Enclosure 3

(Ref. Technical Letter F500-L14-012)

MITRE

Center for Advanced Aviation System Development

Hidalgo Terrain and Airspace Basemap Preparation

Initial Digitization

Prepared for

Aeropuertos y Servicios Auxiliares

January 2014

1. Introduction

MITRE is preparing to assist, via Aeropuertos y Servicios Auxiliares (ASA), the governmemt of the State of Hidalgo, the Fuerza Aérea Mexicana (FAM), and Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM) in identifying a feasible site for developing a new, one-runway airport in the State of Hidalgo.

Three potential sites located near the towns of Tepeji del Río-Tlahuelilpan (hereinafter referred to as Tepeji del Río), Actopan-Santiago de Anaya (hereinafter referred to as Actopan), and Tulancingo are currently being considered. MITRE is now in the process of determining if these three sites warrant more detailed analysis. For example, MITRE is investigating the surrounding orography to determine if it appears appropriate for the development of an airport. Airspace matters, including the potential for interaction with the Nuevo Aeropuerto Internacional de la Ciudad de México (hereinafter referred to as NAICM) near the town of Texcoco, are also being considered.

In order to conduct preliminary aeronautical analyses of the above-mentioned areas, MITRE developed two initial computerized basemaps: one for use in AutoCAD, a Computer Aided Design (CAD) program, and another for use in the MITRE-developed Terminal Area Route Generation, Evaluation, and Traffic Simulation (TARGETS) software tool. The basemaps (sometimes referred to as the "Hidalgo Airport basemaps") include aeronautical and terrain information pertaining to the sites and their surroundings that MITRE has been able to collect so far from available sources. The Hidalgo Airport basemaps will be used by MITRE to conduct aeronautical analyses, such as the siting of new runways, evaluations of instrument approach and departure procedures, and examinations of airspace interactions.

The Hidalgo Airport basemaps have also been integrated with the existing NAICM and Toluca Airport basemaps. As a result, MITRE is able to efficiently examine potential impacts that an airport at any of the potential sites in Hidalgo could cause for operations at NAICM and Toluca Airports. This is critical in order to avoid creating airspace conflicts that could cause capacity-limiting interactions that adversely affect these two important airports.

The objective of this document is to provide ASA with information on the overall development of the initial Hidalgo Airport basemaps. A large multi-disciplinary team of experts in several fields has continuously worked on the development of the basemaps since the start of the project. It is important to mention, however, that the basemaps are still work in progress and should not be considered complete. This is because additional information, including data that has been requested from ASA by MITRE (see Enclosure 6 to MITRE technical letter F500-L14-004, dated November 2013), needs to be incorporated into the basemaps. Furthermore, detailed satellite-based photogrammetric survey data needs to be incorporated into the basemaps later in the project.

This document is organized into several sections. Section 2 provides background on the importance of developing a proper basemap. Section 3 discusses the software and computerized tools MITRE used to create the basemaps. Section 4 discusses the data that were used to develop the basemaps. Section 5 describes MITRE's general basemap development process. Section 6 illustrates some of the key data elements contained within the basemaps. Finally, Section 7 provides some important closing remarks. Appendix A describes the TARGETS tool.

2. Background

Construction of a basemap is a very labor-intensive, but essential effort. A properly created basemap enables better control, usage and manipulation of data, more efficient and accurate analyses, and provides extensive visualization capabilities.

The basemaps provide a three-dimensional (3D) work environment within which MITRE can analyze a wide variety of important aeronautical matters, such as obstacle limitation surfaces and instrument approach and departure procedures. Additionally, the complexities of airspace analyses, procedure development, runway siting, and the sheer amount of data that must be considered necessitate the need for complete and comprehensive basemaps. Therefore, MITRE invests a great deal of time and effort in creating basemaps in order to appropriately conduct its aeronautical analyses.

Advantages of creating basemaps include, for example:

- Improved data control and management
- Maximum use of data formats (e.g., digital terrain data, images, maps, etc.)
- Fast and efficient incorporation of new data
- Improved accuracy and flexibility
- Extensive visualization capabilities

Once complete, a basemap contains all the aeronautical and obstacle data necessary for the development and evaluation of instrument procedures, as well for conducting other analyses (e.g., runway siting). It also allows for the presentation of results in a visually meaningful manner.

3. Software and Specialized Computer Tools

MITRE makes use of a number of software and computerized tools to create its basemaps. These applications and tools are also used by MITRE to conduct many of its aeronautical analyses and to present results clearly. As previously mentioned, MITRE created two separate basemaps for use with software applications and tools that are best suited for MITRE's specific analytical purposes: AutoCAD[1] and TARGETS.

The AutoCAD basemap will primarily be used for runway siting, instrument procedure development, obstacle limitation surface analysis, the examination of noise exposure, and other types of airport siting-related tasks. The TARGETS basemap will mainly be used for the development of advanced satellite-based navigation instrument procedures, as well as for the examination of potential airspace issues. These software applications complement each other in many ways and allow for the efficient transfer and use of data.

[1] MITRE currently uses AutoCAD 3D Map 2013.

AutoCAD is an extremely capable and powerful 3D software application that works with other programs which utilize its capabilities. For example, MITRE uses a program called PDToolKit to develop and evaluate instrument procedures and conduct obstacle assessments. PDToolKit provides a suite of instrument procedure design tools that reside within the AutoCAD environment making full use of AutoCAD's geospatial, drawing, and 3D capabilities. Working in tandem, AutoCAD and PDToolKit allow MITRE engineers to create a 3D environment that contains relevant aeronautical and obstacle information in order to examine and evaluate various aeronautical factors. Figure 1 shows the AutoCAD work environment being used with PDToolKit to accurately and efficiently draw a portion of an Instrument Landing System (ILS) approach procedure.

TARGETS is a MITRE-proprietary software tool developed to study advanced Area Navigation (RNAV) concepts, such as instrument procedures based on Required Navigation Performance (RNP). These types of procedures are ideal for environments where conventional procedures may not be possible due to terrain and/or airspace complications. Much like the AutoCAD basemap, the TARGETS basemap contains relevant aeronautical and obstacle information required to design and evaluate instrument procedures and examine airspace constraints.

TARGETS also has many other additional capabilities that make it ideal for developing RNP instrument approach procedures and for studying airspace issues. For example, TARGETS can be used to ensure that RNP procedures meet appropriate criteria. It can also be used to evaluate the flyability of proposed RNAV arrival and departure procedures to determine if the procedures being designed are within aircraft performance capabilities. Additionally, TARGETS has the ability to read radar track data (in the appropriate format) which can then be used to generate traffic simulations. See Figure 2. The radar track data can be modified to test and evaluate various operational scenarios to determine optimum interaction between traffic flows to or from a single airport or between multiple airports. See Appendix A for additional information on TARGETS.

