MITRE

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Subject: Technical letter: Ground-Based Augmentation System and Wide Area Augmentation System Considerations Pertaining to NAICM and Mexico

Dear Ing. Tapia:

This letter is in response to your request on behalf of GACM through Dr. Bernardo Lisker on MITRE's thinking concerning implementation of Ground-Based Augmentation System (GBAS) in Mexico, principally for the Nuevo Aeropuerto Internacional de la Ciudad de México (NAICM). Information on the application of a Wide Area Augmentation System (WAAS), which is associated to actual implementation of a Satellite-Based Augmentation System (SBAS) in Mexico is also included.

Specifically, the appendices to this letter provide the following information:

- Appendix A provides background on GBAS, as well as some advantages and disadvantages regarding its acquisition and installation at NAICM. Recommendations by MITRE for consideration by Mexican aviation authorities and other stakeholders are also included.
- Appendix B provides background on SBAS, as well as some advantages and disadvantages regarding its application in Mexico. Recommendations by MITRE for consideration by Mexican aviation authorities and other stakeholders are also included.

I hope that this information assists GACM and the Mexican authorities in general in their ongoing navigation planning efforts. Please do not hesitate to contact me if you need any clarification or assistance.

Sincerely,

Ing. Robert W. Kleinhans
Project Technical Coordinator

cc: Dr. Bernardo Lisker, MITRE

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Appendix A

Ground-Based Augmentation System (GBAS) at NAICM

The Mexican authorities are considering the purchase and implementation of a Ground-Based Augmentation System (GBAS) in Mexico, principally for the Nuevo Aeropuerto Internacional de la Ciudad de México (NAICM). The purpose of this paper, requested by the Grupo Aeroportuario de la Ciudad de México (GACM), under its contract with MITRE, is to discuss some of the considerations for using GBAS in Mexico—specifically at NAICM.

A.1 Background

GBAS consists of a set of Global Navigation Satellite System (GNSS) reference receivers in surveyed locations on or near airports.[1] These receive GNSS signals that are subsequently processed by a ground station. Since the reference receivers are in surveyed locations, the ground station is able to determine errors from each GNSS satellite observed. Also, the ground station can detect if any GNSS satellites are malfunctioning and provide integrity of the signal in space. Corrections for each satellite are transmitted to aircraft avionics via a Very High Frequency (VHF) Data Broadcast (VDB), which uses the corrections to provide an accurate location with high integrity. Additionally, the desired path for the aircraft to fly is also transmitted via the VDB. Figure A-1 provides a conceptual overview of GBAS installation and operation considerations.

GBAS can provide vertically-guided instrument approaches, and a single GBAS ground station can provide Category (CAT) I precision approaches to all runways at an airport. It is expected that at some time in the future GBAS will be able to provide CAT II/III precision approaches to airports. Additionally, it is possible for a GBAS ground station to provide service to another airport in close proximity, but this is not a factor for NAICM.

Unfortunately, GBAS avionics are not widespread. Boeing aircraft 787, 747-800, and 737 MAX have GBAS avionics, and Boeing 737 NG aircraft (i.e., -600 through -900) have the capability to install the avionics (only if desired by the operator). Airbus aircraft, in general, have GBAS as an option. However, according to current MITRE equipage surveys done for the United States (U.S.) Federal Aviation Administration (FAA), very few airlines have opted to install GBAS avionics. Therefore, avionics equipage of GBAS is not common. GBAS avionics installation in General Aviation (GA) and business aircraft is almost nonexistent. The equipage of airline aircraft flying into Mexico City or of aircraft that would be flying into NAICM is not known, but it is likely that a great portion of NAICM's aircraft will be a reflection of U.S. airline equipage.

