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RNP AR APCH



07-10 April 2015

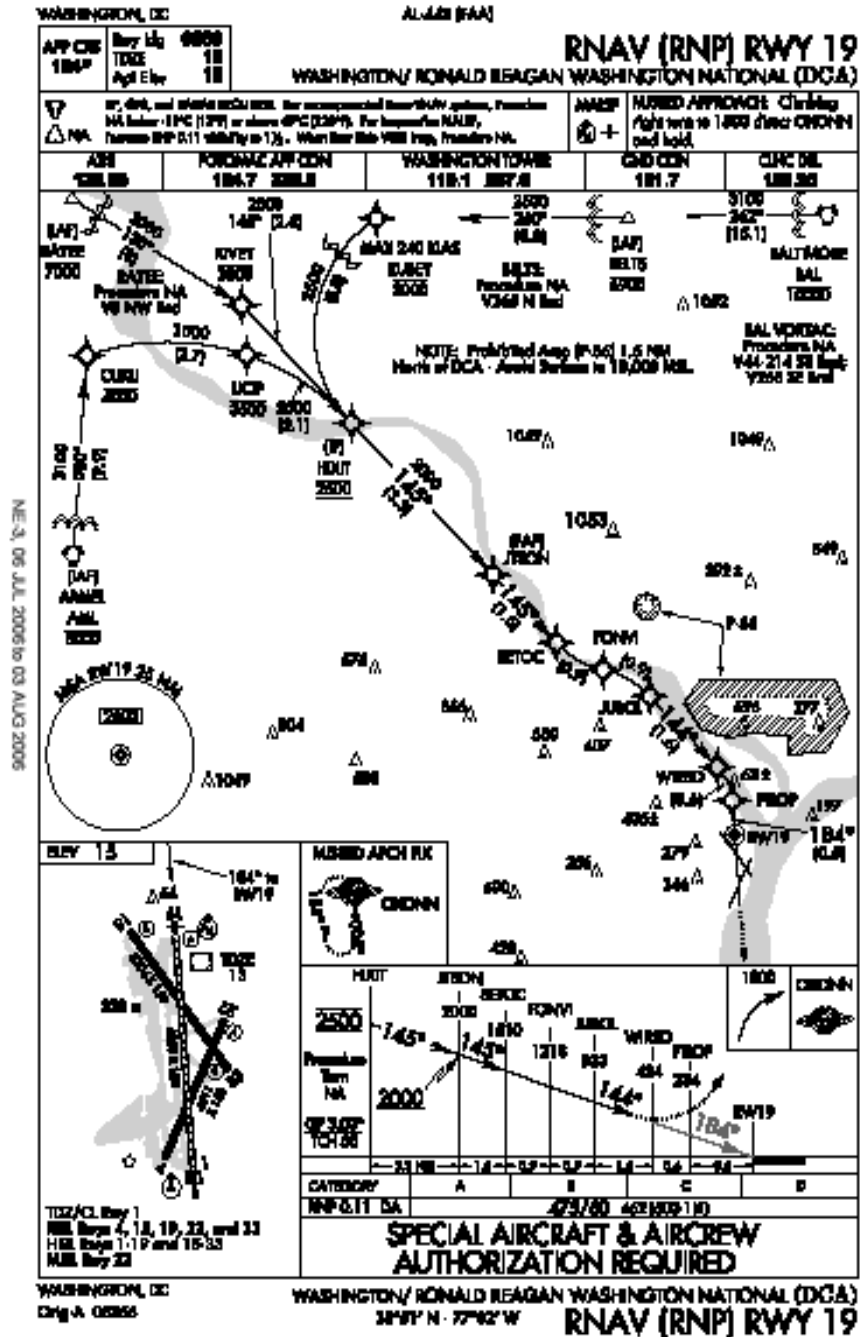


Background on ICAO Guidance for RNP AR APCH Procedures

- **Developed based on operational experience in implementing unique approach procedures in multiple States**
 - United States (Alaska Airlines), Canada (West Jet), New Zealand, Australia (Qantas)
- **Developed to take advantage of navigation capabilities in existing RNP-certified aircraft**
- **“AR” = “Authorization Required”**
 - Similar to how CAT III Instrument Landing System (ILS) is approved by Civil Aviation Authorities (CAA)
 - RNP AR APCH capabilities are available in a limited number of current aircraft and for which current operators have limited experience
 - Specific authorization ensures adequate CAA oversight of aircraft and operator to safely conduct these procedures

