Airplane Navigation Capabilities

Increasing Operational Safety & Efficiency

June 19, 2008

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Navigation Services

Agenda

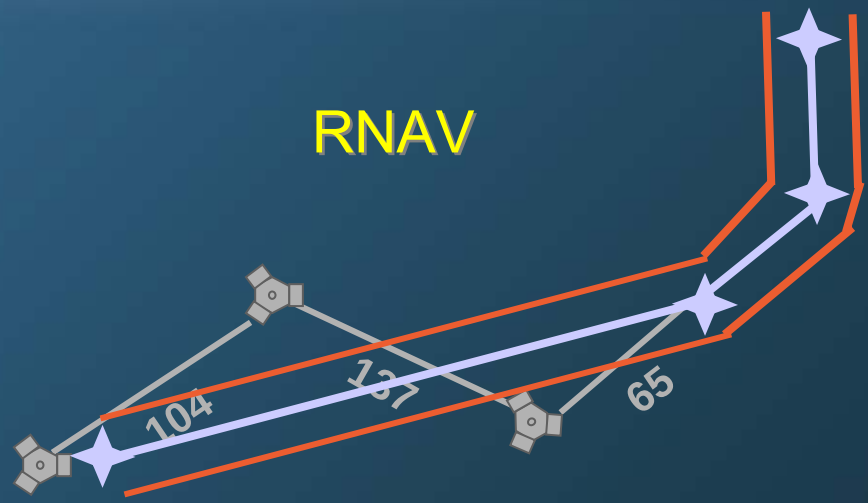
- Performance-Based Navigation
- Why is RNP Important?
- GBAS Landing System
- Example of an RNP AR Project
- Implementing RNP AR Operations

Performance-Based Navigation

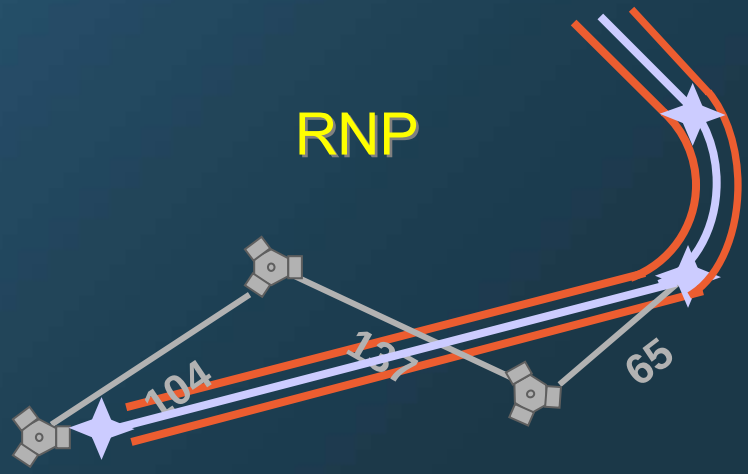
- Performance-Based Navigation refers to the ability of aircraft flight management computing systems and other avionics to fly a digitally defined path in space.
- This aircraft capability is generally categorized as:
  - Area Navigation (RNAV)
  - Required Navigation Performance (RNP)
- Performance Based Navigation also refers to *system performance* requirements for navigation operations with which an aircraft must comply to operate on a particular air route, instrument approach procedure, or in a designated airspace.
- Requirements are defined in terms of accuracy, integrity, continuity, availability and functionality needed for a particular operation when supported by the appropriate navigation infrastructure.

General Categories of PBN

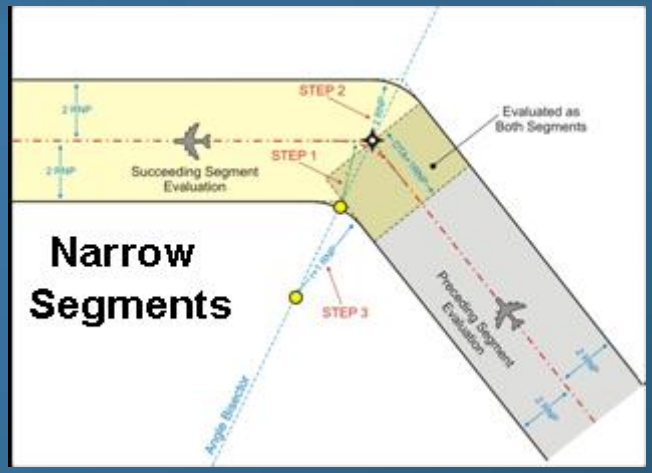
- RNAV is a navigation system enabling aircraft to fly waypoint to waypoint on any desired flight path within the service volume of referenced NAVAIDS or with self-contained navigation systems, or a combination of the two.



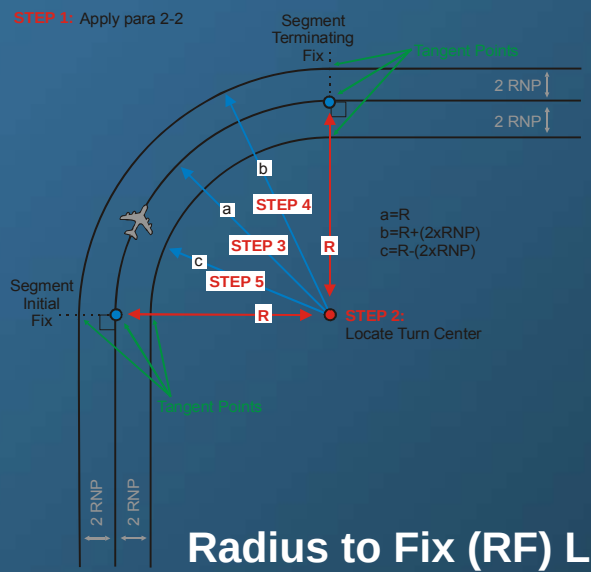
- RNP is RNAV with the added feature of on-board navigation performance monitoring and alerting. RNP also provides curved path capability.



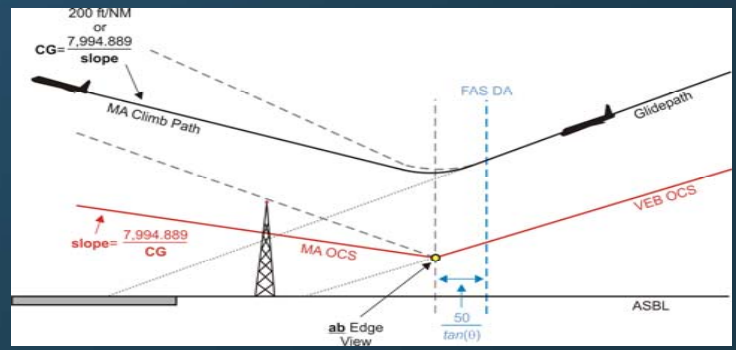
RNP AR Approach Features



- Narrow lateral linear segments (RNP 0.3 or less) with no secondary buffers
- Curved segments (Radius-to-Fix legs with shorter leg lengths) anywhere along the approach
- Guided, narrower missed approaches (RNP 1.0 or less) with Radius-to-Fix legs
- Performance-based Vertical Buffers (Vertical Error Budget)



