Enclosure 3

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MITRE

Center for Advanced
Aviation System Development

Advanced Navigation Capabilities of Aircraft Operating in the Mexico City Area

A General Assessment

Prepared for

Aeropuertos y Servicios Auxiliares

November 2013

1. Introduction

MITRE is supporting Mexico's Aeropuertos y Servicios Auxiliares (ASA) in determining the aeronautical feasibility of constructing a new major international airport at Texcoco. As part of that determination, MITRE has concluded that advanced navigation, such as Area Navigation (RNAV), and/or Required Navigation Performance (RNP) procedures may be needed to support future operations (i.e., triple independent approaches). Whether these types of procedures would be beneficial and therefore warrant development depends largely on the proportion of appropriately equipped aircraft utilizing the new airport.

In order to obtain a better understanding of the current equipage of aircraft operating in the Mexico City area, as well as future air carrier equipage plans, two of MITRE's top experts in the field of advanced navigation procedures and requirements visited Mexico to meet with representatives from six Mexican air carriers.[1] The goal of the visit was to ascertain the current RNAV/RNP status of their fleets operating at the two main airports in the Mexico City basin: Benito Juárez International Airport (Aeropuerto Internacional de la Ciudad de México, hereafter referred to as AICM) and Licenciado Adolfo López Mateos International Airport (hereafter referred to as Toluca). In addition to the current RNAV/RNP capabilities of the air carrier aircraft, the MITRE engineers were also interested in their intermediate and long-term equipage plans.

The results of that visit are described in this report to provide important background information to ASA. Additional information on air carrier equipage situations in the United States (U.S.) has been provided in the appendices of this report for comparison purposes.

This document is organized into several sections. Section 2 provides a brief description of the Performance-Based Navigation (PBN) concept and Flight Management Computers (FMCs). Section 3 discusses some of the key lessons learned by the U.S. and others over the course of development and implementation of RNAV/RNP procedures. That is followed by Section 4, which is an overview of MITRE's visit to Mexico to meet with representatives from the major Mexican air carriers. That section includes a description of air carrier operations at both AICM and Toluca and the level of RNAV/RNP fleet capability of those operations. The final part, Section 5, provides closing remarks. The appendices at the end of the document provide additional complementary information that may be of interest to ASA.

2. Performance-Based Navigation and Flight Management Systems

The International Civil Aviation Organization (ICAO) describes PBN as a "*framework that can be applied to an air traffic route, instrument procedure, or defined airspace. PBN provides a basis for the design and implementation of automated flight paths as well as for airspace design and obstacle clearance. The two main components of PBN framework are Area Navigation (RNAV) and Required Navigation Performance (RNP). Once the required performance level is established, the aircraft's own capability determines whether it can safely achieve the specified performance and qualify for the operation*". The PBN concept defines

[1] The visit by the MITRE experts was conducted in November 2012 as an enhancement to a previous project.

navigation performance in terms of accuracy, integrity, availability, continuity, and functionality. This concept represents a new paradigm for aircraft navigation.

RNAV enables aircraft to fly on any desired flight path within the coverage of ground- or spaced-based navigation aids, within the limits of the capability of aircraft self-contained systems, or a combination of both capabilities.

RNP is RNAV with the addition of an onboard performance monitoring and alerting capability. A defining characteristic of RNP operations is the ability of the aircraft's navigation system to monitor its own navigation performance and inform the crew if the requirement is not met during an operation. Onboard monitoring and alerting enhances the pilot's situational awareness and can enable reduced obstacle clearance. Certain RNP operations require advanced features of the onboard navigation function. These operations are characterized as Authorization Required (AR), as in addition to equipment requirements, aircrews must also meet specific training requirements and crew procedures.

An aircraft's Flight Management System (FMS) consists of navigation radio receivers; inertial reference systems; air data systems; navigation, flight, and instrument displays; flight control systems; engine and fuel systems; and data link. These subsystems are managed and processed by an FMC. The FMC provides the primary navigation, flight planning, optimized terminal routes, and enroute guidance for the aircraft and is typically comprised of interrelated functions such as navigation, flight planning, trajectory prediction, performance computations, and guidance.

However, as with all emerging technologies there have been "glitches" and unintended consequences along the way towards implementation. The following section highlights some of the lessons learned by the U.S.

3. RNAV/RNP Implementation: Lessons Learned

Today, U.S. airspace planners and procedure designers realize that there are many issues regarding RNAV that were not recognized in the beginning of RNAV implementation. MITRE has a long history of supporting the U.S. Federal Aviation Administration (FAA) in RNAV/RNP development and implementation, and has been instrumental in addressing these issues. For example, the FAA specifically tasked MITRE with developing a systematic, repeatable process for the development and implementation of PBN in the U.S. MITRE has played a leading role in identifying and resolving PBN implementation challenges and supporting the FAA in developing new criteria and standards that will enable the transition from conventional navigation to full PBN implementation. Perhaps no other country has the practical experience of RNAV/RNP development than the U.S. This section highlights some of the more important lessons learned by the U.S. during the course of PBN implementation as they relate to aircraft equipage. Appendix A provides an overview of RNAV/RNP implementation in the U.S.

3.1 RNAV Equipage

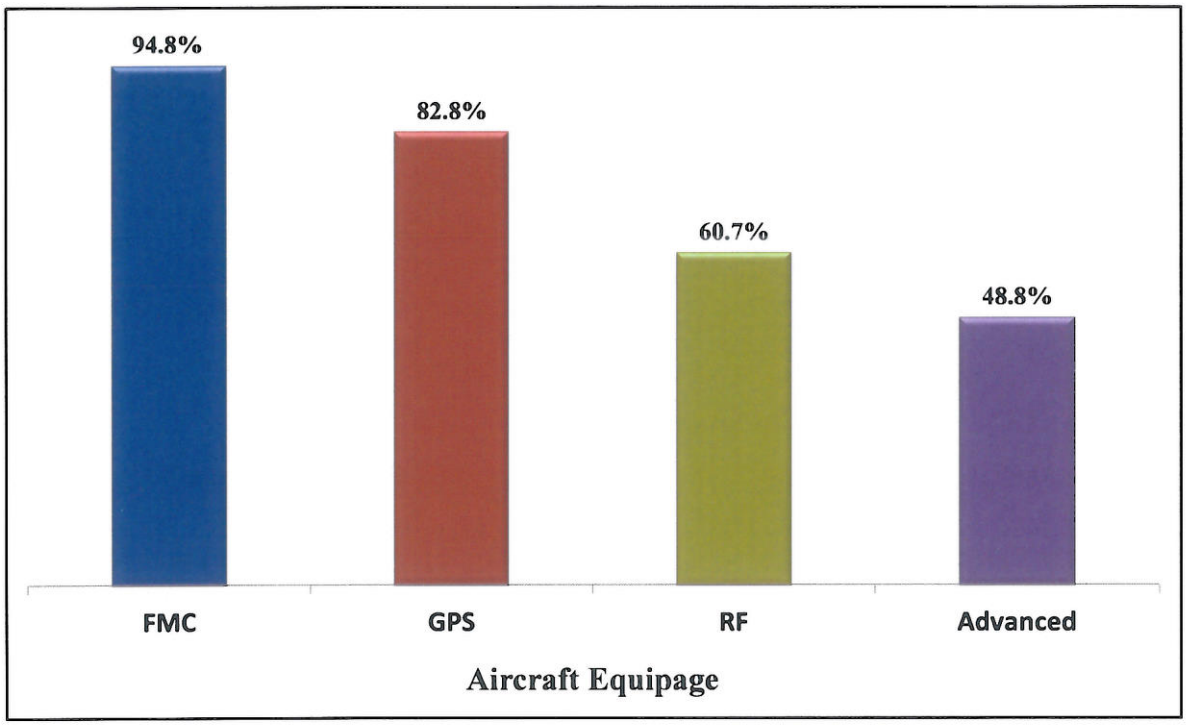
Before the development of RNAV/RNP procedures are even considered for a particular airport, the RNAV/RNP equipage level of the customer base (i.e., air carriers and others as

appropriate) should be determined. This requirement is detailed in the ICAO *Performance-Based Navigation (PBN) Manual, Doc 9613*. The level of RNAV/RNP equipage will determine whether or not the development of RNAV/RNP procedures is even warranted. The FAA has determined that an RNAV equipage level between 75-80% is needed for these types of procedures to be used productively. This figure was based on an extensive number of interviews with air traffic controllers who noted that their workload increased once the proportion of RNAV-equipped aircraft dropped below 75%.

