



## NextGen for Airports, Volume 1: Understanding the Airport's Role in Performance-Based Navigation: Resource Guide

### DETAILS

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# C Case Studies

This section documents the following case studies conducted for the ACRP 03-34 project:

- Hartsfield-Jackson Atlanta International Airport—PBN Departure Implementation.
- Denver International Airport—PBN Departure, Arrival, and Approach Implementation.
- Henderson Executive Airport—PBN Departure, Arrival, and Approach Implementation.
- Houston Metroplex—PBN Departure, Arrival, and Approach Implementation.
- Minneapolis/St. Paul International Airport—PBN Departure and Arrival Implementation.
- Seattle-Tacoma International Airport—PBN Departure, Arrival, and Approach Implementation.

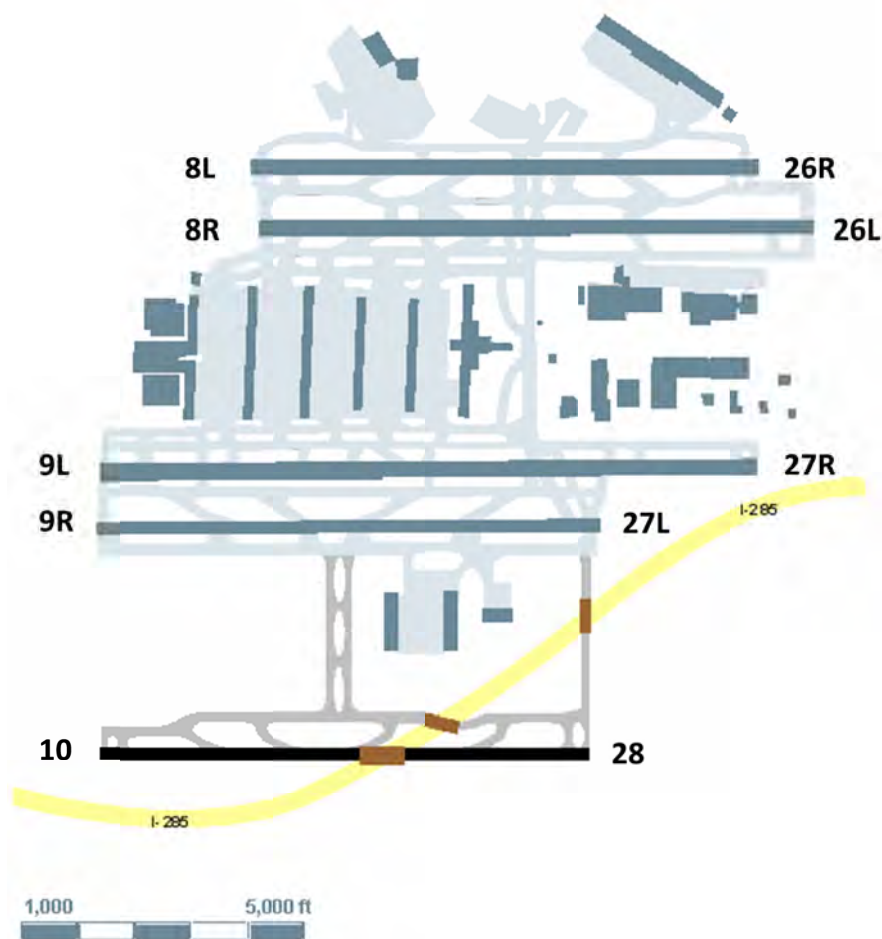
## Hartsfield-Jackson Atlanta International Airport—PBN Departure Implementation

PBN departure implementation was initiated by ATCT personnel to increase capacity. The project team engaged the primary stakeholders in the project including Atlanta TRACON (A80), Delta Airlines, and the ADOA. The team developed new procedure design criteria that supported implementing dual eastbound and westbound departure routes from individual runways into the existing airspace. Community outreach served to educate the community regarding the proposed procedures and address their concerns regarding noise in the design.

### Introduction

According to FAA data, the Hartsfield-Jackson Atlanta International Airport (ATL) has been one of the busiest airports in the world for many years, both in passenger traffic as well as the number of landings and take-offs (operations). Several NextGen capabilities and enabling improvements have been implemented, including Airport Surface Detection Equipment — Model X (ASDE-X), OPD, Automated Terminal Proximity Alert (ATPA), PBN procedures and airspace redesign, basic rerouting, and Adjacent Center Metering, Expanded Low-Visibility Operations Using Lower Runway Visual Range Minima, Wake Recategorization, Phase 1, and Dual Independent Parallel Operations. These improvements are described in ACRP Project 01-27, “NextGen—A Primer.”

The airport operates five runways. The runways are depicted in Figure C-1. Two of the runways are designated as primary arrival runways (Runways 8L-26R and 9R-27L) and two runways are designated as primary departure runways (Runways 8R-26L and 9L-27R). The fifth runway (Runway 10-28) is used for arrivals or departures depending upon the flow and demand. ATL has two terminals with seven concourses, and is a focus city for Southwest Airlines and primary hub of Delta Air Lines and Express-



Source: Federal Aviation Administration

**Figure C-1.** Plan view of Hartsfield-Jackson Atlanta International Airport.

Jet; at nearly 1,000 flights a day, the Delta hub is the world's largest airline hub. In 2013, ATL had 45,308,407 enplanements and 868,359 operations.

The FAA's NextGen Metroplex initiative is currently redesigning airspace and addressing airspace inefficiencies, introducing new PBN procedures, and making use of time based flow management (TBFM) to make the Atlanta Metroplex airspace more efficient and improving access to its airports. The effort focuses on four airports, including Hartsfield-Jackson Atlanta International (ATL), Fulton County Airport-Brown Field (FTY), DeKalb-Peachtree (PDK), and Cobb County Airport-McCollum Field (RYY).

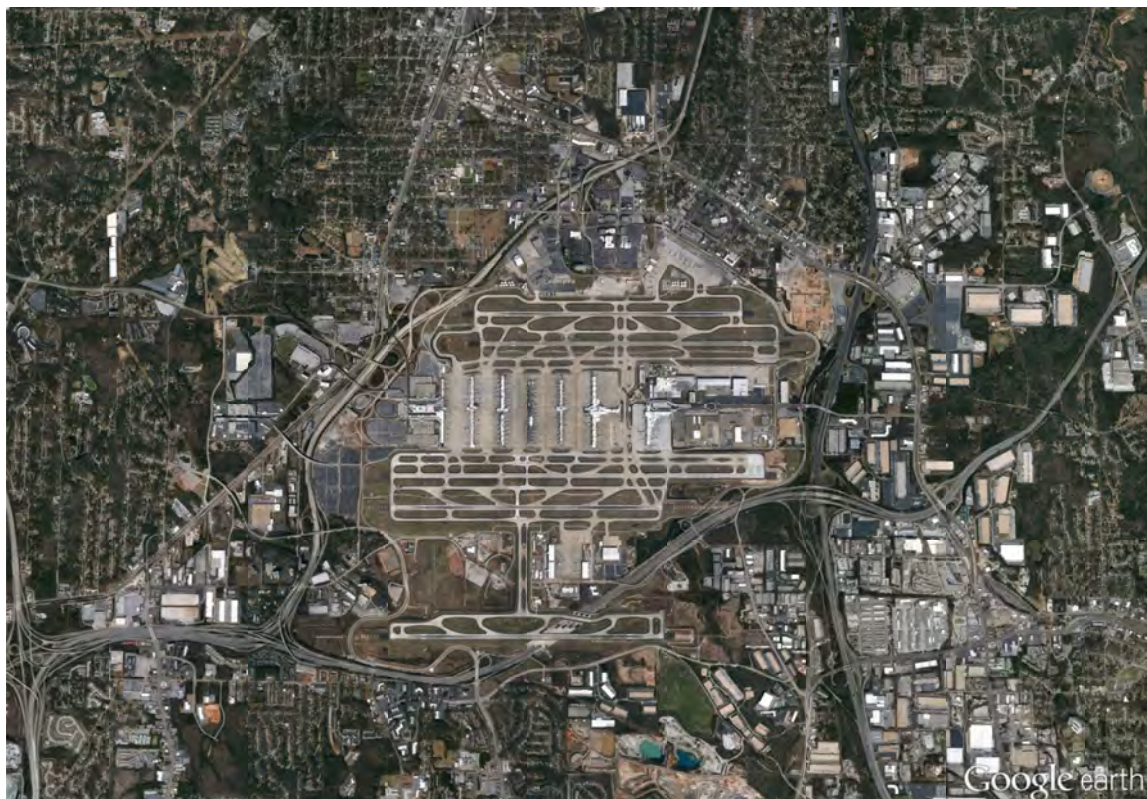
The three other airports within the Atlanta Metroplex are general aviation reliever airports. FTY is located approximately seven miles west of Atlanta's central business district. It is categorized as a local Class D general aviation reliever airport for Hartsfield-Jackson International Airport. FTY has three runways and in 2013 had 397 enplanements and 97,370 operations. FTY has an FAA-operated control tower. PDK is located in Chamblee, Georgia, just northeast of Atlanta. It is categorized as a general aviation reliever airport for the region and has one airline service with Southern Airways Express. The airport is the second-busiest airport in Georgia in the number of flight operations per year and is the seventh-busiest general aviation airport in the U.S. In 2013, PDK had 2,119 enplanements and 284,308 operations. RYY is located 21 miles northwest of central Atlanta. The airport has one runway and is categorized as a general aviation reliever airport for Hartsfield-Jackson International Airport and is home to two charter companies. In 2013, RYY had 265 enplanements and 133,144 operations.

The FAA's PBN Dashboard provides analysis of the equipage levels among general aviation, Part 121 major, regional, and cargo aircraft, as well as IFR operations at ATL as of January 2015 (Federal Aviation Administration 2015). The results indicate that almost all Part 121 aircraft and IFR operations, and 70% of general aviation aircraft, are capable of RNAV with lateral navigation precision of 1 nautical mile (RNAV 1). One hundred percent of the Part 121 regional aircraft, but only 70% of the other categories, are capable of RNP with lateral precision within 0.3 to 1 nautical mile (RNP 0.3-1). Only 30% of general aviation and IFR operations, and essentially none of the Part 121 aircraft, are capable of RNP AR. The FAA's PBN Dashboard indicates ATL has an inventory of 16 RNAV SIDs, seven RNAV STARs, and four RNP approach procedures.

The focus of this case study is the ATL PBN departure implementation project that was initiated in 2007 by ATCT personnel as a way to increase capacity. The project team engaged the primary stakeholders in the project including Atlanta TRACON (A80), Delta Airlines, and the ADOA. The project team also coordinated with a noise advocacy group representing College Park, East Point, and Lake City. FAA personnel provided RNAV and RNP procedure design with input from Delta Airlines, ADOA, and a governmental liaison from the surrounding community. DAL served as the lead carrier in the project, performing flyability assessment from an aircraft performance and pilot's perspective, and ADOA prepared the EA as part of the project.

## Demographics

The land use in the areas immediately surrounding ATL is mostly industrial and commercial with some medium-income residential development to the west and northwest. Figure C-2 depicts ATL and the surrounding community.



Source: Google Maps

**Figure C-2.** Hartsfield-Jackson Atlanta International Airport and the surrounding area.

## Project Description

The PBN departure implementation project was a follow-on to work previously conducted in 2004 that resulted in the implementation of RNAV STARs and SIAPs. RNAV SIDs were originally proposed for the east and west airport configurations as part of this project. However, automation issues were encountered due to the number of en route transitions, rendering the design infeasible. Project efforts were continued by the National Airspace Redesign group and were ultimately taken over and “championed” locally through efforts by ATCT and A80 personnel. The project focused on the implementation of 16 SIDs, each of which is acceptable to any of the five runways at ATL and compatible with automation. Delta Airlines saw potential for increased capacity at the airport and participated in the effort as the lead carrier. The local personnel recommended several key changes in procedures and technologies to enable the PBN departure implementation:

- Updates to the video map for controllers in order to better define the flight tracks for easier blunder identification.
- Requirements for the tower controller to validate the first fix that the aircraft has in its FMS in order to verify pilots have the correct SID loaded in their FMS, thereby eliminating blunders and ensuring separation.
- Changes to the airport ATCT’s procedures so that the tower controller maintains control of the departure until the aircraft initiates the first turn, then hands control of the departure off to the A80 Departure Controller. This procedure serves to verify aircraft are travelling in the correct direction, ensures proper separation, and avoids blunder occurrences when aircraft are transitioning between the radio frequencies of the ATCT Local and A80 Departure Controller.
- The concept and preliminary design of the procedures were developed locally and then handed off to the FAA PBN Office and Flight Standards in Washington, D.C.

## Processes Used

The processes used for the development were based on the National Airspace Redesign program and local initiatives for the development of the preliminary procedures. The local FAA served as leaders and “champions” of the project, working with the airport, community, and FAA headquarters to find solutions to challenges as they arose. When the official request for the development of the procedures was made, the existing work was folded into the FAA 18-step process and the guidelines identified in FAA Order 7400.2 Procedures for Handling Airspace Matters.

