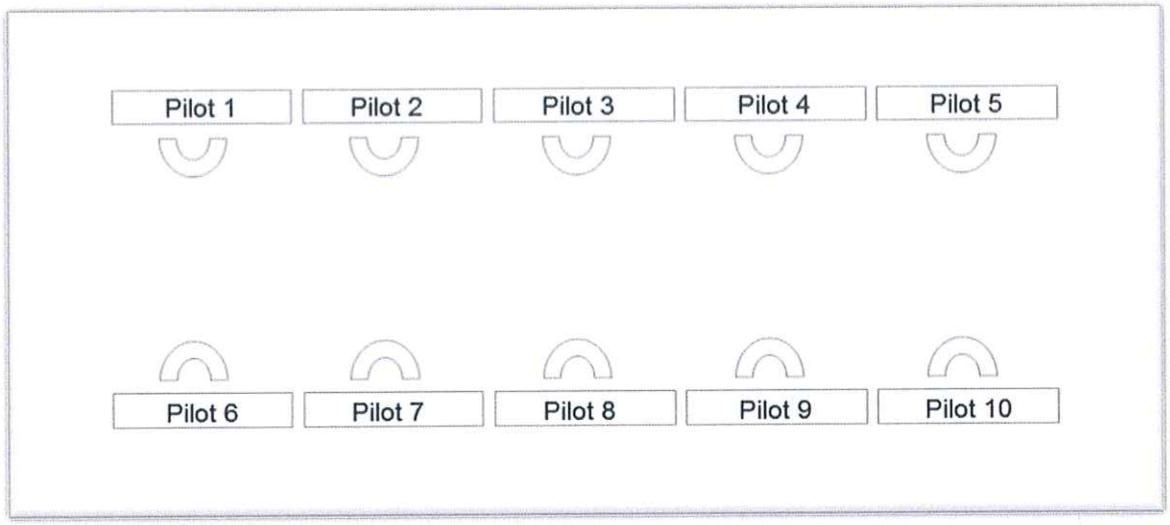

Figure 3. MITRE HITL Laboratory: Pilot Workstation Layout

2.2 Hardware

Hardware used in the simulation will include the following:

1. Each ATC workstation will be composed of one 2048 x 2048 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 up to two computer monitors for the primary pseudo-pilot control interface, one computer to run the simulation software and interface elements being displayed on the pilot workstation, and peripherals (i.e., a keyboard, a standard mouse, a standard headset with microphone, 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, one computer to run the simulation software and interface elements being displayed at the simulation control workstation and peripherals (i.e., a keyboard and a standard mouse).

2.2.1 Displays

The primary displays being used at the ATC workstations are 2048 x 2048 high resolution monitors (referred to as 2Ks). These monitors emulate ATC displays used in the United States National Airspace System (NAS), such as the Federal Aviation Administration (FAA's) Display System Integration (DSI) at Air Route Traffic Control Center (ARTCC) en route facilities and the FAA's Standard Terminal Automation Replacement System (STARS) at Terminal Radar Approach Control (TRACON) facilities. For the MMUN HITL simulation, the 2K displays will be used to display the Thales Eurocat X (i.e., the ATC system currently in use at MMUN) emulation at both the en route and terminal workstations.

Additional HD resolution monitors (either 19-inch monitors with 1280 x 1024 resolution or 24-inch monitors with 1280 x 1024 resolution) will be available at each ATC workstation, as well as at all pilot and simulation control workstations 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/communication systems interface, a 10-inch touchscreen display will be used to display the interactive Voice-Switching and Command System (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, Red Hat 6.0 machines using 64-bit architecture. These machines run all simulation platforms, including background and display software.

2.2.3 Peripherals

Each ATC workstation will be equipped with:

- A custom-designed, Universal Serial Bus (USB) Thales-like keyboard, which is a specialized keyboard similar to those utilized for air traffic control applications in Mexico (a notional example is provided in 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 keyboard (Figure 7)
- A standard USB mouse
- A standard headset with microphone and a PTT hand-held device

Figure 4. Thales-like Keyboard (Notional)

