Enclosure 2

(Ref. Technical Letter F500-L15-032)

MITRE

Center for Advanced
Aviation System Development

Cancún Airport Basemap

Prepared for

Aeropuertos y Servicios Auxiliares (ASA)

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Principal Acronyms and Abbreviations

3D	Three-dimensional
AIP	Aeronautical Information Publication
ARINC	Aeronautical Radio Incorporated
ASA	Aeropuertos y Servicios Auxiliares
ASUR	Grupo Aeroportuario del Sureste
FAA	U.S. Federal Aviation Administration
GIS	Geographic Information System
GUI	Graphical User Interface
HITL	Human-in-the-Loop
MITRE	The MITRE Corporation
NAVAIDS	Navigational Aids
PDF	Adobe Portable Document
RNAV	Area Navigation
RNP	Required Navigation Performance
SENEAM	Servicios a la Navegación en el Espacio Aéreo Mexicano
SRTM	Shuttle Radar Topography Mission
SUA	Special-Use Airspace
TARGETS	Terminal Area Route Generation, Evaluation, and Traffic Simulation
U.S.	United States
WGS 84	World Geodetic System 1984

1. Introduction

As part of MITRE's support to Mexico's Aeropuertos y Servicios Auxiliares (ASA), MITRE has developed computerized terrain and airspace basemaps for Cancún Airport and its surroundings. MITRE will utilize the basemaps to develop preliminary conventional dual independent approach and departure procedures for Cancún Airport, to be validated by Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM), which will later be utilized to support Human-in-the-Loop (HITL) simulations. The basemaps will also help MITRE provide general support to SENEAM regarding airspace design concepts for dual independent operations. The intent of this document is to provide ASA and SENEAM with information on the overall development of the basemaps. A large multi-disciplinary team of experts in several fields has worked on the development of the basemaps.

This document is structured as follows:

- Section 2: Basemap creation process
- Section 3: Software and specialized computer tools
- Section 4: Key data
- Section 5: Sample images of key elements of the basemaps
- Section 6: Closing remarks
- Appendix A. Description of the MITRE-Developed Terminal Area Route Generation, Evaluation, and Traffic Simulation (TARGETS) Tool

2. Basemap Creation Process

For this project, the term basemap refers to a collection of geospatial data and orthorectified imagery contained within a geo-referenced environment. This will allow the various geospatial datasets needed for analyses to be correctly registered with respect to each other. Typical geospatial data that make up the layers for a MITRE-produced basemap for airport and airspace projects include in most cases: runways, taxiways, Navigational Aids (NAVAIDS), airways, Special-Use Airspace (SUA), obstacles, airport infrastructure, terrain, spot elevations, etc. Where available, the basemap includes aerial or satellite imagery. Depending on the type of map, any combination of these layers can be used.

Construction of a basemap is a very labor-intensive, but essential effort. A basemap provides 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 and procedure development, as well as the sheer amount of data that must be considered, necessitate complete and comprehensive basemaps.

The simplified process through which a basemap is created is shown in Figure 1, and is further described below.

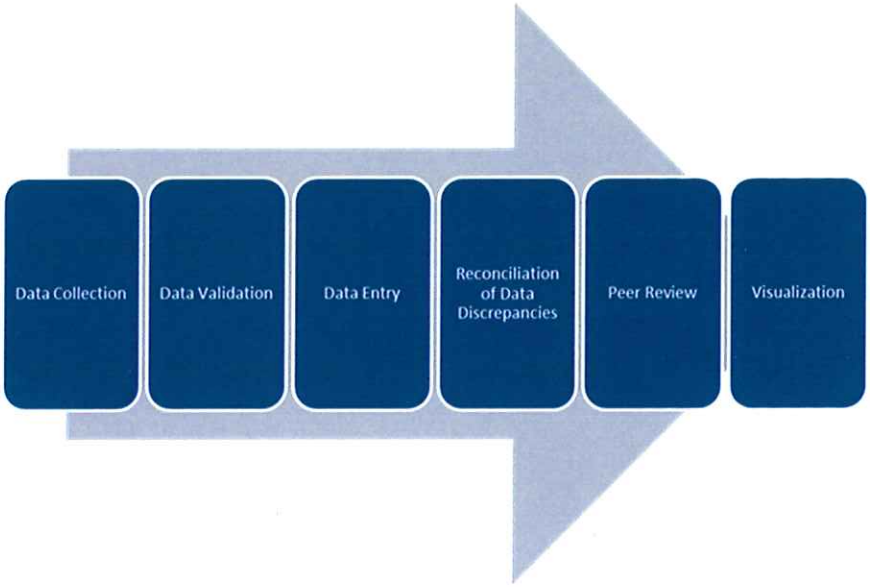


Figure 1. Basemap Creation Process

Data Collection

Current, accurate, and comprehensive data are essential to any project. As per the ASA-MITRE contract, man-made obstacle information is to be provided to MITRE by Mexican aviation authorities as this work does not include the preparation of a survey. Thus, in mid-January 2015, MITRE submitted a data request to ASA for information, including the data to create the basemaps, such as: airport layout information, obstacles, topography, imagery, and airspace information, as well as relevant data for nearby airports. Refer to MITRE Technical Letter F500-L15-007 for additional information. This data request was also provided to officials at SENEAM who led the data gathering effort.

