MMDA Business Case

Multi-mode Multi-function Digital Avionics

Prepared for
NASA Glenn Research Center

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Global Aviation

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Summary

- Business Case Approach
- Voice of the Customer
- Targeted Visions
- MMDA Needs
- Benefits
- Examples of ADS and Node-on-the-Net
- Market Timing Considerations

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Business Case Approach

- Develop business case around expected new global capabilities
- Meet a classic business case for commercial development and fill in information during development
- Meet OMB Exhibit 300 requirements to facilitate continued funding
- Apply Design for Six Sigma (DFSS)

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Design for Six Sigma (DFSS)

The Path for Product Development

(I)dentify Requirements

- **Critical-to-satisfaction metrics**
- **Voice-of-the-Customer**
- **Market/customer research**

Characterize the (D)esign

- **Translate customer requirements to functional requirements**
- **General design alternatives**
- **Evaluate design alternatives**

(O)ptimize the Design

- **Logical and objective performance tolerances**

(V)alidate and Verify the Design

Design Meets Voice-of-the-customer *with Positive Benefits*

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Aircraft Owners and Pilots Association

Phil Boyer, President

AMA

VOICE

Funding Is Critical to Aviation's Vitality

- Excise taxes on aviation fuel are the appropriate ways for GA to help pay for the aviation system
- Because the aviation system is vital to the U.S. economy, general tax revenues should provide at least 25 percent of FAA operating costs

Reduce Existing Costs

- Find ways to cut FAA costs

The FAA and the Aviation Community Together

- Develop and design the next ATC system
- Determine the cost for modernization
- Innovative thinking can bring FAA costs under control and ensure all pilots have access to vital safety services

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Air Transport Association

Jim May, President and CEO

V O I C E

Reduce the Cost of the Current System

- Consolidate Redundant Systems
- Decommission obsolete equipment and procedures
- Rationalize the workforce

Increase Capacity of the Current System

- Leverage navigation equipment already on board
- Create new satellite-based routes for added flexibility
- Achieve VFR rated during IFR conditions
- Rationally segregate different types of aircraft to optimize flow
- Manage total system performance by avoiding local decisions

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Air Transport Association

Jim May, President and CEO

V O I C E

Build a System that Enables Growth

- Embrace a "building-block" approach using a scalable, flexible architecture
- Create incentives for performance and efficiency
- Capacity limitations cannot constrain demand
- Minimize reliance on ground-based equipment
- Create an airborne information-sharing network
- Develop a reliable and dynamic funding mechanism that allocates costs equitably

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National Business Aircraft Association

Ed Bolen, President and CEO

V
O
I
C
E

The imperative is to have a strong and robust air transportation system

- For the past 100 years, the U.S. has been the world's leader in virtually all aspects of aviation, and that leadership has been fundamental to our nation's success

Do No Harm

- We need to proceed into the future thoughtfully before we change out our NAS
- The future of business aviation is directly related to the strength of our aviation system

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Airports Council International North America

David Plavin, President

V
O
I
C
E

Key Challenges

- The failed business models of the legacy airlines
- Lack of preparedness to deal with growth, demand, workload, and investments
- Over-reaching mandates, unsuccessful implementation, inadequate funding and lack of true partnerships in aviation security
- The inability/unwillingness of the federal government to be a reliable partner in operations, regulation and funding
- The inability of airports to respond to increased demand, changing airline business cases, evolving fleet mixes, increased capacity requirements, and an over-regulated environment

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Target Visions

Where do you want to go?

Why do you want to get there?

How will you get there?

At what cost?

What changes do you need to make now?

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Transformation to Aircraft Performance

	Human Ground Centric → Automated Airborne Centric				
	2005	2010	2015	2020	2025 State
Communication 14,450 Facilities	VHF UHF SATCOM HF VOR LOM VDL-2/3/4-(VHF) UAT VOLMET	VHF UHF VDL-3-(VHF/SATCOM) UAT	VDL-3-(VHF/SATCOM) UAT		VDL-X (VHF SATCOM)
Navigation 11,120 Facilities	NDB VOR MLS LAAS WAAS DME ILS GPS LORAN	VOR WAAS **DME** ILS MLS GPS LORAN	DME **GNSS** LORAN		GNSS
Surveillance 1,886 Facilities	MODE3A/C MODE S ASR-8/9/11 ASRS-3/4 ADS-B ATCRBS PRM MULTILAT	MODE S ASR-8/9/11 ASRS-3/4 ADS-B/C MULTILAT	MODE S ASR-9/11 ASRS-4 ADS-B/C	ASRS-4 ADS-X	ADS-X
Infrastructure 3,865 Automation	21 ARTCC 517 Towers 194 TRACONS 16 FSS 60 AFSS 9-Regions Headquarters WJHTC Aeronautical Center			4 ARTCCs Headquarters 35 TRACONS 4 Regions 4 AFSS 300 Manned Towers 500 Remote Towers	35 ATC Facilities 1000 Remote Towers
Policy Procedures	Reduce Separation Eliminate 250 Knot Rule		Revise Certification		Optimization
Costs Capacity	$13B		$7B		+50% Airline Hubs +300% Aggregate for All Users

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Vision Consensus Becoming Clearer

Not yet 20/20

- 4-D trajectory-based separation
- Rich aircraft intent information
- Network-enabled operations
- Automated conformance monitoring
  Separation, Sequencing and Spacing
- The 4-D contract
- Control-by-exception

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Control by Exception?

- Aircraft fly “contracts” built on intent
- Automation performs conformance monitoring and identify aircraft out of tolerances
- Controllers deal with non-conforming flights
- Delay penalties go to those who do not meet their “contract”
- Controller performance based on meeting “contracts” and safely managing exceptions

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Six Key Enablers

Reauthorization - *setting the framework for change and driving the cost message*

Aircraft as a Node on the Net - *Mobile IP to the cockpit for connectivity*

Digital Communications - *getting beyond CPDLC*

Innovative Avionics - *safe, secure, progressive information-based certification*

FAA/ATO Policy and Procedure Changes - *an aircraft-centric NAS*

FAA/AVR Certification Process Changes - *a process built on supporting business cases and 3X traffic growth*

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MMDA Needs

- Two paths: ***node-on-the-net*** for air carriers and getting general aviation into the NGATS transformation with ***4-D trajectories*** and lower-cost approaches to ***node-on-the-net***
- Compelling price point by delivering value-added services and/or replacing existing functions with integrated functions at lower cost and higher convenience
- Integrating security to make it transparent, but available to the users
- Disruptive technology push to drive down costs of certification, acquisition, and maintenance of avionics
- New approach to certification based on information integrity, availability, and use of that information in the context of an integrated network-enabled operation

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Assumptions

- Global network-enabled ATM operations
- 4-D trajectory-based separation, sequencing and spacing
- Commercial MMDA available in 2012
- Two flavors of MMDA
  - MMDA for Communications ⇒ node-on-the-net
  - MMDA for integration of C, N and S
- Node-on-the-Net certified with DFSS
- Fully integrated MMDA focuses on information-level certification as a joint NASA/FAA research effort
- Federal research investment needed to lower the risk of information-level approach to MMDA certification
- Risk-reward benefits built on open systems, commercial standards, and driving cost down for limited market

