Performance Based Navigation (PBN)

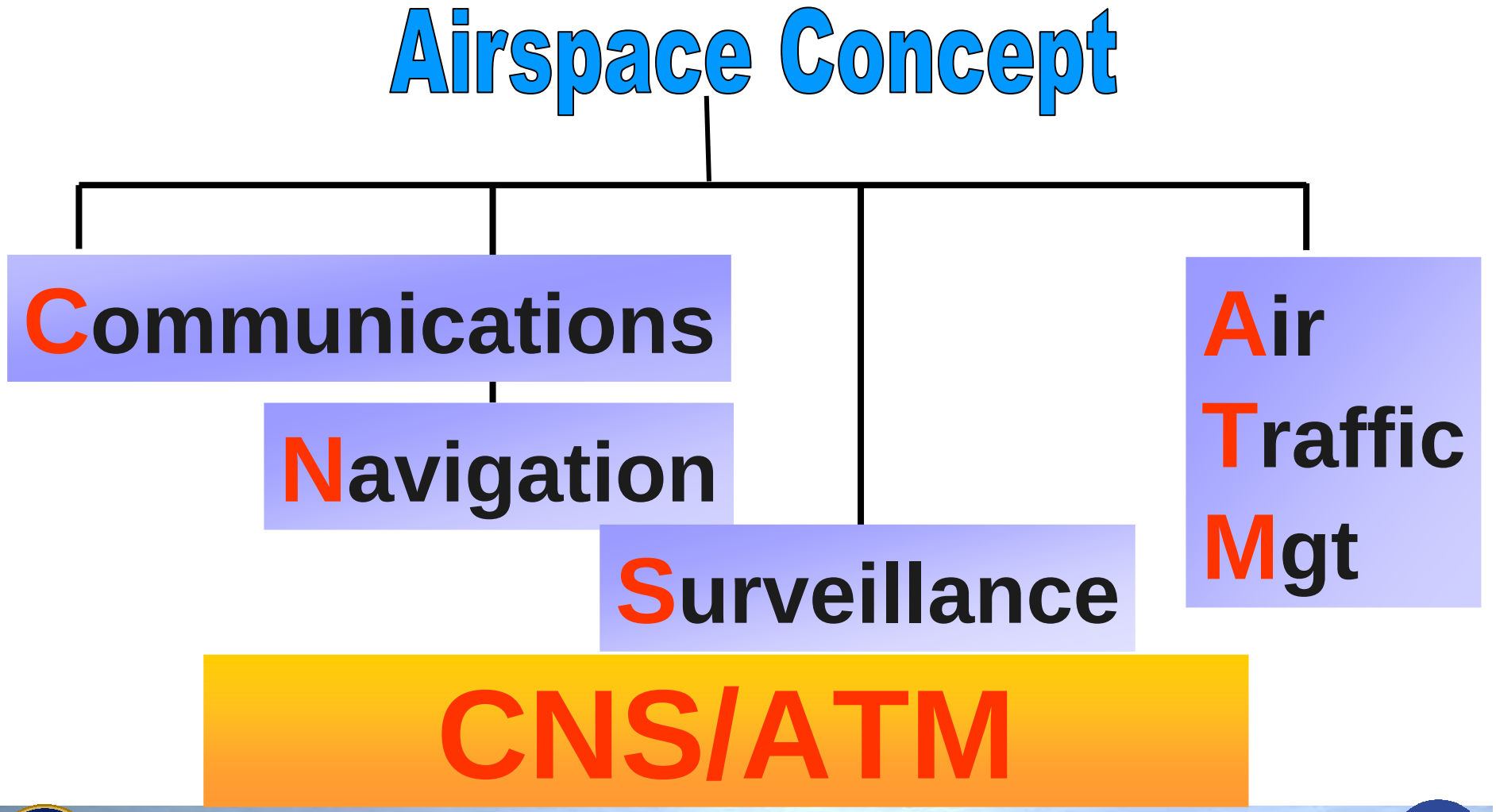
What is area navigation?

What is PBN?

Overview

- Learning Objectives: at the end of this presentation you should:
  - Understand what is RNAV and RNP and how correct use can improve operational efficiency and Airspace Capacity
- This presentation will discuss
  - Navigation in Context
  - Evolution to Performance Based Navigation
  - Performance Based Navigation
    - What Is It?
    - What is Area Navigation (RNAV)?
    - What is Required Navigation Performance?
    - What is the Key Difference?

Navigation in Context



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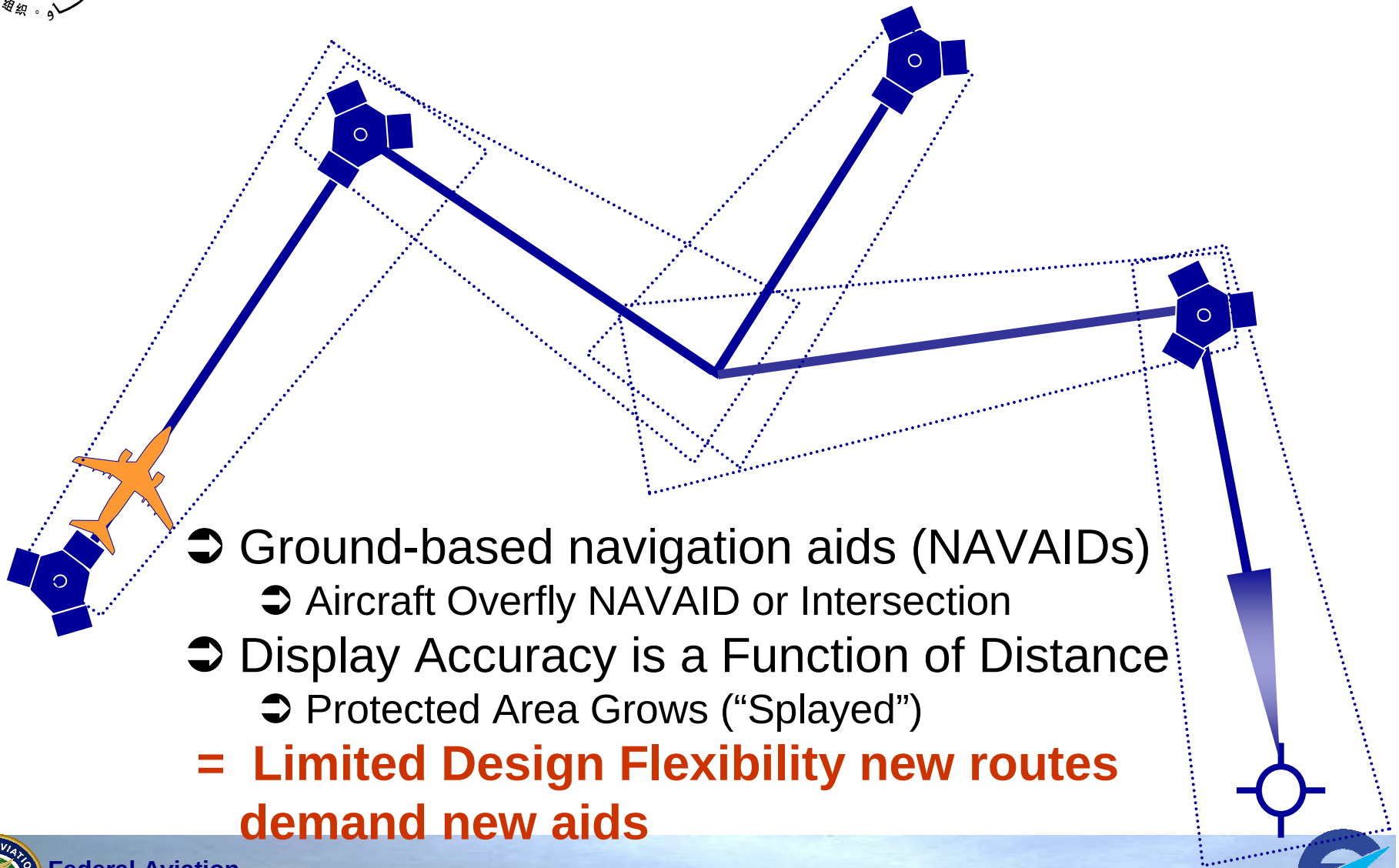
What is area navigation?

Conventional Navigation



- Ground-based navigation aids (NAVAIDs)
  - Aircraft Overfly NAVAID or Intersection
- Display Accuracy is a Function of Distance
  - Protected Area Grows (“Splayed”)

= Limited Design Flexibility new routes demand new aids

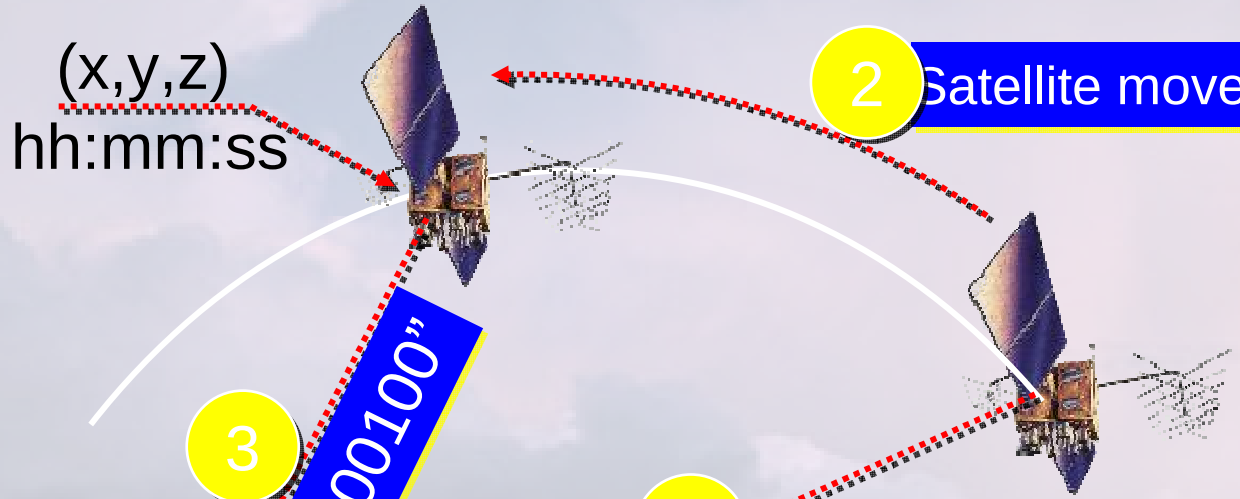
Conventional Navigation Aids

- Routes predicted on flying to or from point source navigation aids
- Primarily VHF Omni-directional Radio Range
  - Pilots Navigate by setting course shown on chart into the OBS of VOR display
- VOR has been primary NAVAID for decades
  - Defines Routes
  - Supports Approach Procedures

