



Special Implementation Project

CNS/ATM Systems – Technology and Operations

(Presented by H.V.SUDARSHAN)

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



Approach to presentation

- Current practices in ATM
- Limitations of current systems
- Need for change
- Development of a concept
 - CNS/ATM
- System description – CNS/ATM systems elements
- Status of SARPs development



CNS/ATM Systems

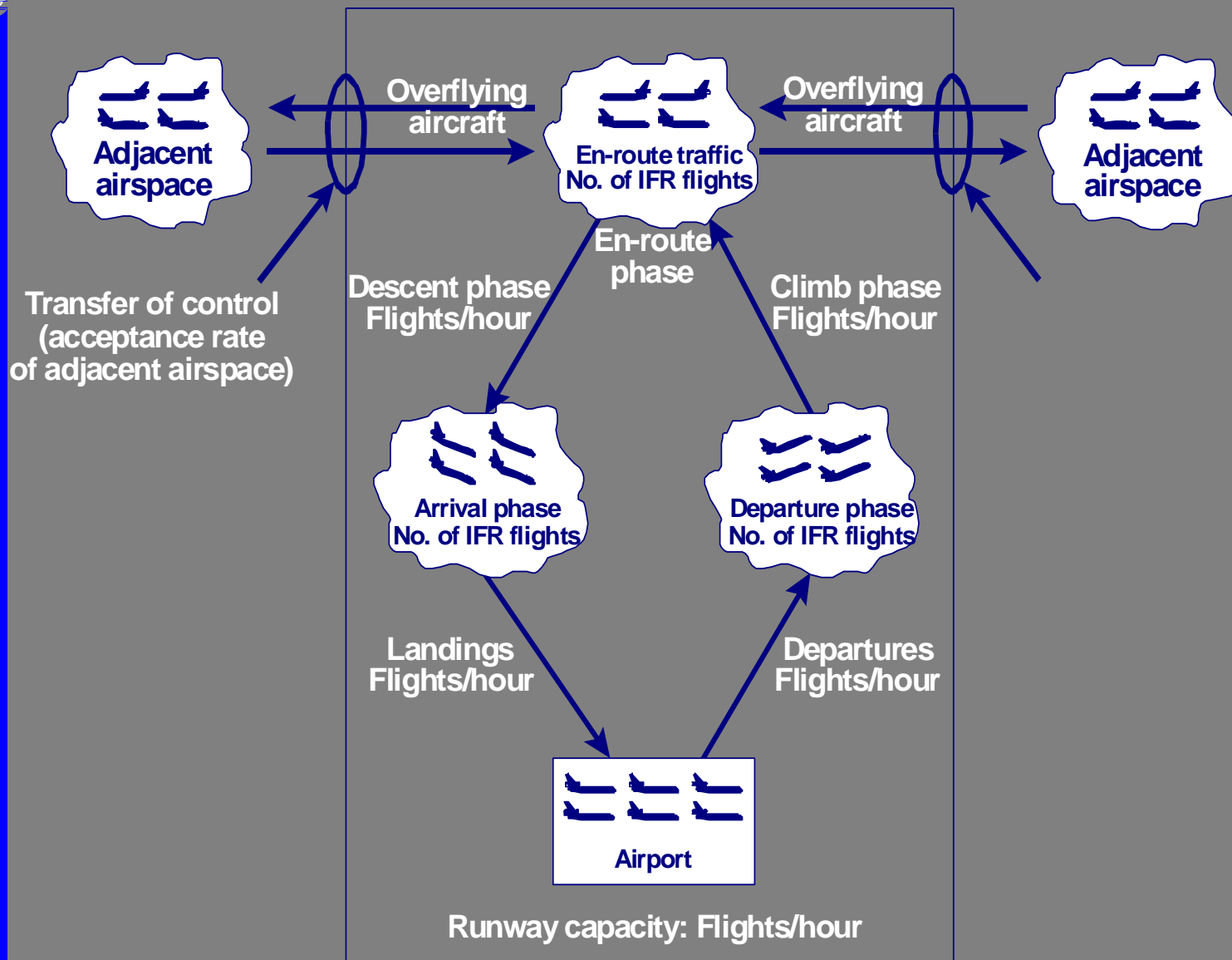
Overview



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**

AREA OF RESPONSIBILITY OF A STATE

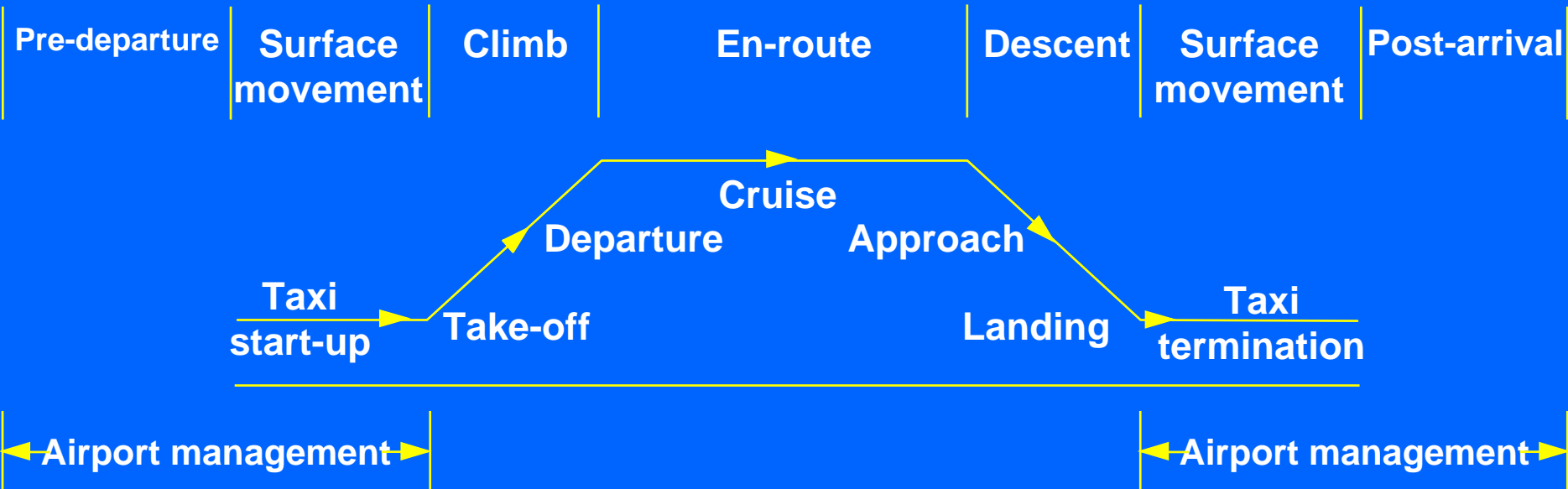


Capacity assessment for ATM



Air traffic management

Gate to Gate Operation



Different phases of flight

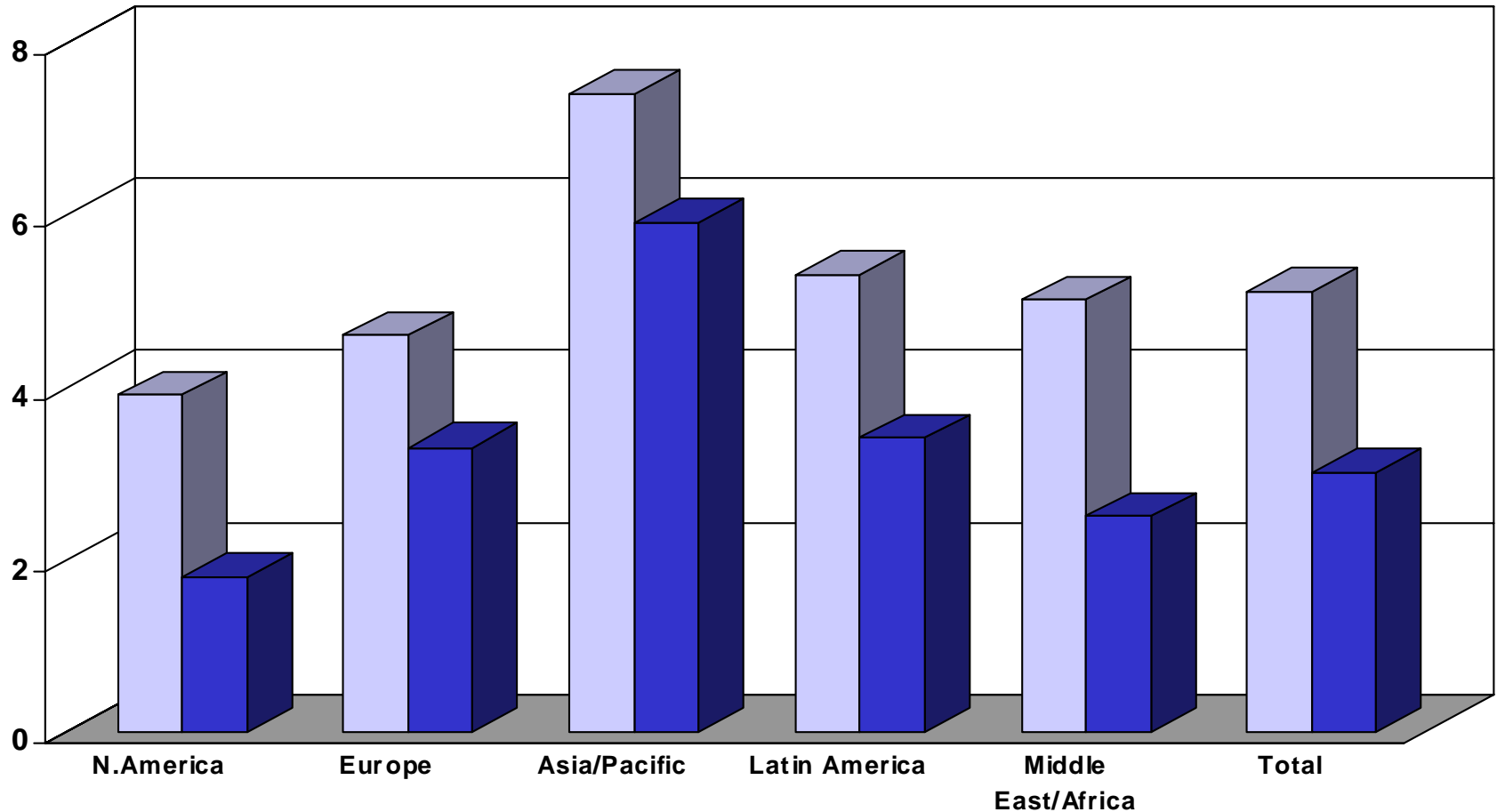


Current limitations

- **Line-of-sight propagation of current CNS facilities**
- **Difficulty in implementation of present CNS systems in large parts of the world**
- **Lack of Digital Air Ground Data interchange Systems**

Projected Growth in Air Traffic Demand

Average Annual Increases in Traffic and Movements 1992 – 2010





Need for change

- Increased growth in air traffic
 - Limitations of current systems
 - New technologies provide solutions
 - Requirement for global consistency
-
- **FANS Committee was established to address the above issues**



Future Air Navigation Systems (FANS)



FANS milestones ...

- FANS phase I committee: **July 84 – Dec. 88**
(Development of systems concept)
- FANS phase II committee: **July 89 - Oct. 93**
(Planning for transition to new technologies)
- 10th Air Navigation Conference accepted FANS concept: **Sept. 91**

(1/2)



FANS milestones

- ICAO Assembly endorses
FANS concept: **Sept. 92**
- ICAO CNS/ATM systems
implementation task force
addressed funding, cost recovery
& promotion of the concept: **Dec. 94**

(2/2)



What is CNS/ATM systems?



CNS/ATM distinct features ...

- a) have a mix of satellite and ground-based systems**
- b) provides global coverage**
- c) uses interoperable systems**

(1/2)



CNS/ATM distinct features

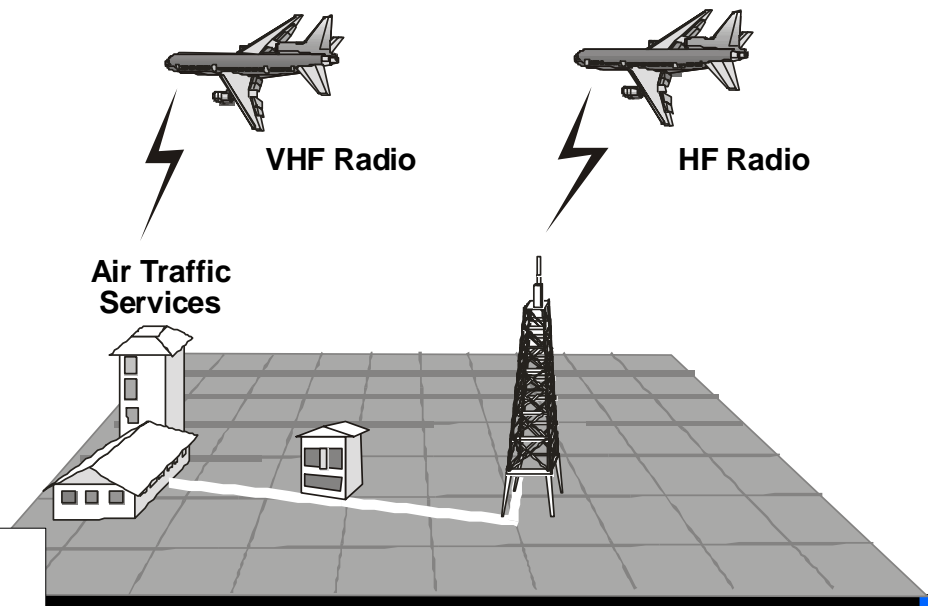
- d) provides seamlessness**
- e) employs air/ground data link**
- f) employs digital technologies**
- g) comprises various levels of automation**

(2/2)

