

Enclosure 6

(Ref. Technical Letter F500-L16-039)



**Center for Advanced
Aviation System Development**

Photogrammetric, Satellite-Based Survey of Toluca Airport and Its Surroundings

Final Quality Control Visit Report

MITRE is responsible for the procurement of a satellite-based photogrammetric survey of Toluca Airport and its surroundings. In May 2016, a team of survey experts from MDA Geospatial Services Inc. (MDA), the company performing the survey, accompanied by a MITRE engineer, visited Toluca to conduct obstacle verification work within critical project areas. The visit is an important component to provide the necessary Quality Control (QC) for the entire project. This enclosure describes that work.

Prepared for

Aeropuertos y Servicios Auxiliares

30 June 2016

Photogrammetric Survey of Toluca Airport and its Surroundings:

Final Quality Control Visit Report

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Acronyms

AGL	Above Ground Level
ARP	Antenna Reference Point
ASA	Aeropuertos y Servicios Auxiliares
ASR	Airport Surveillance Radar
CARNET	International customs and temporary export-import document
CORS	Continuously Operating Reference Stations
CP	Control Point
EGM96	Earth Gravitational Model 1996
GCPs	Ground Control Points
GE-1	GeoEye-1
GIS	Geographic Information System
GPS	Global Positioning System
ILS	Instrument Landing System
Ing.	Engineer in Spanish
km	kilometre
m	metre
MDA	MacDONALD, DETTWILER AND ASSOCIATES LTD.
MITRE	The MITRE Corporation
MSL	Mean Sea Level
PSA	Photogrammetric Survey Area
QC	Quality Control
SCT	Secretaría de Comunicaciones y Transportes
sq km	Square Kilometres
VOR	VHF Omnidirectional Range
WGS84	World Geodetic System 1984
WV-2	WorldView-2
WV-3	WorldView-3

1 INTRODUCTION

The Final Quality Control Visit Report provides an overview of the process and collection of final measurements and Ground Control Points within all Project areas.

The project titled Photogrammetric, Satellite-Based Survey of Toluca Airport and Its Surroundings (hereafter referred to as the "Project") began on 23 July 2015. By that time, the rainy season in Toluca was well underway, a fact that delayed project completion through 2016. The survey will be used to support The MITRE Corporation (hereafter referred to as "MITRE") in conducting aeronautical analyses in support of Aeropuertos y Servicios Auxiliares (hereafter referred to as "ASA"). The first in-country component of the Project was to perform the survey Site Assessment, which took place from 24 August 2015 through 4 September 2015. The purpose of the Site Assessment was to gather data, specifically Ground Control Points (GCPs) to assist in the development of the survey. These points, coupled with field checks, improved detection of features in the satellite imagery and facilitated planning of the ground surveys that followed.

The second in-country component was the Field Validation, Verification and Ground Truth (FVVG) Visit which took place in Toluca from 29 March 2016 through 22 April 2016. The objective of the FVVG Visit was twofold: First, to validate and measure any feature greater than 60 m Above Ground Level (AGL) present within Area B. The final height measurement will reflect the top-height of any feature, including any antennas on the tops of buildings. These features will include buildings, towers, power-line towers (including the power line running between towers), trees, bridges, poles, posts, and antennas (the "Obstructions"). Secondly, to collect Validation points randomly situated throughout the project areas. The heights collected will be used during analysis to ensure that all items are collected to the specification. Verification points were collected to ensure that the heights derived from stereoscopic satellite imagery are accurate.

The third in-country component was the Final Quality Control (QC) Visit which took place in Toluca from 10 May 2016 through 13 May 2016. Present during the Final QC Visit was Mrs. Suzanne Brunke and Mr. Shane McConachie from MDA; and Mr. Wayne Fetty from MITRE, who acted as an observer and liaison in order to provide feedback to MITRE project leaders on the status and outcome of the trip. Assigned to drive the ASA provided van and provide translation and logistics support was Ing. Dave Luna from ASA. Ing. Luna and Ing. Caballero met MDA and MITRE in the lobby of the Airport Hilton hotel on 10 May 2016 at 8 am. Ing. Caballero was brought back to ASA's building and the rest of the Team proceeded directly to Toluca to begin the fieldwork.

The goal of the Final QC Visit was to re-visit strategic critical aeronautical areas determined by MITRE: the Toluca International Airport (hereafter referred to as "Toluca Airport"), the areas off the ends of the runway, Cerro la Teresona, Volcán de Jocotitlán, Santa Cruz Tepexpan, and the community of El Cerrillo. While at these locations, the MDA Team would be looking for Obstructions that were not currently in the database and re-measuring some Obstructions for QC purposes. Critical on-airport features, such as thresholds, the Instrument Landing System (ILS), the Airport Surveillance Radar (ASR) Antennas, and the VHF Omnidirectional Range (VOR) were also re-measured.

2 COORDINATION AND PLANNING

Coordination and planning are critical to the objective of this Project.

2.1 Planning

On 16 March 2016, Mrs. Brunke provided MITRE and ASA with a draft plan for the execution of the Final QC Visit. This plan could be modified in the field, but the main criterion was that the Team be able to visit areas specified in the plan and collect field measurements to compare with the data collected in the project thus far. Ing. Jorge Nevárez assigned Ing. Luna to prepare a driving plan to determine the best way to navigate throughout the project areas.

Mrs. Brunke requested that ASA prepare an official letter on company letterhead, in Spanish, to state the purpose of the survey and description of the equipment that she was bringing into Mexico for the Final QC Visit. This letter was kept by the MDA staff in case there was difficulty bringing the equipment into or out of Mexico with the CARNET.¹ The CARNET eased the temporary importation of the equipment with Mexican Customs.

ASA arranged for the use of a fourteen-passenger Toyota van for the Final QC Visit. Ing. Luna was the driver: he accompanied the Team and provided excellent coordination, translation and logistics support.

2.2 Survey Equipment

In preparation of the Final QC Visit, MDA brought the following survey equipment from Canada to Mexico (shown in Table 1).