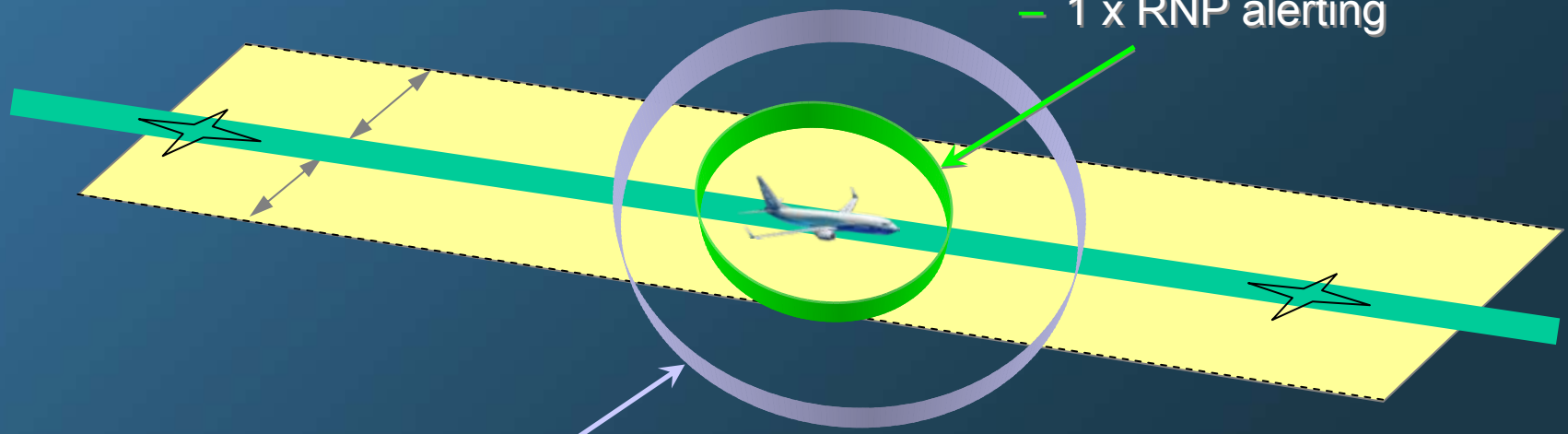
Radius to Fix (RF) Legs



Vertical Error Budget & Guided Missed Approach

RNP is RNAV operations with performance monitoring & alerting.

"A critical component of RNP is the ability of the aircraft navigation system to monitor its achieved navigation performance, and to identify for the pilot whether the operational requirement is, or is not being met during an operation"



- RNP value is measured in nm
  - 1 x RNP alerting
- 2 x RNP Containment
  - Ability to navigate and avoid obstacles

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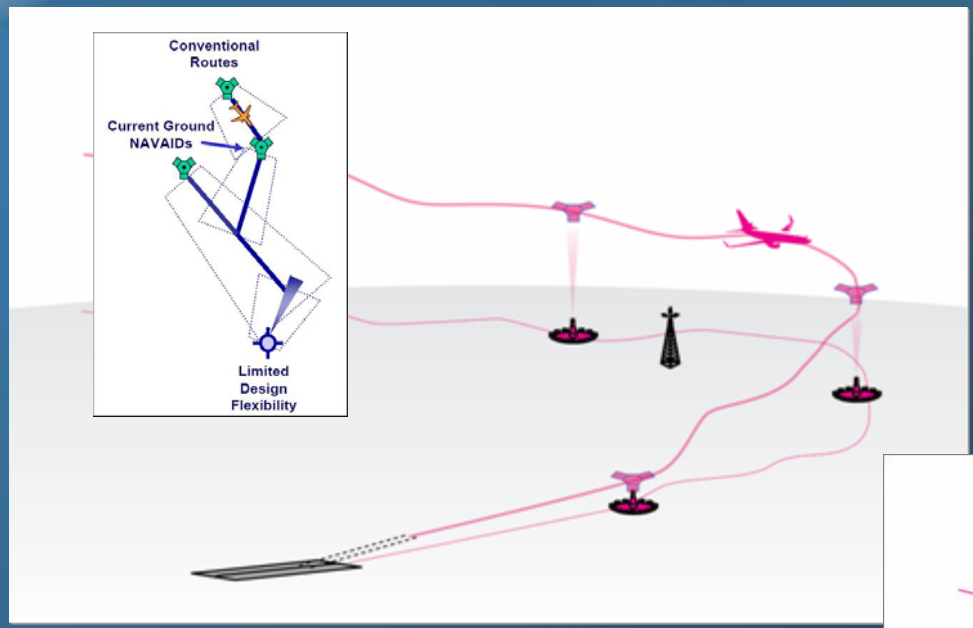
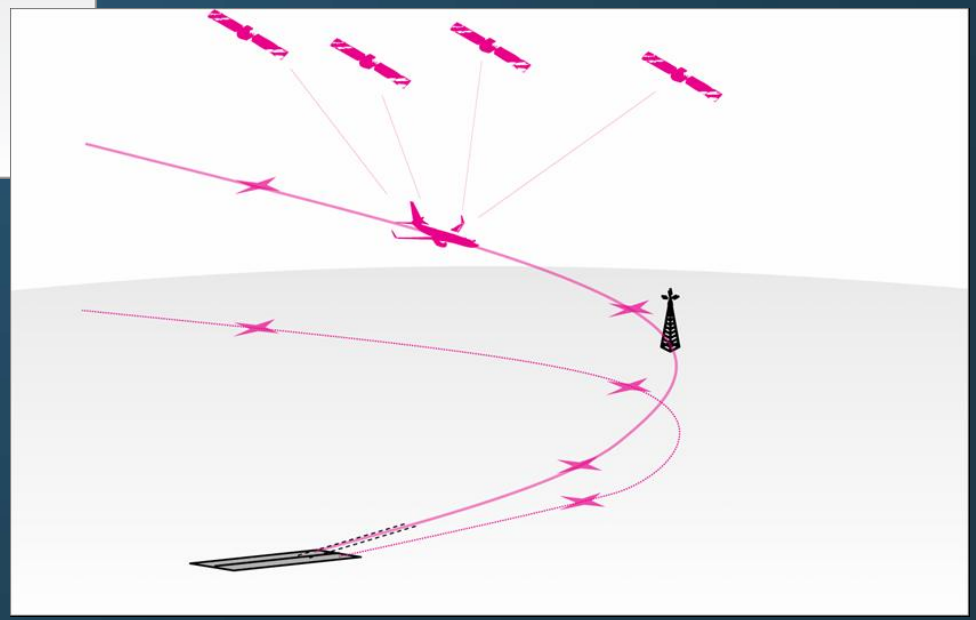
Conventional Navigation vs. RNAV & RNP