## Criteria Development

The RNAV design was based on the use of two new departure routes that provided less than 15 degrees of separation (current minima) from parallel or concurrent runway operations. New ELSO separation criteria were developed and implemented to allow air traffic control personnel to use any combination of RNAV (GPS or RNP) departures for parallel dependent and simultaneous independent operations from dual/triple parallel runways separated by at least 2,500 feet. The ELSO criteria development began with an initial PowerPoint presentation explaining the design concept. The A80 manager and the project leader met with FAA PBN Office and Flight Standards representatives in Washington, D.C. to brief the concept. FAA Flight Standards indicated the need for a SMS review and approval in order to approve the concept.

Following the meeting, The MITRE Corporation was engaged to develop the safety case for ELSO and assist in the safety case analysis. MITRE assembled a team to analyze runway spacing, stagger, airport geometry, and other parameters to compute the divergence required to provide the level of safety

equivalent to vectoring. The key technical component was crediting the lateral containment afforded by the RNAV capability of the aircraft with meeting the separations implied in established minimum requirements. The findings were forwarded to the FAA Safety Risk Management panel for review, validation, and approval. The ELSO criteria were approved in 2008 as a waiver to criteria. The criteria are applicable at other airports in the NAS and are in the process of being incorporated into upcoming revisions to the FAA Joint Order 7100.65 Air Traffic Control.

These new criteria allow a reduced angle between the departure routes from the minimum 15 degrees to as little as ten degrees on parallel runways spaced 2,500 feet or more apart. This permits simultaneous independent operations, not staggered dependent operations in Instrument or Visual Flight Rules (IFR or VFR), with aircraft side-by-side, with ten degrees divergence during the departure. ELSO applies to successive same-runway and non-closely spaced parallel runway departures from three or four runways. That is, successive departures diverge by ten degrees, including aircraft from parallel runways. There are no weather restrictions on ELSO other than SID takeoff minimums, which vary by runway based on their local obstructions. However, during certain wind conditions the ELSO operations are discontinued due to the potential for wind drift of aircraft reducing separation. The discontinuance of ELSO is based on the judgment of the A80 or ATCT controllers. A crosswind component in excess of 25 knots or when an aircraft is observed drifting too far north or south are general rules of thumb for shutting down ELSO. When ELSO is discontinued, departure throughput decreases because operations revert back to radar vectors procedures with aircraft separated by 15 degrees. ELSO may also be discontinued due to errors in the GPS signal, bad navigation databases, and other causes.

## Project Communication and Public Outreach

The ATL PBN departure implementation project was a collaborative effort between FAA ATCT, A80, Delta Airlines, and residential communities of College Park, Lake City, and East Point. FAA ATCT met multiple times with Delta Airlines and ADOA personnel to discuss the design of the procedures, flyability, flight tracks, and potential environmental impacts. Delta Airlines flight technical representatives worked with the FAA on the flyability and equipage issues. The ADOA agreed to prepare and fund an EA associated with the new procedures.

Local FAA project representatives met multiple times with city officials and an advocate representing the communities of College Park, East Point, and Lake City. At these meetings FAA shared the entire project history, what they were doing, why the flight procedures were designed as they were, and communicated that they were trying to find the best possible design of the procedures to satisfy the noise sensitivities of the community. These outreach efforts were able to alleviate community concerns about the project.

A number of design choices were made to mitigate the impact of noise on the surrounding communities. Woodward Academy High school is located northwest of the airport in College Park. The community asked FAA to extend the initial departure leg out to 1.2 miles for aircraft prior to a turn. Aircraft would proceed straight out further before their initial turn, avoiding the school. Residents of East Point were concerned about the northwest departure routes. Of the three departure routes, referred to as the 290, 280 and 270 routes, the 290 route from Runway 26L went over a bridge. The community requested the routes to be farther north of the bridge. The FAA was able to fit in the 4<sup>th</sup> departure route while avoiding moving the northwest 290 departure route farther north beyond the bridge. The southwest route from Runway 10 went over Lake City. Lake City residents wanted the route farther south or north. The FAA was able to use the same waypoint for Runway 9L departures and employed reduced divergence criteria with the departure route from Runway 10 to obtain this goal. The design of the SIDs still gained all the desired efficiencies but minimized their impact on the surrounding community.

## Environmental Analysis

The ADOA agreed to lead the environmental effort for the project and was able to combine the analysis into the EA for the extension of Runway 9L-27R. The EA was conducted following NEPA standards and guidelines. A FONSI ROD was issued by FAA in August of 2009.

## Project Outcomes

Outcomes from the Atlanta PBN departure implementation project include:

- Development and implementation of 16 PBN departure procedures.
- Establishment of ELSO criteria.
- Implementation of two new departure routes enabling simultaneous and concurrent departures along five diverging headings to the east and five diverging headings to the west.

## Post-Implementation Metrics

The airport's primary metric in assessing the impact of the new departure procedures is airport departure throughput. The new design results in an increase of eight to 12 additional departures per hour. The increases can be attributed to the addition of two new departure paths that can be used in simultaneous parallel operations, concurrent operations, reduced departure spacing distances, reduced departure spacing time, and improvements in continuous climb performance. The airport also investigates noise complaints on a case-by-case basis by analyzing flight tracks in response to individual noise complaints. The airport does not continuously monitor or evaluate noise. The FAA's PBN Dashboard provides analysis of the average daily number of IFR operations and the average daily usage levels of individual RNAV SIDs and for a specified calendar year at ATL (Federal Aviation Administration 2015). It indicates an average of 2,395 daily IFR operations, and the average daily usage counts of the RNAV SIDs sum to 1,985 departures.

## Lessons Learned and Best Practices

The lessons learned from the Atlanta case study include:

- PBN initiatives undertaken at a local level can be successful when including all stakeholders.
- Successful implementation requires a champion to spearhead the project.
- The champion must be technically savvy regarding PBN, flight procedures criteria, and flight standards; politically sensitive; and knowledgeable of inner workings of the FAA.
- Procedures requiring the development of new criteria take additional time and effort to implement.
- Outside consultation in the development of a credible safety case for new criteria and procedures bolsters likelihood of FAA approval.
- Design of PBN procedures can address community noise constraints, airspace confines and obstacles while providing significant benefits. Inclusion of community input can enhance the outcomes of PBN projects.
- Community outreach with full explanation and disclosure engenders community understanding and approval.
- Local air traffic control operations support is critical to successful implementation and utilization of PBN procedures.

- Lessons learned are often not communicated to a broader audience. For example, ELSO can be developed and applied at other airports. To assist in communicating the accomplishments and lessons learned, the FAA is developing a lessons learned tool and a project tracking tool to support developing PBN procedures.

## Denver International Airport—PBN Departure, Arrival, and Approach Implementation

PBN departure implementation was initiated by TRACON personnel to facilitate managing arrival traffic to DEN and to improve flight efficiency. The project team included the TRACON, ATCT, federal FAA, aircraft operator, and other industry and airport personnel. Personnel from DEN's noise abatement office were deeply involved in the design to ensure it complied with stringent noise limits, with periodic compliance assessments and hefty fines, stipulated in an inter-governmental agreement. The team leveraged new procedure design criteria for approach procedures to increase use of the parallel runways. The environmental contractor to the FAA conducted extensive community outreach throughout the design. The final design has resulted in significant fuel burn and emissions reductions while meeting the stringent noise limits.

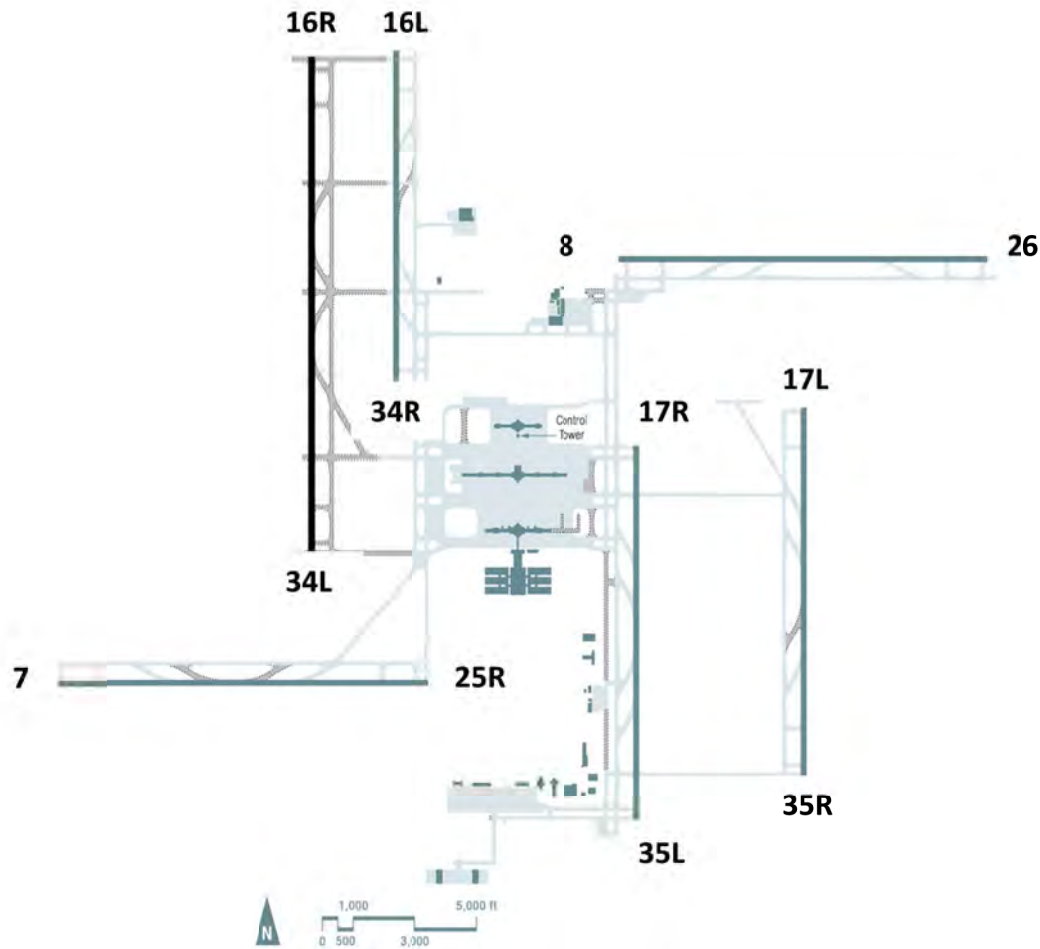
### Introduction

The Denver Metroplex serves the metropolitan area of Denver, Colorado, and includes Denver International Airport (DEN), Centennial Airport (APA), and Rocky Mountain Metropolitan Airport (BJC). DEN is a large hub airport located 25 miles from central Denver and is the largest airport in the U.S. by total area and the fifth busiest airport in North America in terms of passenger traffic. The airport has six runways. The runways are depicted in Figure C-3. Four of them are orientated on a north-south parallel heading (Runway 16L-34R and 16R-34L, and Runway 17L-35R and 17R-35L) and two runways are orientated on an east west alignment (Runway 7-25 and Runway 8-26). The runway configuration supports triple simultaneous arrivals and departures in multiple wind conditions. The airport has one terminal, three concourses, and is the main hub for Frontier and Great Lake Airlines. In 2013, DEN had 25,496,885 enplanements and 1,162,021 operations.

APA is located in Dove Valley, 17 miles southeast of central Denver. The reliever airport has three runways and an FAA-operated control tower. Centennial Airport does not offer scheduled airline passenger service. In 2013, APA had 1,679 enplanements and 601,841 operations. BJC is located 16 miles northwest of central Denver, between Denver and Boulder. The reliever airport has three runways and an FAA operated control tower. BJC does not offer scheduled airline passenger service. In 2013, the airport had 717 enplanements and 230,109 operations.

The FAA's PBN Dashboard provides analysis of the equipage levels among general aviation, Part 121 major, regional, and cargo aircraft, and IFR operations at DEN as of January 2015 (Federal Aviation Administration 2015). The results indicate that over 90% of Part 121 aircraft and IFR operations, and 50% of general aviation aircraft, are capable of RNAV 1. Over 90% of the Part 121 aircraft and IFR operations, and 50% of the other categories, are capable of RNP 0.3-1. Over 50% of the Part 121 major aircraft and IFR operations are capable of RNP AR, while essentially none of the general aviation and Part 121 regional and cargo aircraft are capable of RNP AR. The FAA's PBN Dashboard indicates DEN has an inventory of 16 RNAV SIDs, 16 RNAV STARs, and 12 RNP approach procedures.





Source: Federal Aviation Administration

**Figure C-3.** Plan view of Denver International Airport.

The focus of this case study is the Denver PBN project that was initiated in 2009 by Denver TRACON (D01) and The Denver International Airport and included the Denver ARTCC (ZDV), Jeppesen, United Airlines, Southwest Airlines, and Frontier Airlines as project stakeholders.

