Operations Inside Corridors

October 2020

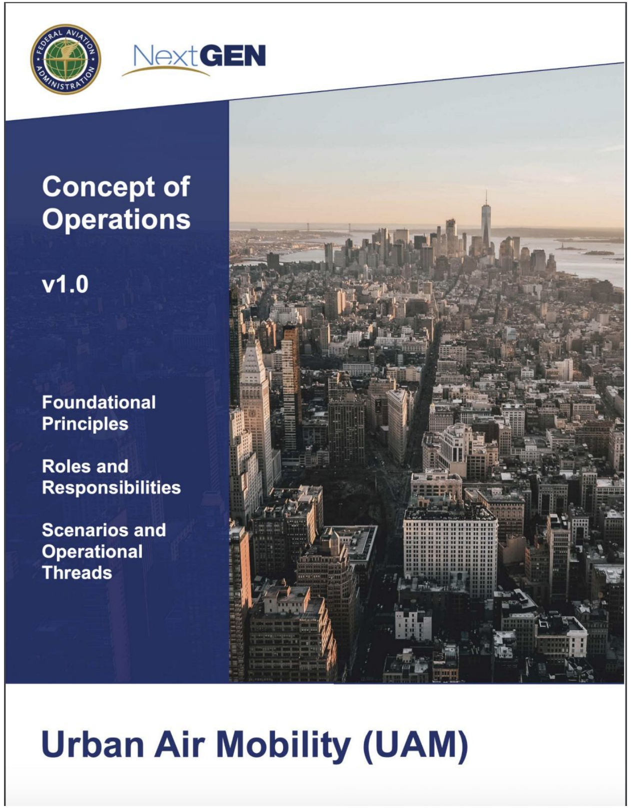
Uber Elevate

Contents

FAA NextGen Concept of Operations v1.0

Overview

- Air traffic management vision for Initial Concept of Operations in the near term
- developed through a series of collaborative activities and engagement in partnership with FAA, NASA, and industry stakeholders
- future collaboration with stakeholders will further mature and modify this document.



FAA Conops v1.0 page 1 (available at https://nari.arc.nasa.gov/)

FAA UAM Conops v1.0

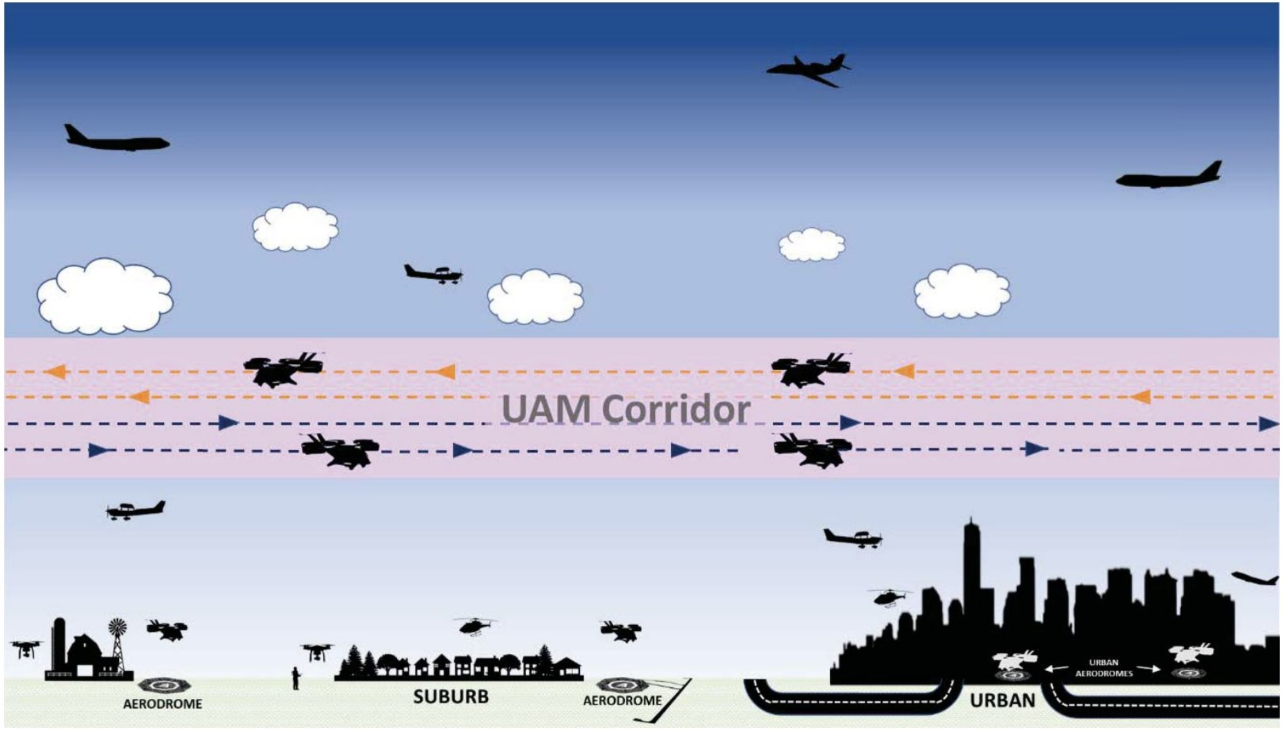


Figure 4-2: UAM Corridor with "Tracks"