Evolution of RNAV

- DECCA Navigator and Long Range Navigation (LORAN)
- Both hyperbolic systems with route definition system in airborne receivers
- Omega Radio Navigation System
- Inertial Navigation
- VOR/DME RNAV
- Multi-sensor Flight Management System (FMS) (DME/DME and VOR/DME) integrated with inertial navigation
- GPS, GLONASS, and Augmentations

How Satellite Ranging Works



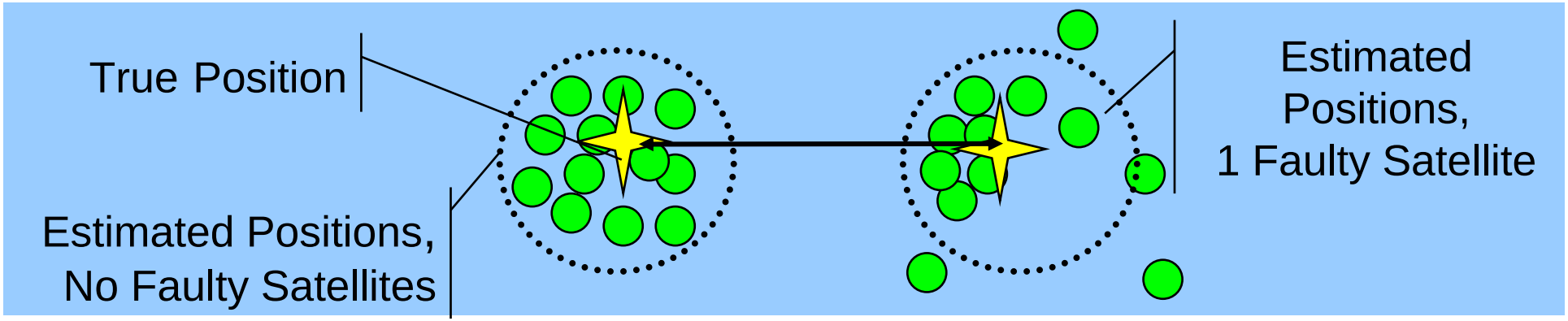
2 Satellite moves on Orbit

3 "01100100"

1 At the next broadcast
- It will be hh:mm:ss
- I will be at (x,y,z)
- I will say "01100100"

4 Receiver — Receives "01100100" with time delay.

What is RAIM?



Checks the integrity of the position fix:

- Includes local errors, such as interference
- Based on the consistency of measurements

Requires:

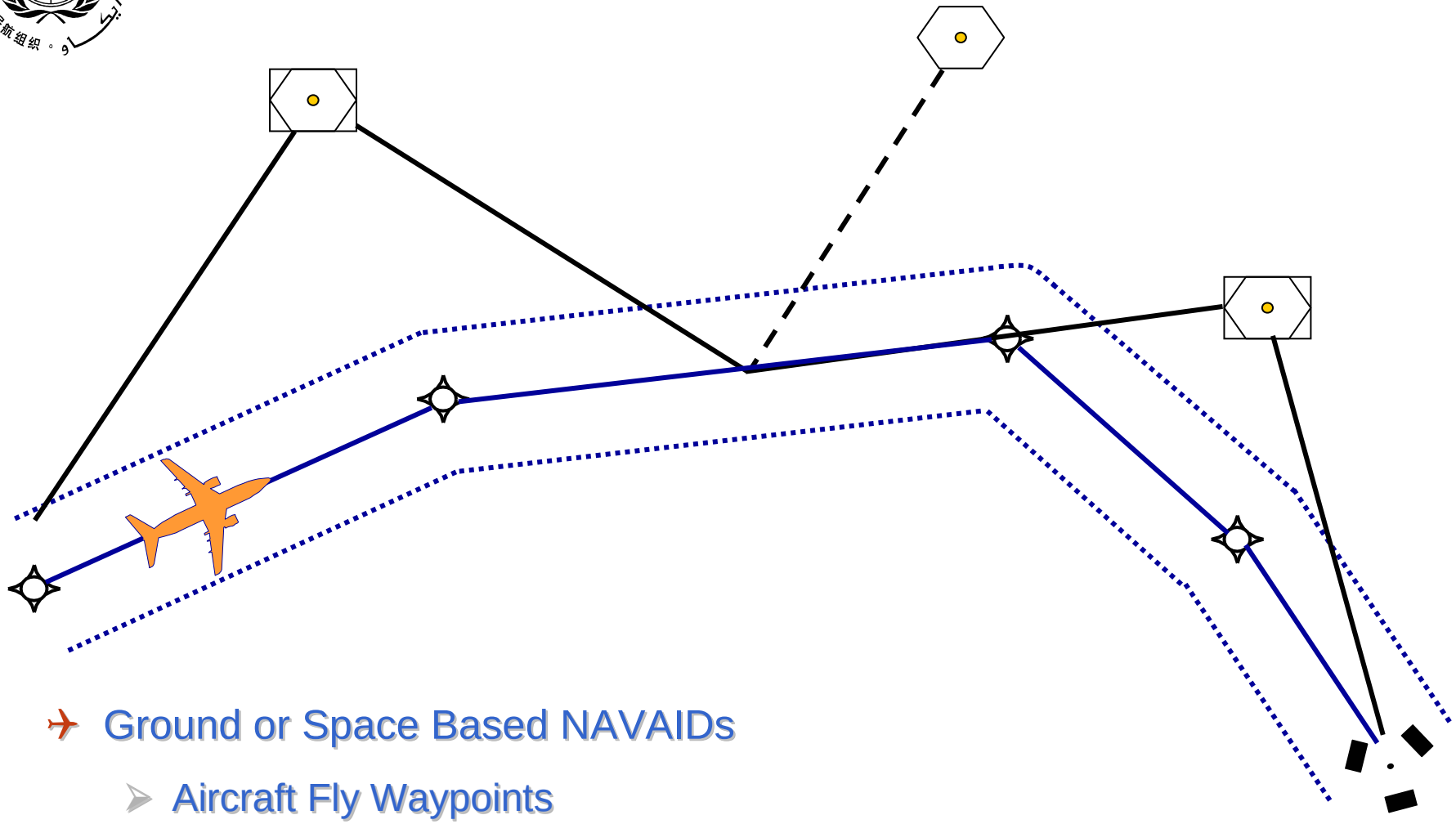
- no data from outside the satellite receiver
- redundant satellite measurements

A “rule of thumb”:

- 5+ satellites to detect a problem
- 6+ satellites to detect & isolate problem

Most assume only 1 faulty satellite - Multiple failures more difficult to detect. New algorithms being developed to cater for increased risk of multiple failures due to increased satellite numbers

Area Navigation



- Ground or Space Based NAVAIDs
  - Aircraft Fly Waypoints

= Increased Design Flexibility

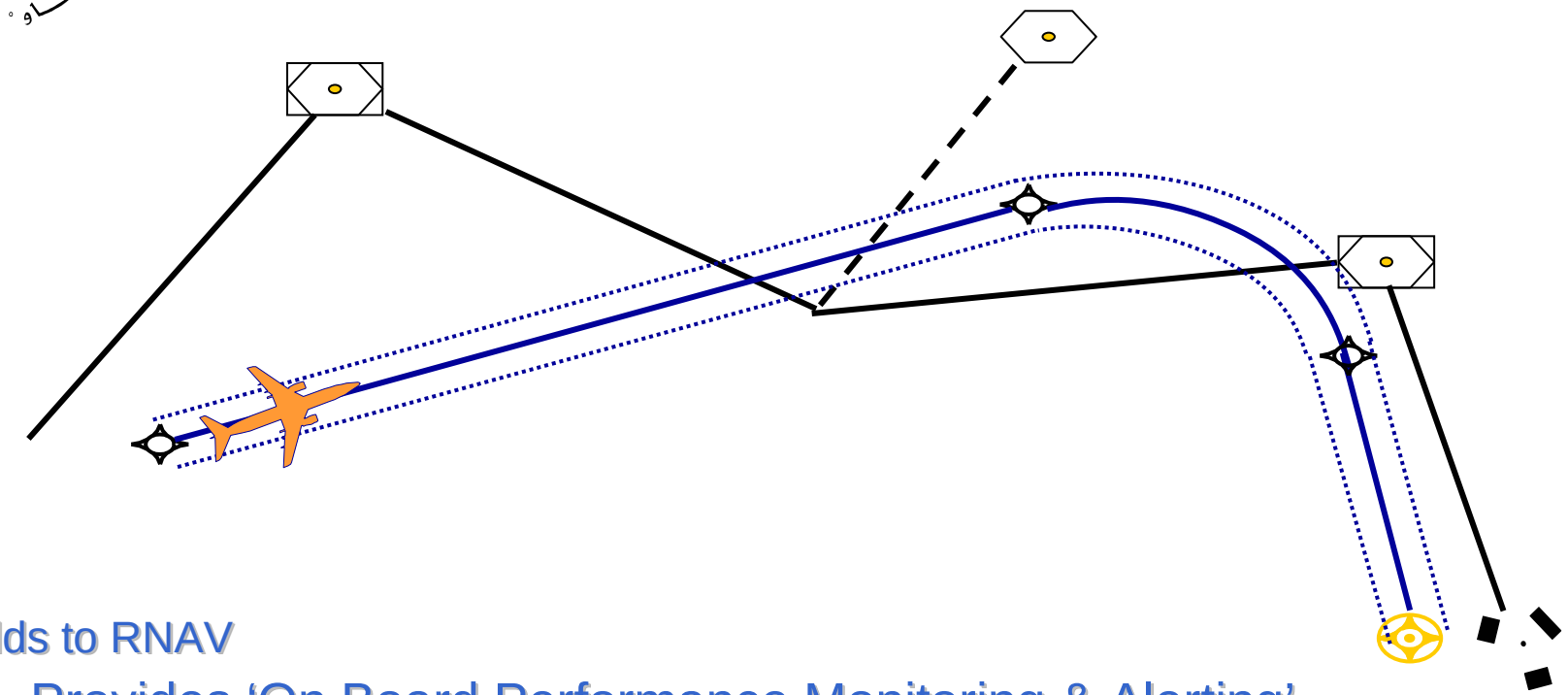
Evolution of Required Navigation Performance

- ICAO: Developed RNP concept
  - Initially defined by ICAO Special Committee on Future Air Navigation Systems (FANS) for "Required Navigation Performance Capability" (RNPC)
  - ICAO Review of the General Concept of Separation Panel refined to "Required Navigation Performance" (RNP)
  - ICAO Doc 9163 Manual on Required Navigation Performance (First Edition 1993)
    - **RNP**: "A statement of the navigation performance necessary for operation within a defined airspace"