## Demographics

DEN is located within Denver County but is surrounded by Adams County. The land use in the immediate area surrounding the airport is primarily industrial and agricultural. There are multiple low density residential areas located to the north and east of the airport. Figure C-4 depicts the areas surrounding DEN.



Source: Google Maps

**Figure C-4.** *Denver International Airport and the surrounding area.*

## Project Description

The Denver PBN project involved the development and implementation of RNAV SIDs, STARs, and RNP SIAPs at DEN. The project also included RNAV SID procedures for APA and BJC. The PBN implementation initiative at DEN was distinct from the FAA Metroplex program. It began as a “home grown” effort initiated by the Denver TRACON (D01). The impetus for PBN implementation was increasing levels of traffic, which created significant inefficiencies with vectoring-based approaches for managing and sequencing traffic in the terminal area. In order to manage inflows of arrivals at each corner post from ZDV, D01 controllers were vectoring aircraft well out of the way of their intended routes. The vector operations created compliance issues with noise agreements established with multiple communities surrounding DEN. As an example, if an aircraft arriving via the south was flying the downwind portion of the arrival route to DEN runway 16L, the aircraft would continue to fly the downwind beyond the base leg, far northeast of the airport, then join the northeast arrival traffic flow, finally landing on a different runway.

When the airport was built in 1995, an inter-governmental agreement (IGA) was established permitting Denver to build the new airport in Adams County. The agreement limits the amount of noise the airport can generate at specific locations in the surrounding areas. Failure to comply with the noise limits results in substantial financial penalties. As part of the noise compliance monitoring efforts, airport staff members routinely worked closely with FAA to monitor flight tracks and procedures in an effort to stay within the noise limits imposed by the agreement. DEN reports annually to the county regarding its performance, identified violations, and mitigations to violations. Penalties of up to \$51 million per year are possible. In particular, the agreement stipulates an LEQ of 30-40 dB as the cumulative annual limit for points along an arc along the west side of the airport and that the 65 DNL contour for the baseline procedures is not exceeded in its geographic limits. The arc along the west

side of the airport comprises 101 grid points spaced a mile apart along the arc to the west. At the end of every year, the annual report documents DEN's compliance with the 65 dB noise contour and the LEQ levels at the points along the western arc. Contour violations can result in a \$500,000 fine. Grid point violations also can result in a \$500,000 fine per event per point. Thus, moving flight tracks even slightly has huge impact on non-compliance and the cost to DEN.

The D01 controllers felt that PBN could mitigate this traffic issue, particularly with improving the predictability of traffic and provide noise compliance. At that time, Denver was not a part of the FAA Metroplex program. Therefore, they decided to pursue the initiative locally by partnering with the DEN ATCT; the Denver Air Route Traffic Control Center, ZDV; the Denver International Airport; United Airlines; Southwest Airlines, and Jeppesen. The project initially focused on the implementation of RNAV arrival and departure procedures but expanded to include the development of RNP approach procedures to each runway. Jeppesen, located in Englewood, CO, had a close relationship with the airport and volunteered to chart RNP approach procedures to showcase the next generation of PBN capabilities and procedures. Southwest Airlines supported the effort as they were particularly interested since they were somewhat equipped to use the RNP procedures. Jeppesen ultimately designed all of the 12 RNP AR approach procedures.

## Processes Used

As previously indicated, the initial design and collaboration efforts were conducted locally through the design team. The procedure development process followed the FAA 18-step process. Development and implementation of the procedures was a three year process beginning in January 2010. The RNAV SIDs and RNAV STARs were implemented in two phases. The RNAV STARs were published in December 2012 and the RNAV SIDs and RNP AR SIAPs were published in March 2013.

The initial design violated the IGA with the communities around DEN, and required re-work to comply with the IGA. This demonstrates the value of collaboration with the airport and communities and an awareness of noise conditions and constraints before designing procedures.

## Criteria Development

DEN obtained a waiver to conduct dual simultaneous RNP AR approaches to its widely spaced parallel runways (centerlines separated by more than 9,000 feet) with visual approach to the middle runway (Runways 16L, 16R and 17R). During months where VFR can be used, DEN may have up to 2,000 RNP AR arrivals. DEN is a second demonstration site for the FAA's Established on RNP procedures, behind Seattle-Tacoma Airport. This technique of air traffic management considers an aircraft on an RNP approach established or stabilized, therefore eliminating the requirement to maintain standard radar separation (3 nm lateral or 1,000 feet vertical) between other aircraft on a simultaneous independent and/or dependent parallel approach path to an adjacent parallel runway. DEN is currently pursuing a waiver in order to conduct RNP AR approaches to the three parallel runways (Runways 34R, 35L, 35R) in IMC.

## Project Communication and Public Outreach

The FAA worked side-by-side with DEN and the environmental contractor. DEN staff was involved throughout the entire process. One component to the successful collaboration was that the TRACON, ATCT, airport, airline staff, and other people on the design team worked well together and trusted one another. Also, several of the FAA and airline staff members on the design team served as project champions who helped move the project forward when serious roadblocks were encountered throughout the development and implementation process. There was a high level of public interest in Denver due

to existing referendums with stringent noise requirements and the IGA's financial penalties of potentially millions of dollars of fines for noise violations.

The IGA governing DEN's operations, which is unique to the airport, drives collaboration, particularly with the city and county surrounding the airport. Such collaboration and openness always has the potential of generating a problem, but it is necessary to be open with such large-scale projects. The design team met with state and national park representatives early in the process to ensure compliance with noise restrictions they impose. The project team included an airspace representative for DEN, but the Airport Noise Abatement Manager oversaw the airspace design aspects because noise abatement became the driving force for design requirements and changes due to the highly sensitive noise restrictions for DEN. The project team met regularly throughout the project and maintained a record of meeting minutes. During the design process, the airport would identify noise sensitive areas and work with FAA representatives to make adjustments to procedures as needed to comply with the stringent noise requirements.

During the environmental analysis phases of the project, the FAA conducted three stages of public and agency meetings: 1) initial scoping meetings, 2) mid-term review meetings of the draft final designs, and 3) draft EA review meetings. Each of these stages included at least one agency meeting for local planning officials and three public meetings at various sites in Denver. The environmental team worked to broadly publish as much information as possible and conducted two levels of outreach: 1) advertisement to the community and 2) distribution packets to elected officials and planning members. Public advertisements to the community included standard legal notices (Federal Register, Denver Business Journal), a published half-page advertisement in the Denver Post during the scoping stage of the project, and a web site. At each stage, the distribution packets with all relevant documentation in hard copy and electronic forms were sent to federal, state, and local elected officials throughout the nine-county Denver metropolitan area.

## Environmental Analysis

The FAA ATO led the development of an EA with the assistance of a private contracting firm. The EA followed the NEPA standard process. They conducted three stages of public and agency meetings. The three stages of meetings were initial scoping meetings, meetings for mid-term review of the semi-final design, and then final meetings once the draft EA was available to review. At each stage, the contractor held three public meetings and one agency meeting. The three public meetings included one meeting close to each of the three airports (Denver, Centennial, and Rocky Mountain). The agency meetings were for local planning officials, and included representatives from Centennial and Rocky Mountain Metropolitan Airports. DEN also conducted its own environmental analysis to ensure compliance with these local constraints prescribed in the IGA, since such analysis did not fit with the FAA's noise analysis methodology. This was an iterative process of conducting its own evaluations of the proposed designs, and then proposing adjustments to the design to eliminate identified noise issues.

## Project Outcomes

Outcomes from the Denver PBN departure, arrival, and approach implementation project include:

- The implementation of SIDs, STARs, and RNP AR flight procedures.
- Shorter routes resulting in fuel and emissions savings:
  - DEN is saving 4.5 nm in flight distance per RNP arrival compared to the similar conventional approach, although this benefit varies by runway configuration. This provides a significant reduction in fuel consumption and noise exposure.

- Using RNP AR approach procedures in IMC, flights could possibly save 20-30 nm in flight distance; this is due to the arrival queue lengths which typically arise in IMC, and how far the aircraft have to fly to conduct the final approach procedure.
- Noise reductions and an associated \$1.5M reduction in noise violation fines.
- Collaborative working relationships; and public outreach.
- Unique use of RNP AR approach procedures to connect the RNAV STARs with the final approach procedures without having to widen downwind legs of the RNAV STARs.
- RNP approaches benefiting non-participating aircraft. This occurs on Runways 34L/R, which are staggered to the north and Runways 35L/R, which are staggered to the south. The flight efficiency benefits of the RNP AR procedures incentivize equipped aircraft to land on runways with longer taxi distances to the terminal, thus freeing the remaining runways for the non-equipped aircraft. This promotes a mixed equipage management policy, supported by D01 controllers, of segregating equipped and non-equipped aircraft by runway: RNP AR aircraft to one runway, non-equipped to other runways.
- To date, DEN has paid \$41M in fines for noise violations. Due to the PBN procedures, DEN is operating well within the boundaries of the 65 dB contours, and three fines totaling \$1.5M due to non-compliance with prior noise levels at specific grid points were eliminated.
- To date, there has been no major negative reaction to the designed procedures since they've been implemented in their final form. The airport has received approximately twelve complaints concerning PBN procedures. Initially there was some skepticism from controllers, but they have come to adopt and appreciate the new PBN procedures.
- The north-south directional STARs implemented to permit large altitude windows for arrivals to conduct OPDs were initially too complex for some controllers and flight crews. Simpler approaches to designing procedures have since been implemented.

## Post-Implementation Metrics

The primary metric for post-implementation assessment of the PBN procedures from the airport's perspective is noise. The LEQ of noise is assessed at points along an arc along the west side of the airport. The DNL of noise is compared to an established 65 decibel noise contour. On an annual basis, DEN conducts flight track analysis to ensure compliance with the local constraints prescribed in the IGA. In addition, a formal assessment of compliance with the contour and grid point noise thresholds stipulated in the IGA is performed annually. DEN is assessed a significant fine of \$500,000 for each exceedance. Analyses indicate a decrease in noise, and increased compliance with IGA noise agreements established through the development of the new airport in 1995.

Additional assessment metrics include airport arrival throughput, flight distance and frequency of RNP AR approach usage. Regarding arrival throughput, DEN monitors its peak arrival throughput, particularly when conducting simultaneous arrivals to its three parallel runways. Regarding flight distance, arrivals to DEN via RNP approach procedures have demonstrated reductions in average flight distance, and greater reductions are expected in IMC. Regarding RNP AR approach usage, DEN is actively tracking how many arrival aircraft are using the RNP AR approach procedures.

The FAA's PBN Dashboard provides analysis of the average daily number of IFR operations, the average daily usage levels of individual RNAV SIDs and RNAV STARs, and the usage levels of RNP AR approaches with RF legs for a specified calendar year for DEN (9). It indicates an average of 1,591 daily IFR operations. The average daily usage counts for the RNAV SIDs sum to 951 departures, and for the RNAV STARs sum to 985 arrivals. RNP AR approaches were executed by 10,939 arrivals among 66,125

candidate aircraft. However, rates of execution were over 50% for the approach procedures to runway 17L and runway 17R.

## Lessons Learned and Best Practices

The lessons learned from the Denver case study include:

- Local participation and coordination was a primary reason for success.
- Collaboration with airport, airline, and industry groups was key to the development of the procedure designs.
- Early coordination with entities impacted by aviation noise, before developing preliminary designs, was critical.
- Outreach was broad across the public and elected officials. It included numerous meetings and was deeply informative.
- PBN improved the airport's compliance with rigorous noise abatement programs, increased the airport's throughput, reduced emissions from aircraft, reduced aircraft fuel consumption, reduced public exposure to aircraft noise, and improved the safety of air traffic.
- All members on the design team have to be involved all the time in the development process from start to finish.
- The design process should not be partitioned or worked independently by individuals during different phases of the process.
- Involvement of airports and local personnel in implementing PBN procedures is successful when those who are included are closest to the problems, know the airspace, and have relationships with and knowledge of the local community. DEN was so heavily integrated in the PBN development process, that it wasn't an issue or a requirement to obtain official airport approval. It was important, though, to make sure the airport involved the public.
- Do not wait too long to involve appropriate people who may be impacted by noise resulting from the new PBN flight procedures. Presenting designs that are largely complete to interested parties results in design issues and conflicts.

## Henderson Executive Airport—PBN Departure, Arrival, and Approach Implementation

The Clark County Department of Aviation (CCDOA) first developed PBN approach procedures as part of its effort to enhance HND as a reliever airport. This motivated a subsequent effort by the FAA's PBN Program Office to develop preliminary designs for PBN arrival and departure procedures for the airport. The National Business Aviation Association (NBAA) lobbied for final implementation of the PBN arrival and departure procedures to enable using HND for its annual Business Aviation Convention & Exhibition (BACE). Terrain and traffic to Las Vegas McCarran airport presented challenges in the design. A Categorical Exclusion for the procedures was ordered on December 2010, so the community was not involved and outreach did not take place.