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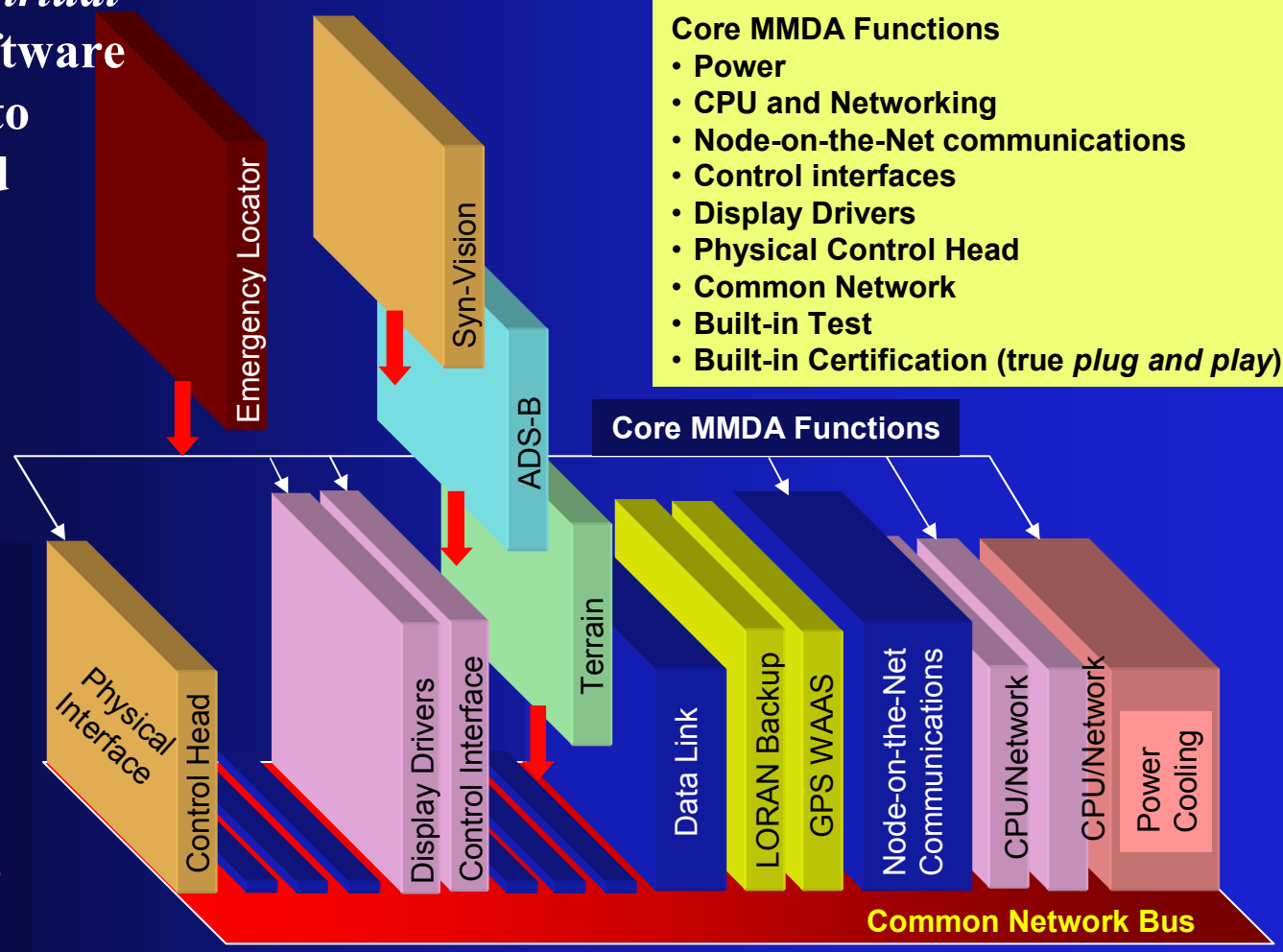
MMDA Vision

"Cards" are *Virtual* and can be software programmed to deliver desired functions

Core MMDA Functions
- Power
- CPU and Networking
- Node-on-the-Net communications
- Control interfaces
- Display Drivers
- Physical Control Head
- Common Network
- Built-in Test
- Built-in Certification (true *plug and play*)



Multi-Mode -
The integration of similar modes of operation of a single avionics CNS function

Multi-Function -
The integration of multiple CNS functions

Benefits

- **General**
  - Providing the leadership to deliver the communications elements of the NGATS
  - Using DFSS to define certification at the information level
  - Moving to open systems and open standards to lower cost
- **Air Carrier**
  - Global digital communications
  - Clear path to link aircraft to the networks
  - 4-D trajectories
  - Optimum flight profiles for fuel savings
  - Network-enabled operations
- **General Aviation**
  - Drive down cost
  - Buy-back weight and space
  - Decrease complexity of avionics
  - Leverage glass cockpit to deliver safety, comfort and convenience

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Two Enabling Technology Needs

4D Separation/Intent

Getting to ADS-B and on to ADS-X

Node-on-the-Net

Getting from A/G Voice to networking

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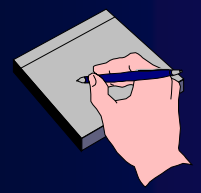
Evolution of ATC/ATM

Past

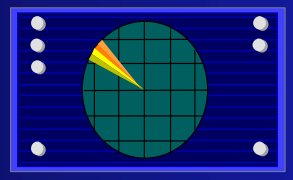
Procedural Separation



Estimate **current & future aircraft positions**

Present

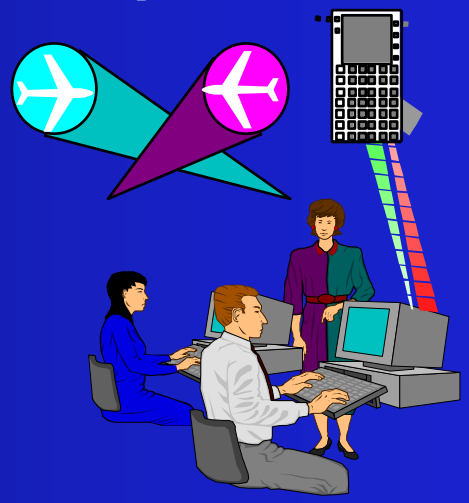
Radar Separation



Know **current &** ***estimate*** **future aircraft position**

Future

4-D Trajectory Separation



Know **current and** ***Know*** **future positions**

Intent

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ADS-B to ADS-X

ADS-B (1090-ES and VDL 4) were selected as the standard for an interim period 2015-2020

Intent beyond the next waypoint was not considered

ADS-B (UAT) was supported because of the broadband data link

Currently designed for electronic "see and avoid," separation in non-radar coverage, and new concept exploration

The ADS-B links lack capacity and security

- 1090-ES will interfere with TCAS at 3X
- VDL 4 lacks capacity now
- UAT broadband link will increasingly be dedicated to ADS-B over the valued services

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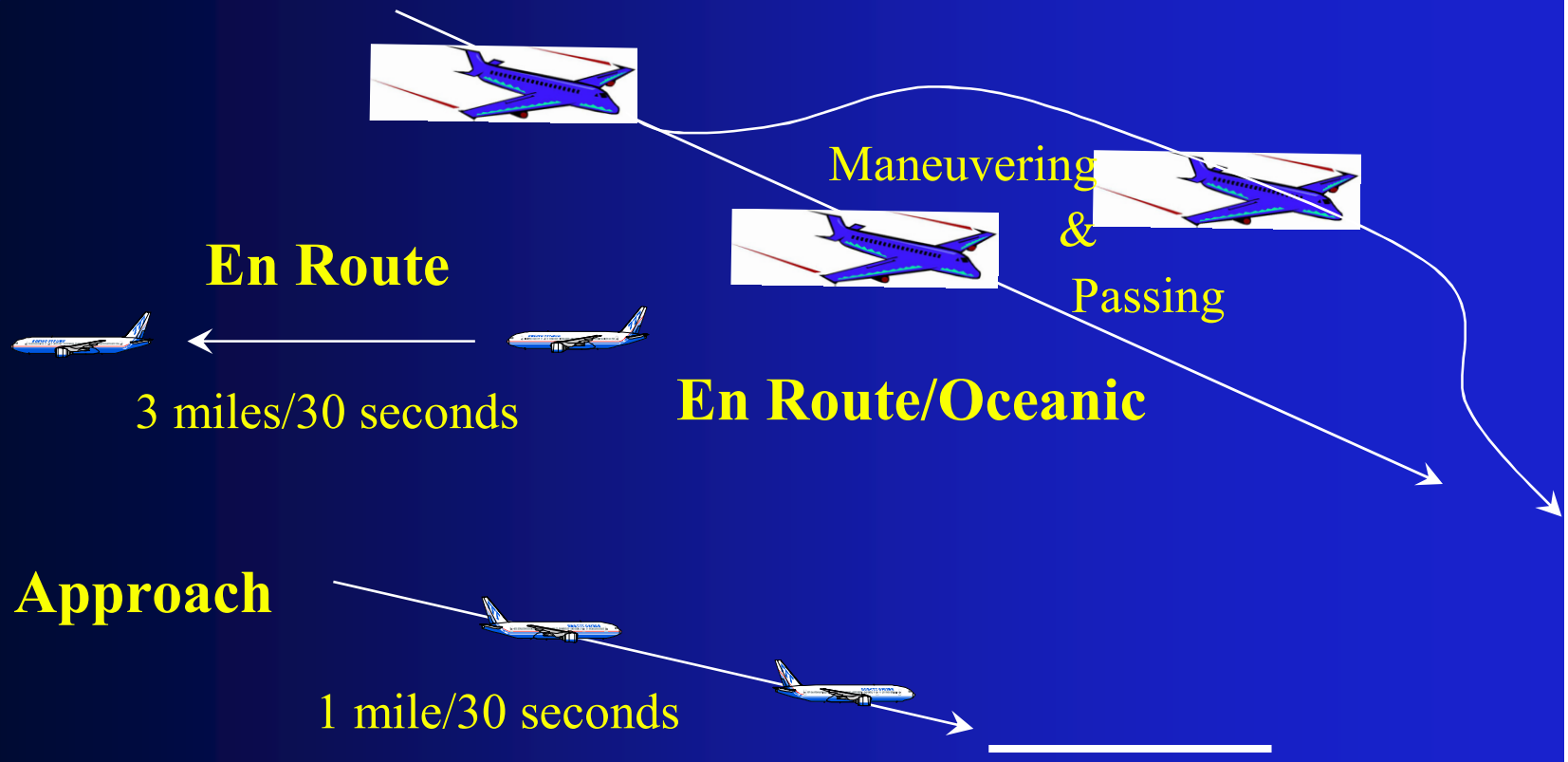
ADS-B to ADS-X

