



Performance Based Navigation

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International Civil Aviation Organization

**Workshop on the development of
National Performance Framework for
Air Navigation Systems**

(Nairobi, 6-10 December 2010)

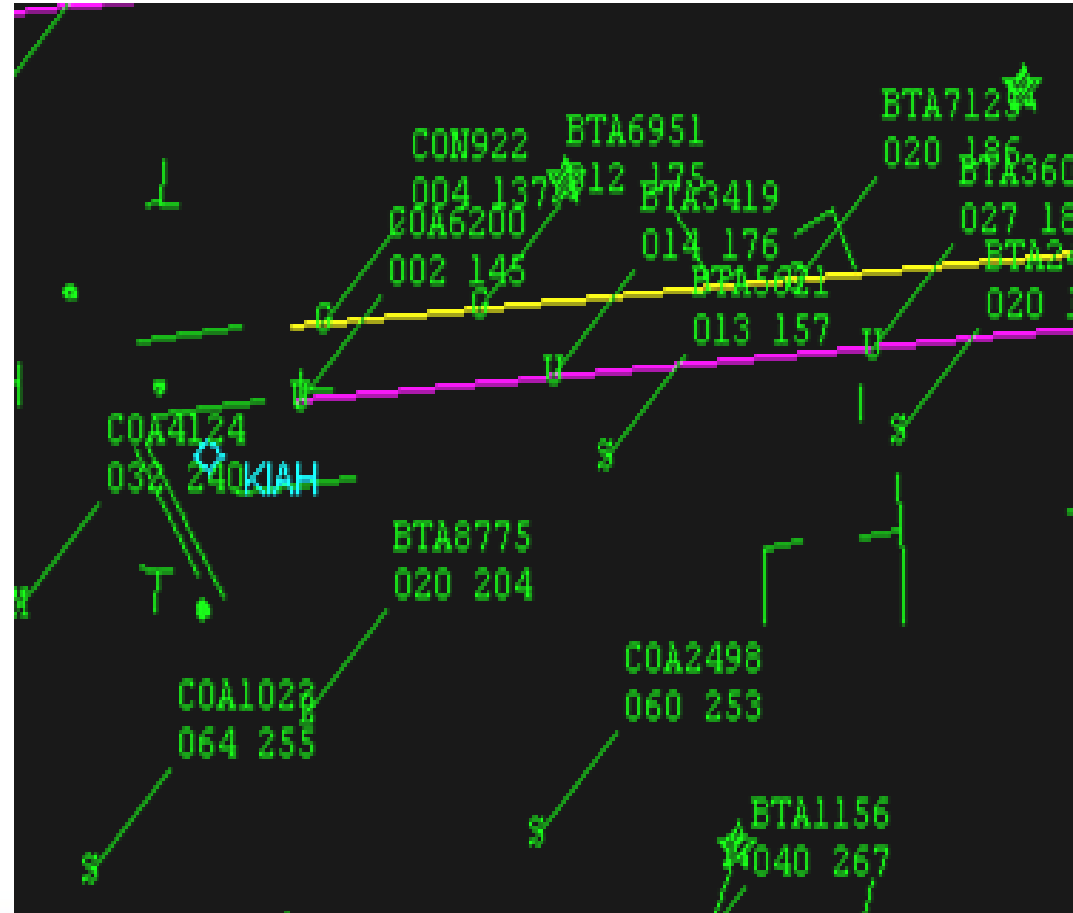




Presentation Overview

Performance Based Navigation

- Navigation in Context
- PBN concept
- Implementation
- Future targets





1 NAVIGATION IN CONTEXT



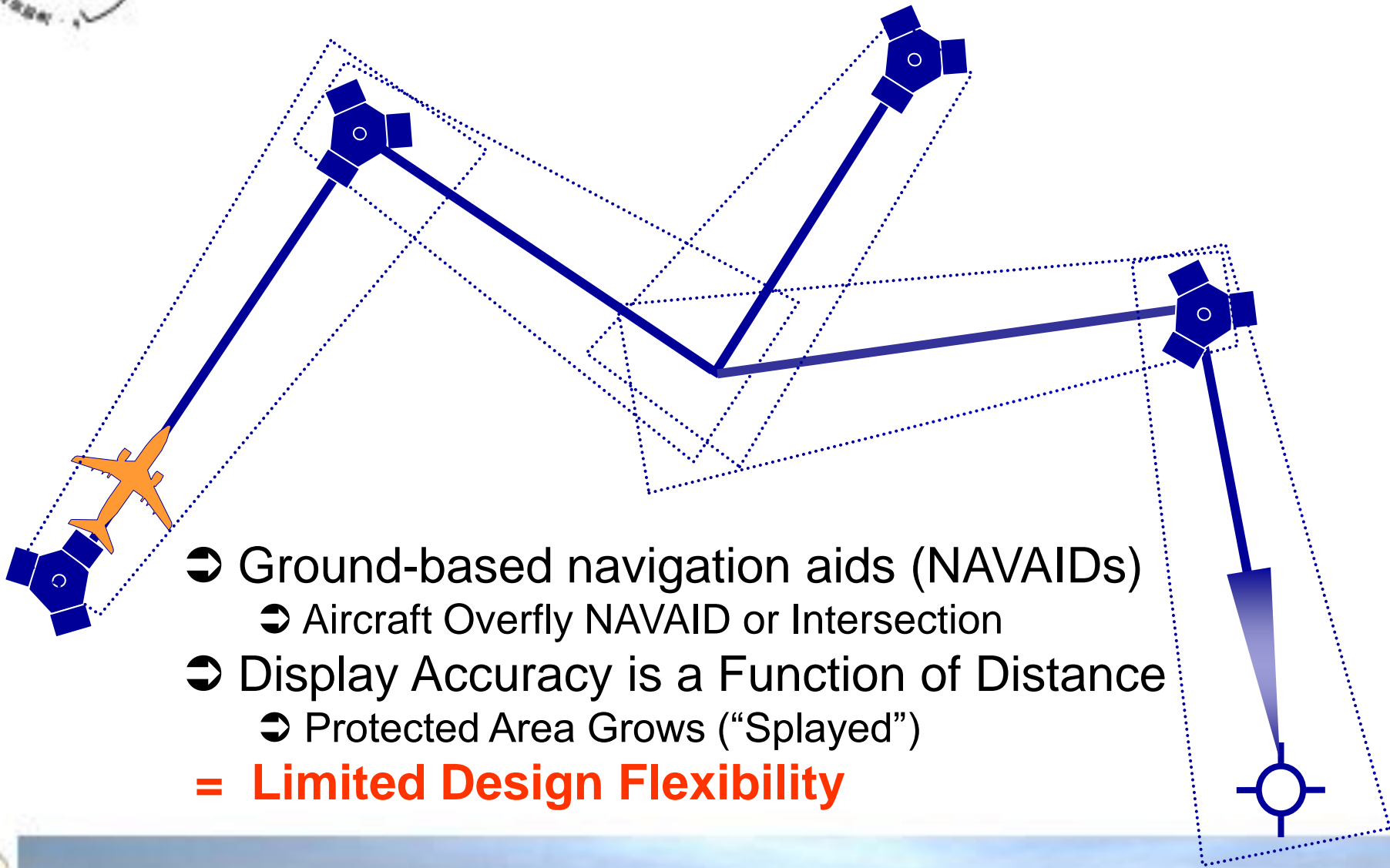


Aviation challenges

- Growing demand for solutions to airspace congestion
- Growing fuel efficiency requirements
- Growing Environmental requirements
- Growing demand for RNAV approaches (safety, accessibility)
- **Most can be met with current technology, but standardization and operational requirements have to be put into place**