To address this need, MITRE has developed an analysis tool capable of assessing the aircraft RNAV/RNP capability at individual airports, both domestic and foreign. The tool uses a variety of data including a MITRE-developed and maintained RNAV/RNP capability database of U.S. and foreign air carriers who operate within the U.S. This information is used by airspace planners and procedures designers to develop procedures appropriate to the capabilities of aircraft operating at a specific airport.

Figure 1 shows the RNAV/RNP capability of U.S. Federal Aviation Regulation (FAR) Part 121[2] aircraft (totaling 6883) as of 1 October 2012. The FMC and Global Positioning System (GPS) columns reflect the percentage of aircraft with RNAV capability. The Radius-to Fix (RF) column refers to an FMC that can process a RF (curved path) path terminator or leg type. The Advanced column represents the percentage of aircraft that are capable of an RNP AR curved approach with RF path terminators and an RNP missed approach. To fly complex RNP AR procedures, aircraft must have dual FMCs (that process RF path terminators), dual GPS, an Inertial Reference Unit (IRU), and RNP alerting. Aircrews must also receive additional training and certification to perform these types of procedures.

[2] FAR Part 121is the U.S. regulation that addresses transport category aircraft in scheduled and non-scheduled operations.



Source: MITRE-developed U.S. air transport fleet RNAV/RNP capability database

Figure 1. Percentage of U.S. Part 121 Aircraft Equipped for RNAV/RNP (6883 Aircraft, 1 October 2012)

3.2 Variations in FMCs

RNAV equipped aircraft do not consistently fly the same procedure the same way. This of course is a key goal of an RNAV procedure (i.e., that all aircraft be able to consistently fly predictable and repeatable paths where individual radar tracks overlie each other). The FAA asked MITRE to investigate the matter and to report back on differences between FMCs.

There are six major manufacturers of FMCs[3]:

- Honeywell (Air Transport and BizJet)
- General Electric Aviation (formerly Smiths Aerospace)
- Thales GE
- Rockwell Collins
- Universal Avionics
- Canadian Marconi Corporation (CMC) Electronics

[3] There are also several manufacturers of panel-mounted GPS/Global Navigation Satellite System (GNSS) systems, the two largest being Garmin International and Avidyne.

Over the course of analyzing and testing the various FMC units, MITRE has collected a very large amount of data on how FMCs and FMSs operate. MITRE established, and now maintains, a detailed database on all FAR Part 121 aircraft operating in the U.S. National Airspace System (NAS) to include their RNAV/RNP capabilities. MITRE's research has shown that the following are the four key reasons why FMCs do not lead to consistent navigational results:

- Variations of FMC path-keeping results between manufacturers
- Variations of FMC path-keeping results between different aircraft models utilizing the same FMC manufacturer (e.g., a Honeywell Pegasus computer installed in a B767 operates differently from one installed in an A340)
- Variations exist in how Aeronautical Radio Incorporated (ARINC) 424 procedures are coded. ARINC 424 coding converts a procedure into FMC format before it is loaded into a navigation database.
- Variations exist between air carrier operating procedures and pilot technique and training

Impact on RNAV/RNP Operations: from analyses conducted by MITRE, some of the FMC differences that affect procedure design and RNAV operations include:

- How Direct-to-Fix (DF), Heading-to-Altitude (VA), and Course-to-Altitude (CA) path terminators are processed from the departure end of the runway
- How RF path terminators are processed (i.e., just the final segment, all phases of flight except the final segment, or in all phases of flight)
- Converting VA path terminators to a Fix-to-Altitude (FA) path terminator
- Honoring a speed at a waypoint unless that waypoint has an associated coded altitude included
- Ability to process runway transitions
- Processing lateral offset differently
- Processing a VA to a Course-to-Fix (CF) path terminator differently
- Availability of a performance-based vertical navigation function
- Availability of a Required Time of Arrival (RTA) function and how the RTA functions in climb, cruise, and descent
- Processing a mandatory block (window or in between) altitude at a waypoint
- Differences in altitude to initially conduct lateral and/or vertical navigation automatically (50 ft Above Ground Level [AGL] on takeoff or 400 ft AGL or higher according to an air carrier's standard operating procedure)
- Requiring manual initiation of lateral and/or vertical navigation

- Ability to display estimated position uncertainty/actual navigation performance or estimated position error alerting

Impact on RNAV/RNP Procedure Design: differences in how FMCs process information requires procedure designers and airspace planners to rethink how best to design procedures. Below are some of the lessons learned when it comes to procedure design:

- Procedures unnecessarily complicated were being designed
- The length of RNAV procedures was getting much longer
- RNAV procedures from the end of the runway using ARINC 424 path terminators could not be utilized by all aircraft FMCs
- Path terminator combinations were flown so differently by various FMCs that the procedures became problematic
- RNAV-equipped aircraft did not follow the intended path on procedures with high-angle turns
- FMCs were computing different turn anticipation points
- Procedures with speeds restrictions could not be honored by all aircraft
- FMCs were determining different flight tracks for aircraft in high-angle climbing accelerating or decelerating turns
- Some FMCs handle procedures with arrival and departure runway transitions better than others
- Leg lengths between waypoints were too short
- RNAV procedures were being designed with excessive climb rates and descent rates
- There were variations on how FMCs handle turns:
  - Distance Measuring Equipment (DME)/DME
    - Requirement for runway update
    - Requirement for DME assessment
  - DME/DME/IRU
    - Requirement for runway update
    - Requirement for DME assessment
  - DME/DME/GPS
  - DME/DME/IRU/GPS
  - GPS
- Some FMCs are not capable of handling procedures with RF path terminators

4. Assessment of RNAV/RNP Capabilities in Mexico

As previously mentioned, two of MITRE's advanced navigation and air carrier avionics equipage experts travelled to Mexico City to meet with representatives of selected Mexican air carriers. The purpose of the visit was to assess the current RNAV/RNP status of the Mexican air carrier fleet and to learn about future equipage plans.

Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM) provided MITRE with aircraft operations data for AICM (26 August through 2 September 2012) and Toluca (26 August through 5 September 2012). Using these data, MITRE identified six Mexican air carriers to be included in the RNAV/RNP assessment: Aeromar, Aeroméxico, Aeroméxico Connect, Interjet, Volaris, and VivaAerobus. Prior to MITRE's visit, a sample RNAV/RNP Capability Survey Questionnaire was sent to each air carrier to help them better understand the type of information that MITRE was interested in gathering. Appendix B provides a sample of an RNAV/RNP Capability Survey Questionnaire. This type of questionnaire, once modified appropriately, can be used by ASA at the appropriate time (in coordination with MITRE) to obtain more information.

The visit proved very useful. The MITRE team held detailed discussions with representatives from Flight Operations, Pilot Training, Operations Engineering, and other departments from each air carrier. MITRE informed the air carriers that any information provided would be treated as confidential and proprietary. Therefore, only aggregate information is presented in this report. The information provided by the Mexican air carrier representatives plus MITRE's comprehensive aircraft equipage knowledge of U.S. and foreign air carriers provides an accurate and thorough assessment of the current level of RNAV/RNP capability of the six selected air carriers operating at AICM and Toluca.

4.1 Current RNAV/RNP Capabilities of Aircraft Operating at AICM and Toluca

The operations data for AICM included 7696 operations to/from AICM. Approximately 79% of the traffic at AICM during that timeframe was generated by the six Mexican air carriers mentioned above, with which MITRE held discussions. Table 1 shows the percentage breakdown of operations at AICM by air carrier and other types of operations.