Table 1 – MDA Equipment used during the Final QC Visit

Quantity	Equipment
2	Trimble GeoXT Explorer 6000 Global Positioning System (GPS)
2	Trimble Tornado Antenna
2	GPS digital cameras
1	Nikon DSLR with Telephoto Lens
2	Car GPS Navigation Systems
2	Dell E6430 Laptops

The Trimble GeoXT Explorer 6000 is a high performance GPS receiver with an on-board computer loaded with ArcGIS Mobile Geographic Information System (GIS) support software (see Figure 1). An external antenna, resistant to signal interference and multipath was used to obtain a higher yield of GPS satellite positions and to improve performance and accuracy. The antenna was connected to the GPS on top of a mounting pole to improve satellite visibility. The

¹ CARNET is an international customs and temporary export-import document, used to clear customs without paying duties and import taxes on merchandise that will be re-exported within 12 months.

GPS collects GCPs and other field data measurements in X, Y, Z, latitude, longitude and height above Ellipsoid.



Figure 1 – A Trimble GeoXT Explorer 6000 GPS used to Collect Field Measurements during the Final QC Visit

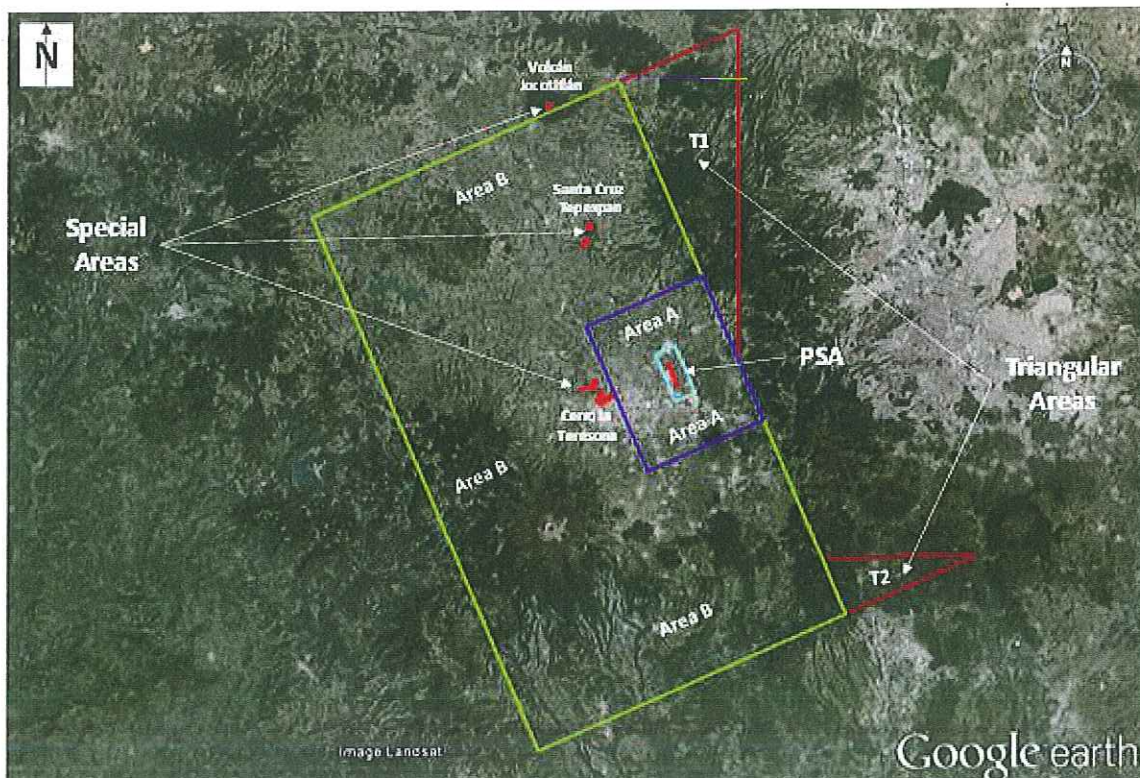
Also included in the equipment were two Canon GPS equipped digital cameras for taking detailed and overview photographs of the field measurement locations, two Car Navigational GPS units outfitted with Mexico street maps for navigating throughout the survey area, and a DELL Laptop for recording and processing data points. Furthermore, one laptop had a copy of ArcGIS Mobile installed that allowed for the post-processing of the daily data collection. This ensured that the collected field measurements met the highest accuracy thresholds required for this survey and if there were any accuracy issues, a problem area or point could be revisited, if so required, while the Team was still in Mexico.

3 LOCATION OVERVIEW

Knowledge of the environmental conditions provides valuable information to support a thorough survey.

3.1 Location

The Project area is centered around the City of Toluca and Toluca Airport. The survey site is composed of the following areas, shown in Figure 2: the Photogrammetric Survey Area (PSA), Area A, Area B, two Triangular Areas northeast ("T1") and southeast ("T2") of the site, and three Special Areas.