Evolution of RNP continued

- RTCA/EUROCAE: Defined performance and functional requirements
  - RTCA DO 236/EUROCAE ED-75 Minimum Aviation System Performance Standards: Required Navigation Performance for Area Navigation (2003)
    - **RNP**: "A Statement of the navigation performance accuracy necessary for operation within a defined airspace"
    - ~~**RNP RNAV**~~: "An area navigation capability that meets all of the requirements of this document"
    - ~~**RNP Type**~~: "RNP Types are established according to navigational performance accuracy in the lateral plane…"
    - ~~**RNP (x) RNAV**~~: "A designator used to indicate the minimum navigation system requirements needed to operate in an area, on a route or a procedure"
- Manufacturers: Delivered "RNP" based on different versions of requirements

RNP

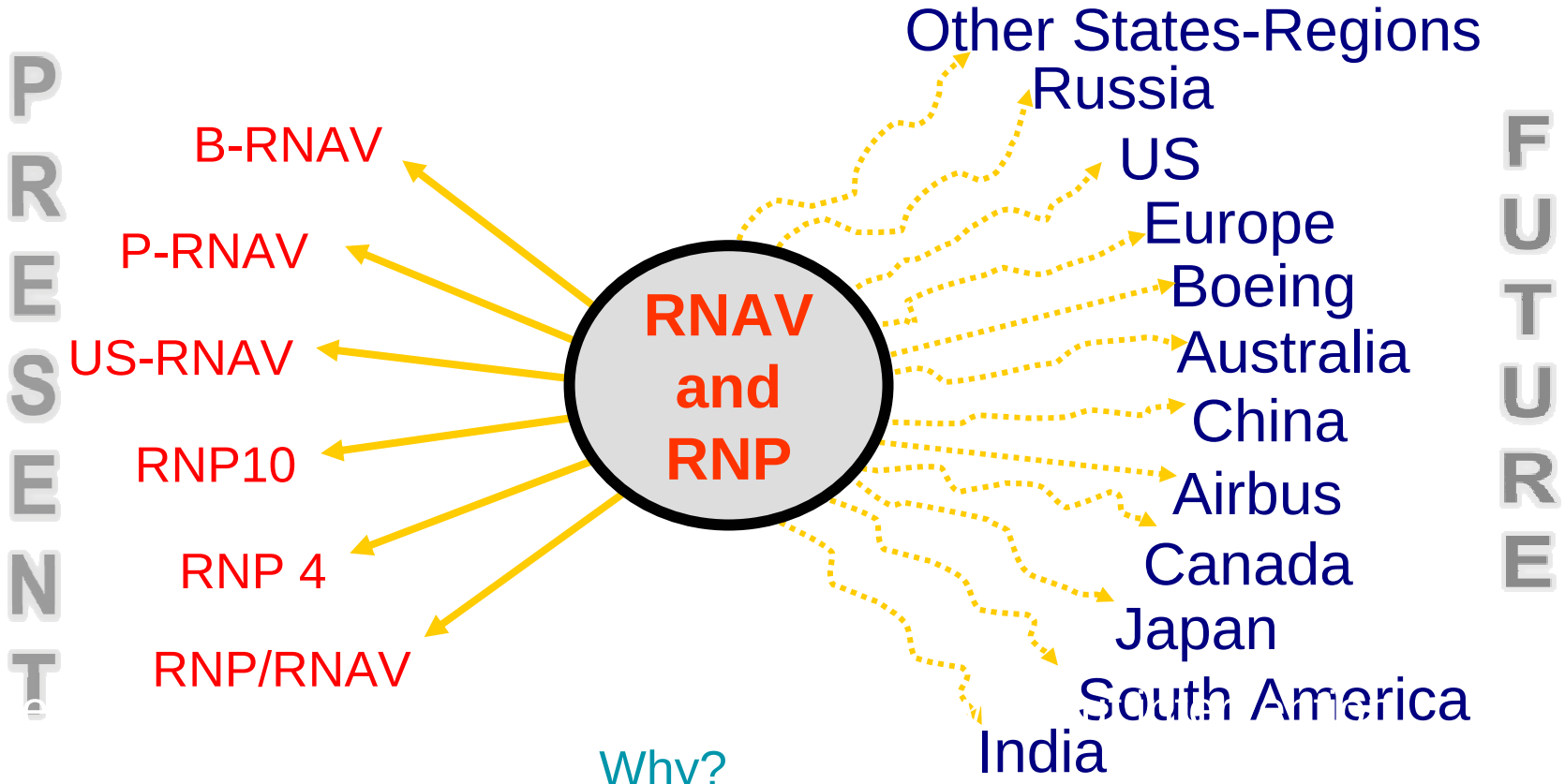


- Adds to RNAV
  - Provides 'On Board Performance Monitoring & Alerting'
    Increased reliance upon correct operation of nav systems
  - May Incorporate additional functionality
    eg Radius to Fix Turns (A-RNP1)

=

Optimize use of Airspace

Why was PBN Required



Why?

RNP majored on accuracy

Implementations needed specific functionality as well as accuracy

The Problem Addressed at ICAO

Need to avoid:

- Confusion over meaning of RNP
- cost of unnecessary multiple certifications against different specifications

GNSSP/4 recommendation 1/1

  - 11th Air Navigation Conference

- Individual Air Navigation Commission Panels not suitable to address the problem
- ANC (163/9) approves establishment of Required Navigation Performance Special Operations Requirements Study Group (RNPSORSG) as coordinating group
  - “ICAO RNP Study Group”

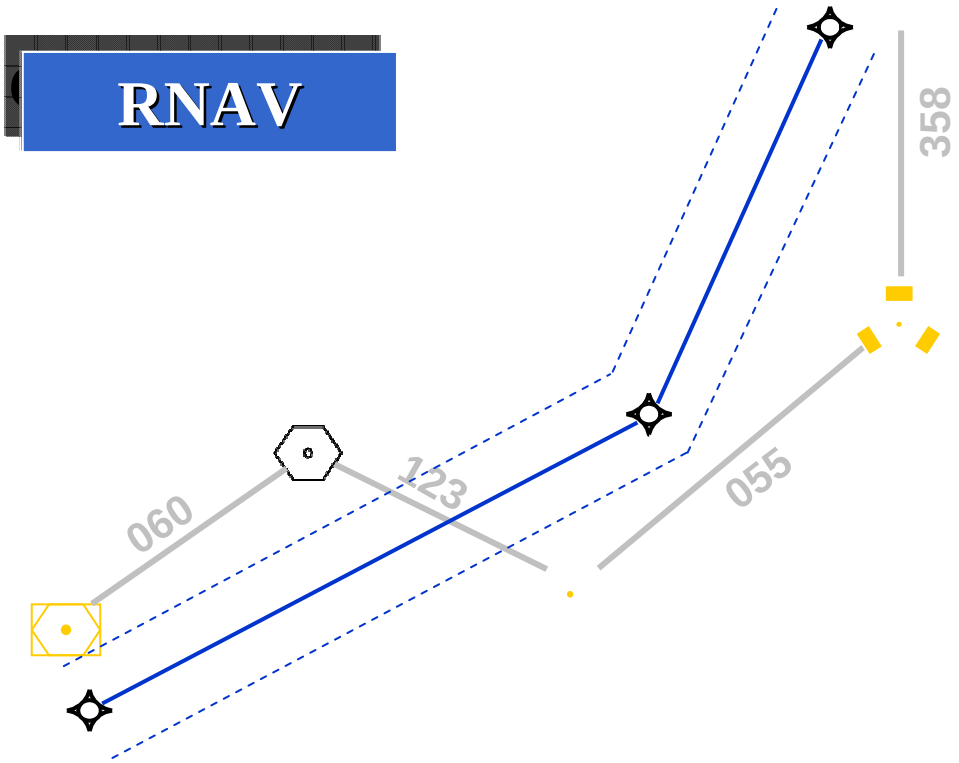
Transition to Performance Based Navigation

- Navigation based on specified system performance requirements for aircraft operating on a air traffic route, instrument approach procedure, or in a designated airspace
  - Potential for aircraft to demonstrate requirements compliance through a mix of capabilities, rather than only specific equipment
  - Regulators will not always need to write new compliance documents for new capabilities

PBN has **2** Key Elements:
RNAV and ***RNP***

Definition of Area Navigation

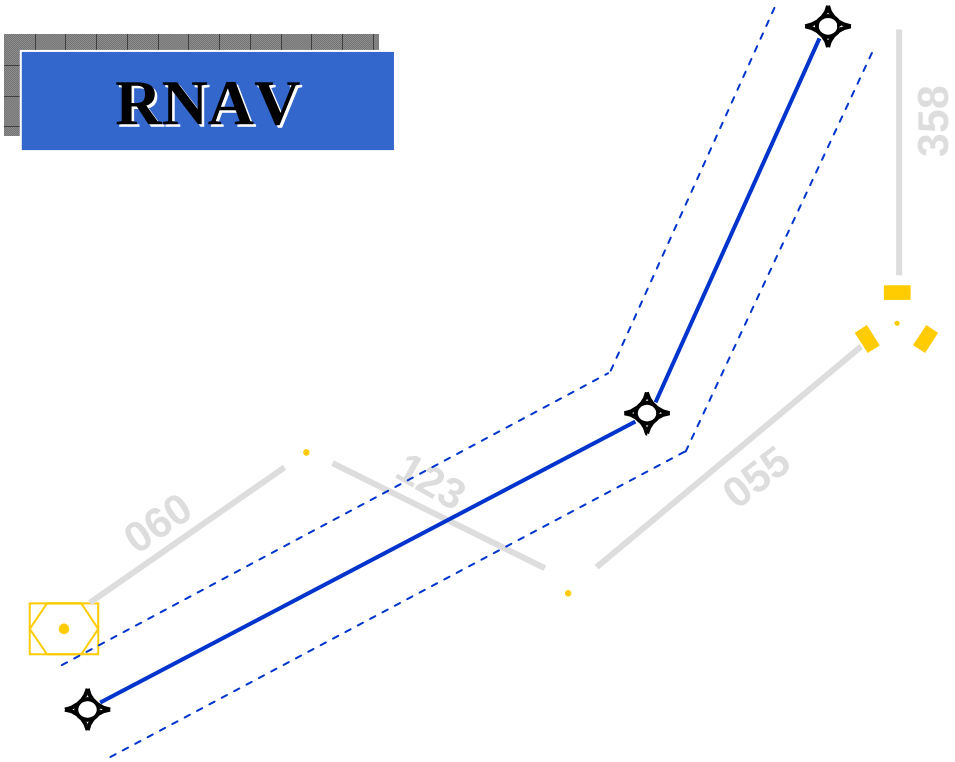
- RNAV is a method of navigation which permits aircraft operation on any desired flight path:
  - within the coverage of station-referenced NAVAIDS, or
  - within the limits of the capability of self-contained systems, or
  - a combination of these capabilities