There are not many prominent man-made obstacles surrounding Cancún Airport. In fact, MITRE was informed by an official from Grupo Aeroportuario del Sureste (ASUR), the operator of Cancún Airport, that obstacles are not a factor and, as a result, ASUR does not have any information on nearby man-made obstacles. Therefore, data on man-made obstacles surrounding Cancún Airport was difficult to obtain.

Data Validation

Once the data are collected, a team of analysts log the information received, analyze its appropriateness for inclusion into one of the basemaps, and validate the technical correctness and accuracy if possible.

Data Entry

MITRE makes use of a number of software and computerized tools to help in the creation of basemaps. These same software and tools are also used by MITRE to conduct many of its aeronautical analyses and to present analytical results. The basemaps include data for Cancún Airport, as well as additional relevant data concerned with other nearby airports.

While much of the data used for this project were obtained in electronic format, there was still a substantial amount that had to be manually entered into AutoCAD, TARGETS, and other software. In some cases, MITRE had to modify the data to ensure proper geo-referencing.

Reconciliation of Data Discrepancies

MITRE uses data obtained from a number of sources. As such, MITRE analysts have to reconcile the discrepancies that can arise when using more than one dataset. Often, different sources publish conflicting information for the same geographical feature. For example, MITRE received three different sets of runway threshold coordinates from three sponsor-provided sources. As such, MITRE used the Mexico Aeronautical Information Publication (AIP) to obtain the official set of runway threshold coordinates for Cancún Airport, but used the other data sources received for informational and supplemental purposes.

Peer Review

The MITRE team conducts a thorough peer-review of its basemaps to ensure completeness and correctness of key features. For the Cancún Airport basemaps, the MITRE team reviewed high and low airways, fixes, NAVAIDS, runways, approach and departure procedures, SUAs, and other appropriate features.

Visualization

Visualization is the last part of the basemap creation process before the basemap gets distributed among internal analysis teams. This includes creating visualizations and other artifacts with the data to confirm that the graphic depiction makes sense; modifying colors, line weights, and labels, as needed; and exporting features to other visualization tools for 3D modeling.

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 in a visually meaningful manner. For the Cancún Airport project, MITRE created two separate basemaps for use with software applications and tools that are best suited for MITRE's specific analytical purposes: AutoCAD[1] (a computer aided design platform), and MITRE's TARGETS tool.

[1] MITRE currently uses AutoCAD 3D Map 2013

The AutoCAD basemap will primarily be used for instrument procedure development. The TARGETS basemap will mainly be used to support instrument procedure development and airspace design work. These software applications complement each other in many ways and allow for the efficient transfer and use of data.

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.

TARGETS was developed by MITRE on behalf of the United States (U.S.) Federal Aviation Administration (FAA) 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 information required to examine instrument procedures and airspace matters.

TARGETS also has many other additional capabilities that make it ideal for studying airspace issues. For example, TARGETS can 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. The radar track data can be modified to test and evaluate various operational scenarios to determine optimum interaction between various traffic flows to or from a single airport or between multiple airports. See Appendix A for additional information on TARGETS.

4. Key Data

MITRE utilized data obtained from a number of sources. The following provides an overview of the data MITRE used in the development of the basemaps:

- **Mexico AIP**: Mexico's AIP provides a wealth of information on runway dimensions, NAVAIDS, the airway structure, SUAs, instrument procedures, etc. The AIP is MITRE's primary source of aeronautical data.
- **FAA Geographic Information System (GIS) Data for Cancún Airport**: As previously mentioned, SENEAM had difficulty in obtaining information on man-made obstacles surrounding Cancún Airport. Fortunately, SENEAM was able to provide MITRE with obstacle data that were previously provided to SENEAM by the U.S. FAA for use by MITRE in its aeronautical work at Cancún Airport.

The U.S. FAA provided SENEAM with GIS data for Cancún Airport, which included the following shapefiles: AIRPORTCONTROLPOINT.shp, COORDINATEGRIDAREA.shp, LANDMARKSEGMENT.shp, MARKINGAREA.shp, NAVAIDEQUIPMENT.shp, OBSTACLE.shp, OBSTRUCTIONAREA.shp, OBSTRUCTIONIDSURFACE.shp, RUNWAY.shp, RUNWAYBLASTPAD.shp, RUNWAYCENTERLINE.shp, RUNWAYELEMENT.shp, RUNWAYEND.shp, and RUNWAYLABEL.shp.

It is important to mention, however, that MITRE did not receive information from SENEAM on the methodology used to collect the obstacle data or when the data were collected. Nevertheless, MITRE feels that the data are useful for the level of preliminary procedure design work being conducted for Cancún Airport to support upcoming HITL simulations, especially since the obstacle environment surrounding Cancún Airport is not a significant problem. However, MITRE recommends that a more detailed obstacle survey be conducted along with appropriate flight inspection activities at the appropriate time to ensure that unknown obstacles are not a problem for future procedures and/or airspace designs.

- **Shuttle Radar Topography Mission (SRTM) Data**: SRTM 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, as determined by the WGS 84 Earth Gravitational Model geoid. SRTM can be manipulated a number of ways for analytical and presentation purposes. It is important to note that SRTM 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.
- **Electronic Airport Layout Plan**: MITRE received a rendering of the airport layout plan in AutoCAD (Plano Cancun proyectado.dwg) from SENEAM through ASUR. The information contained within the AutoCAD drawing needed to be slightly modified in order to reconcile data discrepancies and geo-referencing issues.