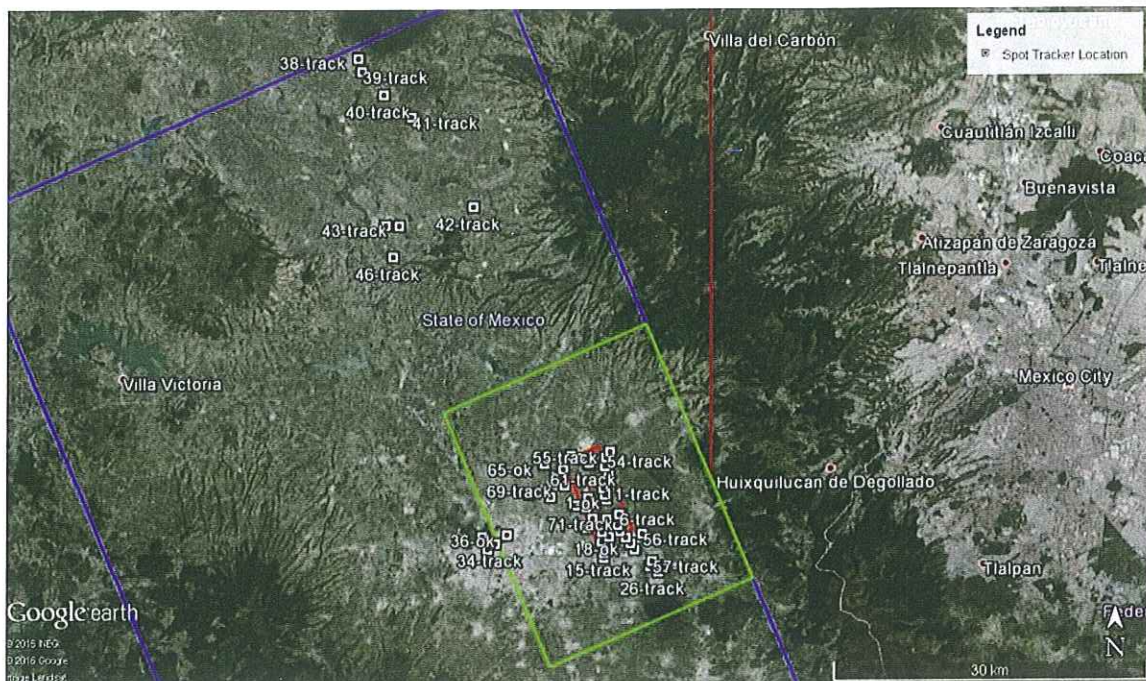
Source: GoogleEarth

Figure 2 – The Project Survey Site: PSA (Cyan), Area A (Blue), Area B (Green), T1 and T2 (Burgundy), and three Special Areas (Red)

3.2 Fieldwork Areas

In order to systematically collect data and measurements throughout all project areas, MDA divided the critical aeronautical areas into daily section goals, hereafter referred to as Fieldwork Areas. There were four sections identified as daily Fieldwork Areas. One business day was allocated for each area.

MDA staff wore GPS trackers the entire time that they were performing field measurements. The tracker signals can be displayed in GoogleEarth and used to monitor progress in the field and also ensure that all areas had been visited for validation. These tracker locations, showing all the areas visited by MDA during the Final QC Visit, can be seen in Figure 3 below.



Source: GoogleEarth

Figure 3 – The GPS Tracking Signals from the MDA Team while Conducting Field Measurements in Toluca

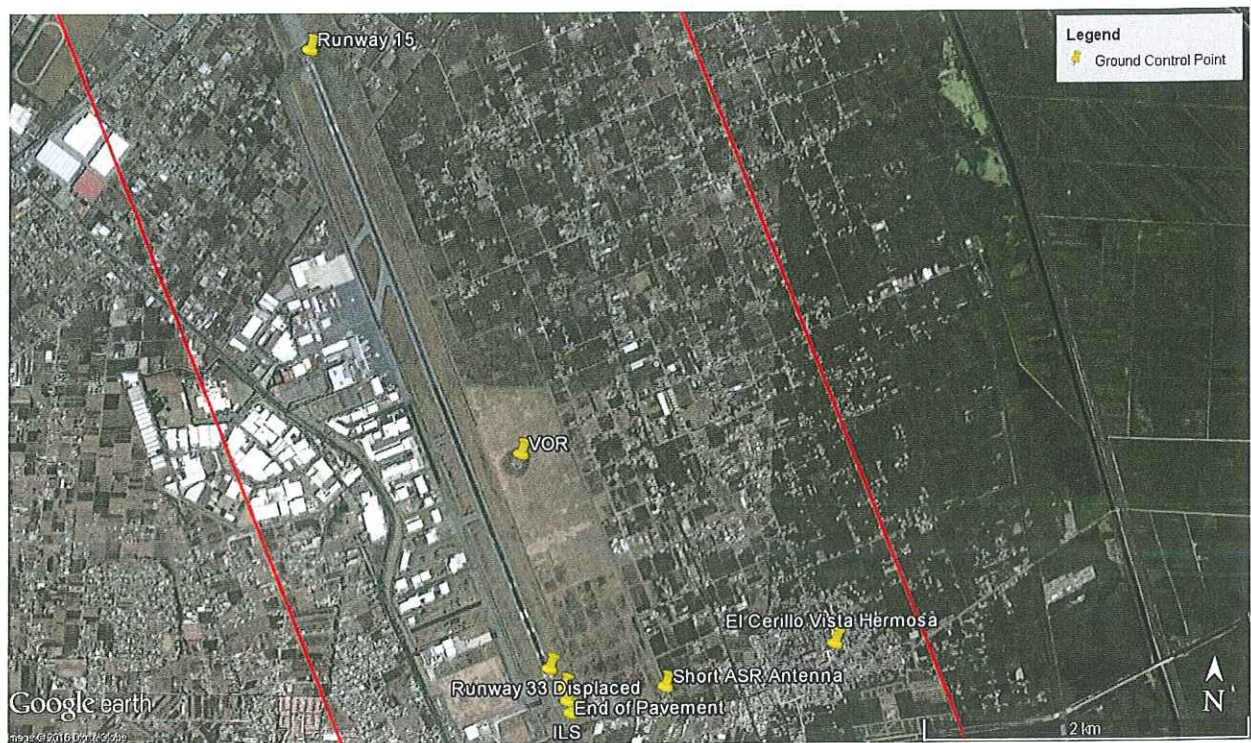
4 DATA INVENTORY

A well-organized data inventory is essential to the success of the survey.

Building a data inventory is a key component and contributor to the success of the survey. It provides vital information relevant to the measurement of terrain and Obstructions and assists with evaluation, planning, execution, and quality assurance of the survey. Data to be integrated into the Project inventory that were collected during the Final QC Visit are: MDA collected GCPs, Obstruction height information, and a final visual check of content within each of the critical aeronautical areas.

4.1 GCPs

Eight (8) new GCPs were collected during the Final QC Visit. The GCPs can be sub-classed as three threshold points, the ILS Localizer Array center location, the ASR antenna, the VOR and the top of El Cerrillo; all the points, except the latter, were located within the fence at the Toluca Airport (see Figure 4).



Source: GoogleEarth

Figure 4 – Location of GCPs Collected During the Final QC Visit

The GCP locations were measured using a high-precision GPS with an antenna, as described in Section 2.2. Photographs were taken of each location for reference (see Figure 5). Full descriptions and coordinate information for each GCP is provided in Appendix A.