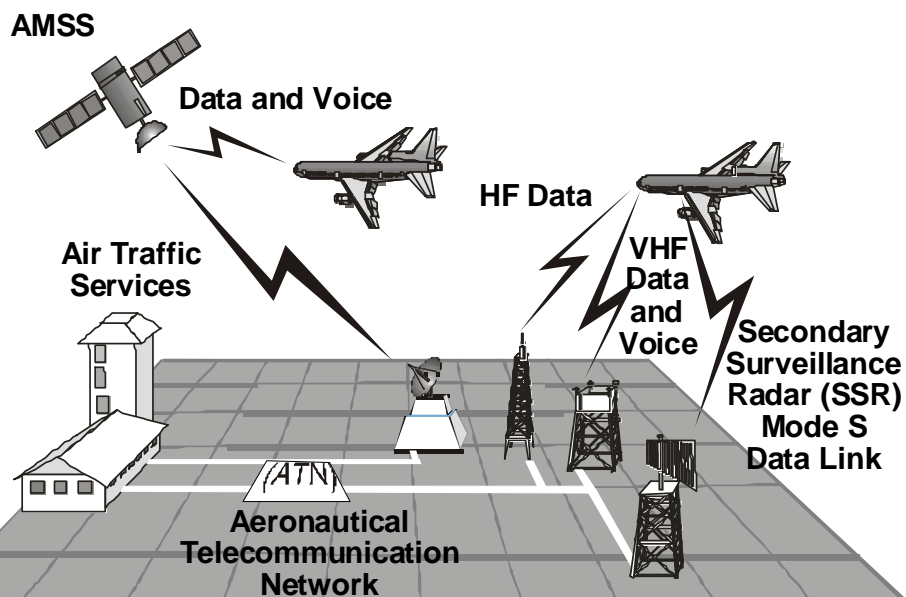


Communications

Communications: Current Environment



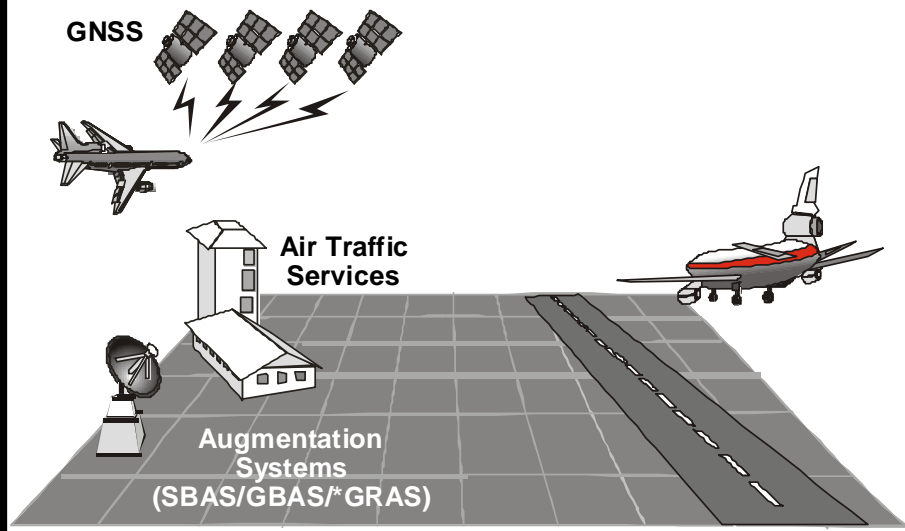
Communications: Future Environment



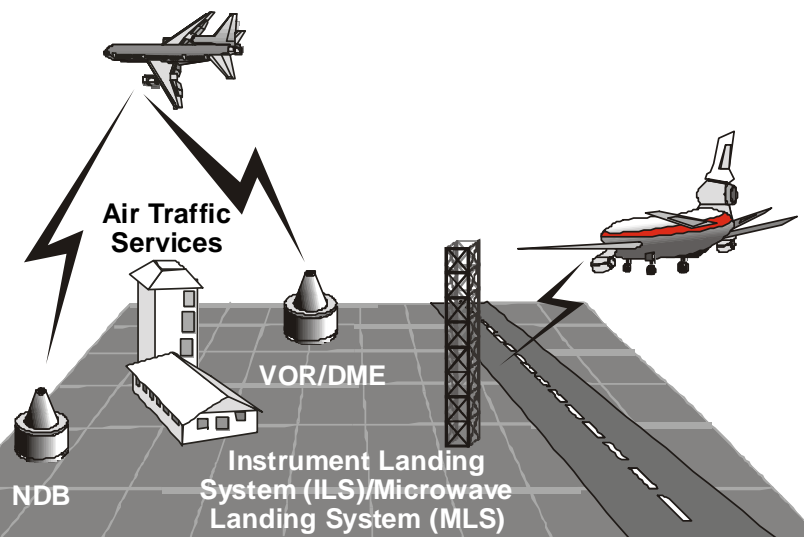


Navigation

Navigation: Future Environment

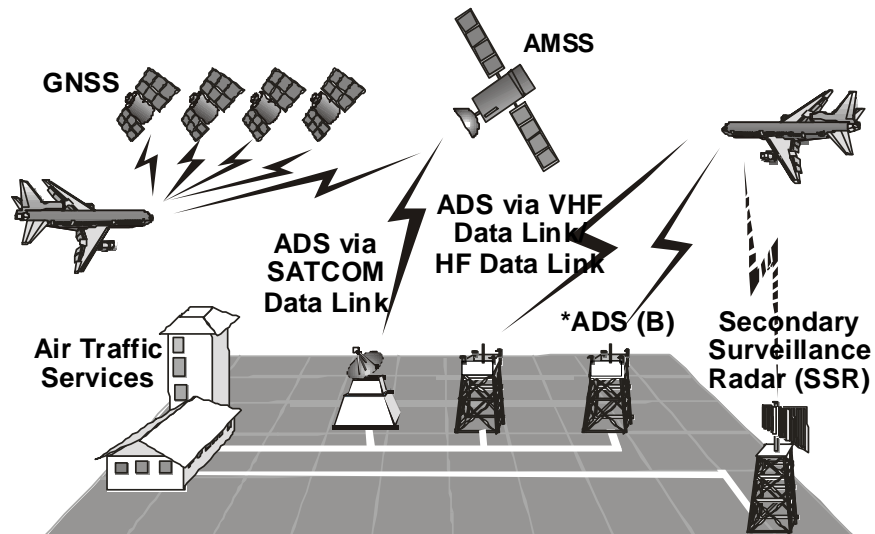


Navigation: Current Environment

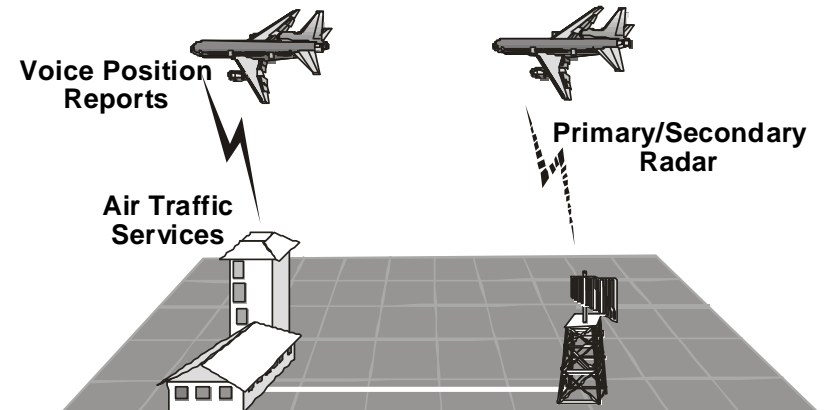


Surveillance

Surveillance: Future Environment



Surveillance: Current Environment





CNS/ATM systems elements — leading to a global ATM system

Communication	Navigation	Surveillance	Air Traffic Management
Data <ul style="list-style-type: none"> • VHF • HF • Mode S • Satellite • ATN Voice <ul style="list-style-type: none"> • VHF • Satellite <i>*emerging systems</i>	GNSS <ul style="list-style-type: none"> • GPS • GLONASS • *GALILEO Augmentation <ul style="list-style-type: none"> • ABAS • GBAS • SBAS • *GRAS 	SSR <ul style="list-style-type: none"> • Modes A/C • Mode S ADS <ul style="list-style-type: none"> • VHF • HF • Satellite *ADS-B	ASM <ul style="list-style-type: none"> • ATS Route structure • RNP and RNAV • Airspace utilization ATS <ul style="list-style-type: none"> • ATC • RHSM and RVSM • Search and Rescue • Decision support systems ATFM <ul style="list-style-type: none"> • Planning • Coordination



Global ATM System



What is a global ATM system?

- The operational concept being developed by ICAO visualizes an integrated, harmonized and globally interoperable ATM system. This is achieved through a progressive, cooperative, cost-effective implementation of CNS/ATM systems worldwide



Air traffic management

Operational concept

- **The operational concept**
 - describes how an integrated global ATM system should operate
 - provides PIRGs, States and industry with clearer objectives for designing and implementing ATM and supporting CNS systems
- **The concept has been approved by AN-Conf/11 and the Council of ICAO**
- **ICAO (ATMC Panel) is continue to work on this concept to develop more details, such as ATM requirements and expected to be available in 2005**



Performance Requirements RCP

- Required communication performance (RCP) was seen as a set of parameters, the values of which would determine the operational requirements for communication systems in the various phases of flight
- ICAO (OPLINK Panel) continues to progress the task and will develop, as necessary, the SARPs, guidance material relating to the use of RCP in the provision of air traffic services



Performance Requirements

RNP

- Required Navigation Performance (RNP) is defined as “A statement of the navigation performance necessary for operation within a defined airspace”. The accuracy in RNP refers to the total navigation accuracy of the aircraft
- The accuracy is expressed as a single parameter, RNP type (the *containment value*), which defines the distance from intended positions within which flights would be found for at least 95 % of the total flying time
- RNP/20; RNP/10; RNP/12.6; RNP/4 ; RNP/5 and RNP/1 have been defined
- ICAO ANC study group (RNP and Special Operational Requirements Study Group) is addressing the open issues of RNP and scheduled to submit its report to ANC by January 2005



Performance Requirements RSP

- Required surveillance performance (RSP) will enable transition to new surveillance systems by defining high-level system performance requirements independent of the used technology and architecture. This will allow the implementation of surveillance applications over various surveillance systems with the same level of performance and results in world-wide harmonization .
- RSP is defined as ‘the set of system performance parameters that are required for a surveillance system to support a surveillance application’
- The RSP concept is still under development by ICAO (SCRS Panel) and expected to be available in 2005



Performance Requirements RTSP

- RTSP would address an internal perception: what functionality of which quality ATM services, infrastructure, procedures, systems and resources should have and/or aircraft and crews should meet
- RTSP would incorporate all system capability aspects. It has been historically seen as a compound of required communication, surveillance or navigation performance, for the communication, surveillance and navigation parts, but the proposed definition differs significantly from that view
- The RTSP concept is still under development by ICAO (ATMC Panel) and expected to be available in 2005

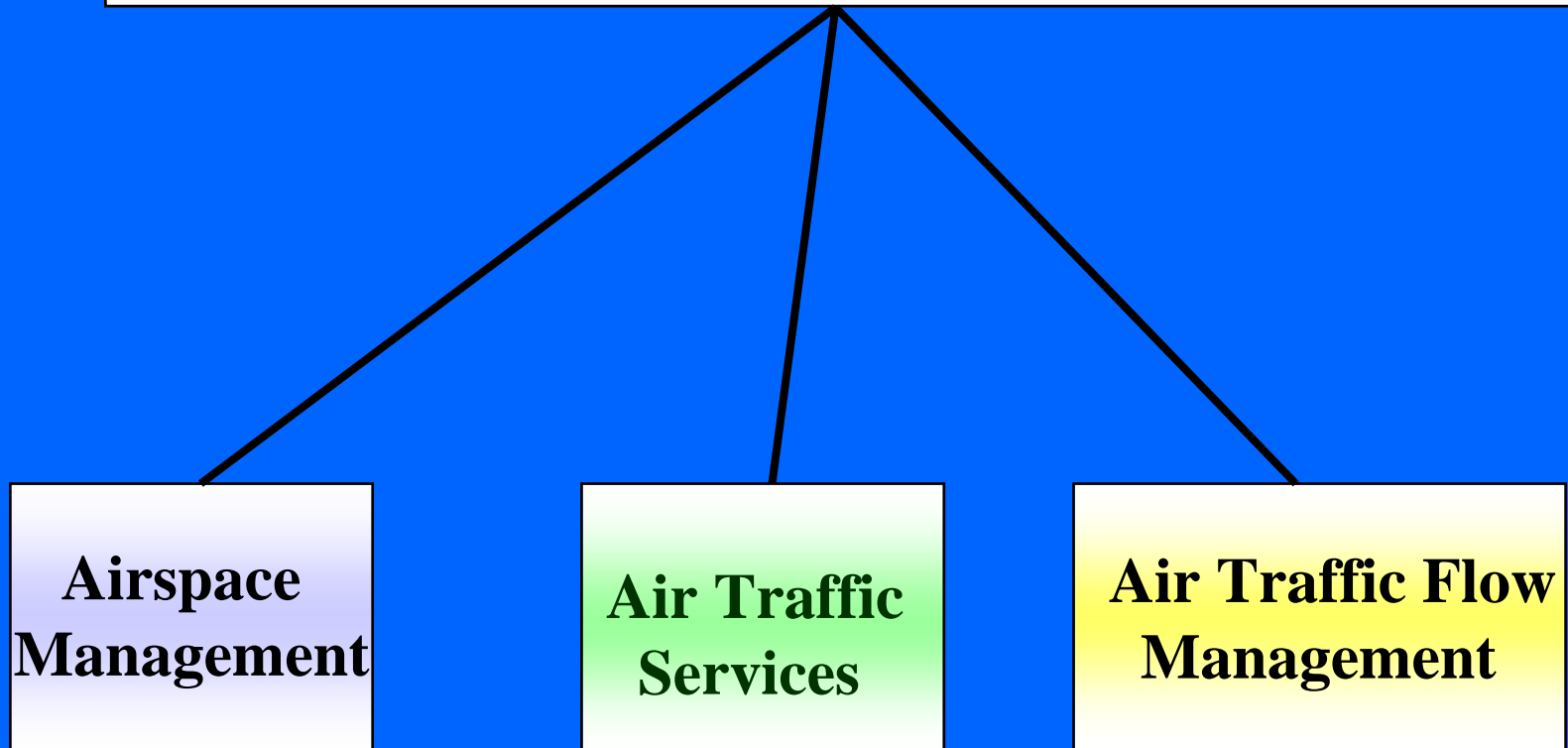


Air Traffic Management



Elements of ATM

AIR TRAFFIC MANAGEMENT





Air Traffic Management Definition

Air traffic management is the dynamic, integrated management of air traffic and airspace — safely, economically, and efficiently — through the provision of facilities and seamless services in collaboration with all parties



Airspace management

➤ ATS route structure

- fixed routes
- RNAV fixed/random/mixed routes

➤ Airspace organization

- fixed and flexible use of airspace
- civil/military coordination
- application of RCP/RNP/RSP/RTSP
- optimized sectorization



Air traffic services...

- **Air Traffic Control**
 - flight information control
 - area control
 - approach control
 - aerodrome control
 - surface movement control
- **Search and Rescue**
 - ELTs (406 MHz and 121.5 MHz simultaneously effective 1 January 2005) for COSPAS/SARSAT

(1/2)



Air traffic services

- **Decision support systems**
 - conformance monitoring; MTCA/STCA; MSAW
 - PRM for independent IFR approaches to closely spaced runways
 - arrival metering and sequencing system
 - AIDC
- **Separation standards**
 - RHSM and RVSM
- **Applications**
 - data link
 - use of curved and segmented approaches
 - A-SMGCS



Air traffic flow management (ATFM) ...

➤ ATFM Objective:

- to ensure an optimum flow of air traffic through areas during times when demand exceeds or is expected to exceed the available ATC capacity

➤ Application of ATFM

- re-routing and allocation of slots

(1/3)



ATFM...

➤ Phases of ATFM Activity

- **Strategic phase:** Strategic activities are research, planning and coordination activities carried out in the period from two days to several months in advance of the day of operation
- **Pre-tactical phase:** Pre-tactical activities are planning and coordination activities carried out within the two days prior to the day of operation
- **Tactical phase:** Tactical activities are ATFM activities carried out on the day of operation
- **Airborne flights:** ATFM shall take action on individual flights before their departure and shall not normally intervene in the progress of airborne flights which are the responsibility of the appropriate ATC unit. However, airborne flights may be subject to additional tactical ATFM measures (2/3)



ATFM

➤ Data requirements

- Data of planned flight operations and revisions thereto, as well as data on ad hoc flight operations
- Data on the availability of air navigation infrastructure (ATS route network, ATC sectorization, etc.) as well as on ATC system capacity figures



ATM evolution

CURRENT		NEW
ATM	<ul style="list-style-type: none">➤ Fixed sectorization➤ Fixed routes➤ MNPS➤ Airspace segregation➤ RHSM➤ Search and Rescue	<ul style="list-style-type: none">Optimized/dynamic sectorization➤ RNAV routes➤ MNPS/RNP➤ Airspace desegregation➤ RHSM and RVSM➤ Search and Rescue➤ Application of RCP/RNP/RSP & RTSP➤ Application of data link➤ Decision support systems➤ User-preferred flight profiles➤ A-SMGCS➤ ATFM (databases, strategic and tactical planning & coordination)



Communications



Ground-Ground Data Communications



Ground-ground data links

➤ Current

- **AFTN (Aeronautical Fixed Telecommunications Network)** (between communication centres)
 - low/medium speed
 - store and forward
- **OLDI (On Line Data Interchange)** (between ATS centres)
 - Not compatible with ATN

➤ New

- **AMHS (Aeronautical Message Handling System)** an ATN application (between communication centres)
- **AIDC (ATS Interfacility Data Communication)** an ATN application (between ATS centres)

➤ Ground/ ground data and voice communications network



How do you interface AFTN/AMHS networks?