Conventional Navigation

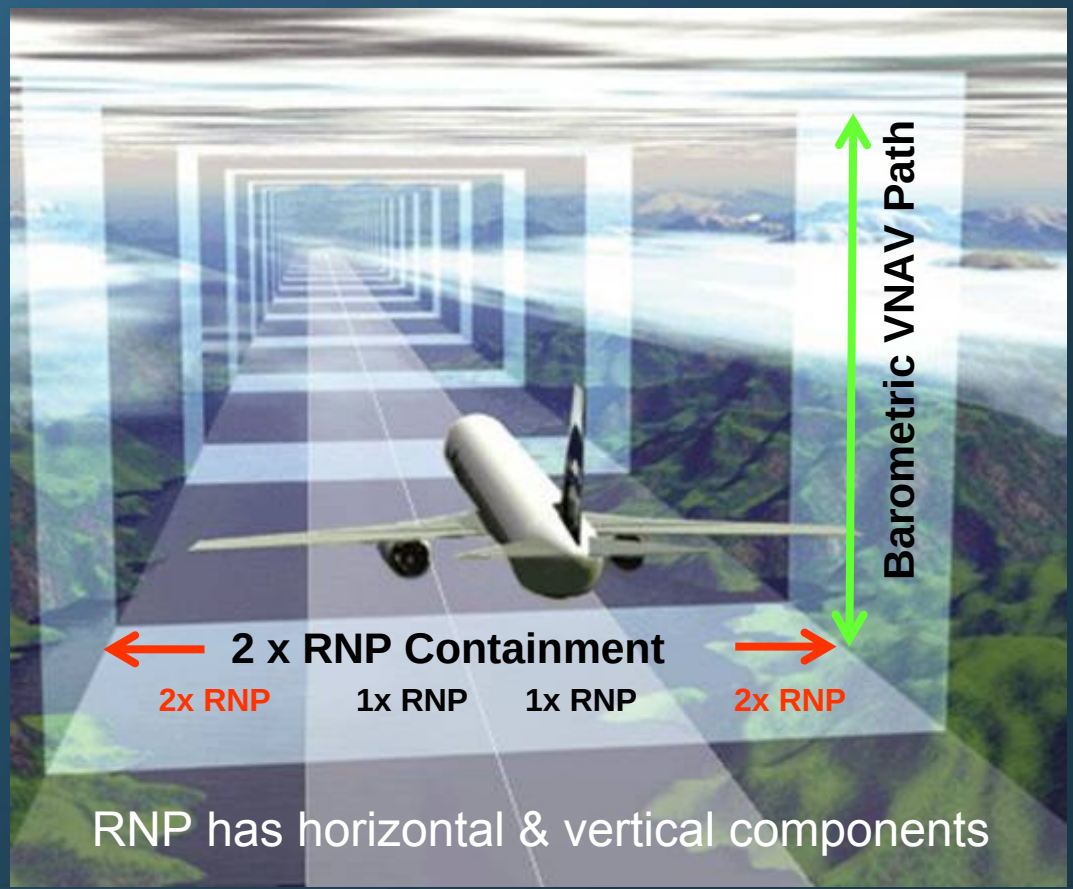
GNSS based RNP



With conventional ground-based navigation aid routes, there is limited design flexibility

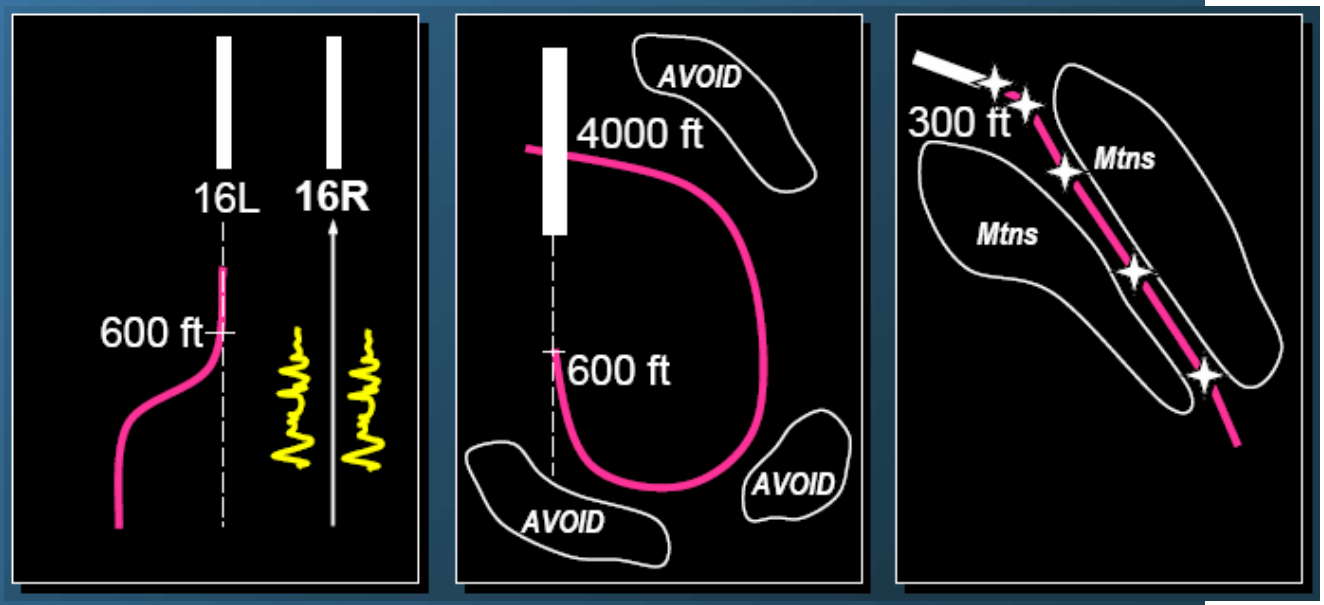
RNP: A Highly Flexible Means of Navigation

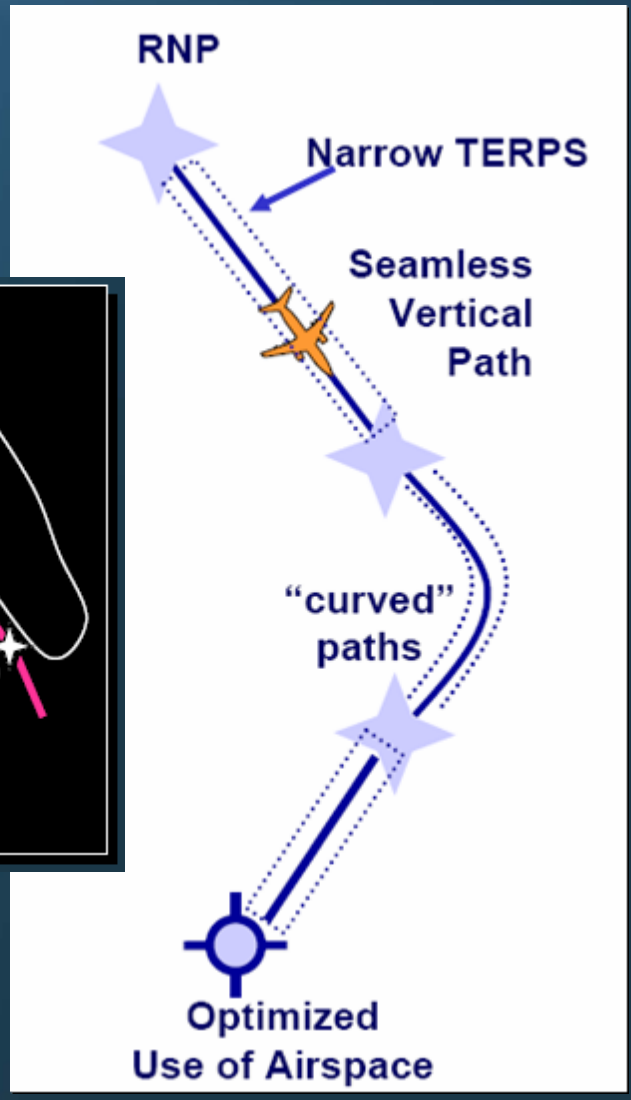
RNP uses advanced flight management systems and GNSS to allow aircraft to fly tightly confined corridors of airspace.