Table 1. Breakdown of Operations at AICM

Air Carriers and Others	Percent
AEROMEXICO CONNECT	26.7%
AEROMEXICO	20.3%
INTERJET	14.4%
VOLARIS	7.6%
AEROMAR	7.1%
VIVAAEROBUS	3.2%
Subtotal of 6 Major Mexican Carriers	*79.3%*
FUERZA AEREA MEXICANA and Others	2.3%
UNITED	2.5%
AMERICAN	2.1%
DELTA	1.5%
MAGNICHARTERS	1.3%
COPA	0.8%
All Others	10.2%
Grand Total	*100%*

Source: AICM flight plan data 26 August 2012 through 2 September 2012
Note: Percentage values are rounded

Operations data for Toluca included 2094 operations. Toluca is a unique airport in that a large portion of their operations are General Aviation[4] (GA) with a modest number of commercial air carrier/cargo operations. Of the 2094 operations at Toluca, only 303 (approximately 14.5%) were conducted by commercial air carrier/cargo operators. Interjet and Volaris, two of the six Mexican air carriers MITRE held discussions with, operate at Toluca and account for approximately 77% of the air carrier/cargo operations. Other air carrier/cargo operators, such as Pak West Airlines, Spirit Airlines, and Federal Express also operate at Toluca, but conduct a small number of operations and, therefore, were not considered in this assessment. Furthermore, due to the large amount and variety of GA activity at Toluca, it was not possible to obtain information on the aircraft equipage of those aircraft.

Before providing the results of MITRE's equipage assessment, it is important to describe the various types of RNAV/RNP procedures, and appropriate uses for each type that exist today. The following part provides information on the levels of RNAV/RNP navigation, accuracy requirements, and appropriate usage (i.e., phase of flight) for each.

- **RNAV 2** - DME/DME aircraft as defined by the FAA Advisory Circular (AC) 90-100A and by the European Aviation Safety Agency (EASA) Acceptable Means of Compliance (AMC) 20-4 or Joint Aviation Authorities (JAA) Temporary Guidance Leaflet (TGL)-2

[4] In the context of this paper, GA mostly includes business jets.

- Accuracy ± 2.0 NM 95% of the time
- Used enroute and for Standard Terminal Arrivals (STARs) and Standard Instrument Departures (SIDs)[5]
- Relevant documents
  - AC 90-100A: *U.S. Terminal and En Route Area Navigation (RNAV) Operations*
  - EASA AMC 20-4: *Airworthiness Approval and Operational Criteria for the Use of Navigation Systems in European Airspace Designated for Basic RNAV Operations*
  - JAA TGL-2: *Airworthiness Approval and Operational Criteria for the Use of Navigation Systems in European Airspace Designated for Basic RNAV Operations*

- **RNAV 1** - DME/DME/IRU or GPS aircraft as defined in FAA AC 90-100A and EASA AMC 20-5 and 20-16 or JAA TLG-3 and -10:
  - Accuracy ± 1.0 NM 95% of the time
  - Used enroute and for STARs and SIDs
  - Relevant documents
    - AC 90-100A
    - EASA AMC 20-5: *Airworthiness Approval and Operational Criteria for the Use of the NAVSTAR Global Positioning System (GPS)*
    - EASA AMC 20-16: *Airworthiness and Operational Approval for Precision RNAV Operations in Designated European Airspace*
    - JAA TGL-3: *Interim Guidance Material on Airworthiness Approval and Operational Criteria for the use of the NAVSTAR Global Positioning System (GPS)*
    - JAA TGL-10: *Airworthiness and Operational Approval for Precision RNAV Operations in Designated European Airspace*

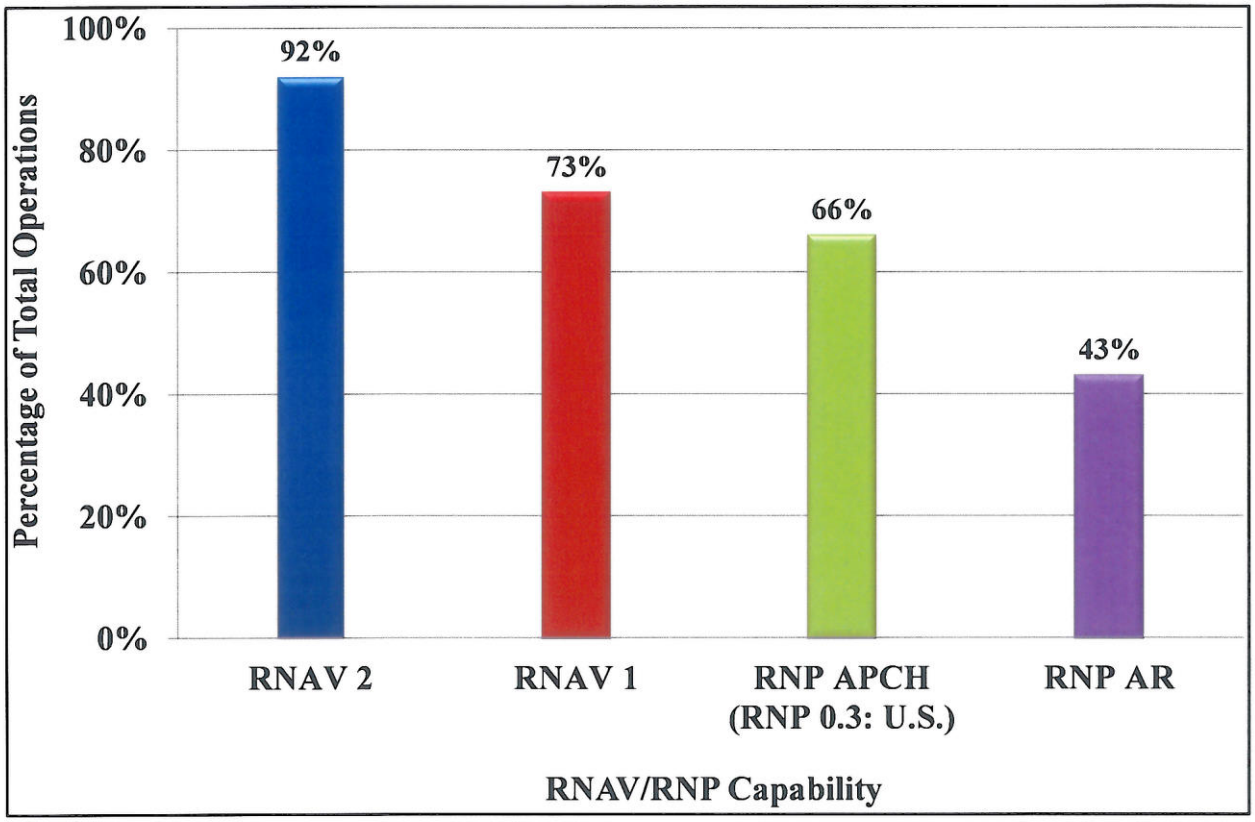
- **RNP APCH (Approach)** - GPS aircraft as defined in FAA AC 90-105 and EASA AMC 20-5, EASA AMC 20-27 (RNP 0.3 or RNAV [GPS] approach) or JAA TGL-3 and -10:
  - RNP 0.3 or greater

[5] Dependent on aircraft equipment (e.g., DME/DME are not able to update on the ground)

- Used for RNP approach or RNAV (GPS) approach
- Relevant documents
  - AC 90-105: *Approval Guidance for RNP Operations and Barometric Vertical Navigation in the U.S. National Airspace System*
  - EASA AMC 20-27: *Airworthiness Approval and Operational Criteria for RNP APPROACH (RNP APCH) Operations Including APV BAROVNAV Operations*

- **RNP AR** - Dual FMS/GPS/IRU aircraft as defined in FAA AC 90-101A and EASA AMC 20-26
  - RNP 0.3 to RNP 0.1
  - Used for RNP AR approach
  - Relevant documents
    - AC 90-101A: *Approval Guidance for RNP Procedures Authorization Required (AR)*
    - EASA AMC 20-26: *RNP Authorization Required (RNP AR) Operations*

Based on MITRE's findings, 92% of the aircraft currently operating at AICM have up to RNAV 2 capability (see Figure 2), well within the 75% to 80% RNAV requirement the FAA deems appropriate for air traffic controller mixed equipage workload. An RNAV 2 capability is appropriate for the implementation of RNAV STARs and SIDs. 73% of the aircraft have RNAV 1 capability, which is approaching the threshold the FAA deems appropriate for RNAV SID development. However, the proportions of aircraft at AICM with RNP APCH and RNP AR capability, 66% and 43% respectively, are well below what the FAA has determined as needed for these types of procedures to be used productively.