- **Through AFTN/AMHS Gateway**
 - provides basic interoperability
 - envelops or converts AFTN messages
 - allows message transfer capability between two dissimilar systems
 - a tool for migration strategy



Routing considerations in AFTN/AMHS (ATN) environment

- **AFTN address is used to globally identify the user, regardless of attachment to AFTN or ATN.**
- **Users do not need to know if their communicating entities are attached to AFTN or ATN.**
- **Store-and-forward message transfer service is available on end-to-end basis.**
- **AFTN routing is by switching centres, whereas gateway routing is via ATN connectivity.**
- **Routing in AFTN is static; ATN routing is dynamic.**



What is the first step in planning for the transition to CNS/ATM systems?

It is essential to have ground/ground networking to transport textual data, radar data, graphics and voice. The selected network platform can be either terrestrial or satellite, or a mix of terrestrial/satellite, depending on economic and technical factors



When establishing ground/ground networking, the following systems (current & future) need to be considered to ensure connectivity:

Data: AFTN, FDPS, FAX, RDPS, SBAS, VHF, HF, AMSS, AMHS, AIDC

Voice: VHF, PABX, VCCS, DSC

Remote operations: NAVAIDS monitoring

Graphics: Weather maps

Video



Ground-Ground Voice Communications



Ground-ground voice links

- **Voice communication between ATS units (direct speech circuits)**
 - Will remain the principle means of communication with AIDC for routine work
- **Private Integrated Service Network Exchange (PINX)**
 - VCCS/VCS
 - New digital voice switching systems are expected to bring more extensive integration and improved controller interface
- **Ground/ ground data and voice communications network**



Air-Ground Data Communications



Basic principles of data link functions

- It will supplement and support voice communications, not replace them
- The initial service is for routine events
- Messaging should be simple
- Procedures should be consistent with current voice systems
- En route, terminal and tower ATC facilities require different data link capabilities



Air-ground data links

➤ Current

- ACARS (Aircraft Communications Addressing and Reporting System)

➤ New

- VHF digital data link
- Mode-S data link
- AMSS data link
- HF data link



ACARS (VHF) and VDL

Mode	Modulation	Modulation Rate Kbits/sec	Access Control	Application
ACARS	AM MSK	2.4	CSMA	A/G Data
VDL 1	AM MSK	2.4	CSMA	A/G Data
VDL 2	D8PSK	31.5	CSMA	A/G Data
VDL 3	D8PSK	31.5	TDMA	A/G Data & voice
VDL 4	GFSK	19.2	STDMA	A/G Data & Sur



ACARS

- **ACARS (Aircraft Communications Addressing and Reporting System)**
 - initially developed for airlines operations communications
 - operates in VHF/HF/Satellite modes
 - supports FANS-1/A
 - does not support ATN



VHF digital link ...

- VHF digital link is compatible with ATN
- Mode 2 has higher capacity; successor to Mode 1
- Mode 3 is suitable for high-density areas and areas experiencing frequency congestion
- Mode 3 provides up to 4 voice and/or data circuits
- Mode 3 and Mode 4 are capable of transmitting time-critical messages and can accept prioritization of messages

(1/2)



VHF digital link

- Mode 4 – allocation of time slot without external unit
- Single VHF radio to operate all the modes with a minimum addition of PCBs
- With VDL, aircraft is not involved in any manual frequency tuning for any station change
- Mode 4 is a candidate technology for ADS-B operations

(2/2)



Mode S data link

- Uplink :1030 MHz
- Downlink: 1090 MHz
- Types of messaging:
 - Level 1 – Receive 56 SLM
 - Level 2 – Level 1 + Send SLM
 - Level 3 – Level 2 + Receive 112 bit ELM
 - Level 4 – Level 3 + Send ELM
 - Level 5 – Level 4 + Multiple Stations



Aeronautical Mobile Satellite Service (AMSS) data link ...

- **GEOS (Geo-stationary Earth Orbit Satellites)**
 - **36 000 km altitude, 24 hours/orbit**



AMSS data link ...

➤ Current service available (by Inmarsat)

- Aero-H (high gain, voice and data, global coverage, suited for long-/medium-haul aircraft) + Swift 64 (64KBit speed) or BGAN(Broadband Global Area Network). BGAN is a new satellite data transfer product which will allow Internet applications at 144 KBit shared speed.
- Aero-I (intermediate gain, voice and data, regional coverage, suited for short-/medium-haul aircraft)
- Aero-L (low gain, data only, global coverage, suited for aircraft that do not need voice or high-speed data communications)

(2/3)



AMSS data link

- **LEOS (Low Earth Orbit Satellites)**
 - **1 000 km altitude, 100 minutes/orbit**
 - **need 66 satellites for global coverage**
 - **SARPs have been developed by ICAO**
 - **service not yet available**

(3/3)



HF data link – Concept ...

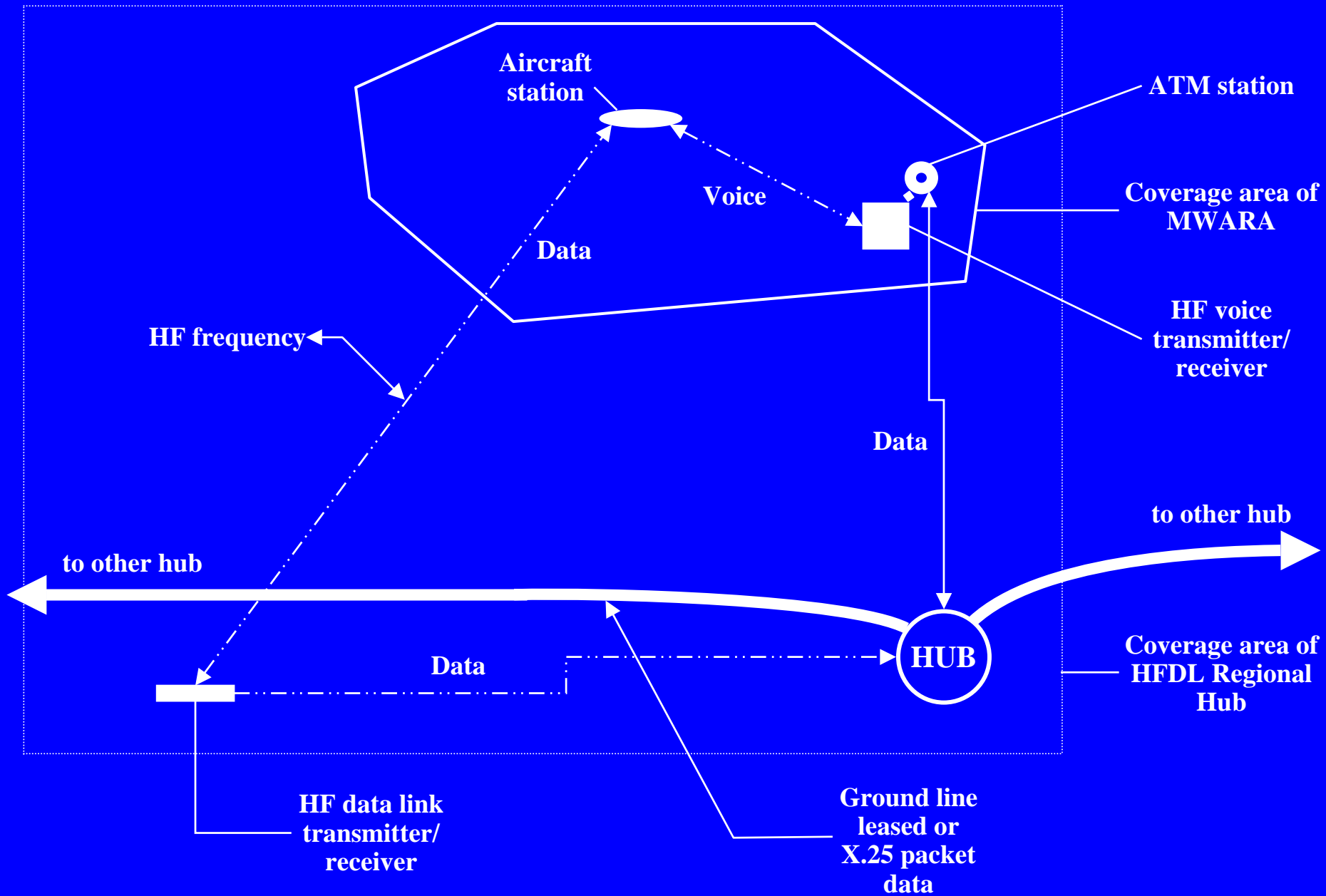
- Network of 15 HFDDL ground stations required for global coverage
- 3 regional hubs, each having 5 ground stations
- HFDDL is different from current HF voice network
- Ground stations are separated by a distance of 3 000 to 5 000 kms

(1/2)

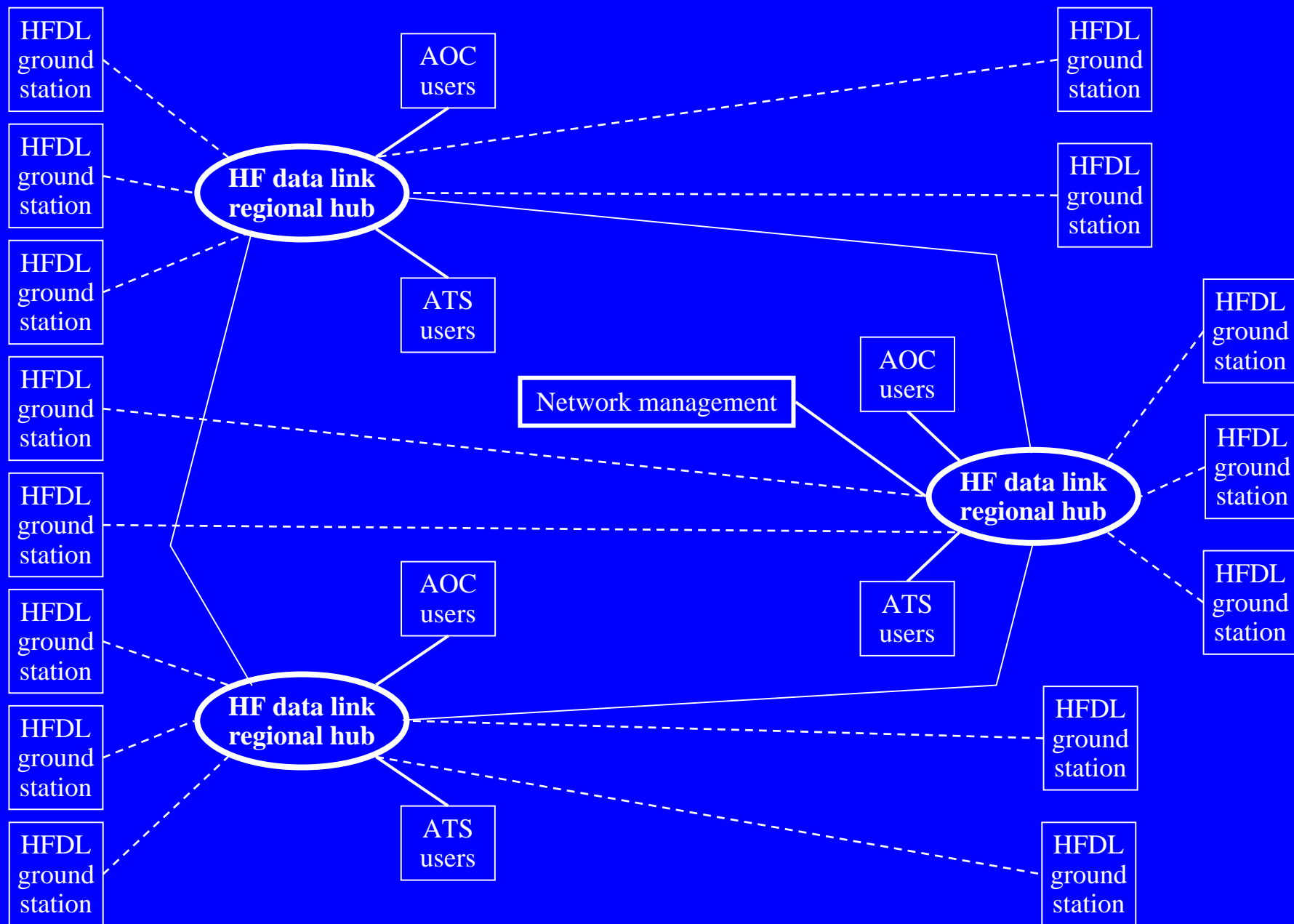


HF data link – Concept

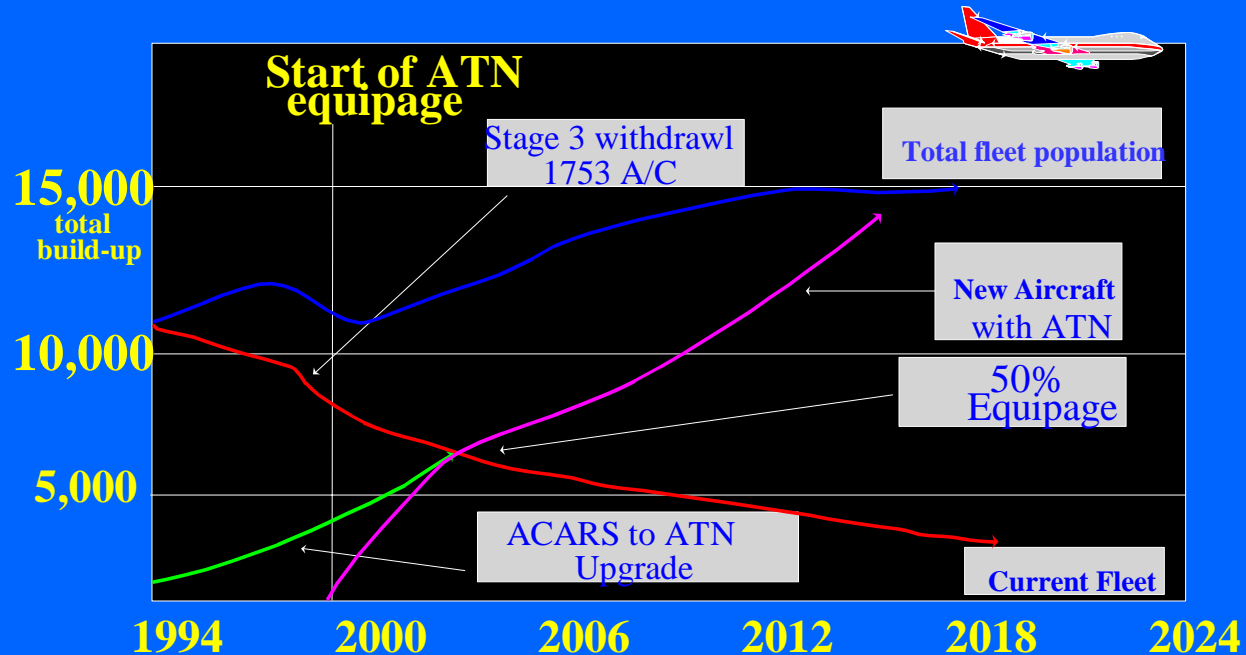
- System capacity is 2 000 aircraft simultaneously
- Pool of 40 to 60 HF frequencies required
- Aircraft can contact 3 or more HFDDL ground stations constantly
- Hubs can become ATN routers
- ARINC operates 14 stations worldwide



Data link versus voice link



Possible scenario for a global network



**Projections for the rate of airliner retirement/
replacement and the introduction of ATN**



Aeronautical Telecommunication Network (ATN)



ATN ...