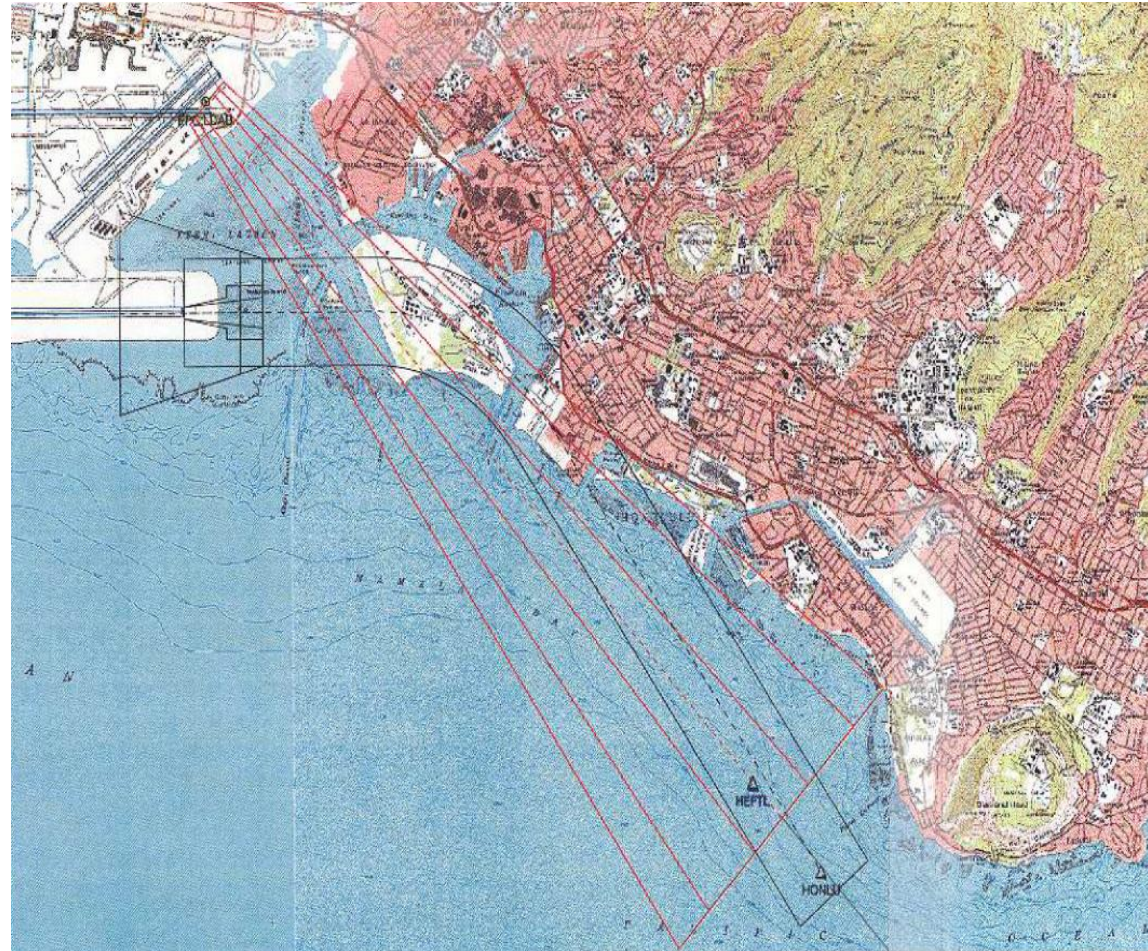
Capabilities

- Reduced Lateral & Vertical Obstacle Clearance
 - Takes advantage of improved aircraft performance
- Curved Paths
 - Use Radius-to-Fix (RF) legs where & when appropriate
- RNP AR Missed Approach Guidance
 - Enable lower minima where extraction requires precise guidance



Applications (1)

- RNP AR APCH can be used to increase safety and access where conventional approach cannot be aligned to runway
- US Honolulu procedure provides stabilized approach with final segment aligned to runway





Applications (2)

- RNP AR APCH can be used to improve safety and increase access in mountainous terrain
- US: Palm Springs procedure provides approach through mountainous terrain

PALEM SPRINGS, CALIFORNIA AL-545 (FAA)

RNAV (RNP) Y RWY 13R
PALM SPRINGS INTL (PSP)

APP CRS 130° Rwy Idg 6857 TDZE 451 Apt Elev 477

RF and GPS required. Procedure NA when control tower closed.
 For uncompensated Baro-VNAV systems, procedure NA below 2°C (35°F) or above 48°C (119°F).
 • Missed approach requires minimum climb of 285 feet per NM to 2400.
 • Missed approach requires minimum climb of 310 feet per NM to 2900.

MISSED APPROACH: Climb to 4000 direct SUYSO and 110° track to TRM VORTAC and hold.