RNP Navigation (continued)

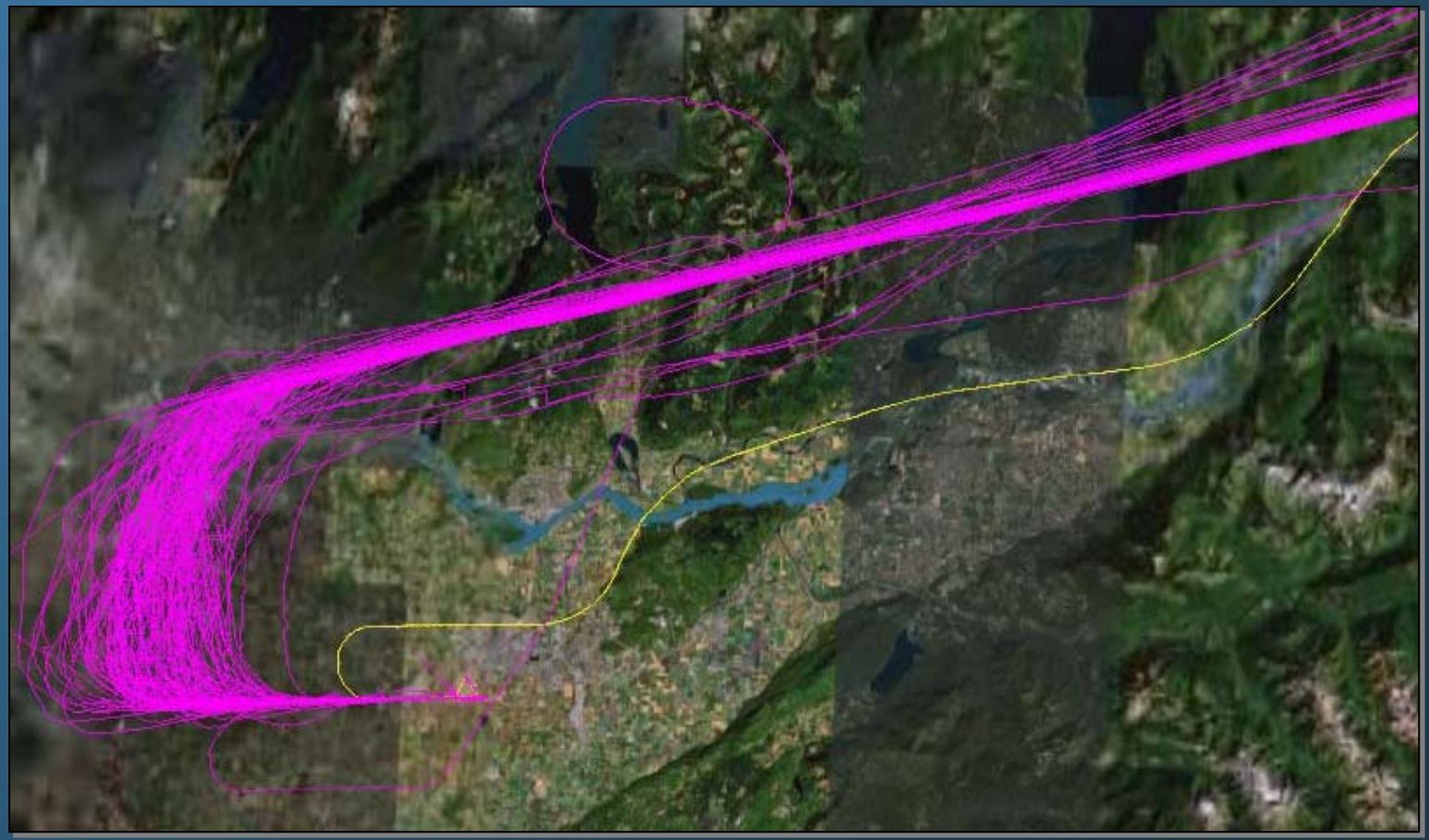
With RNP, airspace use can be optimized.





Benefits of RNP

Reduced track miles = reduced time = reduced fuel = lower costs !



Juneau, Alaska – Gastineau Channel

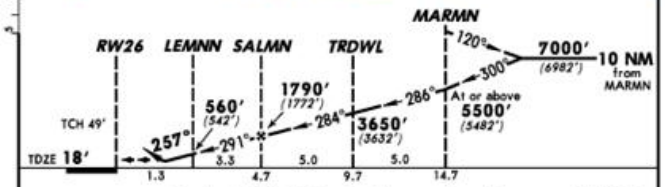
Alaska Airlines — 4 APR 97 — 12-7-1

JUNEAU, ALASKA
JUNEAU INTL
RNP 0.3 Rwy 26
Special Aircrew & Acft Authorization Required
FMS26
Apt. Elev 19'

*ATIS 126.4
ANCHORAGE Center 133.9
*JUNEAU Tower 118.7
*Ground 121.9
JUNEAU Radio (LAA) CTAF 118.7 when Twr Inop.
Alt Set: INCHES

MSA
CGL NDB
6300' 8200' 5700'

COGHLAN I
212 CGL
BARLO
SMGLR
RW26
LEMNN
SALMN
TRDWL
MARMN
FMS26
SISTERS I
114.0 SSR
ELEPHANT
391 EEF
RNP 0.3 MISSED APCH FIX
NOT TO SCALE
SISTERS I VOR
Dual FMC & Dual GPS required.
APPROACH TRANSITION: FROM ROANE TO STVNS VIA RNP 0.5 ROUTE 304° 100.3 7000'
STVNS (IAF)



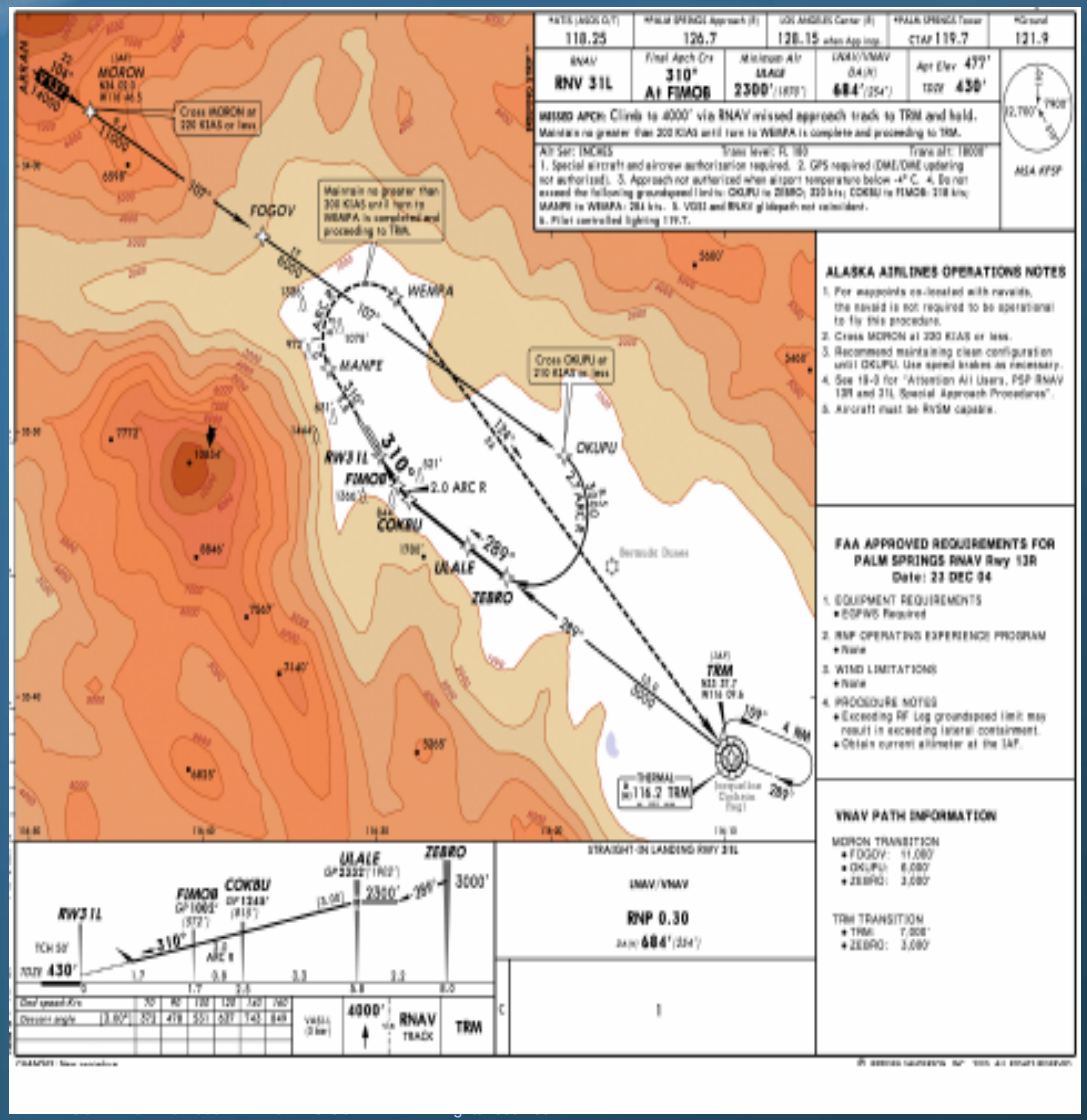
MISSED APPROACH: Climb via RNP 0.3 missed approach path to cross SMGLR at or above 680' and BARLO at or above 3000'. Continue climb to 5200' direct to SSR VOR/EEF NDB and hold.

