SIP/2004/WP19
Business Case

# Special Implementation Project

# GNSS Implementation – Business Case Approach

(Presented by H.V.SUDARSHAN)

**Workshop on the development of business case for the implementation of CNS/ATM systems**
**Cairo, 6–9 September 2004**

# Plan of Presentation

- Planning levels
- Approach to planning for GNSS
  - Operational
  - Technical
  - Organizational
  - Economic
  - Business case

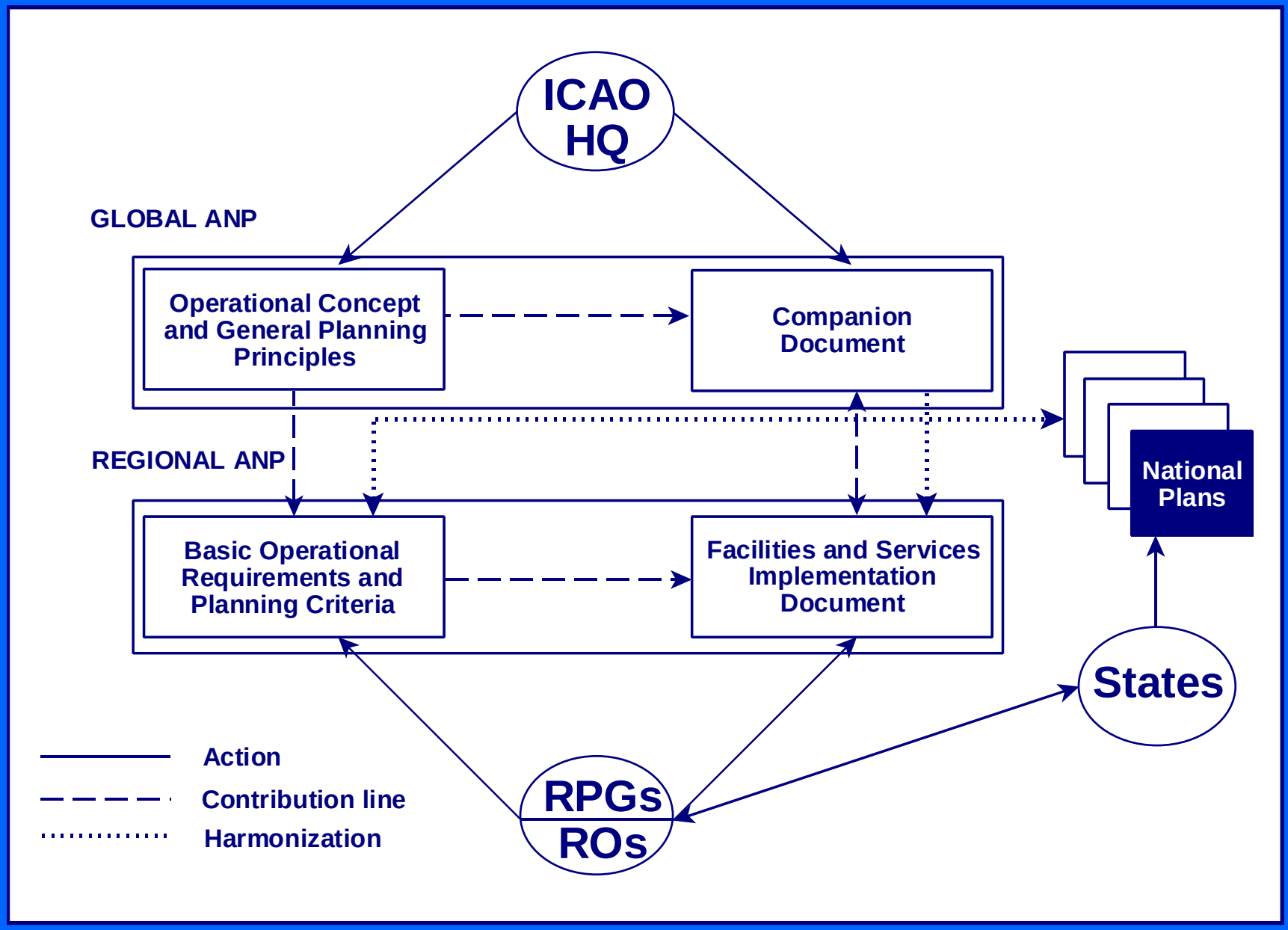
# ICAO and World Civil Aviation Community