ATIS 118.25	SOCAL APP CON * 126.7 370.95 (W-N) 135.275 251.1 (NE-SW)	PALM SPRINGS TOWER * 119.7 (CTAF) 0 377.05	GND CON 121.9	CLNC DEL 128.35	UNICOM 122.95
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ELEV 477 Rwy 13R Idg 6857 Rwy 31L Idg 8500

GP 3.00° TCH 42

WASAK	LACIV	FIVUT	JEXOT	NUDCI	SUYSO	TRM
6000	4400	3800	2900	1716	4000	17000
5.3 NM	2 NM	2.8 NM	3.6 NM	3.8 NM		

CATEGORY	A	B	C	D
RNP 0.17 DA*		728-1	277 (300-1)	
RNP 0.3 DA**		859-1½	408 (400-1½)	
RNP 0.3 DA		1320-3	869 (900-3)	

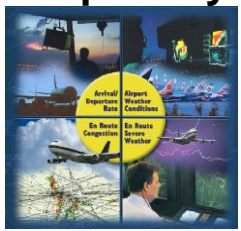
SPECIAL AIRCRAFT & AIRCREW AUTHORIZATION REQUIRED

PALM SPRINGS, CALIFORNIA Amdt 1 07186 33°50'N-116°30'W

PALM SPRINGS INTL (PSP) RNAV (RNP) Y RWY 13R

Successful RNP Implementation Requires All The Elements Be Put In Place

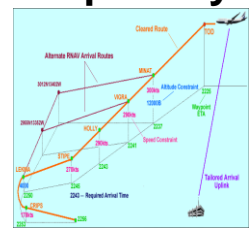
Regulatory Capability



Airport & Facility Capability



Air Traffic Capability



Airline Capability



Airplane Capability



= safe and efficient RNP AR operations



Key Elements of Operational Approval: RNP AR APCH **Operational Approval**

**Procedure Design
Criteria**

**Operational
Procedures and
Standards**

**Equipment/System
Standards**



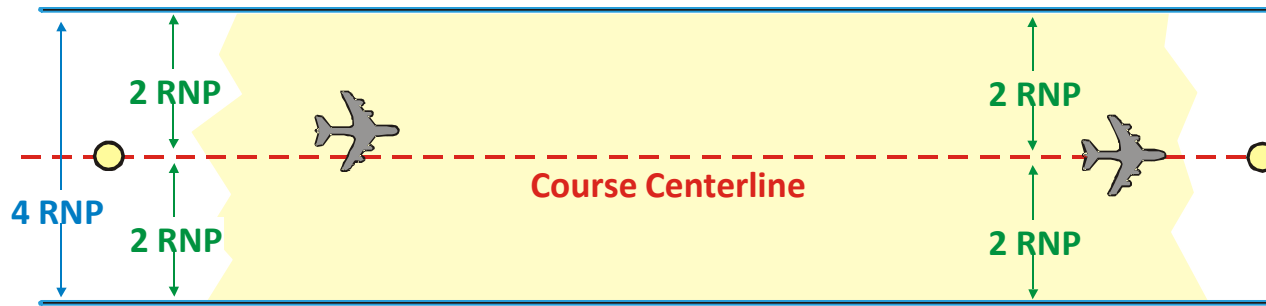
Types of Procedures

- **RNP AR APCH provides several types of procedures to accommodate different aircraft capabilities**
 - Varying accuracy values (RNP 0.3, RNP 0.1)
 - Straight segments only or curved segments (RF)
 - RNP APCH or RNP AR APCH missed approach
- **These characteristics are indicated on each published approach**