Conventional Navigation





Evolution of RNAV

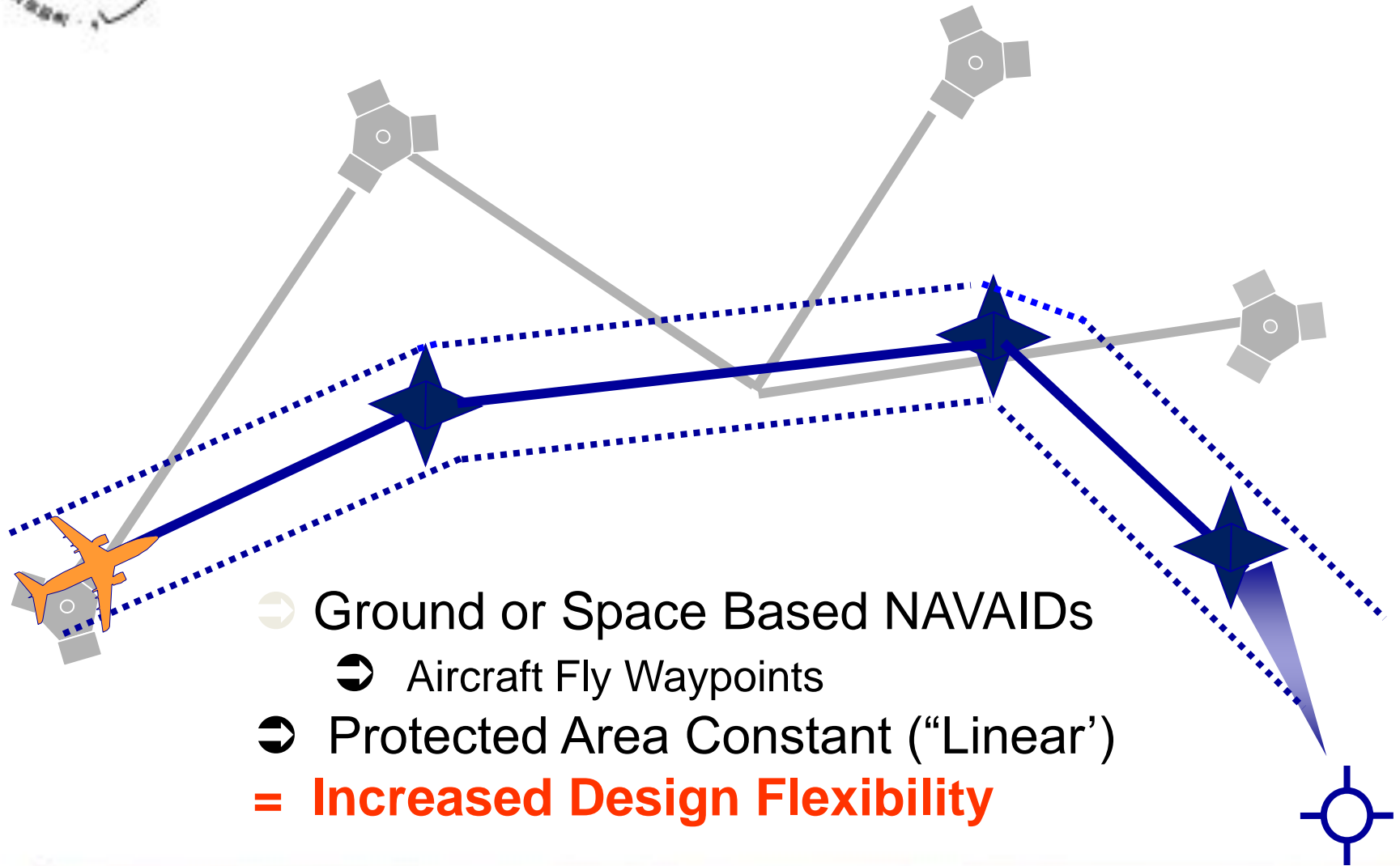
- Long Range Navigation (LORAN)
- Omega Radio Navigation System*
- Inertial Navigation
- VOR/VOR and VOR/DME
- Multi-sensor Flight Management System (FMS)
- GPS, GLONASS, and Augmentations

*terminated in 1997





Area Navigation (RNAV)



- ⇒ Ground or Space Based NAVAIDS
 - ⇒ Aircraft Fly Waypoints
 - ⇒ Protected Area Constant (“Linear”)
- = Increased Design Flexibility**



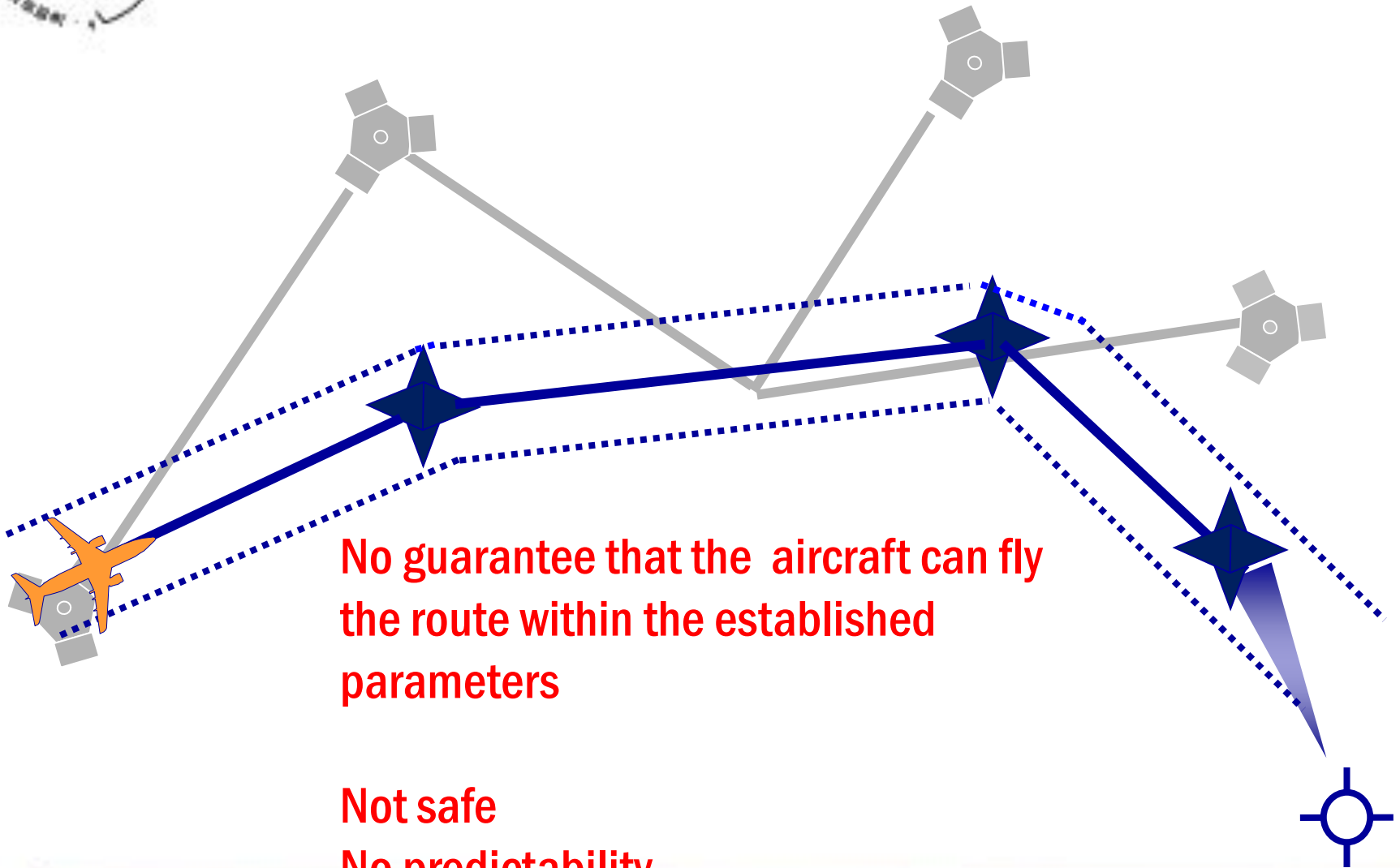
RNAV (Pre-PBN)

Shortfalls

- **Only technology based, No clear specification among States for implementation**
- **No clear guidance for:**
 - **aircraft requirements**
 - **operating procedures**
 - **training requirements**
- **No clear understanding for a match between onboard avionics and nav aids**
- **Problems with inoperability**



Area Navigation (RNAV)



No guarantee that the aircraft can fly the route within the established parameters

Not safe
No predictability
No implementation





RNAV shortfalls

FANS identified need for performance based navigation and developed *Required Navigation Performance* capability concept :

- To avoid need for ICAO selection between competing systems
- Addressed only the en-route phase of flight (RNP-10 and RNP-4) for oceanic and remote applications
- No ICAO RNP requirements for continental enroute and terminal applications.
-
- This led to:
 - Proliferation of national standards
 - Wide variety of functional requirements
 - Variety of required navigation sensors
 - Differing air crew requirements
 - Differing industry concept of RNP (on-board performance monitoring and alerting)