Figure 5. Standard USB Mouse

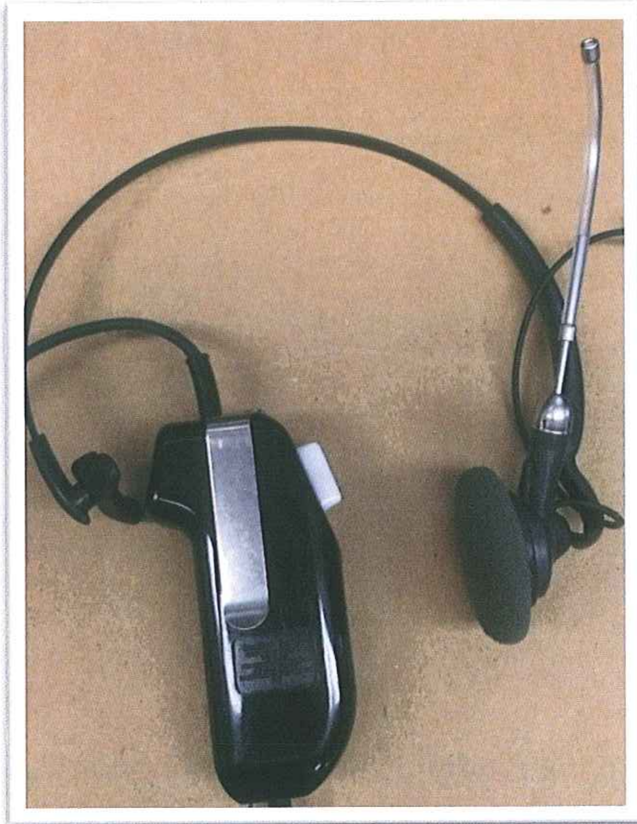

Figure 6. Standard Headset with Microphone and Handheld PTT

Figure 7. Standard Keyboard

2.3 Software

2.3.1 Simulation Control (simBuilder with Simulation Data Distribution Framework)

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 research. The Simulation Data Distribution Framework (SDDF) is a technology that allows different applications within a HITL to communicate and exchange data. SimBuilder is an application that manages and controls a HITL itself. During the HITL development process, an experimenter will use SimBuilder to setup and configure the various software components of a HITL. During data collection, SimBuilder is used to control the start and stop of a HITL 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 provides 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 much 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 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 MMUN HITL simulation.

2.3.3 Simulation Interface Software

MITRE is in the process of developing an emulation of the Thales Eurocat X controller display, which will be used for the MMUN HITL simulation. 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 audio system, which will enable simulated ground-to-air/air-to-ground voice communications, as well as intra-facility and, if needed, inter-facility position-to-position voice communications using a VSCS. The VSCS that will be used for the MMUN HITL simulation is 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 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.

Lastly, some peripherals may require custom or specialized drivers to interpret the hardware. The Thales keyboards, for example, will require use of Java drivers that are available for Linux.

2.3.4 Adaptation Details

The adaptation and maps used within the simulation are based on the adaptation provided to MITRE by SENEAM in May 2016, and will be modified, as needed, up through dry run activities in or around January 2017. This data is then converted to the internal format that MITRE uses for all GRAIL simulations. The video maps that will be used for the MMUN HITL simulation 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, dependent 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 Coordinated Flight Plan (CPL) data. SENEAM has provided MITRE with CPL data for March through April 2016. These two 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. This 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 MMUN HITL simulation.

2.4 FMA and Conflict Probe

The FMA will be integrated into existing display capabilities with a number of features removed or disabled and the aspect ratio stretched. This will be designed to represent a generic FMA capability. A notional example of this display is provided in Figure 8.