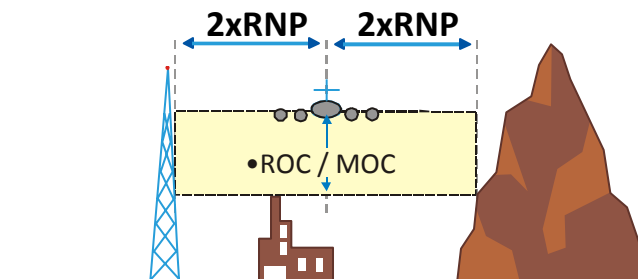


RNP (AR) Approach: RNP Segment Width

PLAN VIEW

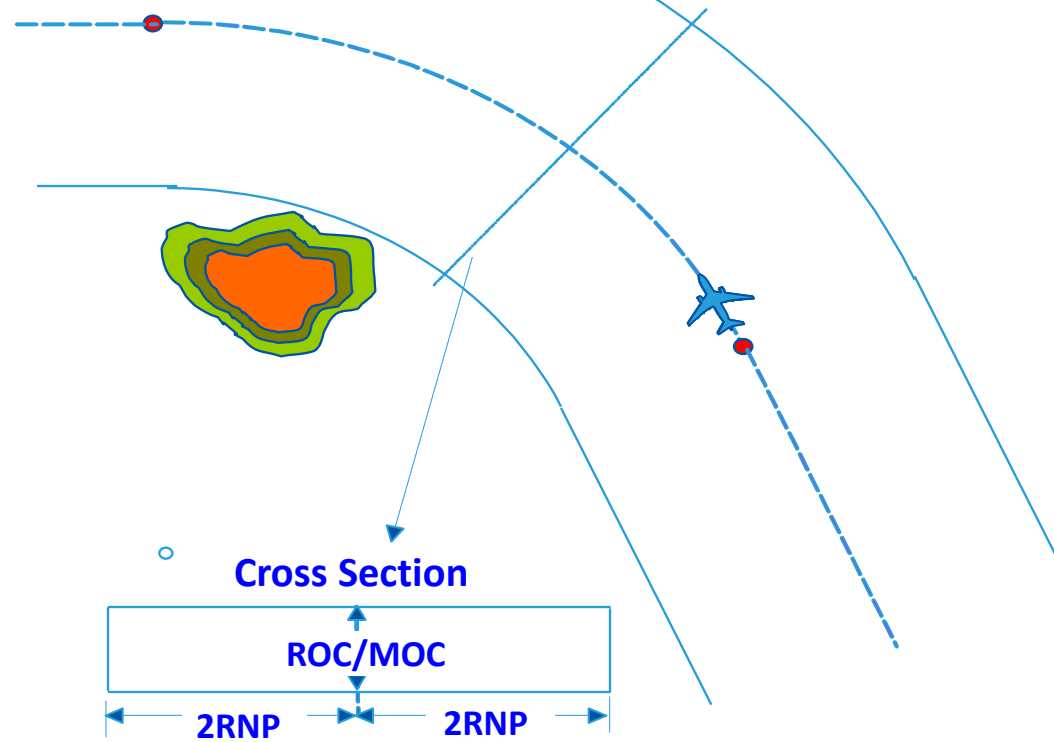


PROFILE VIEW





RNP (AR) Approach Radius to Fix (RF) Turns





Aircraft Eligibility for RNP AR APCH

- **Aircraft eligibility must be determined through demonstration of compliance against the relevant aircraft qualification criteria**
 - Typically documented by Aircraft Manufacturer and accepted by CAA
 - May not require new Aircraft Flight Manual (AFM) entries if previous systems and equipment are adequate
- **Aircraft equipment eligibility includes:**
 - Aircraft qualification
 - Maintenance procedures
 - Minimum Equipment List (MEL) revisions



RNP AR APCH System Performance Monitoring and Alerting

- **Different from other Navigation Specifications**
 - Unique vertical accuracy requirements
 - Unique monitoring and alerting due to reduced obstacle clearance
- **Lateral Accuracy:**
 - Range of accuracy values (0.1 to 0.3 NM)
- **Vertical Accuracy:**
 - Defines 99.7% of system error in vertical direction



C MAX
L354

UPDATE AT
[]
BRG / DIST
--- / --- TO []
PREDICTIVE
<GPS
REQUIRED ACCUR ESTIMATED
0.30NM HIGH 0.06NM
GPS PRIMARY LOST

Monitoring and Alerting - Example





RNP AR APCH System Monitoring and Alerting

- **Alerting relates to:**
 - Lateral and vertical performance
 - Vertical addressed through several operational mitigations
 - Fault-free and faulted performance consistent with safety objective
- **Aircraft and operational requirements work together to meet the requirements for the approach**
 - GNSS and Baro-VNAV equipped aircraft can comply when the aircraft operation is in harmony with the guidance
 - May require new pilot training and procedures
- **Alternate means of compliance for the aircraft can help the operator achieve operational approval**
 - Probability of exceeding the lateral and vertical obstacle clearance volume must be less than 1×10^{-7} per approach



RNP AR APCH Specific Navigation Service Requirements

- **Global Navigation Satellite System (GNSS)**
 - Required to begin any RNP AR APCH
- **Inertial Reference Unit (IRU)**
 - Required for any RNP AR APCH with accuracy value less than 0.3 NM or missed approach with RNP less than 1.0 NM
- **Distance Measuring Equipment (DME)**
 - DME/DME updating may serve as reversionary mode where infrastructure and aircraft can provide required missed approach performance
- **VHF Omni-Directional Range (VOR) Stations**
 - The RNAV system may not use VOR updating