FAA Conops v1.0 page 18 (available at https://nari.arc.nasa.gov/)

FAA UAM Conops v1.0

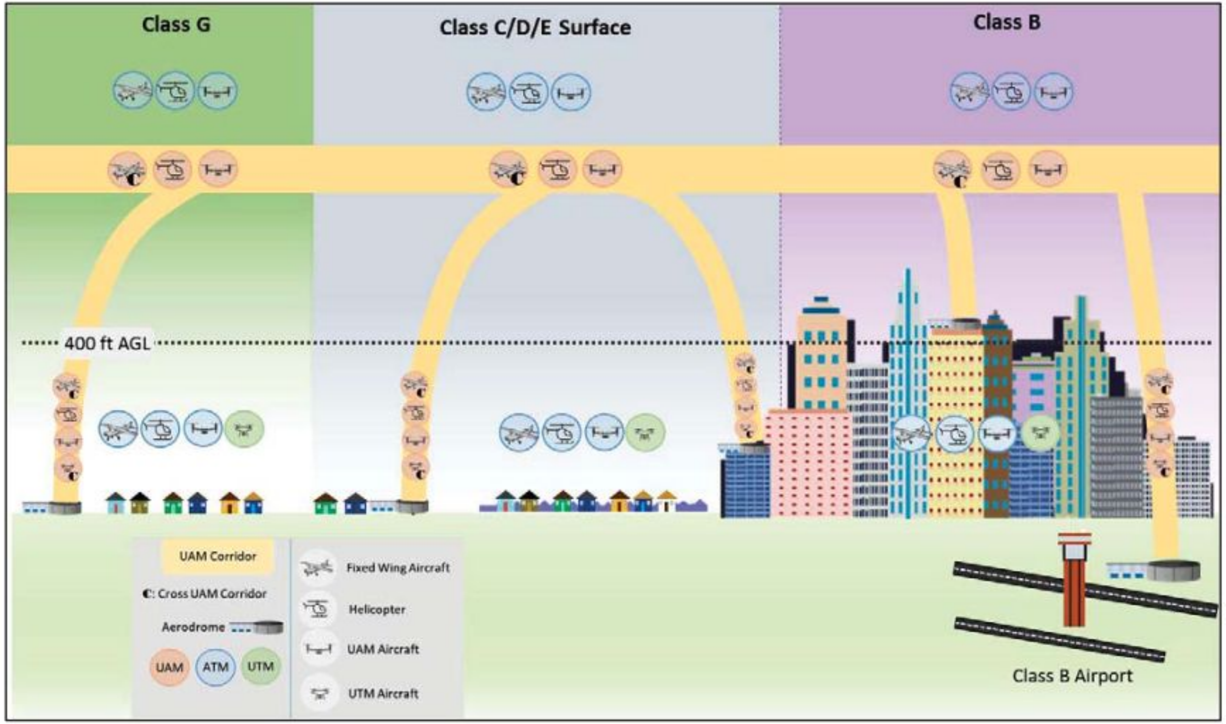


Figure 1-2: UAM, UTM, and ATM Operating Environments

FAA Conops v1.0 page 5 (available at https://nari.arc.nasa.gov/)

FAA UAM Conops v1.0 - Evolution

Initial UAM Operations

- Low operational tempo
- Helicopters or UAM aircraft
- Consistent with current rules and regulations
- Use of existing infrastructure and procedures
- Air Traffic Control services, Helicopter routes, helicopter technology level
- Existing agreements, e.g.LOA
- Pilot on board

Conops v1.0 Operations

- Higher operational tempo requires changes to policies and regulatory framework
- Defined UAM corridors from specific aerodromes based on UAM performance requirements
- Tactical separation within corridors assigned to Operators, pilots and support services, not ATC
- Industry defined community based rules approved by FAA
- Increased level of automation
- Pilot on board

Mature State Operations

- Operational tempo increases significantly
- Network of defined UAM corridors to optimize paths between an increasing number of aerodromes
- Performance requirements may increase
- Additional regulatory changes may be necessary
- More comprehensive community based rules and FAA involvement
- No pilot on board

FAA Conops v1.0 page 8-9 (available at https://nari.arc.nasa.gov/)