## Introduction

HND is a general aviation reliever airport for the Las Vegas McCarran International Airport (LAS) serving the Las Vegas/Clark County region of Nevada. HND is located in Clark County, 11 miles south of central Las Vegas. The reliever airport has one terminal, two runways, and an FAA operated control tower. In 2013, HND had 154,051 enplanements and 182,200 operations.

The FAA's PBN Dashboard provides analysis of the equipage levels among general aviation, Part 121 major and regional aircraft, and IFR operations at HND as of January 2015 (Federal Aviation Administration 2015). HND does not support cargo operations. The results indicate that over 100% of Part 121 regional aircraft, and 50% of the other categories, are capable of RNAV 1 and RNP 0.3-1. No aircraft are capable of RNP AR. The FAA's PBN Dashboard indicates that HND has an inventory of three RNAV SIDs, eight RNAV STARs, and no RNP approach procedures.

In 1996, the CCDOA purchased the airport (named Sky Harbor at the time) as part of an ongoing effort to meet the future aviation needs of southern Nevada. This included servicing the rapidly growing local population, and increasing the capacity for commercial operations at LAS by accommodating additional operations at HND. At that time, the airport had one 5,000-foot runway, a single terminal building with a control tower, several large hangars, ten T-hangars, and a handful of trailers. The name was changed to the Henderson Executive Airport, and the airport was reclassified to reliever status within the National Plan of Integrated Airports. The CCDOA invested more than \$30 million in Henderson Executive Airport to create a premier corporate aviation facility and an attractive, convenient and economical alternative to LAS. Enhancements included two new parallel runways, a new terminal building, hangars, and transient ramp improvements.

As traffic grew in the Las Vegas area commercial capacity became more of a concern at LAS and peaked during the annual NBAA BACE in the early 2000s. The NBAA BACE is the largest non-military aviation trade show in the world and one of largest trade shows—of any kind—in the world. When held in Las Vegas, LAS becomes saturated with business jet and other general aviation activity creating major delays for the scheduled commercial carriers. During the convention, the impact on operations at LAS reached the point of shutting down Runway 01R-19L due to the lack of space for parking in the general aviation ramp area creating runway/taxiway egress constraints. Scheduled commercial service was disrupted causing significant delay, affecting to both local businesses and the NAS. At that time HND did not have any published instrument flight procedures of its own. Instead, HND traffic would follow the published SIDs and STARs for LAS and expect to be vectored to or from the airport in visual conditions.

The CCDOA worked with NBAA to move the home airport from LAS to HND for the annual convention and exhibition. The new improvements made it an attractive airport and eventually resulted in the NBAA Convention moving operations to HND. In 2006, the CCDOA worked to implement VOR/DME and GPS RNAV SIAPs as well as Obstacle Departure Procedures (ODP) to enable IFR operations. However, the procedures were not efficient because they conflicted with LAS traffic and were limited to use by aircraft in approach categories A and B (the lowest approach-related speed ranges typical of small single- and multi-engine aircraft). In addition, HND arrivals and departures still had to share the SIDs and STARs published for LAS resulting in impacts to the traffic flow at LAS and a limited utilization of the runway capacity at HND.

In 2007 the FAA and MITRE began the Las Vegas optimization of the air traffic routes serving McCarran International Airport, Henderson Executive Airport, and North Las Vegas Airport (LAS Optimization). This was motivated by CCDOA planning initiatives for a new commercial airport, and capacity enhancement changes desired by the Las Vegas TRACON (L30) and the Los Angeles ARTCC (ZLA). The initiative was ordered by the vice president of the FAA's Mission Support Services. The FAA's PBN Program Office led and coordinated the 18-step Process to develop the procedures. The result of this program was a complete preliminary design of SIDs and STARs for all airports in the Las Vegas area.

Although the LAS Optimization program resulted in the preliminary design of SIDs and STARs for HND, at its completion there was no plan for integration. Further work was also required to address the deficiencies in the SIAPs including arrival and departure conflicts with LAS traffic, missed approach conflicts with LAS, and the lack of procedures for category C and D aircraft (those with approach-related speed ranges typical of airline and large/military jets).

In 2009, a local initiative, separate from the LAS Optimization program, was established to improve the GPS RNAV SIAP for HND. The request went through the operations support group (OSG) of the FAA's Western Service Center and was reviewed by the FAA's RAPT for approval and development. In 2010, the NBAA lobbied to have the HND STARs and SIDs processed and implemented separately from the LAS Optimization project. A Categorical Exclusion for the procedures was ordered in December 2010, so the community was not involved and outreach did not take place. The HND procedures were implemented in 2011, in time for the NBAA convention.

## Demographics

HND is surrounded by middle-income residential developments to the north and east of and undeveloped Bureau of Land Management park land to the south and southwest of the airport. Figure C-5 depicts the areas surrounding HND.



Source: Google Maps

**Figure C-5.** Henderson Executive Airport and the surrounding area.



## Project Description

A collaborative effort to design new PBN procedures was initiated to develop SIDs and STARs and improve the SIAPs at HND. The stakeholders included L30, ZLA, the NATCA, and Netjets (the designated “Lead Operator” at HND). Representatives from each of these groups made up the design team for the new PBN procedures. Several goals were established including:

- Publication of the procedures one cycle before the NBAA Convention date of October 2011.
- Integration and de-confliction of Las Vegas satellite airports.
- Development independent DME/DME/IRU or GPS RNAV 1 SIDs and STARs to serve HND.

At the time, L30 was participating in the third iteration LAS Optimization project, and had already designed multiple SIDs and STARs based on RNAV 1 procedures when the implementation phase of the project came to an end for unknown reasons. Although the LAS Optimization program was stopped, local interest in implementing SIDs and STARs procedures, and improving the SIAPs at HND, was high. Efforts from the local groups continued to move forward. Four RNAV STARs, three RNAV SIDs, and one RNAV GPS SIAP were included in the final designs. The SIDs and STARs were based on the preliminary designs in the LAS Optimization project. The RNAV GPS SIAP was modified to connect with the STARs, avoid conflicts with LAS traffic, and include approach category C aircraft. Upon the completion of the preliminary design, the FAA took over the formal development of these procedures supported by a contracting firm who served as the project coordinator. Under a separate effort, Netjets developed a number of special use procedures composed of RNAV tracks that could be used in visual meteorological conditions (VMCs). This provided improved and safer operations in and out of HND. A GPS approach was also developed with higher landing minima, but allowed for a missed approach procedure that would de-conflict from LAS and accommodate approach category C aircraft.

The FAA’s Metroplex initiative announced the kickoff meeting for the LAS Metroplex effort for August 4, 2015. It will be an opportunity for HND to engage directly in developing improved PBN procedures and perhaps coordinate more with the community as part of the process. The NBAA will serve as a co-lead operator in the project, which will be a first for an FAA Metroplex initiative.

## Processes Used

The development of the procedures originated from the LAS Optimization project and was conducted by a local procedure design team following the 18-step Process. The design team included airlines and other interested operators, local and regional FAA ATC personnel, FAA Flight Standards, MITRE, and other appropriate contract support. An EA was conducted following the NEPA guidelines and standards.

## Criteria Development

A safety case and waiver to criteria was required to include CAT C aircraft on the GPS RNAV SIAP serving HND. The area required for protection in the missed approach expands based on the category of aircraft. The area required for approach category C aircraft encompasses LAS arrival and departures in many configurations. The operations support group (OSG) of the FAA’s Western Service Center facilitated the changes to the procedure within the lines of business at the FAA. The FAA RAPT gave the final review and approval of the procedure.

## Project Communication and Public Outreach

The LAS Optimization project and the HND PBN implementation effort required communication and coordination between all of the stakeholders. The CCDOA was involved in the development of HND to accommodate business jet traffic, implementation of preliminary SIAPs, and with the initiation of the LAS Optimization (which evolved out of a planning effort for a new commercial airport in LAS). CCDOA supported the FAA's efforts to increase efficiency in the LAS Metroplex and specifically at HND. Multiple public hearings were held associated with the EA completed for the LAS Optimization project. However, relationships with the city of Henderson have been challenging. A community outreach program was not initiated as part of this specific effort. The FAA's Metroplex initiative will be an opportunity for HND to better coordinate and communicate with the community, and to engage with the FAA in procedure development.

## Environmental Analysis

An EA was conducted and completed as part of the LAS Optimization project. In September 2012 a FONSI was issued for the proposed design of the air traffic routes in the LAS area. This EA was sufficient to obtain a Categorical Exclusion for the new SIDs and STARs for HND. The modification of the SIAP was evaluated through the completion of an Environmental Worksheet. The worksheet referenced EA efforts associated with the LAS Optimization project and the EA for the airport expansion as justification for a FONSI.

## Project Outcomes

Outcomes from the Henderson PBN departure, arrival, and approach implementation projects include:

- The CCOA has successfully developed HND as a reliever airport, increasing capacity at LAS.
- The NBAA's BACE has and will return every odd-numbered year, bringing with it the economic benefits that the community wanted.
- Henderson-based flight departments, as well as transient operators, have published, terminal instrument procedures, increasing the safety and utility of this mountainous location.
- HND and LAS have separate STARs and SIDs serving their airports, improving access to both airports.
- Success of the project can be attributed to collaboration of local FAA and industry to achieve common goals through the implementation of PBN.
- The design team's concepts, while sound, were not universally embraced by all controllers in all sectors. ZLA has changed one of the altitude and speed constraints on the Northwest arrival (AD-DEL1 STAR) via a Notice To Airmen (NOTAM) to provide a more comfortable fit with an RNAV STAR for LAS that it shadows. Revised designs have been prepared for when the FAA undertakes its Metroplex initiative in Las Vegas.
- The lack of public outreach in development of PBN procedures may be negatively impacting relationship of HND with the community of Henderson. There may be an opportunity for further outreach as part of the LAS Metroplex initiative in 2015.

## Post-Implementation Metrics

No specific post-implementation assessment criteria or metrics were identified in the case study interviews. Representatives from Netjets have indicated that RNAV SIDs, STARs and GPS RNAV approach

integrate fairly well into the existing Las Vegas airspace scheme. The NBAA convention continues to be held in Las Vegas to this day and has had less impact on commercial operations at LAS.

The FAA's PBN Dashboard provides analysis of the average daily number of IFR operations, the average daily usage levels of individual RNAV SIDs and RNAV STARs, and the usage levels of RNP AR approaches with RF legs for a specified calendar year for HND (Federal Aviation Administration 2015). It indicates an average of 71 daily IFR operations. The average daily usage counts for the RNAV SIDs sum to 4 departures, and for the RNAV STARs sum to 5 arrivals. Usage of RNP AR approaches is not reported.

## Lessons Learned and Best Practices

The lessons learned from the Henderson case study include:

- PBN procedure development projects undertaken at the local level can be highly successful.
- Successful teaming includes local FAA facilities, transportation departments, airports, aircraft operators.
- PBN can be used to overcome significant flight procedure design constraints imposed by terrain and proximate airports.
- Improved access to reliever airports afforded by PBN procedures can make them attractive to additional aircraft operators, with potentially significant local economic impacts.
- Improved access to reliever airports afforded by PBN may increase capacity and/or efficiency at the hub airport in the areas.
- Previous environmental assessments may be sufficiently broad to support new PBN procedure development projects.
- Lack of public outreach in development of PBN procedures can negatively impact the airport's relationship with the surrounding community.