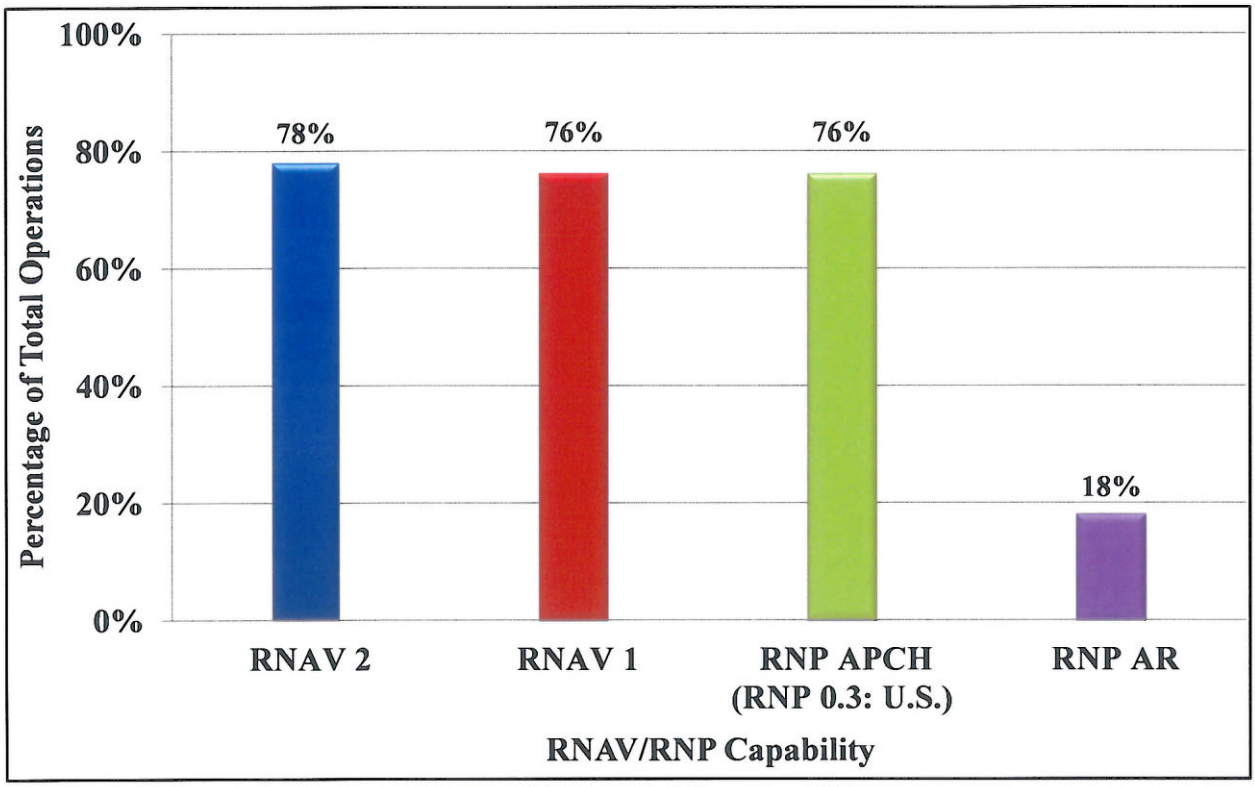
Source: AICM operations data from 26 August 2012 through 2 September 2012

Figure 2. Percentage of Operations at AICM with RNAV/RNP Capability

Assessing the RNAV and RNP capability at Toluca was a more challenging due to the high percentage of GA operations. Both the National Business Aircraft Association and the Aircraft Owners and Pilots Association state that most business jets today are equipped with GPS. Based on that assumption, MITRE assumed that all business jets operating at Toluca were equipped with GPS. Air carrier operations were also assessed separately (i.e., without considering GA) in order to provide a more accurate and useful assessment for those types of operations. As mentioned before, two of the six Mexican air carriers with which MITRE held discussions also operate at Toluca: Interjet and Volaris.

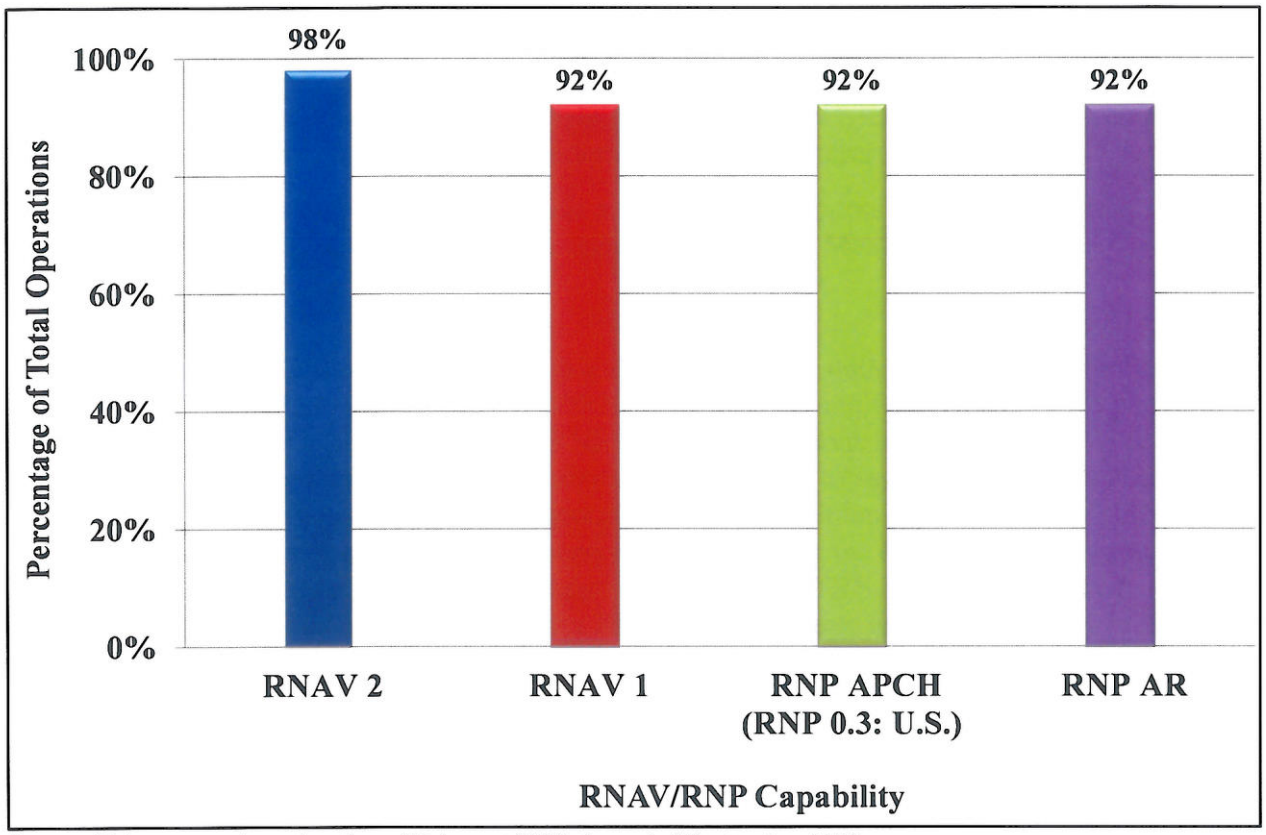
Based on the assumption that all business jets operating at Toluca have GPS, Figure 3 shows that 76% of aircraft operating at Toluca, both GA and the two air carriers (Interjet and Volaris), are capable of RNAV SIDs, RNAV STARs, and RNP APCH procedures. However, only 18% are capable of RNP AR procedures.

The two air carriers operating at Toluca are well equipped for RNAV/RNP. Figure 4 shows that 92% of air carrier operations at Toluca are capable of RNAV STARs, RNAV SIDs, RNP APCH, and RNP AR procedures.