- It is the OSI architecture that has been chosen for use within the aviation industry

It will:

- allow the interconnection of various air/ground administrations such as
 - civil aviation authorities
 - airlines
 - telecommunications service providers

(1/3)



ATN ...

- allow interoperability of different types of data links:
 - VHF
 - AMSS
 - Mode S
 - HF
- allow communications between a wide variety of users
- use the standard set of ISO protocols



ATN

➤ In official terms:

- a unique addressing plan
- a common inter-networking protocol, based on X.25
- a standard routing plan, using routers

➤ In technical terms:

- a network made of various compatible sub-networks based on X.25

➤ In very simple terms:

- the equivalent for data of the current telephone system for voice

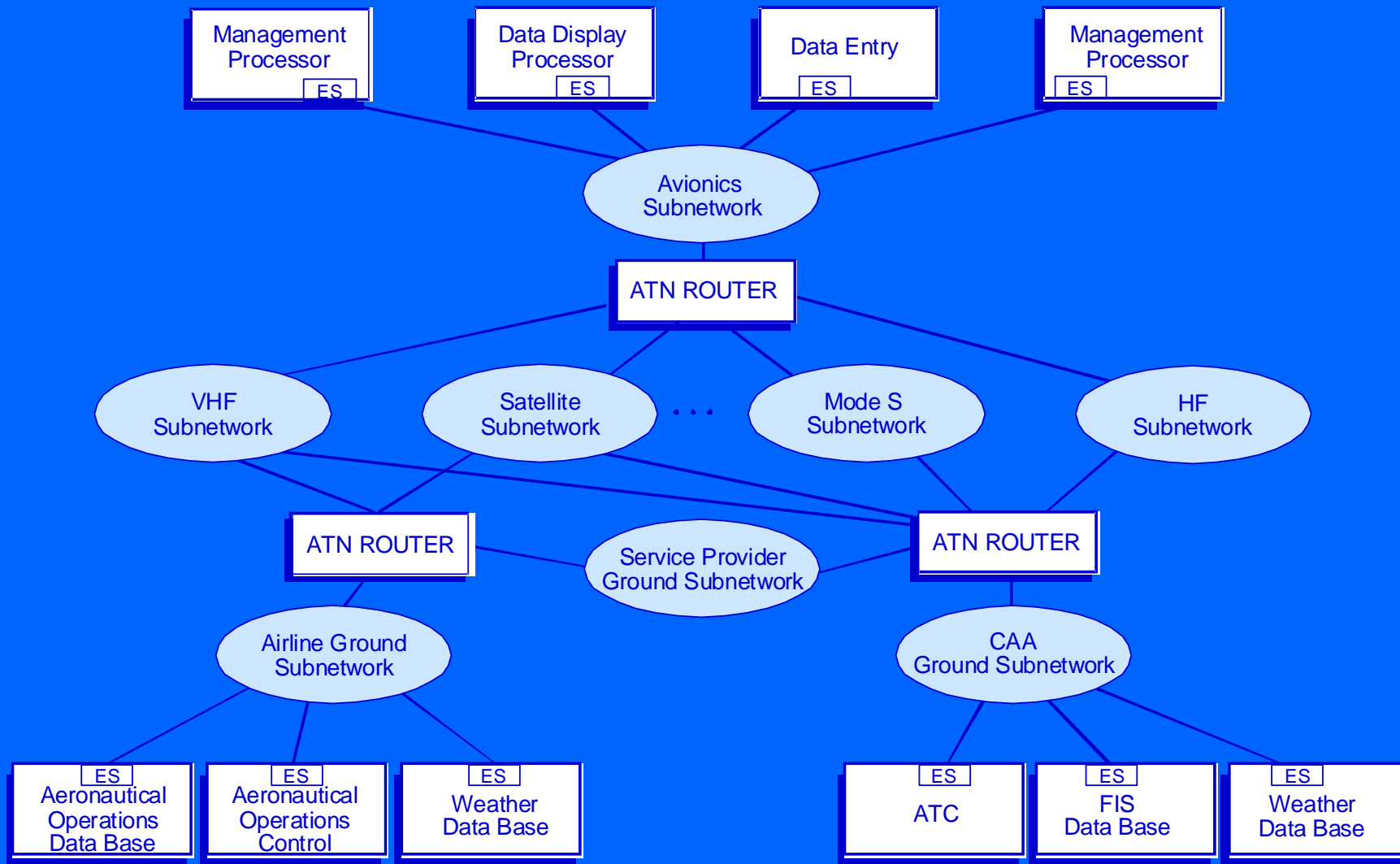


Why implement ATN?

- Need for high-volume data exchange
- Need for low transit times
- Policy decision to move to ISO protocols
- Need for interactive data where multiple messages are exchanged between applications
- Need to communicate with other organizations that are using the ATN
- Need to integrate air-ground and ground-ground data networks

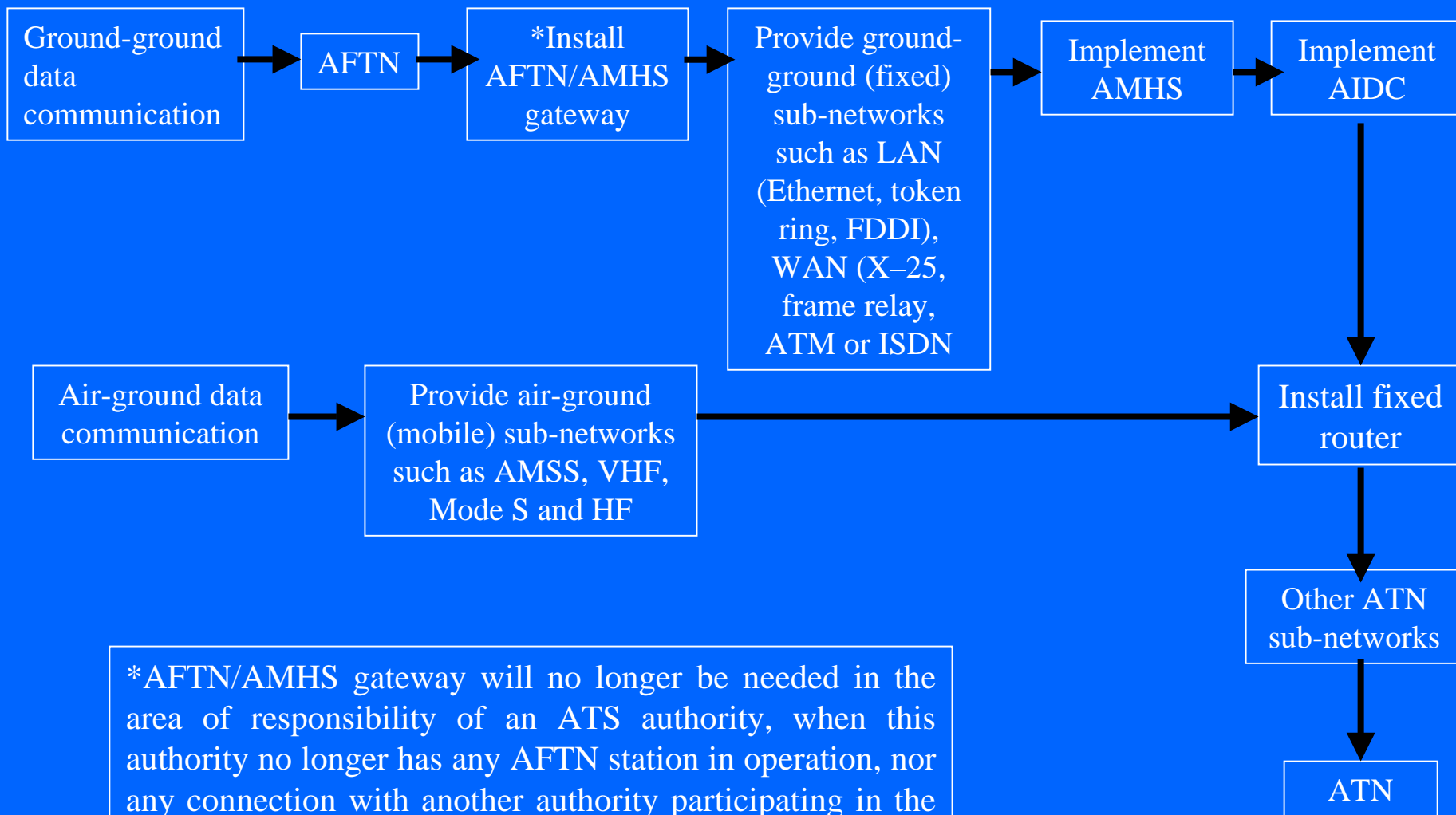


ATN architecture





Approach to implementation of ATN



*AFTN/AMHS gateway will no longer be needed in the area of responsibility of an ATS authority, when this authority no longer has any AFTN station in operation, nor any connection with another authority participating in the AFTN only and not in the ATN.



ATN update...

- Widespread availability, speed, ease of use and low cost of public Internet has been appealing to aviation community
- Several States are already using the public Internet for exchange of aeronautical data for ground-ground applications



ATN update ...

- ICAO established a study group in 2003 to address this issue of using public Internet for aviation use.

Tasks are:

- to develop appropriate ICAO provisions
- to harmonize operating procedures employed in different States
- to develop guidelines

Target date: December 2004

(2/3)



ATN update

- **Aeronautical Communication Panel (ACP) of ICAO is considering the use of TCP/IP protocols in the provision of aeronautical internetworking (for ground-ground) instead of ATN Internet for the following reasons:**
 - **X-25 technology is obsolete;**
 - **TCP/IP infrastructure is available; and**
 - **ATN Internet protocols are not readily available**
- **Report on the use of TCP/IP Internet working for aeronautical communications is expected to be presented to ACP/1 meeting scheduled for late 2005**
- **For air-ground applications such as data links, ATN is the only option**

(3/3)



Air-Ground Voice Communications



Air-ground voice links

➤ Current

- HF voice
- VHF voice (Analogue) channel spacing 25 KHz and 8.33 kHz

➤ New

- VHF digital voice (VDL Mode 3)
- Satellite (AMSS) voice



Air-ground voice communications...

➤ HF voice

- SSB in the band of 2.85 MHz to 22 MHz is used
- widely available in Oceanic and remote regions
- propagation characteristics vary with time of day and other conditions
- audio quality is not good
- HFRT (RDARA) is still employed in en route continental airspace of some States due to lack of continued coverage of VHF RT



Air-ground voice communications...

➤ VHF voice

- DSB-AM analog voice with 25 kHz is widely used for TMA and en route continental airspace
- to overcome the congestion, channel spacing has been reduced from 25 KHz to 8.33 kHz so as to increase the number of available channels (e.g.: in European Region)
- VDL Mode 3 provides both voice and data communications. To be implemented in the long term

(2/3)



Air-ground voice communications

- **Satellite (AMSS) voice**
 - **application in oceanic and remote areas for non-routine and emergency use only**
 - **Security concerns still to be resolved**
 - **no coverage near polar regions**
 - **Services available from INMARSAT using GEO satellites**
 - **future systems envisaged using low earth orbits**



Navigation



Navigation systems

- **Current systems (ground-based)**
 - **Navigation aids for en route/NPA**
 - **Navigational aids for precision approach/landing**
- **New systems (satellite-based)**
 - **GNSS for all phases**



Current en route ground NAVAIDS

- **NDB**
 - **Compass direction to beacon**
- **VOR**
 - **bearing from beacon**
- **DME**
 - **distance from beacon**
- **OMEGA/LORAN C**
 - **position**



Non-directional beacon (NDB)

➤ Ground station

- radiates equally in all directions
- transmits at 200-500 kHz
- range 400 NM depending on power
- usually located at airports/en route

➤ Aircraft

- rotates antenna for maximum signal strength



VHF Omni-Range (VOR)

➤ Ground station

- radiates reference and rotating beam
- transmit at 112–118 MHz
- rotating beam at 30 Hz
- reference beam at 30 Hz modulated onto sub-carrier at 9.6 kHz

➤ Aircraft

- compares phase of the 30 Hz signals
- in-phase when due North of beacon
- Range – 200NM



Distance measuring equipment (DME)

➤ Aircraft

- radiates & receives return
- measures time of travel
- frequency band at 960–1215 MHz
- range 200 NM

➤ Ground

- triggered response at DME station



OMEGA hyperbolic navigation system

- **8 Ground stations**
 - **Norway, Liberia, US (2), La Reunion, Argentina, Australia, Japan**
- **HF frequency band**
 - **10.2, 11.05, 11.33, 13.6 kHz**
- **Withdrawn from service**



Long-range navigation (LORAN-C) ...

- Hyperbolic navigation
- Pulse transmission
- Frequency 90 → 100 khz
- Range: 1200 km
- Accuracy: 30 → 500m
- Subject to interference
- Generally used on supplemental basis by general aviation for en route operations

(1/2)



LORAN-C

- Coverage of specific areas
 - US & Canada
 - Mediterranean & Saudi Arabia
 - Europe
 - Loran-C/Chayka
 - Russia, Japan, Korea, China



Inertial navigation system (INS)

- **Current sole means NAV AID for aircraft**
 - **triple redundancy**
 - **passive – no interference**
 - **dependent on on-board electronic & electro-mechanical devices**
 - **error increased with time**
 - **drift rates better than 1 nm/flight hour**



Area navigation

➤ Combinations

- **DME/VOR**
- **DME/DME**
- **VOR/VOR**



Precision approach and landing systems

➤ ILS

- instrument landing system
- current
 - *bearing in elevation and azimuth*

➤ MLS

- microwave landing system
- proposed (at London Heathrow airport)
 - *bearing in elevation & azimuth*



ILS

- **Primary landing aid**
- **Localizer beam (azimuth) at runway end**
 - two overlapping beams aligned along runway centre frequency at 108 – 118 MHz
- **Glide slope beam (vertical) at runway side**
 - two beams intersect at 3° glideslope approach
 - frequency at 328.6 – 335.4 MHz or IDME
- **Markers (inner, middle & outer)**
 - frequency at 74.8 – 75.2 MHz (VHF)
 - or DME co-located with Localizer



MLS

- **Proposed landing aid:
in Europe until GNSS feasibility**
- **Scanning beams**
 - **coverage to 20,000 ft. altitude &
15 miles width**
 - **frequency at 5 GHz**
- **Curved and segmented approaches
feasible**

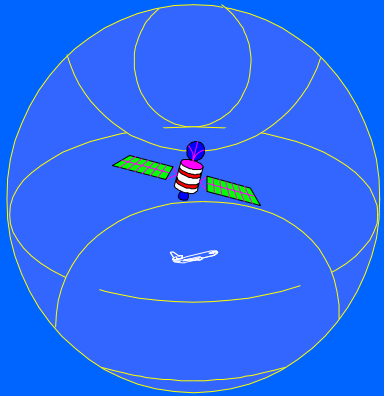


GNSS Definition

A worldwide position and time determination system, that includes one or more satellite constellations, aircraft receivers, and augmentations as necessary to support the required navigation performance for the actual phase of operation