## Houston Metroplex—PBN Departure, Arrival, and Approach Implementation

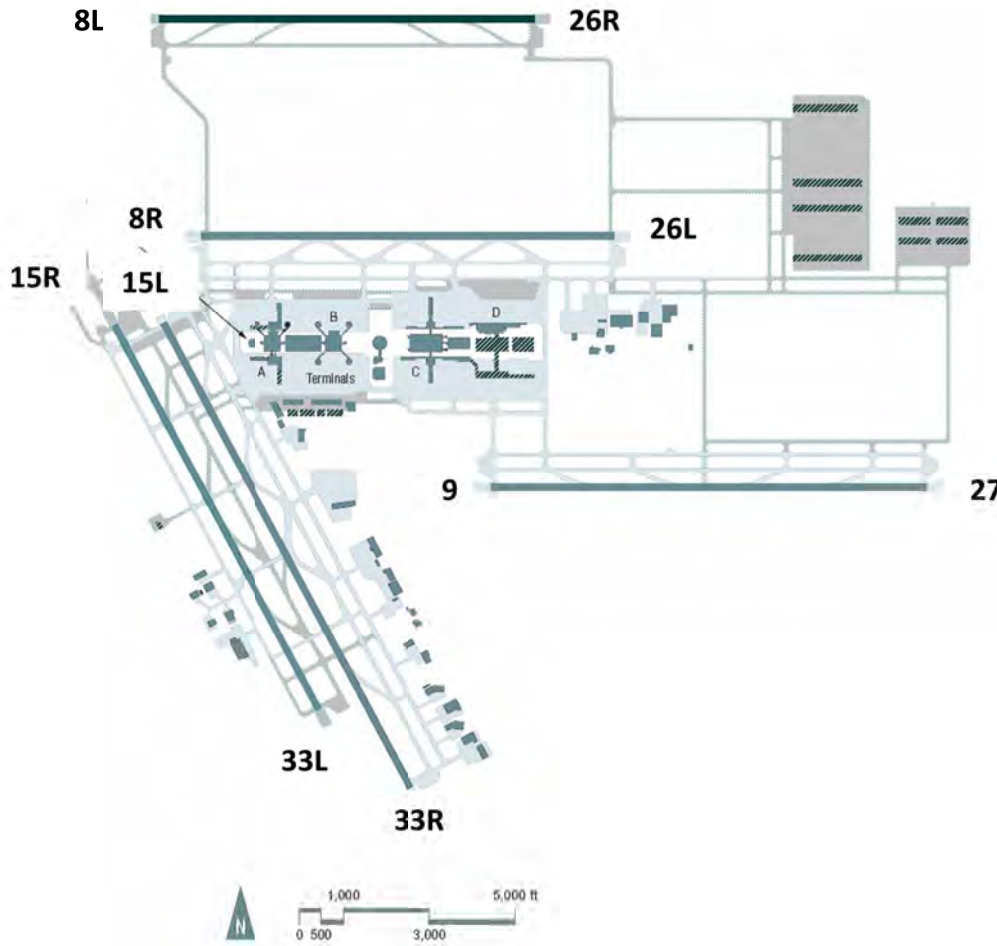
PBN procedures were developed for the Houston Metroplex, in particular for George Bush Intercontinental Airport, by the FAA's Metroplex program. The study team consisted of FAA, NATCA, MITRE, and United and Southwest Airlines representatives. The Metroplex design process resulted in the development of 20 new RNAV STARs, 20 new RNAV SIDs, five new non-RNAV STARs, and four new RNP AR approaches, which have reduced fuel burn, emissions, and noise. The design team conducted limited outreach to the Houston Airports System and local government representatives, and the Houston Airport System (HAS) conducted its own public meetings.

### Introduction

The FAA is redesigning airspace and addressing airspace inefficiencies, introducing new PBN procedures and making use of time-based flow management (TBFM) to make the Houston Metroplex airspace more efficient and improving access to its airports. The Houston Metroplex includes George Bush Intercontinental Airport (IAH), David Wayne Hooks Memorial Airport (DWH), William P. Hobby Airport (HOU), and Sugar Land Regional Airport (SGR). HAS is a department of the City of Houston

that manages city airports. Its administrative offices are on the property of George Bush Intercontinental Airport, and it manages Bush, William P. Hobby Airport, and Ellington Airport.

IAH is a large hub airport located 23 miles north of central Houston and currently ranks third in the United States among U.S. airports with scheduled non-stop domestic and international service and is the 12<sup>th</sup> busiest airport in North America in terms of passenger traffic. The airport has five runways and five terminals, as shown in Figure C-6. IAH is the main hub for United Airlines. In 2014, IAH served more than 41 million passengers and accommodated 508,935 landings and takeoffs.



Source: Federal Aviation Administration.

**Figure C-6.** Plan view of Houston George Bush Intercontinental (IAH).

HOU is located seven miles from central Houston, and is the region's secondary aviation facility, handling the area's domestic flights and is an international point of entry for general aviation activity between Texas and Mexico. The airport has four runways, one terminal, and is categorized as a medium hub airport. In 2013, HOU had 5,377,050 enplanements and 410,372 operations. DWH is a general aviation airport located near the city of Tomball, 23 miles northwest of central Houston. It is the busiest general aviation airport in Texas and one of few privately owned airports with an FAA operated control tower. DWI has one terminal and three runways, including a seaplane landing area and is also home to numerous flight schools. In 2013, the airport had 358 enplanements and 345,137 opera-

tions. SGR is located in Sugar Land, Texas, approximately 17 miles southwest of central Houston. The airport is categorized as a general aviation airport and is the fourth largest airport in Greater Houston. SGR has one runway, one terminal building, and is served by a non-federal control tower. In 2013, SGR had 979 enplanements and 144,036 operations.

The FAA's PBN Dashboard provides analysis of the equipage levels among general aviation, Part 121 major, regional and cargo aircraft, and IFR operations at airports in the Houston Metroplex as of January 2015 (Federal Aviation Administration 2015). The results for IAH indicate that approximately 100% of Part 121 aircraft and IFR operations, and 80% of general aviation aircraft, are capable of RNAV 1. The same levels among the categories except only 70% of Part 121 cargo carriers are capable of RNP 0.3-1. Fewer than 30% of the Part 121 major aircraft and IFR operations, and none of the other categories, are capable of RNP AR. The results for HOU indicate that over 90% of all categories of aircraft are capable of RNAV 1 and RNP 0.3-1, over 50% of general aviation and IFR operations, and over 10% of the Part 121 regional aircraft are capable of RNP AR.

The FAA's PBN Dashboard indicates IAH has an inventory of 13 RNAV SIDs, 13 RNAV STARs, and six RNP approach procedures, and HOU has an inventory of 11 RNAV SIDs, seven RNAV STARs, and no RNP approach procedures (Federal Aviation Administration 2015). The Houston Metroplex program was initiated by FAA in May 2011 and was the fifth airspace design effort under the FAA Optimization of Airspace and Procedures in the Metroplex program (Metroplex). The study team consisted of FAA, NATCA, MITRE, and United and Southwest Airlines representatives. The Metroplex design process resulted in the development of 20 new RNAV STARs, 20 new RNAV SIDS, five new non-RNAV STARs, and four new RNP AR approaches. A number of existing procedures were redesigned as part of this effort incorporating the design components of the new procedures.

## Demographics

The immediate areas surrounding IAH, depicted in Figure C-7, are primarily industrial with the exception of some middle-income residential areas located to the northeast. The immediate areas surrounding HOU, shown in Figure C-8, include industrial areas to the northeast, east, southwest, and west and middle- to low-income residential areas located to the north, southeast, south, and northwest. There are no formal community action groups established who work with the HAS on noise and environmental issues. HAS does receive noise complaints for air traffic to IAH and HOU, but there is no significant opposition from a particular group.

## Project Description

The Houston Metroplex initiative focused on leveraging PBN and TBFM capabilities to create more efficient arrival and departure routes, arrival routes enabling OPDs, and departure procedures with fewer climb restrictions. The project area covered the entire airspace of the Houston TRACON (I90). The project included airspace and procedures at DWH, HOU, IAH and SGR. The FAA study teams, working with United Airlines and Southwest Airlines, selected the procedures to be changed.

## Processes Used

The Houston Metroplex initiative was a three year process that started in summer 2011 and ended in May 2014. The Metroplex initiative is composed of five phases: Study Team and Scoping; Design and Procedure Development; Operational, Environmental; Safety Review, Implementation and Training; and Post-Implementation Review and Modification. The Study and Scoping phase was completed by a study team while the Design and Procedure Development, Operational, Environment, and Safety



Source: Google Maps

**Figure C-7.** *George Bush Intercontinental Airport and the surrounding area.*

Review, and Implementation and Training phases were conducted through the efforts of a Design and implementation team. Implementation of the new procedures followed the FAA 5-step process.

The study team collaborated with local air traffic control personnel and industry to understand the local airspace and traffic characteristics, such as flight paths, traffic levels and aircraft equipment, and to identify what improvements may be made. This process took approximately 90 days. The Study Team forwarded its recommendations to the design and implementation team. The design and implementation team leveraged its PBN expertise and collaborated with an environmental consultant to design the procedures to meet the design recommendations. This took approximately 2.5 years.

The design and implementation team first designed the lateral paths of the flight procedures using Performance Data Analysis and Reporting System (PDARS) data and TARGETS. Then cockpit simulations of the different aircraft and equipment characteristic of the airport's traffic were conducted to determine the altitude profiles of the flight procedures. Finally, human-in-the-loop (HITL) simulations with controllers and pilots were conducted to evaluate the compatibility of the procedures with traffic management automation, in particular the FAA's TBFM tool.

Design principles included avoiding moving the ground tracks closer to those noise-sensitive areas; balancing runway usage while avoiding significant changes to traffic loadings of individual airport runways (which would otherwise shift the noise exposure to other areas surrounding the airport); and, near state and national parks, avoiding changes to ground tracks below 18,000 feet AGL.



Source: Google Maps

**Figure C-8.** William P. Hobby Airport and the surrounding area.

## Criteria Development

No new criteria were required to be developed as part of the Houston Metroplex project.

## Project Communication and Public Outreach

The FAA managed project communications with the study team and the design and implementation team.

As part of the procedure development process used in procedure development projects undertaken by the FAA Metroplex program, the environmental and noise experts of the FAA Metroplex design team typically meet with local airports and noise roundtable groups to understand environmental sensitivities in the preliminary design phases. This includes identifying sensitive land use areas. However, if the surrounding cities and communities don't agree with the procedures design, this can cause conflict. The Houston Metroplex team met with the HAS three times during the process and attended noise round table public meetings held by HAS near William Hobby Airport (HOU). There were specific meetings early on in the project between the FAA Metroplex team and HAS to discuss noise and environment; these meetings are listed in the EA. Other meetings were held by HAS to brief the public and respond to their questions. Airlines, general aviation groups, anyone in industry were also invited to meetings. The design team met the noise requirements imposed by the HAS and the community to the extent possible.

The FAA prepared a project webpage for the study. Project briefing packages were sent out as part of the EA efforts to over 44 Houston area elected officials, multiple state and federal agencies, all counties

in the study area, and the Alabama Coushatta Tribe. Each package contained a cover letter, study area information, and the identification of all entities on the mailing list. The FAA also placed public notices in the 19 area newspapers.

The Houston Metroplex project did not conduct a formal public outreach program as part of the EA of the formal design. Other metroplex projects do have public outreach meetings; this varies site by site, and is decided by the FAA Program Office. The Houston Metroplex project was on the White House Infrastructure Dashboard as a project that could be completed quickly, the environmental process could reasonably be accelerated by making minimal changes to the procedures near the ground, and the outcome would have significant economic impact.

## Environmental Analysis

The FAA Metroplex projects are constrained to three years or less, which limits the environmental process that can be undertaken. Procedure designs avoid changing the ground tracks of aircraft at or below 10,000 feet and are limited in what changes can be implemented between 18,000 feet and 10,000 feet AGL. The greatest design freedom is above 18,000 feet. Within these constraints, the FAA's approach is to take the legacy procedures and to modify them to the newest standards for RNAV procedures, including shortening routes, reducing level-offs, designing routes to yield more predictable flight paths, and deconflicting departures and arrivals to permit climb via and descend via clearances. When developing procedures, the design team identifies noise-sensitive areas, and tries to be conscious of them in the design. The design team avoids moving the ground tracks closer to those noise-sensitive areas.

An EA was conducted by the FAA as part of this project following NEPA standards. The study evaluated environmental impacts in primary and supplemental study areas. The primary study area was a 50 nautical mile radius of a point midway between IAH and HOU, below 10,000 feet AGL. The supplemental study area was an 85 nautical mile radius of a point midway between IAH and HOU, between 10,000 and 18,000 feet AGL. Figure C-9 highlights the study area.

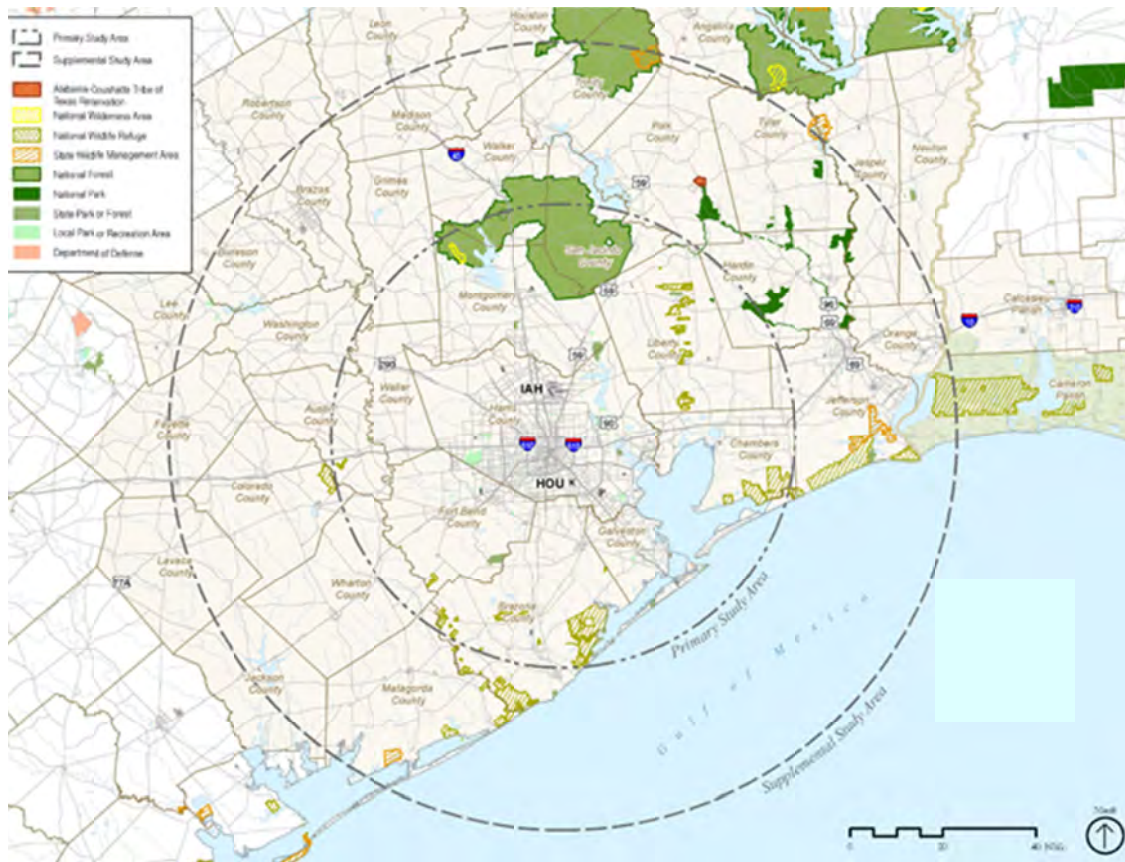
The EA was completed in January, 2013 and a FONSI ROD was issued on June 13, 2013 (Federal Aviation Administration 2013). Noise analysis was conducted as part of the EA and included comparing no action versus proposed action alternatives. Noise data were presented on a scale of low, medium, and high. Results of new departure flight procedures show a reduction in geographic range of noise in medium-high noise ranges. The EA did include a public commenting period. However, not many comments were received.