Source: Toluca operations data from 26 August 2012 through 5 September 2012

Figure 3. Percentage of Operations at Toluca with RNAV/RNP Capability (All Operations)



Source: Toluca operations data from 26 August 2012 through 5 September 2012

Figure 4. Percentage of Operations at Toluca with RNAV/RNP Capability (Air Carrier Operations Only)

It should be noted that RNAV SIDs and STARs and RNAV GNSS approaches are already published for the airport. However, MITRE was informed by air carrier representatives that these procedures are not being used for two reasons: first, there is no government regulatory process for receiving operational approval to fly RNAV in Mexico, and second there seem to be issues with how the procedures are designed.

4.2 Future RNAV/RNP Plans

MITRE also discussed the future plans for new or retrofit aircraft with advance PBN capability with the six Mexican air carriers.

Four of the air carriers have firm orders for new fully PBN capable aircraft, such as the Boeing 737 MAX (which replaces the NG or NextGen), Boeing 787, Airbus A320-233, Airbus A320 NEO (New Engine Option), ATR72-600, and the Sukhoi Superjet 100. Each air carrier will receive deliveries of these new aircraft beginning in 2013. The air carriers also expect all their aircraft to be fully PBN capable, including RNP AR, by 2021.

A fifth air carrier was in the process of making a decision on an aircraft manufacturer to replace their entire fleet, none of which were RNAV 1 capable. Their representatives told

MITRE they were considering the B737MAX, A320 NEO, or the Bombardier CRJ1000, and that they were planning on a first delivery in 2013.

The sixth air carrier stated their entire fleet is already RNAV SID, RNAV STAR, and RNP APCH capable and, therefore, had no immediate plans for new aircraft.

All six air carriers stated that neither their aircraft nor their pilots were certified for RNAV/RNP due to the lack of a regulatory approval process in Mexico.

5. Closing Remarks

Mexico and other Latin American countries are progressing with implementation of the PBN concept and its subcomponents (i.e., RNAV/RNP). In determining which airports are potential candidates for the development of RNAV/RNP procedures, lessons learned from the U.S. and other countries have proven that a first priority should be given to assessing the RNAV/RNP capability of the aircraft operating at that airport. This report demonstrates that both Mexican and foreign air carriers operating at AICM and Toluca are ready for PBN implementation. Many aircraft operated by the six Mexican air carriers with which MITRE met have advanced capabilities now, and others will be receiving RNAV/RNP capable aircraft beginning in 2013. Moreover, these air carriers have stated that their fleets should be fully capable (i.e., through RNP AR) in the 2021 timeframe.

It is important that an additional assessment be conducted to monitor the equipage status and plans of air carrier aircraft operating in the Mexico City area. This will help to ensure that RNAV/RNP air carrier equipage information is up-to-date and appropriate actions can be taken. As part of MITRE's support to ASA, MITRE will conduct another assessment regarding air carrier equipment in order to obtain a better understanding of fleet mix avionics expectations when the new airport for Mexico City opens.

Appendix A

An Overview of RNAV/RNP Procedure Implementation in the U.S.

Aircraft with FMSs and their associated FMCs have been using RNAV in the U.S. and elsewhere in the world to fly conventional (ground-based navigation) procedures since the early 1980s. These procedures included conventional STARs, SIDs, and non-precision instrument approaches, as well as flying on enroute airways. This was done because air carriers wanted to make use of the flight automation capabilities on the flight deck, even though conventional procedures were being flown.

In the mid-1990s, the air carriers began to take delivery of more aircraft with FMCs, retiring their non-equipped aircraft such as the Boeing 727, DC-8, DC-9, DC-10, L-1011, etc., as well as most reciprocating (piston) and many turboprop aircraft. By the early 2000s, the number of RNAV-equipped aircraft increased as more RNAV SIDs, RNAV STARs, and RNAV non-precision approaches started to be developed and implemented. Additionally, FMCs were becoming more advanced. In many cases, GPS was being added to the navigation solution in the aircraft cockpit.

An early lesson learned by the U.S. was the importance of first accessing the RNAV capability of the aircraft operating at a particular airport where RNAV procedures were being considered. The FAA determined that an RNAV equipage level of approximately 75% to 80% was needed before such procedures could be used productively. This percentage was an empirical number derived from air traffic controller interviews. The consensus was that controller workload began to increase once the proportion of RNAV-equipped aircraft dropped below 75%.

Once a prospective airport was selected and RNAV procedures were developed and implemented, unexpected "anomalies" began to appear. A key goal or expectation of RNAV procedures was that all aircraft would fly the same path in the same way on a consistent basis. In other words, aircraft were to fly consistently predictable and repeatable paths where radar tracks of individual flights would overlay each other. Air traffic controllers were some of the first to recognize this was not always the case. These anomalies were due in part to differences in FMCs installed in various aircraft. The FAA asked MITRE to investigate and report on differences in FMCs and the impact of those differences on RNAV procedures. MITRE was also asked to develop a database of the FMCs installed in the U.S. transport category aircraft and to assess the capability of each computer. Section 3.2 of this document lists the principal reasons identified by MITRE as contributors to the anomalies.

The data MITRE collected and now maintains for the FAA contains an extensive amount of information on all the aircraft operating in the U.S. NAS as defined in FAR Part 121, and a compendium of their RNAV/RNP capability.

The database is also used as an input to the MITRE-developed Performance Based Navigation (PBN) Dashboard, which includes a fleet readiness Avionics Analyzer tool. The PBN Dashboard can:

- Quantify RNAV/RNP equipage density at major hub airports in the U.S. and airports around the world
- Identify airports where implementation of RNAV/RNP procedures would have the greatest benefits in the shortest time period
- Assess the benefits and analyze the effects of mixed RNAV and conventional aircraft equipage

Appendix C provides a description of the PBN Dashboard and provides RNAV/RNP equipage information for several major airports in the U.S.

The Avionics Analyzer tool makes use of the data described above and accepts data from the U.S. Enhanced Traffic Management System (ETMS) or foreign airport flight plan data. ETMS is the system used by FAA Traffic Management Personnel to predict, on national and local scales, traffic surges, gaps, and volume based on current and anticipated airborne aircraft. It allows Traffic Management Personnel the ability to evaluate the projected flow of traffic into airports and sectors, and then implement the least restrictive action necessary to ensure that traffic demand does not exceed system capacity. ETMS data are composed of radar hits updated every minute, giving position and altitude of the aircraft in range. Aircraft characteristics such as altitude, equipment type, origin, destination and flight number are then combined with the latitude and longitude of the radar hits to form the data.

Data from the AirCraft Analytical System (ACAS) and its associated Avionics Plug-in, a commercially available software tool from Flight International (AvSoft), is also used. This tool assists airspace planners and procedure designers in selecting candidate airports for the implementation of RNAV/RNP procedures and to understand the capabilities of aircraft operating at a particular airport.

Appendix B

Sample RNAV/RNP Capability Survey

The following represents a MITRE-developed sample survey that has been used to help determine the RNAV and RNP capabilities of particular aircraft within the fleet of specific airlines or aircraft operator at an airport of interest. The survey goes beyond merely ascertaining the level of on-board navigational equipment that each aircraft type has within a fleet. It is also important to be aware of airline operating policies and pilot/flight deck standard operating procedures related to the operation of these systems. This survey includes questions concerning such issues.

A survey at this level of detail would normally be sent out to a limited set of airlines that comprise at least 75% of the total operations at a particular airport. These surveys are normally sent to a single point of contact within the airline's operations department, such as the Chief Pilot or Fleet Manager. It is unlikely, however, that in a large airline, a single person would have the detailed knowledge to be able to complete the survey themselves. More likely, the survey will need to be distributed to individual fleet or aircraft type managers within the operations department.

Once the survey is completed and returned, the data should be collated into a single database from which it will then be possible to determine specific capability levels of individual operators and the capabilities of aircraft using particular arrival and departure procedures. This can assist airspace planners and procedures designers in prioritizing the implementation of RNAV or RNP procedures while also showing which routes would potentially not benefit from the implementation of such procedures due to lack of equipage.