## Strategic Vision

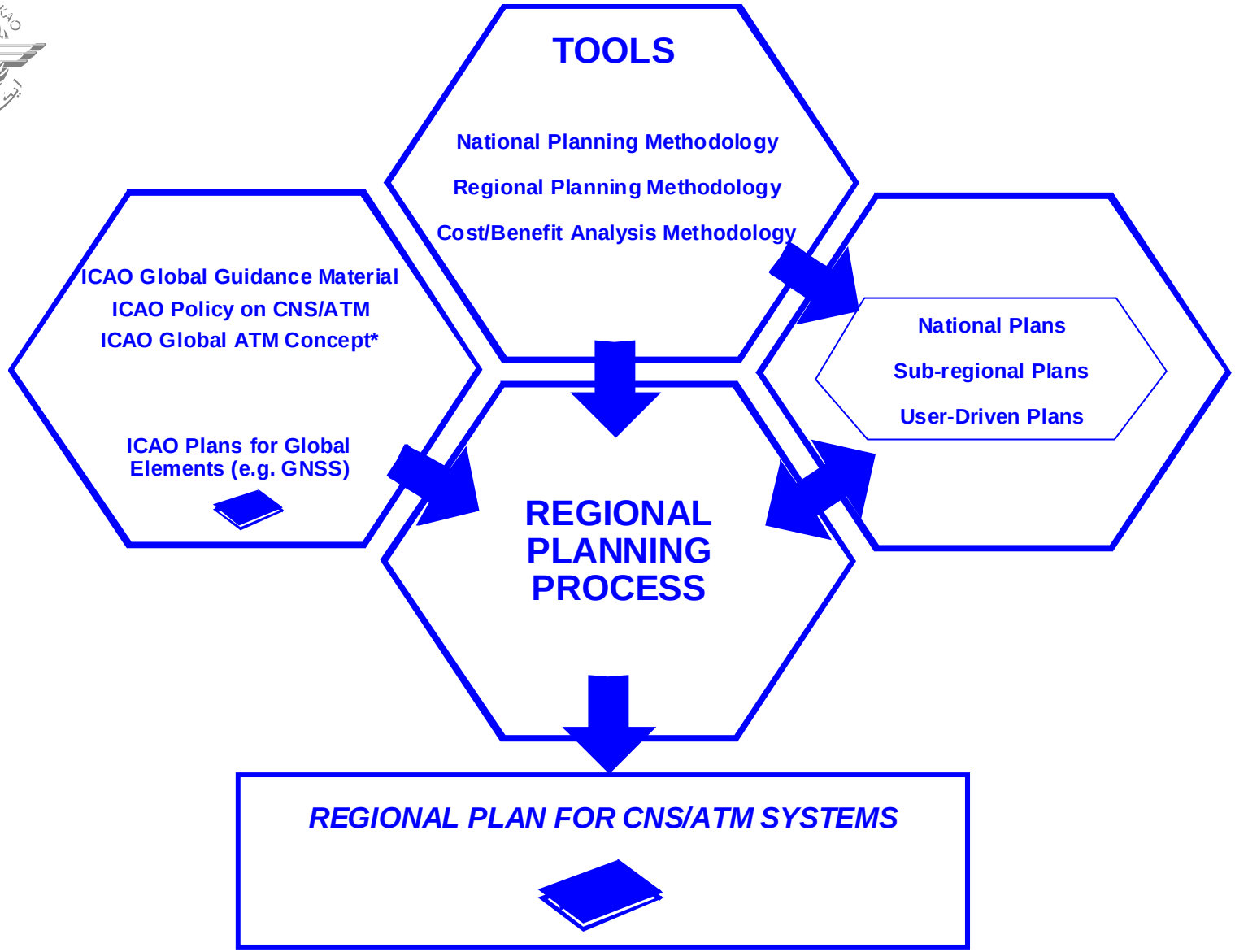
- **To foster the implementation of an interoperable global air traffic management system for all users during all phases of flight that:**
  - **meets agreed levels of safety**
  - **provides for optimum economic operations**
  - **is environmentally sustainable**
  - **meets national security requirements**