Lack of global harmonization





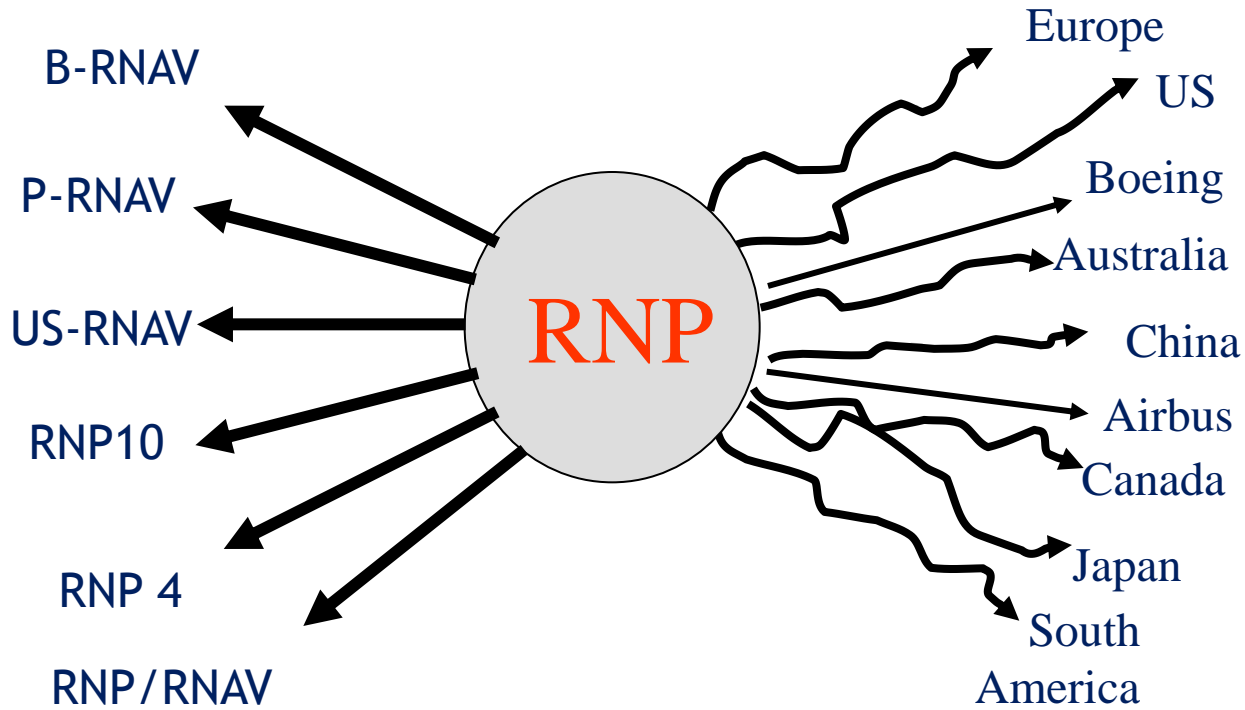
What needed to be done

- Original RNP concept in principle good, however...
- Adjustment to the RNP concept were required.
 - Clear distinction between operations that require performance monitoring and alerting and operations that don't require
 - Harmonization of current RNAV and RNP operations
 - Development of new navigation specification to meet operational demand.
- Clear operational approval requirements needed to be agreed
- Clear implementation guidance needed to be available



Are we now going the right way?

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Not safe, not efficient, costly, confusing



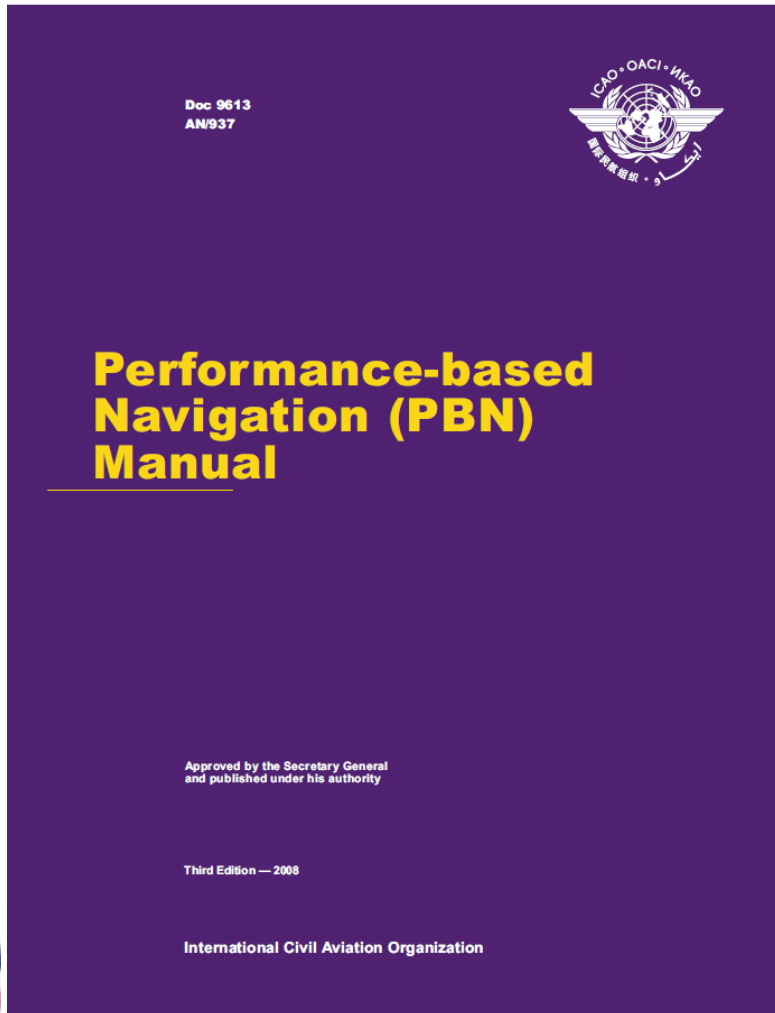


2. PBN CONCEPT





Enter Performance Based Navigation

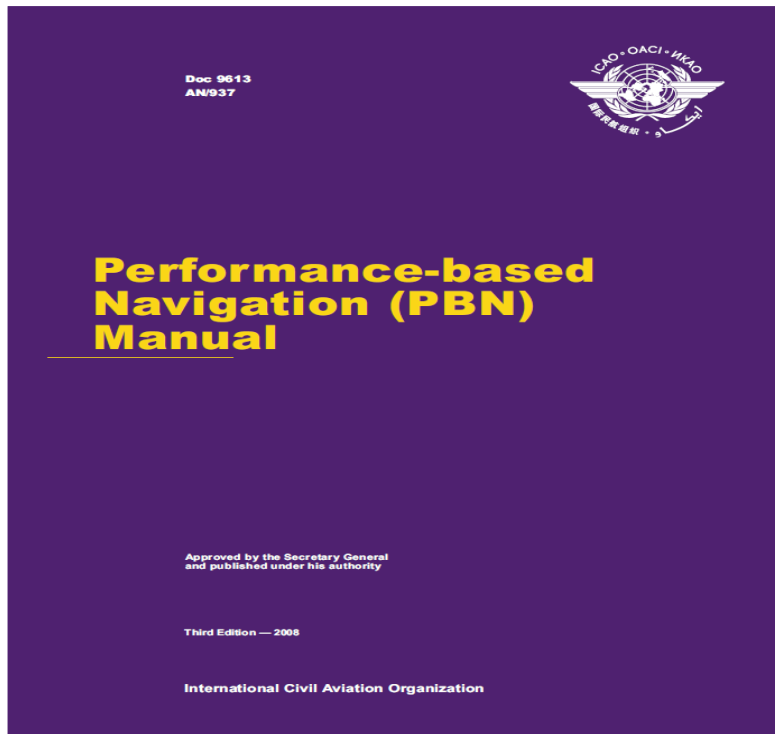


- *PBN Concept* replaced RNP Concept
- Publication of Doc 9613, PBN Manual
- Resolution of ICAO's 36th Assembly



Enter Performance Based Navigation

- ➔ PBN specifies RNAV system performance i.e. accuracy, integrity, continuity, availability + functionality; - written up in navigation specifications