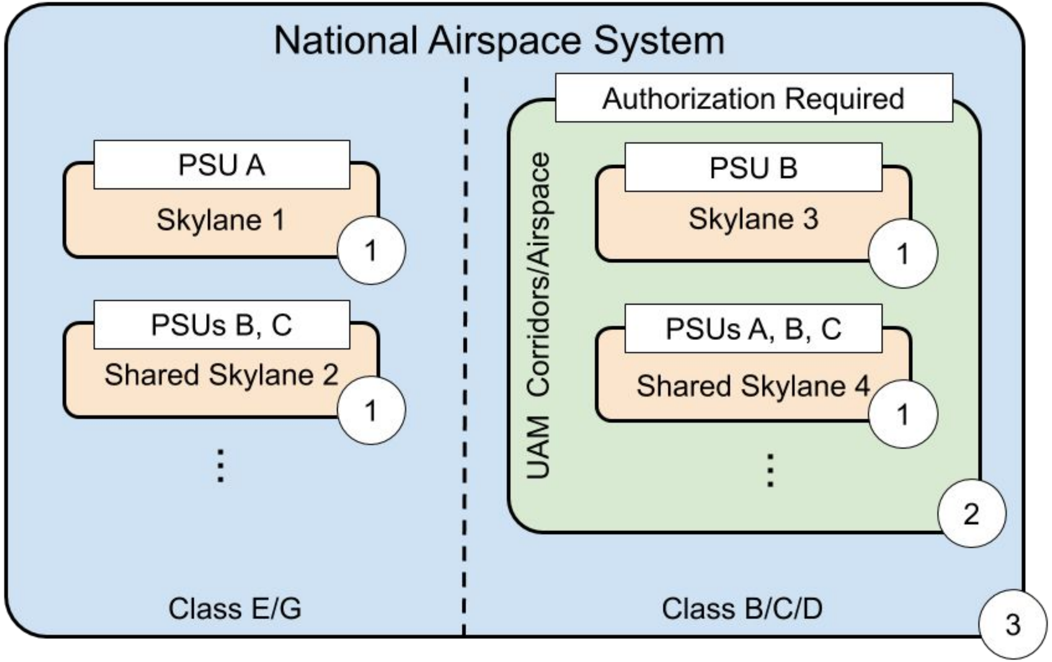
Considerations for Operating Inside Corridors

- Corridors are a near term tool to enable higher tempo UAM operations in designated sections of controlled airspace while trying to minimize impact on the other traffic
- Routes provide predictability and structure and increase throughput at bottlenecks
- VFR corridors and routes are used successfully today
- Shared between users/operators
- Corridors can have multiple tracks or skylanes (for different performance, e.g. speed)
- No extra workload for air traffic controllers controlling traffic outside of corridors (e.g. radio communication/manual controller handoffs)
- Higher navigation performance leads to smaller corridors and/or higher throughput
- Operations and procedures including contingencies should be highly predictable

Airspace Constructs

1. Tracks or skylanes
2. UAM Corridors*
3. National Airspace System

Key throughput requirement: aircraft with significantly differing performance characteristics should use different skylanes



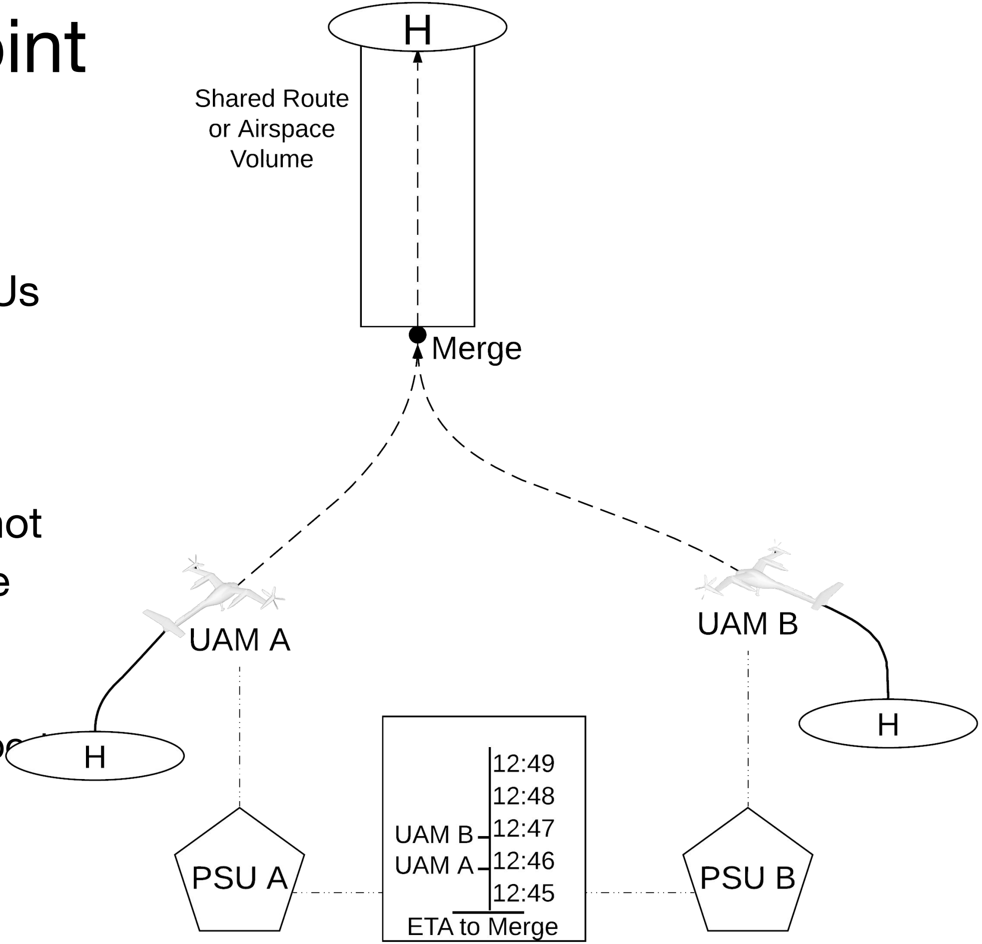
*as proposed in FAA Conops v1.0, when UAM operations become sufficiently dense in Class E and G airspace, UAM corridors may be used for higher density routes there as well