# Planning for CNS/ATM Systems by the Partners

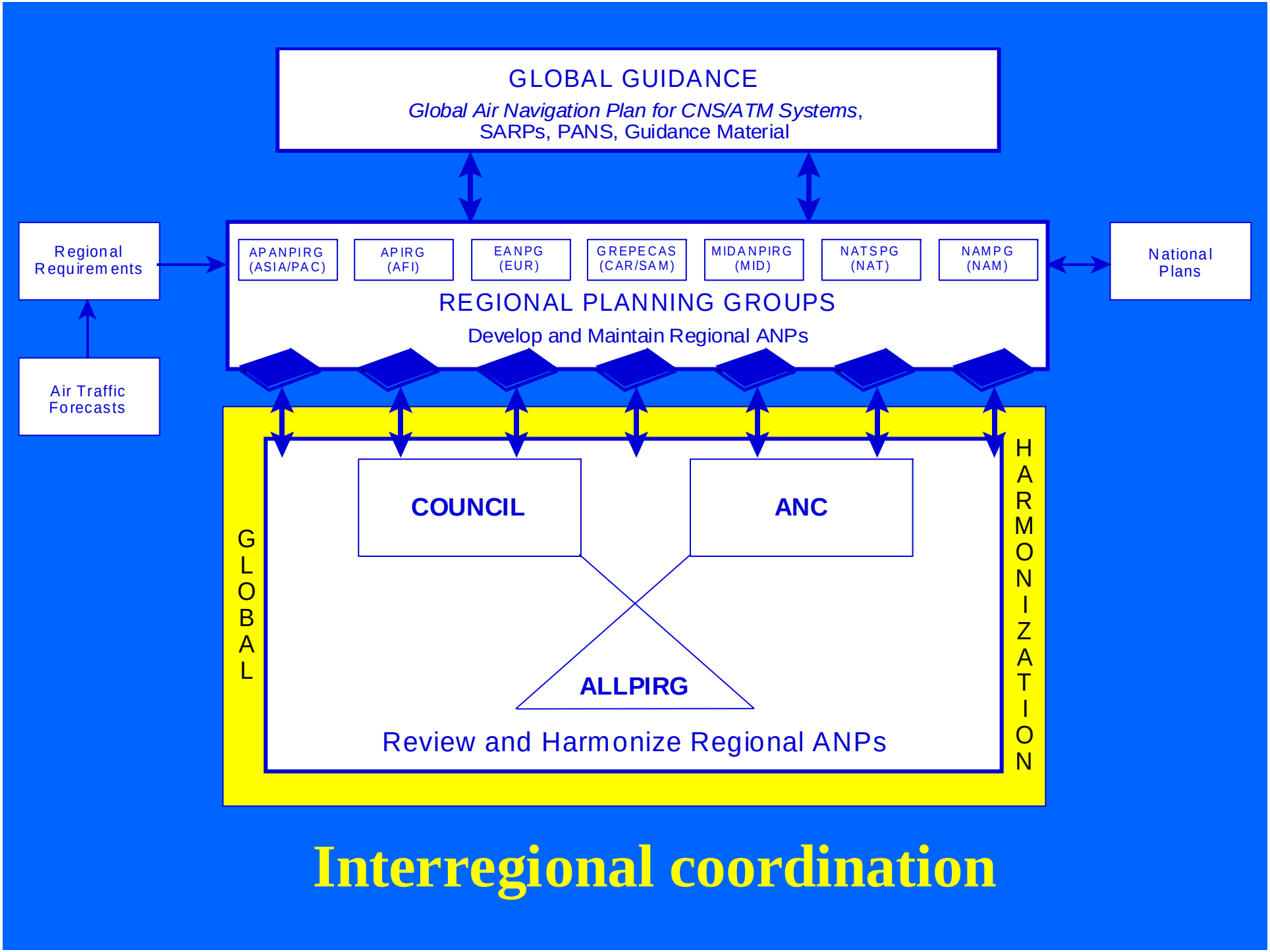
| CNS/ATM Partners | Planning Levels | Deliverables | Guidance |
|---|---|---|---|
| ICAO | Global | Global plan | ICAO policy |
| Regional planning groups | Regional | Regional plan | Global plan |
| Subregional planning groups | Subregional | Subregional plan | Regional plan |
| States | National | National plan | Regional plan |
| Airspace users | Regional, national | User-driven plan | Regional and national plans |
| Service providers | Global, regional, national | Service-provider plan | Global, regional and national plans |
| Industry | Global, regional, national | Manufacturer plan | Global, regional and national plans |




