SIP/2009-WP/17
Emerging
Technologies

# Global Air Navigation System Performance Based Air Navigation Emerging Technologies

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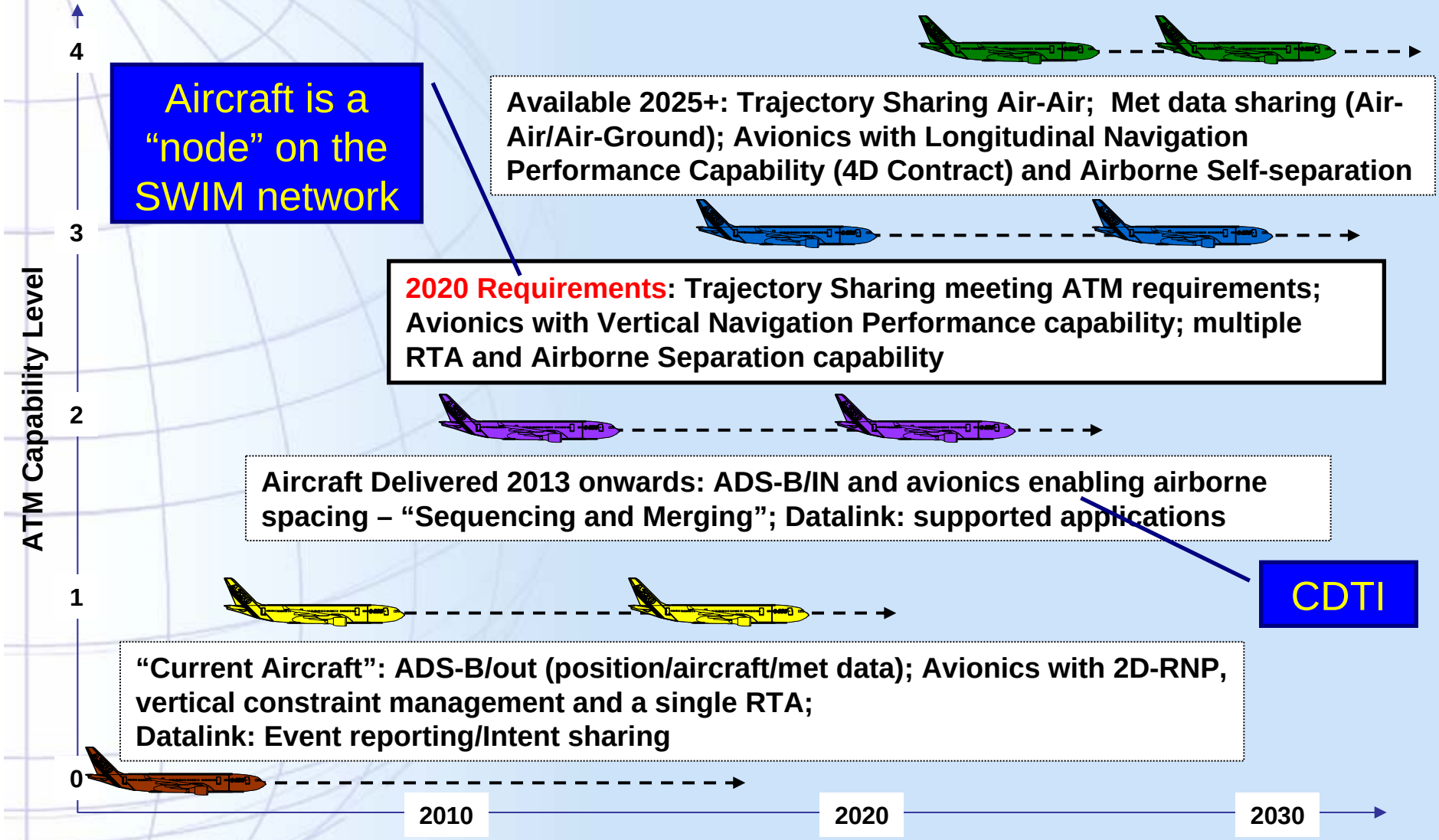
**International Civil Aviation Organization**