	STRAIGHT-IN LANDING RWY 26 RNP 0.3 DA(H) 3000'(2982')	CIRCLE-TO-LAND
A B C D	3	NOT AUTHORIZED

Gnd speed-Kts	70	90	100	120	140	160
VNAV 3.50°	439	565	628	753	879	1004

CHANGES: See other side.

Palm Springs RNP AR Approaches Runways 31L, 13R



- Replaces Non-precision Approach into valley with mountainous terrain
- Guided, stabilized 3D path to runway = Safety Enhancement
- Reduced distance (30-40 Miles)
- “VOR or GPS B” Minima is 2300 – 3
- RNP AR Minima 684 –1
- Cancellations & Diversions Avoided

Courtesy of Alaska Airlines

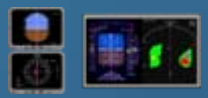
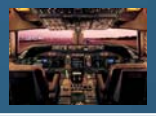
Benefits of RNP

- Improved safety
- Decreased operating costs
- Increased schedule integrity
- Increased revenue
- Reduced environmental impacts

Boeing RNP Capabilities

Model	RNP Operational Approval	Equipage * Optional Features
737NG 	RNP 0.11; 0.10 (with Navigation Performance Scales)	• CDS software 2002 or later • 2nd FMC •Mode Control Panel •Speed & Altitude Intervention Activation •Geometric Path Descents Activation •Standby Power – Captain FMC/MCDU •TOGA to LNAV* •DME Inhibit* •Navigation Performance Scales*
747-8	RNP 0.1 (Planned)	• Standard
777	RNP 0.11	
787	RNP 0.1 (Planned)	• Standard

Retrofit RNP Capabilities In Development

Model	Anticipated RNP Operational Approval	Equipage *Optional Features in development
737 Classic  	RNP 0.11; 0.10 (with Navigation Performance Scales)	• Display (EFIS or Large Format/5-ATI) • FCC & Package upgrade for VNAV path MCP altitude fly away logic** • Dual FMC U10.6 or later • Dual GPSSU or Analog Multi Mode Receiver • Inertial Reference Unit (GPS functionality) • Master Caution Unit (GPS functionality) • Mode Control Panel • Speed & Altitude Intervention (FMC software) • Geometric Path Descent Feature Activation • Standby Power – Capt. FMC/MCDU • TOGA/LNAV* • DME Inhibit*
757/767 	RNP 0.15	• Pegasus FMC with Pegasus ’08 features* • ILS/GPS MMR (3)* • GPS Activation Feature • FCC Upgrade as required for TOGA/LNAV* •TOGA/LNAV FMC Feature*
747-400 	RNP 0.14	• FMC (747-8 FMC Upgrade Package)* • MMR/GPSSU (3)* • GPS Activation Feature • FCC Upgrade as required for TOGA/LNAV* •TOGA/LNAV Feature*
777 	RNP 0.11	• MMR (3) / GPSSU (2) • GPS Activation Feature • GPS Availability Logic Feature* • Navigation Aid Inhibit Feature* • FCC upgrade as required for TOGA/LNAV Feature • TOGA/LNAV Feature* • Navigation Performance Scales*

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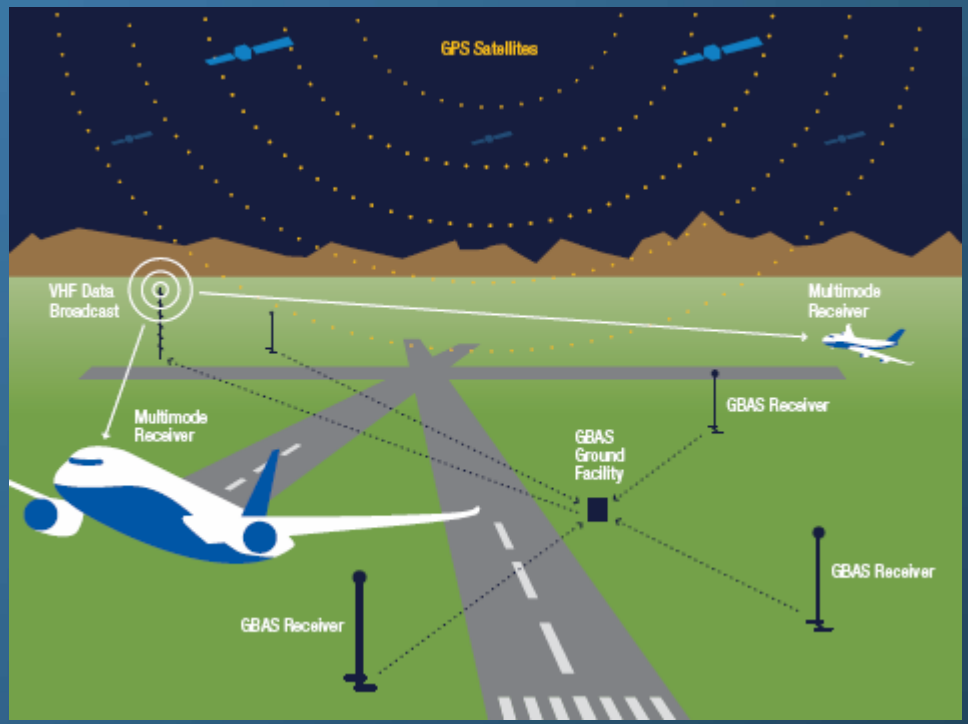
GBAS Landing System



GBAS provides airplane:

- Differential Correction to GPS
- Approach & Departure Trajectories
- Viewed as the landing system of the future
- FAA and Honeywell are working to complete the System Design Approval for CAT I GBAS
- Planning for CAT III capability is in work.