Figure 5 – Reference Photographs Taken of GCP Locations

The GCPs and all field measurements were differentially post-processed at the MDA office in Vancouver using Continuously Operating Reference Stations (CORS) to calculate the difference between the positions transmitted by the satellite systems and the known fixed locations. The CORS system enables positioning accuracies that approach centimetres relative to the National Spatial Reference System, both horizontally and vertically. Generally speaking, the faster the sampling rate, the more accurate the reference station. For example, the 1 second stations are the most accurate survey grade, decreasing in accuracy to the 30 second stations.

The closest base station to the Project area was located in the City of Toluca. The Toluca CORS site location, which transmits at a 1-second interval, is provided in Table 2 and Figure 6 below. The Toluca station was operational during the Final QC Visit, as shown in the data availability profile in Figure 7 for the Julian days 129 through 135 (8 May through 13 May), which includes the days MDA was in the field. There were two periods of inoperability during this time period, shown in grey in Figure 7, as opposed to the operational blue colour. The first period was during Julian day 130, or 9 May, prior to the Final QC trip. The second period was on Julian day 134, 12 May, which lasted until 13 May. On 12 May, the MDA Team collected all data for the critical aeronautical area north of the Toluca Airport runway in the morning before the outage. Some validation points were collected in the afternoon using the GPS, but it is the measurements from the Laser Range Finder that is critical, not the GPS coordinates. For all Fieldwork Areas and data collected in the field, any points above the accuracy tolerance were removed during post processing. While there were outages reported, there was no impact to project accuracies.

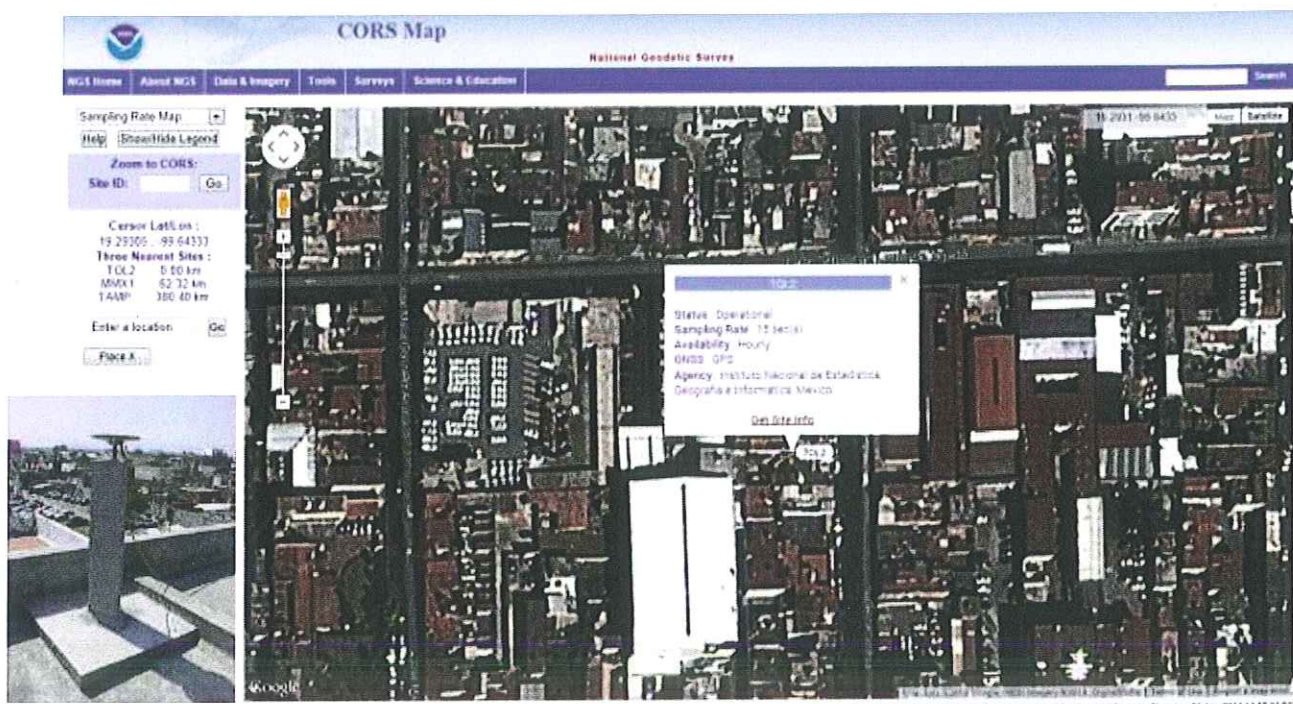
Table 2 – Antenna Reference Point Data Used to Process GCPs

Antenna Reference Point (ARP): TOLUCA CORS ARP

PID = DH8722

Latitude and Longitude = 19° 17 35.64360 N, 99° 38 36.49913 W

The PID is the Permanent Identifier that is assigned to each CORS station as a unique code.



Source: GoogleEarth and NOAA²

Figure 6 – Location of Toluca CORS Site Used to Post Process GCPs

² National Oceanic and Atmospheric Administration (United States).

Data Availability Profile for: TOL2

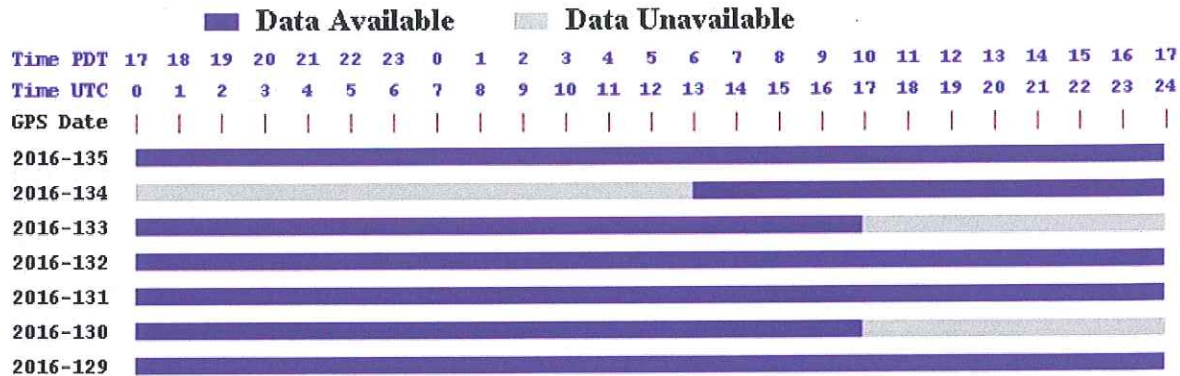


Figure 7 – Data Availability Profile for 1-Second Toluca CORS Base Station

Post-processing improved the accuracies of all the GCPs and Validation/Verification points collected. The final aggregate accuracies of the points processed with the Toluca CORS Base station increased overall accuracy, as can be seen in Table 3 and Table 4 below.