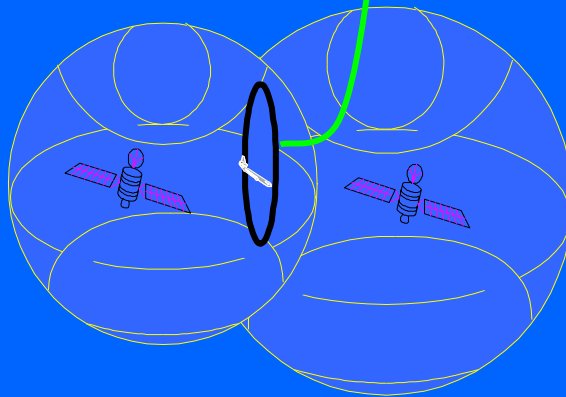
Satellite navigation – Basics

Aircraft is somewhere
on the surface of this
sphere



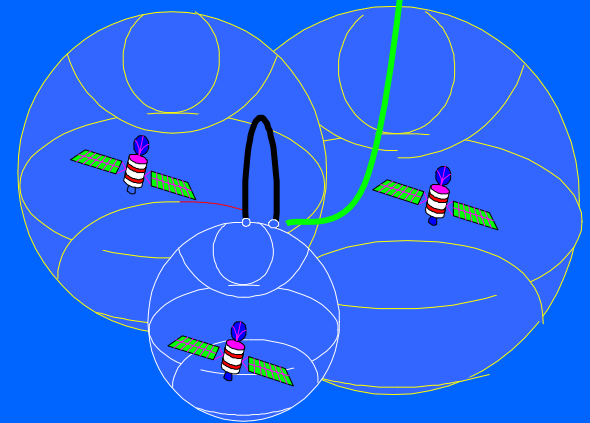
**1-satellite
position**

Aircraft is somewhere
on this circle



**2-satellite
position**

Aircraft is at one of
these two points



**3-satellite
position**

**reference to a fourth satellite eliminates clock errors*



Satellite orbits

- **GEO (Geostationary Earth Orbit)**
 - 36,000 KM; 3 Satellites for global coverage; 24 hours per orbit
 - e.g.: INMARSAT
- **MEO (Medium Earth Orbit)**
 - 20,000 KM; 24 Satellites for global coverage; 12 hours per orbit
 - e.g.: GPS
- **LEO (Low Earth Orbit)**
 - 800KM; 66 Satellites for global coverage; 100 minutes per orbit
 - e.g.: Iridium system now defunct



GNSS

Satellite Constellation + Augmentations + Aircraft Receivers

Elements:

GPS	- ABAS	- Aircraft
GLONASS	- GBAS	Receivers
GALILEO*	- SBAS	
	- GRAS*	

(**emerging technology*)



Comparative study

GPS	GLONASS
Satellite separation by code on the same frequency (CDMA)	Satellite separation by the frequency with an identical code (FDMA)
UTC (<i>Universal coordinated time</i>)	MST (<i>Moscow standard time</i>)
WGS-84 coordinate system	PZ-90 Soviet geo-metric coordinate system
1575.42 MHz carrier frequency	1600+10 MHz carrier frequency for the different satellites
24 satellites	24 satellites



Comparative study

GPS	GLONASS
Military signals are not degraded for civil use (selective availability)	Military signals are not degraded for civil use (selective availability)
Ground control stations are widespread – hence control of satellites is effective	Ground control stations are only in CIS – hence control of satellites when away from Russia is difficult
21 000 km height	21 000 km height
6 orbital planes – 4 each	3 orbital planes – 8 each
12-hour orbit period	11-hour, 15-minute orbit period



Requirement of civil aviation for radio navigation

**These requirements relate to
following areas:**

- **coverage**
- **accuracy**
- **integrity**
- **availability**
- **continuity**



Coverage

Surface area or space volume in which the signals are adequate to permit the user to determine position to a specific level of accuracy



Accuracy

The degree of conformance between the estimated or measured position and/or velocity of a platform at a given time and its true position and/or velocity



Integrity

The ability of a system to provide timely warnings to users when the system should not be used for navigation



Availability

The availability of a navigation system is the percentage of time that the services of the system are usable

Availability is a function of:

- **satellite failure statistics**
- **geometry considerations**
- **expected ranging performance**



Continuity

The continuity of a system is the availability of the total system to perform its function without interruption during the intended operation

Possible causes of interruption:

- **unexpected loss of signal due to shadowing**
- **ionospheric scintillation**
- **hardware failure on the satellite or in the user receiver**



GNSS signal-in-space performance requirements ...

Typical operation(s)	Accuracy horiz. 95%	Accuracy vert. 95%	Integrity	Time to alert	Continuity	Avblty	Associated RNP type(s)
En route	3.7 km (2.0 NM)	N/A	$1 - 1 \times 10^{-7}$	5 min	$1 - 1 \times 10^{-4}/h$ to $1 - 1 \times 10^{-8}/h$	0.99 to 0.99999	20 to 10
En route, Terminal	0.74 km (0.4 NM)	N/A	$1 - 1 \times 10^{-7}/h$	15 s	$1 - 1 \times 10^{-4}/h$ to $1 - 1 \times 10^{-8}/h$	0.999 to 0.99999	5 to 1
Initial approach, intermediate approach, non-precision approach (NPA), Departure	220 m (720 ft)	N/A	$1 - 1 \times 10^{-7}/h$	10 s	$1 - 1 \times 10^{-4}/h$ to $1 - 1 \times 10^{-8}/h$	0.99 to 0.99999	0.5 to 0.3



GNSS signal-in-space performance requirements

Typical operation(s)	Accuracy horiz. 95%	Accuracy vert. 95%	Integrity	Time to alert	Continuity	Avblty	Associate d RNP type(s)
Approach operations with vertical guidance (APV-I)	16.0 m (52 ft)	20 m (66 ft)	$1 - 2 \times 10^{-7}/\text{h}$ per approach	10 s	$1 - 8 \times 10^{-6}/\text{h}$ in any 15 s	0.99 to 0.99999	0.3/125
Approach operations with vertical guidance (APV-II)	16.0 m (52 ft)	8.0 m (26 ft)	$1 - 2 \times 10^{-7}/\text{h}$ per approach	6 s	$1 - 8 \times 10^{-6}/\text{h}$ in any 15 s	0.99 to 0.99999	0.03/50
Category I precision approach	16.0 m (52 ft)	6.0 m to 4.0 m (20 ft to 13 ft)	$1 - 2 \times 10^{-7}/\text{h}$ per approach	6 s	$1 - 8 \times 10^{-6}/\text{h}$ in any 15 s	0.99 to 0.99999	0.02/40

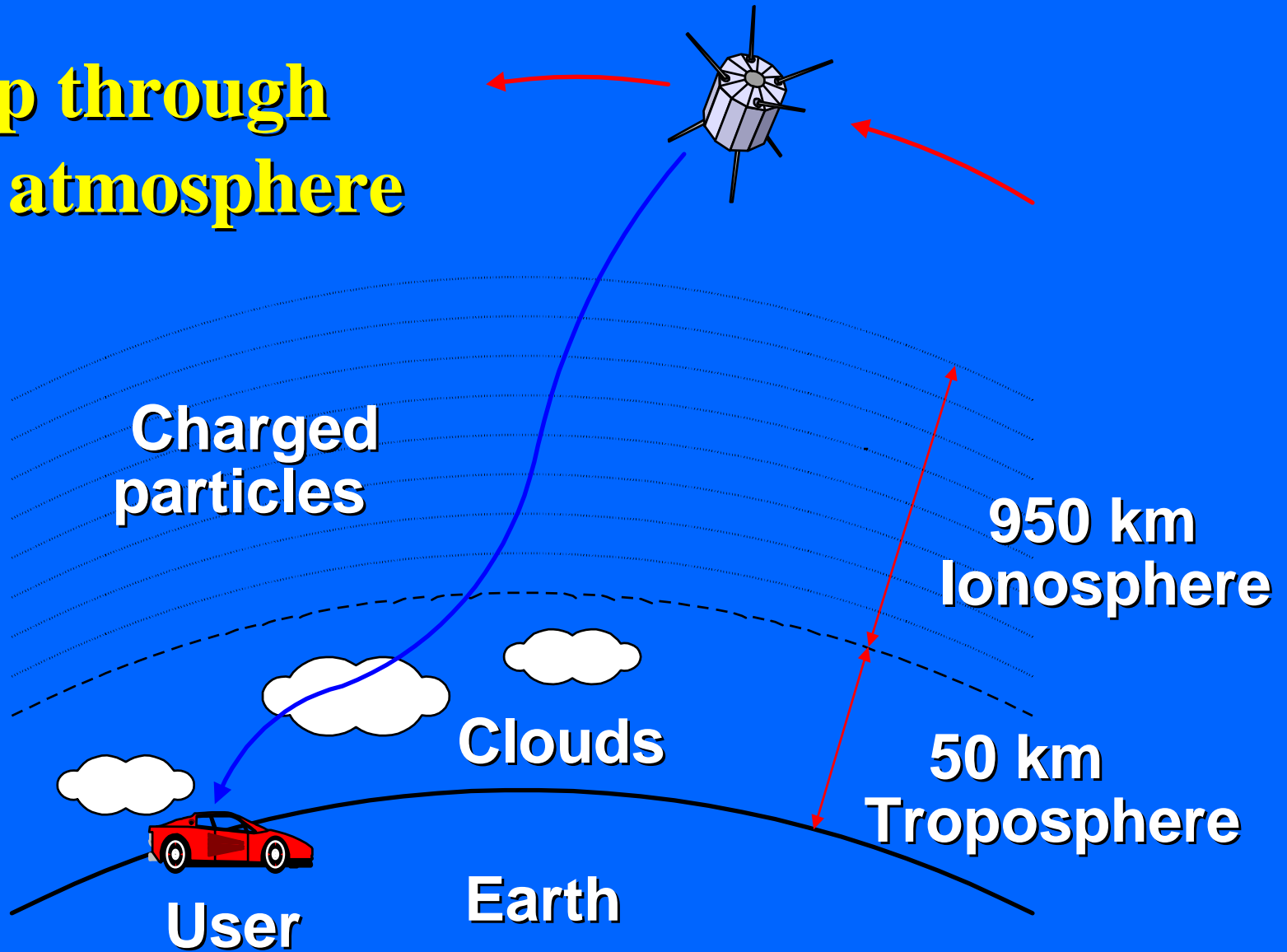


GNSS – error sources

- **Ionospheric delays:** 20 to 30 meters during the day and 3-6 meters during night
- **Tropospheric errors:** 1 to 3 meters
- **Ephemeris errors:** 3 to 4 meters
- **Satellite clock errors:** 3 to 4 meters
- **Multipath errors:** 1 to 2 meters
- **Receiver Noise:** up to 1 meter



Trip through the atmosphere





Ionospheric impacts ...

- Ionospheric delays and ranging errors depend upon:
 - types of ionospheric phenomena
 - signal frequencies
 - season time
- Behaviour is complex and variable



Ionospheric impacts

- Propagation errors can be corrected by:
 - application of ionospheric models (averaged estimates)
 - application of reference station corrections
 - direct measurements on two frequencies (when available)



Why augment GNSS?

Both GPS and GLONASS require varying degrees of augmentation to meet operational performance requirements (accuracy, integrity, availability and continuity) for all phases of flight

To overcome inherent system limitations, augmentations have been proposed in three broad categories:

- **on-board**
- **ground-based**
- **satellite-based**



Types of augmentation systems for GNSS

- **ABAS** (aircraft-based augmentation systems) – RAIM and AAIM
- **SBAS** (satellite-based augmentation system) – WAAS, EGNOS, MSAS
- **GBAS** (ground-based augmentation system) – LAAS
- **GRAS** (ground-based regional augmentation system) – an emerging system



Aircraft-based augmentation system

- **Receiver Autonomous Integrity Monitoring (RAIM)**
A technique whereby an airborne GNSS receiver/processor autonomously monitors the integrity of the navigation signals from GNSS
- **Aircraft Autonomous Integrity Monitoring (AAIM)**
A technique whereby an airborne sensor such as INS/altimetry-aiding is used to augment GNSS. This is particularly employed during short periods when the satellite navigation antennae are shadowed by the aircraft during maneuvers or during periods when insufficient satellites are in view



Receiver autonomous integrity monitoring

- requires redundant satellite measurements
- 5 satellites allow to detect the faulty satellite
- 6 satellites allow to exclude the faulty satellite from position determination

*Radius of the alarm circle is usually
200 m for stand-alone GPS*



Satellite-based augmentation system (SBAS) — service providers ...

- 1. Wide Area Augmentation System (WAAS)**
 - Developed by USA and Initial operating capability commissioned on 10 July 2003
- 2. European Geo-stationary Navigation Overlay Service (EGNOS)**
 - Being developed by European States and planned for commissioning late 2004. This means that a Signal in Space with PA capability will be broadcasting. For aviation use, the signal will need to be validated in an operational environment. This could take few more months



SBAS — service providers

3. MTSAT Satellite-based Augmentation System (MSAS)

- **Provided by Japan for the Asia Pacific Region and expected to be available with 1 satellite in 2004 and 2 satellites in 2006**

4. GPS/GLONASS and geostationary augmented navigation (GAGAN)

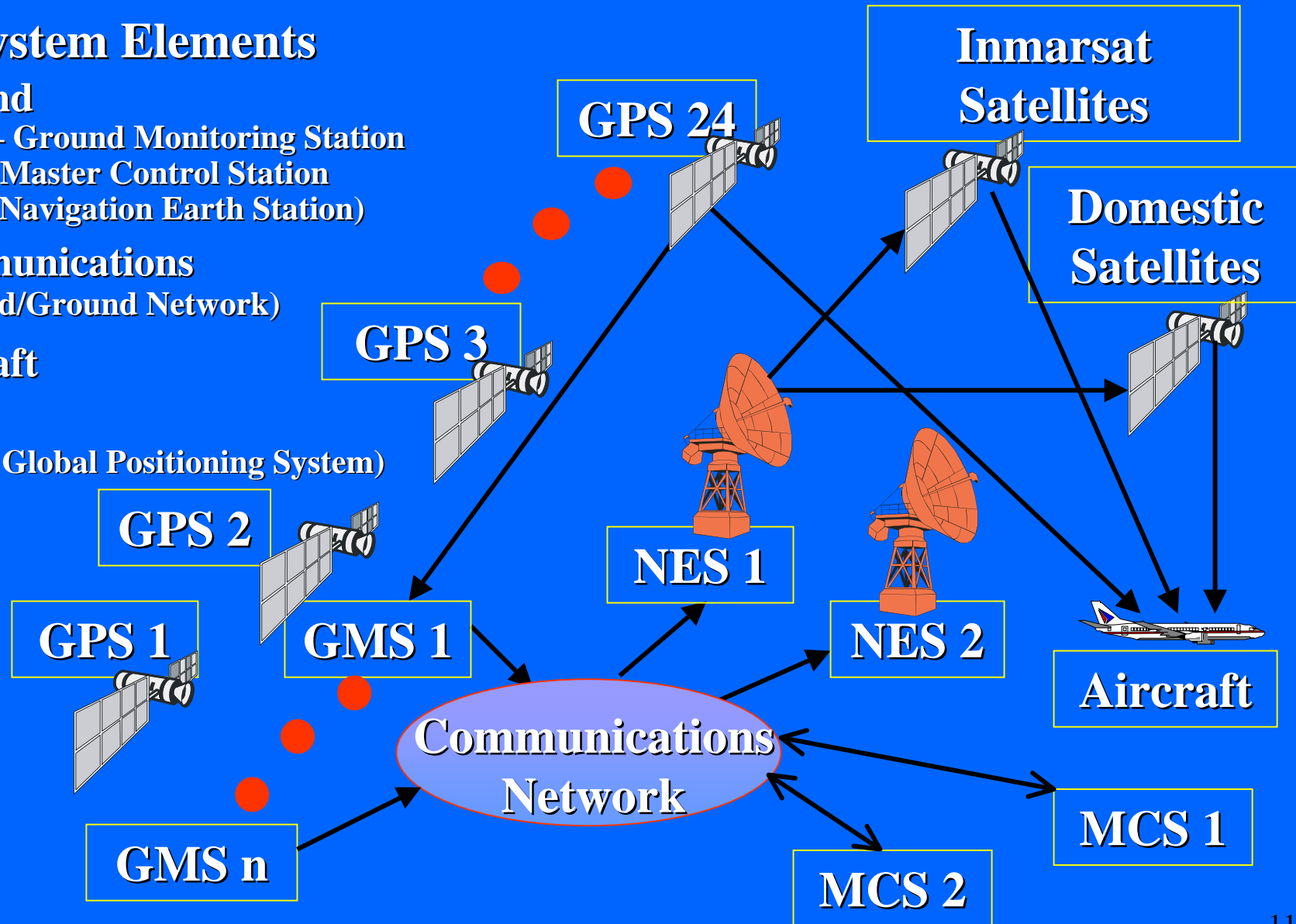
- **Being developed by India to meet the needs of the States of Indian subcontinent and expected to be available in 2006**

