Navigation Services and the United States National Airspace System

CGSIC
Toulouse, France
April 2008

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Chief Systems Engineer
Federal Aviation Administration
Navigation Services

Federal Aviation Administration

Federal Aviation Administration

Vision: To improve the safety and efficiency of aviation, while being responsive to our customers and accountable to the public

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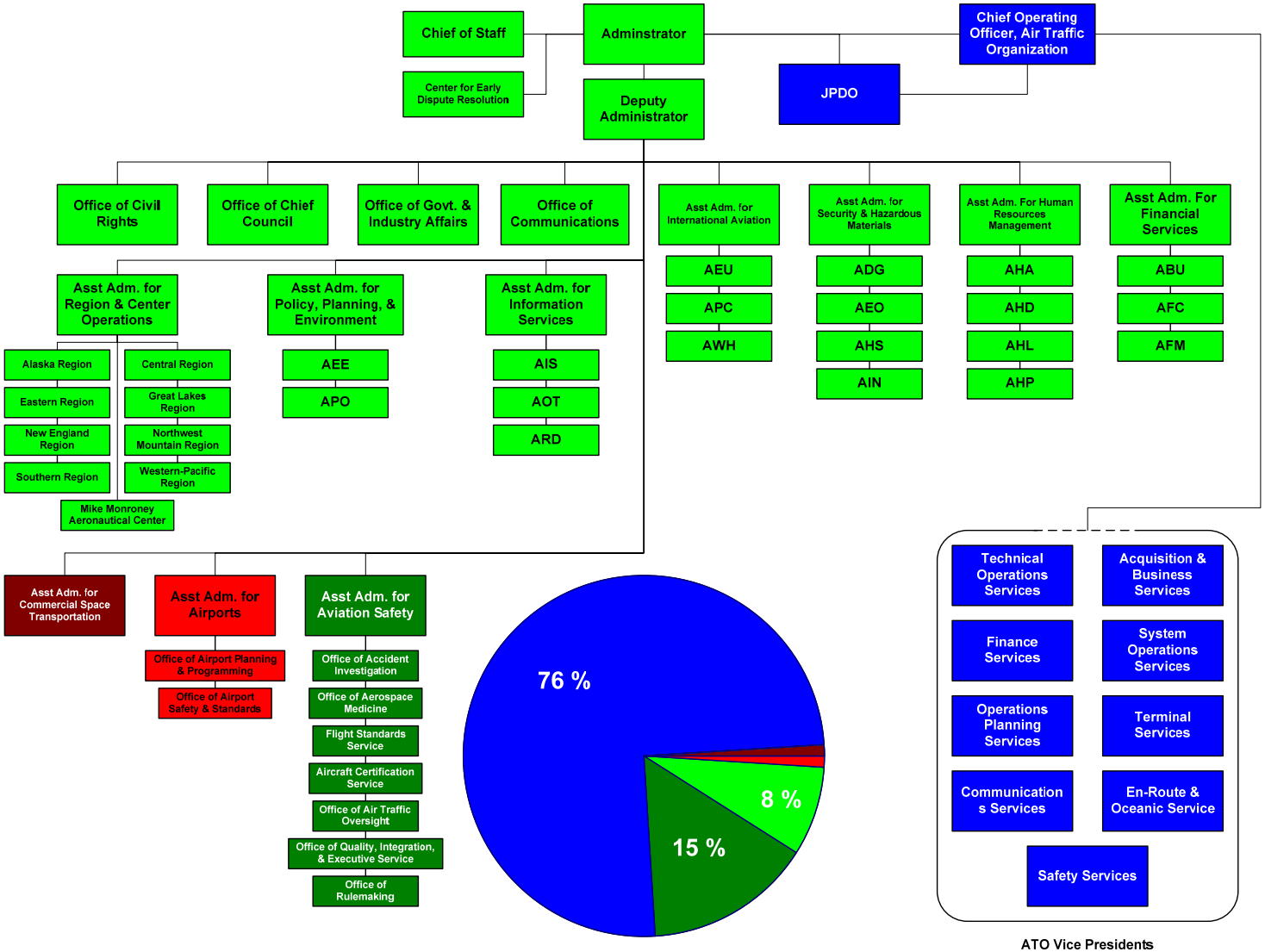
Air Traffic Organization

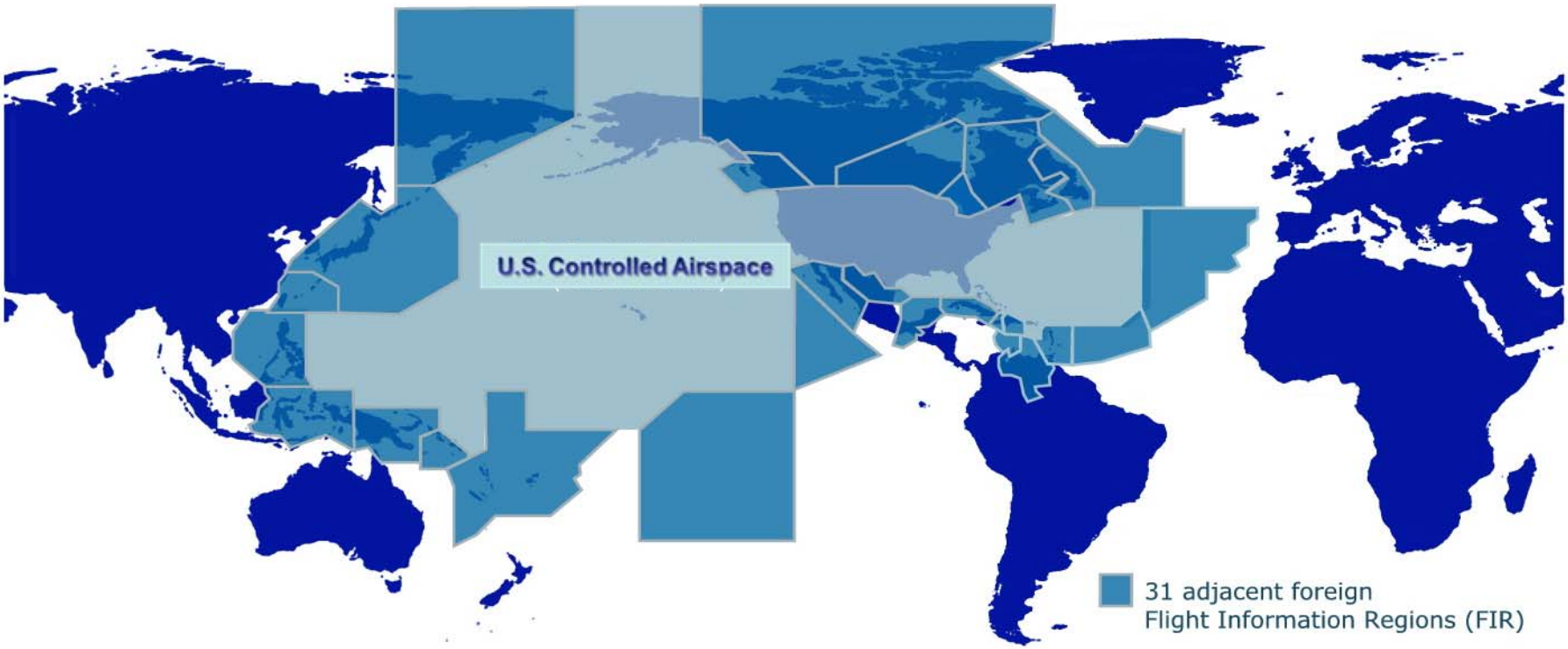
Safety. Service. Value.

Leading Aviation Services into the Future

FAA Organization



Int'l Cooperation… A Necessity



U.S. Assigned Airspace Equals ~77 Million Square Kilometers

Navigation Services Vision

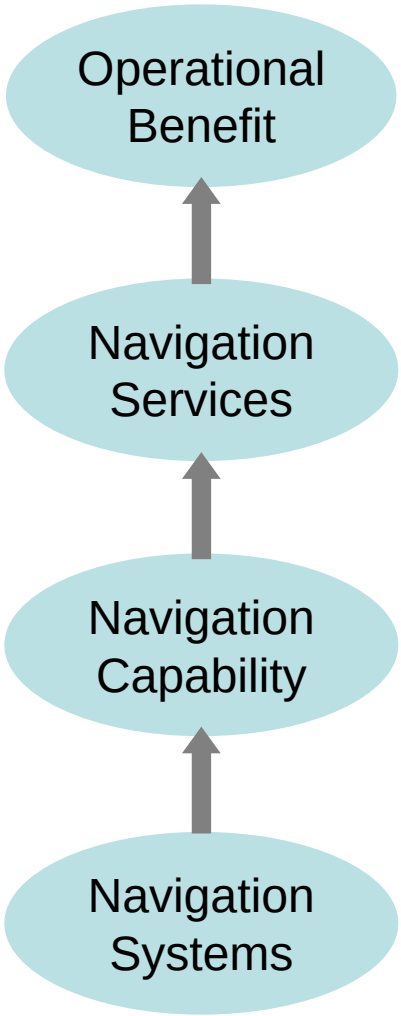
Provide safe, cost effective *position, navigation, and timing* services to meet operational needs of aviation customers

- ***The Navigation Services vision serves the FAA Mission and ATO Corporate Principles***

Navigation Service Roles & Responsibilities

- Provide safe, cost effective position, navigation, and timing services to meet the needs of aviation customers
- Provide precision approach and landing capability to runway ends in the National Airspace System
- Provide non-precision approach and landing capability to runway ends in the National Airspace System
- Provide missed approach capability to runway ends in the National Airspace System
- Provide navigation capability to aircraft flying in the National Airspace System
- Support the operational availability of navigation services/systems in the National Airspace System