Getting Benefits from ADS-B



Reduced Separation Through Common Situational Awareness, RNP, and Surveillance Update Rate over Radar

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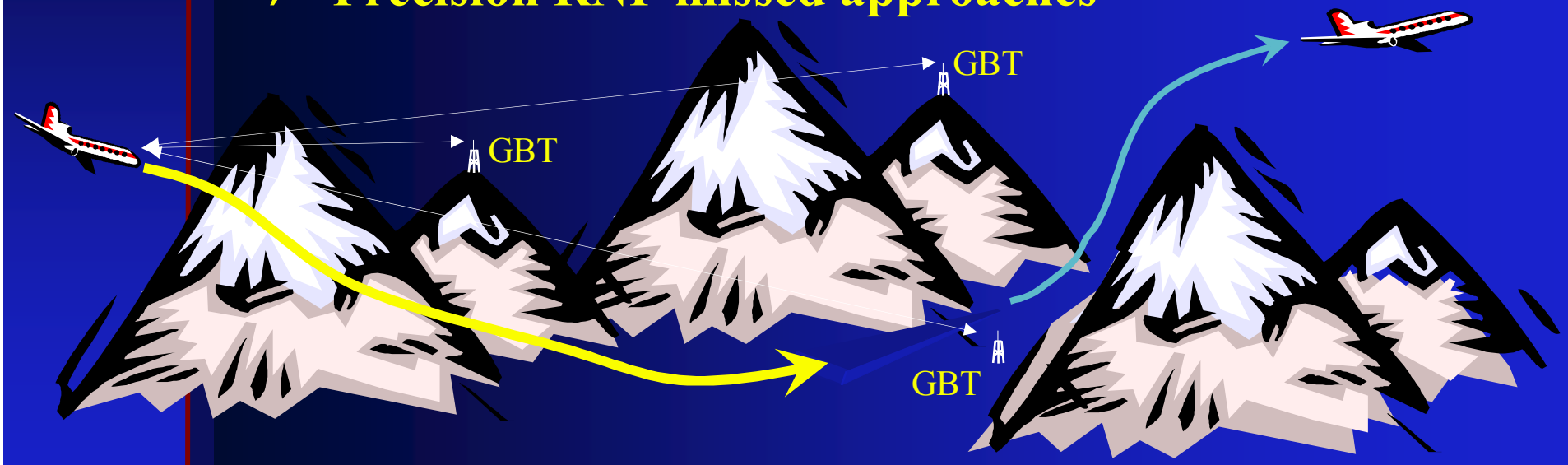
ADS-B to ADS-X

Getting Benefits from ADS-B

Radar Equivalent Services in High-Terrain Airspace Using ADS-B

- **Eliminates "one-in-one-out"**
- **Uses GNSS and RNP for lower minimums**
- **Precision RNP missed approaches**



GBT = Ground-based ADS-B Transceiver

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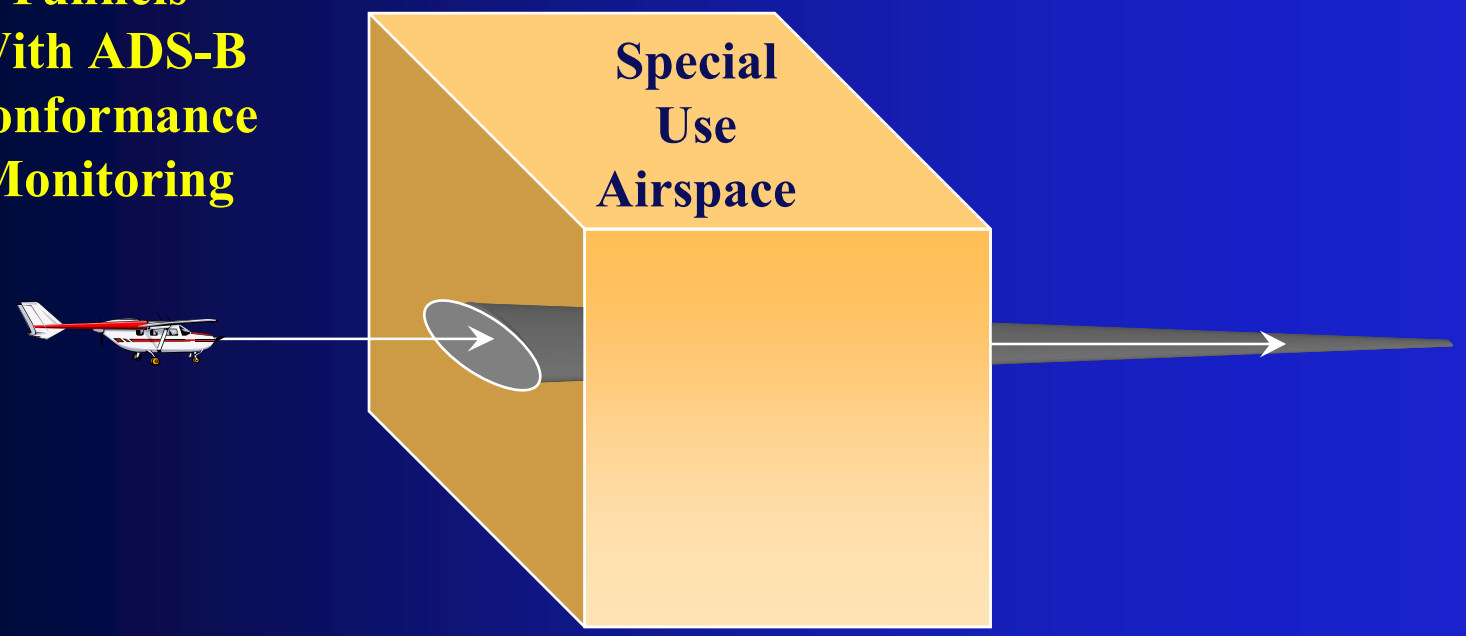
ADS-B to ADS-X

Getting Benefits from ADS-B

RNP 1.0 Tunnels With ADS-B Conformance Monitoring



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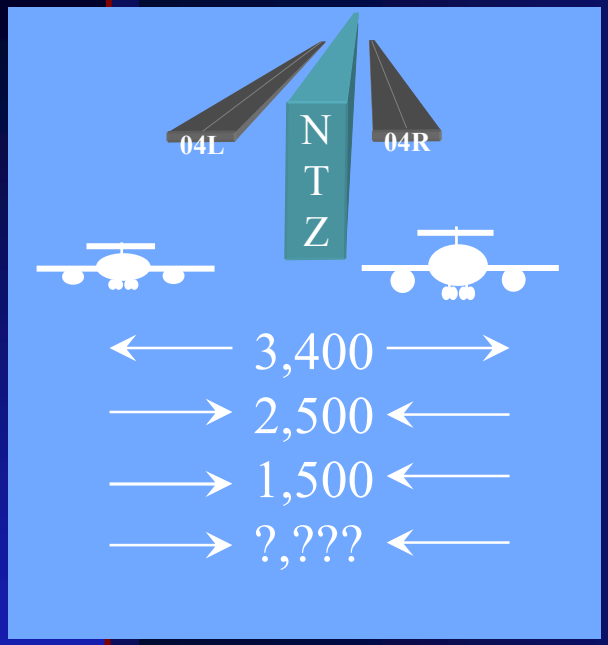
ADS-B to ADS-X