Why GBAS and GLS?
Benefits appear to be site-specific.

Airline Perspective

- Increased Capability
  - Multiple glidepaths, displaced thresholds, staggered touch-downs &, offset localizer paths
  - Low RNP capability in terminal area and for surface operations
  - Precision departure guidance
- Cost Avoidance
  - Fewer diversions
  - Reduced fuel reserves from improved access to ETOPS and destination alternates
  - Reduced landing fees. (Some airports are expected to pass savings to airlines.)
- Improved Safety

ANSP Perspective

- Lower Infrastructure Costs Compared to ILS
  - Single GBAS serves all runway ends at an airport
  - Improved availability
- Improved Performance
  - Not susceptible to beam interference
  - Eliminates need for “ILS critical areas”
- Increased Capability
  - Potential for multiple glidepaths
- Environmental Considerations
  - Community noise abatement
  - Reduced emissions

Situation Update: GLS Implementation

Boeing Model	GLS Status		Airbus Model	GLS Status
737NG	CAT I is certified.		A320	Certification for CAT I (with autoland) in 2008
747-8	'Basic': to be certified CAT I (provisioned for CAT III). (FMC & Autopilot available for retrofit on 747-400.)		A330/340	Certification for CAT I to follow A320.
777	Currently not offered		A350	To be certified as 'basic' feature (CAT I?).
787	CAT I is 'basic' CAT III Planned for 787-9		A380	CAT I is certified as an optional feature (with autoland).

Both Boeing and Airbus publicly support GLS as the preferred landing system of the future

GLS & GBAS Implementation Activity

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Linzhi RNP Project

- General Administration of Civil Aviation of China (CAAC)
- China Eastern Airlines
- Air Traffic Management Bureau (ATMB)
- The Boeing Company
- Jeppesen
- U.S. FAA

Linzhi RNP Project

- Project began in April 2006 to build procedures for Nyngchi Airport at Linzhi.
- Nyngchi Airport was built to promote tourism and development of the at Linzhi.
- Linzhi is located in the Himalayan Plateau in Yalungzangbu River valley in Southeastern Tibet
- The airport is surrounded by mountainous terrain with many peaks higher than 19,000 feet
- Access to the airport is challenging
- Required Navigation Performance (RNP AR) instrument procedures are the ***only*** means to provide for safe and efficient access.

Nyngchi Airport at Linzhi

Airport Description
Formal Name: Nyngchi Airport
ICAO Designator: ZUNZ

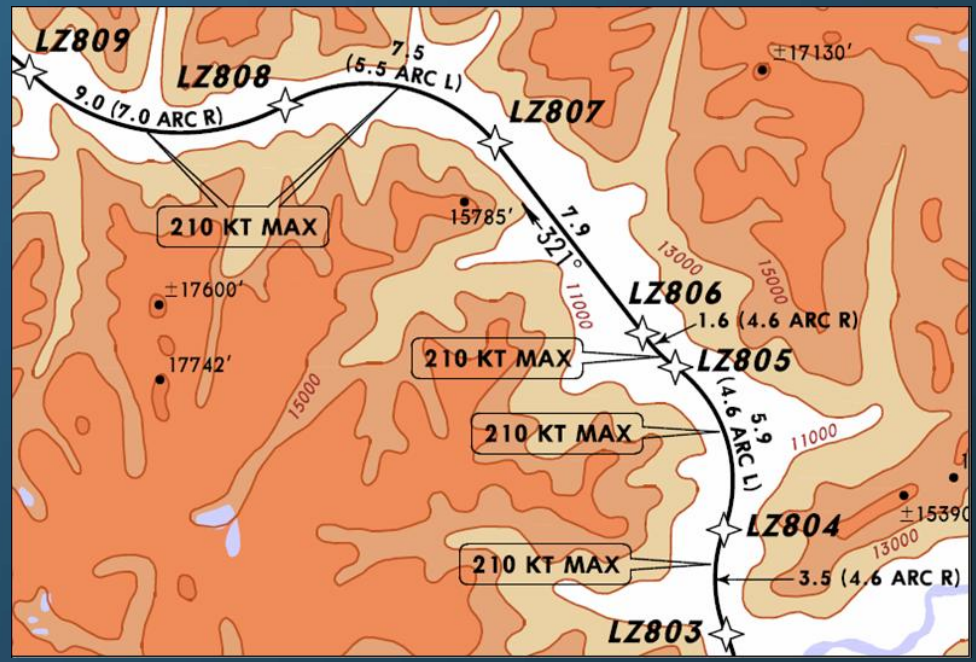
Airport Reference Point
N29 18 13.297
E94 20 06.340
Elevation: 9675 ft

Runway Dimensions (05/23)
Length: 9844 ft (3000m)
Width: 148 ft (45m)
Each end has a 60m (197 ft) asphalt overrun, suitable for stopping.

Radius-to-Fix and Track-to-Fix Legs

- Procedure Designs incorporate Radius-to-Fix (RF) Legs and (TF) Track-to-Fix legs.

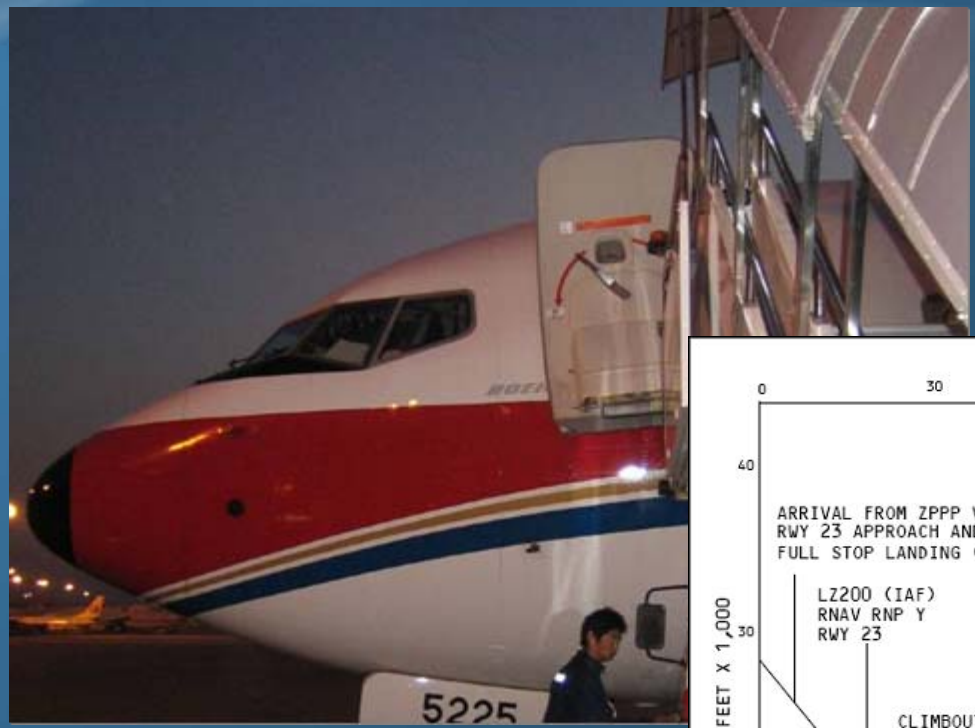
- RF legs allow procedure design flexibility to fly around obstacles while meeting the RNP requirements (RNP 0.3, 0.1).