Components of a Performance Authorization

- **Aircraft performance** (e.g. airspeed, altitude, vertical rates)
- **Operations** (e.g. flight path in uncontrolled airspace or within UAM-authorized corridors, receipt of an automated authorization, noise profile limits)
- **PSU capabilities** (the optional capabilities could be fulfilled through means other than a PSU, for example the pilot can assign a route)
- **Weather thresholds** (e.g. VMC, icing, turbulence, etc.)
- **Equipment** (e.g. VHF radio, Mode-C/S transponder, ADS-B In/Out, GBAS or WAAS IFR-certified GPS, digital datalink to PSU, pressure altitude)
- **Pilot training** (e.g. in addition to the commercial pilot certificate with appropriate category, class and type rating or type specific training for a given eVTOL aircraft, special training may be required by regulation or operator policy).

Sequencing to Merge Point

- Arrival times at merge points may be estimated pre- or post-departure
- Merge ETAs are shared with other PSUs
- Departure times may be adjusted to provide reasonably well-conditioned flows
- But, pre-flight deconflicted flows are not required because other mitigations are available
  - Common voice frequency
  - Flight deck sequencing decision support tools
  - Tactical maneuver advisories by PSU



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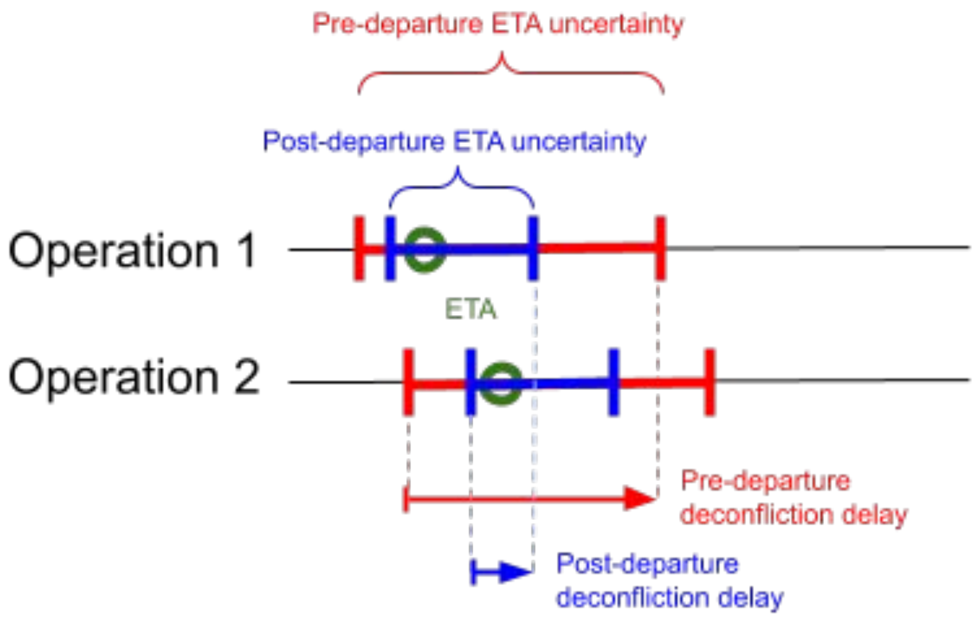
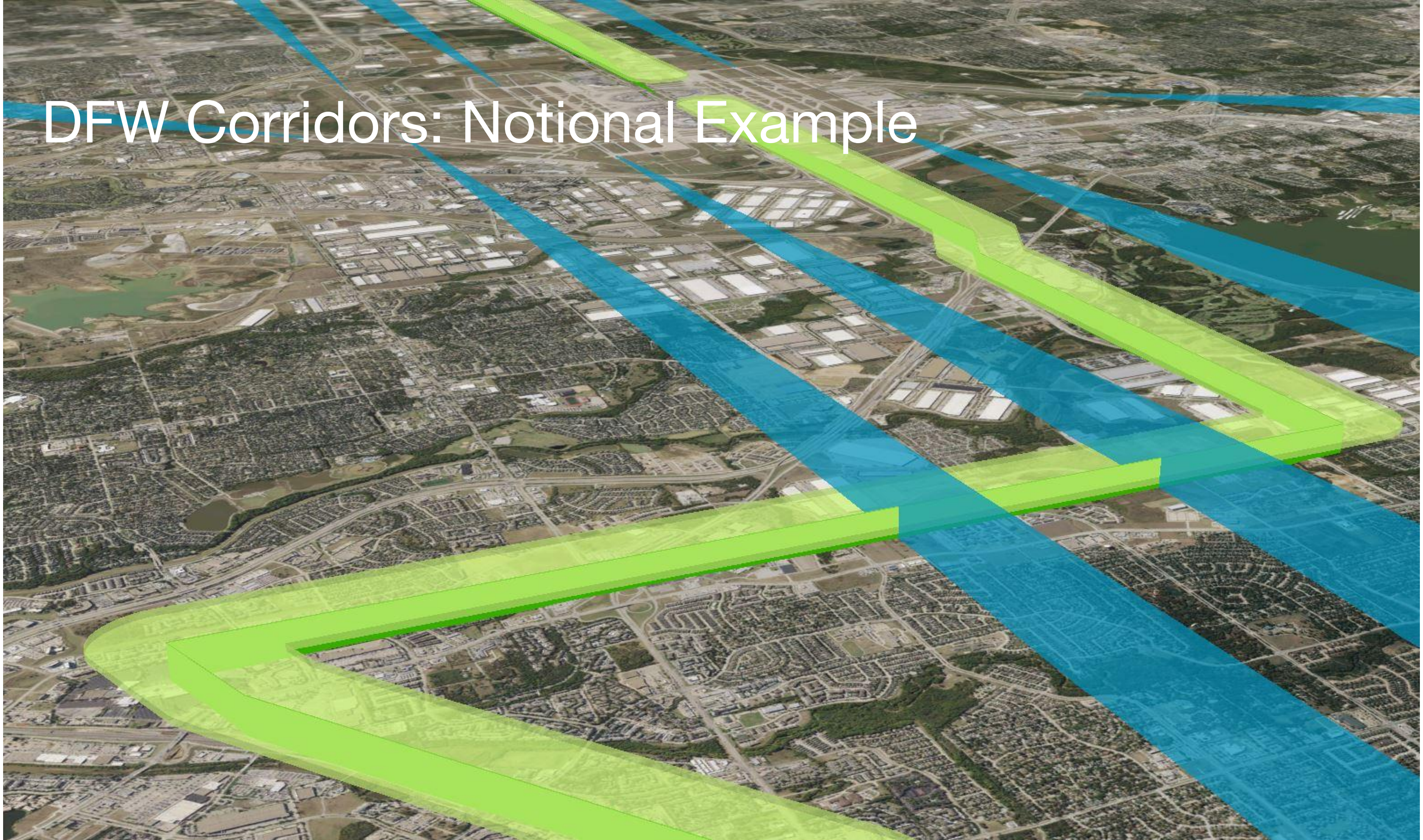
Coordination of Operations: Strategic Deconfliction?

Pre- and Post-Departure Deconfliction Delay

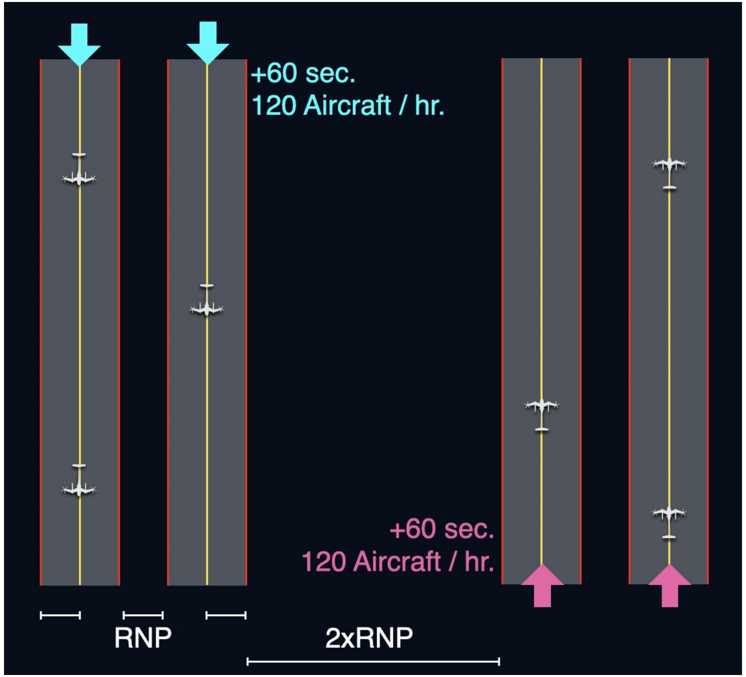
- Green circles are ETAs to the merge point
- Red bars are the uncertainty in the ETA ***before departure***
- Blue bars are the uncertainty in the ETA ***after departure***



DFW Corridors: Notional Example



Notional Performance Analysis



Throughput Estimate
(aircraft per hour)