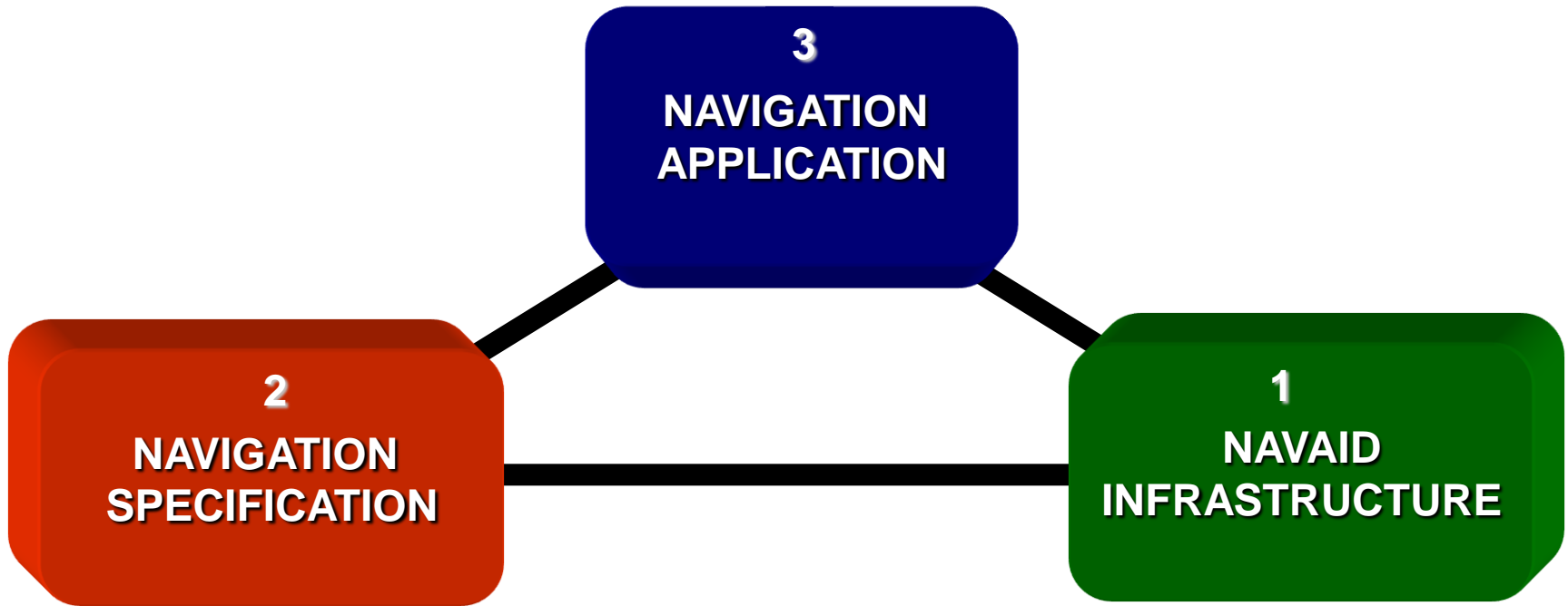


This is different than the RNP concept, which stressed navigation accuracy and 'stopped' at *required performance*. However, PBN is anchored in detailed **navigation specifications**, which contain **performance and functionality requirements**.



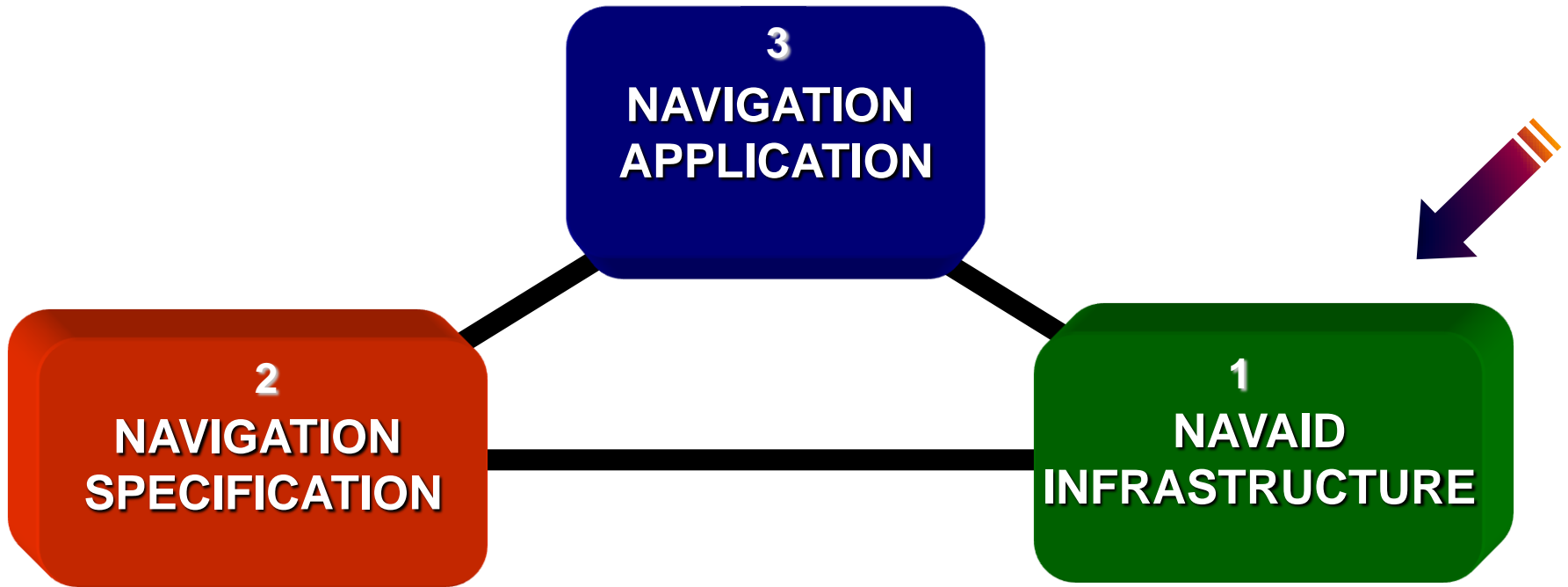


Components of PBN Concept





Components of PBN Concept





Components of PBN Concept

- Navaid Infrastructure -

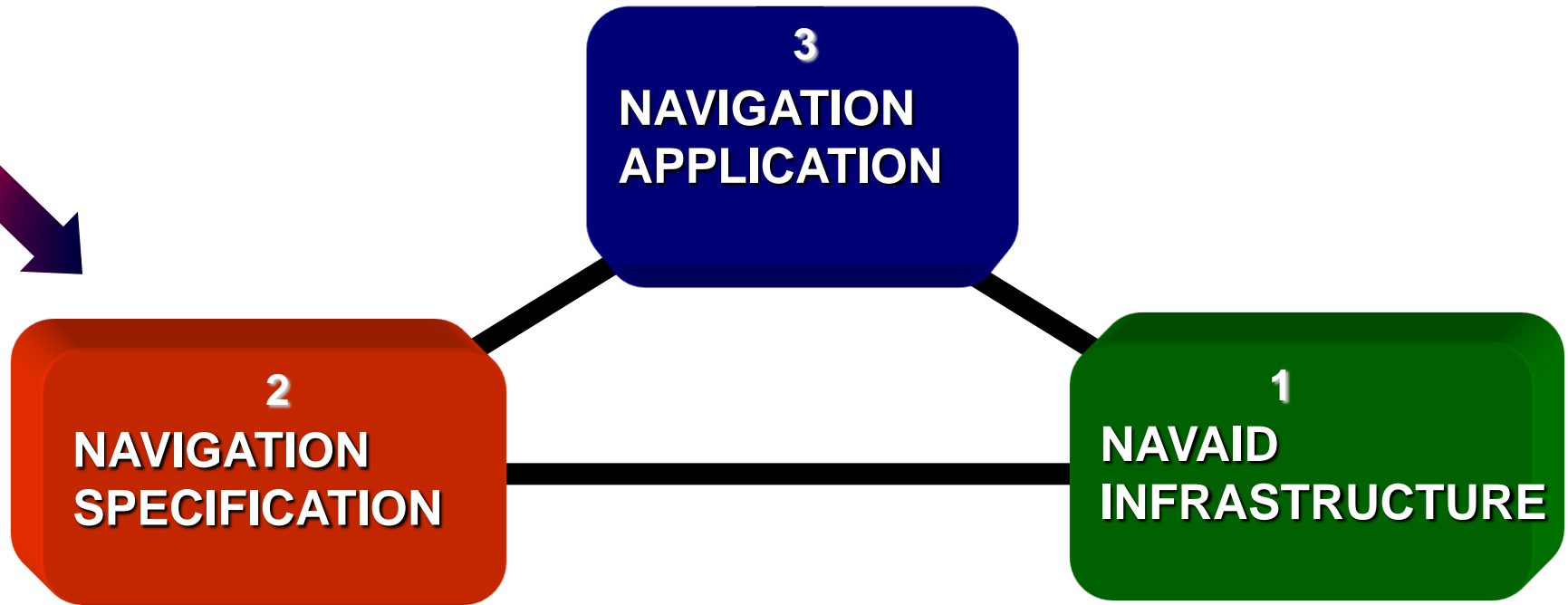
- **Ground-based Navigation Aids (Nav aids)**
 - **VOR; DME; (Not NDB)**