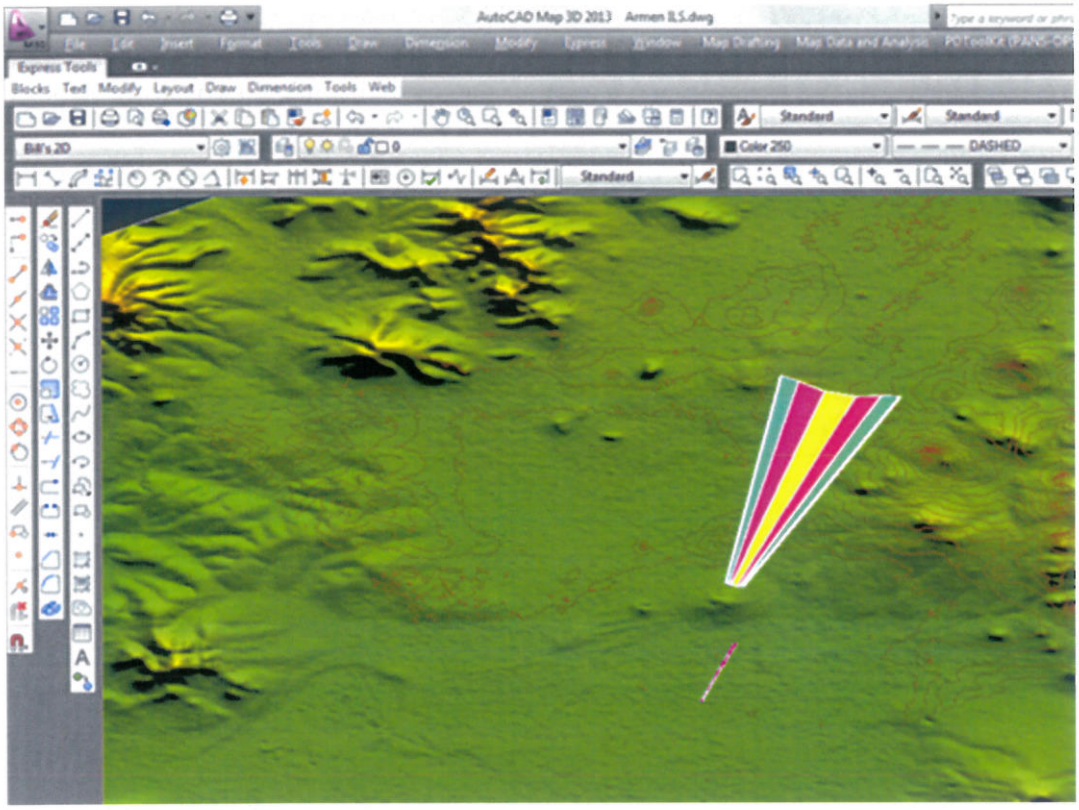

Figure 1. AutoCAD Work Environment Showing Use of PDToolKit to Draw the Final Segment of an ILS Approach

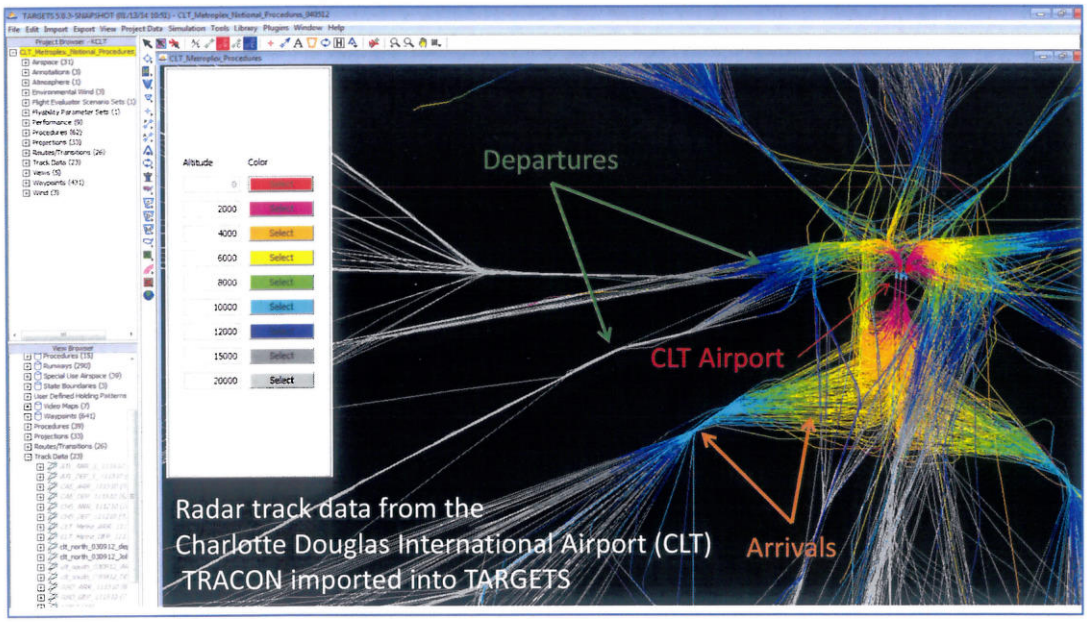

Figure 2. MITRE's TARGETS Tool Showing a Radar Track Data Example

4. Key Data

Current, accurate, and comprehensive data are essential to any project. MITRE utilizes data obtained from a number of sources. While much of the data used for this project comes in electronic format, there is still a substantial amount that has to be entered manually. The following provides an overview of the data MITRE used in the development of the Hidalgo Airport basemaps.

- **Mexican Aeronautical Information Publication (AIP)**: Mexico's AIP provides a wealth of information on runway dimensions, navigational aids (NAVAIDs), the airway structure, Special Use Airspace (SUA), Minimum Vectoring Altitude Charts (MVAC), instrument procedures, etc.

- **Shuttle Radar Topography Mission (SRTM) Digital Terrain Elevation Data (DTED)**: SRTM DTED is a uniform matrix of elevation values indexed to specific points on the ground and is MITRE's primary source of digital terrain data. The horizontal datum used is the World Geodetic System 1984 (WGS 84) and the vertical datum used is Mean Sea Level (MSL), as determined by the WGS 84 Earth Gravitational Model (EGM 96) geoid. SRTM DTED can be manipulated a number of ways for analytical and presentation purposes. It is important to note that SRTM DTED are terrain postings based on a fixed grid system and, therefore, it is possible that a higher elevation point between postings may not be accounted for. To compensate for this issue, terrain points obtained from topographic maps are used to identify spots and peaks that may not be included in the SRTM DTED.