**Workshop on the Development of National Performance Framework to achieve a Global ATM System (Mexico City, 6-10 July 2009)**

# ATM Capability Levels



# User Vision on ATM 2020+ (amongst others)

- The future ATM Network will be 4D trajectory based
  - Collaborative Planning resulting trajectories reflecting user intentions
  - Once agreed A/C flies FMS trajectories, negotiated, updated in real-time
- The system is based on System Wide Information Management and Collaborative Decision Making meaning:
  - All actors have access to all relevant information
  - Decisions driven by common situational awareness
  - CDM introduce airports and airspace users in ATM decision process
- Uncertainty in ATC ground based trajectory prediction is reduced by:
  - A/C derived information or 4D-trajectories sourced by AOC or by the onboard aircraft systems
  - ATM Network shall make full use of the ATM capabilities of modern aircraft

# NextGen & SESAR

- SESAR and NextGen both based on full 4D Trajectory Based Operations
- TBO entails the systematic sharing of aircraft trajectory data between various participants in the ATM process from planning and execution phases
- All ATM decision making and tactical operations based on most recent data available.
- A reference trajectory integrating applicable ATM/Airports agreed before flight and executed with the required precision in all 4 dimensions.
- Trajectories are shared and updated from the source(s) best suited to the prevailing operational circumstances.

# A Trajectory Based Environment

- Trajectory based operations
  - A new approach to airspace design and flexible airspace management
- Business Trajectory ownership
  - User involvement in decision making processes
  - Users determine how constraints shall be applied whenever possible
- Trajectory management
  - An agreed 4D trajectory for each flight – as close as possible to the user preferred trajectory which may include cruise climb - route structures only deployed when/where essential for capacity reasons.
  - Authorised by controllers using new separation modes or executed by the flight crew using airborne separation modes
  - Executed with an agreed precision
  - Trajectory revisions respect the concept of ownership
  - 4D trajectories are the principle language for information sharing

## NextGen Goal

**Achieve a Next Generation Air Transportation System that meets the nations's future air transportation safety, security, mobility, efficiency, and environmental needs**

## SESAR Goal

**To achieve a performance-based European ATM System, built in partnership, to best support the ever increasing societal and States' (including military) expectations for air transport with respect to the growing mobility of both citizens & goods and all the other aviation activities, in a safe, secure & environmentally sustainable & cost-effective manner**

# Summary of Key Characteristics for NextGen and SESAR

- Shift to increase User Focus
  - User preferences and business models
- Distributed and Collaborative Decision-Making
  - Distributed, but optimize on Network Plan
- Implement Just Safety Culture/Safety Management
- Take advantage of Automation; Tailor automation to assist humans
  - Human role will shift to ATM, with less emphasis on tactical control
- Reduce Impact of Weather
  - Equivalent Visional Ops for NextGen
  - 80% equivalence for SESAR
  - Common weather picture and improved decision support
- Migrate to digital and satellite-based technologies

# Similarity in Regional Environment

- Pressures
  - Growth-Capacity Conflict
  - Environment
  - Affordability
- Commercial Customers
- Obligations
  - ICAO Oversight
- Opportunities
  - Advances in Technology
  - Procedure Improvement