Table 3 – Accuracy Results for Post-Processed Observation QC Points

Toluca "TOL2" Base Station Accuracies	
A total of 2326 (100.0%) of 2327 positions were differentially corrected	
Estimated accuracies (68%) for 2327 positions are as follows:	
0 - 15cm	- 32.2%
15 - 30cm	- 0%
30 - 50cm	- 0%
0.5 - 1m	- 14.4%
1 - 2m	- 53.2%
2 - 5m	- 0.1%
> 5m	- 0.0%

Table 4 – Accuracy Results for Post-Processed Threshold GCPs

Toluca "TOL2" Base Station Accuracies	
A total of 9407 (100.0%) of 9407 positions were differentially corrected	
Estimated accuracies (68%) for 9407 positions are as follows:	
0 - 15cm	- 93.1%
15 - 30cm	- 5.2%
30 - 50cm	- 1.1%
0.5 - 1m	- 0%
1 - 2m	- 0%
2 - 5m	- 0%
> 5m	- 0%

5 Final QC Visit

QC Field data provides the necessary final corroboration of accuracy as critical aeronautical areas are visited and GCPs, Obstructions and additional points are collected to support a comprehensive survey.

Although initially planned for four days, field data collection was completed within three days, from 10 May to 12 May 2016, due to no coordination-related delays and better than expected transportation times. The Final QC collection was conducted by one team, consisting of Mrs. Suzanne Brunke and Mr. Shane McConachie, accompanied by Mr. Wayne Fetty of MITRE. The objective of the Final QC Visit was to visually inspect critical aeronautical areas to ensure all Obstructions were measured in the field and also to collect additional GCPs of airport infrastructure, such as thresholds and NAVAIDS (e.g., ILS, VOR).

Fieldwork Areas for the Team were outlined in the Final QC Trip Plan. In order to systematically collect data and measurements throughout all project areas, MDA divided the entire region into four Fieldwork Areas, as shown in Figure 8 below. It was understood that while these Fieldwork Areas were planned, the Team had flexibility while conducting the Final QC Visit to switch days or combine some areas depending on local conditions. As mentioned above, these four daily Fieldwork Areas were completed in three days.



Source: GoogleEarth

Figure 8 – Critical Aeronautical Areas to Visit during Final QC Visit

Additional information on work performed during the Final QC Visit for the Team's fieldwork is provided in the sections below.

5.1 Tuesday, 10 May

On Tuesday, 10 May, Mrs. Brunke, Mr. McConachie, and Mr. Fetty met Ing. Caballero and Ing. Luna in the morning and drove to ASA Headquarters in Mexico City to drop off Ing. Caballero. The Team and Ing. Luna then went over the initial Final QC Visit Plan and the four daily Fieldwork Areas, and suggested adjustments as necessary. The plan was to visit the airport as soon as the Team arrived to Toluca, and begin collecting the critical aeronautical data within the airport area as soon as possible. Table 5 summarizes the actual Fieldwork Areas and dates worked by the Team. As mentioned above, the Team was able to complete the task in three full days, and returned from Mexico on the forth day of the Final QC Visit.

Table 5 – Team Fieldwork Summary for the Final QC Visit

Date	Fieldwork Areas
Day 1: Tuesday, 10 May	Toluca Airport El Cerrillo Eastern side of PSA
Day 2: Wednesday, 11 May	Area South of Toluca Airport Cerro la Teresona Volcán de Jocotitlán Santa Cruz Tepexpan
Day 3: Thursday, 12 May	Area North of Toluca Airport Western side of PSA
Day 4: Friday, 13 May	No longer required

After the meeting, the Team proceeded in the ASA van south to Toluca and started collecting data at Toluca Airport. The representative from the Toluca Airport, Ing. Jesus Soriano, was helpful in trying to clarify numerous questions about the location of items on the airport. The Team was on the airport for approximately four hours. Once all of the measurements were completed at the airport, the Team drove to El Cerrillo, a town located to the east, southeast of Runway 33. The town is located on a small hill and is visible from the airport; see Figure 9 which was taken from the threshold of Runway 33 and Figure 10 taken at El Cerrillo. A total of eight (8) GCPs were collected on 10 May (refer to Appendix A for details).



Figure 9 – Antennas on El Cerrillo as Visible from Runway 33



Figure 10 – Antennas Measured on El Cerrillo

5.2 Wednesday, 11 May

On Wednesday, 11 May, the Team left the hotel in Toluca and headed towards the south of the PSA and into Area A. The Team collected a variety of obstacles directly south of the PSA, including the antenna shown in Figure 11. The Team then went through the City of Toluca looking for tall antennas and buildings that were not already in the database, and drove up the hill directly opposite Cerro la Teresona. The Team observed the antennas on Cerro la

Teresona, and the location also provided an excellent viewpoint to scan the City of Toluca and surrounding urban area.

The Team then travelled north towards Volcán de Jocotitlán verifying multiple obstacles along the way. After observing Volcán de Jocotitlán from several vantage points (see Figure 12), and collecting one antenna in the village of Jocotitlán, the Team then travelled south to Santa Cruz Tepexpan. The Team circled around Santa Cruz Tepexpan getting several vantage points of the church, one of which is shown in Figure 13. The Team collected and verified a total of 21 obstacles.