Relationship between the Global Plan, regional ANPs and national plans

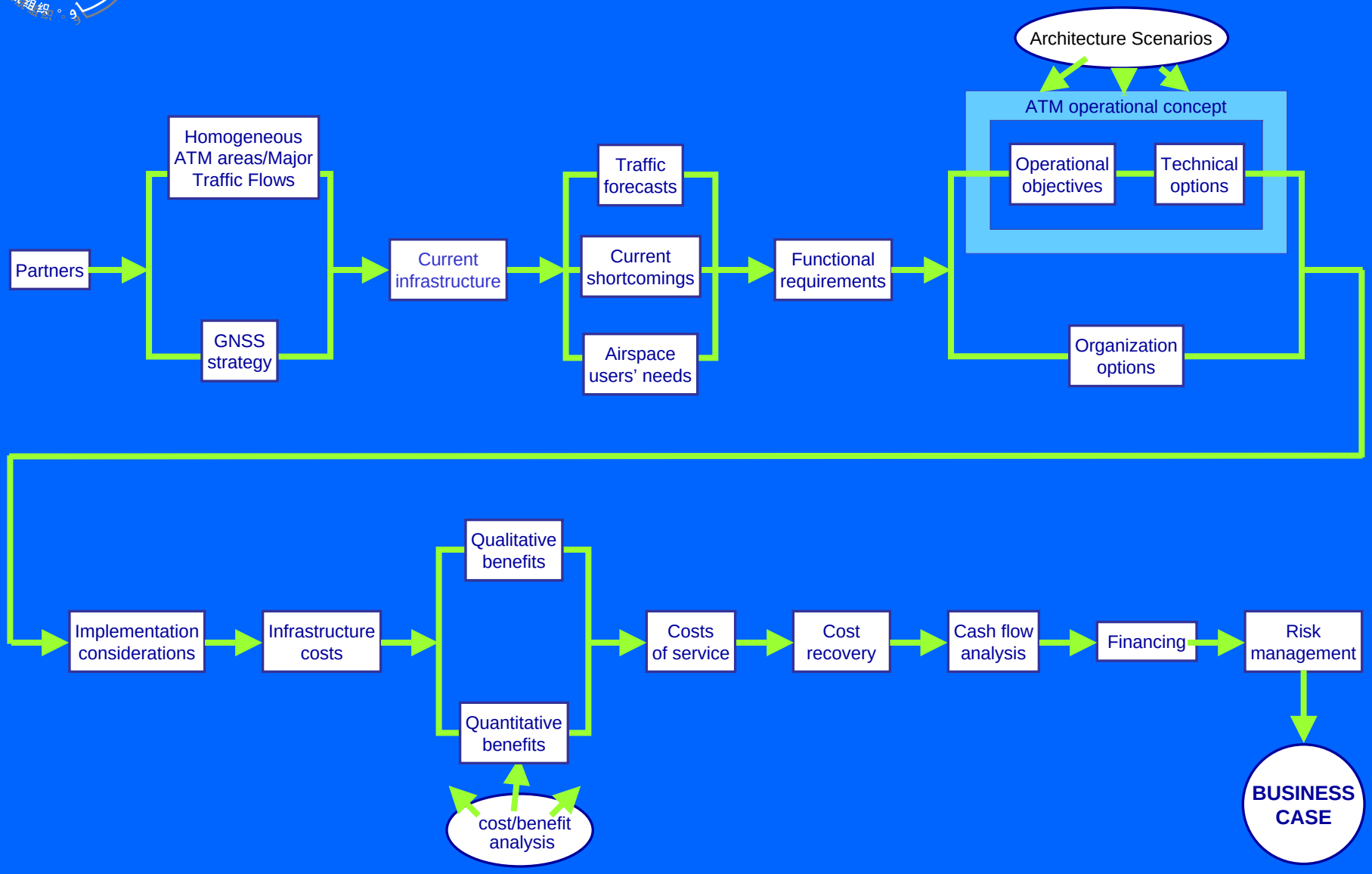



# Regional planning mechanism




# Interregional coordination

# Planning and Implementation of GNSS



# Air Navigation Systems Partners

- States
  - ANS service providers
- Subregional groups
- Regional groups
- Airspace users