5. Sample Images of Key Elements of the Basemaps

This section graphically illustrates some of the key data elements contained within the AutoCAD and TARGETS basemaps. Sample images from the basemaps are listed in Table 1, and are shown in Figures 2 through 7.

Table 1. Sample Basemap Images

Data Element	Basemap (AutoCAD or TARGETS)	Figure Number
FAA GIS Data for Cancún Airport	AutoCAD	Figure 2
Electronic Airport Layout Plan	AutoCAD	Figure 3
Airway Structure	TARGETS	Figure 4
Airway Structure	AutoCAD	Figure 5
Minimum Vectoring Altitude Chart and SUAs	TARGETS	Figure 6
Contours Lines Generated from SRTM	AutoCAD	Figure 7

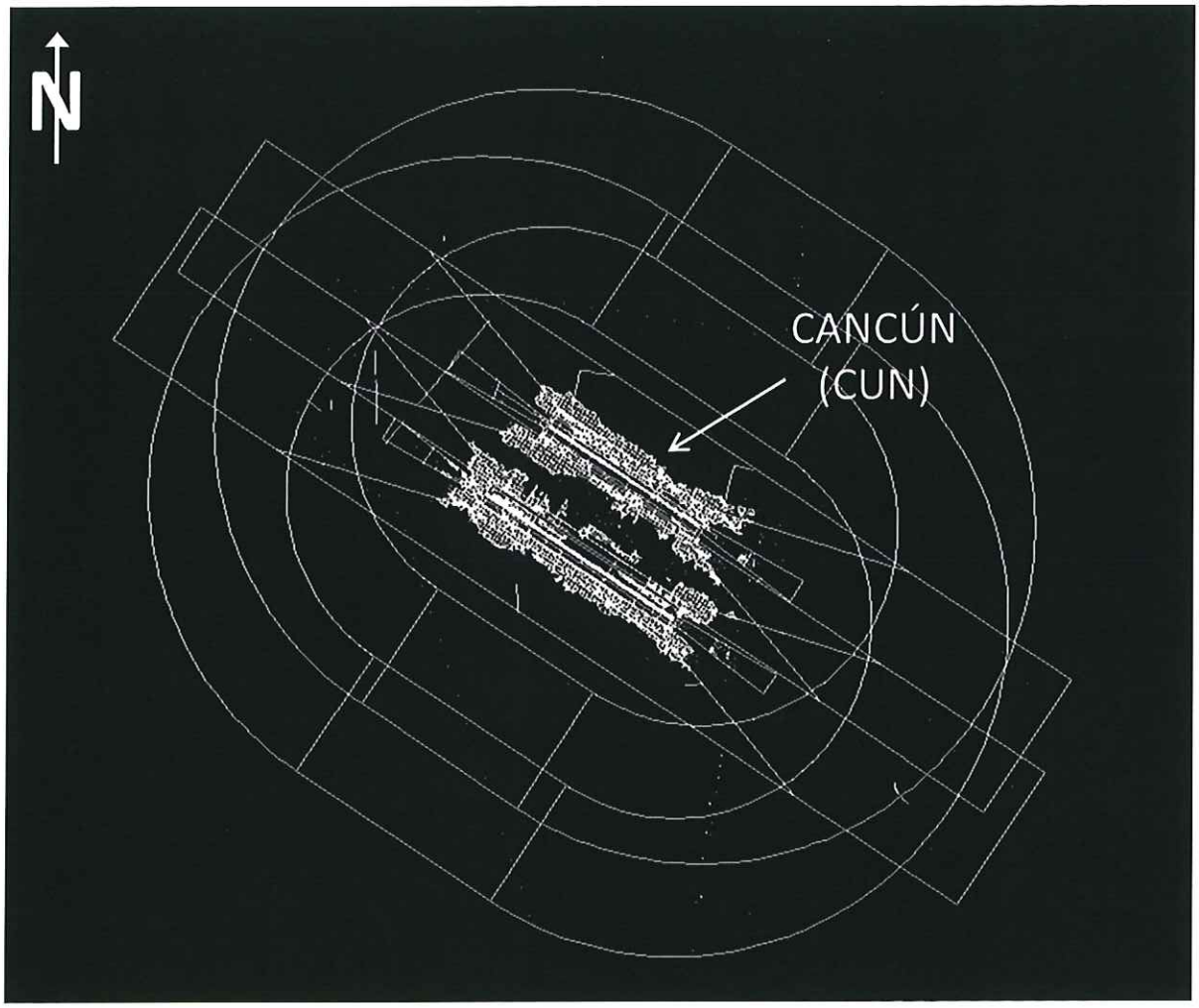


Figure 2. FAA GIS Data for Cancún Airport (AutoCAD)