- **Topographic Maps**: MITRE took the initiative, in the interest of time, to contact several map providers in Mexico and the U.S. and obtained numerous topographic maps, including geo-referenced maps in digital format (in tiff, giff, and ESRI Shape formats) from the Instituto Nacional de Estadística, Geografía e Informática (INEGI). Although some of the available maps date back to the mid-90s, they still provide valuable information about the topography of the sites and surrounding areas. Many of the files have terrain elevation information as well, which will be used to identify spots and peaks in relevant areas to supplement the SRTM DTED.

The terrain data mentioned above are key, but cannot substitute detailed satellite-based photogrammetric surveys, which provide very accurate terrain and other obstacle information (e.g., trees, buildings, towers, etc.). MITRE is responsible for the procurement of satellite-based photogrammetric surveys of the three potential new airport sites in Hidalgo. The surveys will be commissioned once the locations of the three potential new airport sites are more comprehensibly understood. This will occur after MITRE conducts additional preliminary aeronautical analyses of the sites, including actual visits to the areas currently under consideration and technical discussions are held with stakeholders (i.e., federal, state, and FAM officials). MITRE will incorporate the survey data into the Hidalgo Airport basemaps once the surveys are completed.

5. Methodology

The general basemap development process is described below. It is important to mention that this is not an all-inclusive description. Only the most important parts of the overall basemap development process are highlighted.

The development of a basemap is a detailed, laborious and time-consuming effort that requires a systematic process to ensure that a complete and comprehensive basemap is created. The Hidalgo Airport basemaps were developed by a team of MITRE engineers over several months. During the creation of the basemaps, the MITRE team conducted numerous interdependent tasks, many of which occurred simultaneously.

Many members of the MITRE team involved in the development of the basemap will also be conducting the actual aeronautical analyses. As a result, the MITRE team is now extremely familiar with the terrain and airspace environment surrounding the three potential new airport sites in Hidalgo.

5.1 Basemap Development Process

The first step in the basemap development process is to make the appropriate software preparations for the introduction of data. This includes assigning a coordinate system and establishing the units of measurement that the basemap will use. For example, the AutoCAD basemap coordinate system is based on the Universal Transverse Mercator (UTM)/WGS 84 datum. The unit of measurement is meters. The TARGETS basemap uses basically the same coordinate system. As a result, data can be easily transferred between the two basemaps.

The next step is to determine the extent of the basemap work environment that needs to be considered for the basemaps. This is an important step that requires careful planning and input from a number of specialists to ensure that the basemap work environment is large enough to conduct runway siting, procedure design, airspace analyses, noise examinations, and other key tasks. Of course, the size of the basemap work environment dictates the amount of data that must be considered. All of this work requires close coordination and oversight in order to complete the basemaps in an efficient, accurate, and timely manner.

An important consideration when determining the location of a new airport in the State of Hidalgo is the potential for airspace interaction that could result in dependency of operations with the future NAICM (that is planned to be conducting triple independent operations) and Toluca Airport (potentially expanded to conduct dual independent operations). Therefore, the work environment of the Hidalgo Airport basemaps has been extended and enlarged by integrating it with the NAICM basemap, which also encompasses Toluca Airport.

At the same time, the work environment of the Hidalgo Airport basemaps must be large enough to encompass all three potential new airport sites, as well as the necessary aeronautical and terrain data. Therefore, MITRE personnel collected and examined relevant aeronautical and terrain data well beyond the potential new airport sites currently being considered in Hidalgo.

The next step is to begin entering initial data into the basemaps. A large amount of data from the AIP had to be appropriately formatted and then inserted into the basemaps. For example, WGS 84 latitude and longitude coordinate information had to be converted to the UTM

coordinate system and formatted so that it could be inserted into the AutoCAD and TARGETS basemaps. SUAs and airways were also drawn in both basemaps for procedure design and airspace analysis purposes. The entering of data from the AIP into the basemaps is an effort that requires (as it did) a great deal of diligence to ensure the data introduced is accurate and properly formatted.

MITRE also obtained and incorporated fifty-one geo-referenced 1:50,000 scale topographic maps and nine 1:250,000 scale topographic maps from INEGI that cover the entire work area and more. All of these maps provided valuable terrain information to supplement the SRTM DTED. It is important to mention that some topographic maps contain discrepancies. This mainly involved irregularities pertaining to contour line elevation intervals. At the same time, the topographic maps do not precisely match the SRTM DTED elevations. For conservative planning purposes, MITRE will use the higher of the two conflicting elevation intervals.

As a final step in this process, the MITRE basemap teams conducted an extensive peer review to ensure that the basemaps are accurate and complete.

6. Sample Images of Key Elements of the Basemaps

This section graphically illustrates some of the key data elements contained within the AutoCAD and TARGETS Hidalgo Airport basemaps. Sample images from the basemaps are listed in Table 1, and are shown in Figures 3 through 7.

Table 1. Sample Hidalgo Airport Basemap Images

Data Element	Basemap (AutoCAD or TARGETS)	Figure Number
Low Airway Structure	TARGETS	Figure 3
High Airway Structure	AutoCAD	Figure 4
SUAs and MVAC near Potential Airport Sites	TARGETS	Figure 5
Digital Topographic Map	AutoCAD	Figure 6
SRTM DTED Contours	AutoCAD	Figure 7