SBAS architecture



System Elements

- **Ground**
(GMS – Ground Monitoring Station
MCS – Master Control Station
NES – Navigation Earth Station)
- **Communications**
(Ground/Ground Network)
- **Aircraft**
- **Space**
(GPS – Global Positioning System)

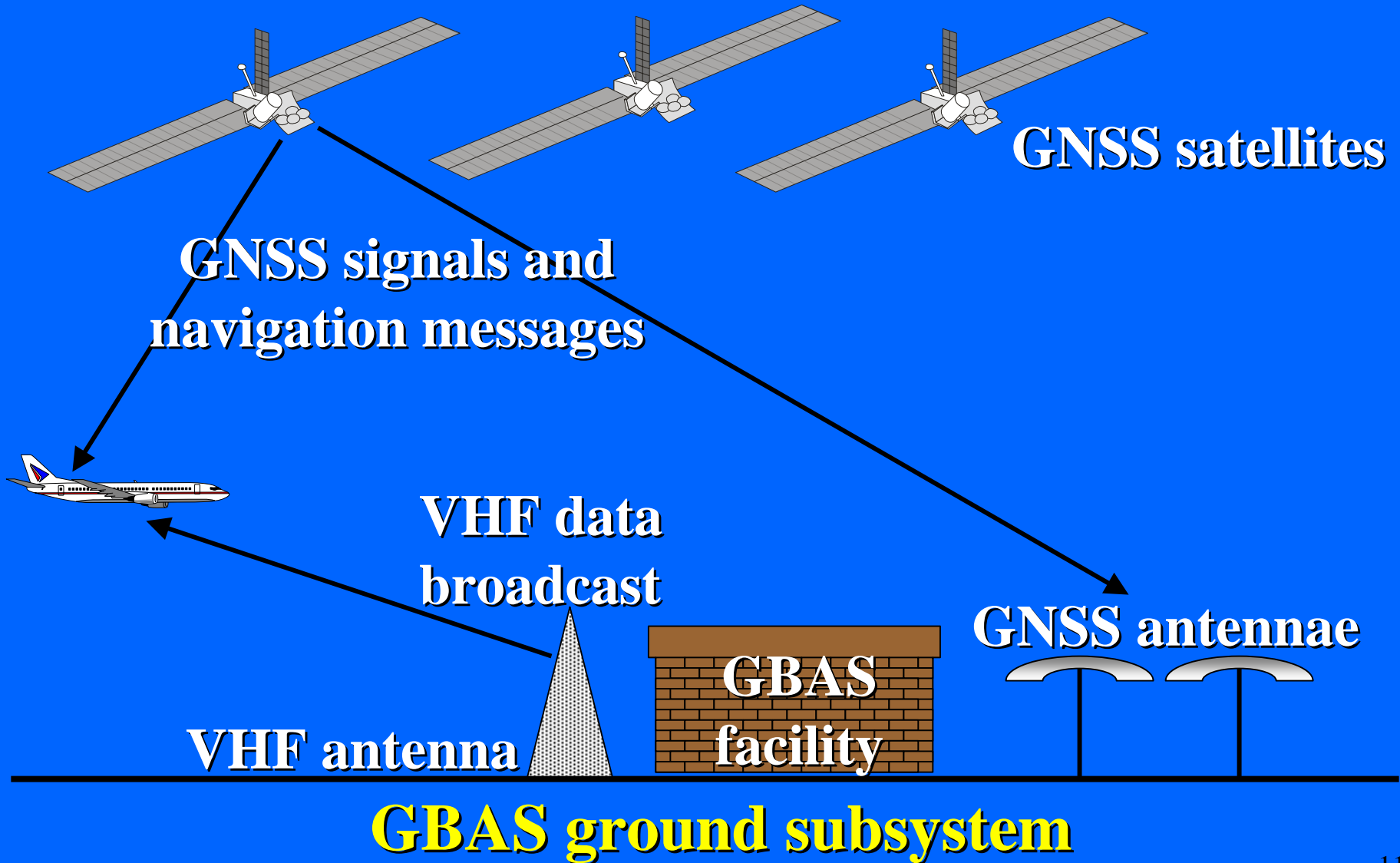




GBAS

- Provides integrity information and differential corrections
- Range limited to a radius of 20 NM
- Requires a VHF data link
- Meets PA Cat. I, Cat. II and Cat. III requirements

The GBAS system





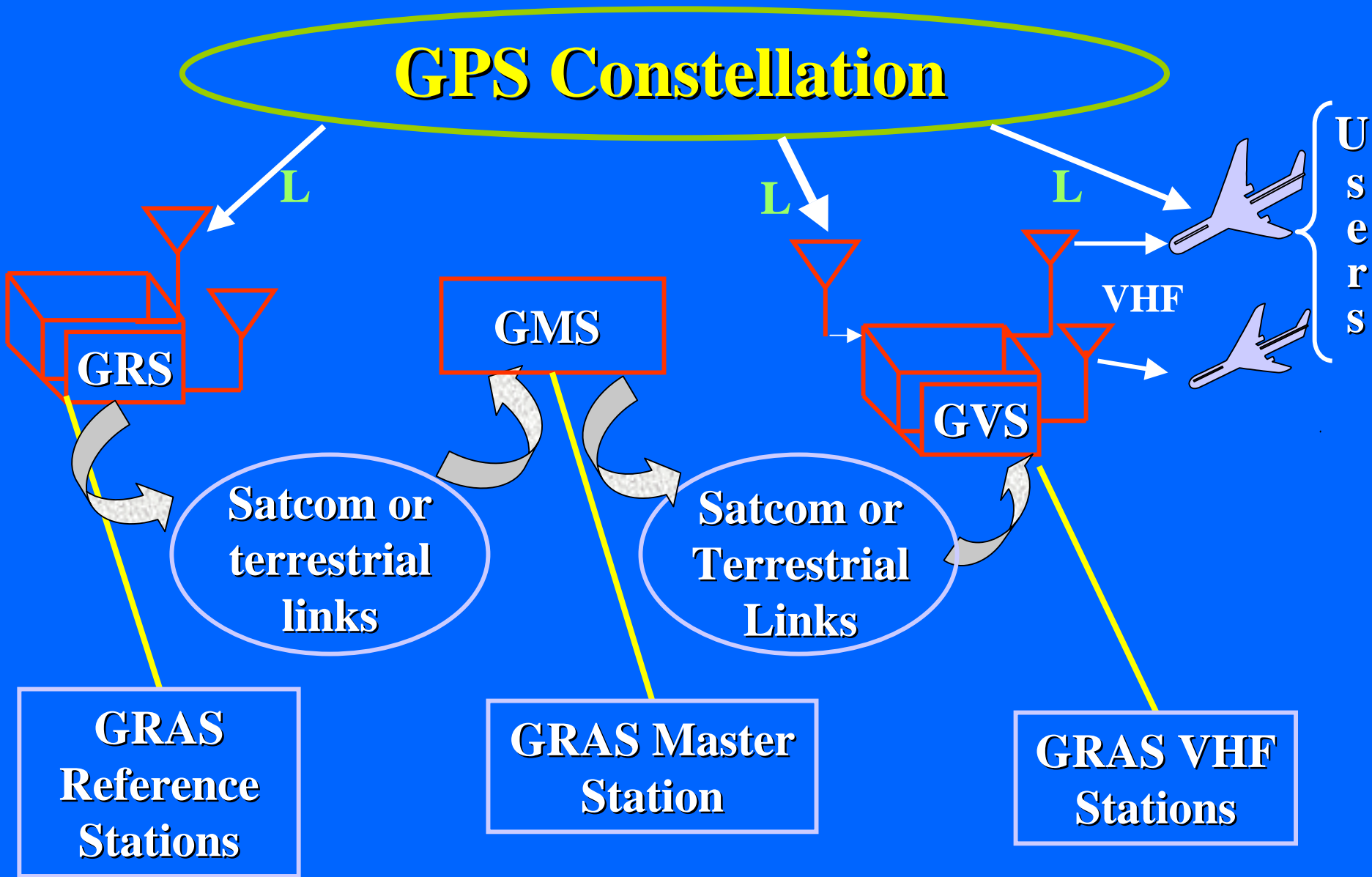
Comparison of SBAS/GBAS

Parameters	SBAS	GBAS
Integrity broadcast	Available	Available
Additional ranging	Available	Not available
Differential corrections	Available	Available
Platform	Satellite-based	Ground-based
Coverage area	Each station having radius of 270 NM	Each station having radius of 20 NM
Precision category	Meets Cat. I	Meets Cat. I–II–III
Data link	Satellite	VHF



Ground-based regional augmentation system (GRAS)

- **Emerging technology**
- **Augmentation through ground-based VHF transmitters**
- **Service area is approximately a radius of 200 NM**
- **Ground component may be interconnected by a network**
- **Expected to support en route, terminal and NPA operations**
- **Development of SARPs to be completed by 2005**



GRAS functional diagram



GNSS Database

Ephemeris

- Data about itself
- Identification, orbit parameters and time
- Used for navigation

Almanac

- Data about other satellites
- Orbit parameter and health statement
- Used to predict available satellites and select good satellite constellation



GNSS receiver function

- **Synchronization of the signals received from the satellite**
- **Extraction of the satellite ephemeris from the message received**
- **Calculation of the position, speed and time by using the data received**
- **Multi-channel receivers are used for aircraft navigation**



ICAO Panel

- GNSS Panel started work in October 1994 and combined the activities of States, aviation industry and other international organizations
- The main task for the GNSSP:
 - to develop SARPs and guidance material for satellite navigation. However ICAO, in June 2003, expanded its role and activities by including all aspects of navigation (terrestrial as well as satellite) and renamed it as Navigation Systems Panel



GNSS SARPs completed

➤ New standard aid to:

- navigation, approach and landing
- applicable from November 2001

➤ System elements:

- satellite constellation – GPS, GLONASS
- augmentation systems – ABAS, GBAS;
and SBAS
- receivers



Requirements & functionalities

➤ Requirements defined

- performance levels
- signal-in-space characteristics
- message structure
- signal processing
- interference immunity

➤ Functionalities met

- en route
- NPA
- APV I and II
- PA Category I



Navigation Systems Panel (NSP) ...

ANC Task No.	Work Programme Item	Estimated Completion Date
CNS-9401	1) Determine navigation system performance requirements to support advanced applications of GNSS	2007
	2) Develop, as required, amendments to SARPs and guidance material for GNSS in Annex 10 for: a) ground-based augmentation system (GBAS) capable of supporting Category II/III operations;	2007



NSP ...

ANC Task No.	Work Programme Item	Estimated Completion Date
CNS-9401 (<i>cont'd</i>)	<p>b) ground-based regional augmentation system (GRAS) capable of supporting en-route, terminal and APV operations;</p> <p>c) GNSS augmentations capable of supporting aerodrome surface and guided take-off, missed approach and curved approach operations;</p>	<p>2005</p> <p>after 2007</p>



NSP ...

ANC Task No.	Work Programme Item	Estimated Completion Date
CNS-9401 (<i>cont'd</i>)	d) interface between satellite-based augmentation systems (SBAS) and dual frequency SBAS;	2007
	e) GPS modernization;	2007
	f) GLONASS modernization; and	2007
	g) Galileo.	2007



NSP ...

ANC Task No.	Work Programme Item	Estimated Completion Date
CNS-9401 (<i>cont'd</i>)	3) Develop guidance material for inclusion in various ICAO documents to support operational implementation strategies for advanced applications and elements identified in Tasks 1 and 2.	Ongoing



NSP ...

ANC Task No.	Work Programme Item	Estimated Completion Date
CNS-03xx	<p>4) Address technical and operational issues related to navigation aids and develop material, as necessary, to ensure their compatible operation and integration with evolving GNSS including:</p> <p>a) application of GNSS and other navaids in support of RNAV and RNP;</p>	<p>Ongoing</p> <p>(5/9)</p>



NSP ...

ANC Task No.	Work Programme Item	Estimated Completion Date
CNS-03xx (<i>cont'd</i>)	b) GNSS integration with other navigation systems;	2005
	c) review Annex 10 SARPs for ground-based radio navigation aids;	2005



NSP ...

ANC Task No.	Work Programme Item	Estimated Completion Date
CNS-03xx (<i>cont'd</i>)	d) NOTAMs status monitoring/ knowledge of aircraft navigation performance/service levels;	2005/2007
CNS-9402	e) testing of radio navigation aids.	2005/2007

(7/9)



NSP ...

ANC Task No.	Work Programme Item	Estimated Completion Date
CNS-9401	5) Identify, as required, elements, functions, implementation and operation aspects of GNSS that could have institutional implications.	Ongoing

(8/9)



NSP

ANC Task No.	Work Programme Item	Estimated Completion Date
CNS-7002	6) Develop, as necessary, material to protect RF spectrum required to support present and future aeronautical applications of GNSS and other radio navigation systems in close co-ordination with the frequency management activities being progressed by ACP.	Ongoing

(9/9)



PANS-OPS requirements for GNSS-based IFR operations

- **Installation certified and approved for intended operation**
- **Equipment is serviceable**
- **Equipment operated in accordance with aircraft operating manual**
- **NOTAM reviewed prior to operation**
- **Pilot/crew has knowledge of equipment operation**
- **RAIM prediction available**
- **Back-up procedures in place**
- **Database correct and current**



Operational issues

- PANS-OPS criteria for basic GPS, GBAS and SBAS (departure criteria only) are available
- Criteria for SBAS approach procedures under development
- Charting requirements are available



OCP work programme (extracts)

ANC Task No.	Work Programme Item	Estimated Completion Date
OPS-8502	<p>Development of procedures for GNSS for inclusion in PANS-OPS, Volumes I and II, based on:</p> <ol style="list-style-type: none"> 1. GNSS, including: <ol style="list-style-type: none"> a) SBAS RNAV in support of departure and arrival operations b) SBAS RNAV in support of APV basic operations c) SBAS RNAV in support of CAT. II and III operations d) Basic GNSS fix tolerance issues 	<p>2005</p> <p>2005</p> <p>2007</p> <p>2005</p>



WGS-84 issues ...

- Accurate satellite navigation is only possible when the ground-derived coordinates, calculated coordinates, and the satellite system-derived coordinates use the same geodetic reference system
- In support of evolving satellite-based technology, ICAO adopted WGS-84 as the common geodetic reference datum for civil aviation with an applicability date of 1 January 1998 (Annex 15)
- Provisions for vertical component added with applicability date of 5 November 1998



WGS-84 issues ...

- The responsible agency for geographic coordinates of a State is usually the national mapping or surveying agency
- The geodetic datums referred to various stations are horizontal datums
- The world's vertical datum is considered to be mean sea level (MSL), to which all elevations are referenced
- There are in excess of 150 different geodetic datums in use throughout the world



WGS-84 issues ...