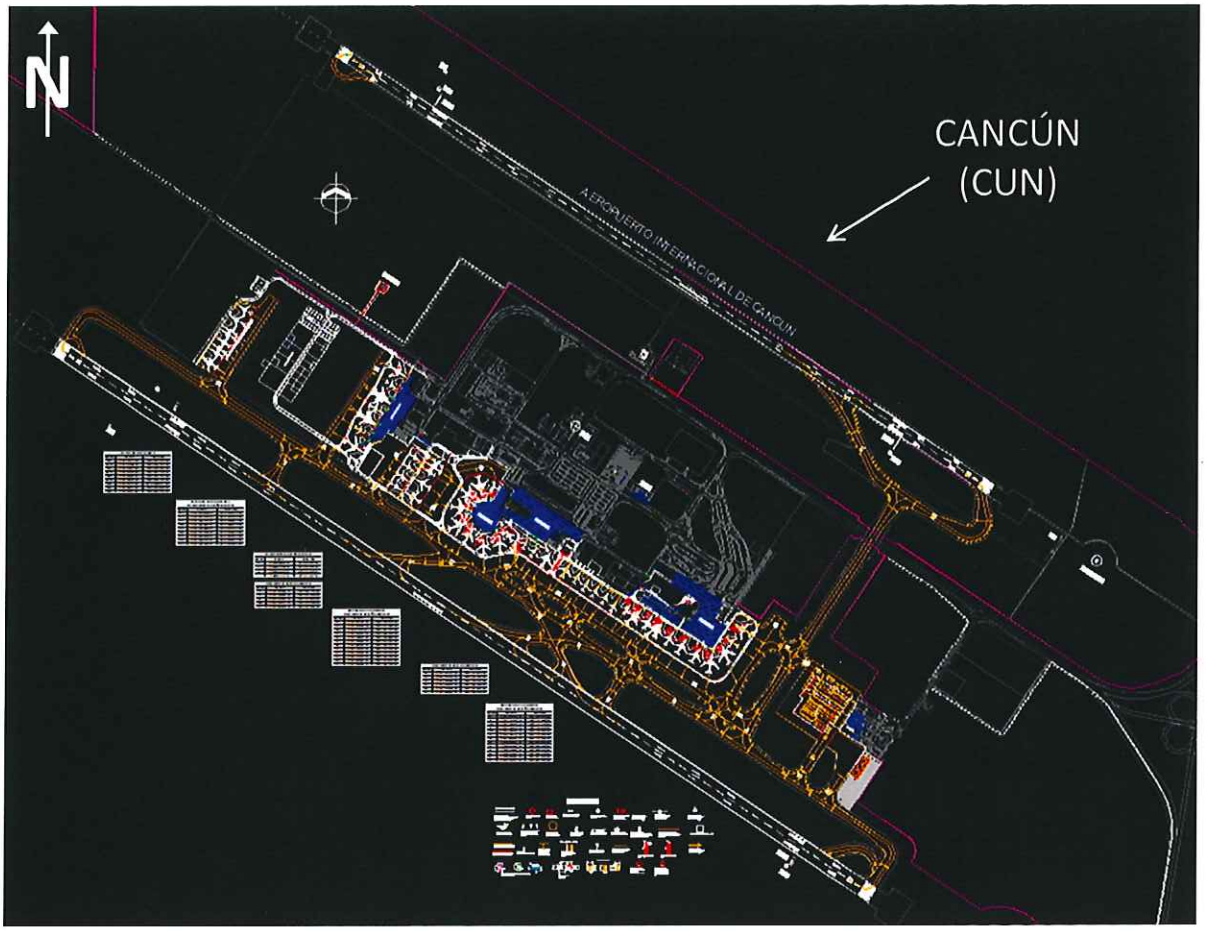


Figure 3. Electronic Airport Layout Plan (AutoCAD)