# GNSS Strategy

- **Develop a GNSS strategy in terms of functional requirements and operational objectives by:**
  - **Studying global vision**
    - **« Global plan**
    - **« SARPs development**
  - **Taking into account the regional plan and the subregional plan**
  - **Considering adjacent States' plans**

# GNSS Planning Group

## Membership

- National administration
- Regulating agency
- ATM service provider
- Airspace users
- Airport authority
- Research & development organizations
- Military authorities
- Other relevant bodies (such as adjacent States)

# Planning Based on Homogeneous ATM Areas and Major Traffic Flows (1/3)

## Homogeneous ATM Area

An airspace with a common ATM interest based on similar characteristics of traffic density, complexity, air navigation infrastructure requirements or other specified considerations, wherein a common detailed plan fosters the implementation of interoperable CNS/ATM systems.

They may extend over States, specific portions of States or groupings of smaller States. They may include large oceanic and continental en route areas.

# Planning Based on Homogeneous ATM Areas and Major Traffic Flows (2/3)

## Major Traffic Flows

***Major traffic flow*: A concentration of significant volumes of air traffic on the same or proximate flight trajectories.**

***Note: Major traffic flows may cross several homogeneous ATM areas with different characteristics***

***Routing area*: A defined area encompassing one or more major traffic flows**

# Homogeneous ATM Areas and Major Traffic Flows (3/3)

- **Within the State/Subegion/Region under consideration, identify:**
  - **Major traffic flows**
  - **Homogeneous ATM area**

# Current infrastructure ! Navigation NDB, VOR (CVOR/DVOR) and DME (Sample matrix)

| SNo | System | Location(s) | Qty | Date of installation | Until When Existing System Expected to Provide Satisfactory Service |
|---|---|---|---|---|---|
| 1 | NDB | XXX | 1 | 30.06.1980 | 30.06.1995 |
| 2 | VOR (DVOR) | XXX | 1 | Î 31.11.2004 | 31.11.2019 |
| | VOR (CVOR) | YYY | 1 | 08.09.1990 | 08.09.2005 |
| 3 | DME | XXX | 1 | q 15.02.2005 | 15.02.2020 |

**Qualifications**

a) Assume 15 years of life.

b) Î Indicates facility under installation.

c) q Indicates facility planned.

# Current infrastructure ¦ Navigation

## ILS/MLS (including DME) (Sample matrix)

| SNo | System | Location(s) | Qty | Date of installation | Until When Existing System Expected to Provide Satisfactory Service |
|---|---|---|---|---|---|
| 1 | ILS (CAT. I) | XXX | 1 | 28.11.1995 | 28.11.2010 |
| 2 | ILS (CAT. II) | YYY | 1 | 24.05.1982 | 24.05.1997 |
| 3 | ILS (CAT II) | YYY | 1 | Î 31.11.2004 | 31.11.2019 |
| 1 | MLS (CAT. I) | ZZZ | 1 | q 01.02.2005 | 01.02.2020 |

**Qualifications**

a) Assume 15 years of life.

b) Î Indicates facility under installation.

c) q Indicates facility planned

d) ILS/MLS system includes markers, locators and DME, as the case may be.

# Current Shortcomings (1/2)

## Check list

1. **Limited coverage and accuracy of VOR, DME and NDB**
2. **Difficult to site VOR/DME/NDB in remote areas and hilly regions, therefore lack of navigation guidance in these regions**
3. **Precision approaches Cat. I not available at many of the airports**
4. **FM interference and channel capacity problem in ILS**
5. **At some airports, difficult to site an ILS**

# Current Shortcomings (2/2)

## Check list

6. **Navigation equipment (NDB/VOR/DME/ILS) is old and performance poor**
7. **Siting decisions of NDB/VOR/ILS are not appropriate**
8. **Lack of ground based navigation guidance (NDB/VOR/DME) in en-route continental airspace and TMA areas**
9. **CVOR experiencing scalloping due to nearby structures/obstructions**