Navigation Operational Benefits Hierarchy



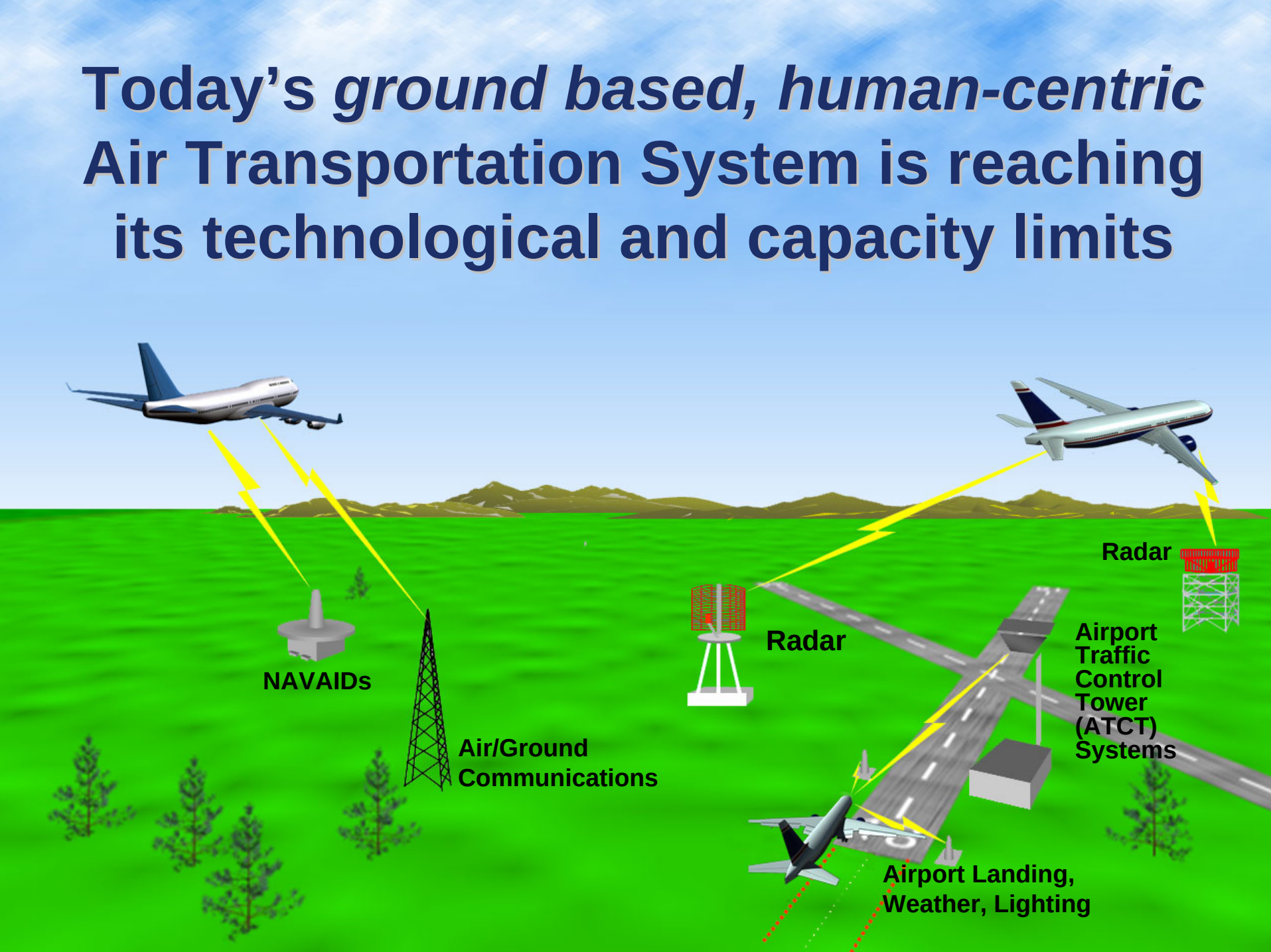
IMC Operations, Gate Management

Departure, Enroute, Approach, Surface

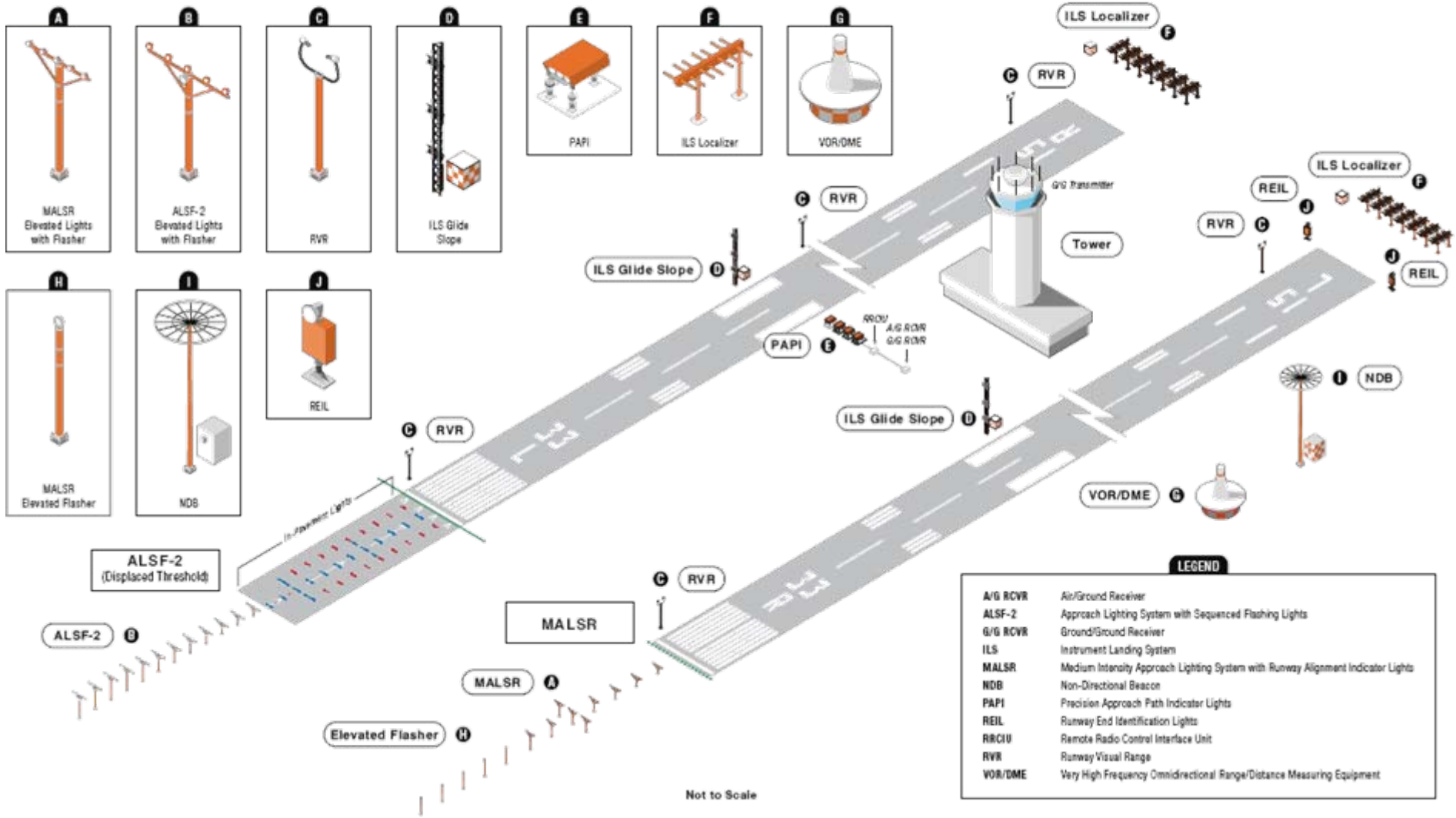
Category I/II/III, RNAV SIDS, RNAV STARS, Q Routes

DME, VOR, ILS, WAAS, GPS, MALSR

Today's *ground based, human-centric* Air Transportation System is reaching its technological and capacity limits