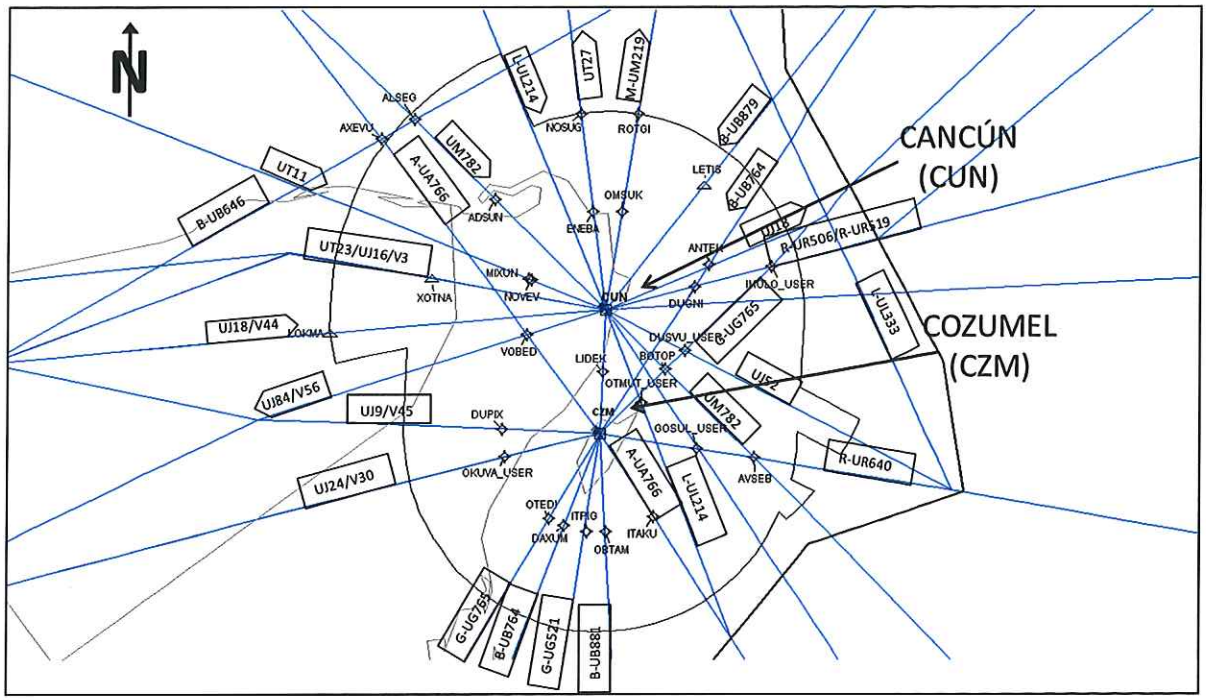


Figure 4. Airway Structure (TARGETS)

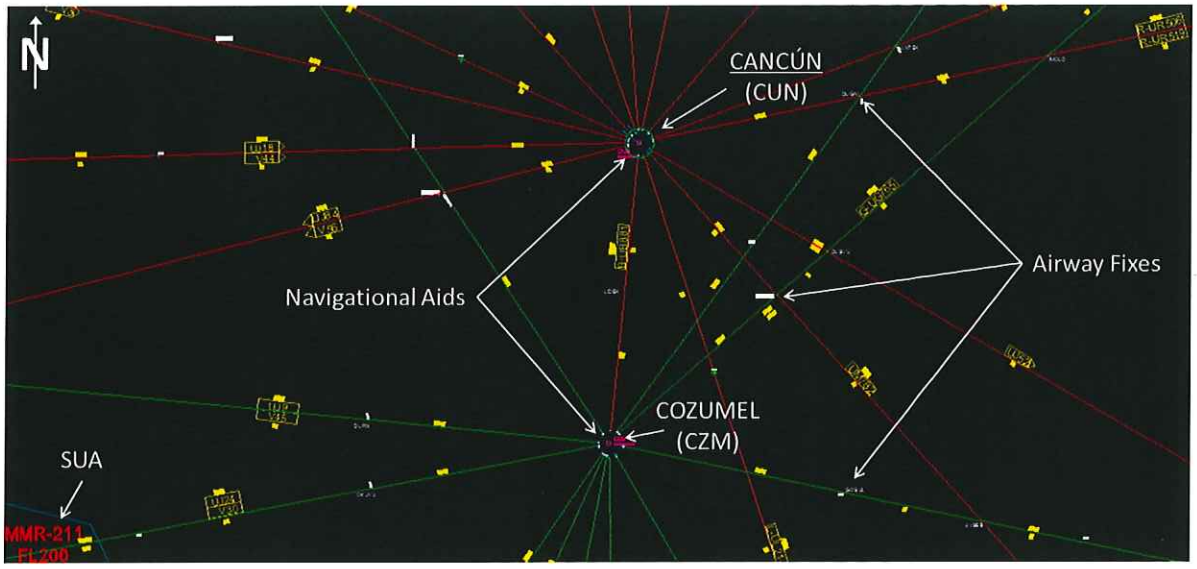
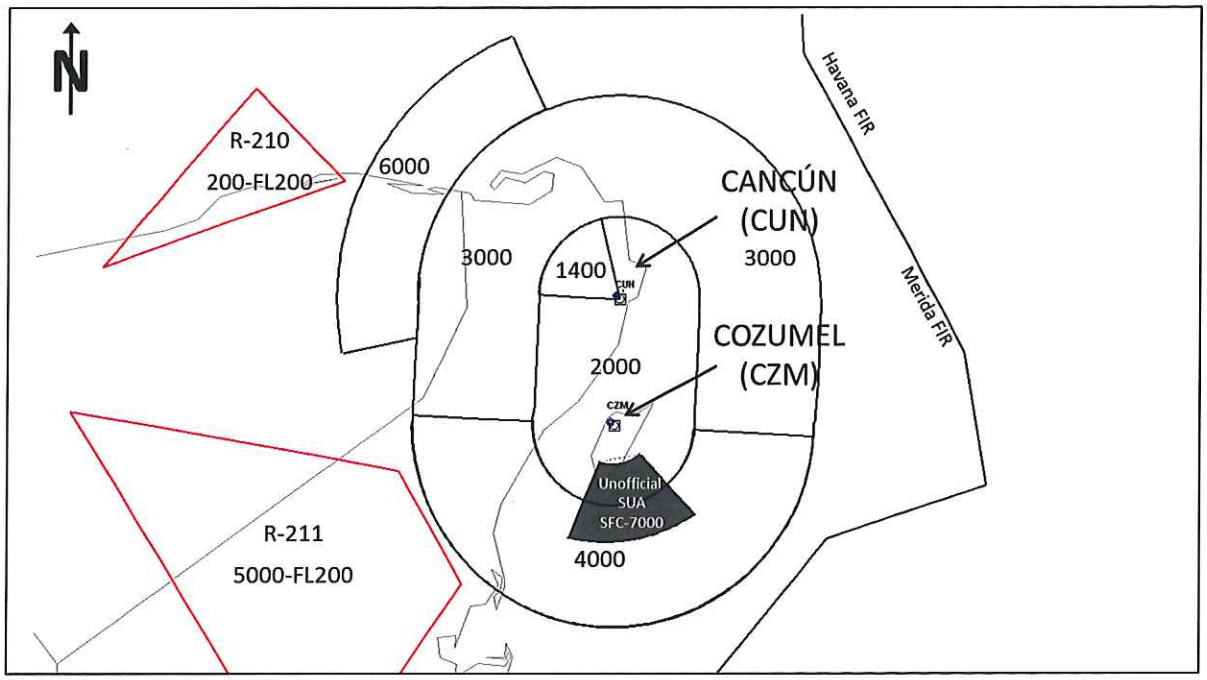