- **Space-based Nav aids**
 - **GNSS**
 - **ABAS and SBAS**

1
NAVAID
INFRASTRUCTURE



Components of PBN Concept



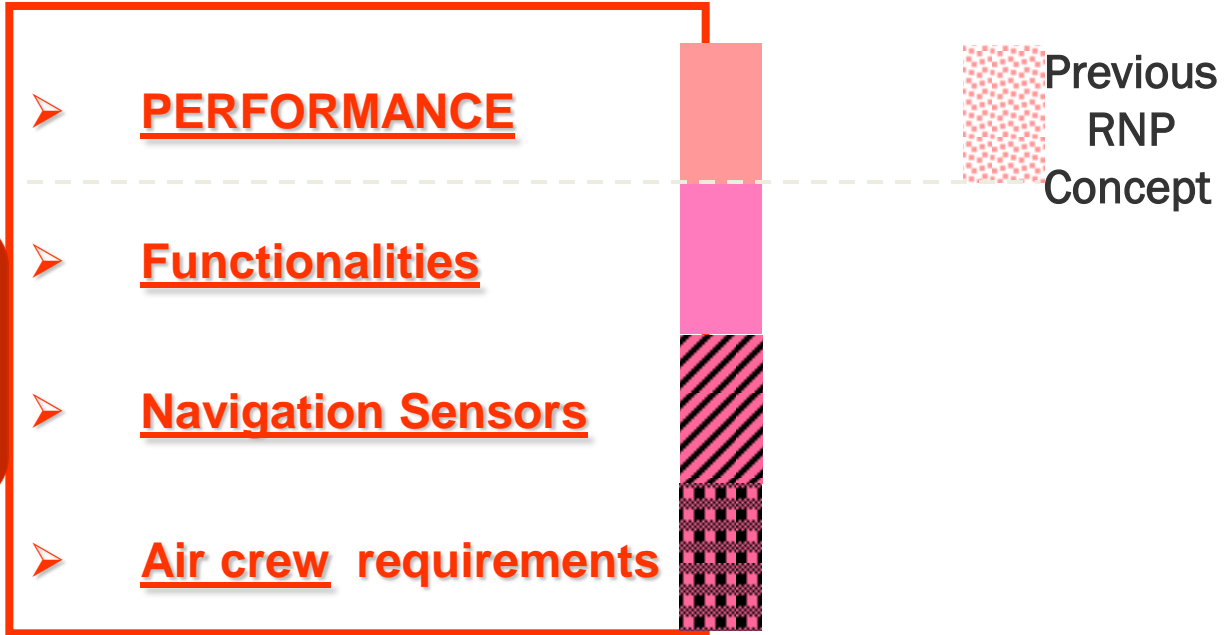


Components of PBN Concept

- Navigation Specification -

International Navigation Specifications published in Volume II of PBN Manual

2 NAVIGATION SPECIFICATION



Document used by State as basis for developing Certification & Operational Approval





Components of PBN Concept

- Navigation Specification -





Components of PBN Concept

- Navigation Specification -

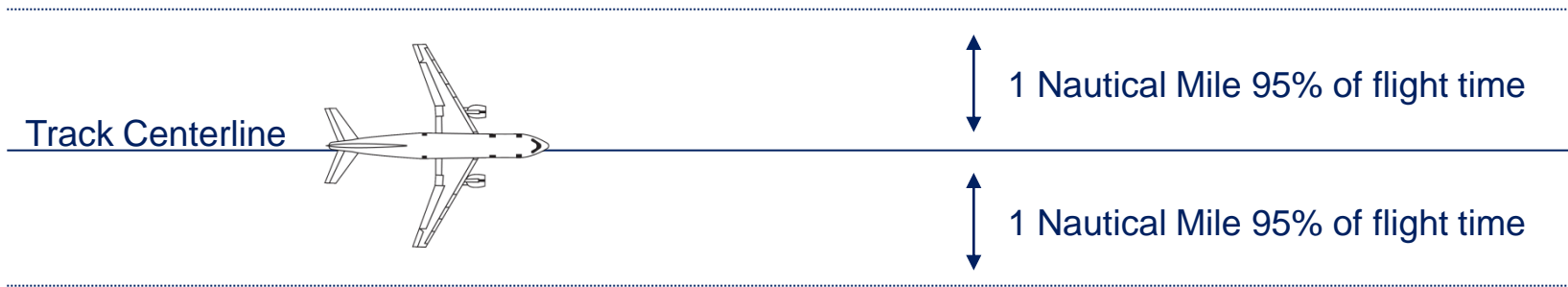


- **On-board performance monitoring and alerting** does not only refer to 'containment' in the MASPS; Annex 11 or PANS-OPS.
- **On-board performance monitoring and alerting** allows the air crew to detect that the RNP system is not achieving the navigation performance required of the RNP system



RNAV Application (notional)

RNAV 1





RNP Application (notional)

RNP 1

Alert to Pilot

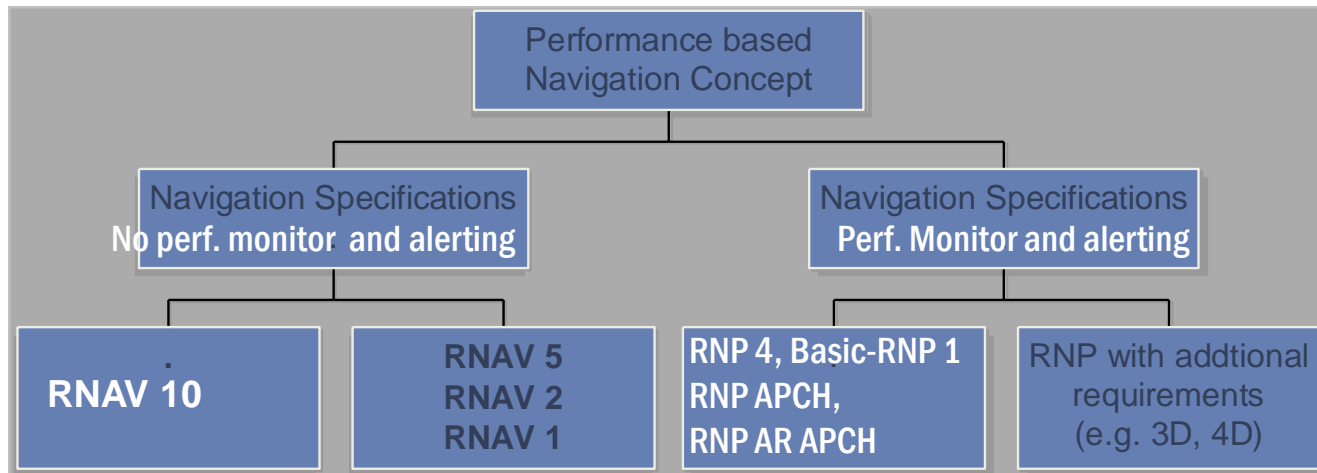


The Key Difference:
On-Board Performance Monitoring and Alerting



PBN Study Group (PBNSG)

Performance Based Navigation Concept



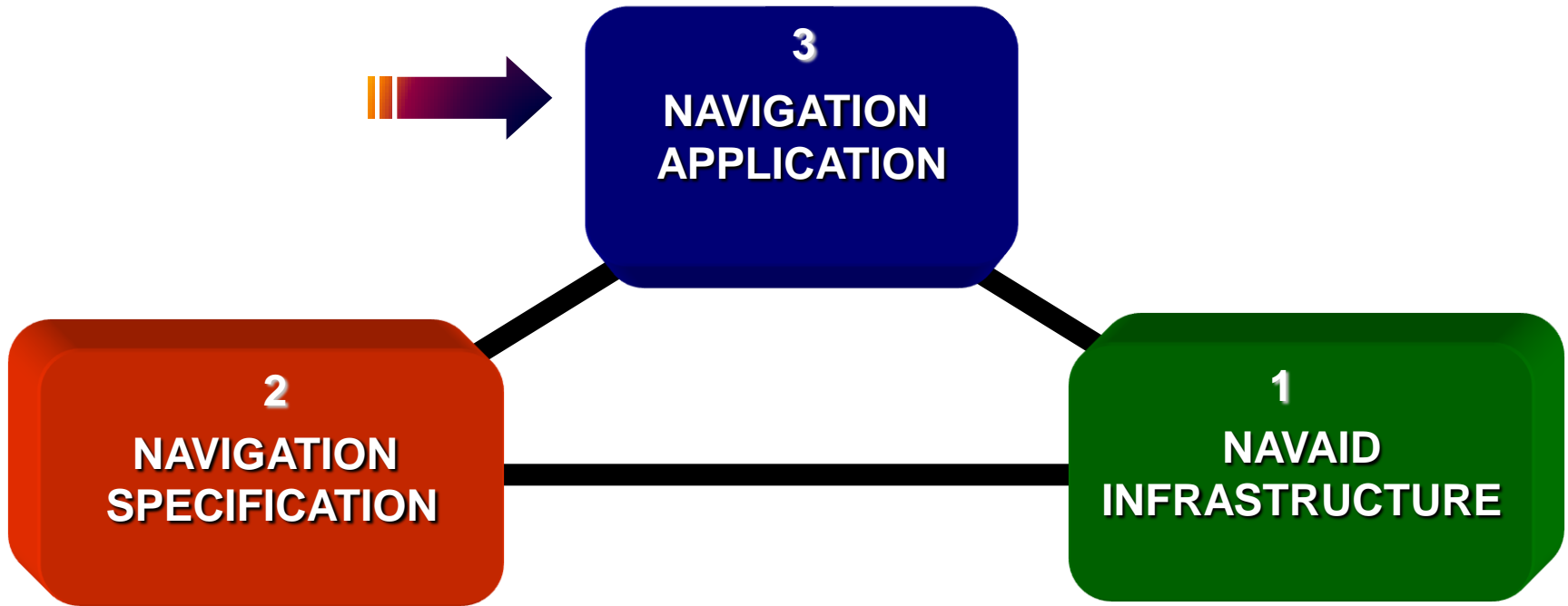
Performance Based Navigation (PBN)