# Differences in Regional Environment

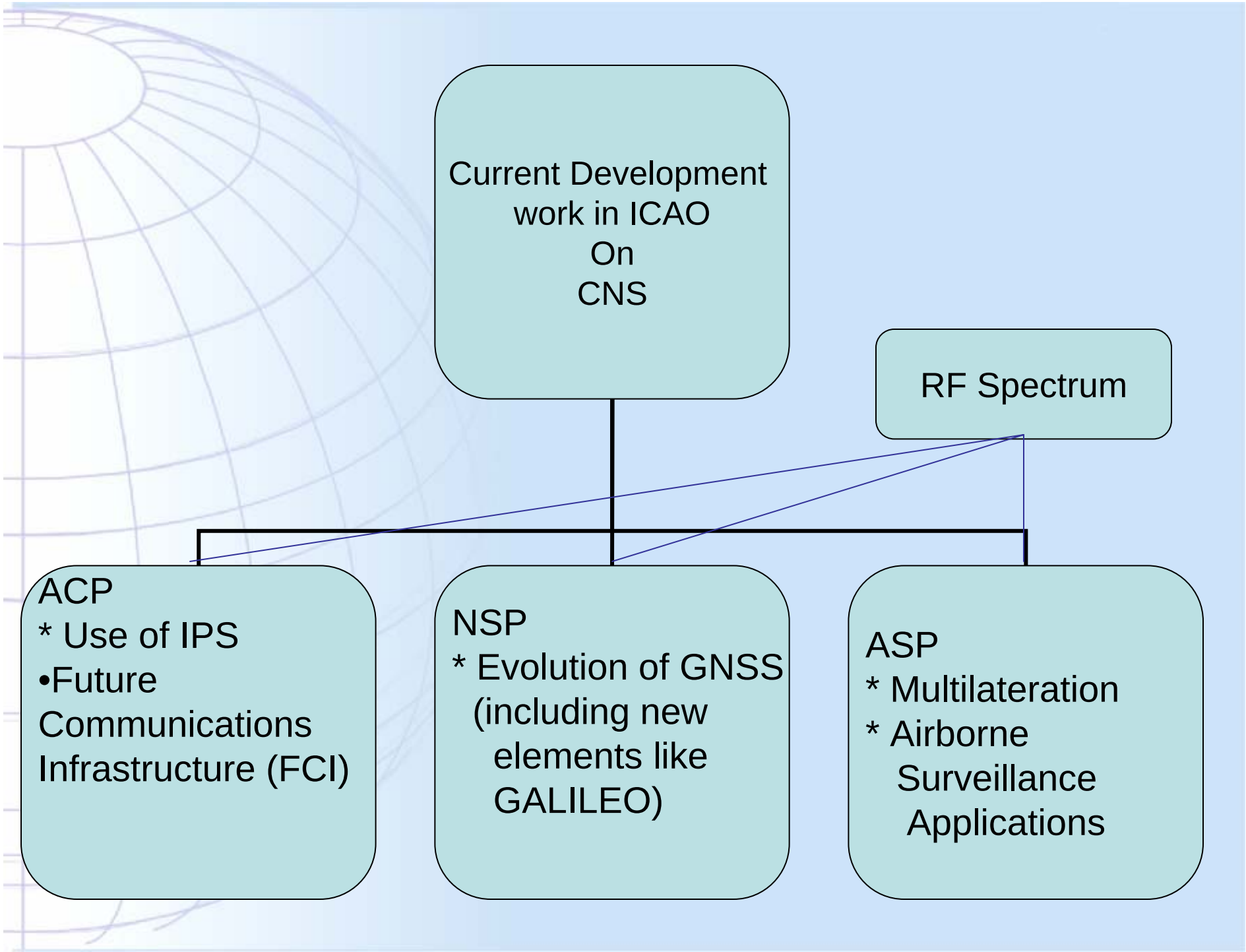
- Geography
  - Weather problem
  - Traffic distribution/density
- ATM Service
  - Number of Service Providers
  - Source and methods of Finance
- Market
  - General Aviation
- Culture and Politics
  - Number/Diversity of States

# NextGen & SESAR Objectives are Similar

- Expand Capacity
- Global Aviation Harmonization
- Ensure Safety (with increasing capacity)
- Protect the Environment
- Improve Service for Aviation Customers

# NextGen Construct differs from SESAR

- Institutional
  - U.S. Government is ANSP (won't change any time soon)
  - FAA funding is not cost-based
  - FAA includes regulation and service provision
- Different stakeholder balance
  - Major lobbies for GA and business users, single military presence
- Scope:
  - NextGen curb-to-curb, security, …
- Industry involvement different
  - NextGen is more government owned and driven
  - Industry participation is through the NGATS Institute to avoid competitive issues


Current Development work in ICAO On CNS
RF Spectrum
ACP
* Use of IPS
•Future Communications Infrastructure (FCI)
NSP
* Evolution of GNSS (including new elements like GALILEO)
ASP
* Multilateration
* Airborne Surveillance Applications