Figure 5. Airway Structure (AutoCAD)



Note: Not all SUAs are Shown

Figure 6. Minimum Vectoring Altitude Chart and SUAs (TARGETS)

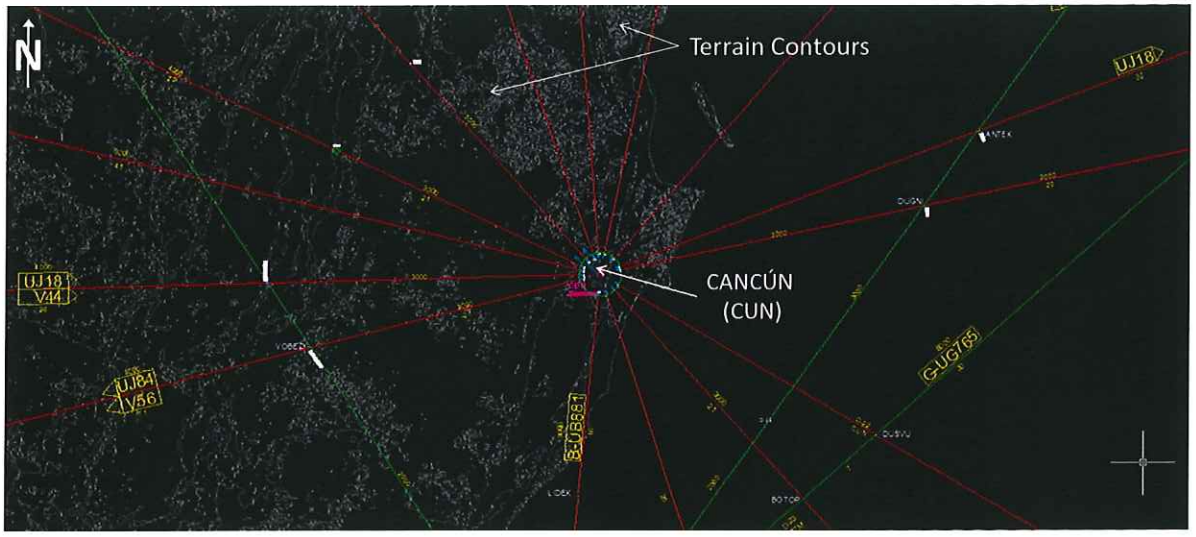


Figure 7. Contour Lines Generated from SRTM

6. Closing Remarks

Construction of a basemap is an extensive and time-consuming process requiring careful planning and coordination. The basemaps not only serve as the repository for project data, but as the operational environment from which MITRE will conduct its preliminary development of dual independent approach and departure procedures, as well as airspace design work to support HITL simulations. The most important available aeronautical information and terrain data provided to MITRE have been entered, and the basemaps have gone through an extensive MITRE peer-review process. Any additional data provided to MITRE by authorities will be included into the basemap upon receipt, as appropriate.

As previously mentioned, MITRE recommends that a more detailed obstacle survey be conducted along with flight inspection activities at the appropriate time to ensure that unknown obstacles are not a problem for future Cancún Airport procedures and/or airspace designs.

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 United States 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).