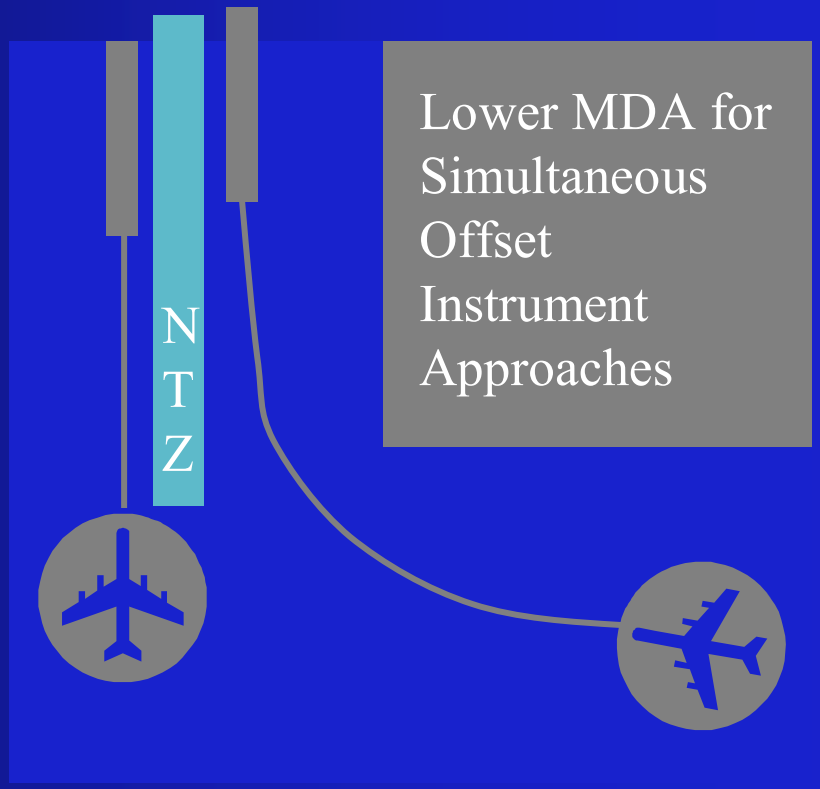
Getting Benefits from ADS-B



Reduced Lateral Separation For Closely Spaced Parallel Approaches

Target

1,500 feet or Less



Lower MDA for Simultaneous Offset Instrument Approaches

Introduce Dependent Parallel and Dependent Offsets with Pilot Spacing

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Trips and Quads
"Seeing" is "Doing"

Quadruple Arrival and Departure Streams Enabled by Common Situational Awareness and Ability to Manage Multiple Missed Approaches Through E-Visual Operations

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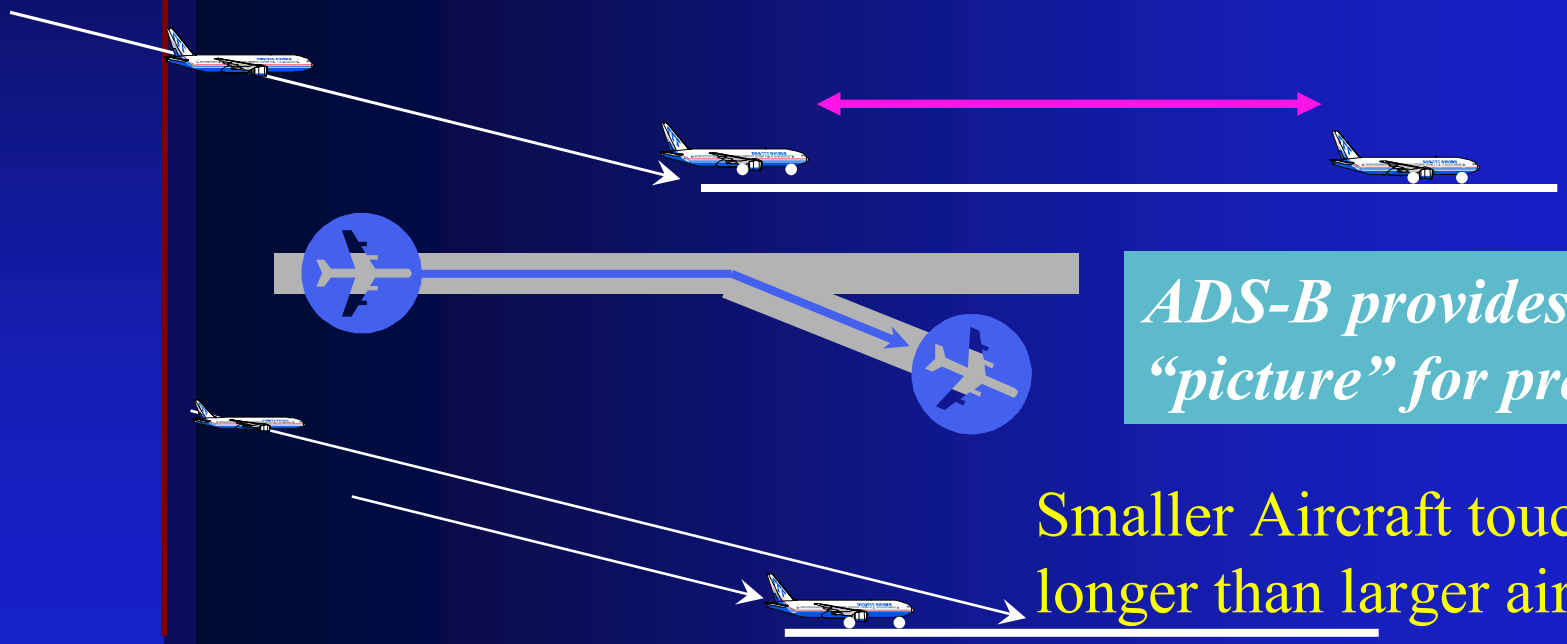
ADS-B to ADS-X

Getting Benefits from ADS-B

Landing Performance Improvements

- Two aircraft on the runway separated by defined distances
- Deceleration vectors for preferred high-speed exit
- Vortex Avoidance Aim Points



ADS-B provides the "picture" for procedures

Smaller Aircraft touch down longer than larger aircraft

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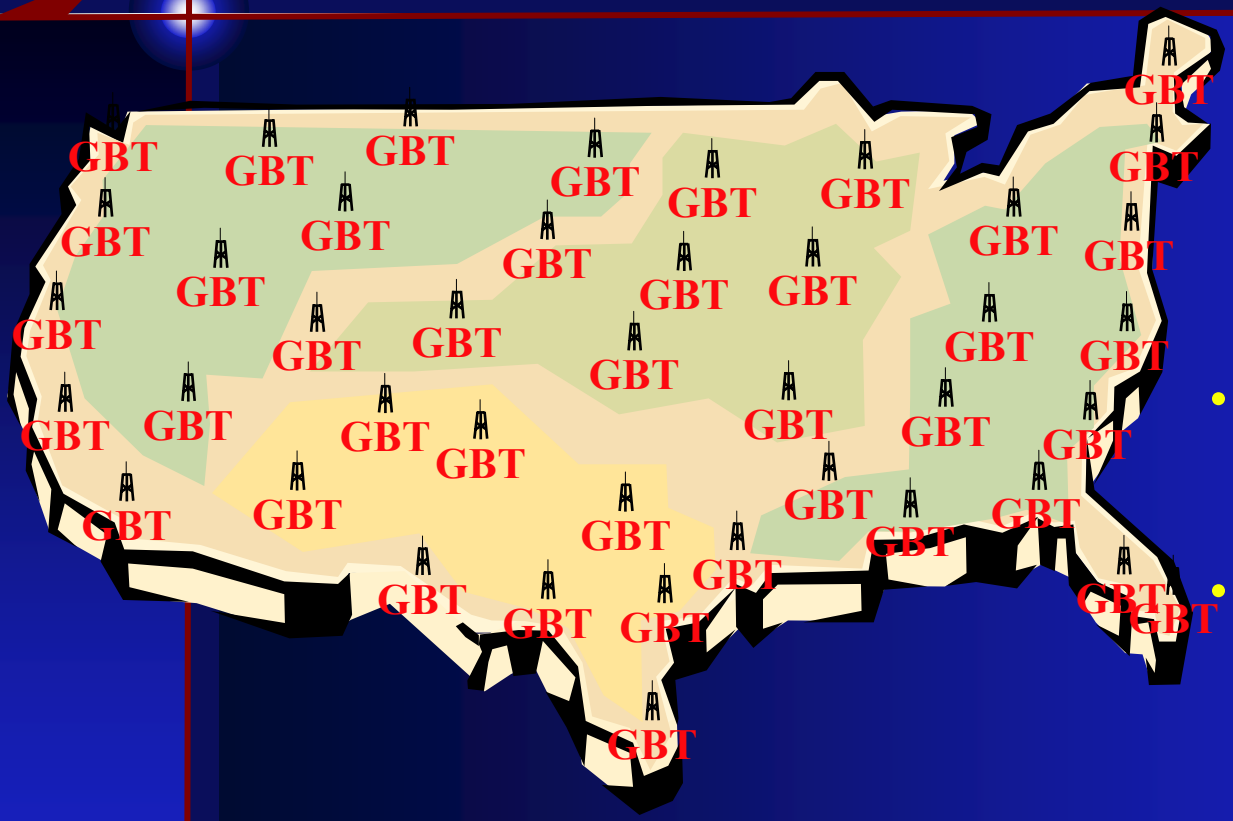
ADS-B to ADS-X

Getting Benefits from ADS-B



- A mix of Airport and RCAG locations where communications exists
- Delivers ADS-B but also provides multilateration as secondary source for surveillance
- Approximately 400 Units with supplemental units in mountainous terrain