Blue line shows RNAV route without constraints of ground-based NAVAIDs

Definition of a RNAV System

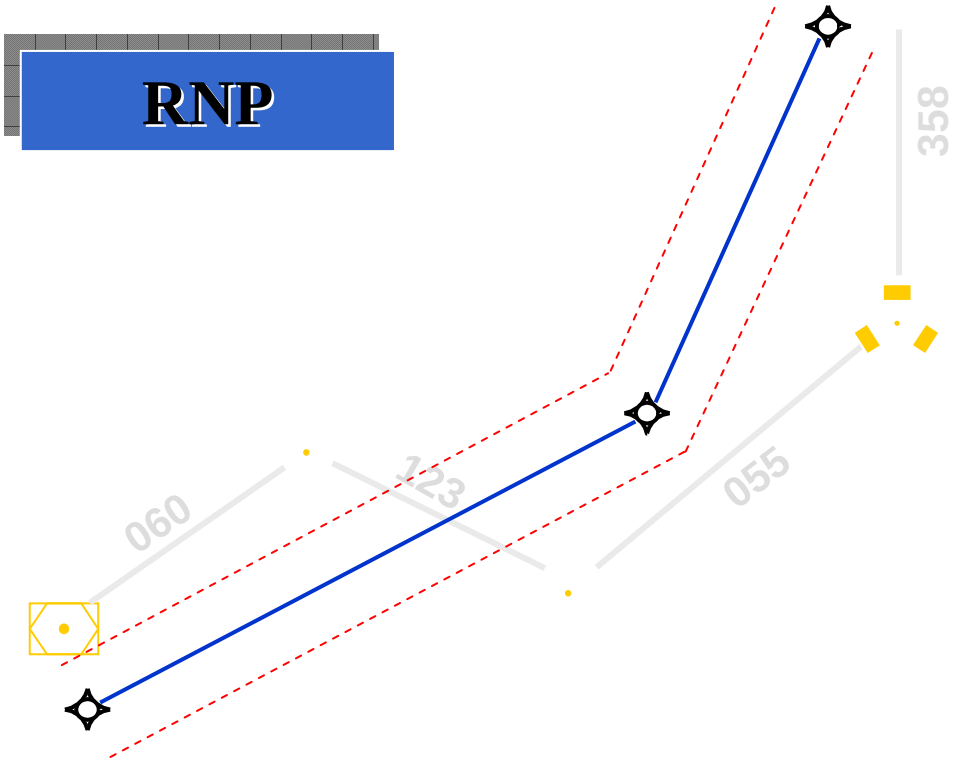
- A **navigation system** which permits aircraft operation on any desired flight path:
  - within the coverage of station-referenced NAVAIDS, or
  - within the limits of the capability of self-contained systems, or
  - a combination of these capabilities



Blue line shows RNAV route without constraints of ground-based NAVAIDs

Definitions for RNP

- RNP Route:
  - An ATS route established for the use of aircraft adhering to a prescribed RNP Specification
- RNP System:
  - An area navigation system which supports on-board performance monitoring and alerting
- RNP Operations:
  - Aircraft operations using a RNP System for RNP applications



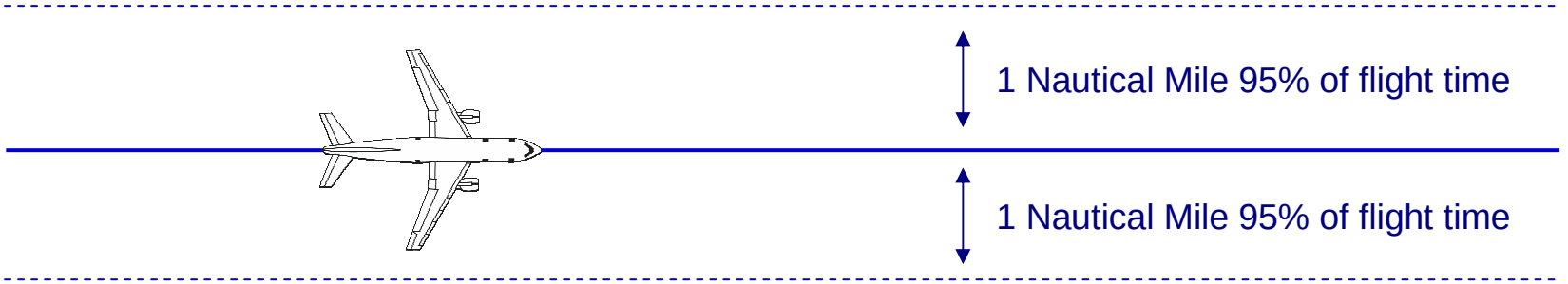
Blue line shows RNP route without constraints of ground-based NAVAIDs

RNAV and RNP

RNAV 1

RNP 1

2*RNP Alert to Pilot



RNP isn't "fundamentally different" from RNAV:
RNP is ***MORE*** Than RNAV

The Key Difference:
On-Board Performance Monitoring and Alerting

Benefits

Transition to a total RNAV environment

- ✈ Flight efficiency, optimise airspace etc

PBN systematises RNAV

- ✈ Avoid proliferation of standards (costs for certification)

RNP allows increased reliance on RNAV

- ✈ Closer routes
- ✈ Avoid need to cross check against point source Nav aids (e.g. VOR)

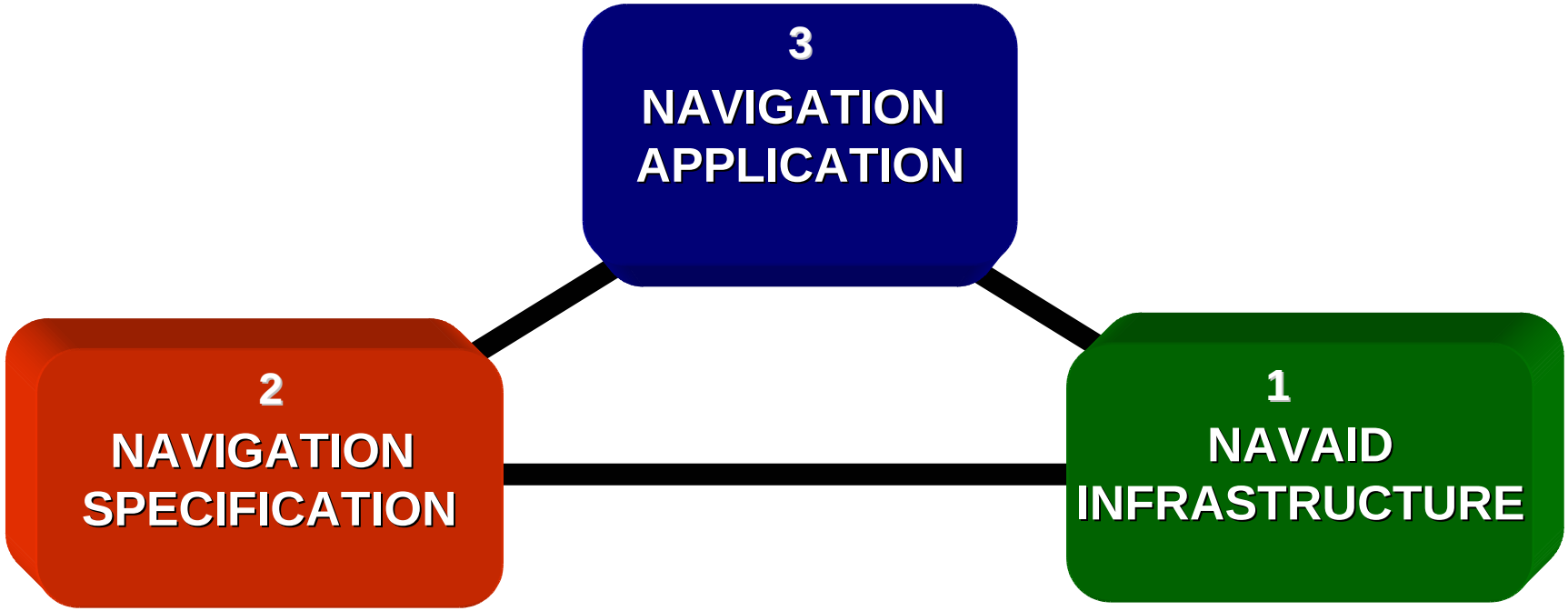
Infrastructure

- ✈ Once Dual GNSS (supported in certain dense airspace by DME)
- ✈ VOR and NDB can be decommissioned

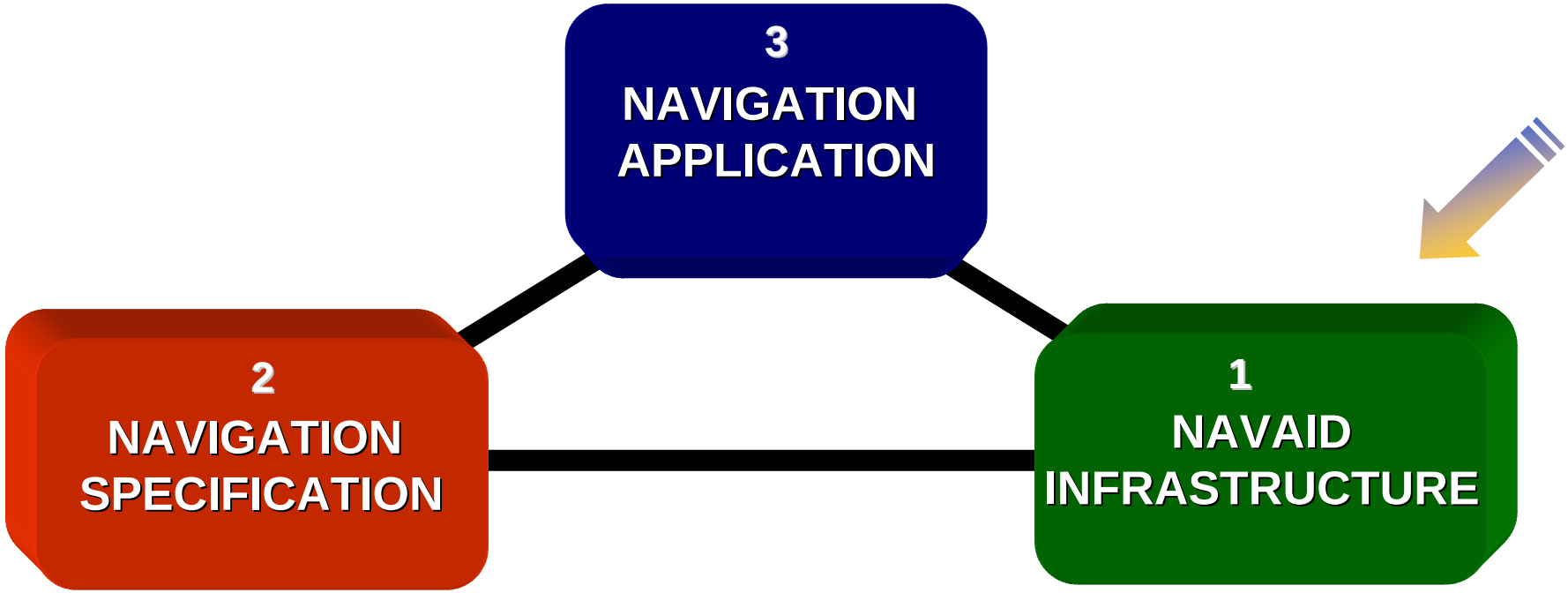
2

What is PBN?