Area navigation based on performance requirements for aircraft that are described in navigation specifications





Components of PBN Concept



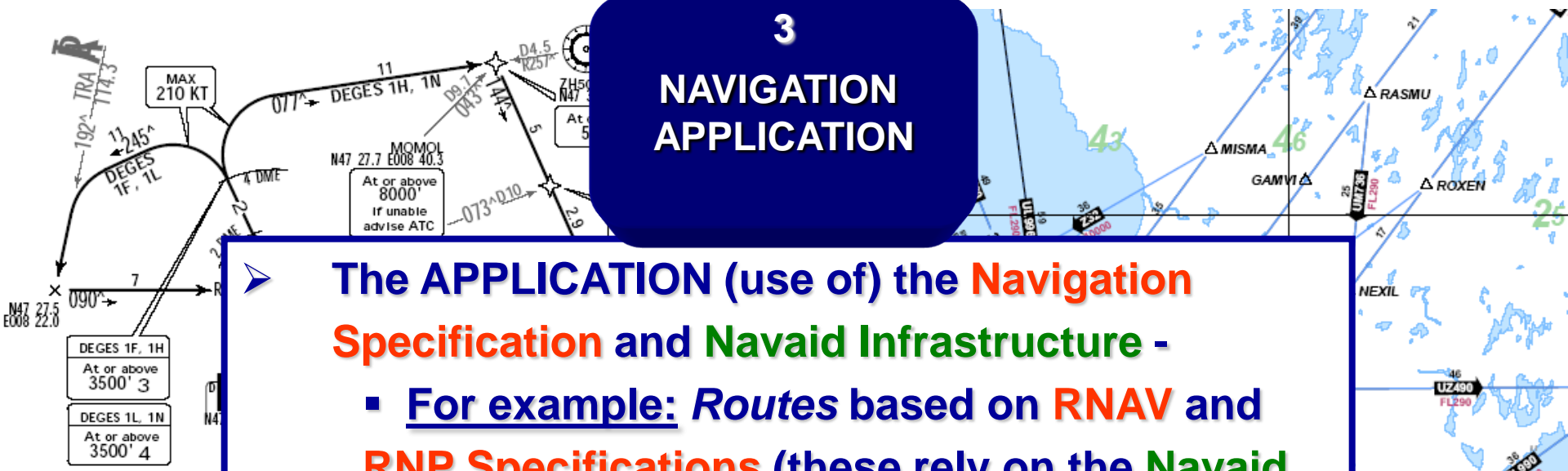


Components of PBN Concept

- Navigation Application -

3

NAVIGATION APPLICATION



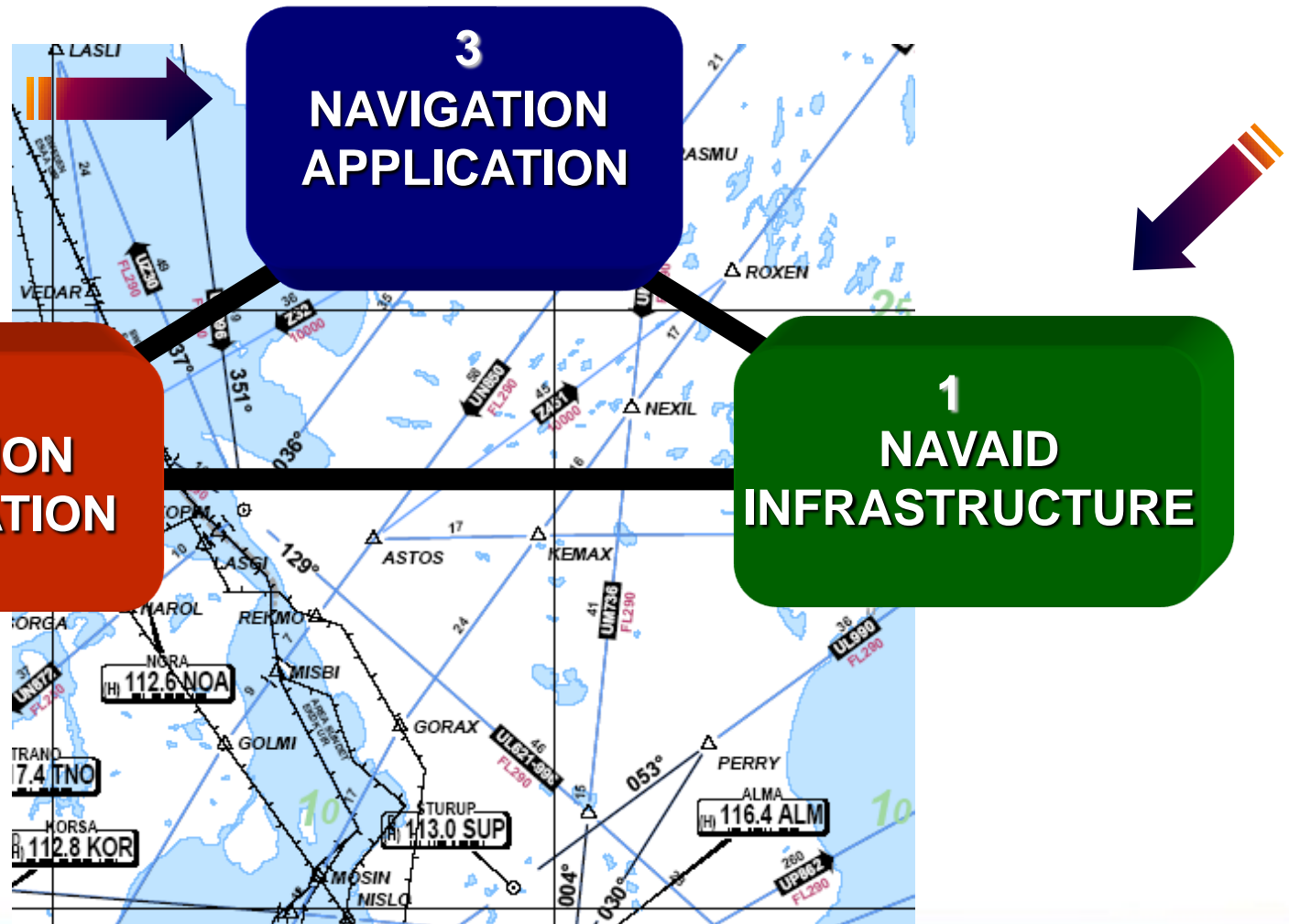
➤ The APPLICATION (use of) the Navigation Specification and Navaid Infrastructure -

- For example: Routes based on RNAV and RNP Specifications (these rely on the Navaid Infrastructure);
- For example: SIDs/STARs based on RNAV and RNP Specifications;
- For example: Approach procedures based on RNP Specifications