# Different Categories of Airspace Users

| Commercial Aviation | Military Aviation | General Aviation | Aerial Work |
|---|---|---|---|
| 1. Scheduled airlines (international carriers)<br>2. Scheduled airlines (regional carriers)<br>3.Non-scheduled airlines (charters)<br>4. Air taxis | 1. Military aircraft not flying under civil control<br>2. Military aircraft planned to have frequent access to regulated airspace<br>3. Military search and rescue aircraft | 1. Executive/ corporate<br>2. Private air travel<br>3. Sporting and recreation aviation | 1. Surveying<br>2.Agriculture<br>3. Search and rescue<br>4. Flying clubs<br>5. Police/ customs |

# Summary of air traffic forecasts for the years 2008/20013/2018 (sample matrix)

| | Actual 2003 | Estimate 2004 | Forecast | | | Average Annual Growth Rate (%) | | |
|---|---|---|---|---|---|---|---|---|
| | | | 2008 | 2013 | 2018 | 2004–2008 | 2009–2013 | 2014–2018 |
| **Passengers (millions)**<br>Domestic<br>International<br>TOTAL | | | | | | | | |
| **Freight (thousand metric tonnes)**<br>Domestic<br>International<br>TOTAL | | | | | | | | |
| **Aircraft movements (thousands)**<br>Domestic<br>International<br>TOTAL | | | | | | | | |
| **Over-flying aircraft (thousands)**<br>TOTAL | | | | | | | | |

*Qualification: If passenger and freight forecasts are not available, the State is to focus on aircraft movements/over-flying aircraft.*

# Average Flight Duration in National Airspace

| Movement | Average Flight Duration in National Airspace *(in hours)* |
|---|---|
| **International** | |
| **Domestic** | |
| **Over flights** | |

# Functional Requirements

## Navigation

- Introduction of common geodetic reference system
- Enhanced navigation accuracy allowing for improved systems availability, continuity and capability for all phases of flight, *viz*. oceanic, remote, continental, terminal, airport and surface areas
- Increased landing capabilities with adequate minima to all runways for all aircraft types
- The consolidation of navigation function into a single system enabling seamless navigation

# Operational Objectives

## Defining of Navigation Objectives

- Implementation of WGS-84
- Oceanic/continental en-route areas
  - RNAV operations with defined RNP values
- Terminal areas
  - RNAV operations (NPA ⟹ APV-I (DH 350 feet, APV-II (DH 250feet) with corresponding RNP values
- Airport/surface areas
  - At designated airports depending on existing/planned PA facilities, the weather data and traffic volume implement
    - » PA Cat I/II/III ; A-SMGCS

# Technical Options

- Space segment
  - GPS/GLONASS/*Galileo/GEO for overlay
- Augmentations systems
  - ABAS ( RAIM/AAIM)
  - SBAS (WAAS/EGNOS/MSAS)
  - GBAS (LAAS)
  - *GRAS

*Emerging systems

# Architecture Scenarios (1/4)

## Possible Scenarios with Current infrastructure

**Scenario 1: Current navigation systems (do nothing)**

**Scenario 2: RNAV using VOR/DME for en-route continental and ILS Cat. I for precision approaches plus RNP**

**Scenario 3: RNAV using INS/IRS for oceanic/remote airspace with suitable RNP**

# Architecture Scenarios (2/4)

## Possible Scenarios with GNSS Infrastructure – Space Segment

**Scenario 1: GPS**
**Scenario 2: GPS + GLONASS**
**Scenario 3: GPS + GEO**
**Scenario 4: GPS + GLONASS + GEO**
**Scenario 5; GPS + *Galileo**
**Scenario 6: GPS + *Galileo+GEO**
**Scenario 7: GPS + *Galileo+GLONASS +GEO**
**Scenario ….**