# RADIO FREQUENCY SPECTRUM

- **Develop ICAO Policy for WRC-2011**
  - ✓ **Development of ICAO policy and other provisions to ensure the availability of sufficient spectrum for current/future CNS systems as well as for their protection against electromagnetic interference.**
  - ✓ **Update the ICAO RF Handbook accordingly**

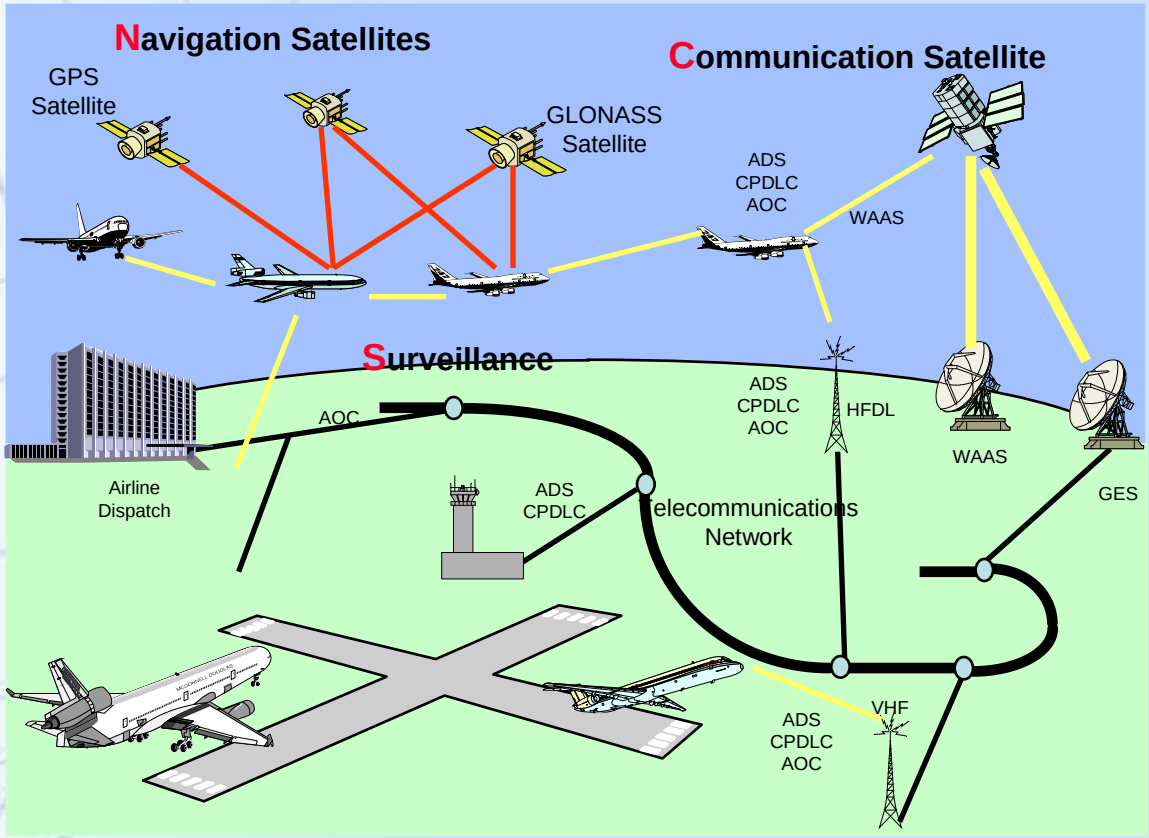
-

# SURVEILLANCE
## (SITUATIONAL AWARENESS)

- High level SARPs for multilateration systems
  - ✓utilizing the work of EUROCAE
  - ✓centred around the protection of the RF environment (1030/1090 MHz) and performance
- Airborne surveillance applications
  - ✓operational use of ADS-B IN reports in the cockpit