Figure 11 – Antenna South of the PSA in Area A



Figure 12 – Antennas on Volcán de Jocotitlán as Visible from the Village of Jocotitlán

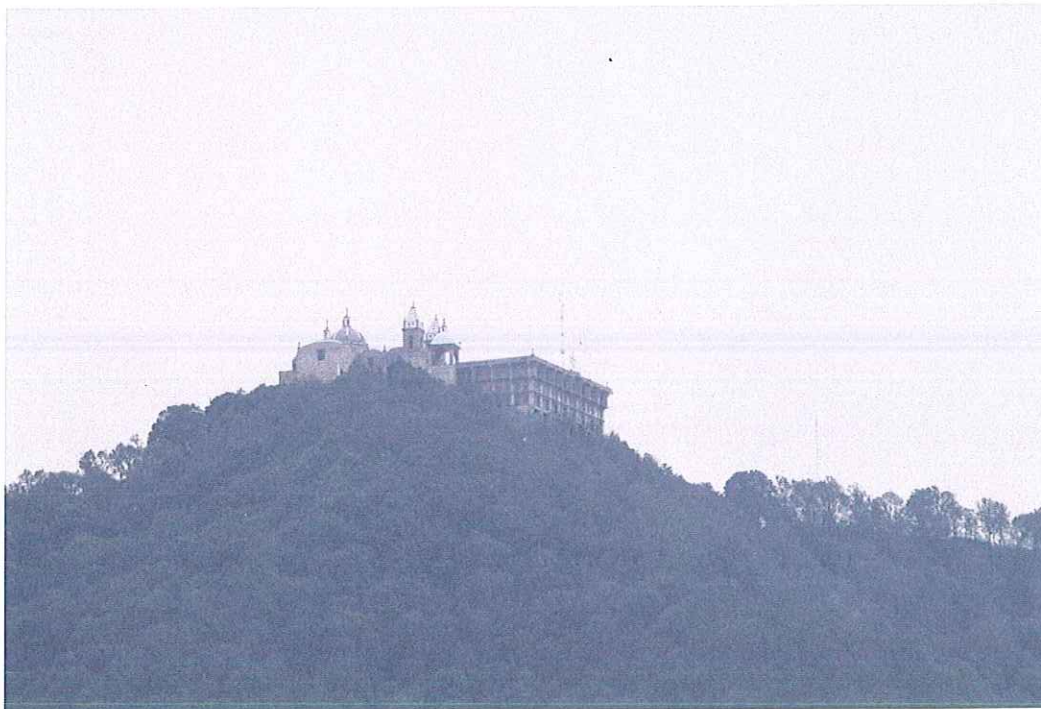


Figure 13 – Church on Top of Santa Cruz Tepexpan

5.3 Thursday, 12, May

On Thursday, 12 May, the Team headed to the north and northwest of Toluca to collect and verify random obstacles in the area north of the Toluca Airport. In the late afternoon, the Team proceeded to collect three anchor points³ with 47 random validation targets while navigating the west side of the PSA. A total of 27 Obstructions and three anchor points were collected that day. Figure 14 shows Mr. McConachie documenting an anchor point. Once collections were complete the Team returned to Mexico City in the late afternoon.

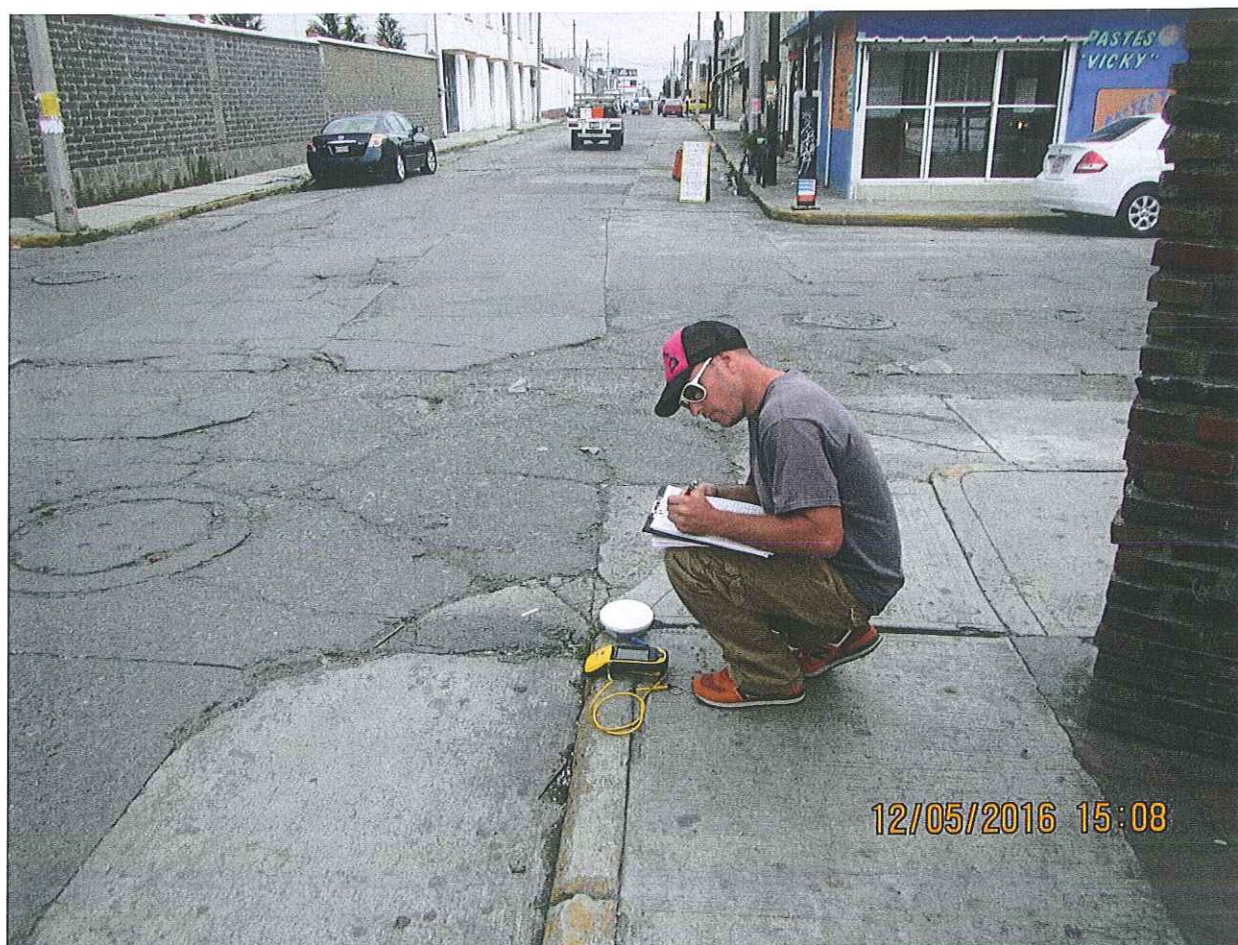


Figure 14 – Mr. McConachie Recording Information from the Trimble GPS used for Validation