Key Altimetry Functions for RNP AR APCH

- **Altimetry performance is a key component of RNP AR APCH**
- **Criteria requires two, independent altimetry sources in the pilots' primary field of view**
- **Requires a flight crew altimeter crosscheck within $\pm 100'$**
 - Confirms satisfactory input to FMC providing the vertical path
 - Requirement may be met by automated comparator monitor function
 - Absence of automated function requires procedural mitigation → flight crew procedures
- **When the flight crew sets the altimeter, this must also set the RNP system's (FMC) altimeter input through a single action**



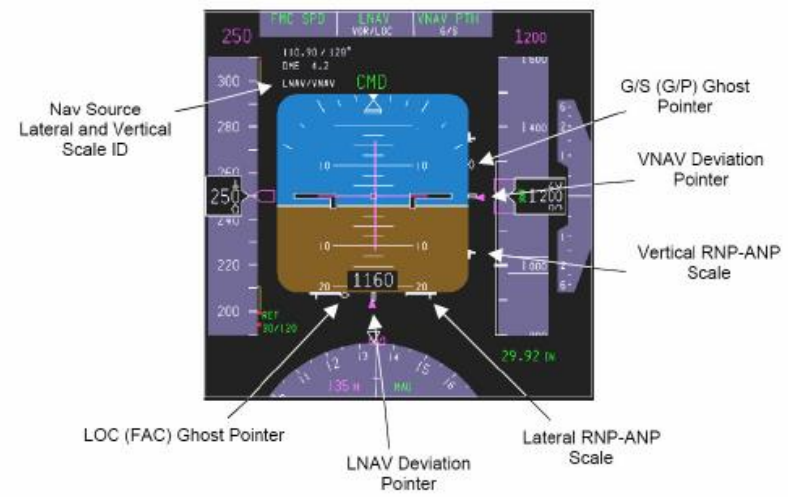
Displays that support flight crew monitoring of lateral and vertical deviation