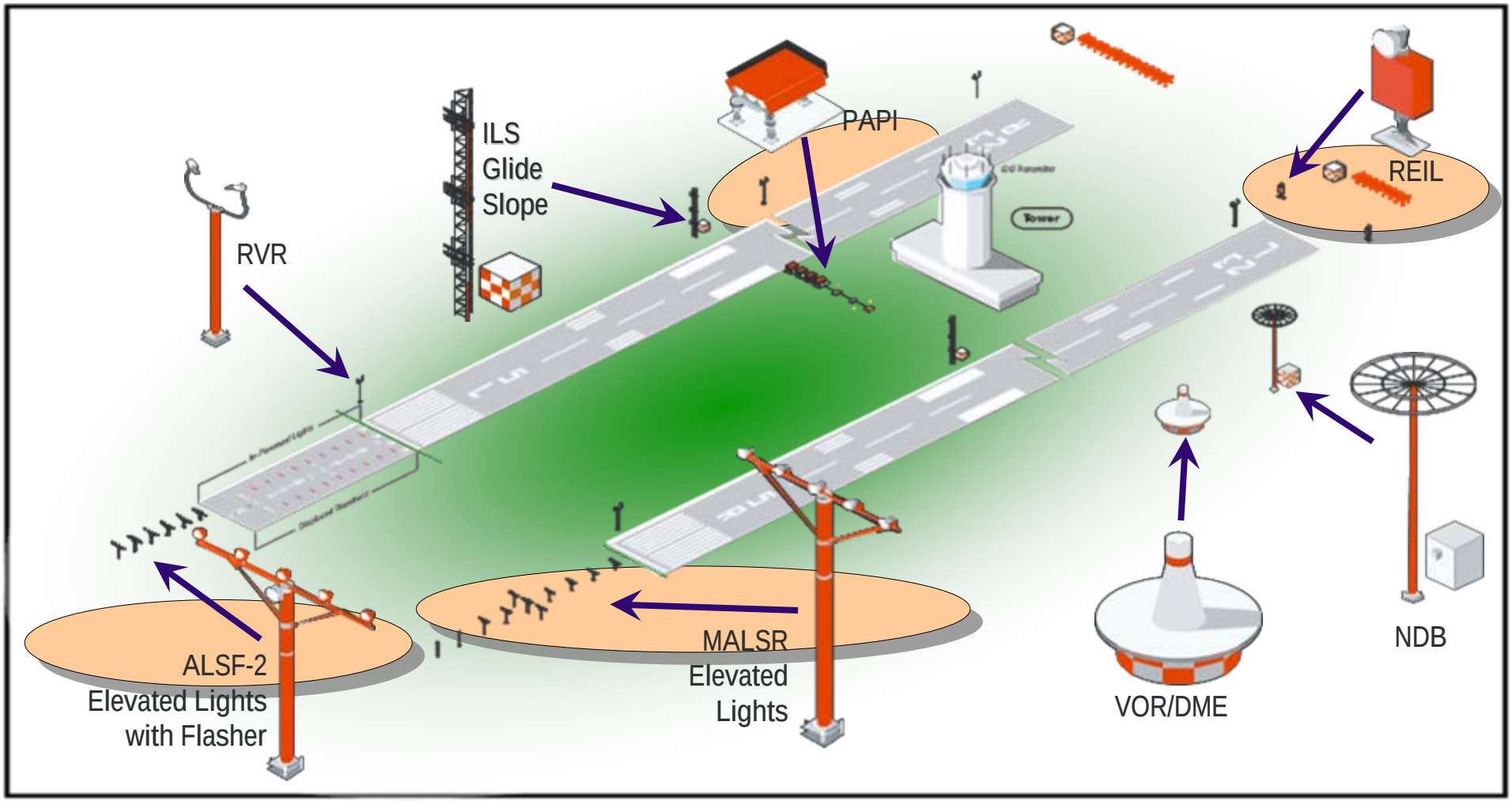
Navigation and Landing Equipment



LEGEND

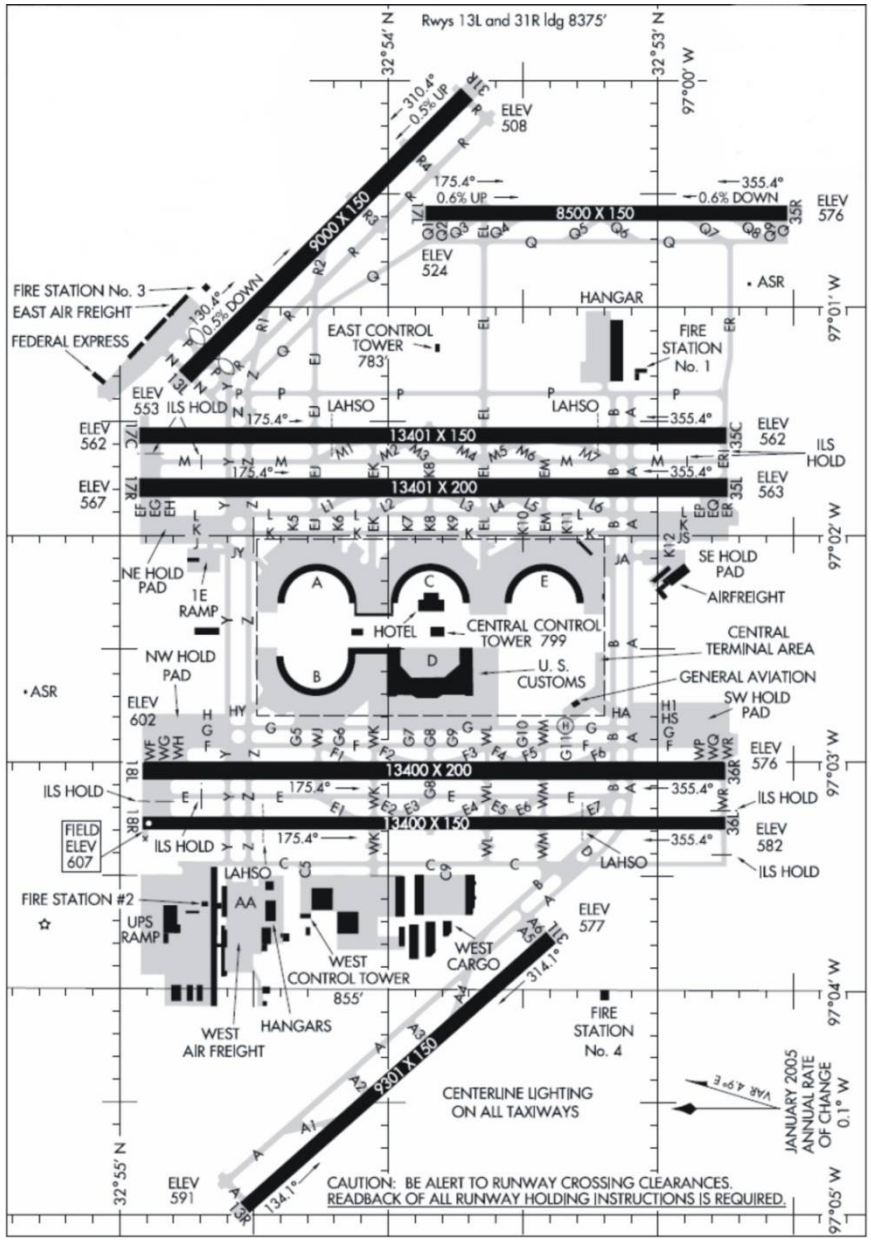
A/G RCVR	Air/Ground Receiver
ALSF-2	Approach Lighting System with Sequenced Flashing Lights
G/G RCVR	Ground/Ground Receiver
ILS	Instrument Landing System
MALSR	Medium Intensity Approach Lighting System with Runway Alignment Indicator Lights
NDB	Non-Directional Beacon
PAPI	Precision Approach Path Indicator Lights
REIL	Runway End Identification Lights
RRCIU	Remote Radio Control Interface Unit
RVR	Runway Visual Range
VOR/DME	Very High Frequency Omnidirectional Range/Distance Measuring Equipment

Navigation and Landing Facilities (Terrestrial-Based)

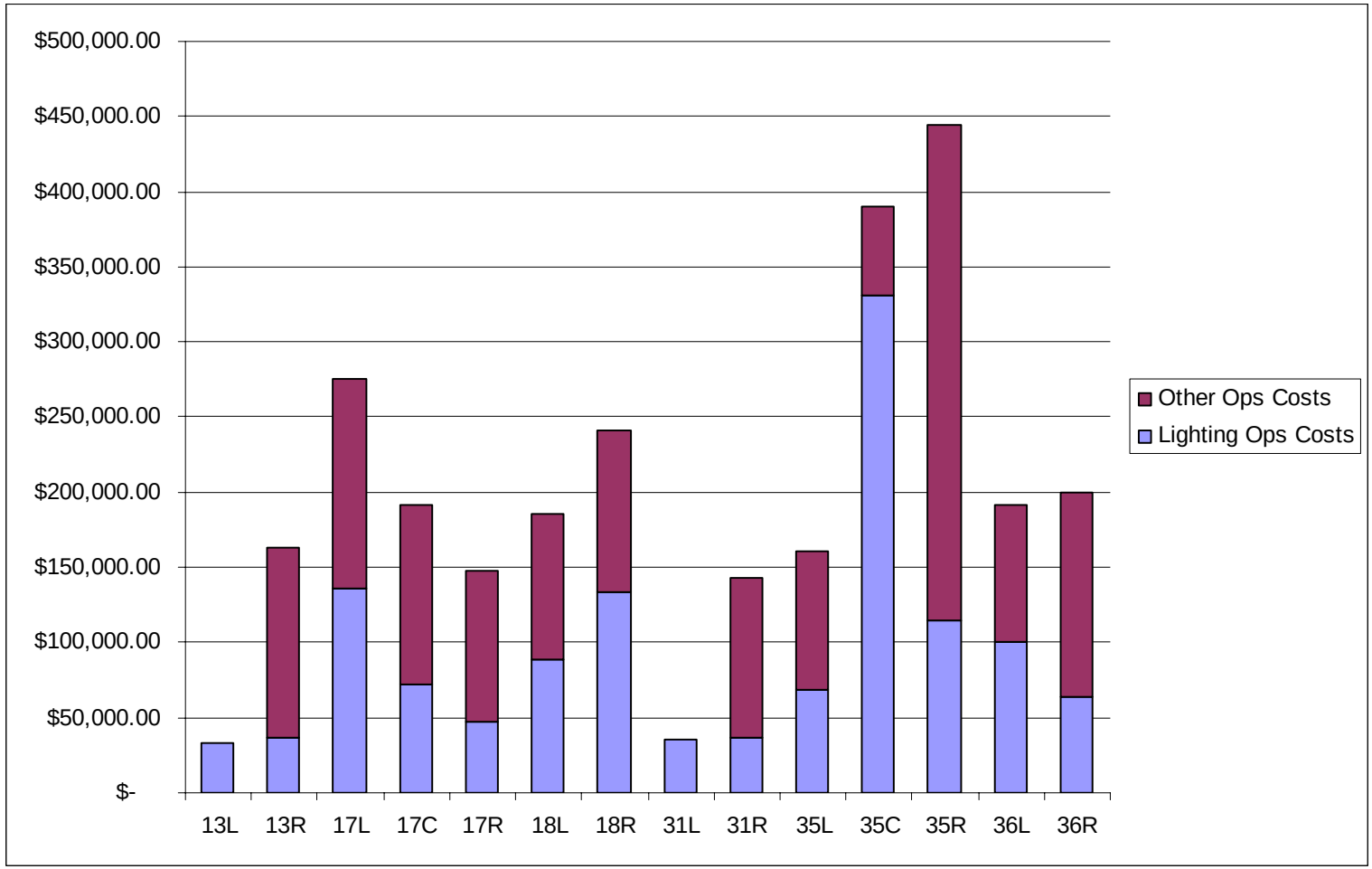


Dallas-Fort Worth

- **World's 3rd Busiest Airport by Traffic**
  - ~ 700,000 Movements
- **14 Runway Ends**
  - 2 Non Precision
  - 7 Cat I
  - 5 Cat II/III