## Project Outcomes

Outcomes from the Houston Metroplex PBN departure, arrival, and approach implementation project include:

- Development of 20 new RNAV STARs, 20 new RNAV SIDS, five new non-RNAV STARs, and four new RNP AR approaches. A number of existing procedures were re-designed as part of this effort incorporating the design components of the new procedures.
- Expansion of the four corner post configuration of arrival fixes at the TRACON boundary with dual approaches at each corner to increase airspace capacity.
- Improved unrestricted climbs for departing aircraft.
- Shorter arrival and departure paths.
- Improved efficiency of arrival and departing aircraft within the Houston airspace system.





Source: Federal Aviation Administration

**Figure C-9.** The primary study area for the Houston Metroplex environmental assessment.

- Fuel savings and noise reduction.
- Reports from industry of significant fuel reduction, increased miles saved, and increased ease-of-use by aircraft flight crews by enabling greater use of flight deck automation.
- Controllers are issuing fewer speed, altitude, and heading clearances, which reduces workload and provides extra time to observe traffic.
- The project has had mostly a positive response from the community based on reduced noise from departures as a result of enabling unrestricted climbs.
- The HAS has received questions from the community about how the routes were changed, why the community wasn't notified. The HAS refers all questions to the FAA.

### Post-Implementation Metrics

Post-implementation assessment has focused on impacts to industry and air traffic control. Primary metrics of interest to industry have been fuel consumption, flight distance, and flight crew workload. There have been significant reports about fuel reduction, miles saved, and reduced flight crew workload through greater use of flight deck automation. Primary metrics of interest to the ARTCC controllers are number of vectors, deviation from defined routes, and number of clearances issued. Vectoring of aircraft within 200 miles of the airport has been mostly eliminated, and there is minimal deviation from the defined routes. Controllers now typically issue a clearance to descend; speed, altitude and

heading clearances have been significantly reduced. There are no post-implementation noise data for the procedures at this time.

The FAA discusses the Houston Metroplex project in its NextGen Performance Success Stories (Federal Aviation Administration 2015), however no particular metrics or data are provided. The FAA's PBN Dashboard provides analysis of the average daily number of IFR operations, the average daily usage levels of individual RNAV SIDs and RNAV STARs, and the usage levels of RNP AR approaches with RF legs for a specified calendar year for airports in the Houston Metroplex (Federal Aviation Administration 2015). For IAH, it indicates an average of 1,407 daily IFR operations. The average daily usage counts for the RNAV SIDs sum to 700 departures, and the RNAV STARs sum to 1,700 arrivals. RNP AR approaches were executed by four arrivals among 9,928 candidate aircraft. For HOU, it indicates an average of 528 daily IFR operations. The average daily usage counts for the RNAV SIDs sum to 230 departures, and the RNAV STARs sum to 475 arrivals. Usage of RNP AR approaches is not applicable.

## Lessons Learned and Best Practices

The lessons learned from the Houston case study include:

- RNAV can be leveraged to increase airspace capacity with additional routes, and to reduce emissions and noise from aircraft with more efficient departure procedures.
- The FAA is willing to undertake the development of PBN procedures without the involvement of the airports served by the PBN flight procedures, in particular if the procedures are changes in altitude regimes sufficiently high to not immediately impact the airport.
- The FAA conducts an EA including noise analysis and public outreach in its process.
- The airport may not be responsible for noise issues or other environmental impacts of arrival and departure traffic above 3,000 feet AGL.
- If the land use surrounding the airport is otherwise not dense residential, the level of outreach required to gain community approval may not be as high as what is required for airports with dense populations surrounding them.

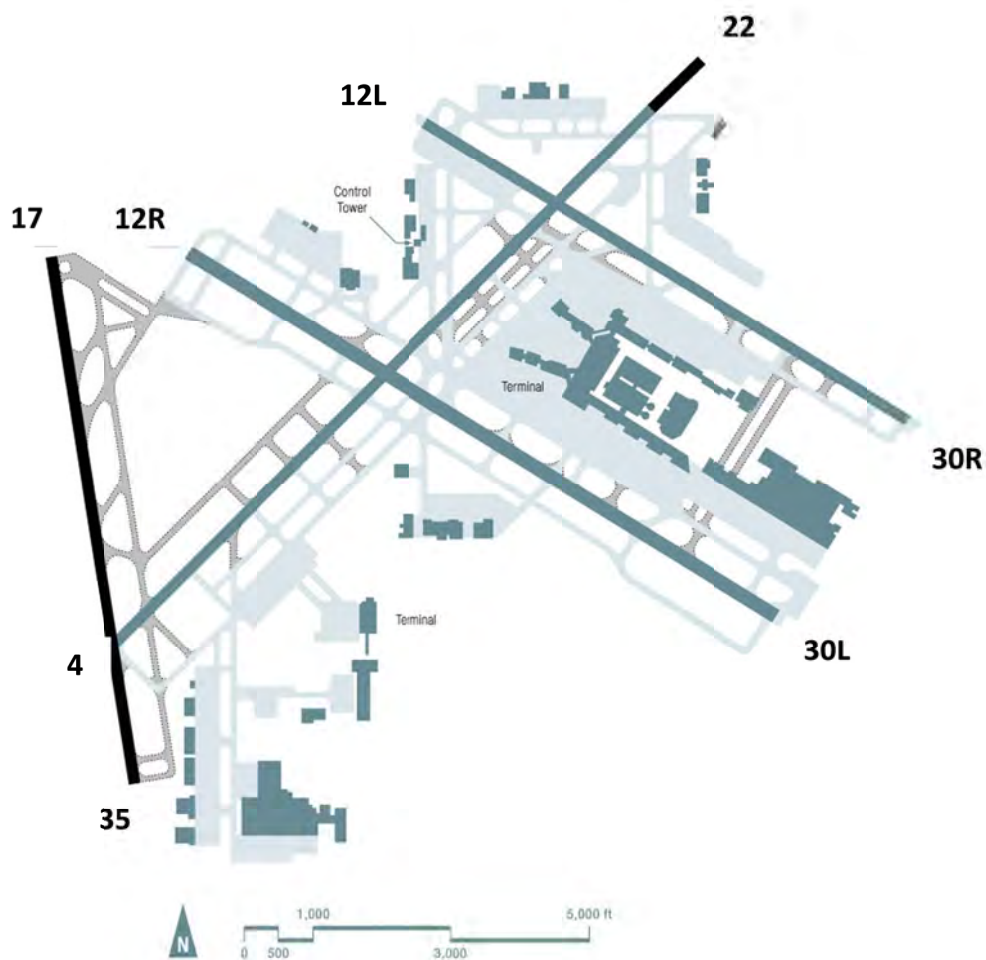
## Minneapolis-St. Paul International Airport— PBN Departure and Arrival Implementation

PBN routes were first developed by MSP's Noise Oversight Committee to reduce fuel burn and emissions of aircraft and to reduce noise impact on the surrounding community. In turn, local FAA ATCT personnel, with support from the FAA PBN Program Office, expanded upon these procedures with an airspace-wide design of PBN procedures. The design was a collaboration among FAA, airlines and NATCA, and the airport monitored the process. Insufficient time was allocated for the public outreach campaign to educate the community regarding the designed procedures. Community opposed the RNAV departure procedures to the north due to concentration of operations that increased noise to discrete segments of the population.

### Introduction

The Minneapolis-St. Paul Metroplex serves the Twin Cities metropolitan area of Minnesota and includes MSP, Airlake Airport (LVN), Anoka County-Blaine Airport (ANE), Crystal Airport (MIC), Flying

Cloud Airport (FCM), Lake Elmo Airport (21D), and St. Paul Downtown Holman Field (STP). MSP is a large hub and joint civil-military public-use international airport. Located within ten miles of both downtown Minneapolis and downtown St. Paul, it is the largest and busiest airport in the six-state upper Midwest region of Minnesota, Iowa, Nebraska, North Dakota, South Dakota, and Wisconsin. MSP is owned and operated by the MAC. The airport has four runways and two terminals, as depicted in Figure C-10. MSP serves as a major hub for Delta Airlines and is home to the Minneapolis–St. Paul Joint Air Reserve Station. In 2014, MSP served over 35 million passengers and had 412,695 operations.



Source: Federal Aviation Administration

**Figure C-10.** Plan view of Minneapolis-St. Paul International Airport.

The other larger airports within the Metroplex are general aviation airports. ANE is located approximately 11 miles from downtown Minneapolis and 12 miles from downtown St. Paul. It is categorized as a minor-use general aviation reliever airport. ANE has two runways and a non-federal aircraft control tower. In 2014, the airport had 73,951 operations. FCM is located approximately 11 miles southwest of the central business district of Minneapolis. It is categorized as a minor-use general aviation reliever airport for the region and popular as a home base for corporate business jets and turbo-props. It has three runways, an FAA-operated control tower, and an instrument landing system. In 2014, FCM had 75,759 operations. STP is located just across the Mississippi River from downtown St. Paul. It is cat-

egorized as an intermediate general aviation reliever airport and is considered to be the metro area's primary facility for private business aviation. The airport has a FAA-operated aircraft control tower, three runways, and is the only reliever airport in the region with a runway longer than 5,000 feet. In 2014, STP had 69,185 operations.

The FAA's PBN Dashboard provides analysis of the equipage levels among general aviation, Part 121 major, regional and cargo aircraft, and IFR operations at MSP as of January 2015 (Federal Aviation Administration 2015). The results indicate that almost 100% of aircraft across all categories are capable of RNAV 1. Almost 100% of general aviation and Part 121 regional aircraft, and over 70% of Part 21 major and cargo aircraft and IFR operations, are capable of RNP 0.3-1. Fewer than 30% of the Part 121 major aircraft and IFR operations, and none of the other categories, are capable of RNP AR. The FAA's PBN Dashboard indicates MSP currently has an inventory of four RNAV SIDs, six RNAV STARs, and five RNP approach procedures.

MSP has an established history of formally acknowledging and addressing air traffic noise. Coordinated noise abatement efforts first began through the establishment of the Metropolitan Airport Sound Abatement Council (MASAC) in 1969.

Over time, the airlines became dissatisfied with the processes followed by the MASAC, resulting in the abandonment of the group in 2000 and the establishment of the Noise Oversight Committee (NOC) in 2002. The NOC is the primary advisory body to MAC on topics related to aircraft noise at MSP. NOC members are officially selected to represent their respective community group and airport user group constituencies and vote accordingly. The NOC is composed of six community and six airport user representatives. The NOC functions as a policy advisory board to the MAC on airport noise issues. The NOC, and its accomplishments, are viewed as a model in the industry.

In July 2007, the NOC began investigating aircraft navigation technology to reduce noise at MSP. In general, RNAV and OPDs were viewed as a critical element to reducing aviation noise exposure to the community as were RNAV SIDs that enhanced compliance with existing vectored noise abatement departure procedures at the airport. In July 2009, the Crossing-in-Corridor and Runway 17 River RNAV departures to route aircraft over noise-compatible land-use areas were submitted to the FAA. Subsequently in 2010, the FAA became interested and proposed a comprehensive airspace-wide PBN project in Minneapolis. The FAA undertook this ambitious airspace design and incorporated the Crossing-in-Corridor and OPD flight procedures into this airspace-wide initiative.