FTE Monitoring: Airbus L/DEV



L/DEV Scale 0.2NM

FTE Monitoring : Boeing NPS



FMC CDU



Operational procedure:
Numeric display

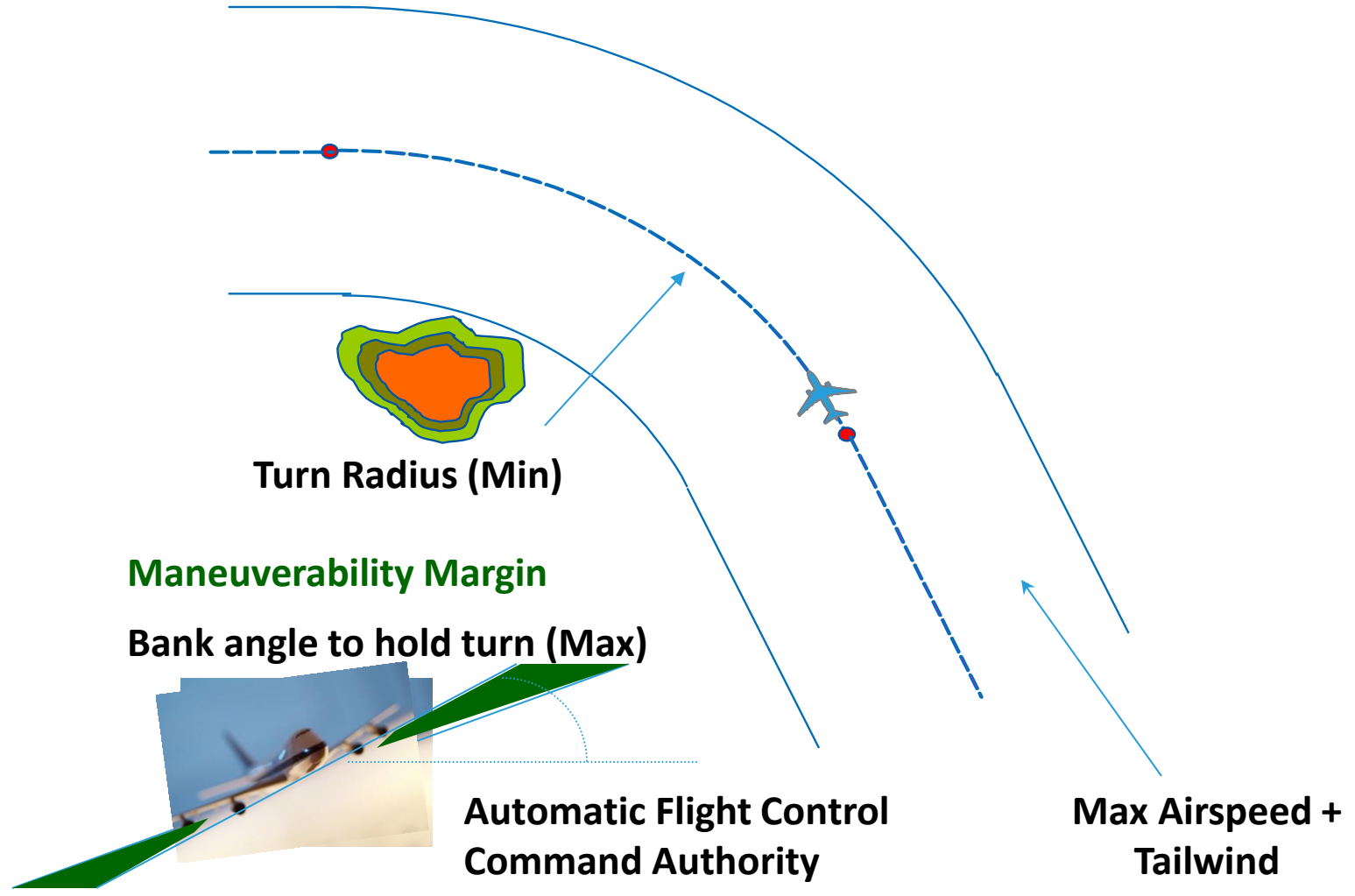


Requirements for RNP AR APCH with RF Legs

- **For approaches where RF legs are used (indicated on chart):**
 - Navigation system *must* have the capability to execute RF legs between two fixes
 - Aircraft *must* have an electronic map
 - The FMC, flight director and Autopilot *must* be capable of commanding 25° of bank at or above 400' AGL and 8° of bank below 400' AGL
 - 5° maneuverability margin over the 20° used in procedure



Example: Radius to Fix (RF) Turns





Key Requirements for RNP AR APCH Less Than RNP-0.3

- **No single point of failure can cause loss of guidance required for the approach**
 - Aircraft typically require: dual GNSS sensors, dual FMS, dual air data systems, dual autopilots and a single IRS
 - Loss of display of lateral guidance is *hazardous*
- **System performance, monitoring and alerting of vertical errors consistent with safety objective**
 - Vertical obstacle clearance reduced with increased lateral accuracy
 - System crosscheck can provide operational mitigation



Key Requirements for RNP AR

Missed Approach Less than RNP-1.0

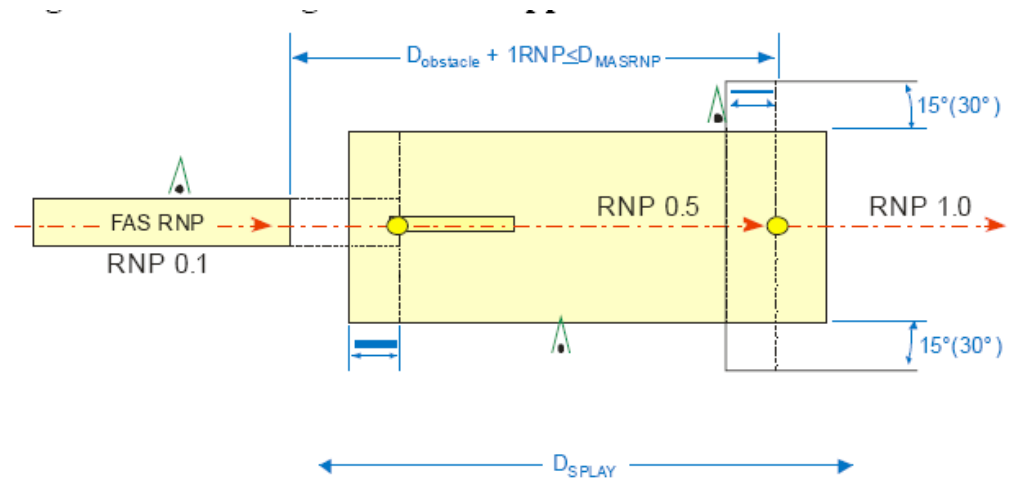
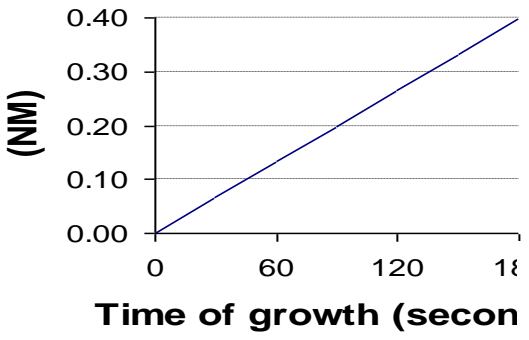
- **When possible, missed approach will use RNAV or conventional criteria**
 - Enables participation by more aircraft
- **When missed approach requires accuracy value < 1.0 NM (RNP AR missed approach):**
 - No single point of failure can cause loss of guidance → dual equipage (same as RNP AR APCH < 0.3)
 - Loss of display of lateral guidance is *hazardous*
 - *Must* be able to couple Autopilot/Flight Director by 400' AGL
 - Upon loss of GNSS, aircraft *must* revert to another means of navigation complying with the navigation accuracy requirement