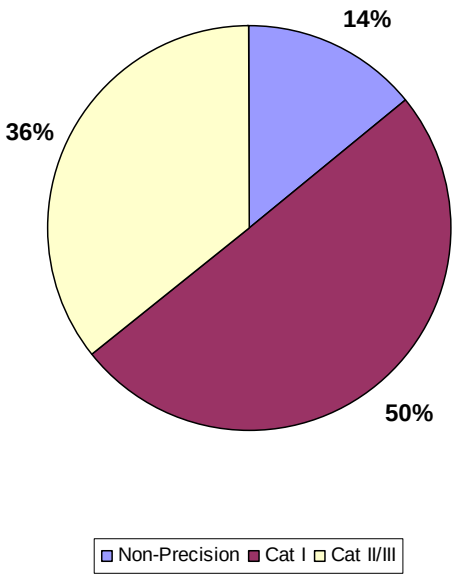


Annual Ops and Maintenance Costs DFW - 2005

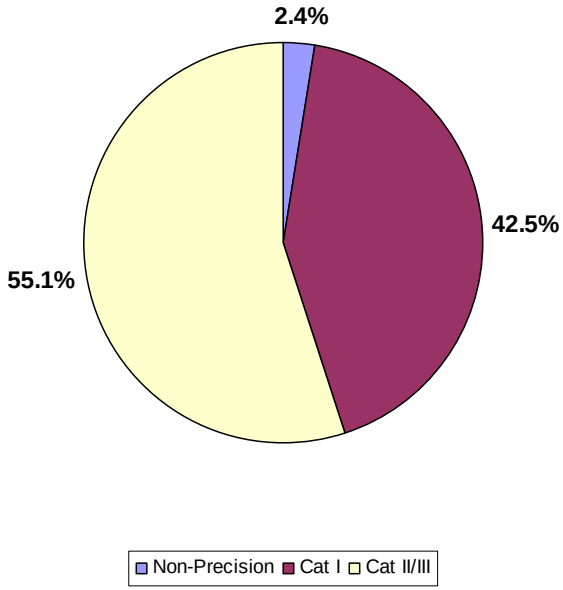


Annual Ops and Maintenance Costs DFW - 2005

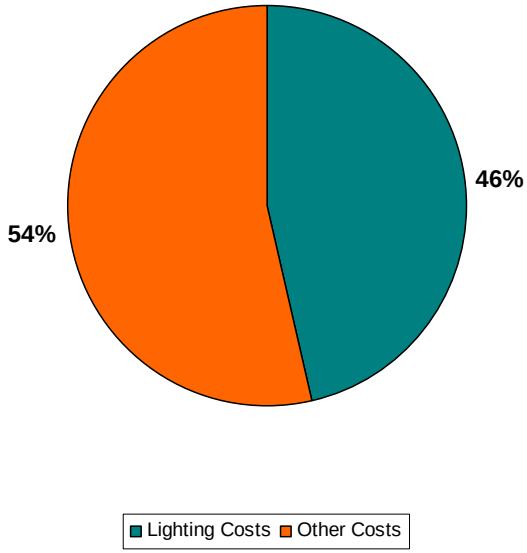
Approach/Landing Facilities at DFW



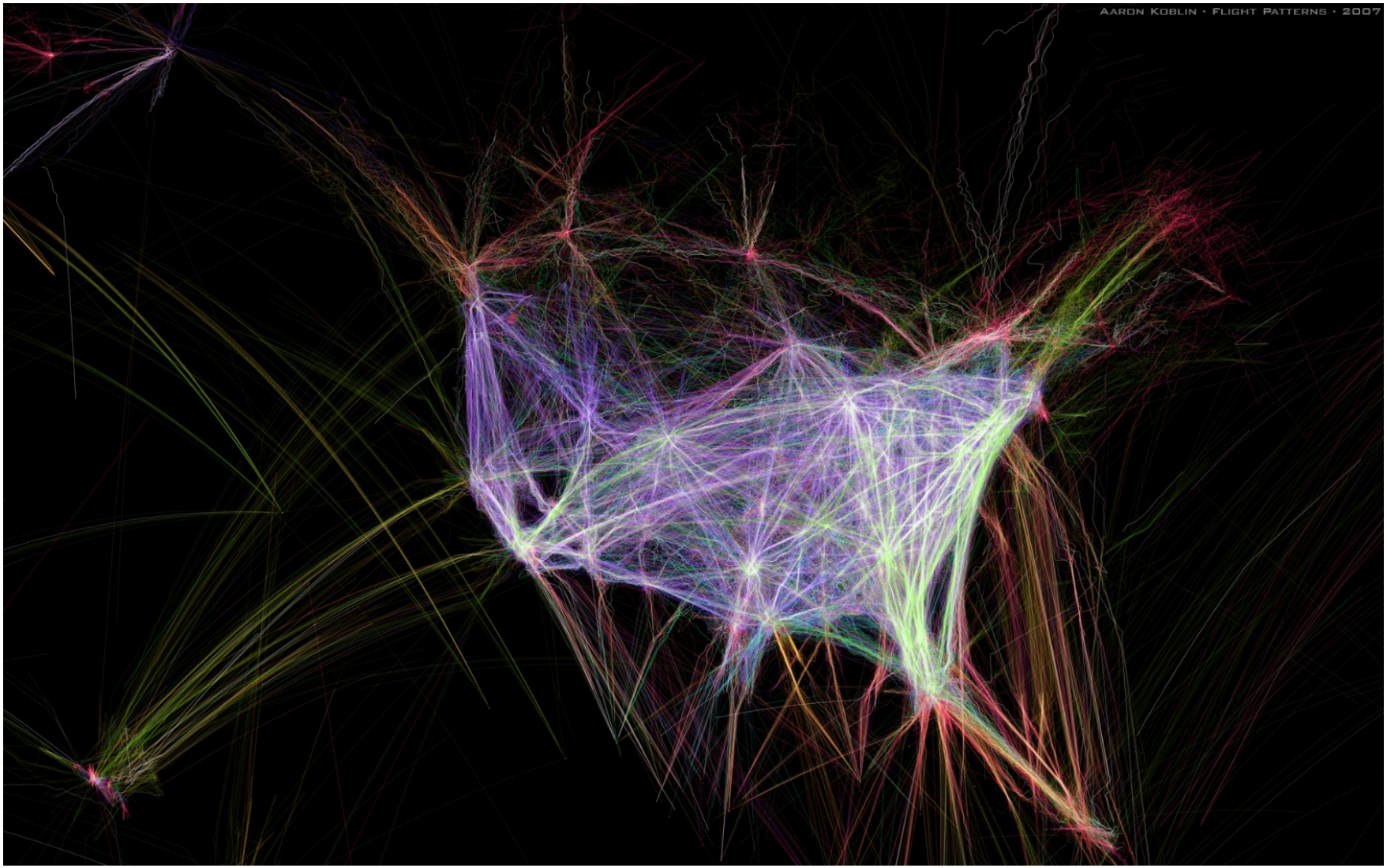
Ops Costs by Facility Type



Ops Costs by Equipment Type



Daily Flight Traffic Over the U.S.



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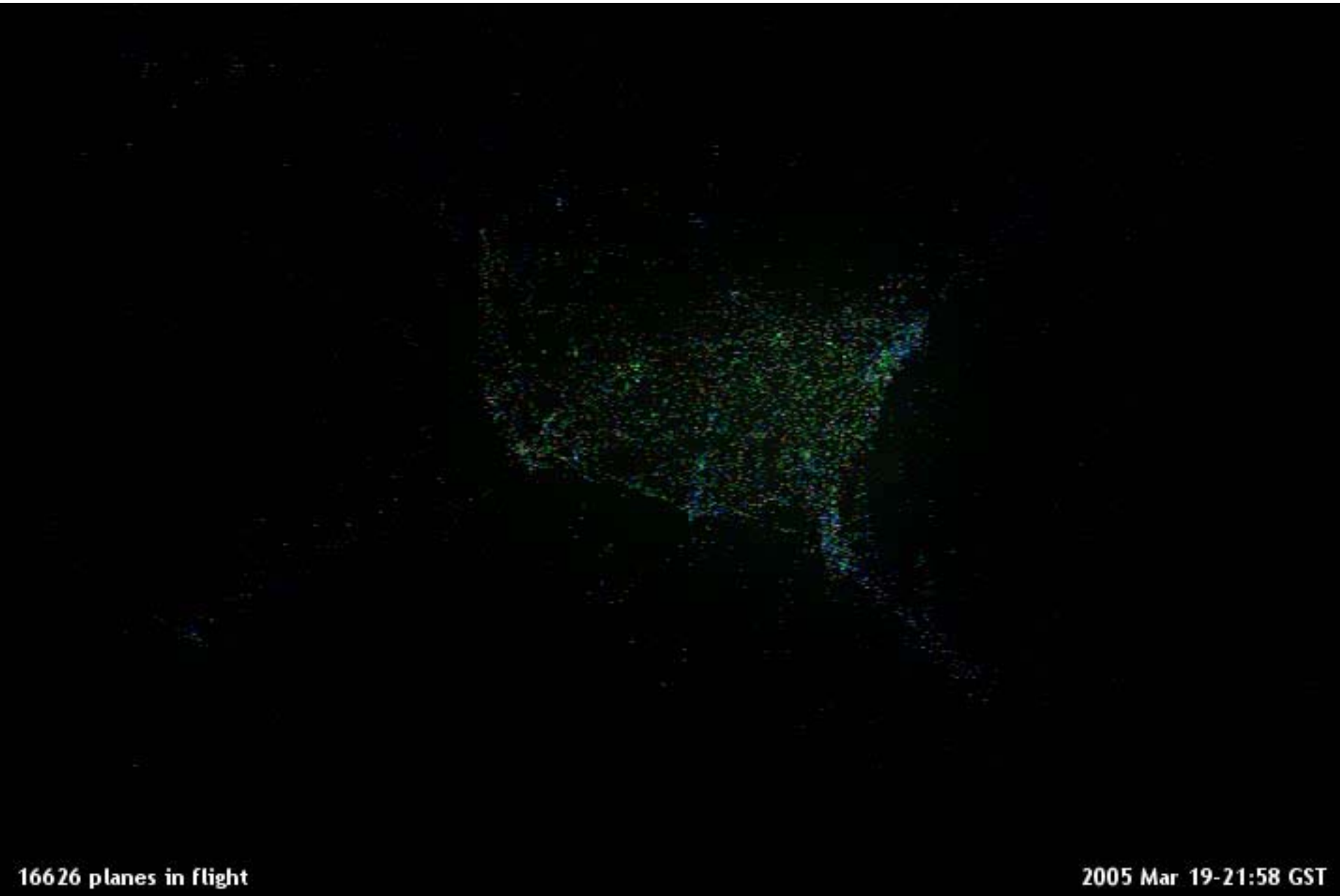


NextGen Senior Policy Committee

- **Department of Transportation**
  - Mary E. Peters, Secretary of Transportation
  - Jeffrey N. Shane, Under Secretary for Policy
- **Department of Defense**
  - Michael W. Wynne, Secretary, United States Air Force
- **Department of Commerce**
  - Vacant, Deputy Secretary
- **Department of Homeland Security**
  - Paul A. Schneider, Acting Deputy Secretary
- **White House Office of Science and Technology Policy**
  - Dr. John Marburger, Director
- **NASA**
  - Dr. Michael Griffin, Administrator
- **FAA**
  - Robert Sturgell, Acting Administrator

Path to Performance-based NAS

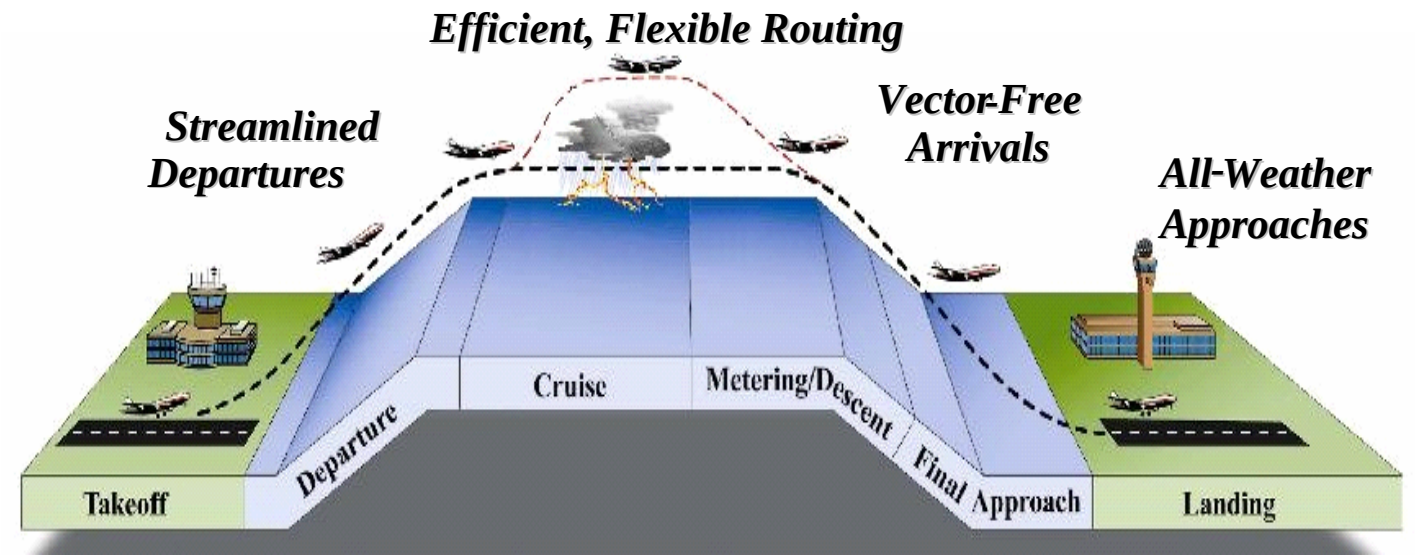
- **The Next Generation Air Transportation System (NextGen) Plan Defines A System That Can Meet Demands For The 21st Century**
  - Precision Navigation is one of the 9 Key capabilities
- **The Roadmap for Performance-Based Navigation v2 was published in 2006**
- **FAA Navigation Services has developed the Navigation Evolution Roadmap that defines the infrastructure now and in the future for implementation of RNAV, RNP and NextGen**

What Is "Performance-Based Navigation?"