³ Anchor points are a GPS-set locations, from where the obstructions are being measured using distance and bearing from the Laser range finder.

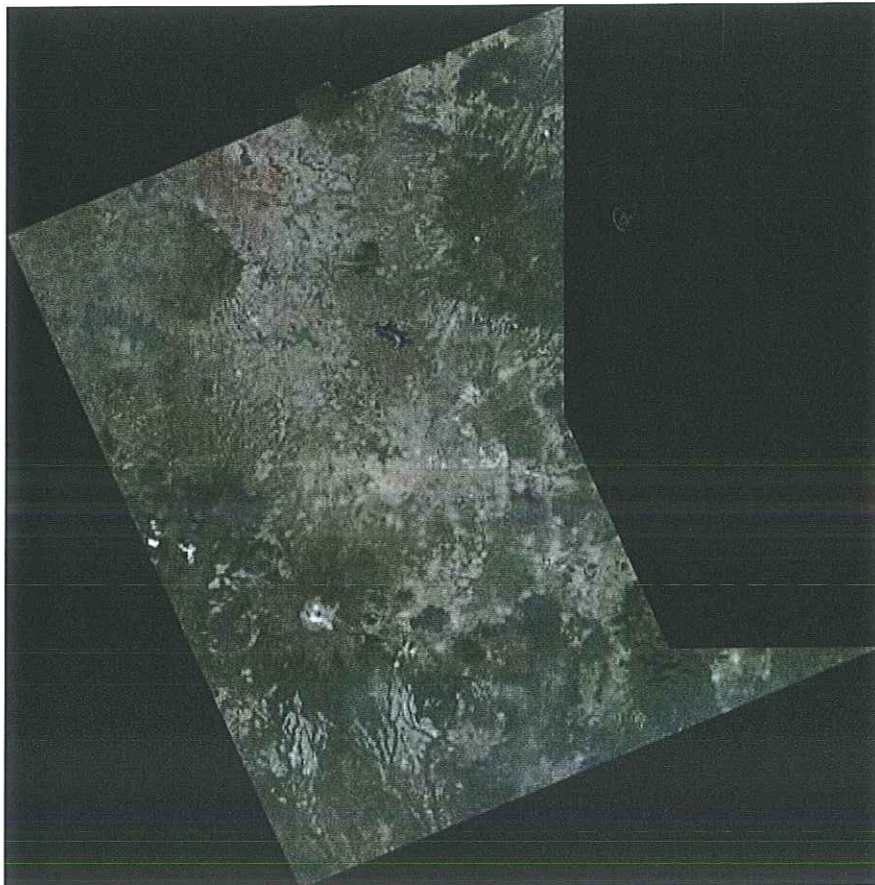
6 CONCLUSION

The next steps towards completion of the survey.

MDA will utilize the Final QC Visit data in conjunction with the previous, FVVGT Visit data and satellite image mosaic of all of the Project areas to validate and verify the stereoscopically collected data, enter the measurements of those features identified in Area B, and ensure completeness and accuracy of all Project areas

6.1 Colour-Balanced Image Mosaic

WorldView-2 (WV-2), WorldView-3 (WV-3) and Geo-Eye-1 (GE-1) were tasked to acquire the colour imagery over all of the Project Areas. The image resolution is 0.30 m for Area A and will be pan-sharpened for delivery. Area B, the Triangular Areas and the Special Areas will have an image resolution of 0.5 m. Figure 15 provides an illustration (generated from all of the source image QuickLooks) of what the final image mosaic for all Project areas will look like.



Source: MDA, All Rights Reserved © 2016

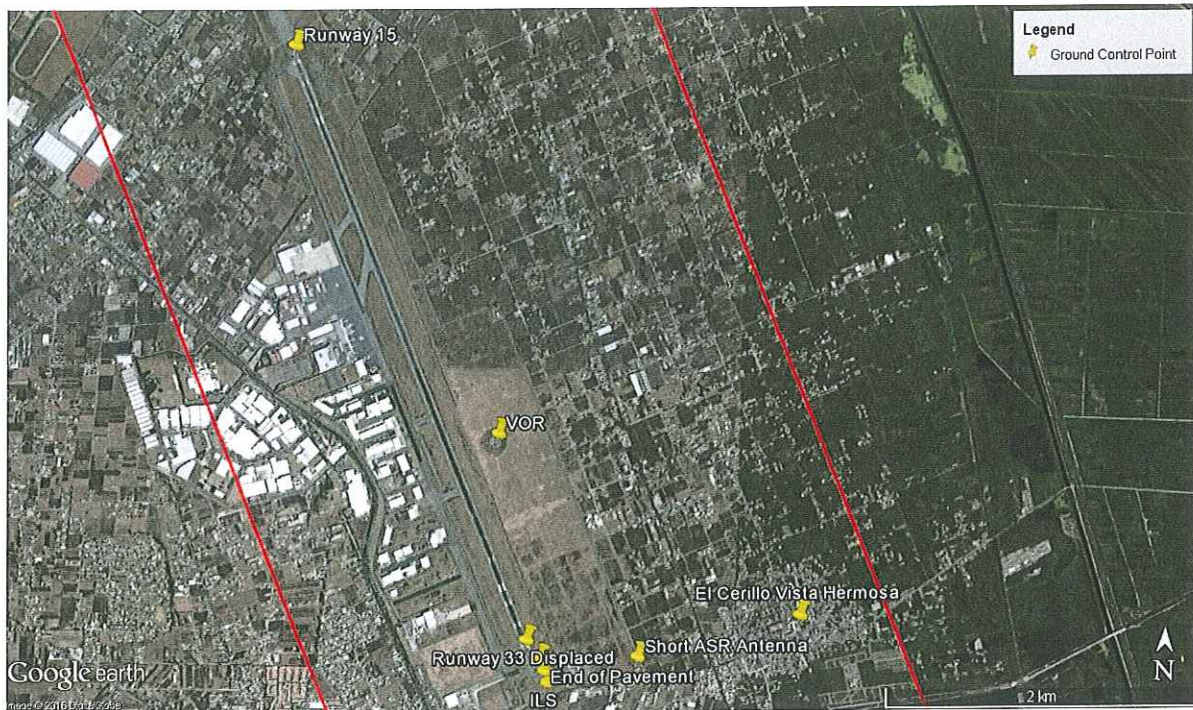
Figure 15 – The Final QuickLook Mosaic for Toluca