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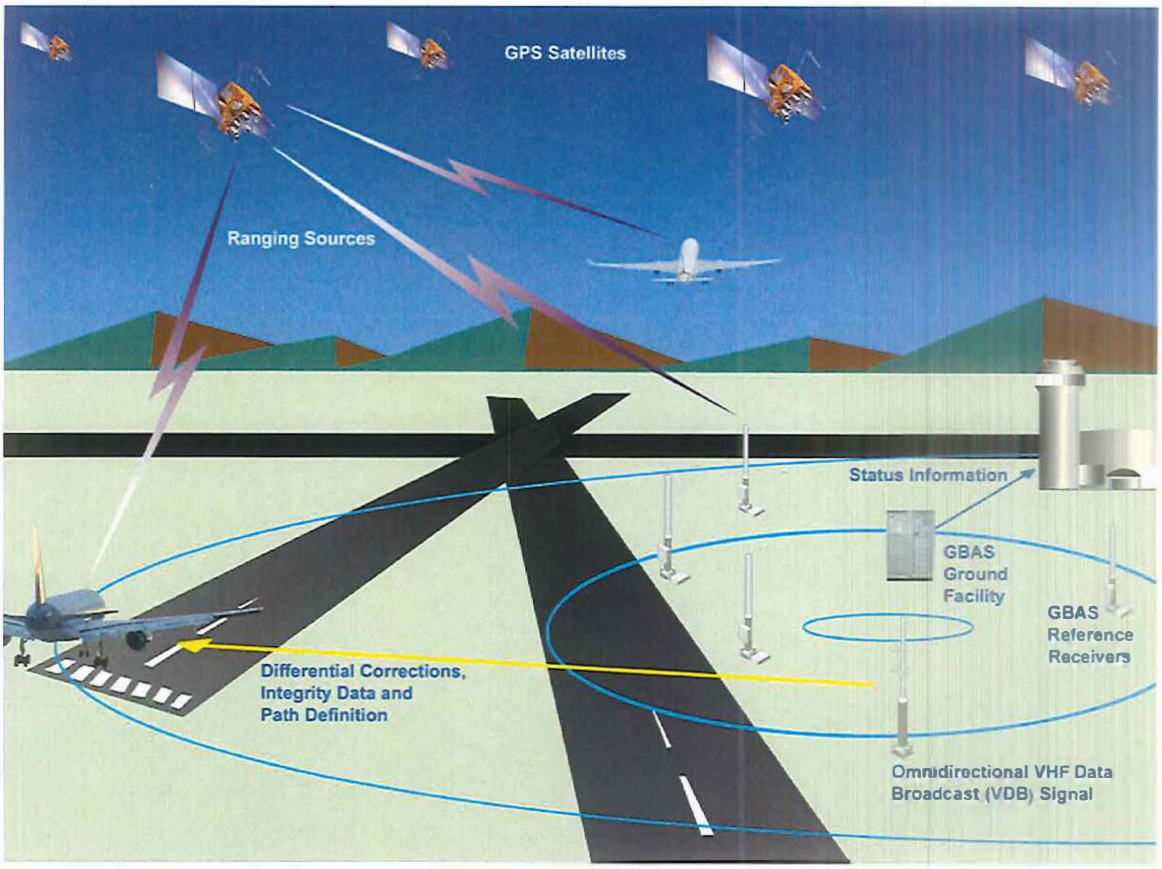
[1] Current GBAS equipment installed in western aircraft uses the Global Positioning System (GPS). Other GBAS installations may use other GNSS satellite constellations, and in the future all GBAS should use multiple constellations.



Source: FAA

Figure A-1. Conceptual Overview of GBAS Installation and Operation

The GBAS ground station is also costly—nearly two million dollars (U.S.) for purchase and installation. This does not include airport surveys and instrument approach procedure design. Also, Mexico's geographic location is near the magnetic equator, which implies increased ionospheric activity. This may necessitate the development of a GBAS Ionospheric Threat Model (GITM) with the associated data collection and safety analysis.[2]

A.2 Advantages and Disadvantages of GBAS at NAICM

The following provides some positive and negative considerations regarding the acquisition and installation of GBAS at NAICM.