Components of PBN Concept



Components of PBN Concept

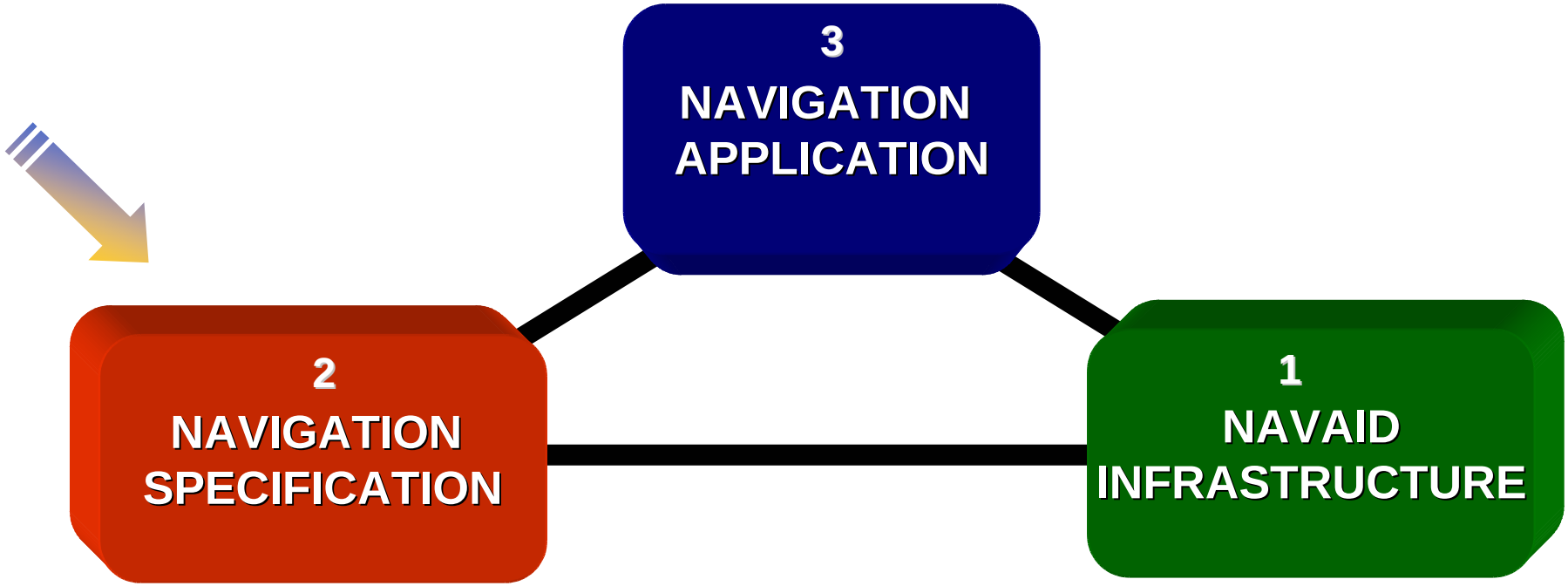


Components of PBN Concept
- Navaid Infrastructure -

- **Ground-based Navigation Aids (Navaids)**
  - **VOR; DME;** (Not NDB)
- **Space-based Navaids**
  - **GNSS**
    - **GPS; Glonass;** ***future*** **Galileo**

1
NAVAID INFRASTRUCTURE

Components of PBN Concept



Components of PBN Concept
- Navigation Specification -

Aim is to limit number of Nav. Specs in global use

2
NAVIGATION SPECIFICATION

International Navigation Specifications published in Volume II of PBN Manual

- **What PERFORMANCE is required of the RNAV system?**
- **What Functionalities must RNAV system have to achieve *Performance***
- **What Navigation Sensors must be integrated in RNAV system to achieve *Performance***
- **What requirements are placed on the Air crew to achieve the required *Performance* from the RNAV system?**

Accuracy
Integrity
Continuity
Availability

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

Components of PBN Concept
- Navigation Specification -

International Navigation Specifications published in Volume II of PBN Manual

2
NAVIGATION SPECIFICATION

- **PERFORMANCE**
- **Functionalities**
- **Navigation Sensors**
- **Air crew requirements**

Previous RNP Concept

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

Components of PBN Concept
- Navigation Specification -

ICAO NAVIGATION SPECIFICATIONS

RNAV SPECIFICATIONS

Designation
RNAV 10
For Oceanic and Remote Continental navigation applications

Designation
RNAV 5
RNAV 2
RNAV 1
For En Route & Terminal navigation applications

RNP SPECIFICATIONS

Designation
RNP 4
For Oceanic & Remote Continental navigation applications

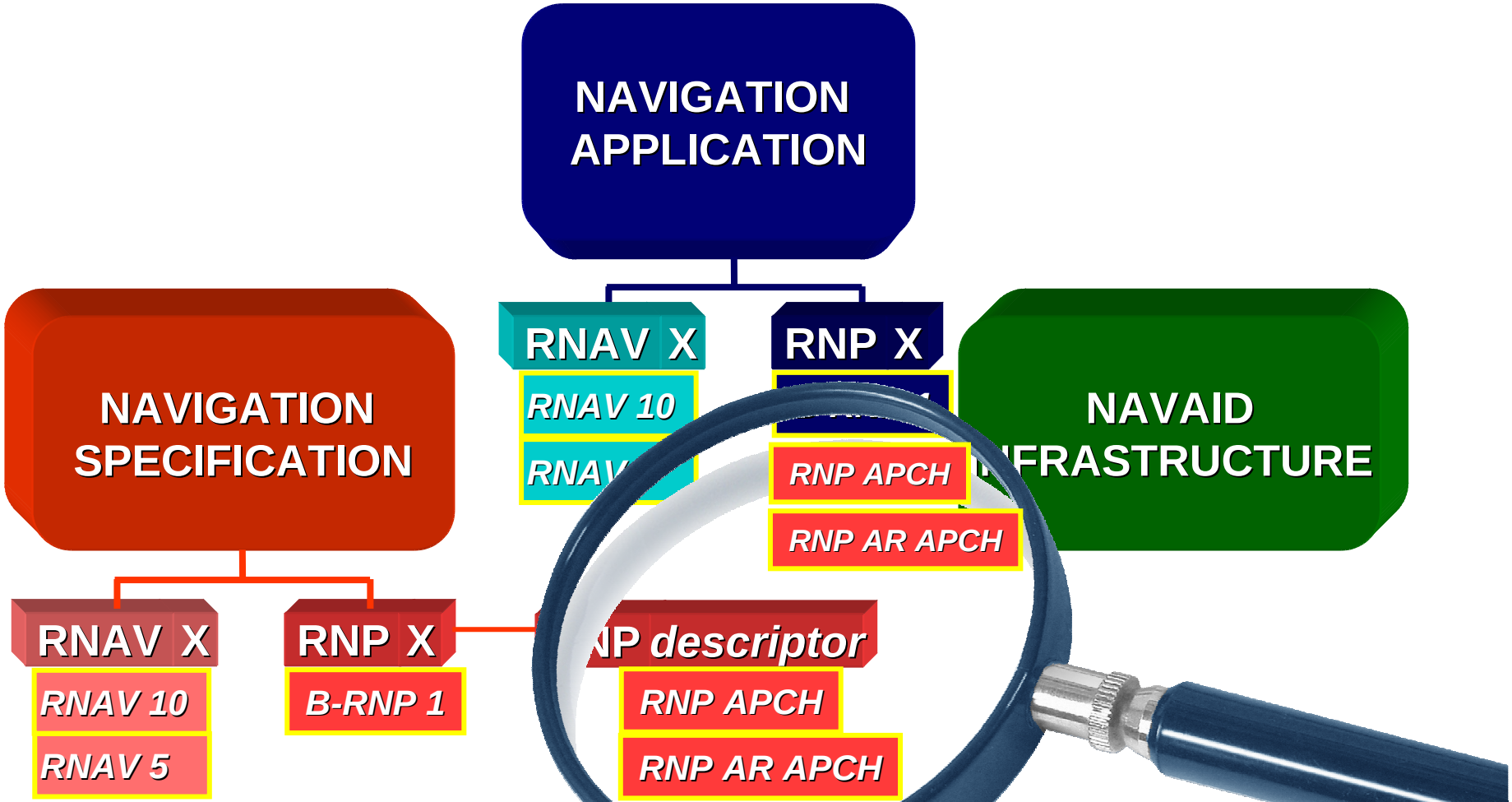
Designation
RNP 2*
B-RNP 1
A-RNP*
RNP 0.3*
RNP APCH*
RNP AR APCH
for various phases of flight

Designation
RNP with additional requirements to be determined
(e.g. 3D, 4D etc)

* *Under development*

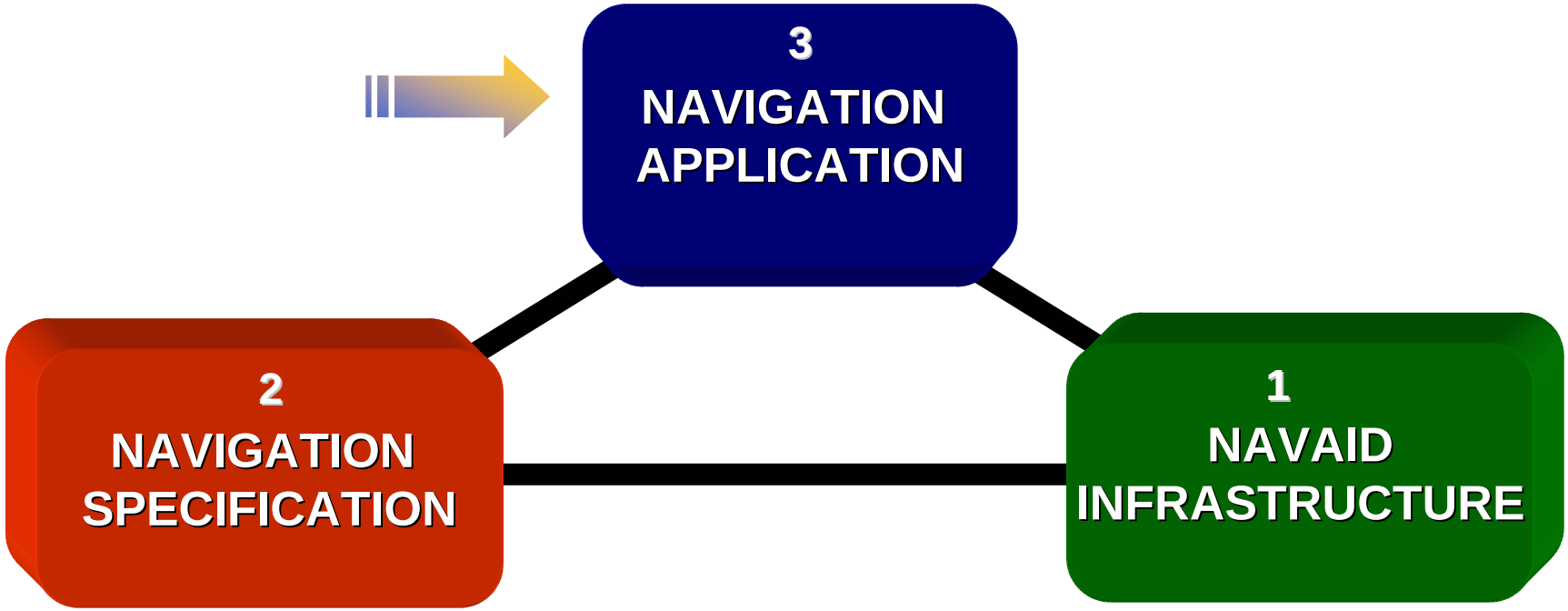
International NS in Volume II of PBN Manual