These surveys, once developed, should be updated regularly (minimum 6 to 12 month intervals) through continued contact with the appropriate airlines so that longer-term trends in RNAV or RNP capability levels can be determined. This will also assist airspace planners in monitoring the accuracy of any forecasted changes in aircraft capabilities. These updates can be conducted through the use of a web-based survey system.

Finally, such surveys and the data derived from them can also assist the relevant regulatory authorities in decisions concerning the mandating of specific RNAV/RNP equipage levels in specific sectors of airspace.

SAMPLE RNAV/RNP CAPABILITY SURVEY

Date _____

Completion of survey by:

Name	Position	Company / Department

GENERAL QUESTIONS

1. Are all your aircraft certified for P-RNAV?

   (circle one)

   Yes No

2. If the answer to Number 1 (above) was "No," which type of aircraft are <u>not</u> certified? AND, what is the target certification date for those aircraft?

(complete only for aircraft you operate to and from Mexico City)

Examples	*B757-200*	*A319*	*A320*	*A321*	*A340-300*	*A340-600*	*ATR-72*					
Not Cert.												
Target Date												

4. Which company is your chart provider?

_____

5. Which company is your navigation database provider?

_____

6. Do your pilots use VNAV?

(circle one)

Departures:	Yes	No
Arrivals:	Yes	No
RNAV approaches:	Yes	No
NPA	Yes	No

7. What is the standard operating procedure for not being able to comply with a published minimum altitude restriction on a departure?

_____
_____
_____

8. Plans for future equipment, if not currently installed

GPS/GNSS

Yes No

SBAS (EGNOS/WAAS)

Yes No

GBAS (LAAS)

Yes No

9. Do your flight crews train for RNAV approaches?

Yes No

10. Do your flight crews train for RNP procedures?

Yes No

Aircraft Specific Questions

(Answer Yes, No, Name or with a number and complete only for aircraft you operate at Mexico City)

Examples	*B757-200*	*A319*	*A320*	*A321*	*A340-300*	*A340-600*	*ATR-72*				
Number of each type of aircraft in service today											
Number of each type of aircraft projected for service in 2020											
Number of aircraft with Dual or Single FMC	D __ S___	D__ S___	D__ S__	D__ S___	D__ S___	D__ S__	D__ S__	D__ S___	D___ S___	D__ S___	D__ S___
FMC Manufacturer											
FMC Model/Version											
RNP Certification value from the AFM											
Aircraft with AHRS only											
Aircraft with IRS (Triple/Dual/Single)	T__ D__ S___	T__ D__ S___	T__ D__ S___	T__ D__ S___	T__ D__ S___	T__ D__ S___	T__ D__ S___	T__ D__ S___	T___ D___ S___	T__ D__ S___	T__ D__ S___
Aircraft with GPS (Dual or Single)	D__ S___	D__ S___	D__ S___	D__ S___	D__ S___	D__ S___	D__ S___	D__ S___	D___ S___	D__ S___	D__ S___
When flying an RNAV departure what is the standard operating procedure altitude for engagement of the following:											
LNAV											

Examples	*B757-200*	*A319*	*A320*	*A321*	*A340-300*	*A340-600*	*ATR-72*				
VNAV											
Flight Director											
Autopilot											
DEPARTURES											
Will the FMC process a RF leg?											
Will the FMC process a DF leg as the first leg of a departure on a coded SID?											
Will the FMC process a CF leg as the first leg of a departure on a coded SID?											
Will the FMC process a FA leg as the first leg of a departure on a coded SID?											
Will the FMC process an IF not associated with the DER?											
Does the FMC process a "V" leg (VA, VI, etc.) as a heading? (some convert to "C" or course)											
ARRIVALS											
Will the FMC process a RF leg?											
Is there the capability to select STAR runway transitions in the FMC?											
APPROACHES											

Examples	*B757-200*	*A319*	*A320*	*A321*	*A340-300*	*A340-600*	*ATR-72*				
Will the FMC process a RF leg in the final segment?											
Do you have authorization to fly RNAV (GPS) approaches at other airports?											
Is there the capability to select from a menu of multiple RNAV approaches to the same runway?											
GENERAL											
Will the FMC compute RTAs											
Is the aircraft datalink capable?											

Appendix C

Performance-Based Navigation (PBN) Dashboard

The PBN Dashboard, powered by a back-end PBN Analysis System, offers several advanced reporting capabilities for analysis, design, and operational assessment of PBN in the U.S. NAS. Developed by MITRE under sponsorship of the U.S. FAA, this tool is being used to provide operational information to support development and analysis of RNAV procedures, RNP approaches, integrated airspace design, site packages, and many other studies.

MITRE developed advanced automated processing methods using various types of data to generate an extensive set of validated metrics for all major airports in the NAS on a daily basis. These metrics focus on understanding PBN operational changes in all phases of flight across the NAS and at the local level. This is a transformational capability for providing a complete operational picture of NAS-wide PBN and the ability to monitor changes in the system and their impact.

Dashboard Displays

Three PBN Dashboard displays have been implemented for the FAA. These three displays are called public, FAA observer, and analyst.

Public Display

This display is accessible to the general public through the FAA Next Generation Air Transportation System (NextGen) public website: http://www.faa.gov/Nextgen/pbn/dashboard/

As the most basic Dashboard, the public display, shown in Figure C-1, contains static information and metrics for the most current year and month available. This display is updated with new data quarterly and contains a separate page of information and metrics for each PBN airport. Each airport-specific page provides airport operations counts. List, counts, and average daily procedure usage of PBN RNAV and RNP procedures are also provided, along with airport operator equipage and a listing of the most prevalent operators at each PBN airport.

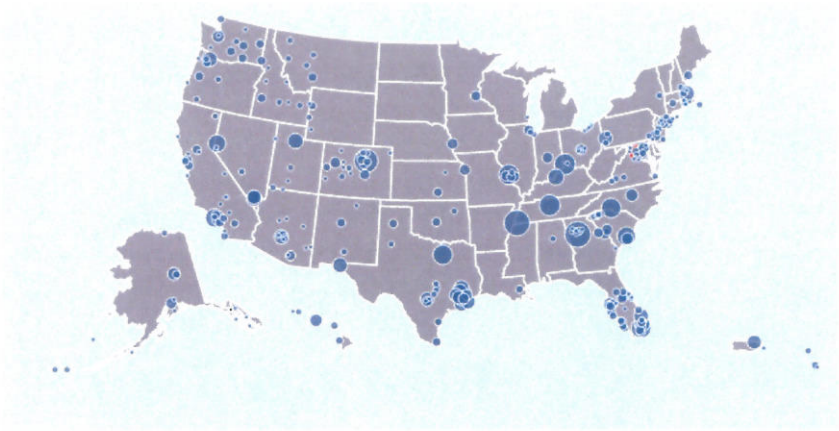


Figure C-1. Public Display of the PBN Dashboard

FAA Observer Display

The FAA observer display is accessible only from the FAA network and allows for more detailed and customized data analysis than is found in the public display. Metrics and information presented in the FAA observer display are made available for each day by total airport frequency and specific air carrier frequency.

The FAA observer display contains total airport operations and runway usage metrics, including the percentage of time an airport is in each runway configuration. The percentage of flights using each airport runway configuration is also given. This display provides the total number of PBN procedures available to candidate aircraft and the times used. Usage is available for each individual PBN Procedure. Q/T/J/V/AR route usage is also provided.