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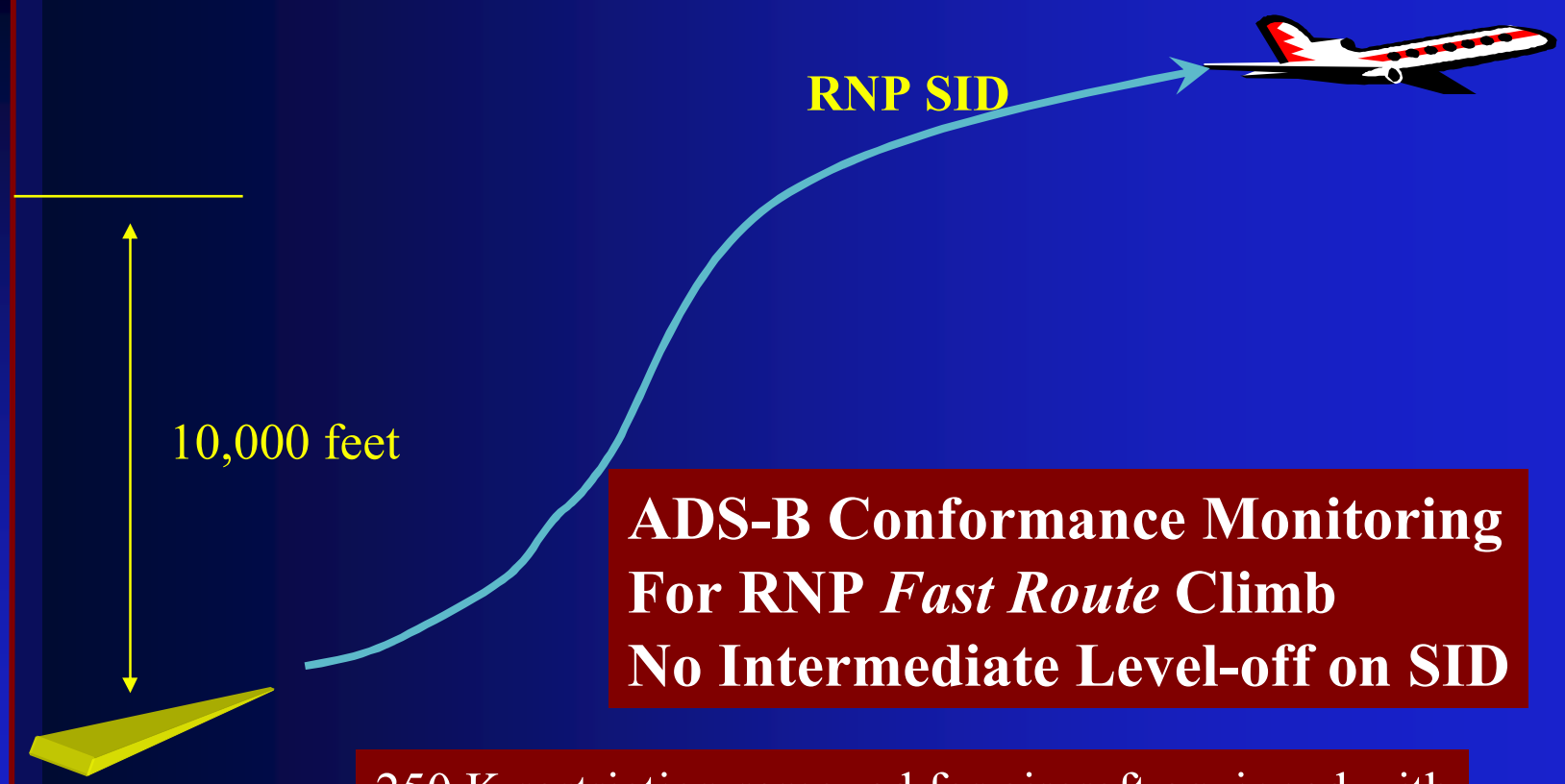
ADS-B to ADS-X

Getting Benefits from ADS-B



ADS-B Conformance Monitoring
For RNP *Fast Route* Climb
No Intermediate Level-off on SID

250 K restriction removed for aircraft equipped with ADS-B and RNP < 0.5

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Why ADS-X

- Automation-to-automation A/G network transactions not possible with ADS-B
- Significant reliability and integrity requirements relating to aircraft flight trajectories
- Provides the transition from using the concepts of ADS-B to control by exception and self-separation performance based on traffic density
- Supports safety and security functions when needed
- Provides capacity and efficiency functions as required by the user for the business case

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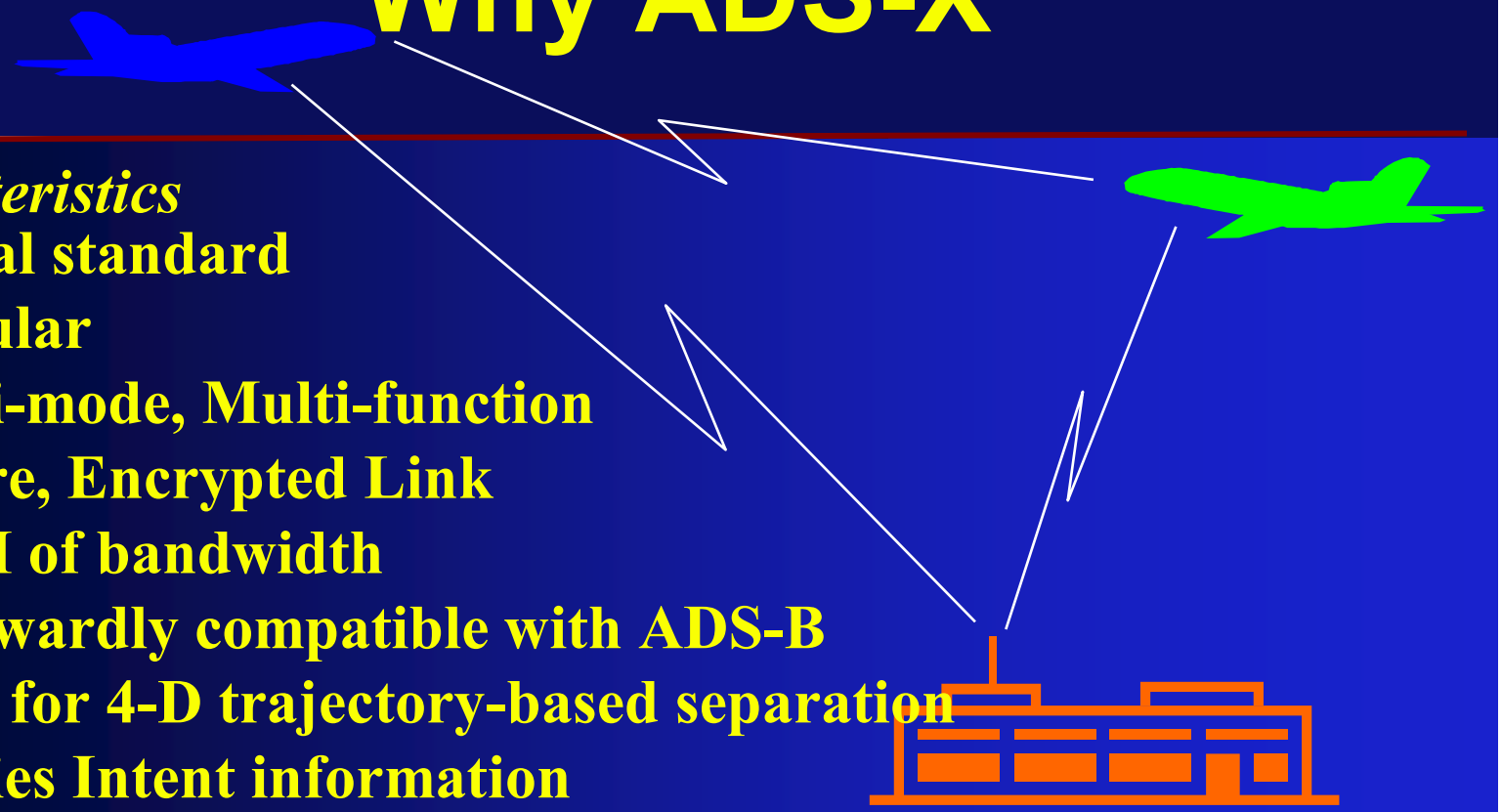
Why ADS-X



Characteristics

- Global standard
- Modular
- Multi-mode, Multi-function
- Secure, Encrypted Link
  > 1 M of bandwidth
- Backwardly compatible with ADS-B
- Basis for 4-D trajectory-based separation
- Carries Intent information
- Negotiated strategic and tactical "contract"
- Contract becomes the basis of control by exception
- Contains elements for pilot self-separation, sequencing, and spacing
- Does not replace TCAS