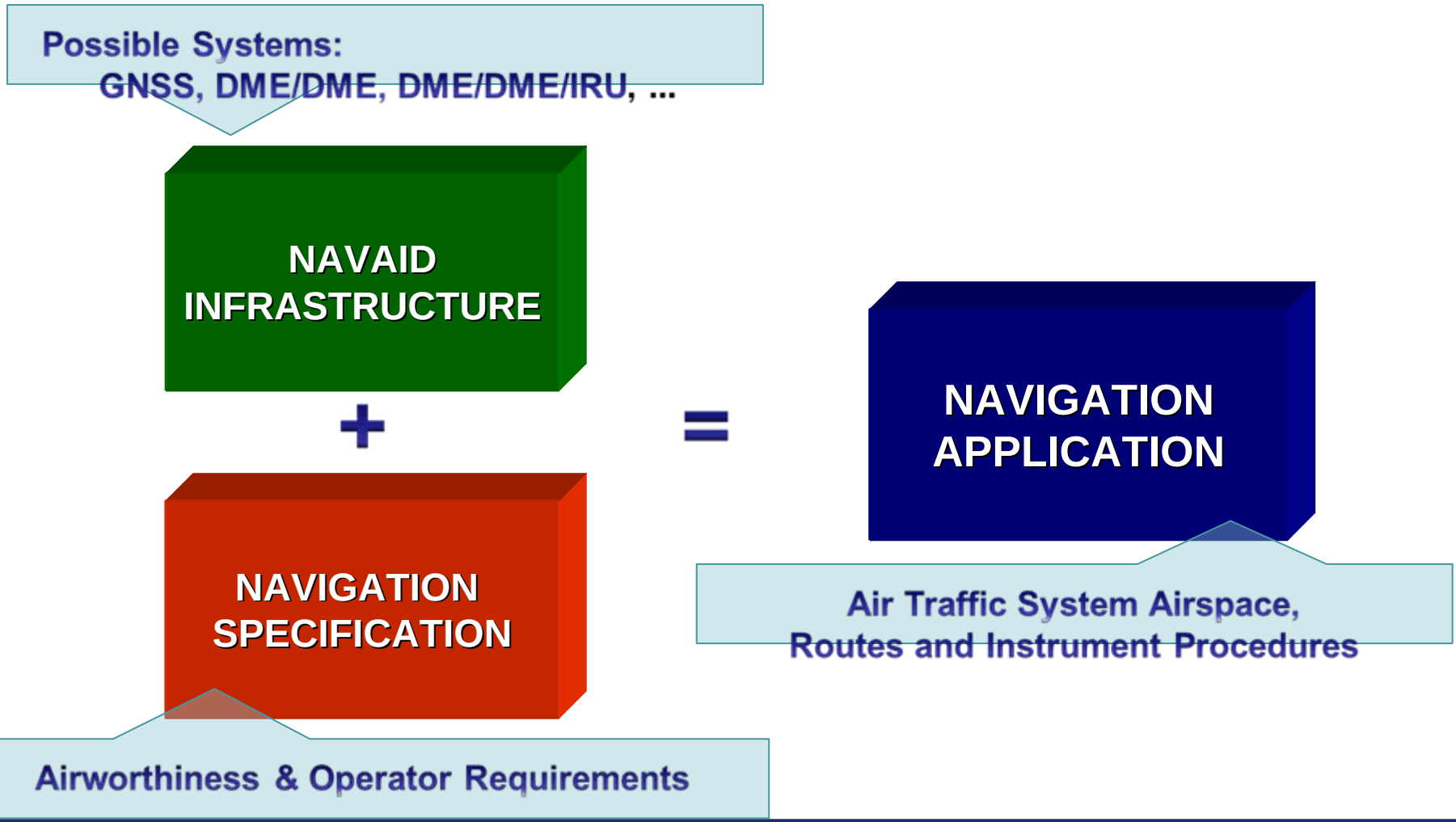
- **An End-to-End Air Transportation System Based On Performance Standards Rather Than Specific Technologies Or Equipment**
  - Area Navigation (RNAV)
  - Required Navigation Performance (RNP)
- **Recognizes The Ability Of Modern Aircraft To Operate Safely And Efficiently Using A Variety Of On-Board Systems and External Signals**

Performance-Based Navigation

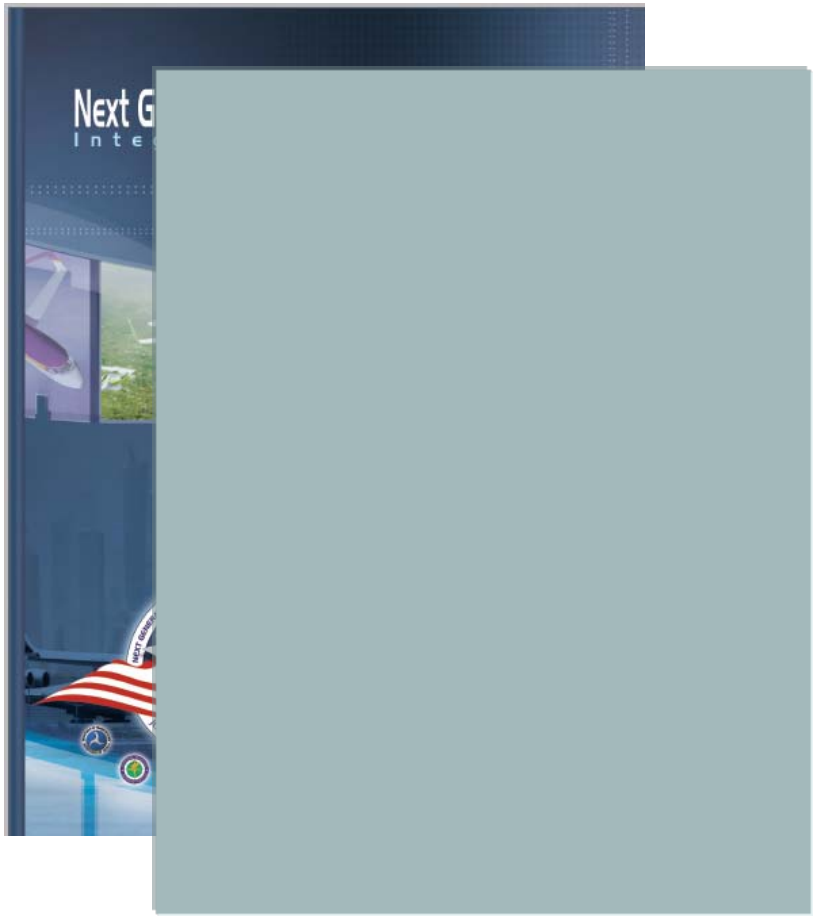
- Complete Transition By 2025
- Consistent With ICAO Global Vision
- Operational Capability Based On GPS And Augmentations
- Enhance Safety, Capacity, Efficiency
- Reduce Cost For Legacy Navigation Systems



ICAO: Basic Elements of PBN Implementation (RNAV or RNP)



The Next Generation Air Transportation System (NextGen) Plan Defines A System That Can Meet Demands For The 21st Century



Capabilities

Trajectory-Based Operations

Performance-Based Operations and Services

Precision Navigation

Weather Integration

Network-Centric Information Sharing

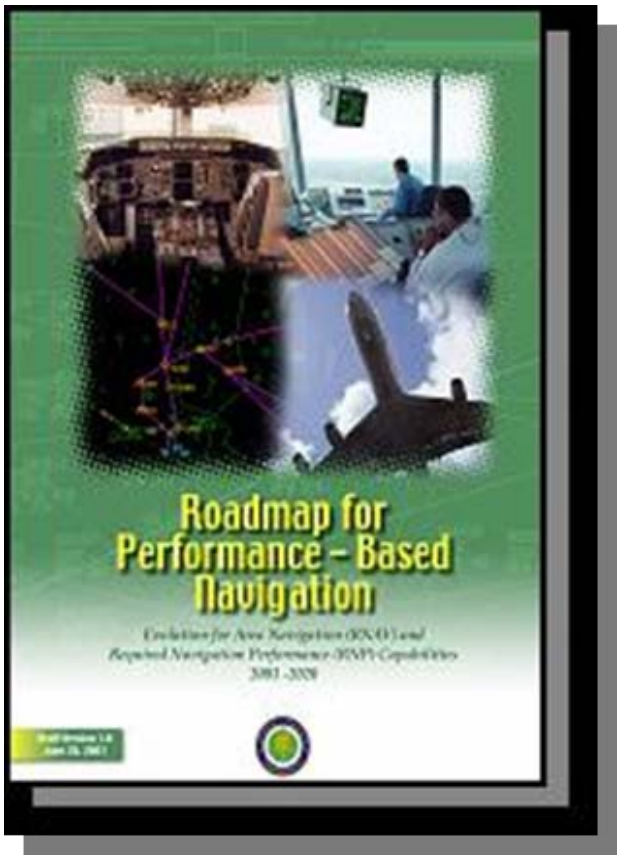
Surveillance Services

Equivalent Visual Operations

Super Density Operations

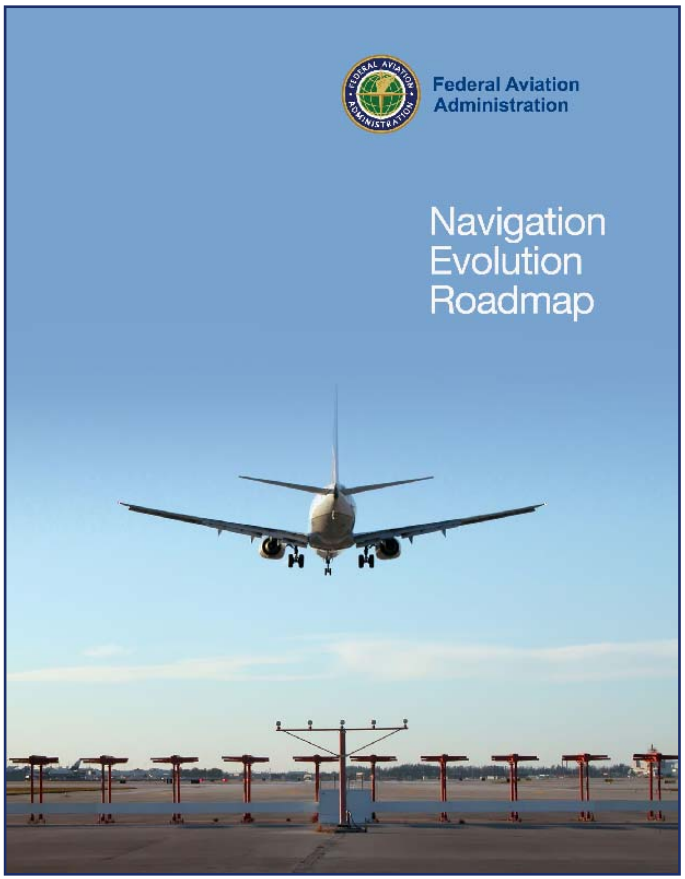
Layered, Adaptive Security

Roadmap for Performance-Based Navigation



- The Roadmap for Performance-Based Navigation v2 was published in 2006
- FAA Navigation Services has developed the Navigation Evolution Roadmap that defines the infrastructure now and in the future for implementation of RNAV, RNP and NextGen