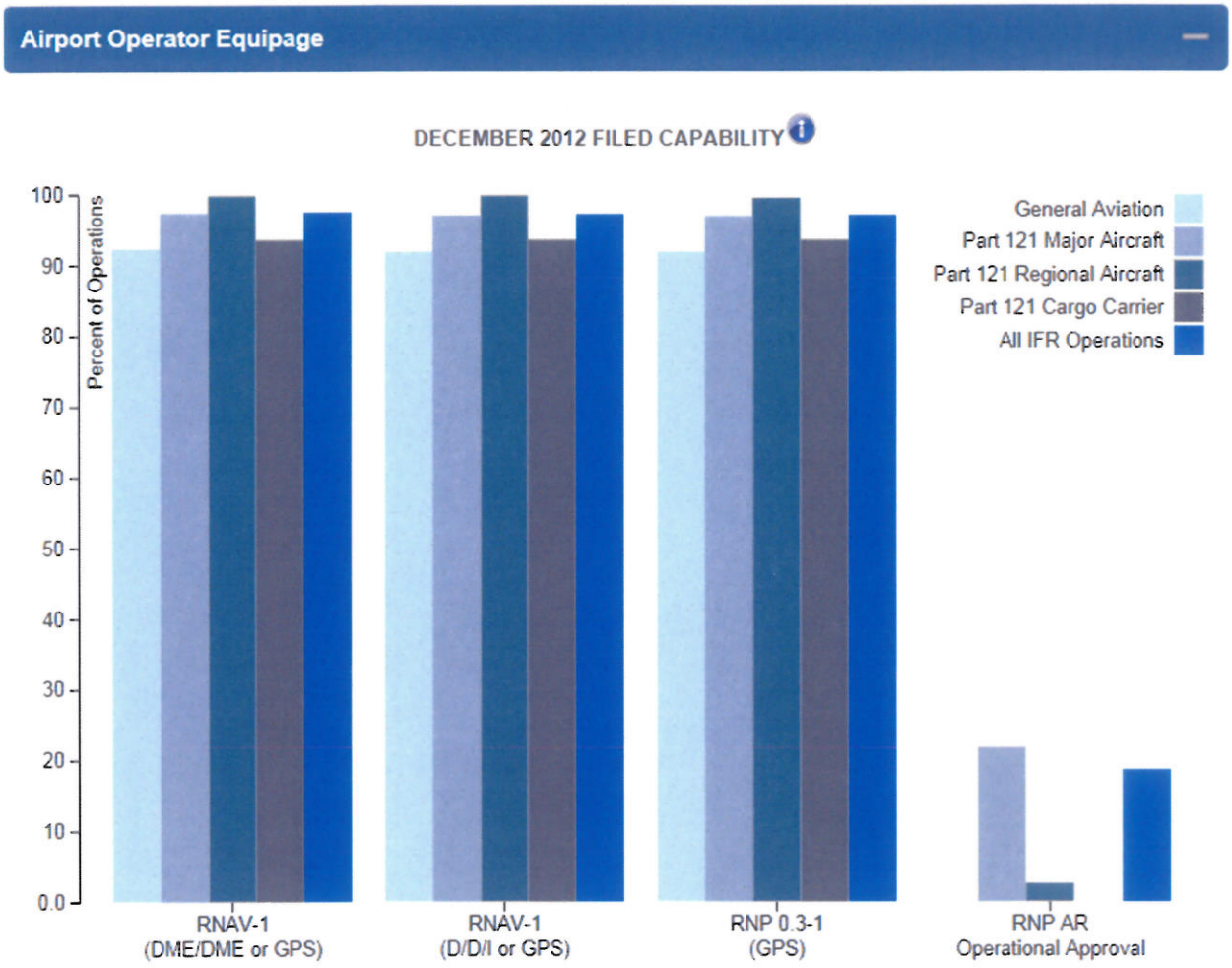
Analyst Display

The analyst display of the PBN Dashboard is accessible only from the FAA network for use by approved FAA personnel. This display contains all of the items available in the public and FAA observer displays.

Additional capabilities and metrics unique to the analyst display allow users greater ability to view changes at airports, as well as pre- and post-implementation. This display allows users to compare track time, track distance, and time in level flight differences between pre- and post-implementation PBN procedures. Differences are also available to compare post-implementation Q/T routes to pre-implementation J/V routes. Operational changes between city pairs are also tracked and provided in the analyst display. Pre- and post-implementation comparisons are further available for airport operations counts and runway usage data. Information, metrics, and data provided in the three Dashboard displays are also currently being used to support many other reporting tools, such as the NextGen Snapshot.

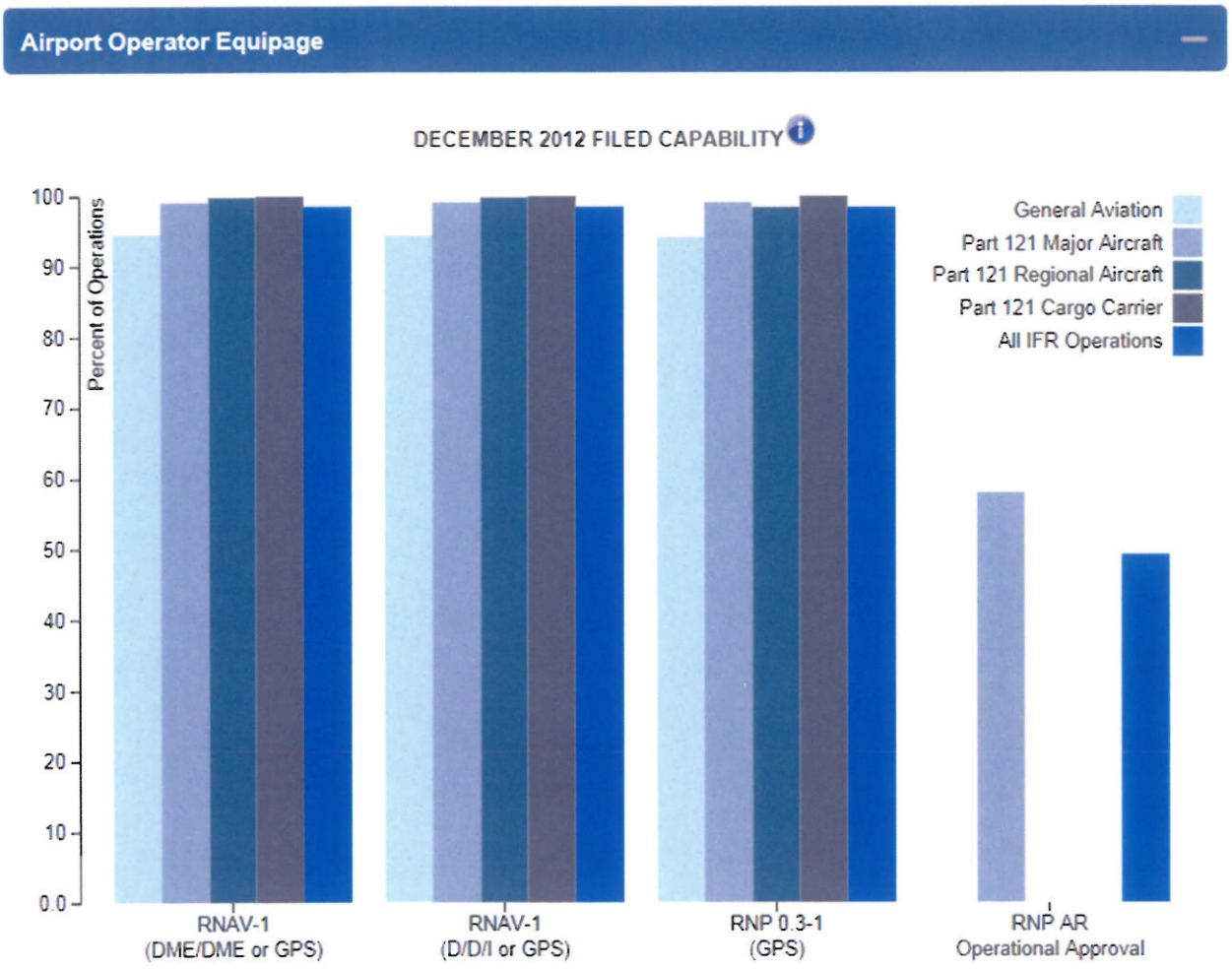
Samples of U.S. Airport RNAV/RNP Aircraft Equipage

Figures C-2 through C-5 show the RNAV/RNP capability of aircraft operating at Houston's George Bush Intercontinental Airport, Chicago Midway International Airport, John F. Kennedy International Airport, and Portland International Airport during the month of December 2012. The information is based on the flight plans filed by aircraft operating at those airports, which indicates how each aircraft is equipped.