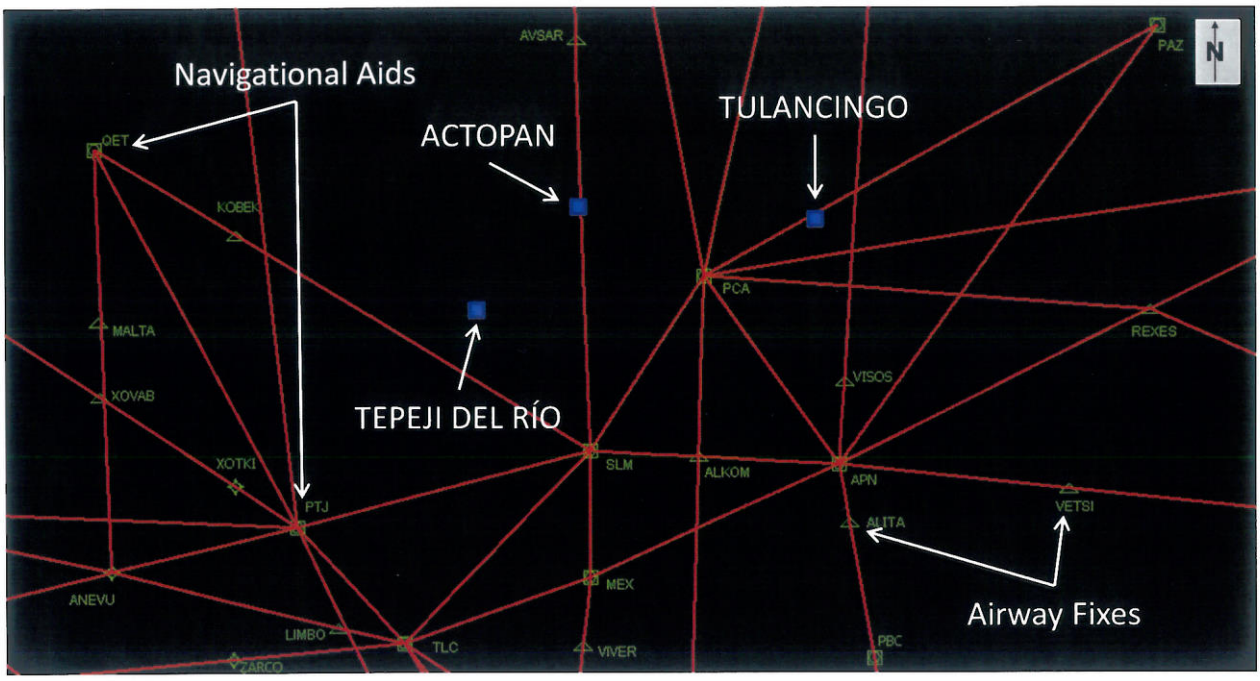

Figure 3. Low Airway Structure (TARGETS)

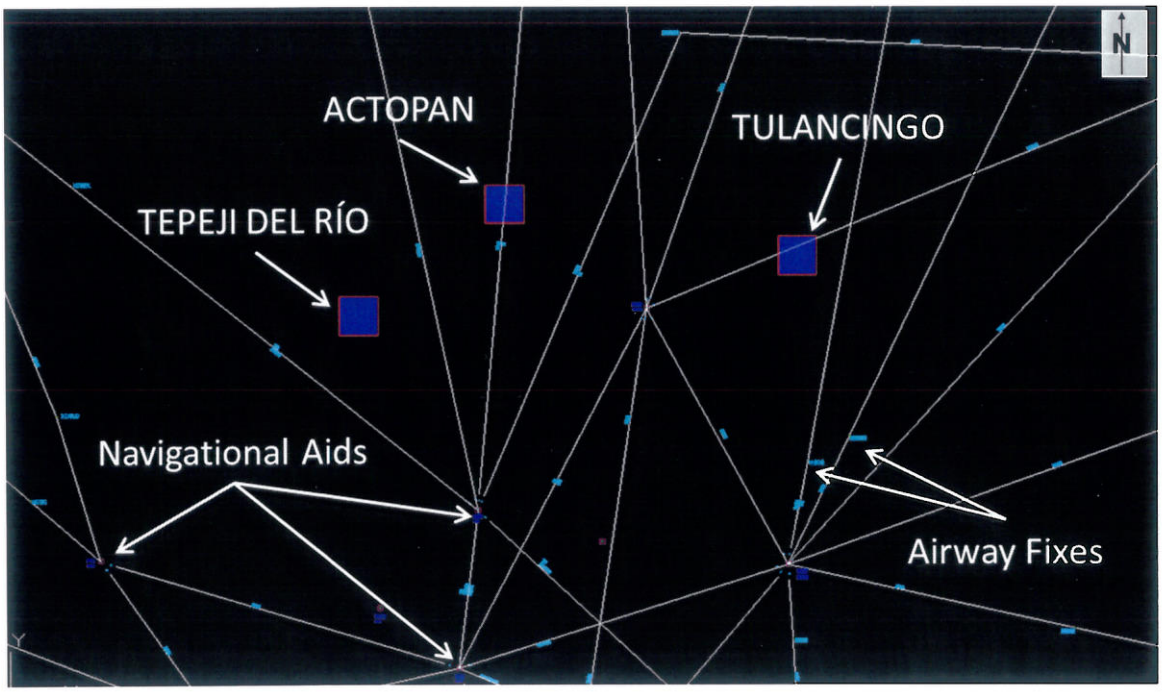

Figure 4. High Airway Structure (AutoCAD)

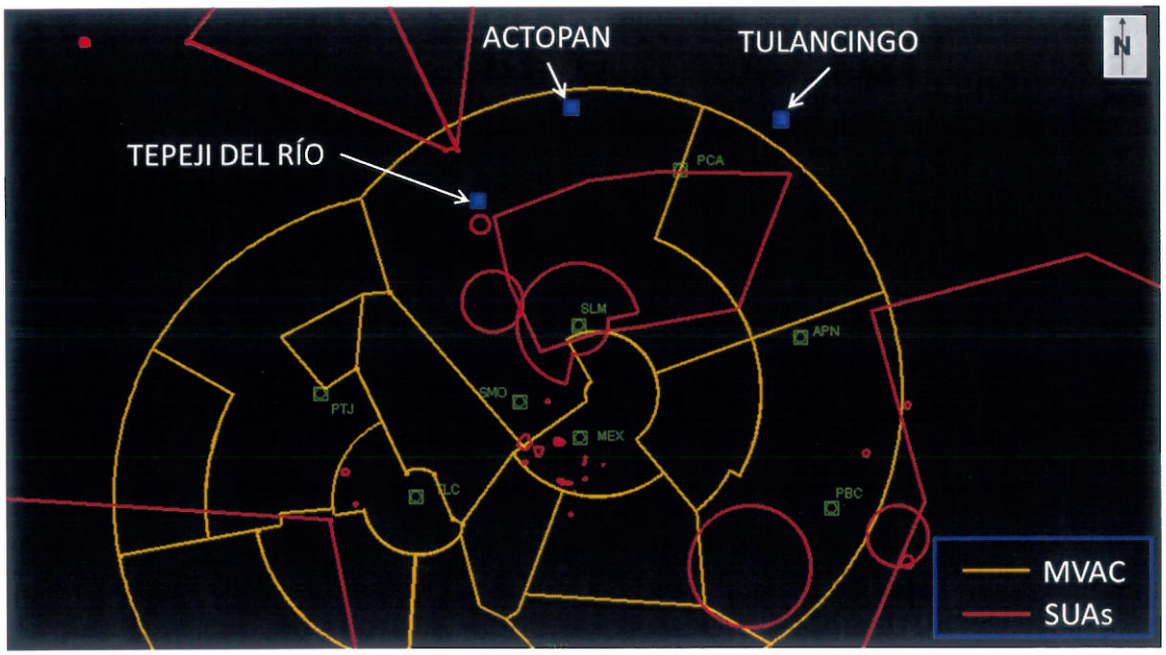

Figure 5. SUAs and MVAC near Potential Airport Sites (TARGETS)