Example: Missed Approach with Inertial

Loss of GNSS updating is considered (e.g., interference):
Immediate effect is to revert to inertial navigation.

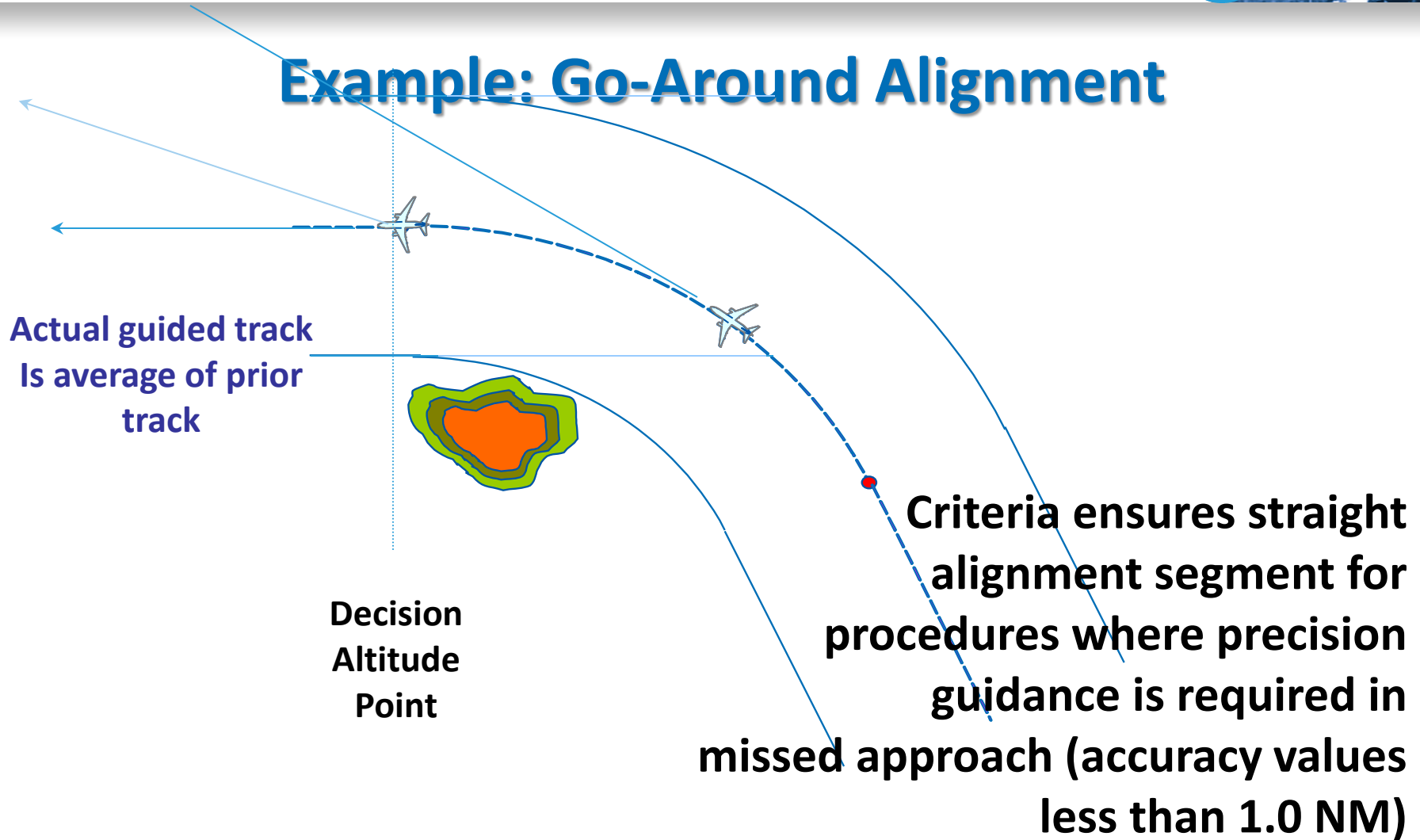
Growth in 95% Accuracy (NM)