Navigation Evolution Roadmap

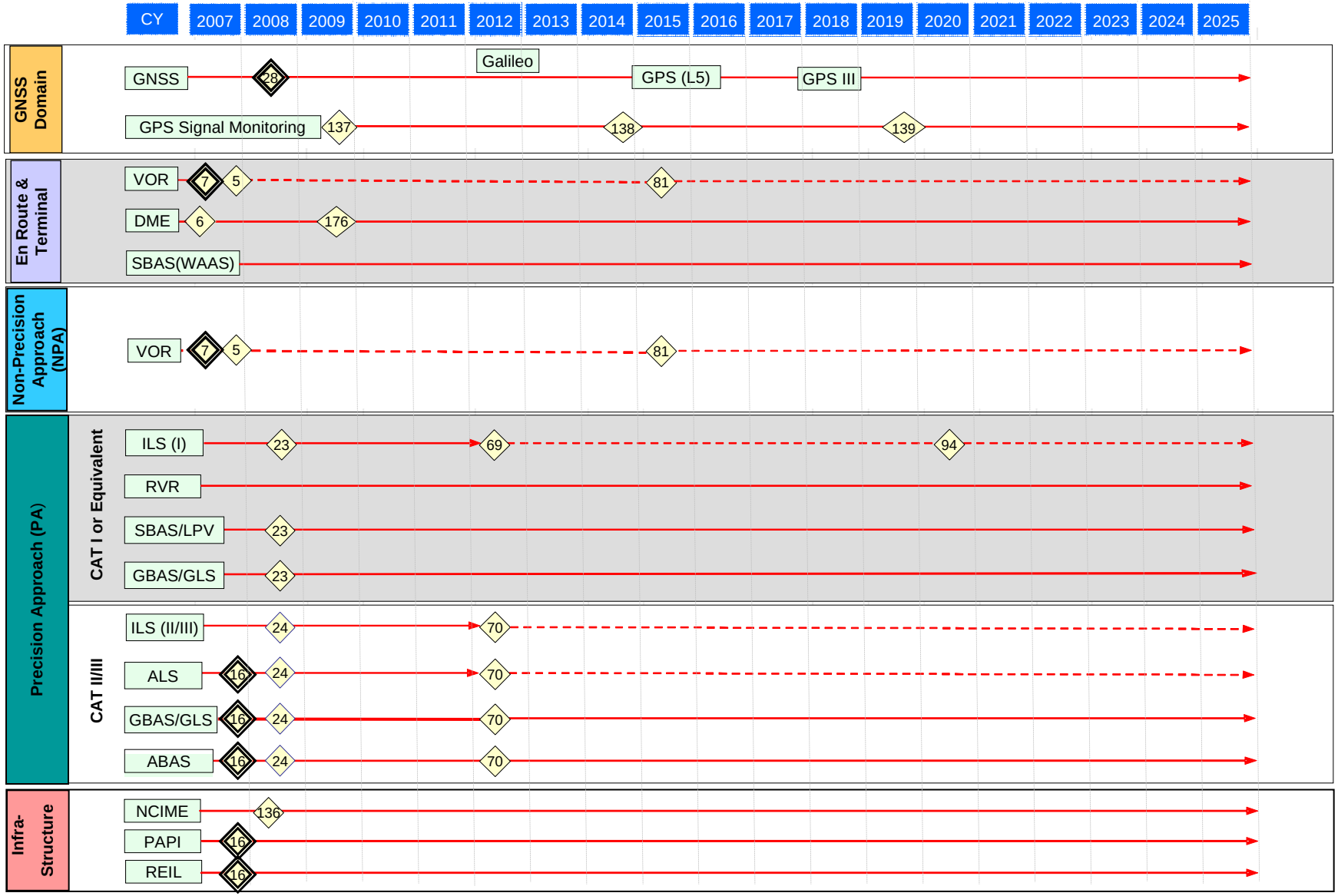


- **In formal coordination for signature by FAA Administrator**
- **Provides a high-level framework for transition to performance-based navigation from navigation services primarily based on terrestrial-based systems**
- **Collaborative effort with aviation community**
- **Companion business plan**

Navigation Evolution Roadmap

– *An element of the FAA's strategic planning*

Navigation Roadmap



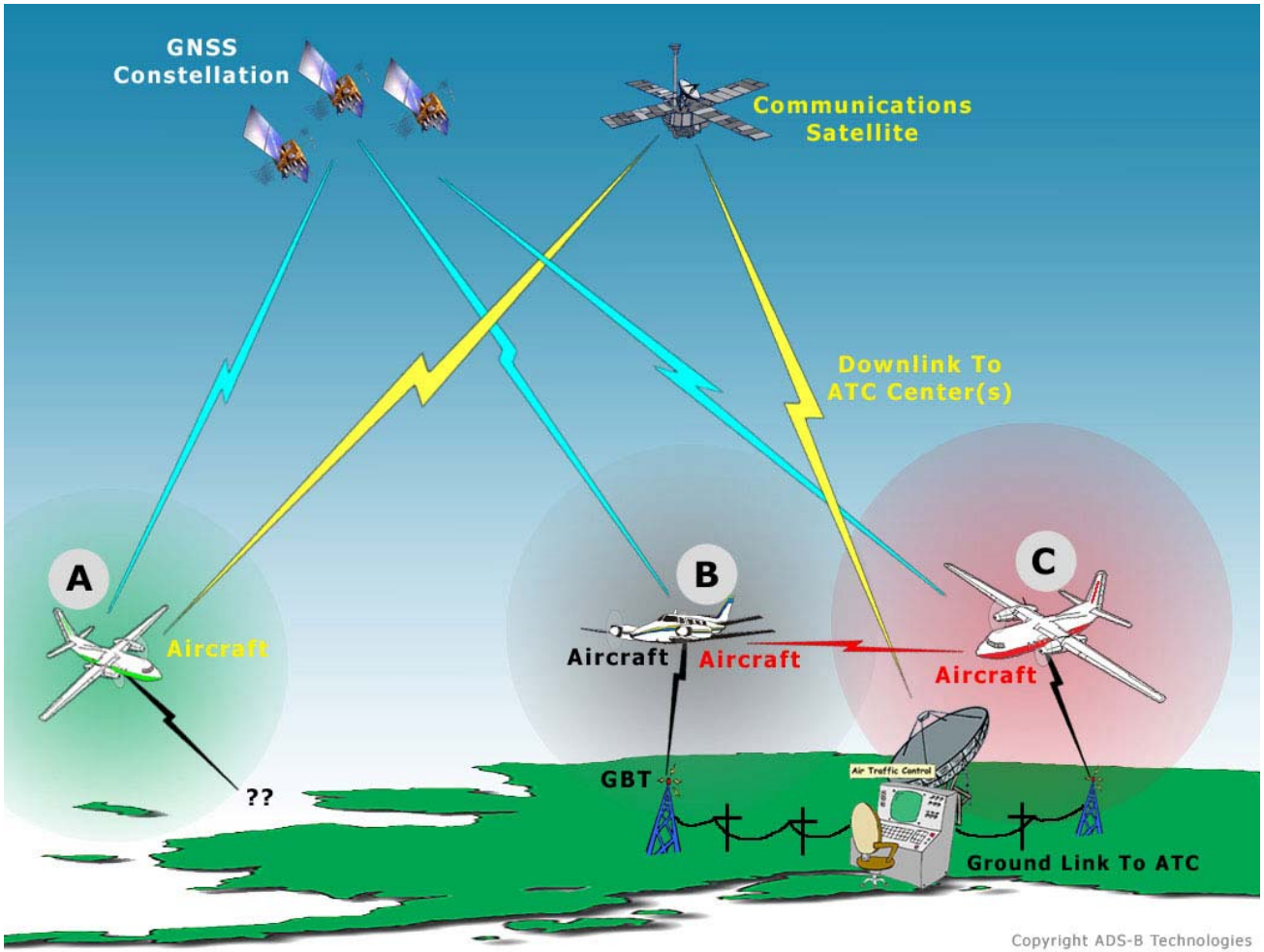
Navigation Roadmap Decision Points

- 5 — 2007 - VOR decision for drawdown based on GNSS
- 6 — 2007 - Develop rightsizing DME Requirements, e.g., service volume, architecture, pathway
- 23 — 2008 - Decision on NextGen CAT I landing system
- 24 — 2008 - Decision on NextGen CAT II/III service, pending feasibility & schedule of potential ABAS/GBAS solutions and risk mitigation strategies
- 69 — 2012 - Begin ILS CAT I drawdown - limited backup at OEP airports
- 70 — 2012 - Determine if CAT II minima is the appropriate requirement at specific airports
- 81 — 2015 - VOR decision on complete drawdown
- 94 — 2020 - Decision on complete ILS CAT I drawdown

Navigation Roadmap Decisions (cont.)