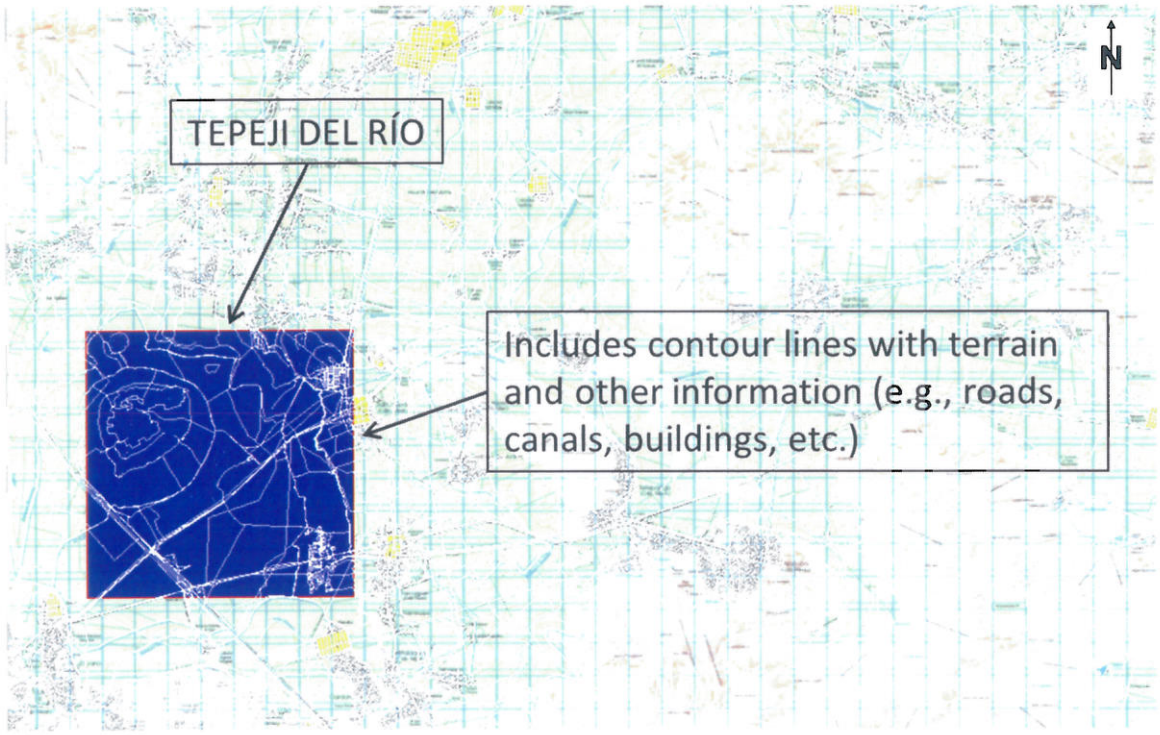

Figure 6. Digital Topographic Map
(Showing the Potential Airport Site near Tepeji del Río - AutoCAD)

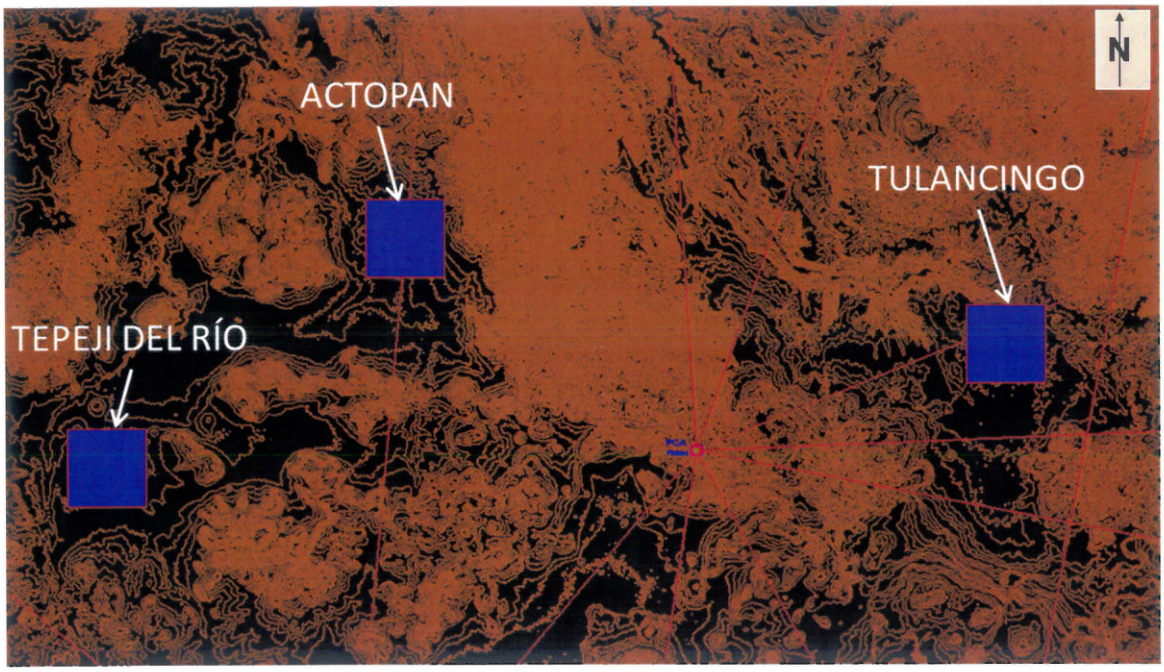

Figure 7. SRTM DTED Contours (AutoCAD)

7. Closing Remarks

Construction of a basemap is an extensive and laborious process requiring careful planning and coordination by very diligent engineers. The basemaps not only serve as a repository for project data, but as the operational environment from which MITRE will conduct many of its aeronautical analyses. The initial preparation of the Hidalgo Airport basemaps is now complete. Specifically, the most important aeronautical information and terrain data have been entered, and the basemaps have also gone through an extensive peer review process. As a result, MITRE can proceed with conducting initial aeronautical examinations to assist the authorities with the identification of potential new airport sites that warrant more detailed analyses.