[2] Areas with high ionospheric activity can incur risks of Hazardously Misleading Information (HMI) using GBAS. **An assessment of ionospheric activity would need to be performed to determine the severity of the ionosphere near Mexico City.** It is possible that historical data could be used to perform this assessment.

Advantages

- NAICM has significantly abrupt terrain under its approach paths, and it is possible that Instrument Landing Systems (ILSs) may have some signal degradation due to terrain. GBAS has no such difficulty and would avoid signal degradation such as has been observed in ILSs.
- One GBAS station can provide instrument approaches to all 12 runway ends when NAICM is completed.
- GBAS approaches are authorized for independent approaches in the U.S.

Disadvantages

- Each GBAS equipment and installation generally costs a few million dollars (U.S.). Permanent maintenance needs to be considered. It is a matter of amount of usage versus real need.
- The equipage rate of GBAS avionics of aircraft in Mexico has not been determined but it is probably low. Accordingly, few aircraft could use GBAS approaches.
- GBAS is very susceptible to GPS interference. Accordingly, NAICM would likely desire to retain ILS installations so that operations could be continued if there was a GPS outage.
    - The few U.S. airports that have GBAS have retained all ILS installations to account for low GBAS aircraft equipage and for potential GPS interference.
- A data collection may be required to develop a GITM. This would involve dual-frequency GNSS receivers and a data collection over a long-time period. However, it is possible that GPS data collected by Mexican sources, such as weather services or universities, could be used if it exists and if data are appropriate. After commissioning, the data collection would need to continue in order to update the GITM.
- As an alternative, vertically-guided approaches could be developed for NAICM, using Barometric Vertical Navigation (Baro-VNAV) technology. These approaches would require no additional ground navigation equipment to be installed at the airport. The only cost would be for approach design and for an obstacle survey, and these will be relatively inexpensive compared to the cost of a GBAS.[3]
    - The avionics equipage rate for Baro-VNAV approaches is likely high in Mexico, at least that of U.S. airlines. If this is the case,

[3] Note that GBAS approaches would also incur similar costs for approach design and an obstacle survey, but with the additional cost of the purchase, installation, and maintenance of the GBAS ground station.

Baro-VNAV approaches would be useful for a large proportion of the users.

- Required Navigation Performance (RNP) Authorization Required (AR) approaches are one type of Baro-VNAV approach and MITRE has developed procedures for it.

- A GBAS station will not provide CAT II or III service at this time.

A.3 Recommendation Concerning GBAS

MITRE recommends that the Mexican aviation authorities delay the purchase of a GBAS system. For safety purposes and to improve airport access, MITRE recommends that Mexico develop Baro-VNAV approaches to all runways ends at NAICM (and to all instrument runways in Mexico).

Mexico should work with stakeholders (i.e., mostly airlines) to determine the forecasts of GBAS avionics equipage in the future. Should these forecasts indicate a high rate of GBAS avionics equipage in the future, then GBAS should be considered for purchase and installation.