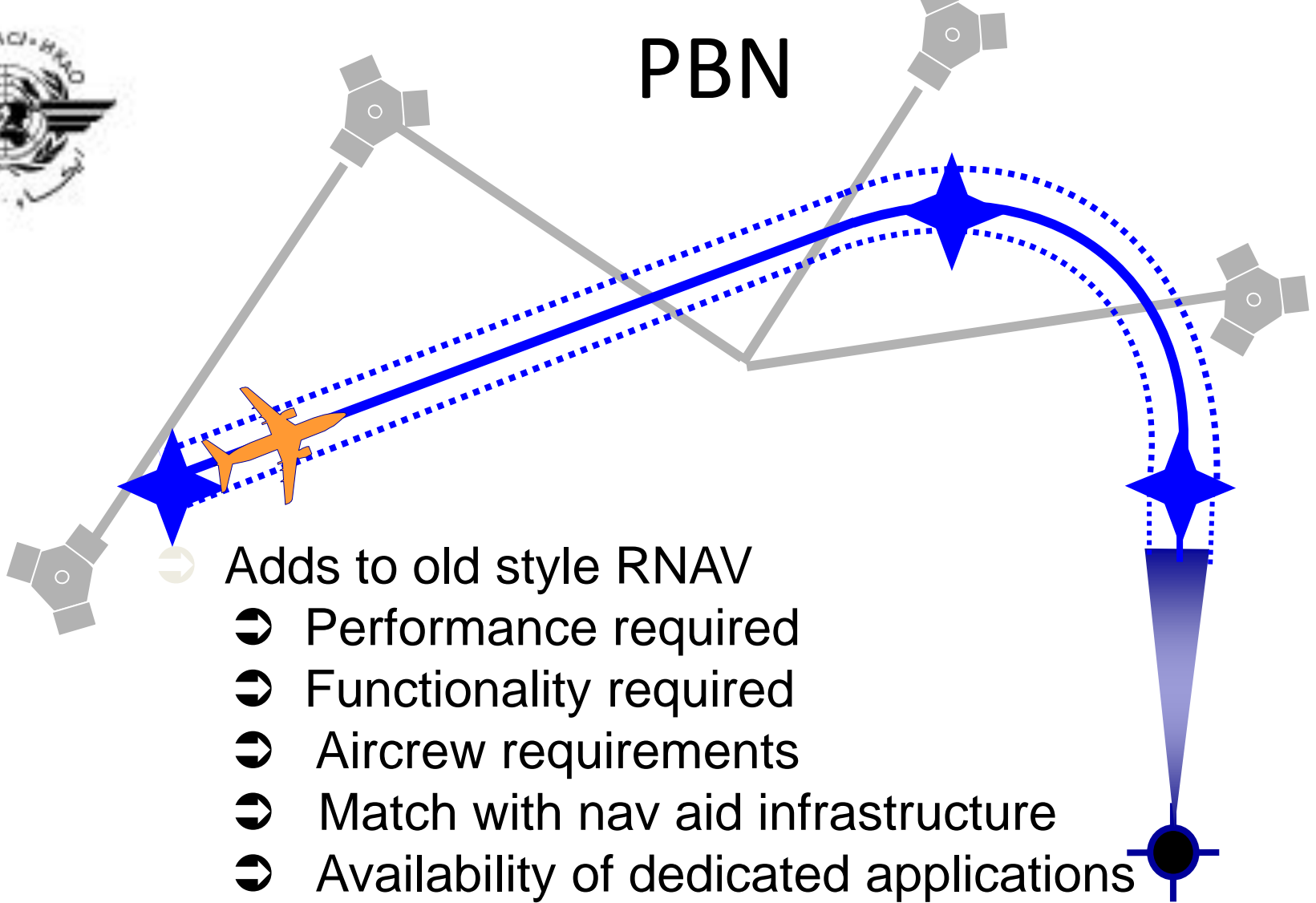


Components of PBN Concept





PBN



Adds to old style RNAV

- ➔ Performance required
- ➔ Functionality required
- ➔ Aircrew requirements
- ➔ Match with nav aid infrastructure
- ➔ Availability of dedicated applications

= **Optimized Use of Airspace**



ICAO Provisions

Performance Based Navigation Manual

- PBN Manual to provide a “one-stop shop” for States on how to implement RNAV and RNP in their airspace
- PBN Manual developed: Two Volumes:
 - Volume I – An Application of RNP and RNAV
 - Concept of PBN and how it is used
 - Implementation Guidance to States / Regions
 - Volume II – Compendium of Navigation Specifications

RNAV 10	RNAV 1	RNP APCH
RNAV 5	RNP 4	RNP AR APCH
RNAV 2	Basic RNP 1	Advanced RNP1* RNP 2*



* Work in progress



PBN Convergence....

P
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B-RNAV
P-RNAV
US-RNAV
RNP10
RNP 4



EUROPE
US
Boeing
Australia
China
Airbus
Canada
Japan
South America

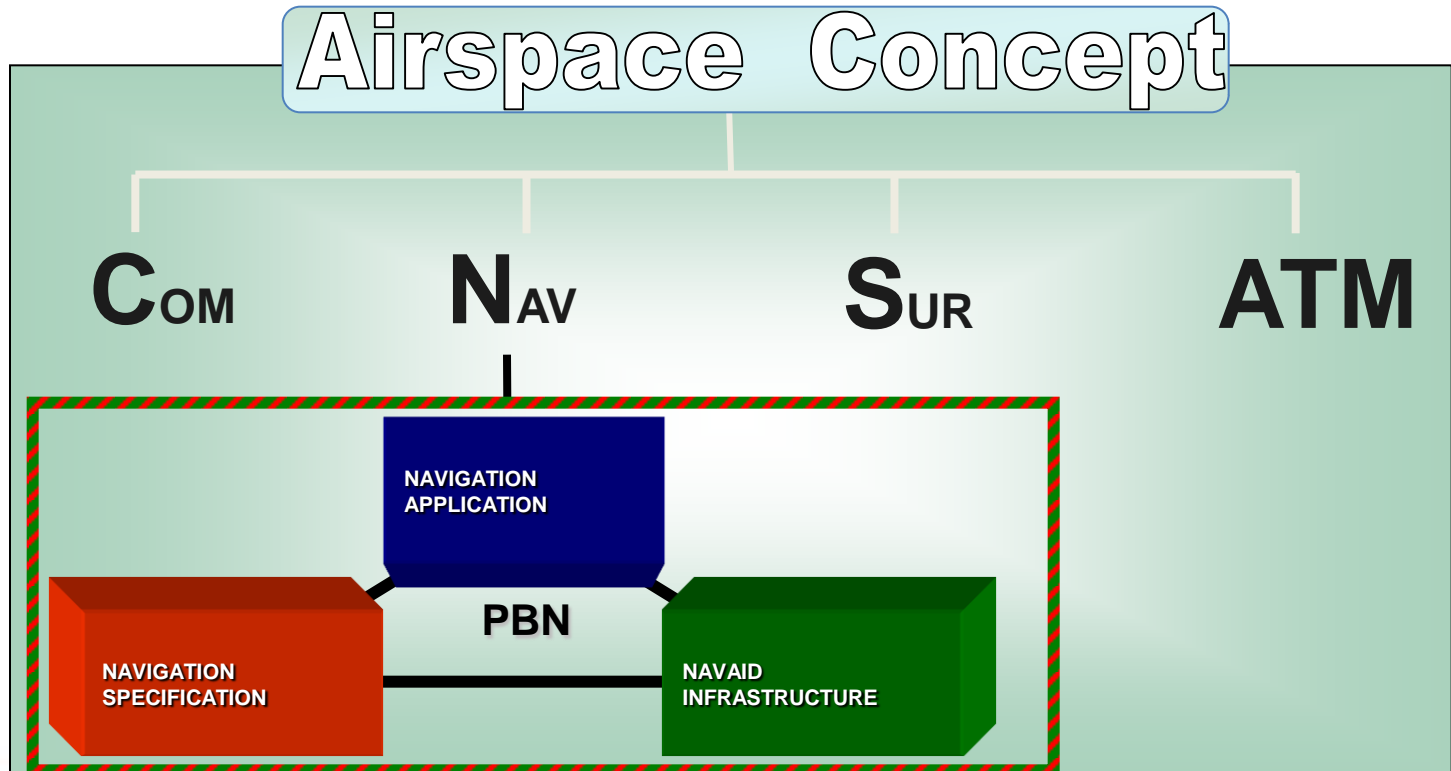
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Context of PBN

ICAO GLOBAL ATM OPERATIONAL CONCEPT





Required Communication Performance (RCP)

Critical elements of the concept

- *Required communication performance (RCP)*. A statement of the performance requirements for operational communication in support of specific ATM functions.
- RCP is performance-based, human-centered, operationally significant, independent of specific technologies and applicable to both voice communications and data link communications.

ICAO provisions:

- Recent amendments to Annex 6, 11 and the PANS-ATM include the initial high-level provisions necessary to support the introduction of RCP.



Required Surveillance Performance (RSP)

Initiation

- Need identified by ICAO to complement PBN and RCP
- Work programme currently established by ICAO
- RSP can be used for both existing and future surveillance applications, airborne as well as terrestrial. It is envisaged that RSP will interact with other performance parameters (PBN, RCP) in meeting **Required Total System Performance levels.**



3 IMPLEMENTATION



ICAO Implementation Goals

(as contained in A36-23)

States and/or regions to develop an **implementation plan** by 2009 to achieve the following goals:

- where RNAV operations are required, enroute (oceanic and continental) and terminal ATS routes to be implemented according to PBN,
- all instrument runway ends to have an approach procedure with vertical guidance (APV), either as the primary approach or as a back-up for precision approaches by **2016**
- States are encouraged to develop APV's for runways that are currently non-instrument runways and operated by aircraft in excess of 5700 kg.