Key Requirements for RNP AR

- **Flight guidance *should* remain in LNAV upon TOGA or other means of go-around/missed approach**
 - Navigation system may revert to ‘track-hold’ or ‘heading hold’, and if followed, drive aircraft off procedure path

Example: Go-Around Alignment





Preflight Planning for RNP AR APCH

- **Minimum Equipment List (MEL)**

- Varies depending on the RNP AR APCH operation & the required navigation accuracy for the procedure
 - May require dual equipment
- RNP AR APCH operations requires operable Class A TAWS
- RNP < 0.3, or RF legs, require flight director or autopilot

- **RNP Prediction**

- Each operator must have a predictive capability
- Desired performance must be available at the destination
- The flight crew must apply prediction during preflight
- Prediction must account for known outages in navigation services
- Prediction software must use same algorithms the aircraft uses



General Operating Procedures

- **Follow the procedures and limitations of the Aircraft Flight Manual (AFM)**
 - Manufacturer documentation of RNP AR APCH capability may act as a supplement to the AFM
- **Verify the flight plan loaded in the aircraft**
- **Load the entire RNP AR APCH procedure by name**
- **Ensure correct accuracy value is loaded in flight management system**



General Operating Procedures

(continued)

- **Only fly procedures for which you are authorized**
 - Appropriate accuracy value, use of RF legs, missed approach with accuracy value less than 1.0 NM
- **Required equipment must be available and operational prior to beginning the approach**
 - Like RNP APCH, failure of any required equipment prior to the approach should result in coordinating an alternate ATC clearance
- **Verify GNSS updating of the RNP system prior to beginning an RNP AR APCH**
 - Manufacturer documentation of aircraft performance and function may eliminate the need for this flight crew check
- **Ensure a current, local altimeter setting is set prior to commencing the final approach segment**



General Operating Procedures

(continued)

- **The flight crew may need to disable radio updating**
 - Depends on aircraft qualification and procedure
- **Expected pilot performance will keep cross-track deviation limited to:**
 - ½ times the required navigation accuracy on straight segments
 - 1 times the navigation accuracy (1.0 nm) during and after turns
- **Initiate a go-around if maximum deviation occurs:**
 - 1 x RNP laterally
 - 75 feet vertically
 - May require new crew procedures and training, particularly for aircraft without suitably scaled non-numeric deviation displays



General Operating Procedures

(continued)

- **The flight must abandon an RNP AR APCH if a loss of GNSS occurs or a loss of required performance occurs**
 - Aircraft alerting may help meet this requirement (e.g., ‘UNABLE RNP’)
- **Manage track compliance during go-around**
 - Particularly during early go-around on procedure with RF legs, maintain appropriate track and re-engage LNAV
- **Adhere to airspeed limits published on a procedure**
- **Apply the temperature limits published on a procedure**
 - Can be waived for aircraft with temperature compensation



RNP AR APCH Training

- **RNAV training and experience → may provide a solid foundation for RNP approach operations**
 - Unique attributes of RNP approach operations require training
- **Understand operations procedures and best practices**
 - Critical to safe operations during RNP AR APCH
- **Individuals must complete appropriate ground &/or flight training before engaging in RNP approach operations**
 - May require expanded aircraft systems training
 - Operators may address topics separately, or
 - Integrate RNP approach training with other training curriculum



RNP AR APCH Navigation Database

- **The operator must validate the delivered aircraft navigation database against the published procedure**
 - Must ensure the flight path is same as the published procedure
 - Must ensure the flight path is compatible with aircraft avionics
 - Database provider may or may not offer validation services
- **The validation process must include ability to detect unintended changes in navigation database**
- **Avionics upgrades and software updates may require re-evaluation if they affect the path or performance**

ANSP Considerations

- **RNP AR APCH procedures are based on GNSS**
 - Ensure no local interference
- **Ensure procedure design is in accordance with criteria**
 - Any characteristics outside scope of the procedure design criteria can have significant impact on the aircraft qualification and operational procedures



Summary

- **RNP AR APCH operations based on diverse experience with modern aircraft**
- **Typical applications include airports in mountainous area or with airspace constraints**
- **Varying accuracy value, curved paths and RNP AR missed approach capabilities**
 - More flexible than RNP APCH, fewer capable aircraft depending on RNP AR characteristics used on the procedure
- **Important to coordinate among operator, ANSP, regulator and aircraft manufacturer when implementing**
 - Initial approvals can be complex, take advantage of previous approvals in same aircraft





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