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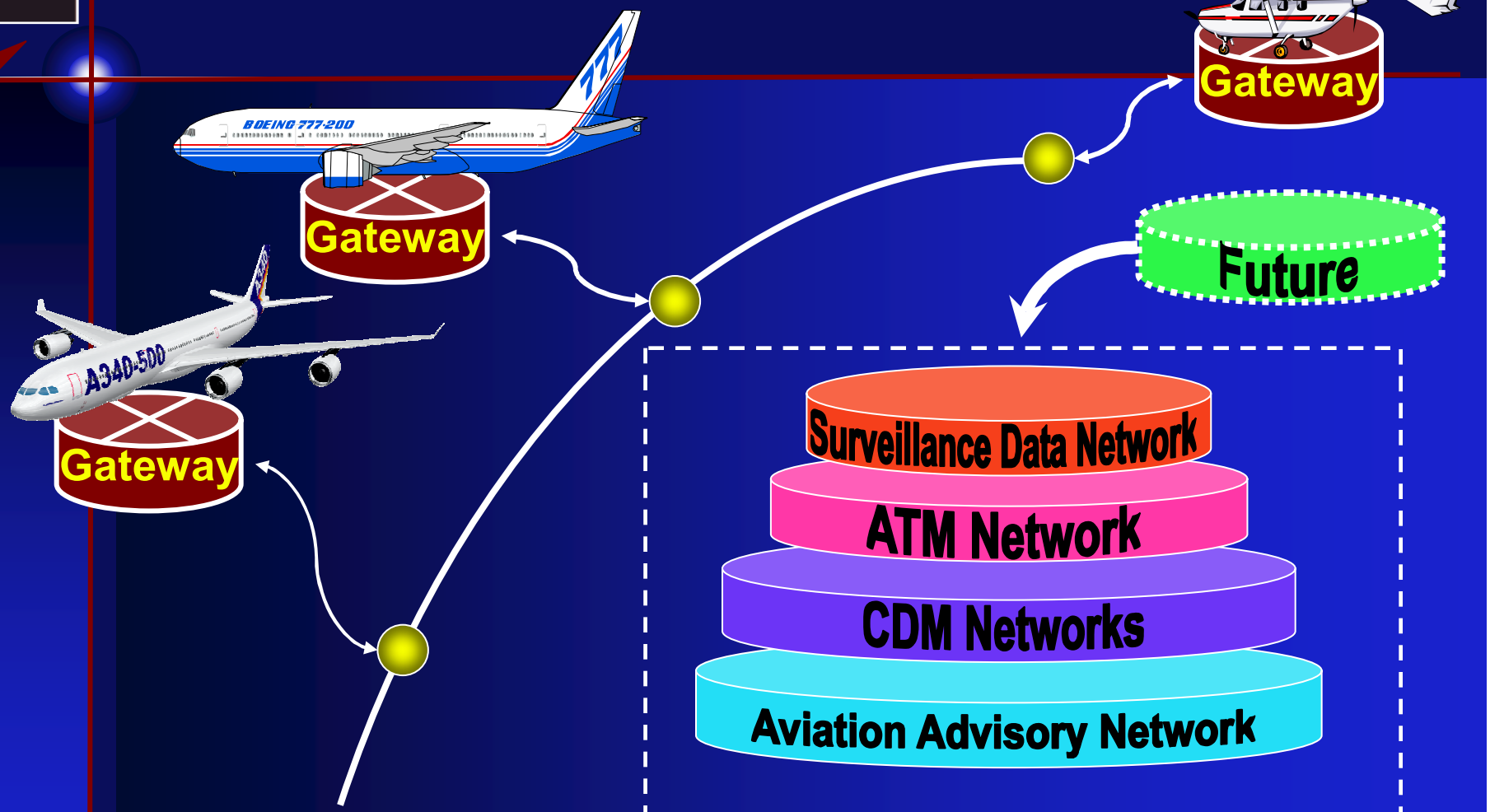
Node-on-the-Net



Network-Enabled Operations (NEO)

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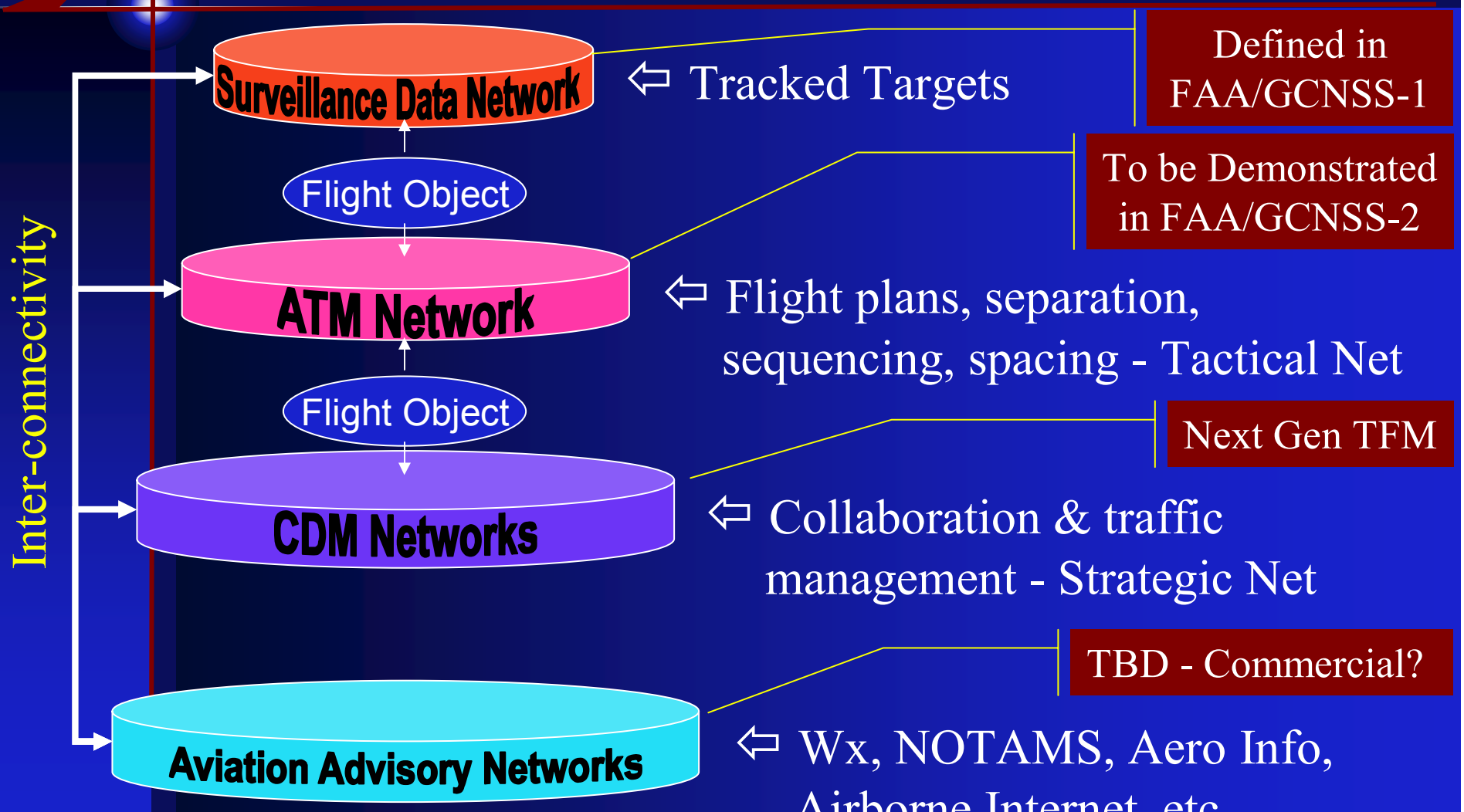
Network-Enabled Operations Stacks



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Flight Object

Flat files about the aircraft that are updated with each transaction

Manifest Information

Aircraft Performance Information

4-D Position and Intent Information

- **Who am I**
- **Where am I**
- **What do I want to do**
- **When do I want to do it**
- **Where do I want to do it**

Transaction (Def'n): exchange of information air-to-air or air-to-ground that changes a data field in the flight object

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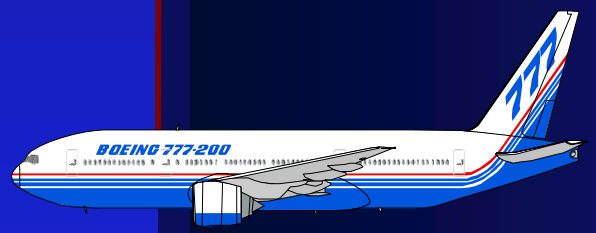
Research Toward a Global Standard

- **Node-on-the-Net** becomes the **Global Aeronautical Network**
- Modifies Aeronautical Telecommunications Network (ATN)

- Value-added
  - Global Performance
    - Link Independent
      - Interoperable
        - Perform Critical ATM Functions
          - Secure
            - Authentication, Authorization and/or Encryption