- 136 **2008 – NCIME Acquisition Decision**
- 137 **2009 – GPS Signal Monitoring Acquisition Decision**
- 138 **2014 – Signal Monitor Integration with GPS OCX Acquisition Decision**
- 139 **2019 – GPS Integrity Message Service ISD and WAAS Transition Decision**
- 176 **2009 - Develop phased approach for DME service to support RNAV/RNP**
- 7 **2007 – See Surveillance Roadmap**
- 16 **2007 - See Aircraft Roadmap**
- 28 **2008 – See Aircraft Roadmap**

Automatic Dependent Surveillance (ADS-B)

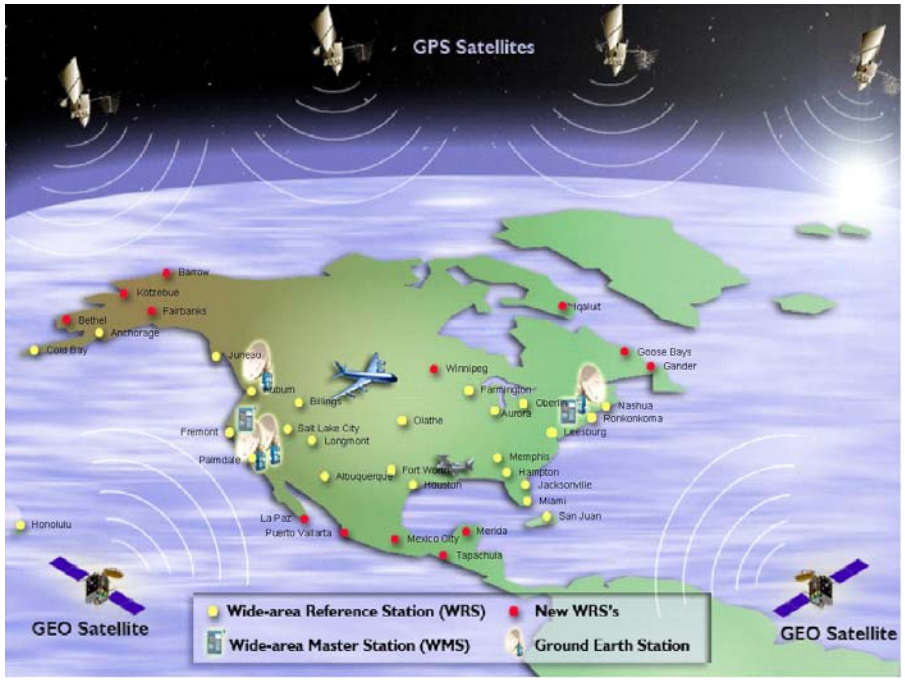


ADS-B Program

- **Benefits**
  - Safety Improvements By Increasing Situational Awareness Both In-flight And On The Ground
  - Increased Operational Efficiency Through Higher Air Traffic Throughput
- **Schedule**
  - Final Rulemaking Issued 2010
  - Avionics Implementation 2010-2020
  - Ground Infrastructure Completion 2013
- **FAA Lifecycle Costs to 2035: ~ $2.4B**

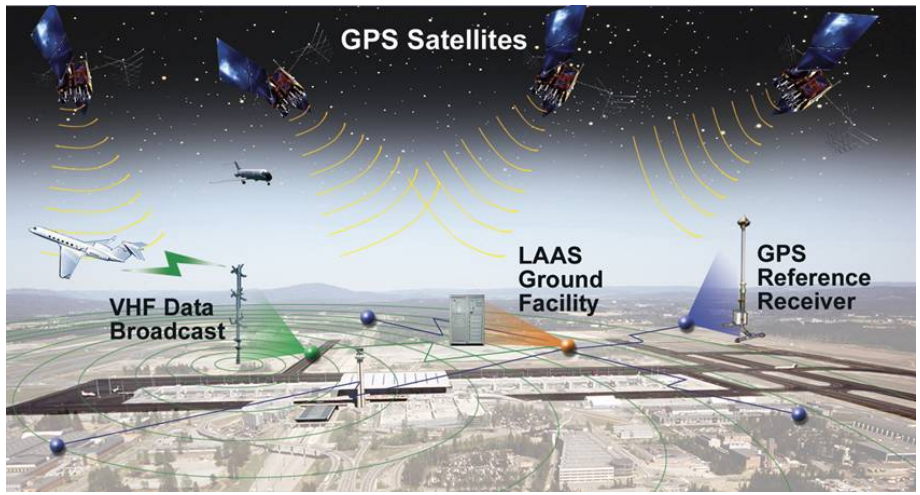
ADS-B is a Primary Building Block for NextGen

Status of SBAS and GBAS Programs

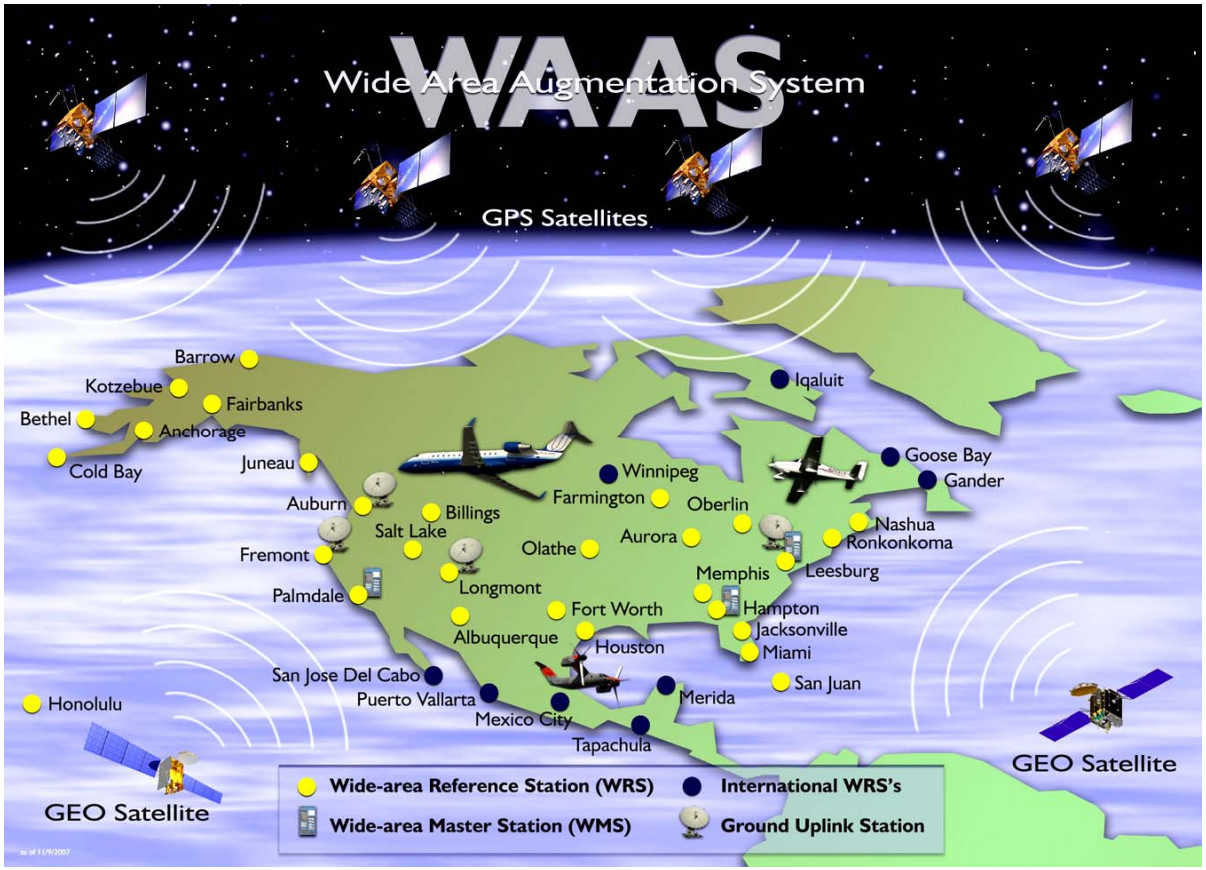


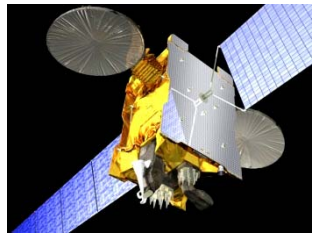
Wide Area Augmentation System (WAAS)

Local Area Augmentation System (LAAS)



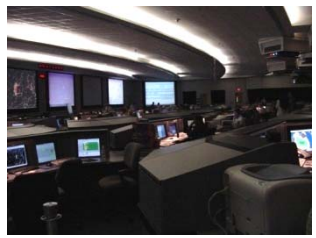
WAAS Architecture





2 Geostationary Satellite Links

4 Signal Generator System/ Ground Earth Stations



2 Operational Control Centers

3 Master Stations

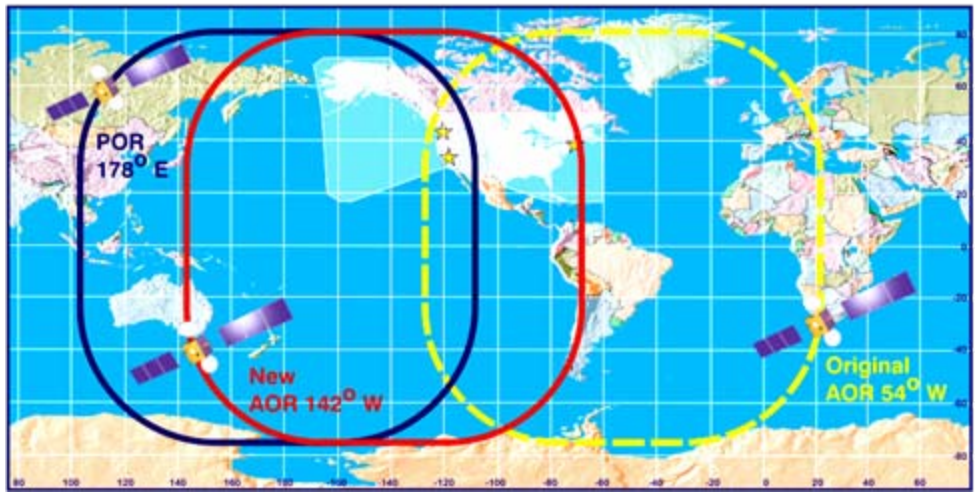
38 Reference Stations

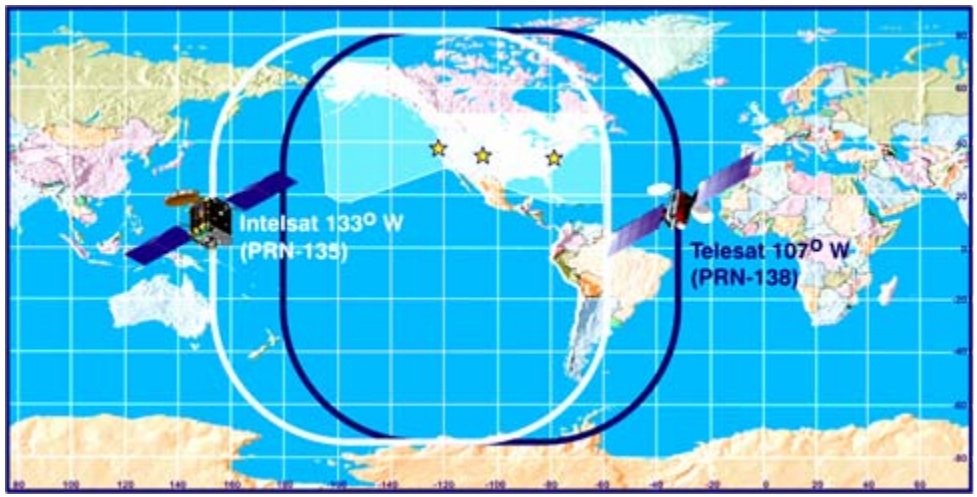
WAAS Phases

- **Phase I: IOC (July 2003)**
  - Provided LNAV/VNAV/Limited LPV Capability
- **Phase II: Full LPV (2003 – 2008)**
  - Improved LPV availability in CONUS and Alaska
  - Consists of additional WRS, hardware updates, software optimization, improved human factors, and GEO replacement
- **Phase III: Full LPV-200 (Cat I Equivalent) Performance (2009 – 2013)**
  - Development, modifications, and enhancements to include tech refresh
  - Steady state operations and maintenance
- **Phase IV: Dual Frequency Operations (2013 – 2028)**
  - Originally scheduled for 2009
    - Delayed to align with DoD's GPS Modernization Program (L5)
  - Will significantly improve availability and continuity during severe solar activity
  - Provide additional protection against unintentional GPS interference
  - Will continue to support single frequency users
  - Steady state operations and maintenance