Components of PBN Concept
- Designation -

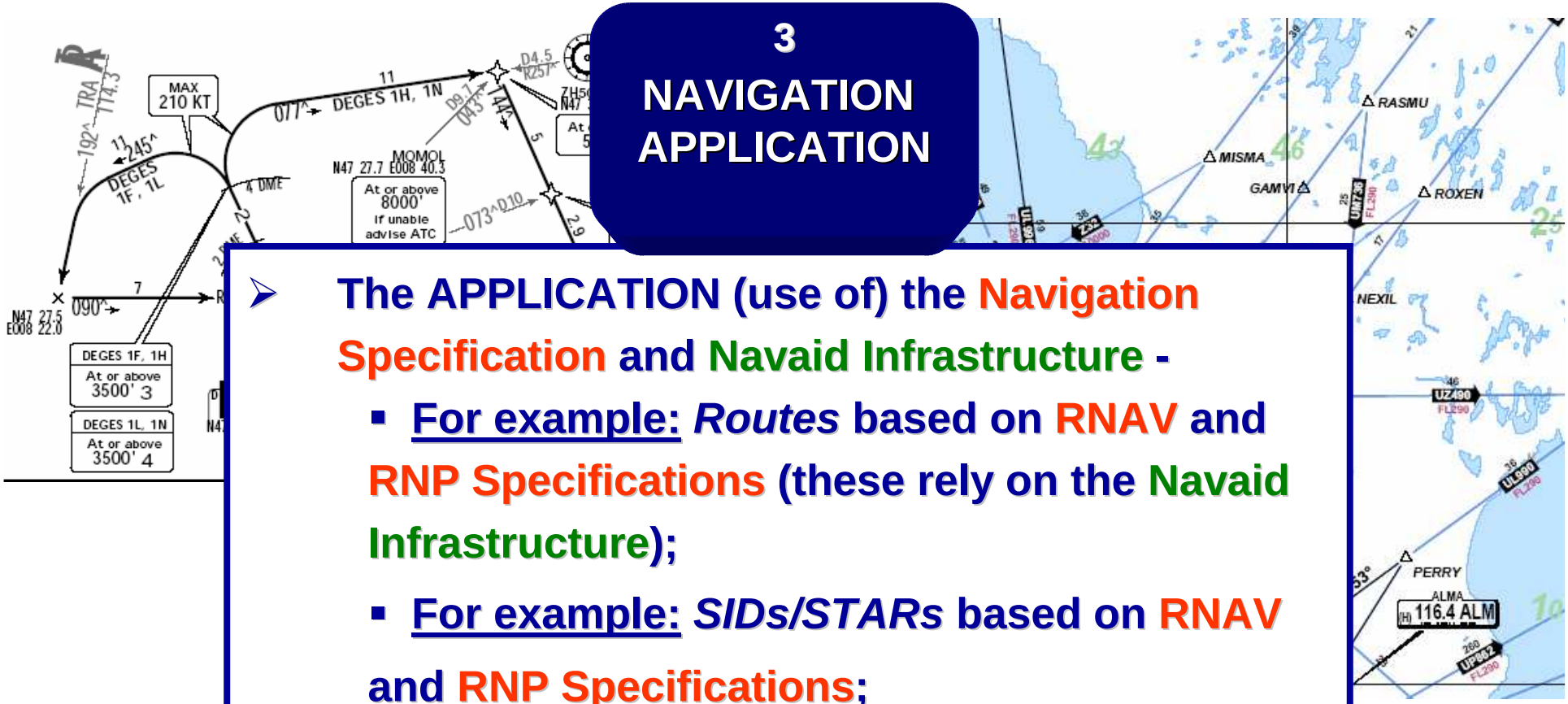


X = Navigation Accuracy in NM

Components of PBN Concept

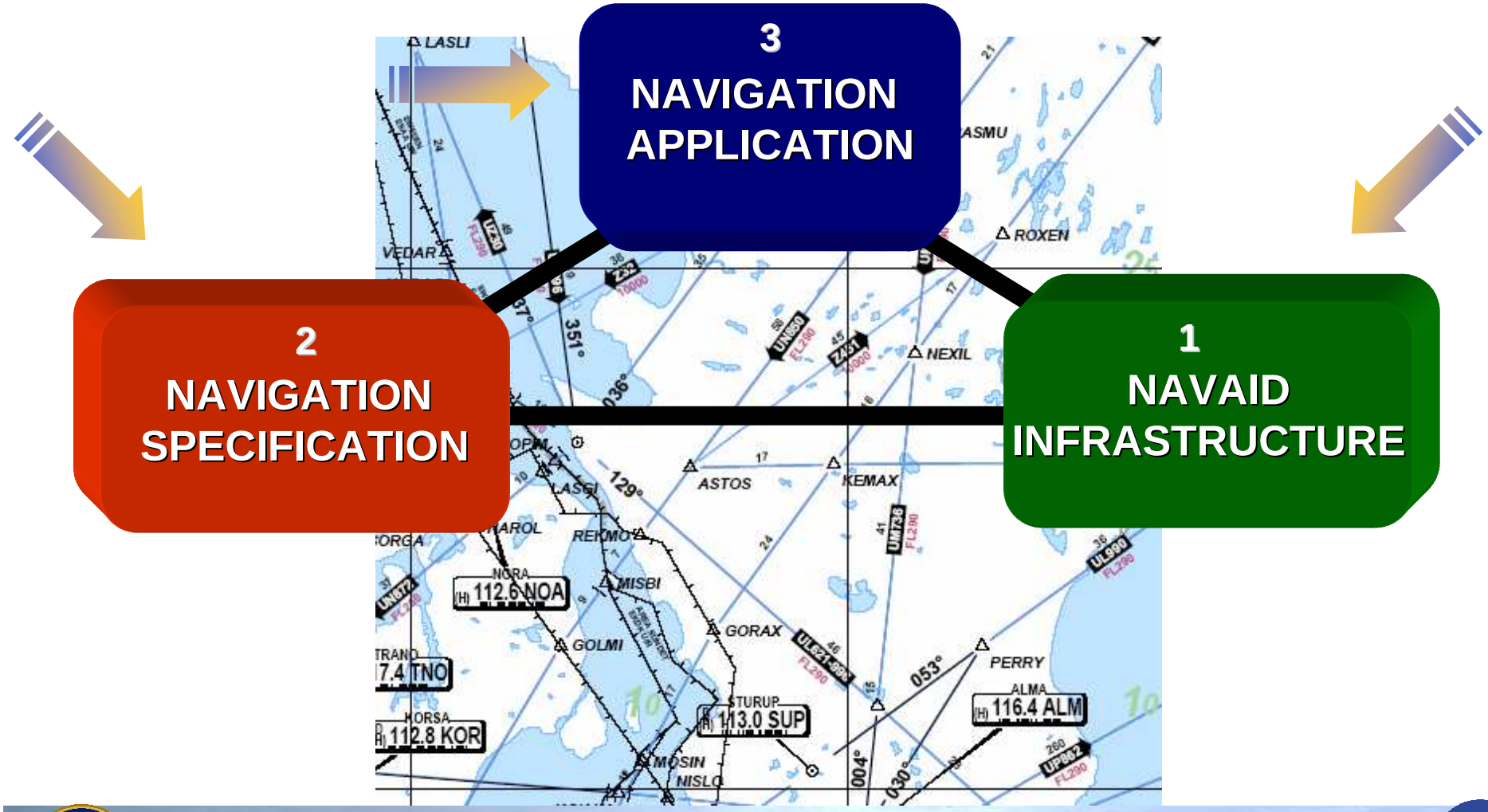


Components of PBN Concept
- Navigation Application -

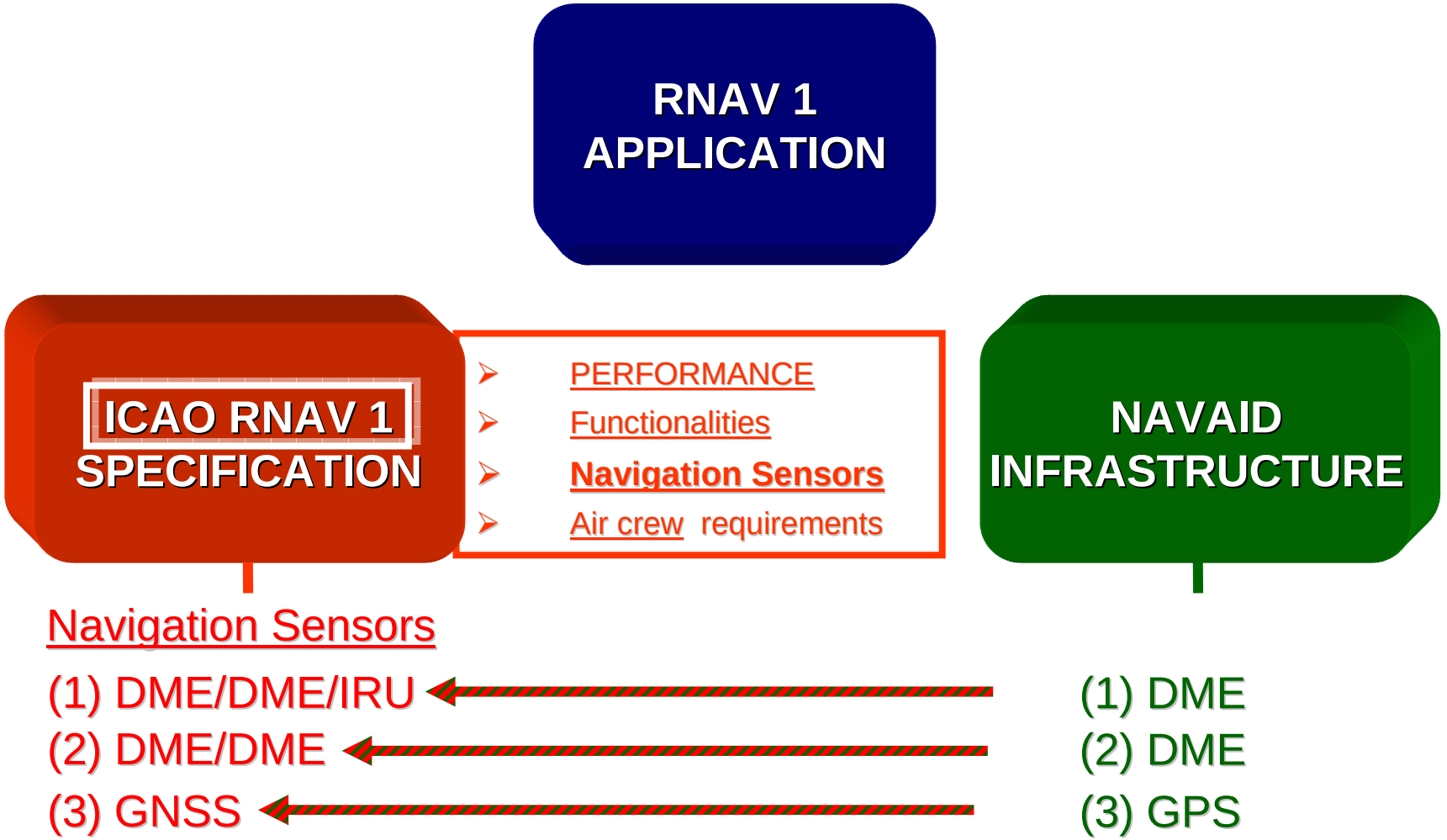


- **The APPLICATION (use of) the Navigation Specification and Navaid Infrastructure -**
  - **For example: *Routes* based on RNAV and RNP Specifications (these rely on the Navaid Infrastructure);**
  - **For example: *SIDs/STARs* based on RNAV and RNP Specifications;**
  - **For example: *Approach procedures* based on RNP Specifications**