		RNP		
Corridor	**Layers**	**0.3**	**0.1**	**0.01**
DFW Spine	**Single**	17	17	240
	Dual	120	120	480
2 nmi Width	**Single**	120	360	1320

Assumptions

- Capacities are for a single altitude band (for 2 nmi corridor) and dual altitudes (for DFW spine)
- Pilot-provided well clear separation
- Cruise speeds of 120 kts with 2 nmi in-trail distance (1 minute)
- Uniform fleet performance
- Opposite-direction skylanes have an additional buffer separated by value of 2*RNP or 1000 ft, whichever is greater

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Oshkosh EAA Airventure

- To get to OSH aircraft fly .5 NM (20 seconds) in trail via Ripon/Fisk at 1800 ft and 90 knots, up to 180 aircraft per hour. Higher performing aircraft use 2300 ft and 135 knots
- At Wittman alone, in 2019 there were 16,807 aircraft operations in the 11-day period from July 19-29, which is an average of approximately 127 takeoffs/landings per hour.
- 32 page NOTAM with contingencies

Fisk VFR Arrival to OSH

General Information

This procedure is to be used by all VFR aircraft landing at OSH from Friday, July 19, through Sunday, July 28, 2019 (except those using the Turbine/Warbird, Ultralight or NORDO arrivals).

The procedure starts at Ripon, WI (15 NM SW of Oshkosh) and requires visual navigation. Pilots follow a railroad track from Ripon to Fisk, WI. ATC at Fisk controls traffic flow and assigns OSH landing runways and approach paths (pages 8-11).

Planning

Plan your arrival to avoid airport closure periods, such as the daily airshows listed on page 1. Arrivals normally resume 30 minutes after daytime airshows. Allow ample time to arrive and park before the daily airport closure at 8 PM CDT.

Plan your fuel load carefully. If you do not have sufficient fuel for unexpected holding and possible landing go-arounds, divert to an alternate. **If your fuel status is critical, notify ATC immediately.**

First, fly the aircraft. If you are not comfortable with the OSH AirVenture procedures, please consider flying into FLD or ATW and taking public transportation to OSH.

Approaching Ripon

Ensure lights are on within 30 miles of OSH. Leave transponder on throughout approach.

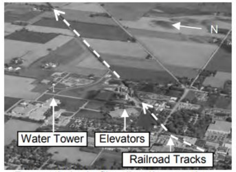
Obtain Arrival ATIS (125.9) no later than 15 miles from Ripon and note arrival runways in use. Have NOTAM arrival pages mentioned on ATIS available. Then monitor Fisk Approach (120.7).

Arrive at Ripon at 90 knots and 1,800'. For aircraft unable to operate comfortably at 90 knots:

- Slower aircraft should use maximum cruising speed. ATC recommends arrival at Fisk 7:00-7:30 AM CDT, if practicable.
- Faster aircraft use 135 knots and 2,300'.

Ripon to Fisk

If holding is not in progress, enter the VFR Arrival Procedure over the northeast corner of Ripon (OSH 232°, 15.5 DME).



Proceed single file, directly over the railroad tracks from Ripon northeast to Fisk (10 miles). Remain at least ½ mile in-trail behind any aircraft you are following. Do not overtake another aircraft unless authorized by ATC.

Do not "S-turn" to follow an aircraft; instead, break off the procedure; return to Ripon; and follow another aircraft of similar speed.

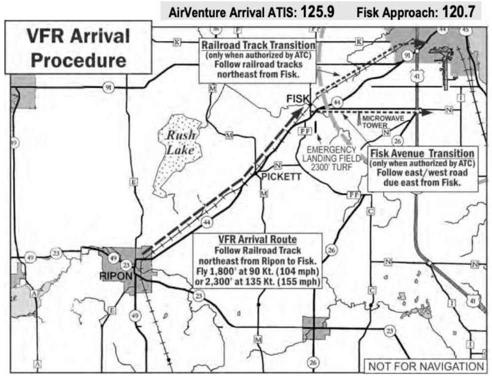
GPS-equipped pilots may reference RIPON and FISKE intersections, but must visually navigate directly over the railroad tracks.

If possible, lower your landing gear prior to reaching Fisk.

The small town of Pickett is about 4 miles from Fisk (you may see steam from the grain drying facility adjacent to the tracks). At this point, listen very carefully for ATC instructions directed at your aircraft.

Fisk VFR Arrival to OSH

AirVenture Arrival ATIS: 125.9 Fisk Approach: 120.7



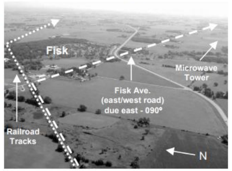
At Fisk

Controllers will call your aircraft by color and type (if known). No verbal responses are required. If you do not understand the ATC instructions, or need clarification, request instructions on frequency.