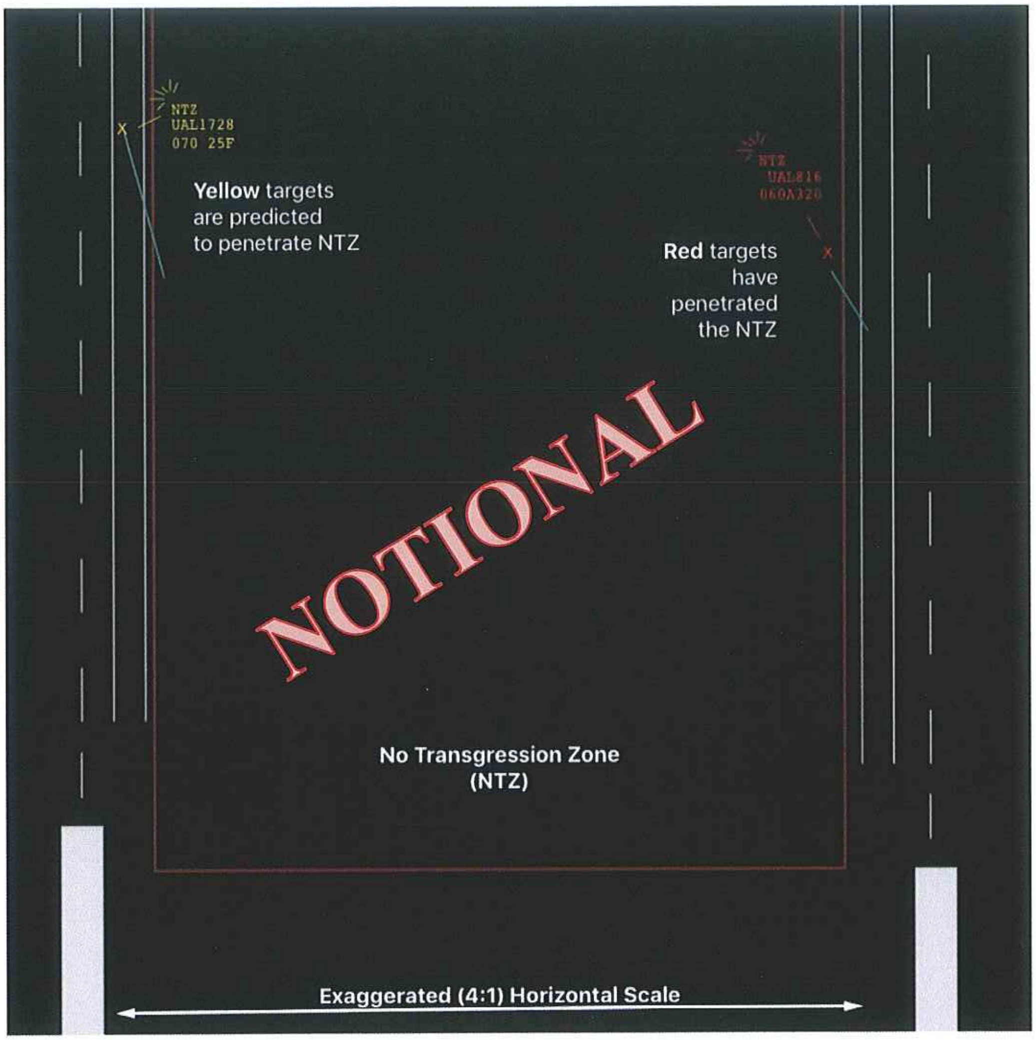

Figure 8. Notional FMA Emulation Display

This notational FMA display contains a variety of elements. The display shows a vertical scene depicting both runways and the associated arrival targets. 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 No Transgression Zone (NTZ) is also depicted. If a target penetrates the NTZ it will be drawn in red, if it is predicted to penetrate it is drawn in yellow. All other targets will be drawn in white.

The Trial Planning/Conflict Probe capability will be modeled after the Conflict Probe and Trial Planning capabilities in Eurocat X. MITRE-developed capabilities will use algorithms from the Joint Enroute DSS Infrastructure (JEDI), as well as input from SENEAM to simulate the Trial Planning and Conflict Probe algorithms built into Eurocat X. The interface in 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 from each participant during the MMUN HITL simulation: subjective measures and objective measures. Subjective measures refer to metrics based upon participant experience or interpretation, such as participant responses to a survey question on perceived workload (see Figure 9) or comments from a participant. Objective measures are metrics of direct performance, such as the number of communications between a controller and aircraft within that controller's sector, or the number of command inputs into the ATC 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 9. Example of Subjective Measures (Responses to Survey Questions)

Three methods of data collection will be used in this simulation activity: electronic questionnaires, system-recorded data/voice, and observations. Questionnaires will be administered electronically on MITRE-provided devices 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 HITL simulation scenarios, including perceived workload, acceptability, preferences, perceived efficiency, interactions, and issues. System-recorded data/voice will include command and system inputs from participant, 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. Summary

This document provides an initial description of the technical capabilities needed to prepare for the upcoming MMUN HITL simulations necessary to support the implementation of dual independent test-bed operations at MMUN. This is a "living" document, meaning the content may change or evolve up to the start of the MMUN HITL simulation based on discussions, discoveries or lessons learned throughout the development process. **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, if required.**

MITRE will continue to work closely with SENEAM to further define and or refine scenarios and other aspects of the MMUN HITL simulation in preparation of the implementation of dual independent operations.