*** Emerging technology**

# Architecture Scenarios (3/4)

## Possible Scenarios with GNSS Infrastructure – On-board Segment

**Scenario 1:** GPS receiver + ABAS + ILS/GBAS + MMR

**Scenario 2:** GPS, GLONASS combined receiver + ABAS + ILS/GBAS + MMR

**Scenario 3:** GPS receiver + ABAS + SBAS + GBAS

**Scenario 4:** GPS,GLONASS combined receiver + ABAS + SBAS + GBAS

**Scenario 5:** GPS, *Galileo combined receiver + ABAS + GBAS

**Scenario 6:** GPS , *Galileo combined receiver + ABAS + SBAS or possibly *GRAS + GBAS

**Scenario 7:** GPS, *Galileo and GLONASS combined receiver + ABAS + SBAS/*GRAS + GBAS

**Scenario…….**

*** Emerging technology**

# Architecture Scenarios (4/4)

## Possible Scenarios with GNSS Infrastructure – Ground Segment

**Scenarios 1 and 2: ILS/GBAS**

**Scenarios 3 and 4: SBAS + GBAS**

**Scenario 5: GBAS**

**Scenarios 6 and 7: SBAS or possibly *GRAS + GBAS**

**Scenario…….**

*** Emerging technology**

# Organizational Options (1/3)

## Space Segment

- One government (GPS by US and GLONASS by Russia)
- A group of governments (*GALILEO by European States)
- An international operating agency with its own legal entity (INMARSAT)

* Emerging system

# Organizational Options (2/3)

## On-board Segment

- GNSS receiver for GPS/GLONASS/*GALILEO
- Augmentation systems: ABAS (RAIM/ AAIM)/SBAS/GBAS/*GRAS
  - Part of avionics
  - Aircraft operator's responsibility

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# Organizational Options (3/3)

## Ground Segment

- **Augmentation systems: SBAS/*GRAS**
  - **One government (WAAS by US; MSAS by Japan)**
  - **A group of governments(EGNOS by European States)**
  - **An international operating agency with its own legal entity**
- **Augmentation systems: GBAS**
  - **Does not require international environment**
  - **Service provider could be a Government department or an autonomous entity or private organization**

# Implementation Considerations (1/7)

## Operational Evaluation

- **Progressive use of GNSS**
  - **Awareness/simulation studies/test bed**
  - **Supplemental/primary/sole means**
- **Flight inspection standards**
  - **En-route/NPA/PA**
- **Instrument procedure design**
  - **Overlay/stand-alone NPA**
  - **Initial, intermediate and final approach segment**
  - **Holding patterns/missed approach segment**
  - **Departure segment**
  - **Publication of procedures (AIS)**

# Implementation Considerations (2/7)

## Training, Certification and Procedures

- **Training needs**
  - **CAA and airline personnel**
- **Certification**
  - **Airworthiness approvals (national authority to approve aircraft installations)**
  - **Operational approvals (in granting operational approval for an RNP type, the State of Operator should consider not only the navigation equipment but also the operational environment)**
- **Procedures**
  - **Pilot procedures**
  - **ATC procedures**

# Implementation Considerations (3/7)

## Transition Considerations

1. The ground infrastructure for the current navigation systems must remain available during the transition period
2. The GNSS should be introduced in an evolutionary manner, with improvements in GNSS capability generating increasing benefits
3. States/regions can consider segregating traffic according to navigation capability and granting preferred routes to aircraft with better navigation performance, where this can be done without reducing airspace capacity

# Implementation Considerations (4/7)

## Transition Considerations

4. As GNSS is introduced for en-route operations, States/regions should coordinate to ensure that harmonized separation standards and procedures are developed and introduced concurrently in all FIRs along major traffic flows to allow for a seamless transition to GNSS-based navigation
5. Schedule for provision and/or adoption of a GNSS service, including aircraft and operator approval processes
6. Extent of existing ground based navaids

# Implementation Considerations (5/7)

## Transition Considerations

7. Strategy for transition schedule to GNSS capability (i.e. benefits-driven or mandatory)
8. Appropriate level of user equipage with GNSS capability
9. Provision of other air traffic services (i.e. surveillance and communication)
10. Density of traffic/frequency of operations
11. Mitigation of risks associated with radio frequency interference

# Implementation Considerations (6/7)

## Harmonization – Interface Issues

- **Technical**
  - **Ground-based and satellite-based navigation aids**
  - **Different satellite constellations (GPS, GLONASS and *Galileo)**
  - **Different GNSS augmentation systems (SBAS, GBAS and *GRAS)**
- **Operational**
  - **Different RNP environments**
  - **Different operational approvals for RNP**
  - **Different ATC procedures arising out of number of technical options ???**