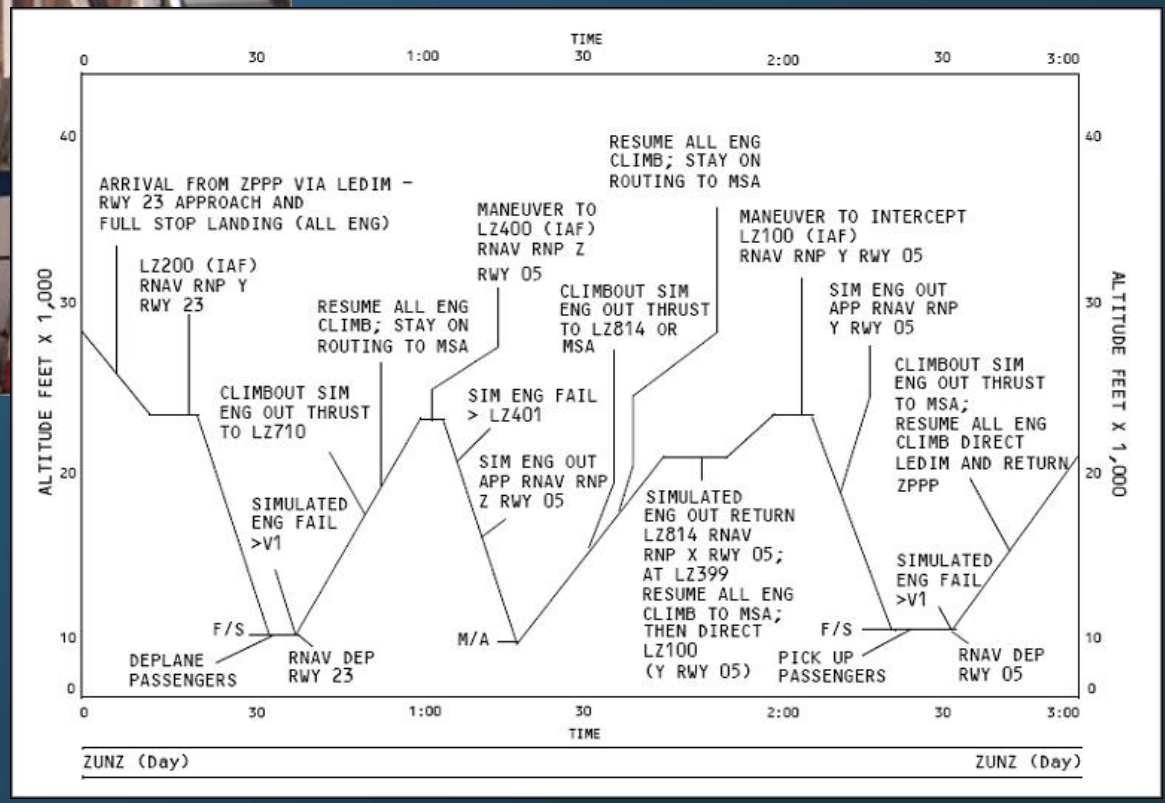


Jeppesen designed the Linzhi Procedures

- Preliminary Design Review of the RNP procedures
- CAAC, ATMB, CEA, Boeing, Jeppesen
- Series of Structured Design Reviews
  - Internal to the Boeing and Jeppesen project team
  - With the FAA
  - With the CAAC, ATMB, CEA, Boeing and Jeppesen
- Demonstration in full flight simulator (Kunming)
- Formal demonstration flight
  - Flown by trained China Eastern Airlines Pilots
  - Witnessed by Principle Operations Inspector (CAAC)

The Demonstration Flight

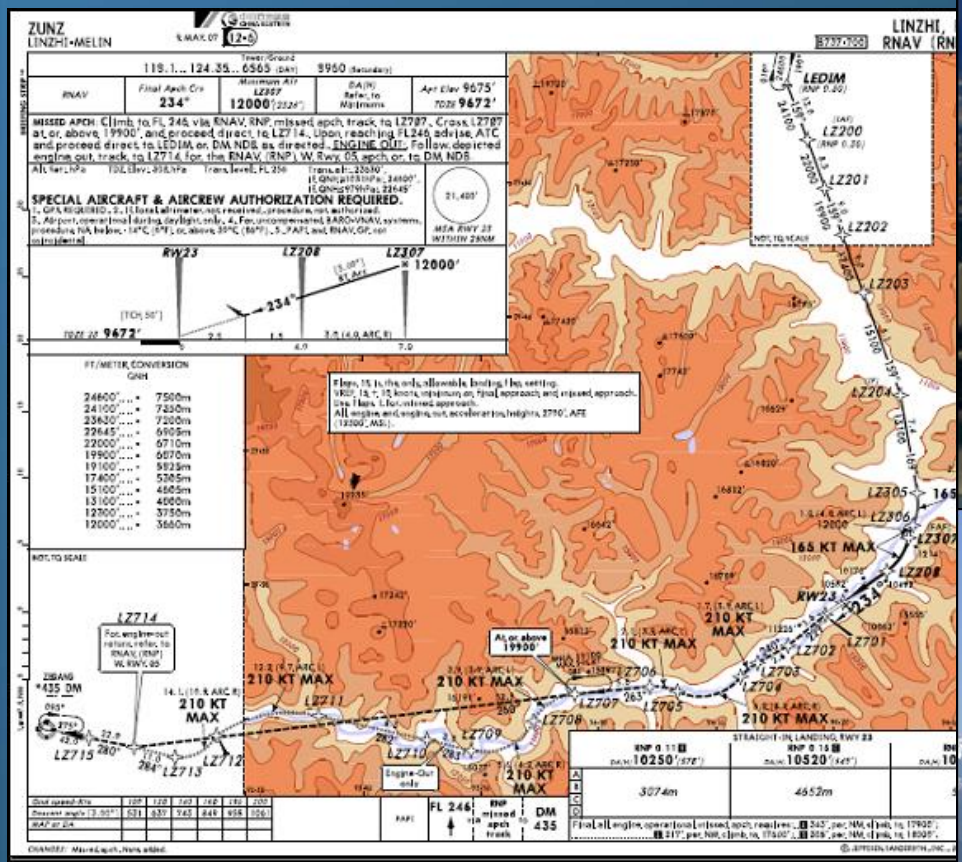




Himalayan Mountains on the Way to Linzhi

Airplane and Crew Procedures

RNAV (RNP) Y Runway 23 Approach



Many, Many Meetings….

- Flight Operations Policy
- Flight Crew Standard Operating Procedures
- Flight Crew Training and Qualification
- Dispatch Policy and Procedures
- Flight Operations Monitoring and Reporting
- Airplane Navigation System Requirements
- Navigation Data Base Validation and Quality Checks

Arriving On Approach to Runway 23

- FAA completed review of RNP procedure designs, and application documents (including training materials) and provided a “no technical objection” letter to the CAAC
- Selected China Eastern Airlines flight crews completed RNP training.
- China Eastern Airlines dispatchers completed RNP training as well.
- Validation Flight, May 29, 2007, from Kunming to Linzhi

Validation Flight Completion

- CAAC granted conditional approval for China Eastern Airlines RNP operations at Linzhi
- Issuance of Operations Specifications for revenue service to Linzhi
- RNP 0.3, Visual Flight Rules (VFR) only for first 100 operations
- RNP Monitoring Program
- Final Approval (Instrument Flight Rules) is pending.