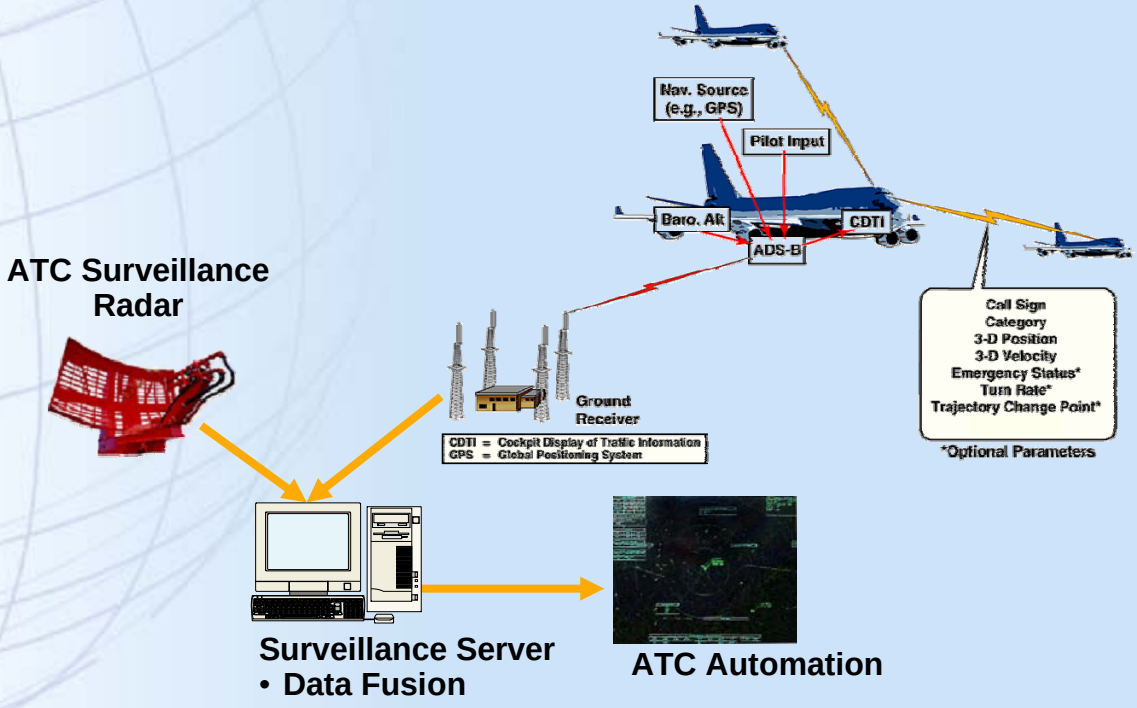
# Surveillance Environment

Separation assurance using radar, FANS, or procedural.
TCAS for collision avoidance.



# Surveillance Evolution

- ADS-B proposed for two categories of applications
  - Ground surveillance using ADS-B-out
  - Airborne surveillance using ADS-B-In and CDTI



# ADS-B Equipage

**Mode S**

**ADS-B Out**

**ADS-B In**

**Mode A /C Mode S**

*Altitude*
*Code*
*AC Addr*

Interrogated data

**Elementary Mode S**

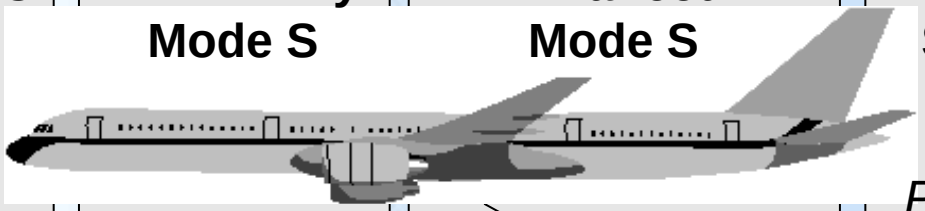
*Flight ID*

Interrogated data

**Enhanced Mode S**

*Selected Alt .* *TAS*
*Mach No .* *IAS*
*Mag. Hdg.* *GS*
*Roll Angle* *VS*
*Track Angle*
*Track Angle Rate*