These Hidalgo Airport basemaps are called "initial" because they will continue to be enhanced with additional data received from ASA and other sources in order to make them more complete and comprehensive. For example, MITRE may obtain additional data during ground and aerial visits to the potential new airport sites and during discussions with State of Hidalgo and FAM officials. Also, an upcoming satellite-based photogrammetric survey, which is extremely important to MITRE's aeronautical analyses, will be incorporated into the basemap as soon as they are received.

Appendix A

Description of the MITRE-developed Terminal Area Route Generation, Evaluation, and Traffic Simulation (TARGETS) Tool

The Terminal Area Route Generation, Evaluation, and Traffic Simulation (TARGETS) tool offers a unique combination of capabilities for the design, analysis, and operational assessment of procedures and airspace. Developed by MITRE, the tool is used to support the implementation of Area Navigation (RNAV) and Required Navigation Performance (RNP) operations.

TARGETS incorporates data visualization capabilities with readily accessible design elements to enable procedure designers to rapidly and easily develop advanced procedures. The integrated capabilities of TARGETS enable quick assessment of alternative design concepts, leading to robust solutions that satisfy operational needs and comply with design constraints. TARGETS integrates with standard office applications, making it easy to prepare presentations or document procedure design. TARGETS data output is formatted to support operational, certification, and charting needs.

Some of the key features of TARGETS include:

- Integration of essential capabilities into a single desktop application, featuring multi-platform compatibility
- An interface utilizing a comprehensive Geographic Information System (GIS) to display information that expedites procedure development
- Capture of route/procedure design information in project files and distribution packages for dissemination to dispersed stakeholders
- Automated evaluation of key procedure areas to ensure compliance with U.S. Federal Aviation Administration noise, and operational requirements
- Data export capabilities that include seamless exchange with standard office applications, auto-population of regulatory forms, electronic data exchange using web services, and flat files
- Java-based software with object-oriented design that runs on a variety of platforms, including most desktop PC systems
- Plug-in architecture, which provides user controlled modularity and extensibility

TARGETS Graphical User Interface

The TARGETS Graphical User Interface (GUI) contains a plan view where users can display videomaps and overlay navigational aids (NAVAIDs), fixes, routes, holding patterns, and other data from several readily available aviation databases. Users can also display a number of different images including geo-referenced aviation charts and satellite photographs (see Figure A-1). Data files containing historical aircraft tracks can be imported into TARGETS and

overlaid on the plan view. The TARGETS tool also provides users with the capability to create user-defined waypoints and Special Use Airspace (SUA) via a user-friendly point-and-click interface. Users can pan and zoom the plan view or re-center the view on airports, NAVAIDs, or waypoints. At any time, the view and its contents can be saved as an image file (e.g., JPEG).

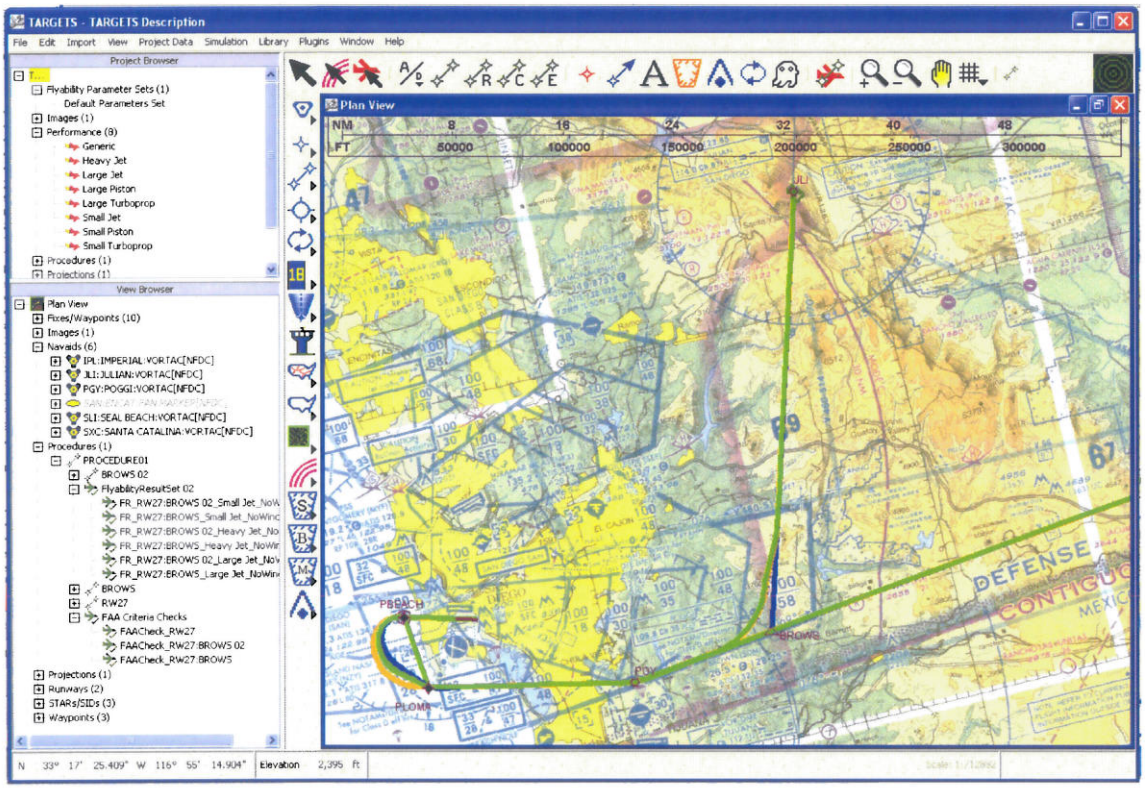

Figure A-1. A Typical TARGETS Screen Interface

Procedure Design

TARGETS provides stakeholders with an automated tool that allows them to work collaboratively to examine the many constraints that must be considered and evaluated during the development of a procedure. By providing a design tool that takes advantage of a vast array of data and design capabilities, a procedure designer can rapidly develop, evaluate, modify, and assess a procedure, thereby enabling a much quicker and higher quality design. TARGETS users follow a straightforward process to develop new arrival, departure, and approach procedures as follows:

Step 1 – Import supporting data

All of the needed reference and visualization data (i.e., airport information, runways, waypoints, obstructions, terrain, etc.) are imported into a project.

Step 2 – Build a route, procedure, or approach

Using a graphical point-and-click interface, the user places waypoints that define the two-dimensional path including en route transitions, common routes, and runway transitions, final approach segments, missed approach segment, etc.