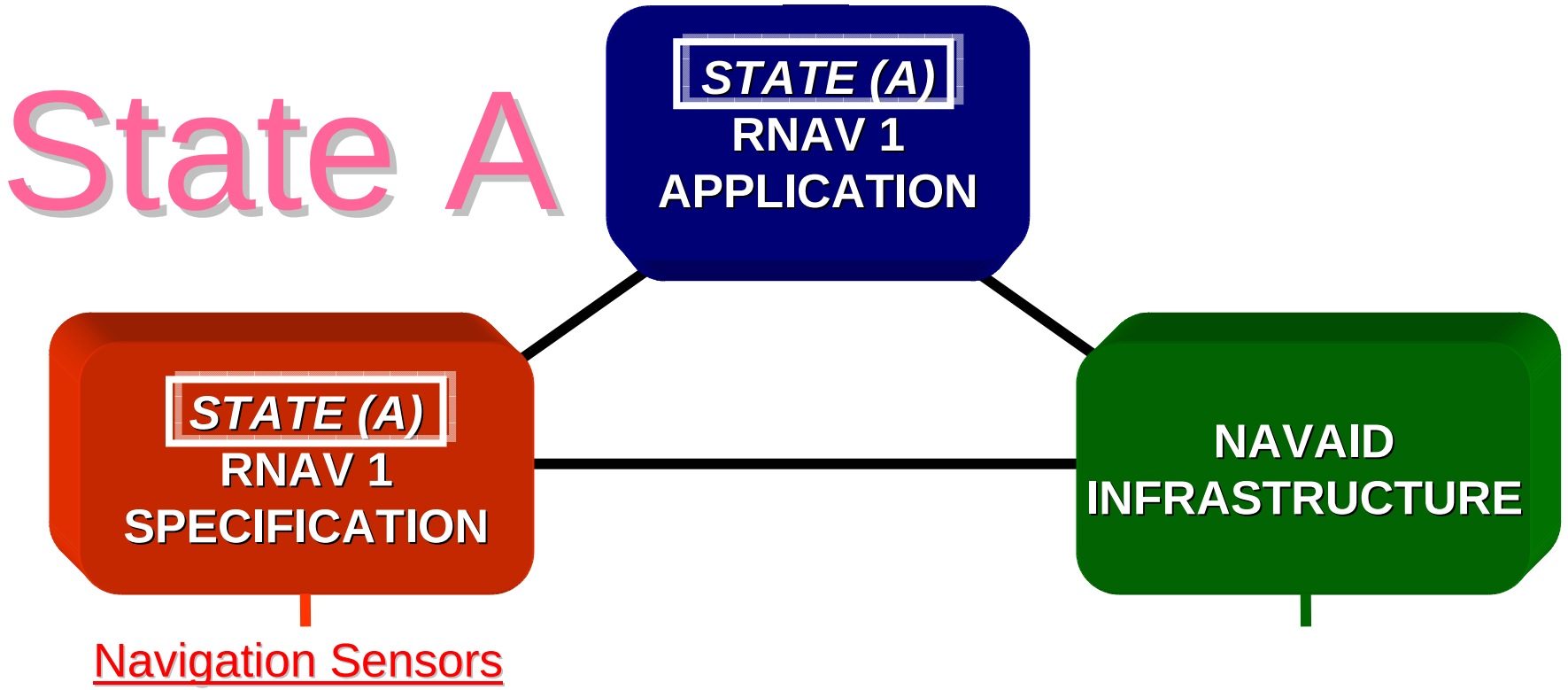
Components of PBN Concept



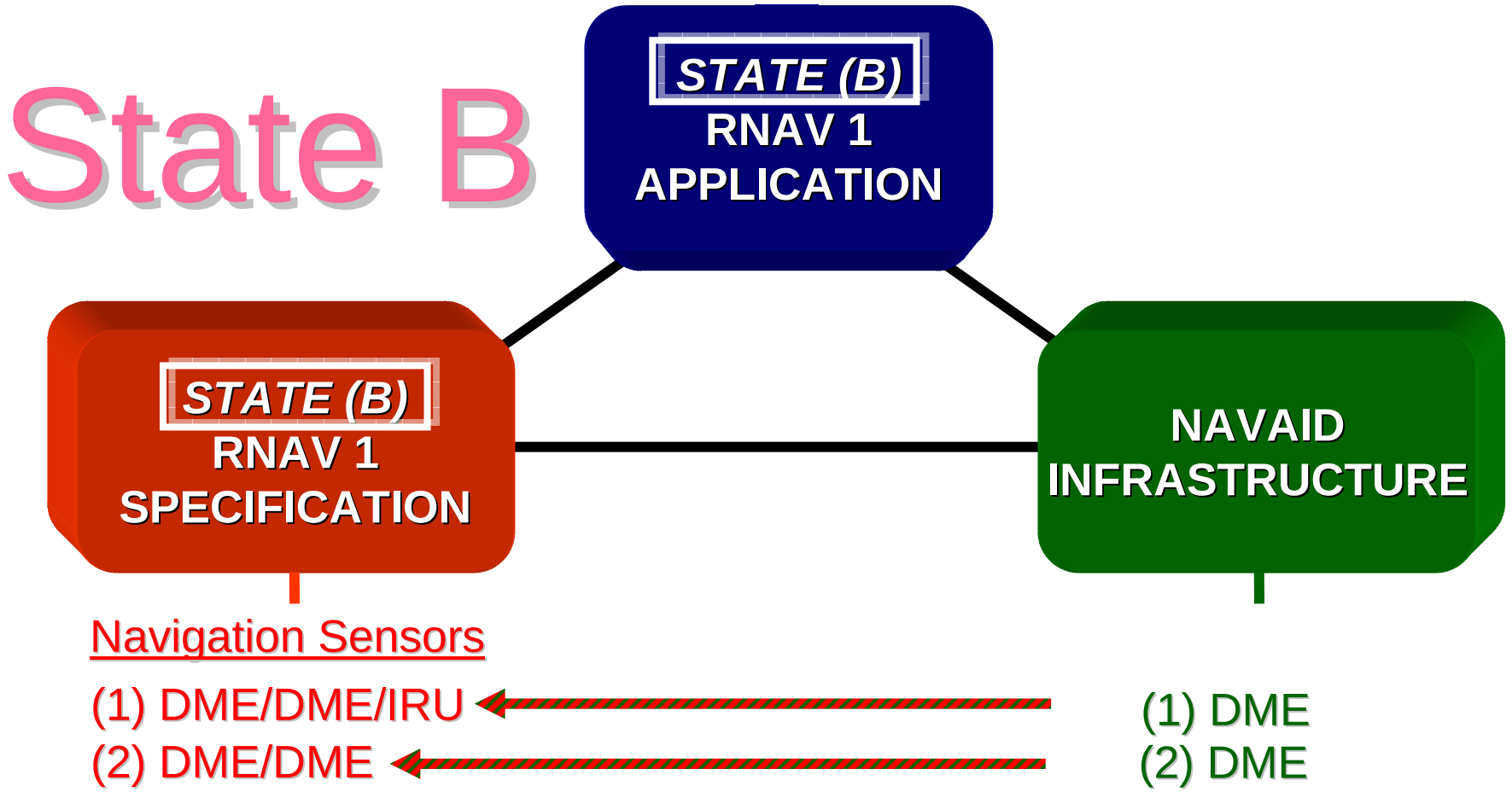
Example: RNAV 1 Specification



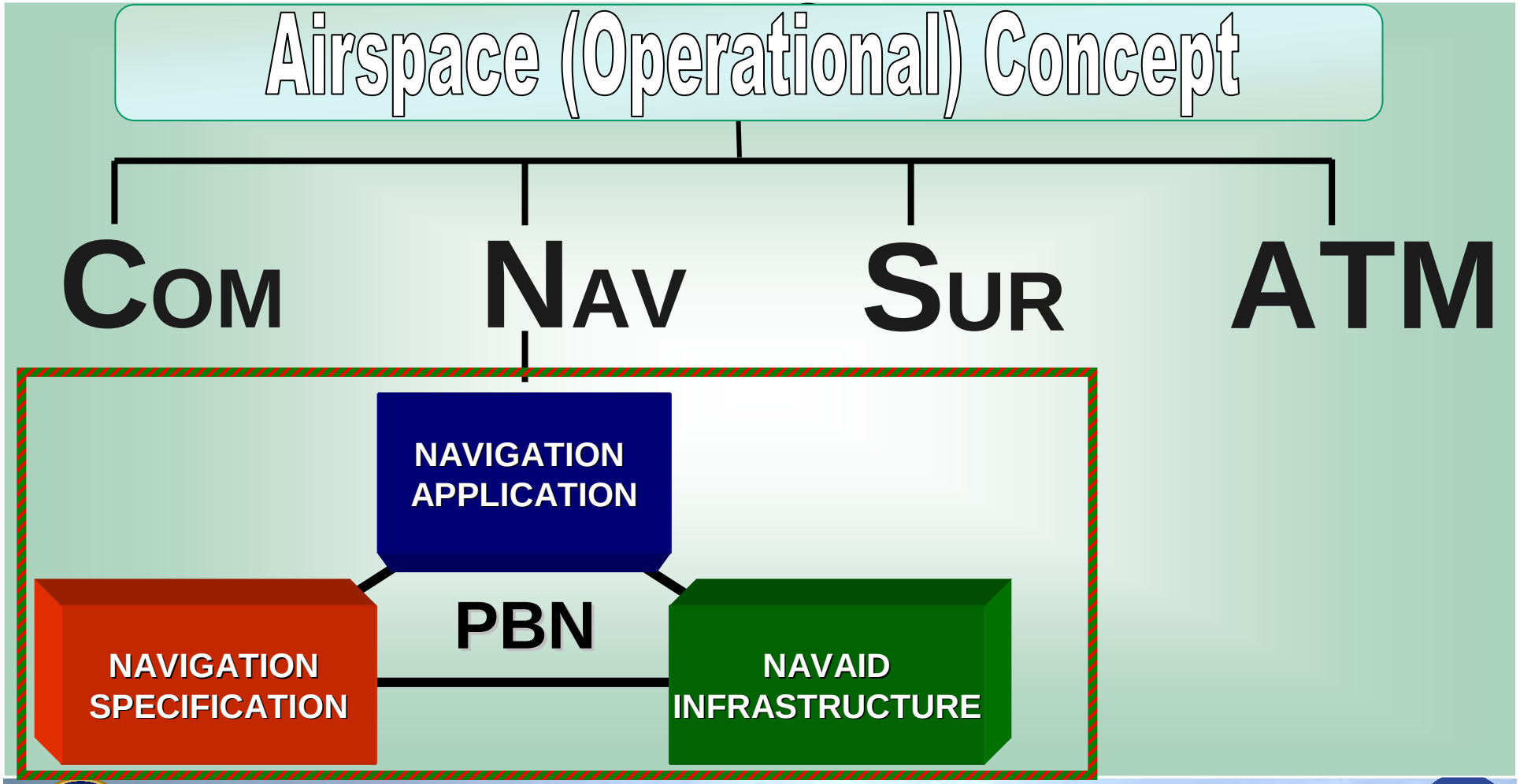
E.G: RNAV 1 Specification (A)

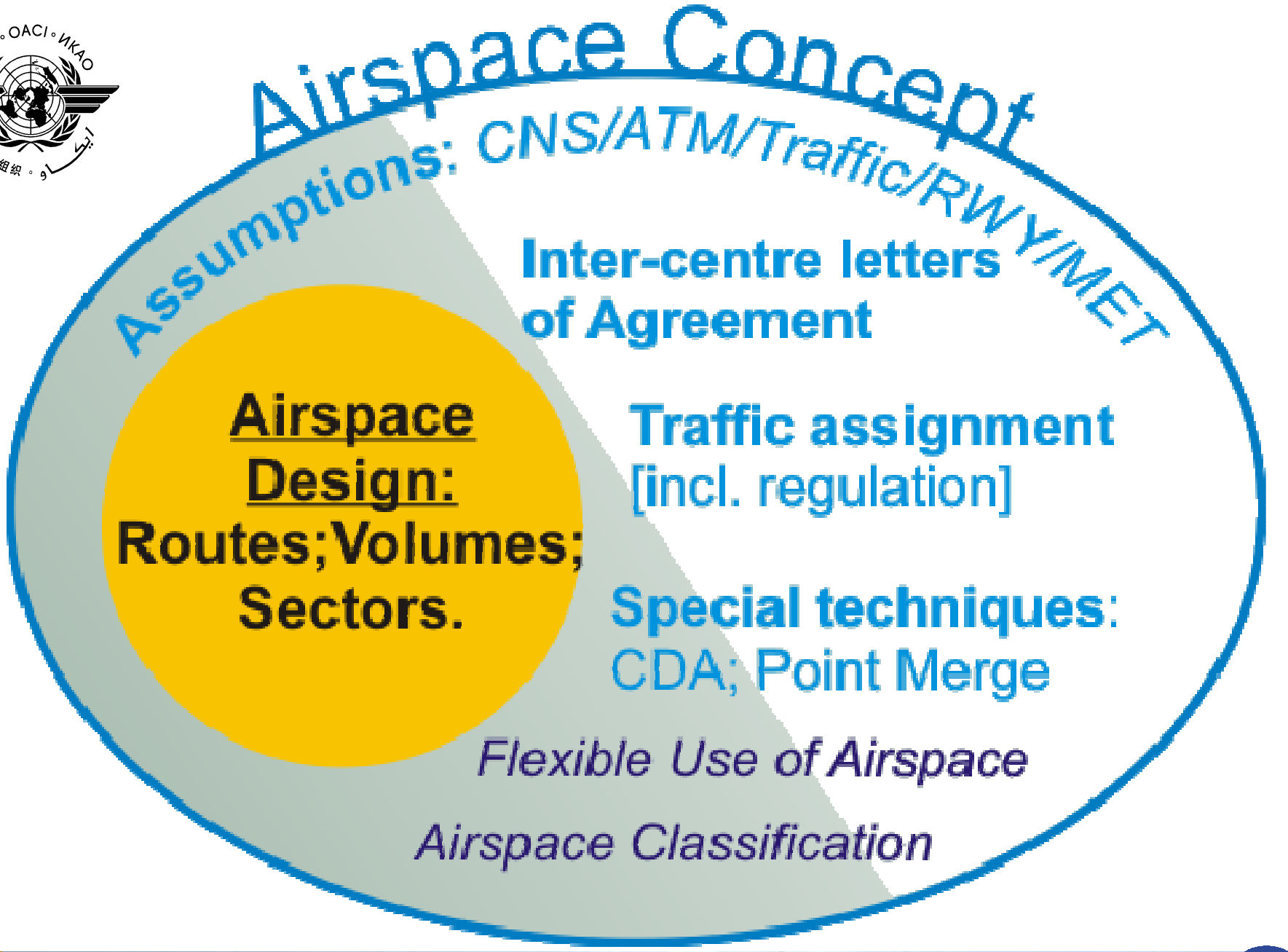


E.G: RNAV 1 Specification (B)



PBN in Context: *Part* of the Solution




Airspace Concept
Assumptions: CNS/ATM/Traffic/RWY/MET
Inter-centre letters of Agreement
Airspace Design: Routes;Volumes; Sectors.
Traffic assignment [incl. regulation]
Special techniques: CDA; Point Merge
Flexible Use of Airspace
Airspace Classification

Airspace Concept

Airspace Design: **particularly Routes and IFPs**

Conventional Navigation