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General Aviation Disruptive Technology

- 4-D Trajectory-based separation, sequencing and spacing
- Precision Positioning from augmented GPS with backup
- New on-board tracker to generate intent
- New transponder functions that support both interrogation and dependent surveillance with security functions
- Eliminate NDB, VOR, Emergency locator
- Pilot configured human interfaces
- Software programmable functions for redundancy and dispatch reliability
- Node-on-the-Net communications with access to NEO stacks

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Market Timing Considerations

- Clearer opportunity to influence general aviation avionics market than air carrier market due to changes in the market place
  - Low-end GA
  - Very Light Jets
  - Business jets
- Global market in GA is primarily the US market
- For disruptive technology, look beyond the aviation market for opportunities
- Market timing for MMDA is 2009 for research - no new air carrier aircraft are expected but substantial growth in regional jets and fractional ownerships
- Fuel costs likely to drive toward optimum flight profiles

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Backup Materials

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Next Steps

- Coalesce on MMDA development paths
- Set in motion the NASA/FAA certification path(s)
- Build business cases for node-on-the-net for air carriers and general aviation
- Build business case for general aviation transformation for NGATS

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Operational Concepts General

- ***Two significant operational concepts for the Next Generation Air Transportation System (NGATS)***
  - 4-D precision positioning + intent
    - Separation, Sequencing, Spacing
    - Tailored flight profiles that optimize aircraft efficiency
  - Network-Enabled Operations
- ***Challenges***
  - Exchanging existing information available on air carrier and business aircraft
  - Providing general aviation with disruptive technology that emulates larger aircraft capabilities
  - Significantly driving down the cost of integrated CNS/ATM
    - Value-driven decision to equip through improved access and lower avionics replacement cost with greater functionality
    - More convenience, comfort, and safety for the same or less cost

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Operational Concepts
Air Carrier

- MMDA starts with new communications concept for information transfer with global capabilities well beyond today's NAS
- Voice for ATM continues as is
- Data travels as a **node-on-the-net** either directly with the ANSP or through a commercial service provider
- Many "pipe" options (modes) for exchange of diverse information (functions) and each mode and function have a pre-defined quality of service

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Operational Concepts General Aviation

General aviation needs disruptive technology integration to drive down costs and make GA capable of being a node-on-the-net, adding:

- 4-D trajectory capabilities
- New access to network-provided information
- Consolidation of weight, space, and panel congestion over existing avionics
- Software programmable functions to match the flight profile
- Plug-and-play to stimulate 3rd party development and ease of upgrade
- Safety, comfort, and convenience improvements through shared common situational awareness
- Improved security for access to airspace and airports

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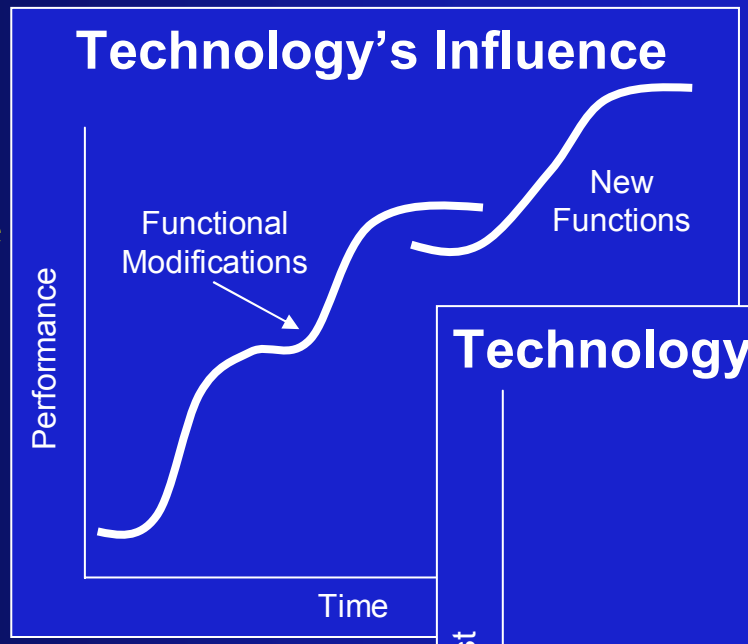
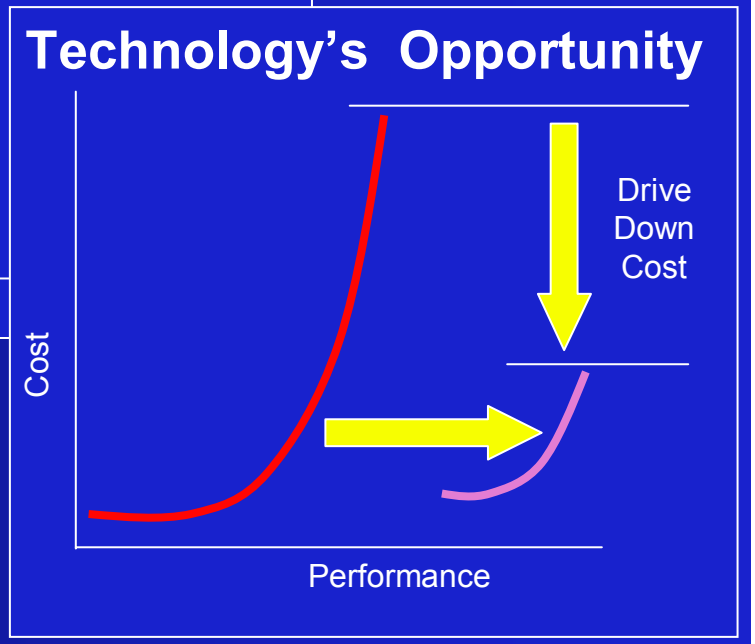
Performance and Cost

Technology adds functions with better performance over time

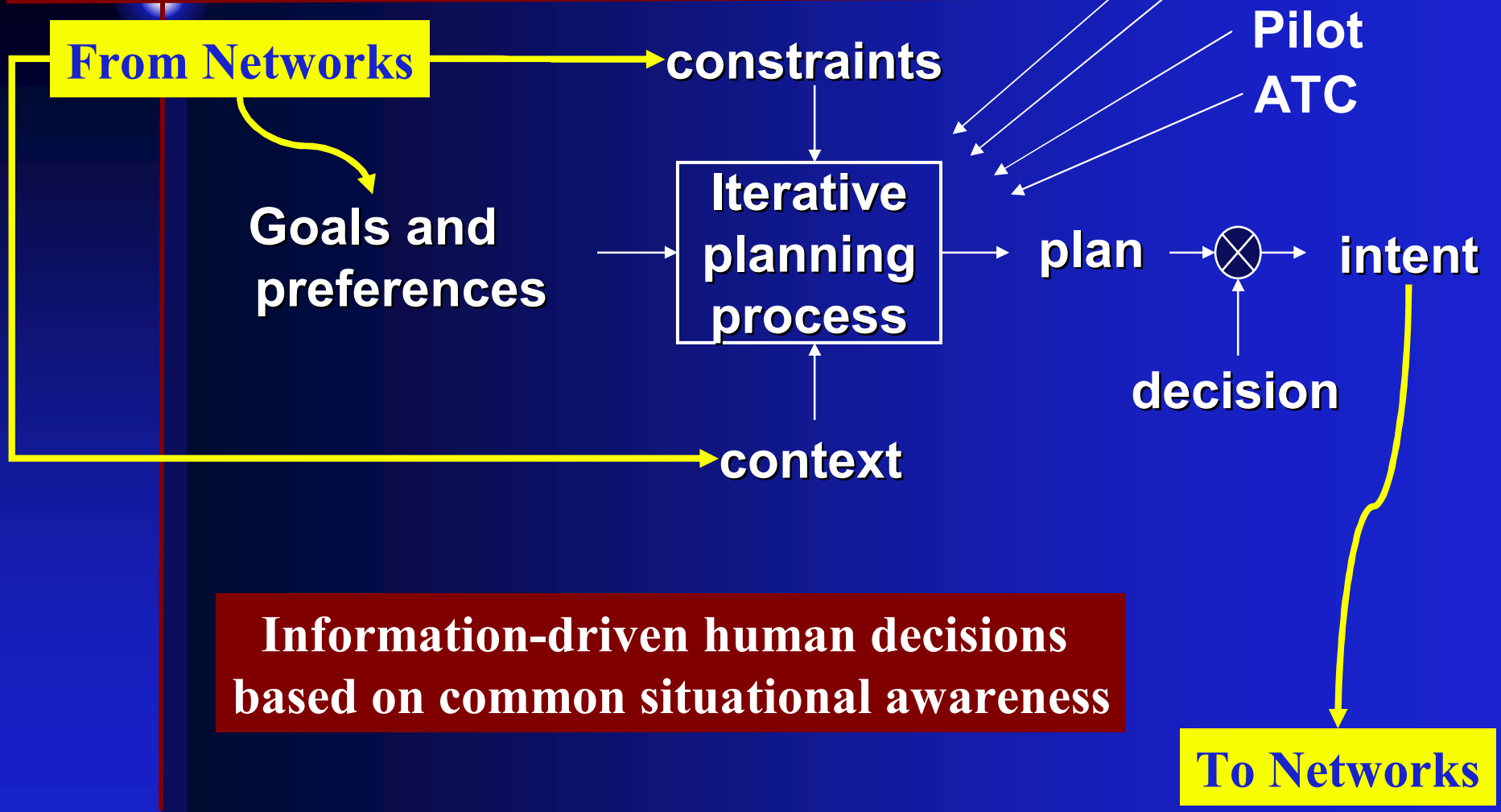


Cost Climbs Faster than Performance



Disruptive technology can drive a significant increase in performance while driving cost down by at least a factor of 3