When you are in the immediate vicinity of Fisk (less than 2 miles), ATC will issue a runway assignment, transition to the airport and appropriate Tower frequency to monitor. **Do not proceed beyond Fisk or change to Tower frequency without ATC authorization.**

Fisk to Oshkosh

Transition instructions to the airport will either be "**Follow the railroad tracks northeast**" or "**Reaching Fisk, turn right and follow east/west road (Fisk Ave.)**".



(continued on next page)

Further Thoughts on Navigation Performance

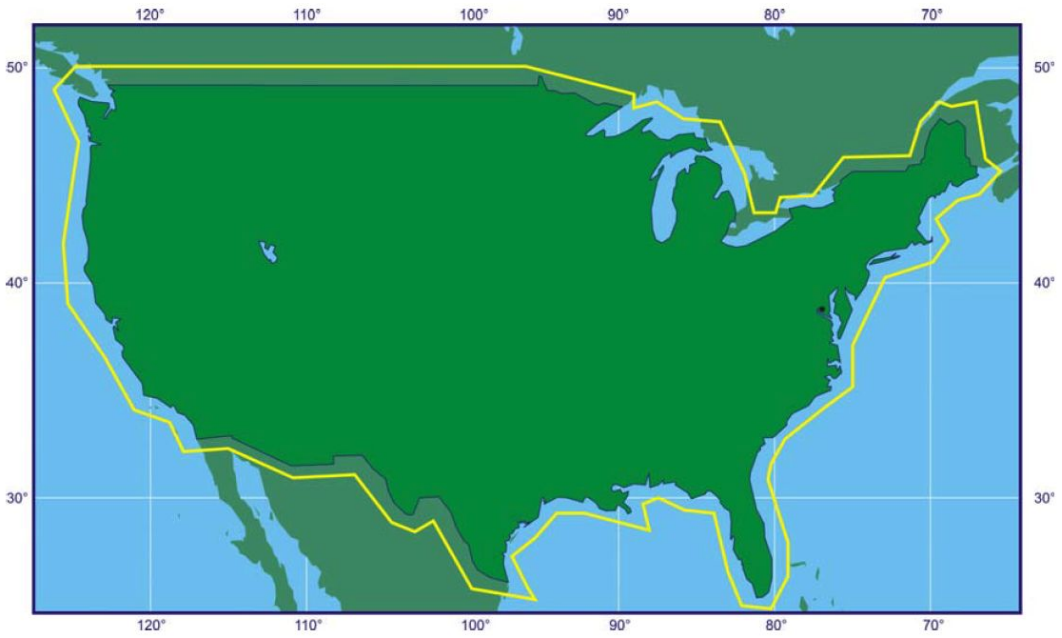
WAAS Accuracy
(LPV Approach, 200-ft Decision Height)

	Alert Level (HAL/VAL)	Accuracy Requirement (95%)	LPV-200 Actual Performance (95%)
Horizontal	40 m	16 m	0.7 m
Vertical	35 m	4 m	1.2 m

Sources:
Alert Levels and Accuracy Requirements: FAA, *Global Positioning System Wide Area Augmentation System (WAAS) Performance Standard*, 1st Edition, Table 3.2-1, 10/31/2008.
Actual Performance: FAA, "Satellite Navigation - WAAS - Benefits", last modified 12/23/2016.

WAAS Coverage in CONUS

Zone 1 - Zone 1 is defined as the region from the surface up to 100,000 feet above the surface of the 48 contiguous states, extended to 30 nautical miles (nm) outside of its borders.



Source: FAA, *Global Positioning System Wide Area Augmentation System (WAAS) Performance Standard*, 1st Edition, Figure 3.1-1, 10/31/2008.