Interrogated data



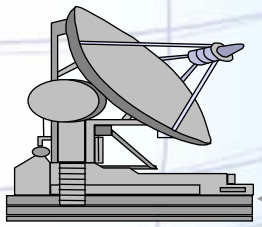
**Extended Squitter**

*Position*
*Velocity*
*Flt ID*

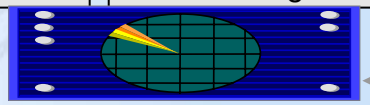
ADS-B Broadcast data

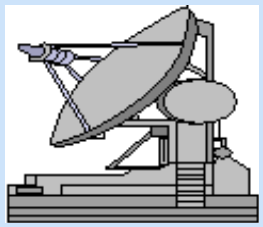
**ADS-B/CDTI Applications**

- *Surface Surveillance*
- *In Trail Procedures*
- *Sequencing & Merging*
- *Etc. (Package 1)*



***RADAR***





***RADAR***

***AIR TRAFFIC CONTROL***

# ASAS Self Separation

**Nextgen and SESAR both plan to migrate Separation method from ATC as done today, progressing to airborne self-separation**

- **NextGen (EN-0032) Self Separation timeline 2022**
- **SESAR timeline is IWP3; post 2020**

# Airborne Separation Assistance System (ASAS)

- "Application" is an industry-selected term
  - Each application considered here is a procedure supported by ADS-B surveillance on the flight deck
- Application categories under current consideration:
  - Situational awareness enhancement
    - In-Trail Procedures in procedural airspace (ITP)
    - Enhanced Visual Separation on approach (VSA)
    - Enhanced Visual Acquisition
    - Traffic Situation Awareness – airborne and on airport surface
  - Spacing from other aircraft
    - Sequencing & Merging – ASAS version
    - Merging and Spacing – UPS/FAA version
  - Separation assurance from other aircraft
    - Flight crews accept responsibility for separation from other aircraft
- Display Integrated in Forward Field of View (FFOV) is generally preferable for CDTI applications although some situational awareness and spacing applications could be on non-FFOV display.

# NAVIGATION

- Evolution of existing GNSS (GPS & GLONASS)
- - dual frequency SBAS
- - multi-frequency GPS & GLONASS
  - CAT II / III GBAS
- * New GNSS elements such as GALILEO
- Implementation strategy
- - involving ground and satellite-based systems

# Planned GNSS

- Global Constellations
  - GPS (US)
  - GLONASS (Russia)
  - Galileo (EU)
  - Compass (China)
- Regional Constellations
  - QZSS (Japan)
  - IRNSS (India)
- Satellite-Based Augmentations
  - WAAS (US)
  - MSAS (Japan)
  - EGNOS (EU)
  - GAGAN (India)

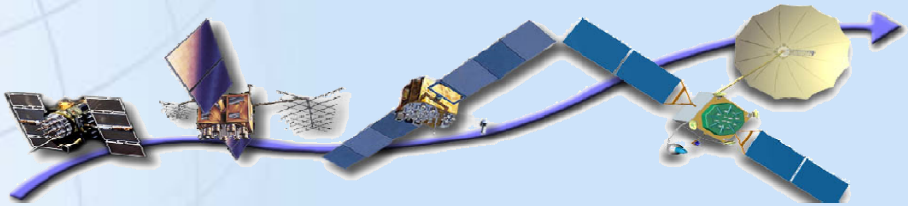
# All Segment – GPS Modernization

## Satellites

**Legacy (Block IIA/IIR)**
- Basic GPS
- C/A civil signal (L1C/A)
- Std Pos. Service
- Precise Pos. Service
  - L1 & L2 P(Y) nav

**Modernized (Block IIR-M)**
- 2nd civil signal (L2C)
- M-Code signals (L1M, L2M)

**Modernized (Block IIF)**
- 3rd civil signal (L5)



**GPS III (Block C)**
- Increased accuracy
- Increased signal strength
- Signal integrity
- Search and Rescue
- Common Galileo OS/GPS (L1C)

# Third Civil Signal (L5)

- Designed to meet demanding requirements for aviation safety
  - Uses highly protected Aeronautical Radionavigation Service (ARNS) band
- Wider bandwidth improves resistance to interference
- Signal Structure for enhanced performance
- Higher power than other GPS signals