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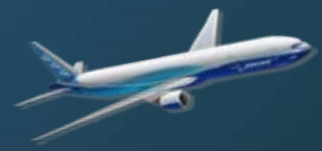
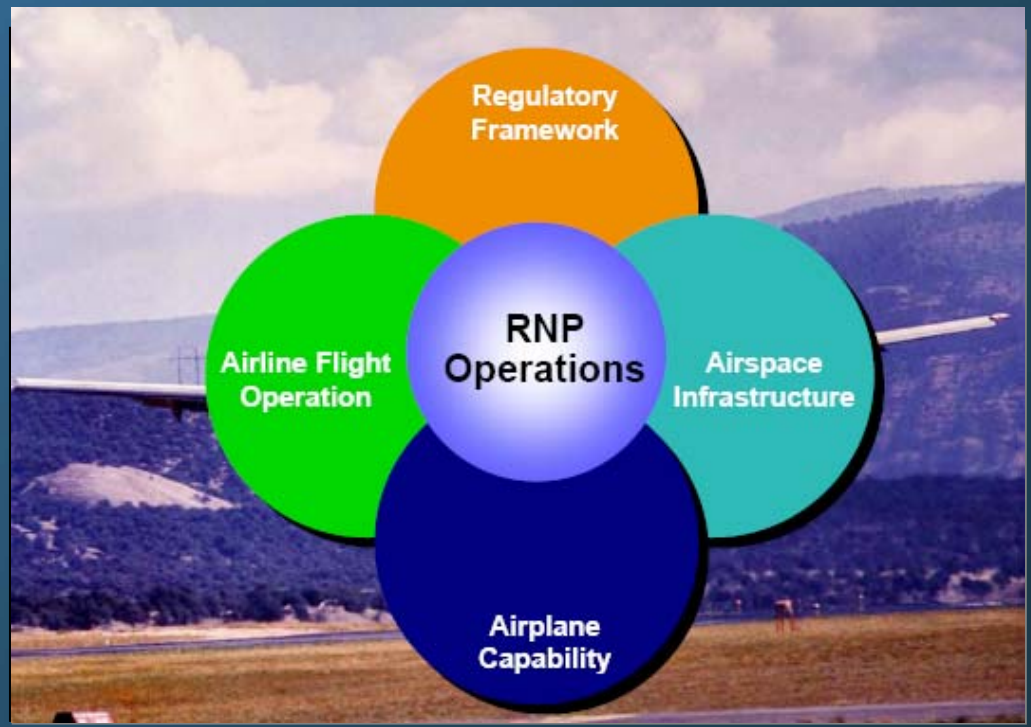
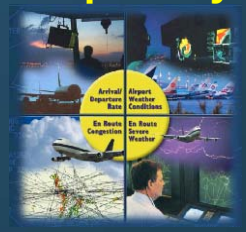
Successful RNP Operational Implementation Requires All the Elements Be in Place

Regulatory capability  X **Airport and facility capability**  X **Air traffic capability**  X **Airline capability**  X **Airplane capability** 

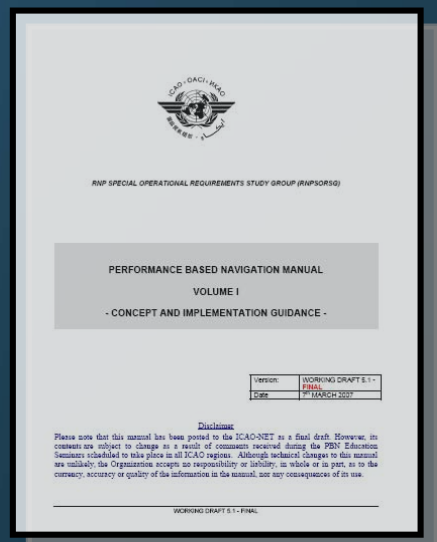


Regulatory Capability for RNP AR APCH Operations

Regulatory Capability



- Regulators must provide the regulatory basis
- Procedure design criteria
- Operations requirements
- Approval process



RNP SPECIAL OPERATIONAL REQUIREMENTS STUDY GROUP (RNPSORSG)

PERFORMANCE BASED NAVIGATION MANUAL

VOLUME I

- CONCEPT AND IMPLEMENTATION GUIDANCE -

Version:	WORKING DRAFT 5.1 - FINAL
Date	7th MARCH 2007

Disclaimer

Please note that this manual has been posted to the ICAO-NET as a final draft. However, its contents are subject to change as a result of comments received during the PBN Education Seminars scheduled to take place in all ICAO regions. Although technical changes to this manual are unlikely, the Organization accepts no responsibility or liability, in whole or in part, as to the currency, accuracy or quality of the information in the manual, nor any consequences of its use.

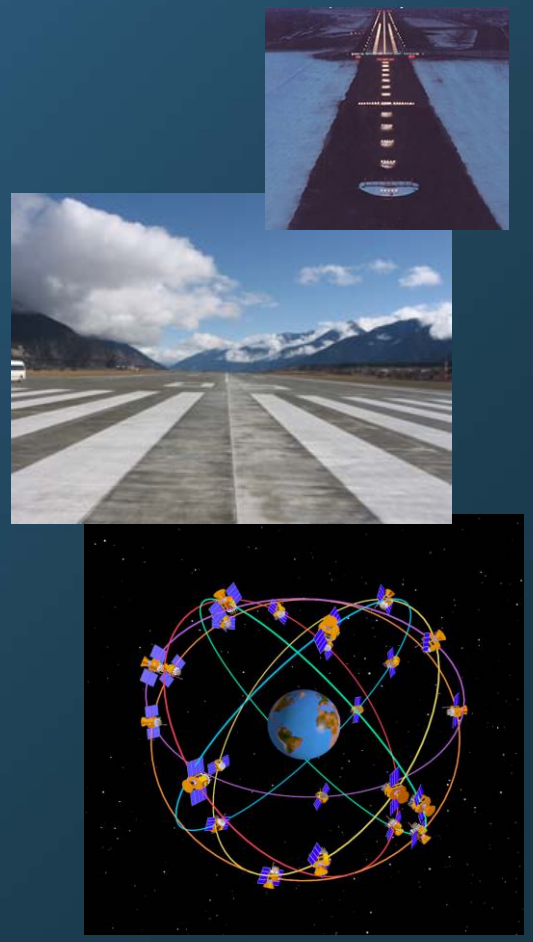
WORKING DRAFT 5.1 - FINAL

- ICAO Performance Based Navigation Manual

Airport and Facility Capability for RNP AR APCH Operations

Airport & Facility Capability

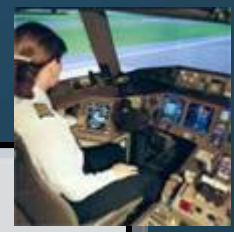
- GNSS (GPS) availability. RNP AR approaches are only authorized based on GNSS as the primary navigation service.
- Location / Characteristics of Runway and Special Airport considerations
- Airport / aeronautical / terrain data compliant with ICAO Annex 15



Airline Capability for RNP AR APCH Operations

- Obtain RNP AR Instrument Procedures (in house, public, 3rd Party)
- Validate Navigation database integrity
- Acquire qualified aircraft
- Revise maintenance procedures
- Develop Flight Crew procedures
- Revise airline dispatch procedures
- Implement RNP Monitoring and Reporting
- Prepare an application documenting how RNP AR APCH requirements are met

Airline Capability



Questions ?