## Demographics

The demographics of the areas surrounding MSP are such that commercial and industrial land uses exist to the south and southeast with homogeneous residential development to the north and west of the airport. The communities, particularly those northwest, and west of the airport are primarily white-collar, and middle to high socioeconomic status. These communities are engaged on the airport noise issues and may have connections with local community and business leaders. Figure C-11 shows the areas surrounding MSP.



Source: Google Maps

**Figure C-11.** Minneapolis-St. Paul International Airport and the surrounding area.

## Project Description

With support from the FAA PBN Program Office, local FAA ATCT personnel moved forward with the airspace-wide RNAV and RNP implementation at MSP. With the exception of one procedure that proceeded independently, all of the noise-specific RNAV work conducted by the NOC was incorporated into the airspace-wide FAA initiative. In 2011, the NOC began the process of establishing procedure design noise criteria to be forwarded to the FAA for consideration in the procedure development/implementation process at MSP. Given that the FAA was expanding the procedure design and implementation process beyond just a noise reduction effort, the Committee unanimously adopted noise abatement goals and criteria for the FAA to consider in its procedure design and implementation process.

The NOC sent a letter outlining the five key guidelines for the FAA to consider in its procedure design: 1) noise analysis comparing the noise contours and other metrics of the PBN procedures against the legacy procedures, 2) a public information program to inform public, 3) design of the procedures to reduce overflights over sensitive land use areas, 4) design to reduce arrival aircraft noise, and 5) maximize use of RNAV noise tracks as part of the runway use system.

Minneapolis and Edina residents opposed the RNAV departure procedures to the north. The new procedures deviated from the established policy of controllers fanning departures using vectoring in order to disperse the noise of aircraft. Prior to the redesign, local FAA controllers were very good at implementing and adhering to this policy. The “pencil lines” representing a concentration of RNAV operations and increased noise to discrete segments of the surrounding community became the typical “not

in my back yard” situation, with no one wanting to bear the brunt of the concentrated aviation traffic if others were more isolated from it. Although the RNAV design was predicated on overlays of legacy flight tracks, they presented a source of real concern and prompted a community member to start the Fair Skies Coalition. The Fair Skies Coalition leveraged social media to speak out against the design.

On November 14, 2012 the NOC determined the FAA adequately considered the NOC criteria in its process. This effort resulted in the establishment of local support for RNAV/RNP OPD STARs to all of the major runways (six different approaches) at the airport and RNAV SIDs for departure operations off of three of the five major runway ends at the airport. Opposition to RNAV SIDs to the northwest of the airport remained significant. After hearing the concerns of the community, the MAC Commission was not able to fully support the PBN design. A compromise was reached involving a partial implementation of RNAV procedures and on November 19, 2012, the MAC Full Commission took action in support of a partial implementation of the RNAV procedures, excluding the RNAV departure procedures for Runways 30L and 30R to the northwest of MSP. In response, the FAA initiated a safety study to evaluate the partial implementation of the procedures.

On February 1, 2013, the MAC sent a letter to the FAA recommending 5 outreach requirements. The requirements included the following: 1) Timing, requesting partial implementation of the FAA's proposed SIDs/STARs until public outreach to affected communities could be completed as planned; 2) Local FAA Leadership, requesting local FAA personnel be placed in leadership positions to communicate with the community; 3) Holistic Outreach, calling for outreach to communities impacted by the partial implementation, as well as those to be impacted by the remaining implementation; 4) Early Coordination with Local Community Leaders, calling for outreach to community representatives of cities surrounding the airport, and addressing their specific concerns; 5) Adequate Resource Allocation, calling for FAA staff and consultant resources sufficient to adequately conduct the outreach and respond to community concerns.

On February 19, 2014, FAA issued a letter to MAC indicating the safety risk management analysis determined that partial RNAV SID implementation “...introduces unacceptable safety risks into the National Airspace System.” The letter explained that the determination was driven by the following:

- Runway configuration changes 2-3 times daily.
- Requirement to use automation procedure referred to as the “deck” to change En Route Automation Modernization (ERAM) software preferential departure routes from RNAV procedures to legacy procedures, based on runway configuration.
- Runway configuration changes would require termination, or activation, of the deck with reissuance of revised departure instruction to each aircraft that has already pushed back from the gate or previously received its departure clearance prior to taxi.
- Reissued departure clearances after push back and taxi require head-down operations by the flight crews during a heavy workload time on the flight deck.

The NOC recommended 5 key provisions for how the FAA could conduct PBN design: 1) NOC support of RNAV STARs, 2) OPDs for STARs to all runways at MSP; 3) a case study of successful RNAV SID implementation at another airport with similar challenges, particularly, dense population surrounding the airport; 4) future RNAV SID designs and implementations incorporate previous outreach guidelines; 5) adequate time to prepare and conduct case study and community outreach plan. In March 2014, the FAA took the initiative to redesign all of the previous locally supported RNAV STARs and SIDs, enhancing the design and optimizing efficiency. In March 2015 the FAA implemented the RNAV STARs incorporating OPD at MSP. RNP STARs with OPD were implemented in April 2015.

The FAA reported that between March 24, 2015 and May 11, 2015 a total of 24,778 arrival operations at MSP used the new procedures. Based on the associated fuel burn and emission reduction estimates

made by the FAA, over 1.2 million gallons of jet fuel were saved and carbon emissions were reduced by as much as 12.2 metric tons. Although not documented, the implementation of these measures will also reduce other pollutants.

## Processes Used

The process used to initiate the preliminary design of the procedures was based on local collaborative effort between MAC, the local FAA, and Delta Airlines. The effort was taken over by the National PBN office after the NOC made the request for the development of the OPDs and SIDS. The FAA followed its 18-step process to develop the procedures for implementation. The NOC developed and initiated its own public outreach program and prepared its own noise contour analysis to inform the FAA's final design.

## Criteria Development

No new criteria were developed as part of the MSP PBN project.

## Project Communication and Public Outreach

The procedure design phase was a collaborative effort between FAA, NATCA, Delta Airlines, and MAC. The NOC was updated on a regular basis and was knowledgeable of the interactions and design trade-offs being made throughout the process.

The public outreach campaign planned by the NOC was multi-faceted. It included a web site, city council briefings, open houses, news channel presentations, and newspaper articles. The web site was to describe both PBN and the project. Two open houses were held with MAC and FAA representatives, and a Delta Airlines captain detailing the procedures and noise. A Star Tribune (Minneapolis local paper) publication and local TV coverage advertised the web site, the open house meetings, and other information. Briefings were to be given to mayors and other staff of communities. There were also additional presentations to the public.

## Environmental Analysis

Neither an EA nor an EIS was conducted as part of this effort. The FAA prepared an environmental worksheet and issued a non-published Categorical Exclusion for the proposed PBN procedures. Further environmental analysis was conducted by the MAC staff. Analysis consisted of a comparison of the DNL contours of the existing flight procedures and the proposed flight procedures as well as modeled DNL and alternative metric noise levels at various locations around the airport.

While the FAA, in controlling and conducting the PBN development and implementation process should take the lead on community outreach and noise analysis, the airport can provide a supporting role in helping to translate local expectations relative to these activities.

## Project Outcomes

Outcomes from the Minneapolis PBN departure, arrival, and approach implementation project include:

- The FAA prepared RNAV SIDs and STARs for all runways at MSP as part of this project.

- The MAC supported all procedures except the RNAV SIDs for Runways 30L and 30R. In November 2013, the FAA rejected the partial implementation recommendation based on safety and postponed the PBN implementation.
- Following the rejection of the partial implementation recommendation and the RNAV procedure postponement, the FAA worked to refine the design of the RNAV SIDs and STARs to improve efficiency and reduce environmental impacts.
- The MAC and the NOC established a framework for community engagement and impact analysis that was supported by all stakeholders as a roadmap for possible future RNAV SID design and implementation activities at MSP. In March 2015 the FAA implemented the RNAV STARs incorporating OPDs at MSP. RNP STARs with OPD were implemented in April 2015. This has significantly reduced aircraft fuel burn and emissions at the airport.

## Post-Implementation Metrics

To prepare for the implementation of the STARs designed by the FAA, the MAC developed methods for post-implementation assessment of the PBN procedures. First and foremost, they are trying to evaluate how often OPDs are used at the airport. There have been few efforts at other airports to capture this type of data. The FAA's own assessment tools, such as the PBN Dashboard, do not adequately present the data.

The MAC is working with the FAA to get radar flight tracks 100 to 120 nm from the airport. MAC plans to develop target vertical profiles by aircraft type, and to conduct a spatial analysis on flight tracking data to identify aircraft conducting OPDs. Once the aircraft executing an OPD are identified, these data will be analyzed quantitatively in more detail. One particular evaluation metric of interest is the airspace dwell time of aircraft.

The FAA's PBN Dashboard provides analysis of the average daily number of IFR operations, the average daily usage levels of individual RNAV SIDs and RNAV STARs, and the usage levels of RNP AR approaches with RF legs for a specified calendar year for MSP (Federal Aviation Administration 2015). It indicates an average of 1,116 daily IFR operations. Average daily usage counts are listed for 4 RNAV SIDs, and sum to 17 departures. Average daily usage counts for the RNAV STARs indicate an average of 646 daily operations. RNP AR approaches were executed by 57 arrivals from July 2014 through June 2015.

## Lessons Learned and Best Practices

The lessons learned from the Minneapolis/St. Paul case study include:

- Airports may initiate and sponsor PBN procedure development projects. Because MSP had initiated the PBN development task and process, the airport established itself as a key stakeholder and team player in PBN development with FAA.
- The FAA, as the agency controlling schedules and budgets for the design and implementation of PBN procedures, will ideally lead all elements of the process, including those elements intended to meet local expectations, such as noise analysis and public information components.
- FAA ATO will ideally recognize airports as a critical component to successful design and implementation efforts.
- Airport operators should focus their role in the PBN implementation on acting as a valuable resource to the FAA by defining local expectations of how the PBN design and implementation process should be conducted in order to ensure successful meeting of those expectations.



- By serving as an important resource to ATO in its formalization of a proactive community dialogue plan, airports can ensure that the local community perspective is understood.
- By airports advising ATO on the establishment of community and industry dialogue mechanisms, procedure design environmental and operational goals can be enhanced, a framework for planning and environmental review can be focused.
- In addition to providing a locally coordinated position on procedure design and environmental review expectations, airports bring data regarding their operations, air traffic characteristics, established procedures, and local technical knowledge to the process.
- Procedure design requirements are airport specific and should consider the demographics of the area and noise-sensitive land use surrounding the airport.
- If the community surrounding the airport is aware of and monitoring airport operations and aviation noise, more extensive outreach may be required to educate them regarding proposed PBN procedure development initiatives and their potential impacts, and to ultimately gain their acceptance of new or altered flight procedures.
- Airports wanting to participate in a PBN implementation project should have a team of people knowledgeable of PBN and capable of advising FAA in design, conducting community outreach, and coordinating between airport, airlines, and community and action groups.
- Local FAA airport representation working with airport management can be a more effective approach to outreach.
- Personnel from local FAA facilities can be quite helpful with outreach, but need to be able to effectively communicate technical issues and impacts to a wide array of interest groups.
- Airports and FAA need to establish and maintain a working relationship with community and local government groups.
- Sufficient time must be allocated to community outreach for a particular initiative, and outreach should be initiated early.
- If the community expects the impacts of the proposed procedures to be significant, they will ideally be allowed time to understand the impacts of, and respond to, proposed procedure changes. If there is no expected impact or it's minimal, less time may be required.

## Seattle-Tacoma International Airport—PBN Departure, Arrival, and Approach Implementation

The Alaska Air Group and Port of Seattle—Seattle-Tacoma International Airport staff, The Boeing Company, and local FAA ATO personnel pursued the Greener Skies project to develop PBN flight procedures for the airport to reduce the environmental impact of air traffic. The approach procedures utilized radius-to-fix navigation capability of aircraft, and applied Established on RNP criteria permitting reduced separation between aircraft on RNP and ILS approaches to the airport's parallel runways. The airport supported placement of navigation waypoints in the arrival procedure to address known sensitivities of the community to aviation noise. The FAA conducted its own public outreach campaign and encountered community opposition. SEA personnel assisted with outreach to engender community understanding of and support for the procedures.

## Introduction

The Seattle Metroplex serves the Seattle/Tacoma metropolitan area of Washington and includes SEA, King County Airport—Boeing Field (BFI), Snohomish County Airport (PAE), and Tacoma Narrows Airport (TIW). SEA is a large hub international airport. Located 12 miles south of central Seattle, it was the fastest growing large hub airport in the U.S. in 2014. SEA is owned and operated by the Port of Seattle. The airport has three runways, one central and two satellite terminals and four concourses, as shown in Figure C-12, and is the main hub for Alaska Airlines and Horizon Air. In 2013, SEA had 16,690,295 enplanements with 657,664 operations.



Source: Federal Aviation Administration.