Intent Generation Process



Information-driven human decisions based on common situational awareness

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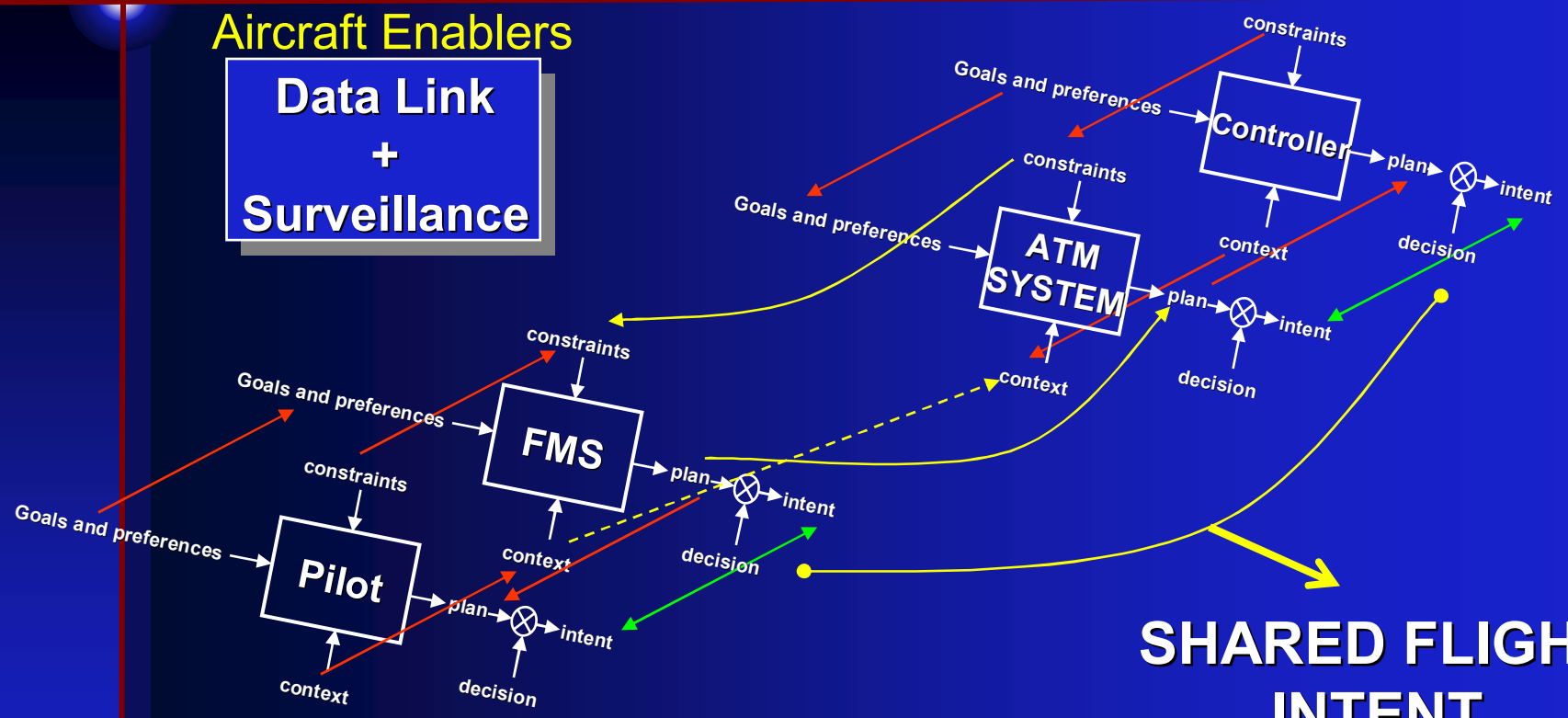
Intent Model
Pilot/Aircraft - Controller/ATM System

Aircraft Enablers

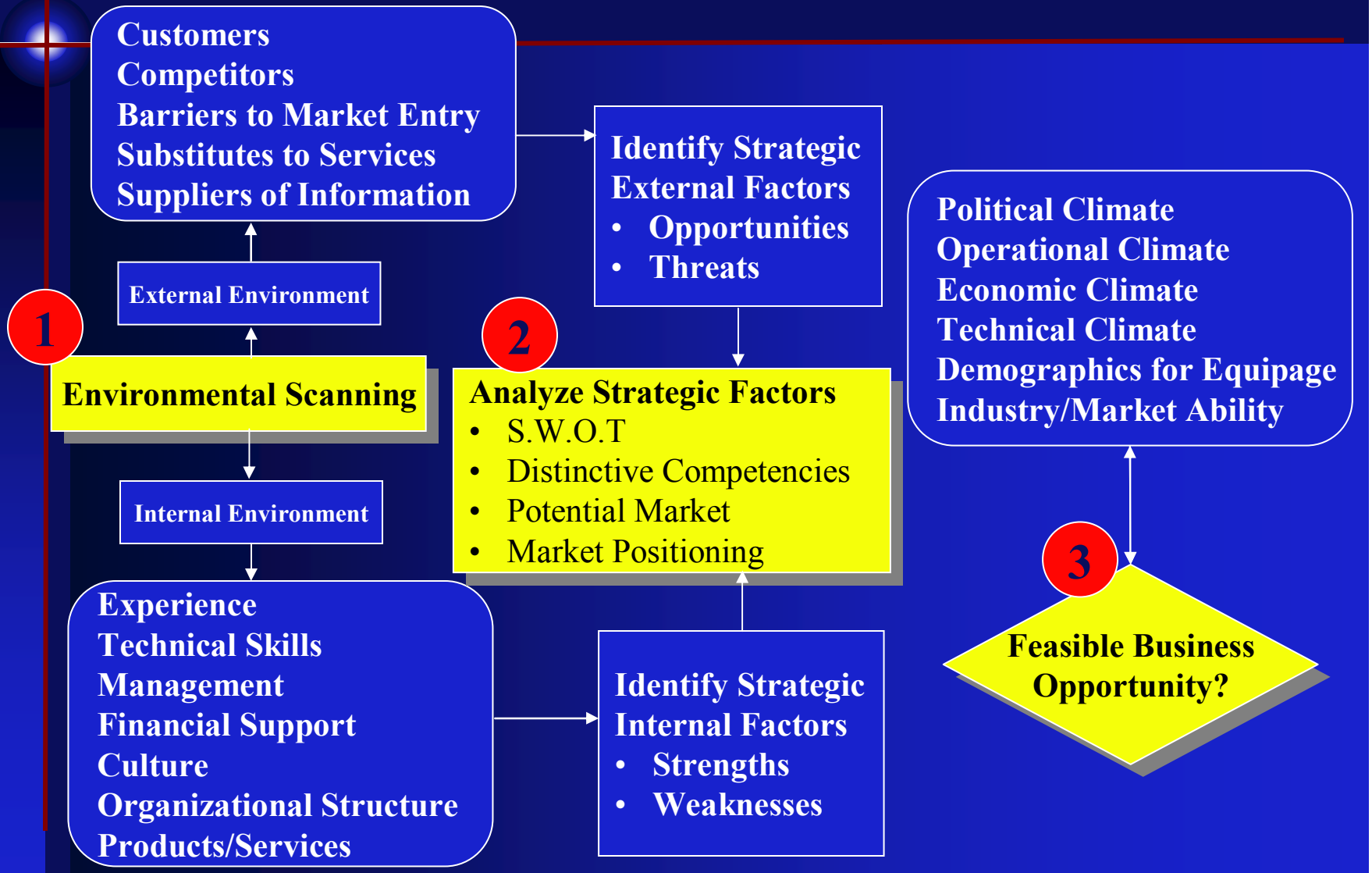
Data Link + Surveillance



SHARED FLIGHT INTENT

From: Wim Post, National Aerospace Laboratory (NLR)

Commercial Business Case Model



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OMB Exhibit 300 Flows