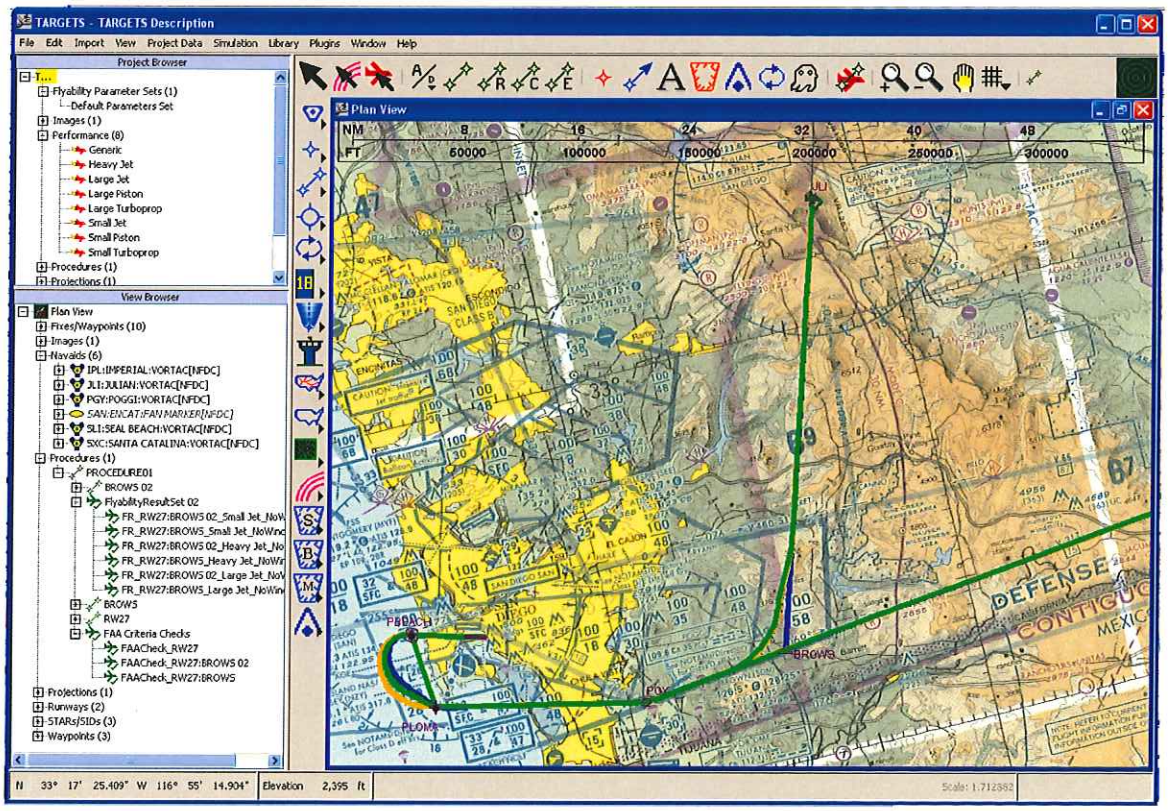


Figure A-1. A Typical TARGETS Screen Interface

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 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 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.