Step 3 – Add a speed and/or altitude constraint

After placing the waypoints the user can specify altitude and speed constraints as needed.

Step 4 – Assign leg types

The user can specify Aeronautical Radio Incorporated (ARINC) 424 leg types to assist the users with procedure design. TARGETS has internal rules that govern standardized RNAV route coding. TARGETS will verify that the leg type selected is valid and sequenced properly.

Step 5 – Flyability assessment

After the procedure has been defined, a flyability assessment can be performed to determine the usability of the proposed procedure. The flyability assessment is done using a generic medium-fidelity Flight Management System (FMS) model. The default flyability performance set used in the TARGETS evaluation is for heavy, large, and small jets as shown in Figures A-2 through A-4. Flyability parameters are based on surveillance data from multiple sources and sensors.

The TARGETS flyability assessment analyzes the ability of aircraft to comply with the procedure speed and altitude constraints. Also, the flyability assessment determines if the distance between waypoints is adequate enough for the aircraft to complete the turn, stabilize the aircraft, and stay on the route. Lastly, the TARGETS flyability assessment provides an expected ground track and vertical profile of aircraft flying the procedure. Figure A-5 shows the graphic flyability results of the default small, large, and heavy jets.

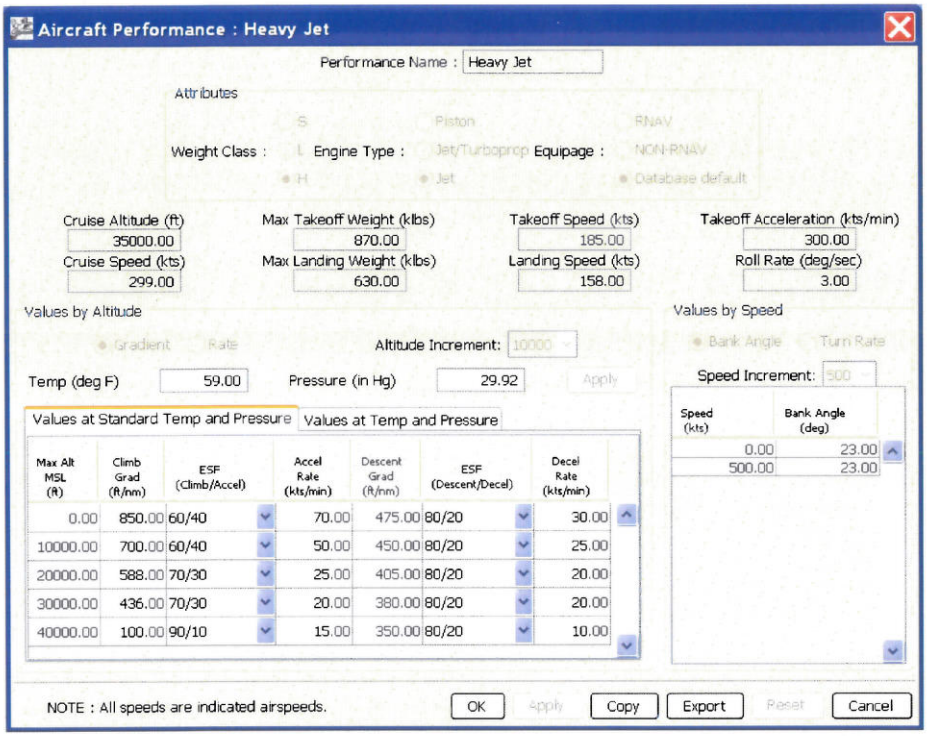

Figure A-2. A TARGETS Performance Profile for a Heavy Jet

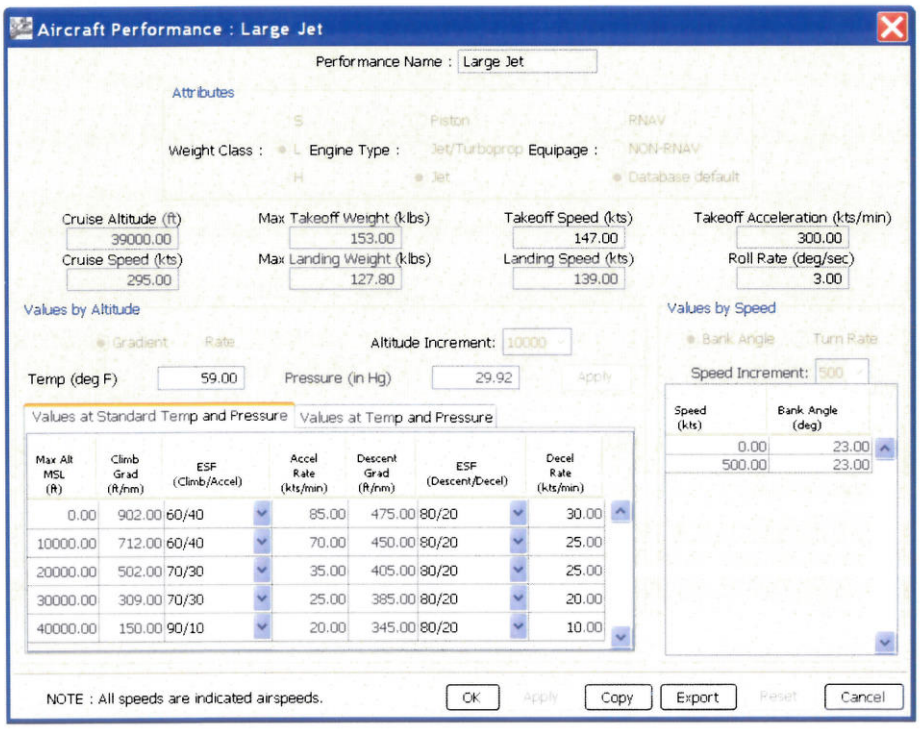

Figure A-3. A TARGETS Performance Profile for a Large Jet

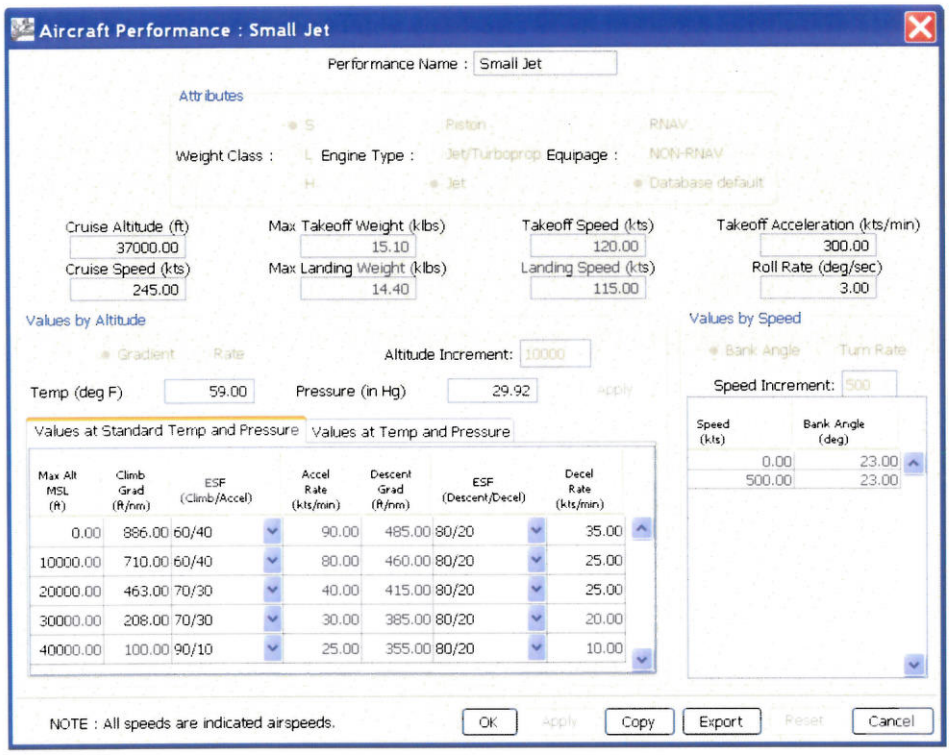

Figure A-4. A TARGETS Performance Profile for a Small Jet

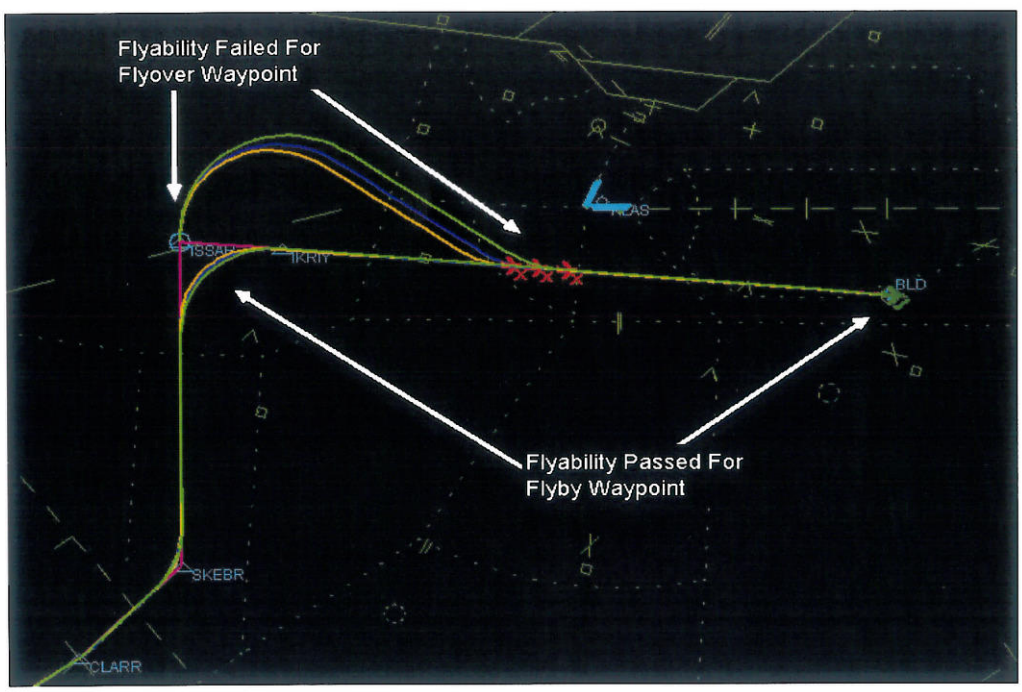

Figure A-5. A Typical TARGETS Flyability Results Graphic

Data Exchange

Once the procedure has been designed and assessed, TARGETS users are able to share the procedure data in either a Comma-Separated file or an Adobe Portable Document (PDF) distribution package. An example of the Comma-Separated output file is shown in Figure A-6.