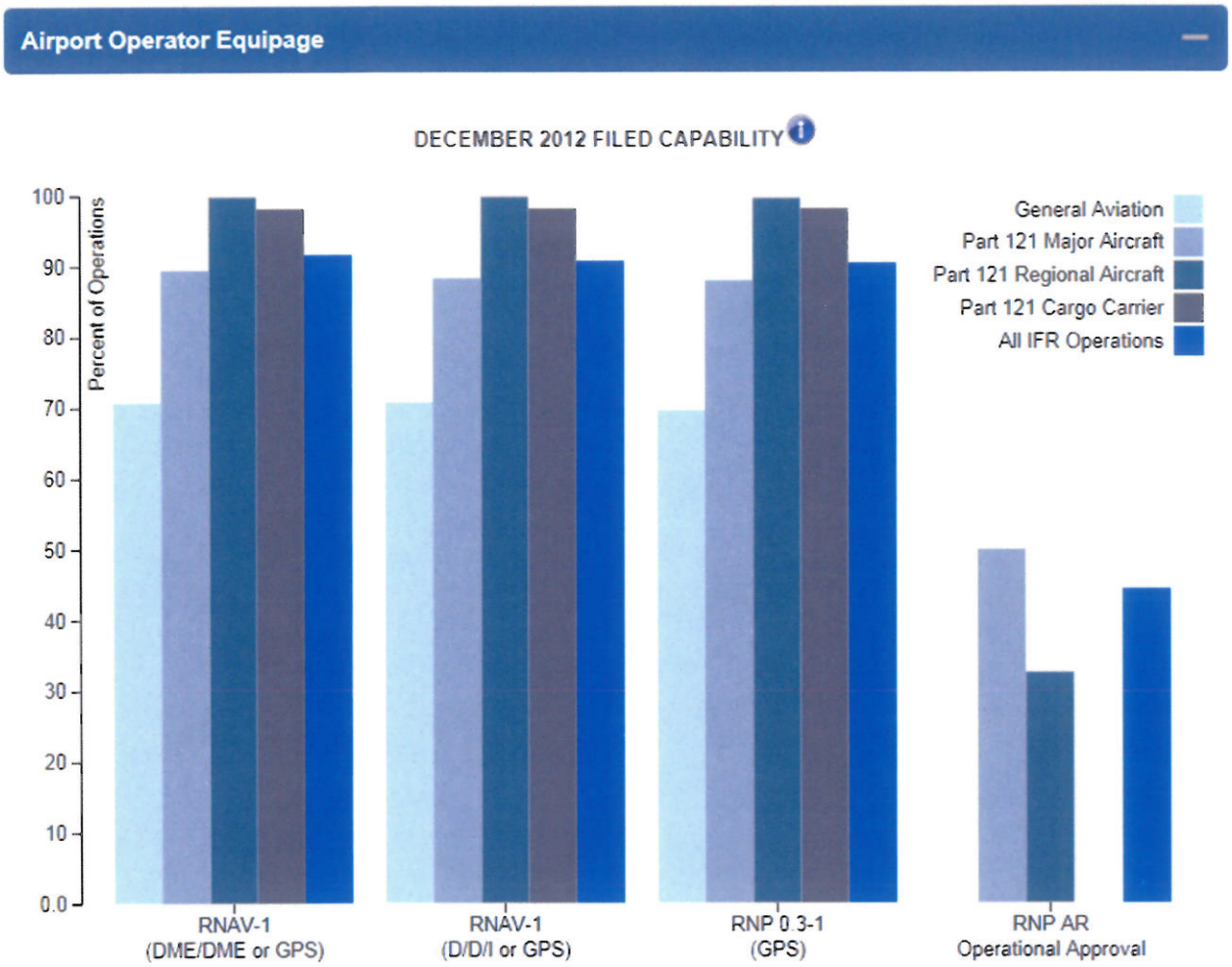
Source: PBN Dashboard (December 2012)

Figure C-2. RNAV/RNP Aircraft Equipage Operating at Houston Intercontinental



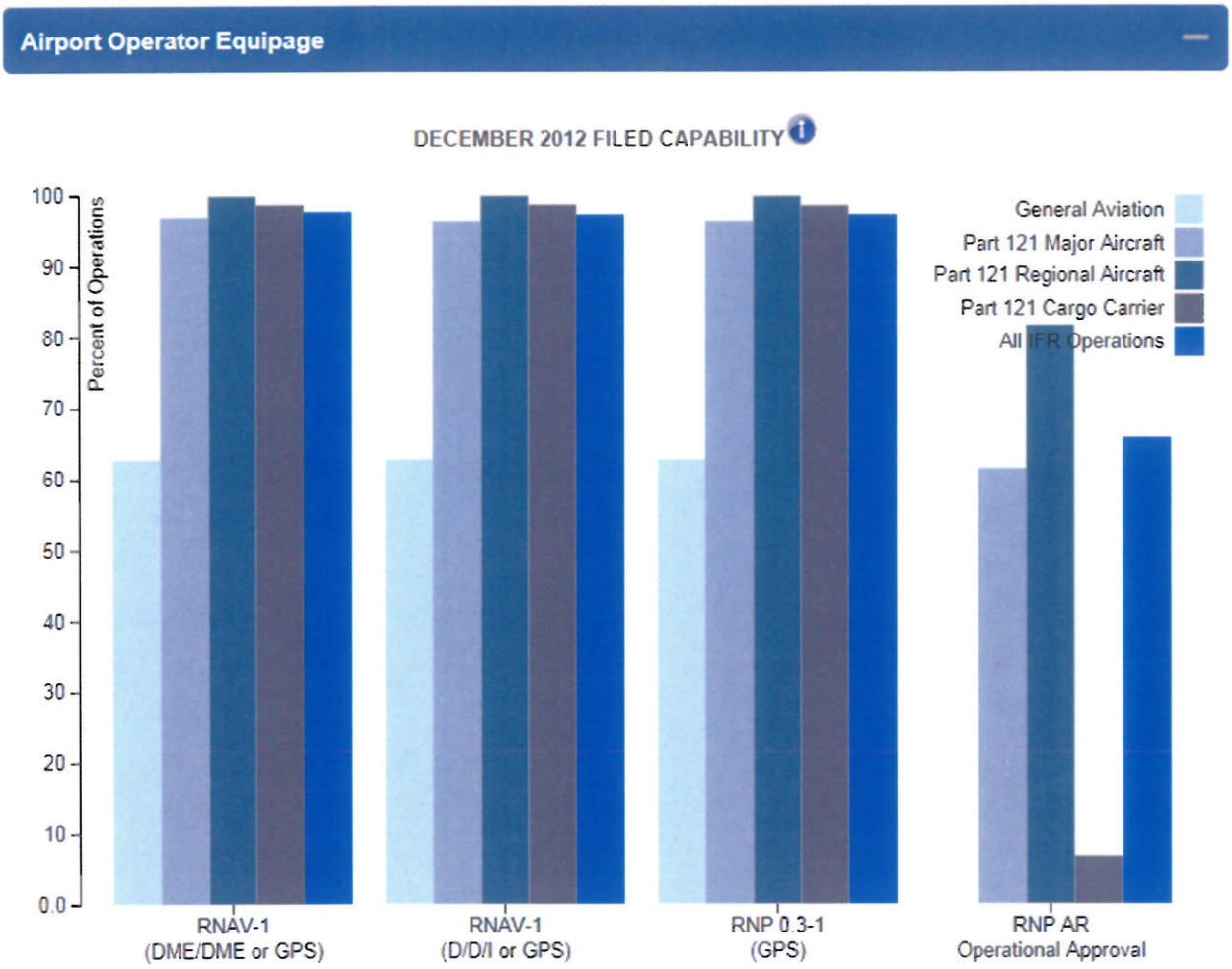
Source: PBN Dashboard (December 2012)

Figure C-3. RNAV/RNP Aircraft Equipage Operating at Chicago Midway



Source: PBN Dashboard (December 2012)

Figure C-4. RNAV/RNP Aircraft Equipage Operating at John F. Kennedy



Source: PBN Dashboard (December 2012)

Figure C-5. RNAV/RNP Aircraft Equipage Operating at Portland