- **Transition path to WGS-84**
 - transformation
 - surveys
- **Conversion of current coordinates to WGS-84 format can be carried out by the software programme such as MADTRAN (US) or DATUM (Europe)**
- **ICAO has prepared detailed guidance material on establishing WGS-84 (Doc 9674)**
- **ICAO website related to WGS-84 (test site to be made available in Dec. 2004) provides all relevant information such as SARPs, Annexes, requirements, implementation status and provision of technical assistance**



WGS-84 issues

(Appendix 5 to Annex 11 — accuracy requirements)

- Outside control area
 - FIR, prohibited areas
 - 2 km
- Inside control area
 - navigational aids/fixes
 - holding SID/STAR
 - 100 m
- Final approach fixes/final approach points
 - 3 m



WGS-84 issues — airline concerns

- Airlines are concerned not only with the availability of coordinates to support GNSS operators but also the quality of the coordinates
- Use of GNSS in mixed datum, e.g. the difference between latitude and longitude of a point as referred to local datum and WGS-84 in the Asia/Pacific area ranges from approximately less than 1 – 11 seconds in latitude and from 4 – 11 seconds in longitude
- States should provide the WGS-84 coordinates to preclude an operator from having to make transformation



GNSS satellite constellations

Update ...

➤ GPS

- additions of new signals on L2 at 1227 MHz by 2004 and L5 at 1176.45 MHz by 2006 for civil use (improves accuracy, Ionospheric corrections, availability and interference)
- increased constellation from present 30 to 36 satellites (improves availability, accuracy and geometry)
- increased satellite power (improves availability).
- anti-jam capability (improves availability)

(1/3)



GNSS satellite constellations

Update ...

➤ GLONASS

- plans to expand up to 18-20 satellites by 2005, including GLONASS-M
- enhanced data structure for combined use of GPS/GLONASS
- improved stability of space segment
- new signal on L2 for civil use
- additional signal power on L2
- plans for GLONASS-K after 2010



GNSS satellite constellations

Update

- **GALILEO (an emerging system)**
 - **proposed 30 MEO satellites**
 - **GEO satellite as a complement to regional enhancement**
 - **development and validation 2002-2005**
 - **deployment 2006-2008; FOC: 2008**
 - **civil controlled: liability and certification issues being addressed**



Second civil frequency

- Major issues can be addressed
 - ionospheric corrections
 - susceptibility to interference
- Advantages expected
 - direct measurement of ionospheric errors in user equipment
 - signal redundancy
 - increased signal strength
 - reduced dependency on external augmentations



Need for multi-modal airborne landing capability

- **For the foreseeable future, a number of landing systems will be in service:**
 - **ILS**
 - **GNSS**
 - **MLS**
- **To meet the precision approach requirements globally, airlines are required to carry both current and new systems**
- **MMR (Multi-mode receiver) is the solution to interface all the systems**



Advantages of MMR ...

- MMR is a universal flight-critical interface between current aircraft guidance control systems and existing future landing guidance sensors (ILS/MLS/GNSS)
- ILS lookalike operations and architecture for all the landing modes
- Cost-effective solution for transitions to MLS/GNSS
- Minimum operational dislocation



Advantages of MMR

- Meets specifications of RNP
- No modifications to existing aircraft architecture
- Minimal pilot retraining as operational procedures are unchanged
- Certifiable for all categories of landing for ILS & MLS; expected to be certifiable for all categories of GNSS
- As such, MMR is an excellent interface for the present and future systems

(2/2)



Global strategy for implementation of non-visual aids to support precision approach, landing & departure operations*...

- a) continue ILS operations to the highest level of service as long as operationally acceptable and economically beneficial;**

Proposed by AN-Conf/11 (Montreal, Sept/Oct. 2003) and approved by the Commission for its incorporation in Annex 10, Volume 1



Global strategy for implementation of non-visual aids to support precision approach, landing & departure operations ...

- b) implement MLS where operationally required and economically beneficial while making every effort to ensure airport access is not denied to ILS-equipped aircraft;**
- c) implement GNSS with augmentation as required for APV and Category I operations where operationally required and economically beneficial;**

(2/4)



Global strategy for implementation of non-visual aids to support precision approach, landing & departure operations ...

- d) promote the development and use of a multi-modal airborne landing capability;**
- e) promote the use of APV operations, particularly those using GNSS vertical guidance, to enhance safety and accessibility;**



Global strategy for implementation of non-visual aids to support precision approach, landing & departure operations

- f) identify/resolve operational and technical feasibility issues for GNSS with GBAS to support Category II & III operations. Implement GNSS for Category II & III operations where operationally required and economically beneficial; and**
- g) enable each region to develop an implementation strategy for these systems in line with the global strategy**

(4/4)



Supplemental-means GNSS

- Supplemental-means GNSS must meet accuracy and integrity requirements for a given operation or phase of flight; availability and continuity requirement may not be met
- Other navigation systems supporting a given operation or phase of flight must be on board



Primary means of GNSS

- Primary-means GNSS must meet accuracy and integrity requirements, but need not meet full availability and continuity of service requirements for a given operation or phase of flight
- Safety is achieved by limiting operations to specific time periods and through appropriate procedural restrictions. Other navigation system can be retained on board to support the primary means GNSS



Sole means of GNSS

Sole-means GNSS must allow the aircraft to meet, for a given operation or phase of flight, all four requirements:

- accuracy
- availability
- integrity
- continuity of service



GNSS & RNAV operations

- In the future when GNSS will meet requirements concerning reliability, integrity and accuracy, it will be used as sole mean of navigation
- RNAV, based on GNSS and established RNP values, will allow increased capacity through reduced separation minima



Impact of satellite navigation on TMA operations

CURRENT

- NDB
- VOR
- DME
- ILS
- INS/IRS
- BARO ALT.
- VOR/DME
- RNAV



CNS/ATM ENVIRONMENT

- GNSS
- RNAV/RNP
- SBAS/GBAS/
GRAS
- BARO. ALT



RESULT

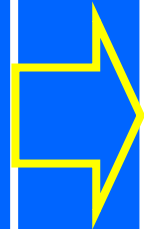
- More accurate navigation
- Increased airspace capacity



Impact of satellite navigation on en route operations

CURRENT

- NDB
- VOR
- DME
- VOR/DME
- LORAN
- INS/IRS
- BARO. ALT



CNS/ATM ENVIRONMENT

- RNAV/ RNP
- GNSS
- INS/IRS
- BARO. ALT



RESULT

- Increased capacity
- More accurate navigation data
- More flexible airspace design
- More closely spaced routes



Impact of satellite navigation on oceanic operations

CURRENT

- INS/IRS
- LORAN
- BARO. ALT



CNS/ATM ENVIRONMENT

- INS/IRS
- GNSS
- BARO ALT



RESULT

- More accurate navigation data
- Reduced separation minima
- Increased airspace capacity



Impact of satellite-based navigation on ATM

CNS/ATM Functions

- GNSS
- ILS
- MLS
- RNP/RNAV

CURRENT

- NDB
- VOR/DME
- ILS

Technical elements + Procedural aspects

AIR

- GNSS receiver
- ILS
- MLS
- FMS
- MMR

GROUND

- ILS
- MLS
- Augmentation systems

STRUCTURE

- Application of RNP
- Airspace organization including separation criteria
- RNP certification/approval

PROCEDURES

- Approach procedures

BENEFITS

- Increase airspace capacity by reduction in separation minima due to increased positional accuracy
- Improved airspace utilization



Benefits of GNSS

- Improved accuracy and high integrity
- Four-dimensional navigation
- Single set of avionics
- Improved runway utilization
- Increased airspace capacity
- Reduced separation minima
- Reduced ground-based NAVAIDS



Trends in implementation

- GPS-based operations spreading (en route, NPA)
- Augmentations development progresses but with delays
- GNSS (GPS) vulnerability recognized
- “Sole means” concept no longer advocated
- Development of new GNSS elements advances (GPS L5, Galileo)
- Marginal user support for SBAS and GBAS services



Navigation – the future ...

- Transition to satellite navigation is a long-term commitment
- ICAO and industry standards available to support near-term and mid-term applications
- SBAS service, GBAS stations and respective avionics will be generally available in the near term
- Near-term focus to continue on approvals for en route (oceanic and remote), terminal and NPA operations using basic GPS avionics
- Mid-term focus on SBAS-based APV and GBAS-based PA Category I

(1/2)



Navigation – the future

- **Two core satellite systems and dual frequency operations to begin beyond 2010**
- **User community commitment to transition is crucial factor**
- **ICAO 11th Air Navigation Conference (22 September – 3 October 2003) reviewed GNSS status and navigation policy issues**

(2/2)



Surveillance



Types of surveillance

- **Independent surveillance**
 - **PSR (Primary Surveillance Radar)**
- **Cooperative independent surveillance**
 - **SSR (Secondary Surveillance Radar)**
 - **Conventional SSR**
 - **Monopulse SSR**
 - **Mode S SSR**
- **Automatic Dependent Surveillance(ADS)**
 - **ADS-C (Contract) also known as ADS-A (Addressed)**
 - **ADS-B (Broadcast)**



Primary radar

- Received signal = echo + noise + clutter
- PSR offers: range, azimuth
- PSR limitations: identification? FL?
- Solution: SSR
- No airborne equipment required
- Enroute PSR range is 200 NM and Terminal PSR is 60 NM
- Use of PSR for en route airspace is declining



Secondary radar

- **SSR characteristics:**
 - **line of sight**
 - **need for airborne transponder**
 - **position information: range and azimuth**
 - **ID (Mode A) and FL (Mode C)**

- **Types of SSR**
 - **conventional SSR (No longer in use)**
 - **monopulse SSR**
 - **SSR Mode S**



Monopulse SSR

- Very widely used world over
- Uses Mode A and C
- **FRUIT**-False replies unsynchronized in time (ie replies coming from interrogations generated by other ground stations giving rise to false targets) and **Garbling** (two closely spaced aircraft replying to same interrogation) not eliminated entirely
- Shortage of Mode A codes
- Very limited downlink data link
- Can be upgraded to Mode S



SSR Mode S...

- **Improved version of SSR**
- **Selective addressing – individual interrogation to reduce problems of garbling experienced in M SSR**
- **Elimination of Mode A code shortages**
- **Compatible with SSR Mode A/C**
- **Altitude data in 25-foot increments**

(1/2)



SSR Mode S

- **Improved accuracy**
- **Supports air/ground data link for enhanced surveillance**
- **Short squitter of Mode S supports ACAS II implementation**
- **Extended squitter of Mode S supports ADS-B application**

(2/2)



Comparison of SSR characteristics

OPERATIONS	Conventional SSR	Monopulse SSR	SSR Mode S
Replies per scan	20 – 30	4 – 8	1
Range accuracy (rms)	230 m	13 m	7 m
Bearing accuracy (rms)	0.08°	0.04°	0.04°
Height resolution	100 ft	100 ft	25 ft
Garble resistance	Poor	Good	Best
Data capacity (uplink)	0	0	56 – 1 280 bits
Data capacity (downlink)	23 bits	23 bits	56 – 1 280 bits
Number of codes/ Addresses available	4 096	4 096	> 16 million



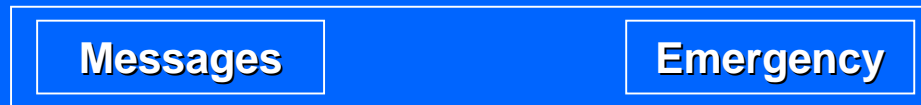
Automatic dependent surveillance (ADS)

- **A surveillance technique for aircraft**
- **Requires a data link, on-board navigation and a position-fixing system**
- **Provides aircraft identification, 4-D position and additional data as appropriate on a one-to-one basis**
- **ATC will get a radar-like picture**
- **Also known as ADS-A (addressed) or ADS-C (contract)**



ADS functions

Pilot interface



Avionics



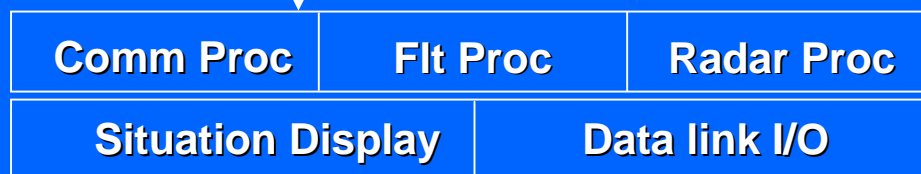
Data link



Communication



ATC automation



Controller interface



Automatic dependent surveillance – broadcast (ADS-B) ...

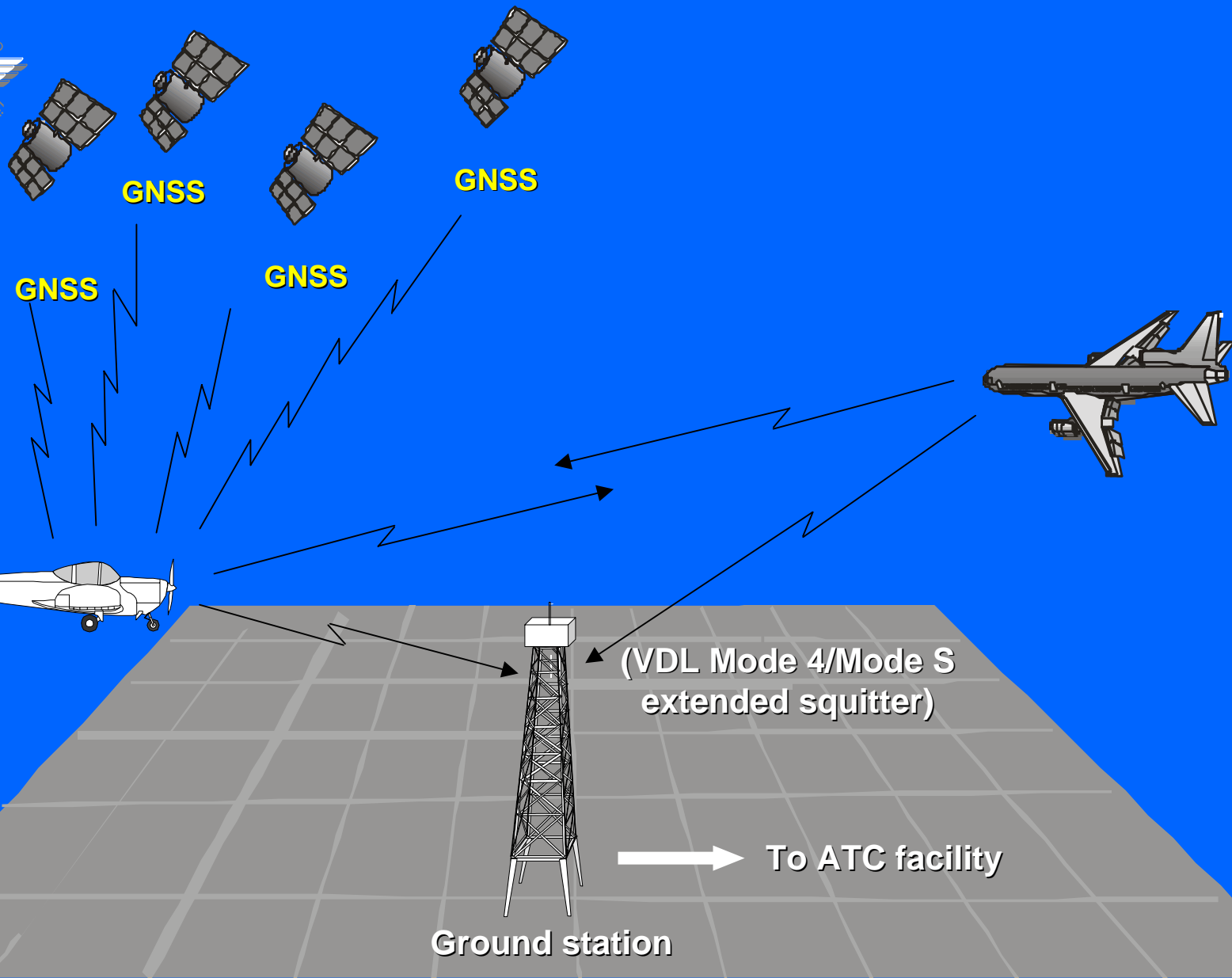
- **A surveillance technique for aircraft and ground users (like vehicles)**
- **Requires a data link and on-board navigation system**
- **Provides parameters such as position, track and ground speed via a broadcast mode at specified intervals**
- **Applications for air/ground, ground/ground and air/air surveillance**
- **Mode S extended squitter, Universal Access Transreceiver and VDL Mode 4 (STDMA) are three candidate technologies for ADS-B** (1/2)