WAAS vs. RTK

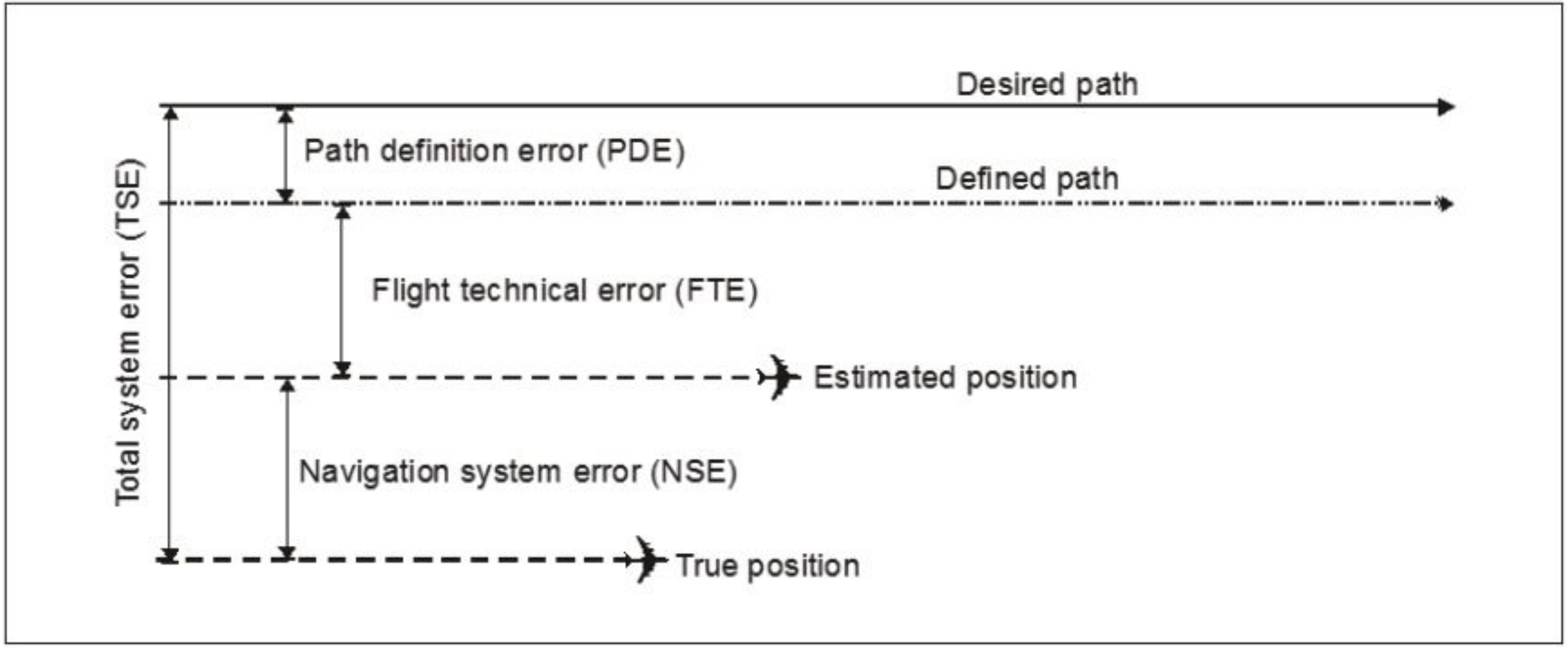
- RTK is nearly 2 orders of magnitude more accurate than WAAS:
  - WAAS: 0.7 m
  - RTK: 0.01 m

- But RTK may not be needed:
  - RNP of 0.01 nmi ~= 18.5 m (actual WAAS accuracy of 0.7 m is significantly lower).
  - Effort might be better invested in ensuring autopilots can meet FTE budget for TSE.

- Sample issues with RTK:
  - Multi-path (errors up to 5-6 cm)
  - Cycle-slip (errors up to several meters)

RTK Data Source: Imparato, Davide, Ahmed El-Mowafy, Chris Rizos, and Jinling Wang, "Vulnerabilities in SBAS and RTK positioning in intelligent transport system: An overview", *Proceedings of the International Global Navigation Satellite System Association IGNSS Symposium*, 2018.

Total System Error (TSE)



Source: FAA, AC 90-105A, *Approval Guidance for RNP Operations and Barometric Vertical Guidance in the U.S. National Airspace System and in Oceanic and Remote Continental Airspace*, Figure 4-2, 3/7/2016.

Navigation Accuracy by NavSpec/Flight Phase

Navigation Specification	Flight Phase						
	En route Domestic	STAR/ Feeder/TAA	Initial	Intermediate	Final	Missed[1]	Departure
RNAV 2	2	2					2
RNAV 1[2]		1					1
RNP 2	2						
RNP 1[2]		1					1
RNP APCH[2,3]			1	1	0.3[4]/40m[5]	1	
A-RNP[2,6, 9]	2 or 1[8]	1 or 0.3	0.3	0.3	RNP APCH	0.3	1 or 0.3
RNP AR APCH			1 - 0.1	1 - 0.1	0.3 - 0.1	0.1 - 1	
RNP AR DP							0.3 - 1
RNP 0.3[7]	0.3	0.3	0.3	0.3		0.3	0.3

1. Missed approach section 2 only. RNP AR APCH sections 1a and 1b.
2. STAR/Feeder/TAA, departure, initial, intermediate, and missed section 2. Beyond 30 NM from ARP the effective Cross Track Tolerance (XTT)/Along Track Tolerance (ATT) for the purpose of IFP design is 2.
3. RNP APCH part A is enabled by GNSS and baro-VNAV and part B is enabled by SBAS.
4. Part A only.
5. Part B along-track performance is 40 meters; angular performance requirements apply to lateral.
6. A-RNP permits a choice of RNP lateral navigation accuracies in some flight phases. Apply the largest lateral navigation accuracy for the flight phase unless a smaller value is operationally required to achieve the desired ground track.
7. Primarily intended for helicopter operations only. RNP APCH applies to the final flight phase.
8. Remote Continental use 2 (see latest version of AC 90–105 for definition of remote continental).
9. Use of A–RNP STAR/Feeder/TAA or departure XTT less than 1 requires Flight Standards approval.

Source: FAA, Order 8260.58B, *United States Standard for Performance Based Navigation (PBN) Instrument Procedure Design*, Table 1-2-1, 8/24/2020.