*** Emerging Systems**

# Implementation Considerations (7/7)

## Harmonization – Application of Interface Tools

- Align implementation timelines
- Apply harmonization tools
  - ILS/MLS/GNSS: Multi-Mode receiver
  - GPS/GLONASS/*GALILEO: Integrated GNSS receiver
  - WAAS/EGNOS/MSAS: Interoperability through implementation of SARPs
  - SBAS/GBAS/*GRAS: Integrated with GNSS receiver
  - Different RNP environments: Application of suitable ATC procedures
  - Different operational approvals: Application of a common standard approval

* Emerging systems

# Infrastructure Costs (1/2)

## Capital, Operations and Maintenance Costs

- Space segment
  - Assume no cost to the States
- Ground segment
  - SBAS [reference stations/master stations/access to GEO (leasing)/ ground-to-ground communications]
  - GBAS (reference station/data link)
  - GRAS* (reference stations/ground-to-ground communications/data link)

*Emerging systems

# Infrastructure Costs (2/2)

## Capital, Operations and Maintenance Costs

- On-board segment
  - GNSS receiver for GPS/GLONASS/*GALILEO with ABAS
  - Data links to receive SBAS, GBAS, GRAS* augmentation
  - Multi-mode receiver for harmonization of ILS/MLS/GNSS

*Emerging systems

# Qualitative Benefits (1/2)

- All partners:
  - Improved safety
- Airlines:
  - Uniform equipage for all phases of flight
  - User-preferred flight profiles
  - Shorter routes
  - Possible reduced crewing
  - Enhanced accuracy
  - Availability of NPA and PA approaches at a greater number of airports
  - More alternate airports

# Qualitative Benefits (2/2)

- States (service providers):
  - Higher navigation accuracy allow for increased capacity by reducing separation
  - Improved level of service
  - Consolidation of facilities
- Passengers:
  - Decreased diversions in instrument meteorological conditions (IMC)
  - Radiant smiles

# Quantitative Benefits

- **Airline benefits**
  - **Route optimization (savings in flying time and resultant fuel costs)**
  - **Reduced contingency fuel**
  - **Greater payload capability**
  - **Higher revenue generation**
- **State benefits**
  - **Decreased maintenance costs**
  - **Avoided capital costs**

# Cost/Benefit Analysis

- **Measure of economic viability**
  - Net present value (preferred option)
  - Cost-effective
  - Least cost
  - Snapshot
  - Utility value
  - Pay-off period
- **Sensitivity analysis**
  - Analysis to ensure wide fluctuations in changing data conditions are taken into account
  - Validate the model using the best judgment

**(Refer to ICAO Circular 257 and Circular 278 for more information)**

# Costs of Service

- Cost determination
  - Identification of facilities and services
- Scope of cost basis
  - Cost basis for charges to include all costs incurred in addition to facilities and services
- Allocation of costs
  - Aeronautical and non-aeronautical
  - Airport and en-route operations
  - Commercial and non-commercial users

# Cost Recovery

- **Cost allocation and cost recovery principles are set forth in ICAO Document 9082**

- **Methods of cost recovery**
  - **Direct collection from users**
  - **Joint charges collection agency**
  - **Delegation to external agency**

# Cash Flow Analysis

- Cash flow analysis is required to determine working capital needs

- The exercise includes:
  - Cash in-flows
  - Cash out-flows
  - Payback period
  - Internal rate of return

# Financing

- Sources of financing include:
  - Contribution from governments (national or foreign)
  - Commercial sources (debt financing)
  - Accumulated excess of revenues over costs (profits)
  - Bonds
  - Equity financing (share capital)
  - Leasing

# Risk Management (1/2)

## Approach

- Risk management demands that hazards and deficiencies be identified, evaluated, ranked and eliminated or mitigated to the greatest extent possible
- Methodology:
  - Risk identification (such as human, non-human, environmental, managerial elements)
  - Risk evaluation (such as catastrophic, critical, marginal, non-critical)
  - Risk control (measures to be in place to control the risk elements, unless the system can tolerate a specific risk element)

# Risk Management (2/2)

## Risk Elements – Check List

- Levy of user charges
- Unresolved legal matters such as GNSS liability and certification
- Loosing the sovereignty of the State
- Intentional/unintentional Interference
- Institutional issues
- Unavailability of funds

# Results in a business case for the implementation of GNSS