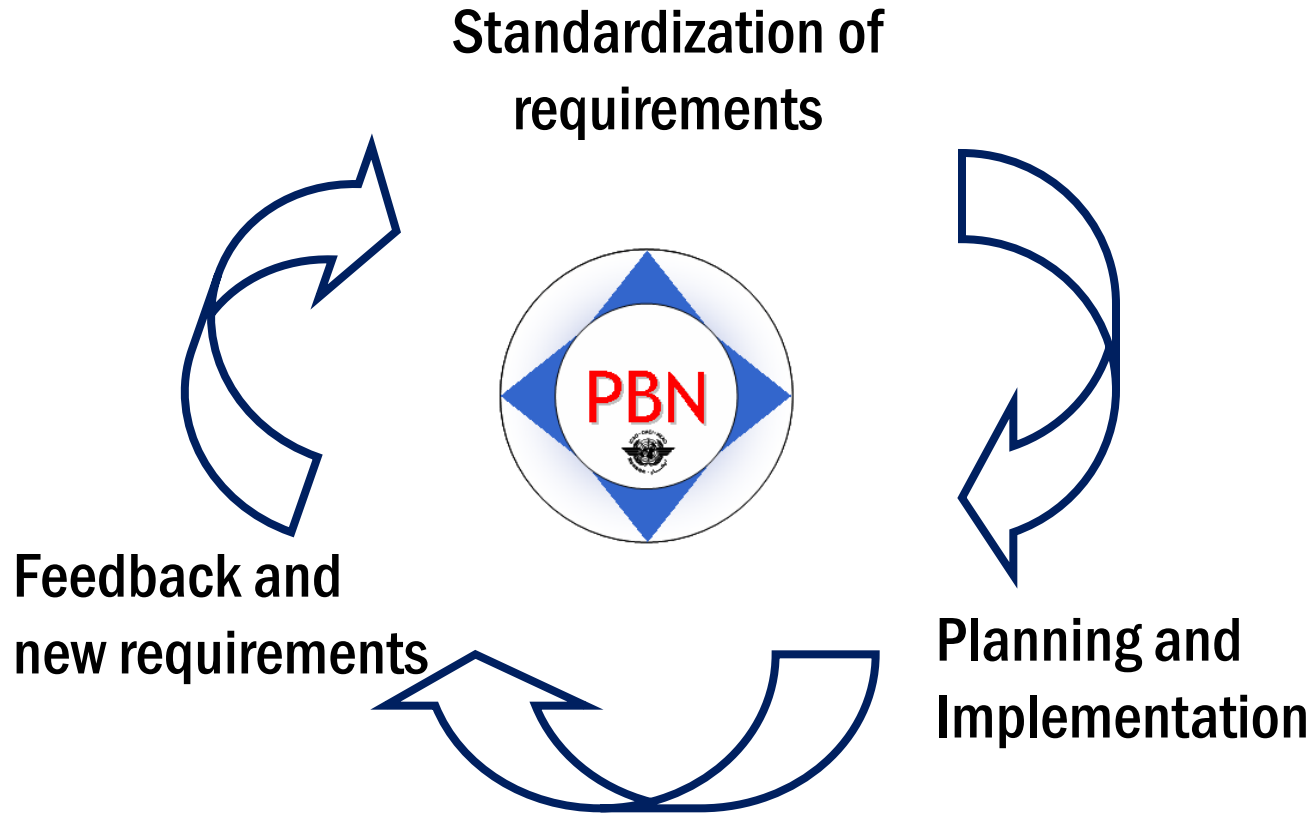
Shared responsibility of ICAO, Regions, States and stakeholders





ICAO PBN Programme

An integrated approach





ICAO Documentation

Standards and Guidance

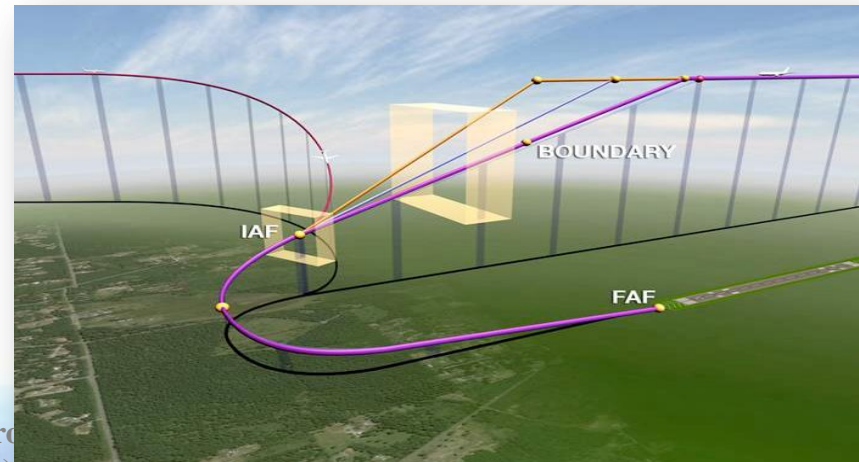
- 2007: Assembly resolution 36-23 is adopted
- 2008: ICAO established a PBN study group
- 2008: ICAO Doc 9613, *Performance Based Navigation (PBN) Manual*
- 2010: ICAO Doc 9931, *Continuous Descent Operations (CDO) Manual*
- 2010: ICAO *PBN Operational Approval Manual*
- 2010: Develop a *Continuous Climb Operations (CCO) Manual*
- 2010: Update *Global Navigation Satellite System (GNSS) manual*
- 2010: Assembly resolution 37-11 is adopted, which is the revised version of A36-23
- 2011: Revised ICAO Doc 9613, *Performance Based Navigation (PBN) Manual*





Optimizing Airspace Today

- Need: Expedite benefits-driven PBN implementation via PBN TF
- Plans this upcoming triennium:
 - Joint ICAO/Industry Go-Teams (4 per year)
 - Airspace Design Workshops (4 per year)
 - Ops Approval Workshops (3 per year)
 - Continuous Descent/Climb Operations Workshops (3 per year)
 - New PBN Guidance with focus on:
 - Increased route predictability
 - Increased aerodrome accessibility
 - A37 resolution:
 - Continued push on State implementation plans
 - Need for LNAV in addition to APV





Planning

ICAO established PBN taskforces in each region

Based on Assembly resolution A36-23:

- All Region have developed a regional strategic PBN implementation plan
- 126 States have developed their national implementation plan
- Remaining States targeted to have their national plan finished by this year.



Implementation

Training, Education, and Familiarization

- 2007-09: PBN Seminars conducted in every ICAO region
(in coordination with Eurocontrol and FAA).
- 2010-11: ICAO Continuous Descent Operations (CDO) seminar conducted in every ICAO region.
- 2010-11: ICAO PBN Airspace Workshop conducted in every ICAO region (in coordination with Eurocontrol and FAA).
- 2010-11: ICAO PBN Operational Approvals Workshop conducted in every ICAO region.



Implementation

Global PBN Task Force:

- Promotion Team.
- Implementation Support Team (IST).
- Implementation Management (GO) Team.
- 2010-11: ICAO PBN Go-Team visits to every ICAO region, which will do gap-analysis and practical application of PBN and CDO to States (in coordination with IATA and industry partners).



Asia Pacific Flight Procedure Program (FPP)

**Expedite PBN
implementation through
our partnership with States
in the region**

*Pool of resources from the
region*

*Build a minimum common
level of IFP expertise across
the region*

*Create win – win situation
for States as well as
industry*



4 FUTURE



Existing + Future Nav Specs

NAVIGATION SPECIFICATION	FLIGHT PHASE							DEF
	En Route OCEANIC /REMOTE	En Route Continental	ARR	APPROACH				
				Initial	Interm.	Final	MISSED	
RNAV 10	10							
RNAV 5		5	5					
RNAV 2		2	2					2
RNAV 1		1	1	1	1		1 ^b	1
RNP 4	4							
RNP 2		2						
Advanced RNP (Scal)		2 - 1	0.5	0.5	0.5	0.3		0.5
Basic-RNP 1 + RF			1 ^{a,c}	1 ^a	1 ^a		1 ^{ab}	1 ^{a,c}
RNP 0.3		0.3	0.3	0.3				
RNP APCH + LPV + RF				1	1	0.3	1	
RNP AR APCH				1-0.1	1-0.1	0.3 – 0.1	1-0.1	0.x

** Scalable RNP





Future

Courses:

- OPS approval
- Airspace design
- CDO design

GO-TEAMS:

- Assist in direct implementation

Hands-on guidance:

- OPS approval
- Airspace design



Summary

PBN replaces “old style RNAV” to ensure performance, functionality and infrastructure match is established, making **RNAV and RNP implementable**

ICAO has established efforts to move States through planning processes towards **implementation of PBN**

ICAO and partners are assisting States in implementation through **training and direct implementation**





Summary Cont'd)

States have **focus on PBN** , an increasing number submitted implementation plans, and significant **PBN implementation projects started and/or completed**.

The number of PBN navigation specification are expanding to address **continued operational needs**.

ICAO is now **focusing on implementation** with partners and everyone is **welcome to join**.





Thank you.

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Workshop on National Performance Framework
(2010)