- Increasing interoperability
  - Galileo E5a, GLONASS, Compass, QZSS, WAAS & other SBAS
- Demonstration signal in 2008
- 24 satellites by 2018

# COMMUNICATIONS

* Introduction of Internet Protocol Suite (IPS)

  - For G-G and A-G communications

  - Based on already available industry standards

  - Cost effective, proven and widely available

- * Future Communications Infrastructure (FCI)

  - various candidate technologies and frequency bands are being investigated

# ICAO
# Future Communications Study (FCS) Overview

# Presentation Outline

- FCS Study Background & Objectives
- FCS Considerations
- A Different Approach
- The Steps So Far
- General Conclusions
- Results – Technology Shortlist
- More Work Needed
- Next Steps

# FCS Background

## Drivers

- Aeronautical air-to-ground voice and data communications capacity in the VHF band for Air Traffic Management (ATM) is reaching saturation
  - Most severe in Europe and parts of the United States
    - Full implementation of 8.33 kHz channel spacing in Europe will only address frequency congestion up to 2020
    - 25 kHz channel spacing will support operation in the US until at least 2015
- New Applications anticipated by SESAR and NextGen will increase the demand for communications capacity.

## Action

- ICAO sought a common, global solution through the Aeronautical Communications Panel (ACP)
- FAA and Eurocontrol took part in a bi-lateral study of the problem

# FCS Objectives

- Identification of requirements and operating concepts
  - **DONE**
- Investigation into new mobile communication technologies
  - Technology Pre-Screening
    - **DONE**
  - Technology Alternatives Assessment
    - **DONE**
- Improvements to maximize utilisation of aeronautical spectrum resources
    - **On-going Activity**
- Industry involvement
    - **DONE and will continue**

QinetiQ

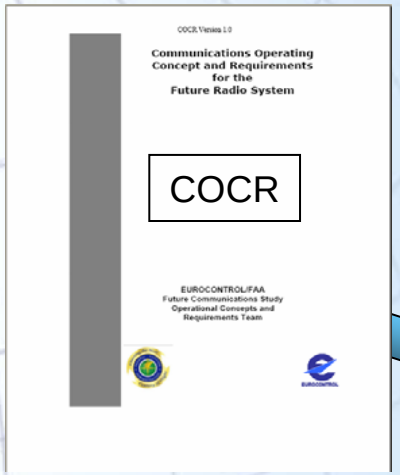
EUROCONTROL

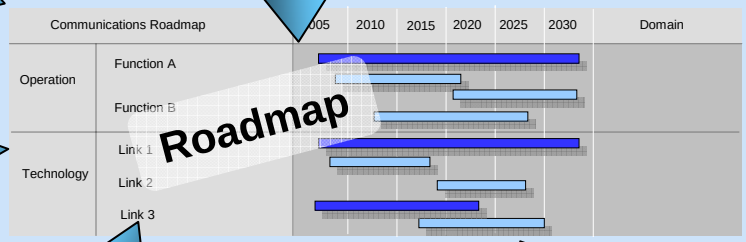
NASA

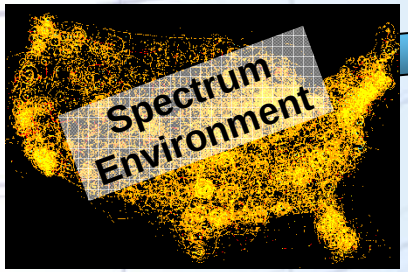
MITRE

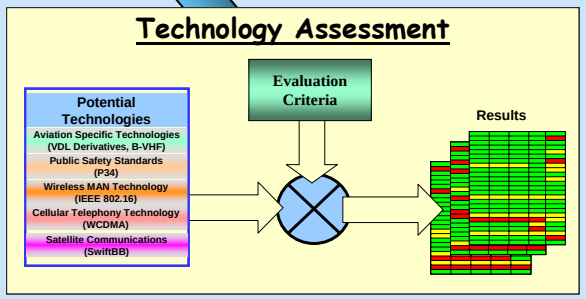
ITT Industries
*Engineered for life*

# FCS Considerations







# A Different Approach

- **This study was different.**

  ***Why?***

  – ***Industry participation….***

  – ***Operational concepts/requirements were developed out until 2020+***
    - ***Adding a dose of reality.***