Airspace Design based on assumptions that all aircraft equipped with NDB/VOR and/or DME and airspace designed on those assumptions.

RNAV (pre-PBN)

Airspace Design based on assumptions that 'RNAV equipped' aircraft can use RNAV routes. Exceptionally, Nav Spec required e.g. RNP 4.

PBN

Airspace Design must, in all cases match....

(a) **Aircraft fleet capability,** *which must match...*

(b) **An ICAO PBN Navigation Specification**

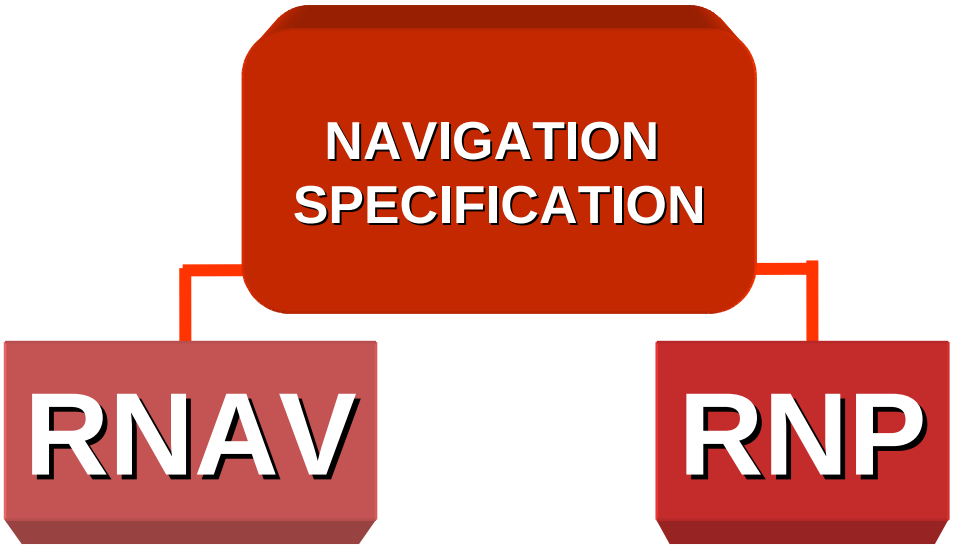
\+

(c) **... and available NAVAID Infrastructure**

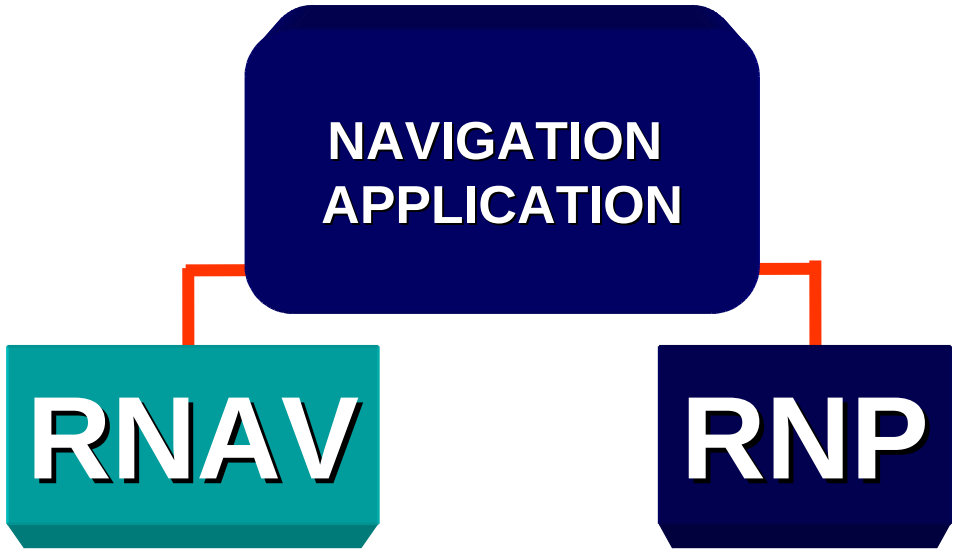
What's new with PBN

- RNAV system needed
- Operational approval needed for airspace implementation
- Different sensors can be used to achieve the same performance

Concept Summary



Concept Summary



Thank you