APPENDIX A

Ground Control Points (GCPs)

10 May 2016

This Appendix contains information on all eight (8) collected GCPs, shown in Figure 16 below. Each GCP is described on a separate page, with the coordinates, date collected and field photographs.



Source: Google Earth

Figure 16 – GCPs Collected during QC Visit

Project: Toluca Area Survey	Country: Mexico	Region: Toluca Area, Mexico
Control Point ID: Runway 33 Displaced Threshold	Collection Date: 10 May 2016	Instrument: Trimble GeoExplorer
Latitude: 19° 19' 15.58" N	Longitude: 099° 33' 31.50" W	Height (above sea level): 2579.142 m
Project Area: PSA		Datum: World Geodetic System 1984 (WGS84) / Earth Gravitational Model 1996 (EGM96)



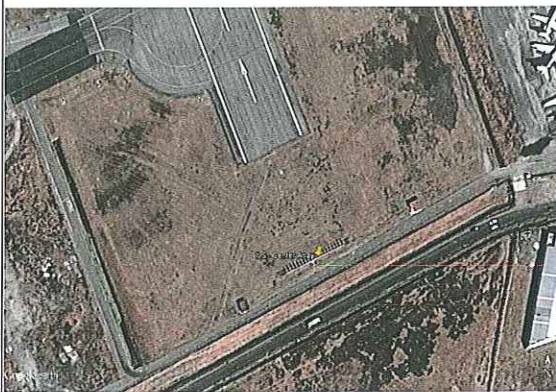
Project: Toluca Area Survey	Country: Mexico	Region: Toluca Area, Mexico
Control Point ID: Runway 33 Threshold	Collection Date: 10 May 2016	Instrument: Trimble GeoExplorer
Latitude: 19° 19' 10.78" N	Longitude: 099° 33' 29.33" W	Height (above sea level): 2578.920 m
Project Area: PSA		Datum: WGS84/EGM96



Project: Toluca Area Survey	Country: Mexico	Region: Toluca Area, Mexico
Control Point ID: Runway 33 End of Pavement	Collection Date: 10 May 2016	Instrument: Trimble GeoExplorer
Latitude: 19° 19' 08.90" N	Longitude: 099° 33' 28.48" W	Height (above sea level): 2578.43 m
Project Area: PSA		Datum: WGS84/EGM96



Project: Toluca Area Survey	Country: Mexico	Region: Toluca Area, Mexico
Control Point ID: ILS Localizer Center Array	Collection Date: 10 May 2016	Instrument: Trimble GeoExplorer
Latitude: 19° 19' 06.60" N	Longitude: 099° 33' 27.44" W	Height (above sea level): 2578.218 m
Project Area: PSA		Datum: WGS84/EGM96



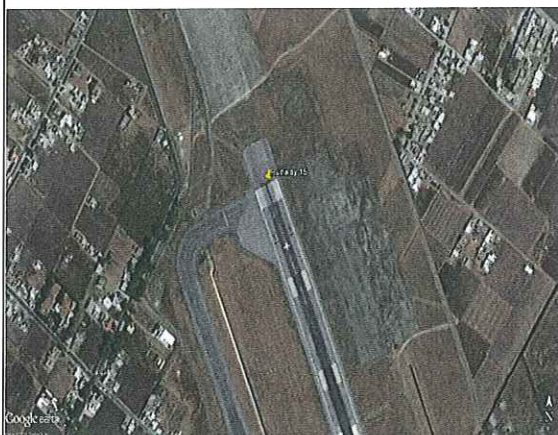
Project: Toluca Area Survey	Country: Mexico	Region: Toluca Area, Mexico
Control Point ID: ASR	Collection Date: 10 May 2016	Instrument: Trimble GeoExplorer
Latitude: 19° 19' 12.15" N	Longitude: 099° 33' 07.69" W	Height (above sea level): 2577.762 m
Project Area: PSA		Datum: WGS84/EGM96



Project: Toluca Area Survey	Country: Mexico	Region: Toluca Area, Mexico
Control Point ID: VOR	Collection Date: 10 May 2016	Instrument: Trimble GeoExplorer
Latitude: 19° 19' 59.26" N	Longitude: 099° 33' 39.53" W	Height (above sea level): 2578.419 m
Project Area: PSA		Datum: WGS84/EGM96



Project: Toluca Area Survey	Country: Mexico	Region: Toluca Area, Mexico
Control Point ID: Runway 15	Collection Date: 10 May 2016	Instrument: Trimble GeoExplorer
Latitude: 19° 21' 16.25" N	Longitude: 099° 34' 26.14" W	Height (above sea level): 2578.744 m
Project Area: Area PSA		Datum: WGS84/EGM96



Project: Toluca Area Survey	Country: Mexico	Region: Toluca Area, Mexico
Control Point ID: El Cerrillo Church	Collection Date: 10 May 2016	Instrument: Trimble GeoExplorer
Latitude: 19° 19' 21.99" N	Longitude: 099° 32' 31.52" W	Height (above sea level): 2600.911 m
Project Area: Area PSA		Datum: WGS84/EGM96