  – ***Bi-lateral cooperation***
    - ***Parallel teams working independently with close coordination.***
      – ***Action Plan 17***

  – ***Multi-dimensional assessments that went beyond technical issues.***
    - ***Spectrum, institutional, cost (ground and air)***

# The Steps So Far

- **Technology Pre-Screening**
  - Completed in 2005
- **Phase II: Technical Evaluation**
  - Called for development of operating concepts and requirements
  - Result: The COCR defining communications until 2020 and beyond
  - Completed in 2006
- **Phase III: Detailed investigation of Institutional and Technical Issues.**
  - Completed in 2007
  - Result: Airport/Surface Environment **OK**
    Oceanic/En-route Environment: **OK**
    Continental/En-Route Environment: **More work needed**

# General Conclusions

- Sustain voice communications in VHF Band as long as possible
  - Make optimum use of current equipage
- 8.33 kHz channel spacing is an alternative when current 25 KHz spectrum no longer meets operational needs
- New technical solutions should be pursued only after all other solutions to extend the lifetime of current systems have been exhausted
- Aeronautical Data Link System (ADLS) is important
  - Use existing VHF capabilities / equipment to provide ADLS until Future Communications Study decisions and milestones are set
    - VDL Mode 2, 1090 MHz, Universal Access Transceiver (978 MHz)

# The Results - Technology shortlist

| NASA – ITT | Common Recommendations | | Eurocontrol |
|---|---|---|---|
| **Continental**<br>• INMARSAT Swift Broadband<br>• Custom Satellite<br>• Link 16 | • P-34<br>• Wideband CDMA<br>• L-band Datalink [(x)DL3] | • P-34<br>• Wideband CDMA<br>• L-band Datalink [(x)DL3] | **Continental**<br>• [(x)DL4] |
| **Oceanic** | • INMARSAT Swift Broadband<br>• Custom Satellite | • INMARSAT Swift Broadband<br>• Custom Satellite | **Oceanic** |
| **Airport** | • IEEE 802.16e | • IEEE 802.16e | • ADL **Airport** |

# The Results - Technology shortlist (2)

## Some Comments:

- The two teams, led by the FAA and Eurocontrol respectively, chose slightly different approaches to their assessment and hence there were differences in their final conclusions.
- This was not a problem as the teams did arrive at a common list of acceptable technologies.
  - Shown in the previous diagramme.

## *What issues were there??*

# More Work Needed?

## Why?

- **The Continental/En-Route environment proved challenging.**
- **The evaluation considered various factors:**
  - Technical – Range; Data rate, Availability, etc
  - Cost Models – number of facilities, sites, etc.
  - Interference to/from other aviation facilities
  - Institutional – maturity, certifiability, spectrum,
- **None of the short-listed technologies could meet all of the interference requirements in the chosen radio spectrum.**
  - DME and SSR main concerns.
- **No COTS technologies could be found which would meet all of the requirements**.

## What Next??

# Next Steps

- Further action on the part of the ACP to conclude the selection of an L-band technology for use in the continental environment.
- The development of SARPS for a new system to be used in the surface/airport environment. This system will be based on the IEEE 802.16e standard operating in the C-band.
  - ***IOC required by SESAR in 2015***
- Action as necessary to secure and protect the spectrum needed for the FCS.
  - ***Preparation for WRC11***
- On-going action on the part of the ACP to monitor the development of aeronautical satellite systems.
- ACP continue to  provide a technical forum to monitor and review FCI development.
  - ***Recommendation 1/2 of ACP Working Group of the Whole.***

# Actions for Approval

## As proposed by ACP WGW/2 in April 2008:

- ***Recommendation 1/1***

  *Develop ICAO material for the VHF-band, L-band, C-band and satellite systems in support of the future communications infrastructure as soon as relevant material is available from industry and external standardization bodies*

- ***Recommendation 1/2:***

  *ACP provide a technical forum within ICAO to monitor the progress of the FCI development*

  - *To meet on a yearly basis.*

# Thank You