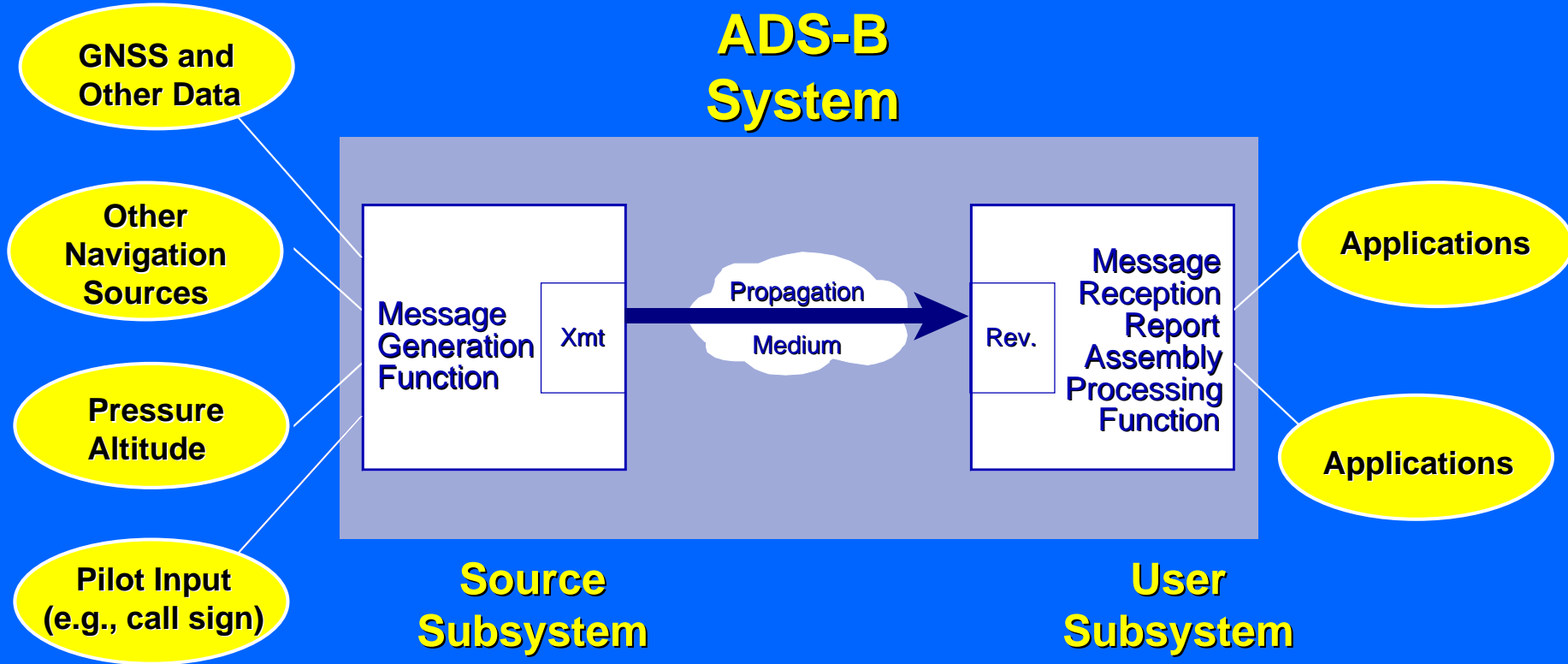
ADS-B

- Aircraft broadcasts position (based on GPS or INS) to all listeners, to both ground ATC and other aircraft
- Ground-based receiver stations collect position information
- Position information can be used to simulate radar-type surveillance for ATC use
- Aircraft operators can use position data for more precision aircraft dispatching
- Other aircraft use position information for traffic display/collision avoidance

(2/2)



Automatic dependent surveillance – broadcast



Functional relationship between ADS-B and surveillance applications



ADS-B capability ...

- The transponder pseudo-randomly “squits” (broadcasts):
 - ADS airborne position report (Lat, Lon, Alt, Time)
 - approximately twice per second
 - Flight identification report (8 characters, alphanumeric)
 - approximately once every 5 seconds
 - ICAO aircraft address (24-bit aircraft ID)
 - approximately once per second

(1/2)



ADS-B capability

- **The transponder receives broadcast uplinks:**
 - **GPS differential corrections (for all satellites in view)**
 - **approximately twice per second**



A-SMGCS

- An advanced surface movement guidance and control system (A-SMGCS) is a fusion of radar and air field lighting technologies
- Used for routing, guidance, surveillance and control of aircraft and vehicles on the ground
- Maintain acceptable movement rates under all weather conditions, while improving the required level of safety



CNS evolution

CURRENT SYSTEMS		→	NEW SYSTEMS
Communication	<ul style="list-style-type: none"> ➤ VHF voice ➤ HF voice 		<ul style="list-style-type: none"> ➤ VHF voice and data ➤ HF voice and data ➤ AMSS voice and data ➤ SSR Mode S data ➤ ATN
Navigation	<ul style="list-style-type: none"> ➤ MNPS ➤ Barometric altimetry ➤ INS/IRS ➤ ILS/MLS ➤ OMEGA/LORAN- C ➤ NDB ➤ VOR/DME 		<ul style="list-style-type: none"> ➤ MNPS/RNP/RNAV ➤ Barometric altimetry ➤ INS/IRS ➤ GNSS
Surveillance	<ul style="list-style-type: none"> ➤ PSR (ASDE/ASR/ARSR) ➤ SSR Mode A/C ➤ Voice position reports on oceanic & remote areas 		<ul style="list-style-type: none"> ➤ ADS (VHF); ADS-B ➤ SSR Mode A/C; SSR Mode S ➤ ADS (HF/satellite)



Spectrum Issues



Civil aviation use

Radio Frequency Spectrum Percentage (%)

	LF	MF	HF	VHF	UHF	SHF	Total
COM	-	2.2	6.9	6.5	0.6	-	2.9
NAV	7.1	14.8	-	4.1	12.5	1.0	6.2
SUR	-	-	-	-	6.2	8.6	3.2
TOTAL	7.1	17.0	6.9	10.6	19.3	8.6	11.8



Spectrum regulatory aspects

- **Current allocations**
- **Allocations to support system**
- **Enhancements and expansion**
- **Compatibility issues**



ITU trends

- **Fast progress and growth in public communications**
- **Regional development of proposed solutions**
- **Increased frequency of the World Radio Conferences (WRC)**
- **Growing pressure on aeronautical spectrum**
- **ICAO activities in ITU**
 - **Assembly Resolution A32-13**
 - **timely development of ICAO position**
 - **aviation participation at WRCs**



Main spectrum issues in ITU...

- **Potential allocation to the MSS in the band 1559-1610 MHz**
- **ICAO position:**
 - **total band 1559-1610 MHz is required for current and future GNSS**
 - **sharing with MSS will cause unacceptable degradation and restrictions on GNSS systems**
 - **no allocation to MSS in the band**

(1/3)



Main spectrum issues in ITU...

- **Use of the band 1559-1610 MHz by fixed service**
- **ICAO position:**
 - **fixed service is not compatible and cause interference to GNSS**
 - **exclude the band 1559-1610 MHz from allocation to fixed service**

(2/3)



Main spectrum issues in ITU

- **New allocation to RNSS in the ARNS band 960-1215 MHz**
- **ICAO position:**
 - **studies allocation should not interfere with present ARNS systems**
 - **compatibility to continue**

(3/3)



Interference issues

- In-band interference
- Out-of-band interference
- On-board sources
- Intentional interference



Interference monitoring & mitigation

- States to ensure freedom from interference
- Monitoring activities:
 - inspections
 - ground monitoring
- Mitigation techniques:
 - integration of navigation sensors
 - technological enhancements
 - frequency management and coordination



Future work on spectrum issues

- **Compatibility criteria for GBAS in the 108-117.975 MHz band**
- **Studies of potential sources of interference (e.g. ultra wide band systems, out-of-band sources)**
- **Compatibility of newly allocated RNSS with present allocations**
- **Termination of interfering services and sources affecting GNSS operation**
- **Participate in ITU activities**



Follow-up

- Global coverage and performance to support all phases of flight are dependent upon resolution of spectrum issues
- States are to ensure freedom of RF interference when approving GNSS operations
- GNSS RF spectrum protection requires coordinated effort by States and ICAO



ICAO's role

- Analyze the agenda of WRC's (World Radio Communication conferences)
- Develop the ICAO position
- Work with ITU and Regional Telecommunications Organizations (APT, CEPT, CITELE, ...)
- Submit the position (approved by the Council) to States and ITU
- Participate in WRCs



What is expected from States?

- Assist in the development of the ICAO position
- Participate with aviation experts in the work of ITU and Regional Telecommunications Organizations
- Send aviation experts to WRC's (A32-13)
- Support ICAO position (Assembly Resolution A32-13)
- Next WRC is scheduled in 2007



An update on spectrum issues

- **Aeronautical Communications Panel (ACP) to draft ICAO position for WRC-2007 by October 2004.**
- **The Air Navigation Commission (ANC) is scheduled to finalize the draft in early 2005 and seek approval by the Council**
- **The approved ICAO final position will be subsequently sent to States**



SARPs

Development for CNS/ATM Systems



Panels and study groups directly involved in CNS/ATM-related activities ...

Panels of the ANC

ACP	Aeronautical Communications Panel
ATMCP	Air Traffic Management Operational Concept Panel
NSP	Navigation Systems Panel
OCP	Obstacle Clearance Panel
OPLINKP	Operational Data Link Panel
OPSP	Operations Panel
SASP	Separation and Airspace Safety Panel
SCRSP	Surveillance and Conflict Resolution Systems Panel



Panels and study groups directly involved in CNS/ATM-related activities

AN Study Groups

ADMSG	Aeronautical Data Modeling Study Group
AISMAPSG	Aeronautical Information and Charts Study Group
AUPISG	Aviation use of the Public Internet Study Group
HFSG	Flight Safety and Human Factors Study Group
HRPTSG	Human Resource Planning and Training Study Group
METLINKSG	Meteorological Information Data Link Study Group
RNPSORSG	RNP and Special Operational Requirements Study Group



SARPS development progress management domain ...

Element	SARPs Development
Global ATM	2005
RTSP	2005
ATM requirements for CNS	2004
ATS applications for air-ground data links	2005
Data interchange between automated ATS systems	2004



SARPS development progress management domain

Element	SARPs Development
Interoperability and functional integration of flight operations, ATS, ATFM and ASM	2005
Separation between aircraft	2005
ATFM systems and procedures	2005
ATS (uplink of MET data)	2004



SARPS development progress – infrastructure domain ...

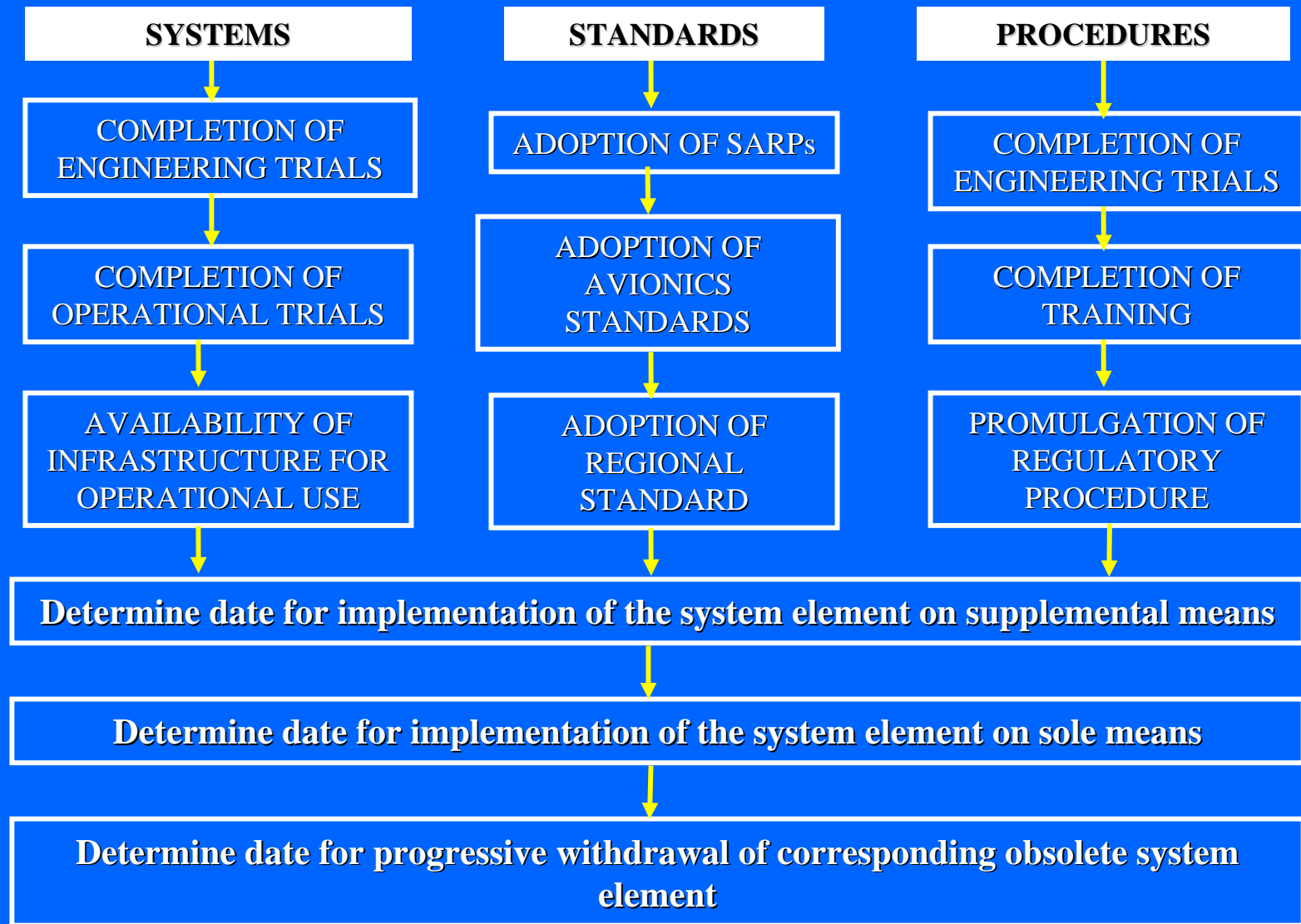
Systems		SARPs Development
Communications	1. AMSS	Completed
	2. HF and VHF	Completed
	3. SSR Mode S	Completed
	4. ATN	Completed
	5. UAT	2007



SARPS development progress – infrastructure domain

Systems		SARPs Development
Navigation	1. WGS 84	Completed
	2. Aeronautical data bases	2005
	3. GNSS +ABAS+ SBAS+GBAS	Completed
	4. GRAS	2005
	5. GALILEO/GLONASS M/ GPS second civil frequency	2007
	6. GNSS(CAT II/III, curved approaches, A-SMGCS)	2007
Surveillance	1. ADS procedures	2004
	2. SSR Mode S	Completed
	3. ADS-B and equivalent	2005

Element of CNS/ATM



Milestone determination