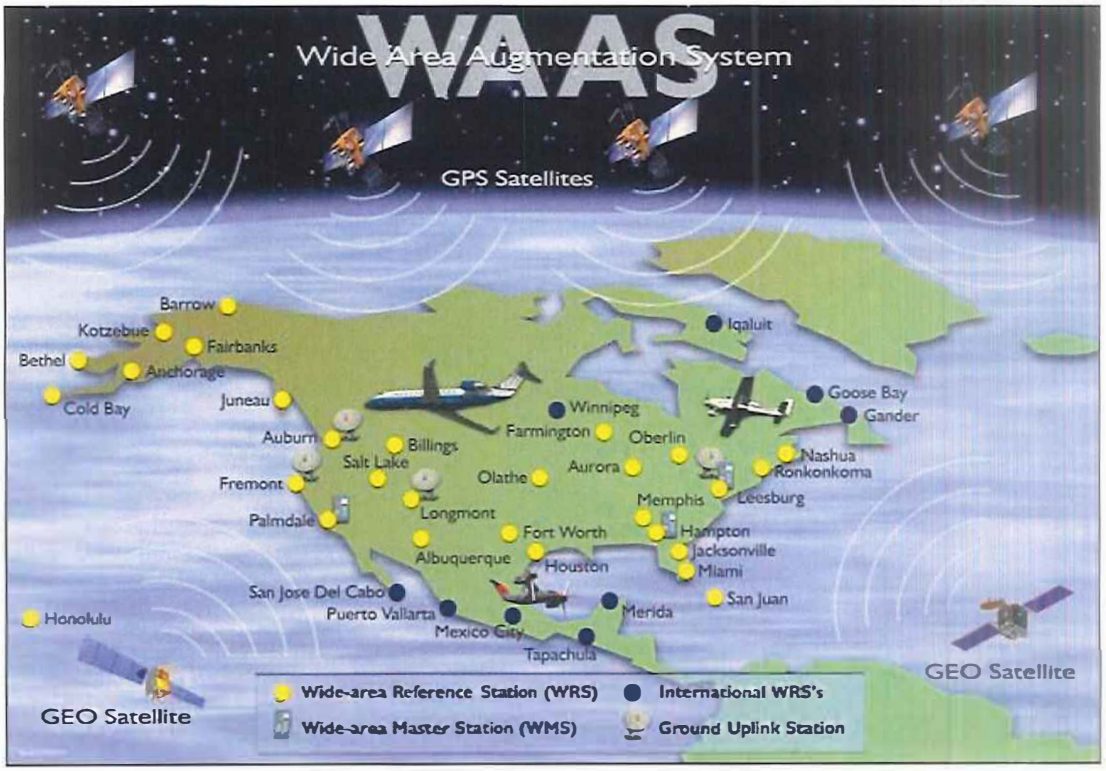
Appendix B

Wide Area Augmentation System (WAAS) in Mexico

The United States (U.S.) Federal Aviation Administration (FAA) has completed the Wide Area Augmentation System (WAAS) in the U.S. Importantly, cooperation with the Canadian and Mexican governments has extended the WAAS system into Canada and Mexico.

B.1 Background

WAAS is the U.S. implementation of Satellite-Based Augmentation System (SBAS). Europe, India, and Japan also have SBASs. SBAS consists of a set of Global Navigation Satellite System (GNSS) reference stations in surveyed locations over a wide area. See Figure 1 for the distribution of WAAS Reference Stations (WRSs). The WRSs receive GNSS signals that are subsequently sent to a WAAS Master Station (WMS), which are also shown in Figure 1. Since the WRSs are in surveyed locations, the WMS is able to determine errors from each satellite. Also, the WMS can detect if any GNSS satellites are malfunctioning and provide integrity information to users.



Source: FAA

Figure 1. Distribution of WAAS Reference and Master Stations

The WMS creates a grid of error corrections for the service area (Alaska, Canada, the U.S., and Mexico for WAAS). These corrections are uplinked to a Geosynchronous Satellite (GEO). The GEO transmits the information to the user. Also, if a GNSS

satellite is transmitting incorrect information, WAAS will notify the user to not use the satellite.

WAAS provides sufficient accuracy and integrity to provide vertically-guided approaches to airports. These approaches, called Localizer Performance with Vertical (LPV) are equivalent or nearly equivalent to Instrument Landing System (ILS) Category I approaches. An advantage of WAAS is that there is no navigation equipment required at the airport (but the airport requires appropriate runways and markings).

WAAS performance in Mexico is very good. See Figure 2. The areas in red provide more than 95-98% availability of LPV. This is at minimal cost to Mexico, since the U.S. largely pays for the cost of WAAS.