WP	Distance	Leg Type	Turn Type	Latitude	Degrees	Minutes	Seconds	Longitude	Degrees	Minutes	Seconds	Altitude	Speed	True Course	Magnetic Course	Turn Angle
RW27:DER				N	32	44	13.62	W	117	12	15.66					
PBEACH	3.79	DF	FO	N	32	45	16.37	W	117	16	35.09			285.99	272.99	110.66
PLOMA	5.38	DF	FB	N	32	39	54	W	117	16	4			175.34	162.34	72.8
PGY	14.99	TF	FB	N	32	36	37.22	W	116	58	44.68			102.54	89.54	19.29
BROWS	10.67	TF	FB	N	32	37	52.02	W	116	46	11.71			83.25	70.25	
BROWS	0	IF		N	32	37	52.02	W	116	46	11.71					
JLI	31.89	TF	FB	N	33	8	25.65	W	116	35	9.36			16.9	2.9	
BROWS	0	IF		N	32	37	52.02	W	116	46	11.71					
IPL	64.26	TF	FB	N	32	44	55.91	W	115	30	30.88			83.36	69.36	

Figure A-6. TARGETS Procedure Comma-Separated Output File

Traffic Simulation

In addition to route definition and assessment functions, the TARGETS tool contains a traffic simulation capability. Having the appropriate data, users can quickly and easily define traffic scenarios which can include traffic flying RNAV routes, aircraft departing from specified runways, aircraft flying vectors, and aircraft that follow selected Automated Radar Terminal System tracks. For each aircraft in the scenario, users can specify aircraft identification, aircraft type/performance, RNAV equipage, controller identification, data block offset direction, and other information. "Control Lines" can be drawn on the screen that will trigger certain automatic actions such as vectors or joining an RNAV route when aircraft cross them. When scenarios are run, aircraft appear in the plan view. Scenarios can be run in real time or fast time. Aircraft in the scenario can be vectored, given speed or altitude instructions, or cleared to an RNAV route via keyboard entries.

Hardware/Software Architecture

The TARGETS tool is written in the Java programming language, primarily using the Java Swing architecture for GUI components. It uses a local MySQL instance to store data that can be loaded from a variety of sources. Development and testing are done using both Linux and Window (XP/7/8) platforms on Intel-based hardware. The object-oriented design and modular architecture of the TARGETS software minimizes the effort required to add new functions and features.