**Figure C-12.** Plan view of Seattle-Tacoma International Airport.

BFI is located approximately five miles south of central Seattle. It is categorized as a primary non-hub airport and is considered one of the busiest in the nation. BFI has some passenger service, but is mostly used for operations associated with Boeing aircraft manufacturing, general aviation, and cargo. FTY has two runways and an FAA-operated control tower. In 2013, the airport had 13,008 enplanements and 361,335 operations. PAE is located in unincorporated Snohomish County, between Mukilteo and Everett, Washington. It is categorized as a general aviation airport and is home to the Boeing Everett Factory, Aviation Technical Services, one of the nation's largest aviation maintenance facilities, and four

flight schools. PAE has three runways (one is closed except for taxiing) and is served by an FAA-operated control tower. In 2013, PAE had 127 enplanements and 224,942 operations. TIW is located in Pierce County, approximately five miles west of central Tacoma. The airport is categorized as a general aviation airport and the county's primary business jet facility. TIW has one runway and is served by an FAA-operated control tower. In 2013, TIW had 93 enplanements with 95,165 operations.

The FAA's PBN Dashboard provides analysis of the equipage levels among general aviation, Part 121 major, regional and cargo aircraft, and IFR operations at SEA as of January 2015 (Federal Aviation Administration 2015). The results indicate that approximately 100% of Part 121 aircraft and IFR operations, and 35% of general aviation aircraft, are capable of RNAV 1 and RNP 0.3-1. Seventy percent or more of Part 121 major and regional aircraft and IFR operations, and fewer than 10% of Part 121 cargo aircraft, are capable of RNP AR. The FAA's PBN Dashboard indicates SEA has an inventory of four RNAV SIDs, two RNAV STARs and nine RNP approach procedures.

In 2009, Alaska Air Group (AAG), the holding company for Alaska Airlines and Horizon Air, and Port of Seattle—Seattle-Tacoma International Airport staff, in cooperation with The Boeing Company and local FAA ATO personnel, initiated development of a plan to investigate new PBN flight procedures for SEA that would utilize these latest navigational technologies and allow aircraft operators to fly optimal descent paths with radius to fix legs, while reducing their environmental impact during approaches to land. The program was ultimately named the "Greener Skies Over Seattle" or simply "Greener Skies." Greener Skies consists of procedural changes that begin in the Seattle ARTCC (ZSE), continue into the airspace of the Seattle TRACON (S46), and eventually end in the airspace controlled by Seattle ATCT as aircraft descend from cruising altitude all the way to landing on one of SEA's six runway ends. In 2010, the FAA NextGen Management Board authorized Greener Skies and took over responsibility for the development of criteria supporting simultaneous RNP operations, and the completion of the final design and implementation of the procedures, consistent with the Agency's functional role in controlling aircraft.

## Demographics

The land use of the areas immediately adjacent to the airport boundary to the north is composed of commercial, industrial, and park areas. Residential areas exist beyond these areas further to the north. The areas to the south are primarily commercial, industrial, and park/recreation. Residential areas exist beyond these areas to the northwest. The demographics of the residential areas are mostly middle class, with pockets of upper class. Most of the community is knowledgeable of the types of airplanes associated with the various operations at the airports in the Metroplex. There are no formal noise committees or noise groups in the areas. SEA receives approximately 1,000 noise complaints per year. SEA holds occasional open houses to inform and engage with surrounding community. Figure C-13 shows the areas surrounding SEA.



**Figure C-13.** *Seattle-Tacoma Airport and the surrounding area.*

## Project Description

The Greener Skies project specifically involved development and implementation of multiple PBN procedures:

- A new STAR procedure for traffic arriving from the northwest to land on any of the six runway ends at SEA.
- A new STAR for aircraft arriving from the southwest that would reduce the number of flight miles flown when landing on any of the six runway ends.
- Implementation of 21 new RNP and RNP-to-ILS procedures utilizing RF legs northwest and southwest of SEA.
- Optimized Profile Descents from both the northwest and southwest.

A unique aspect of this project was the use of RF legs. At the time no other airspace design effort was attempting to implement RF legs due to the advanced equipment and training required for the airlines. However, the Alaska Airlines was fully equipped and certified for RNP procedures and RF legs.

The Greener Skies project was split into three initiatives: 1) Designing PBN procedures for implementation into the SEA Metroplex; 2) performing research and safety studies needed to validate ATC separation rule changes utilizing a technique called “Established on RNP,” which allows for simultaneous operations on RNP approaches or RNP and ILS approaches; and 3) modification of ATC standards to allow applicable PBN standards to be implemented across the NAS based on the confirmed safety identified in initiative 2.

In 2011, the final draft designs of the PBN instrument flight procedures were completed. In 2012, the procedure designs were tested by Alaska Airlines in a 737 flight simulator and by Alaska Airlines, Horizon, US Airways, and SkyWest in flight trials. In 2013, the final procedures were implemented for use. The FAA final designs also included efforts to assure broad availability of the new procedures to all appropriately equipped aircraft, advancing the use of the technology in SEA's complex airspace that includes step-down approaches, confliction points, and frequent pilot/controller radio communications.

## Processes Used

Greener Skies was a collaborative effort and a prime example of PBN implementation with airport involvement. The project ultimately transitioned to the FAA for implementation, however, the airport and Alaska Airlines (the representative carrier) remained deeply involved throughout the process. During the FAA's development process, airport representatives attended every meeting. The FAA met with the airport representatives, controllers, and airlines to decide on the placement of flight tracks of waypoint for each procedure. In many cases, the location of a waypoint shifted numerous times before the final design was settled upon. The FAA used the 18-step process in some form to develop the procedures, followed the Acquisition Management System Engineering and Safety Risk Management (SRM) processes for criteria development, and NEPA standards for the environmental analysis.

## Criteria Development

Extensive criteria development was conducted in support of a procedure called "Established on RNP." The need for these new criteria arose from the lack of parallel operations criteria based on the use of RNP operations including the use of RF legs. When a leading aircraft on a straight in ILS approach to one runway, and a following aircraft on an RNP approach with RF turn onto final on other runway, there is the potential for the aircraft to be separated less than 3 nm apart. Criteria exist to allow the separation of aircraft on ILS final approaches to drop below 3 nm, but no criteria had been established for RNP operations in a similar scenario.

The FAA utilized the Systems Engineering 2020 program to acquire additional contract staff support as part of the effort to solve the separation standards issue. The Greener Skies team conducted evaluations and modeling to prepare criteria for the development of separation standards enabling the operation. The team established a project plan, concept of operation for the proposed procedures, and conducted modeling simulation and data analysis to evaluate the safety, flyability, and feasibility of the procedures in support of the SRM process required by FAA for the proposed rule changes.

The FAA completed the SRM in January 2013 and conducted HITL modeling to verify and validate the findings. The FAA Air Traffic Organization requested a waiver to standards in April, 2013 to enable the implementation of the procedures. On April 7, 2015, SEA implemented "Established on RNP" procedures allowing for the simultaneous use of the PBN and ILS procedures. The FAA is continuing to evaluate the procedures and perform analysis to address issues that have arisen with controller training, pilot training, and familiarity. SEA will stop using Established on RNP until October 2015 due to an airport construction project.

## Project Communication and Public Outreach

The project study and design phase was a collaborative effort between FAA, airlines, The Port of Seattle, and the Boeing Company. Multiple meetings were held and all parties were invited to all of the meetings. Boeing, Alaska, and the Airport were invited to attend, however, were not able to participate in a significant or meaningful way.

The FAA conducted a public outreach as part of the EA. The process included two public scoping meetings—one held south of SEA on January 25, 2012 in Federal Way and one north of SEA on January 26, 2012 in Shoreline. A tribal scoping session was held at FAA's offices on January 26, 2012 in Renton. At each meeting the FAA presented an introductory workshop session, disseminated project information, made two formal presentations, and solicited comments.

## Environmental Analysis

The FAA with support from a commercial contractor prepared an EA based on NEPA standards. A FONSI ROD was issued on October 31, 2012 for multiple procedures including:

- A new STAR for traffic arriving from the northwest to land on any of the six runway ends at SEA. The new procedure is expected to increase slightly the number of flight miles flown for some aircraft, taking them farther north than at present. Instead of overflying northern portions of Kitsap County as now, more of that traffic would approach the runways from over Hansville and Puget Sound south of Island County. However, compensating benefits derived from aircraft operating at slightly higher altitudes, undergoing fewer level-off segments, and maintaining lower thrust settings during the approach offset the penalty of increased flight miles.
- A new STAR for aircraft arriving from the southwest that would reduce the number of flight miles flown when landing on any of the six runway ends. In particular, the removal of a significant “dog leg” to the west over Olympia, Washington would be replaced by more direct routings generally over the former Fort Lewis Military Reservation and to either side of the former McChord Air Force Base, the two installations now collectively merged and known as Joint Base Lewis-McChord (JBLM).
- Implementation of new RNP and RNP-to-ILS procedures northwest and southwest of SEA. New approach procedures would provide high-precision extensions of the STARs onto curved approach paths and short straight-in final approaches to touchdown with less need for intervening interaction by air traffic controllers.
- Fifteen of the RNP procedures would provide instrument guidance for landings on runways 16L, 16C, and 16R (five to each runway end). Twelve of the 15 would lead aircraft in over Elliott Bay and the industrial area south of Harbor Island, and the other three would provide guidance to aircraft generally overflying areas of north Seattle subject to overflights now but guided by instructions from ATC.
- An additional six RNP procedures would guide aircraft along curved approach paths over the Port of Tacoma, keeping them north of Interstate Route I-5 and lining them up to land on runways 34L, 34C and 34R. Three other procedures represent transitions to longer straight-in instrument approaches very similar to now.

The airport was not included in the environmental process. Including the airport would have been instrumental in garnering public support and promoting the benefits of PBN to the community making the public outreach process smoother.

## Project Outcomes

Outcomes from the Greener Skies project include:

- The overall outcomes of the Greener Skies initiative were considered to be positive in terms of improving flight efficiency, enabling Established on RNP operations and satisfying the majority of the communities' concerns regarding noise.

- As previously discussed, the effort included the implementation of multiple OPD STAR procedures, and multiple RNP and RNP to ILS approach procedures.
- Equally important is the development of criteria development associated with EoR procedures allowing simultaneous RNP and RNP/ILS procedures to occur.
- The benefits of these new criteria include shortened flight path miles flown, avoidance of highly populated residential areas, reduction in noise and emissions, flexible use of airspace, and increase in capacity. These criteria will also serve to provide similar benefits at airports throughout the NAS.

## Post-Implementation Metrics

It is too early to say what the effects of Greener Skies are at this time. According to SEA data, there are 10 to 12 aircraft/day conducting Established on RNP procedures, most are Alaska Airlines flights. In a recent article (Environmental Leader 2015) concerning the Greener Skies initiative, post-implementation assessment focuses on impacts to industry and the local environment, including fuel burn, flight time, and emissions. Alaska Airlines predicts it will save 87 gallons of fuel, reduce flight time by nine minutes, and reduce carbon emissions by one metric ton for each arrival to SEA. Analysis of arrivals from the southwest when SEA is in a south flow configuration, assuming all aircraft can conduct EoR arrival procedures, estimates annual fuel savings of 2.7 million gallons and carbon emissions reductions of 25,600 metric tons.

Regarding local airport impacts, noise is a fundamental concern. SEA is installing a brand new noise monitoring and flight tracking system. A contractor to the airport is trying to implement the system to monitor tracks on per-aircraft and per-airline bases to understand and evaluate utilization and impact of PBN procedures. This is a new initiative to try to evaluate aircraft at a specific altitude and location. Flight tracks of participating and non-participating aircraft will be compared to determine the level of compliance to flight corridors in the original design of the procedures.

The FAA's PBN Dashboard provides analysis of the average daily number of IFR operations, the average daily usage levels of individual RNAV SIDs and RNAV STARs, and the usage levels of RNP AR approaches with RF legs for a specified calendar year at SEA (Federal Aviation Administration 2015). It indicates an average of 942 daily IFR operations. The average daily usage counts for the RNAV SIDs sum to 76 departures, and the RNAV STARs sum to 433 arrivals. RNP AR approaches were executed by 206 arrivals among 72,440 candidate aircraft, with usage concentrated to approaches to runway 16L and runway 16C.

## Lessons Learned and Best Practices

The lessons learned from the Seattle case study include:

- Airports can successfully initiate and lead their own PBN development projects though aircraft operator and FAA involvement is also required.
- Knowledge of PBN supports meaningful engagement with the FAA in PBN development.
- Airports can contribute knowledge of local noise constraints and other considerations to the PBN development process.
- Airports can affect design changes to the proposed procedures to meet local noise constraints and other needs. However, this depends on the specifics of the project. In some cases, airports may be unable to affect change or the ability is limited due to project priorities and other factors.
- The FAA will lead its own environmental analysis and public outreach effort.

- Airports should be prepared to engage with the community concerning FAA-led initiatives and their impacts.
- Benefits and impacts of PBN procedures should be presented in community-understandable terms.

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