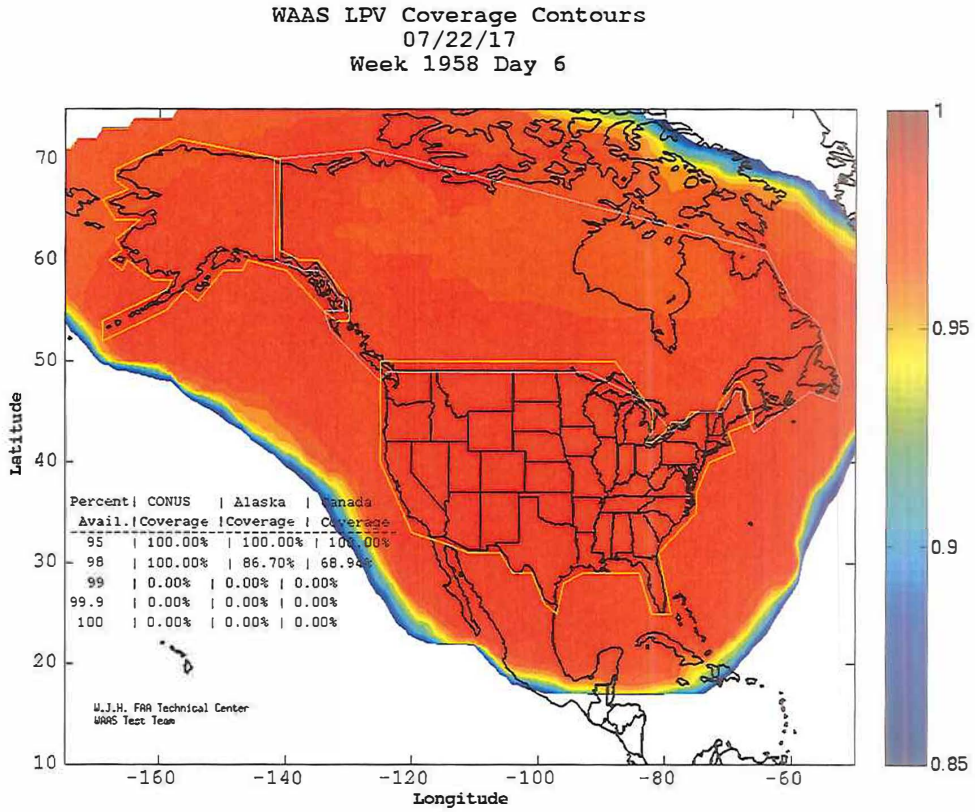


Figure 2. WAAS LPV Coverage in North America

WAAS avionics are widespread in the U.S. for General Aviation (GA) aircraft. Airline aircraft have been slow to equip, but are now beginning to do so since WAAS is advantageous for Automatic Dependent Surveillance-Broadcast (ADS-B), which is mandated in the U.S. starting in 2020. The extent of WAAS avionics equipage in Mexico is not known by MITRE.

B.2 Advantages and Disadvantages for WAAS in Mexico

The following provides some positive and negative considerations regarding the application of WAAS in Mexico for consideration by decision-makers.

Advantages

- WAAS can provide LPV approaches to all runways without the necessity of installing navigation equipment at the airport.
    - An obstacle survey and approach procedure design are required.
- WAAS is largely paid for by the U.S.
- WAAS can also provide high availability of ADS-B.

Disadvantages

- Airline avionics equipage is low, so WAAS would not be advantageous for NAICM until equipage increases.
- The extent of aircraft avionics equipage in Mexico is not known by MITRE.

B.3 Recommendations

MITRE recommends that Mexico consider using WAAS in Mexico. Mexico should work with users to determine the forecasts of WAAS avionics equipage. For safety purposes and to improve airport access, MITRE recommends that Mexico develop LPV approaches to all runway ends in Mexico if avionics equipage warrants.