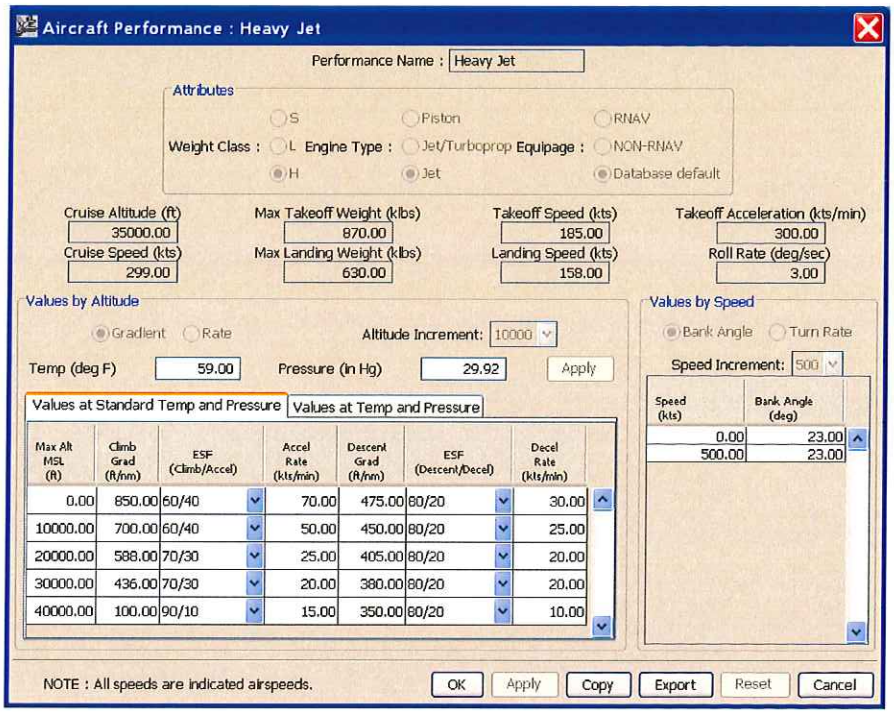


Figure A-2. A TARGETS Performance Profile for a Heavy Jet

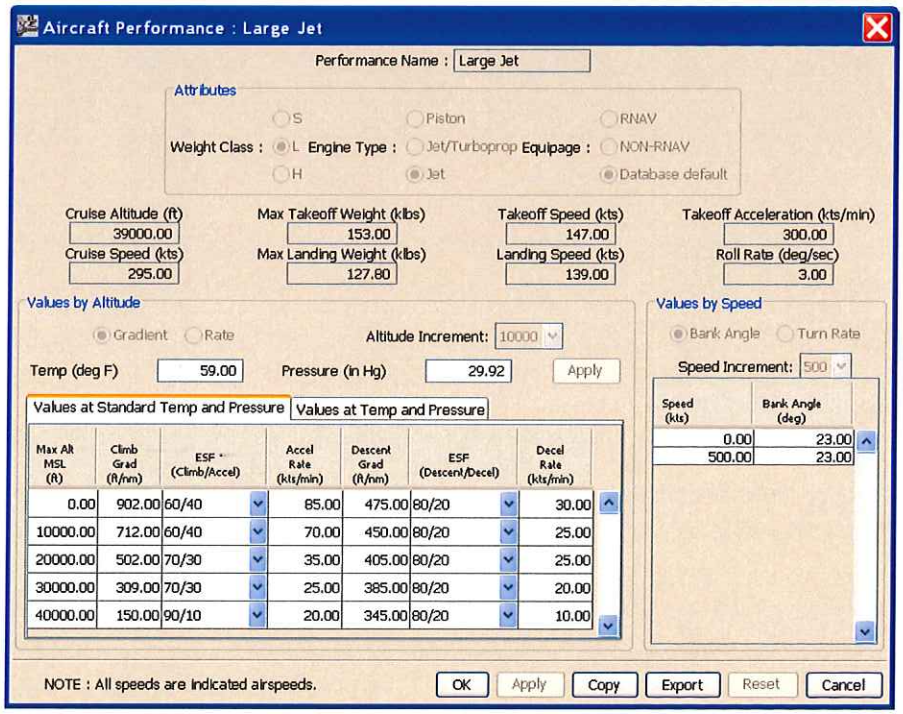


Figure A-3. A TARGETS Performance Profile for a Large Jet

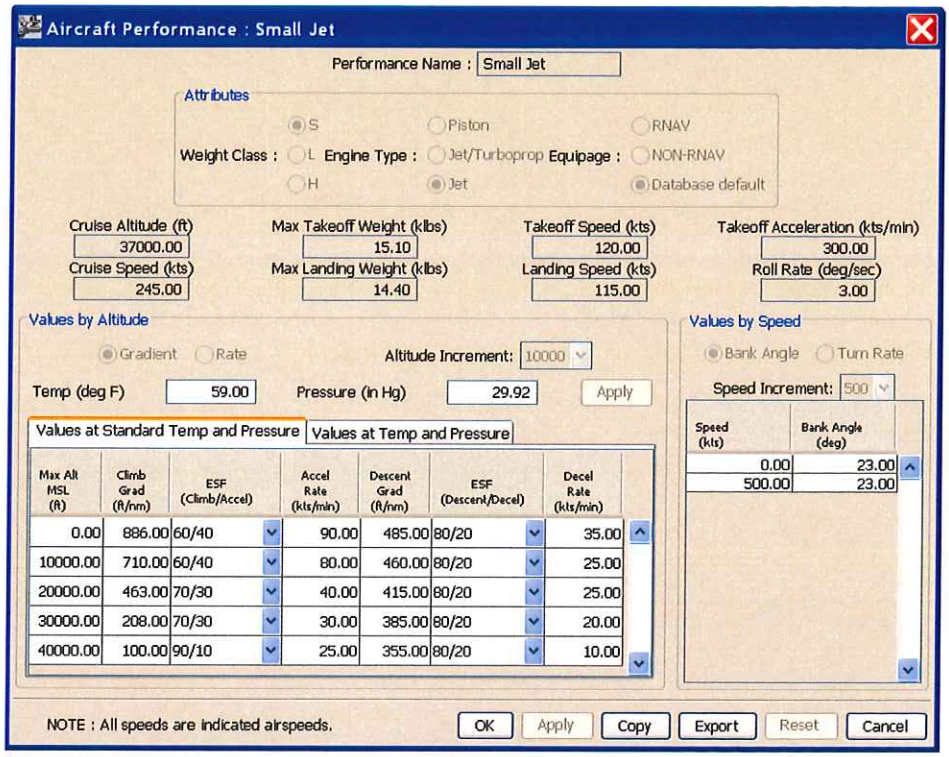


Figure A-4. A TARGETS Performance Profile for a Small Jet

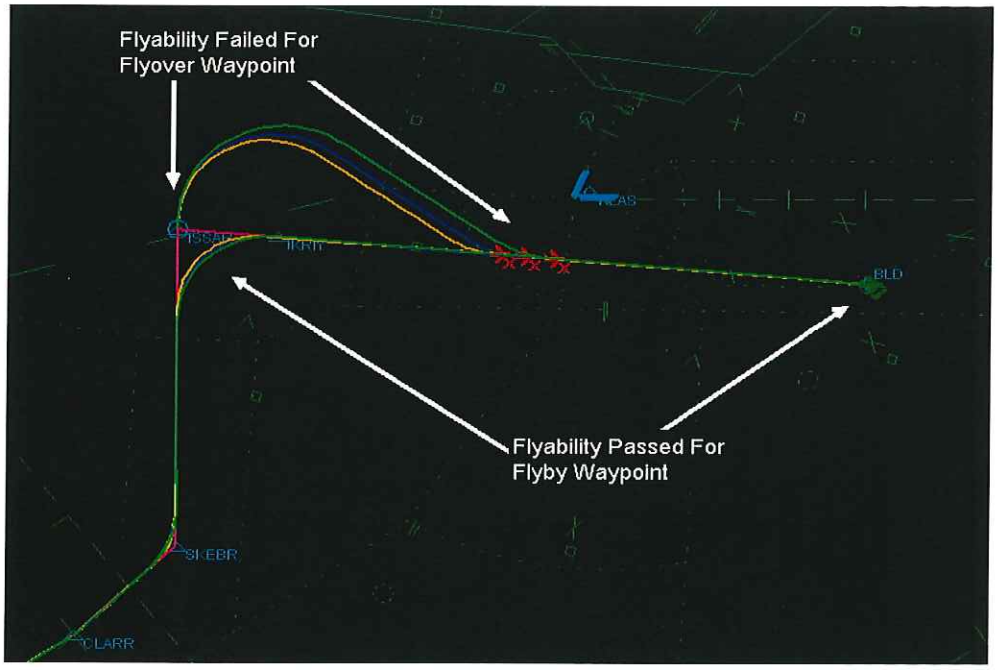


Figure A-5. A Typical TARGETS Flyability Results Graphic

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.