GEO Satellite Improvements

- **IOC WAAS (Commissioned system) utilized two Inmarsat satellites**
  - Provided single satellite coverage over the majority of the U.S.
  - Relocated to the west by owner
    - Lost coverage in New England
  - Inmarsat satellites removed from operational WAAS July 2007
- **Two replacement satellites launched in 2005, operational in July 2007**
  - Intelsat (Galaxy XV)
  - Telesat Canada (Anik F1R)

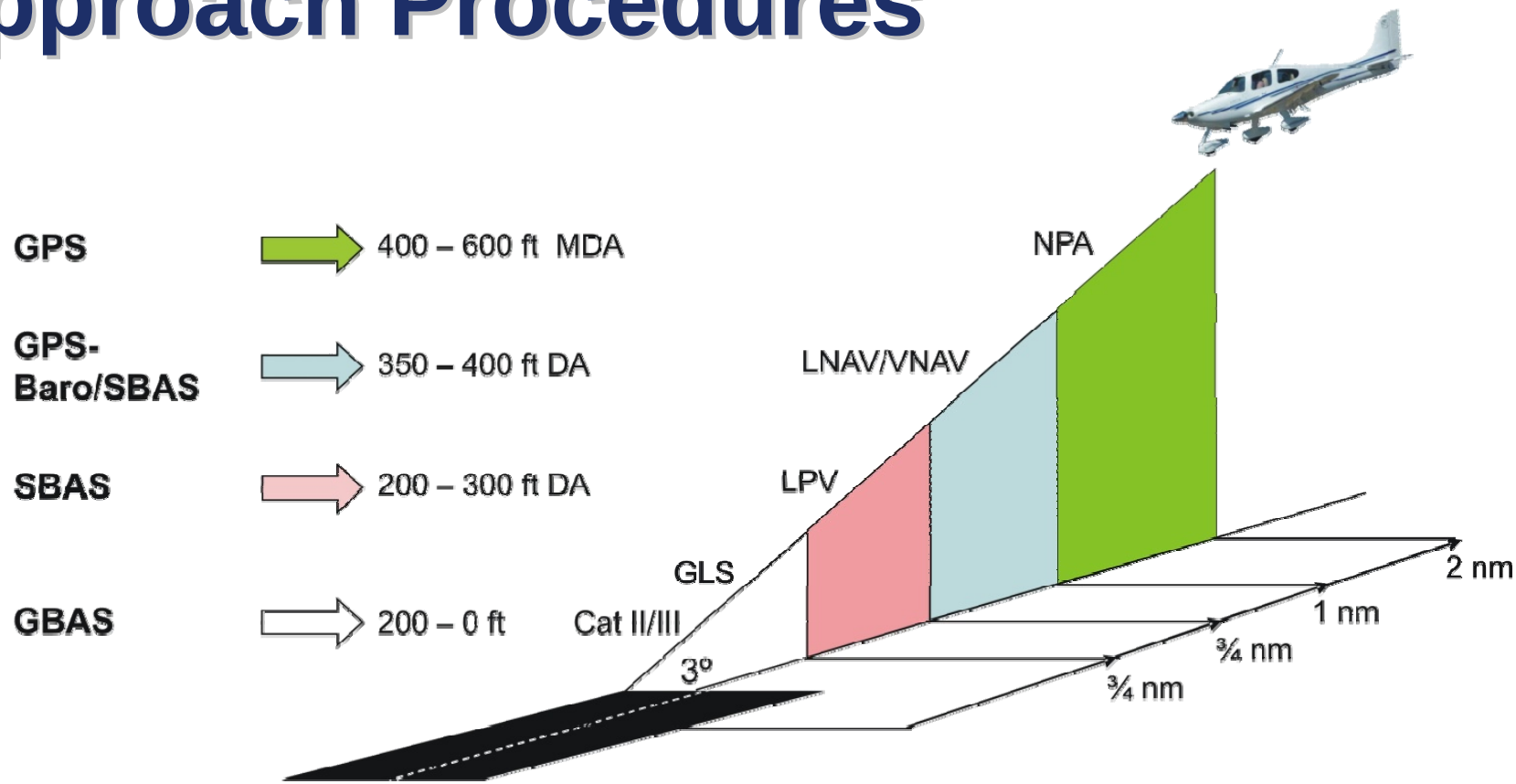




New WAAS Procedures

- **LPV-200’ Minimum**
  - Minimum decision height of new LPV approaches lowered 250’ → 200’
  - First approach published in 2006
  - Will re-evaluate LPVs’ for lower decision height after flight inspection aircraft upgrade (2011)
- **LP Approach**
  - Flown like a Localizer approach
  - Can be developed at approaches that fail to meet LPV criteria due to obstacle clearance surface (OCS) penetrations (same TERPS for ILS)
  - Criteria development in formal coordination; Publication starting in 2008
  - Unlike an ILS, will have LPV or LP on approach chart, but not both.
  - If WAAS correction is lost, avionics defaults to LNAV procedure

Approach Procedures



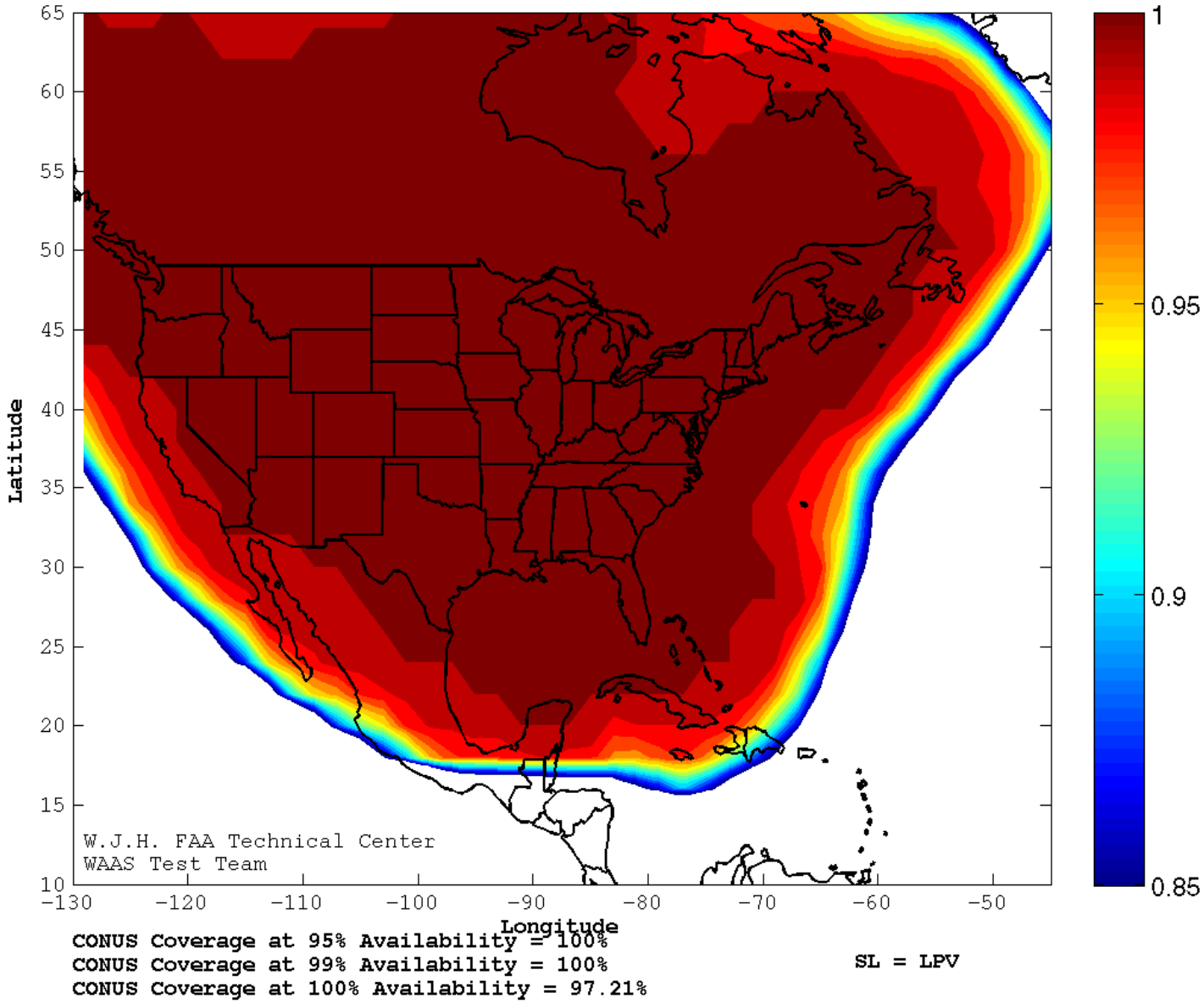
- **Existing Procedures (as of 2/14/08 publication cycle):**
  - 4,411 GPS NPA (LNAV)
  - 1,251 LNAV/VNAV
  - 1028 LPVs (14 of which are below 250')

WAAS Avionics Status

- **Total WAAS avionics receivers sold ~25,000**
- **Approximately 40% of est. 120,000 IFR equipped GA aircraft are equipped with Garmin receivers**
  - New GNS-400/500 series WAAS equipped
  - Legacy GNS-400/500 series WAAS upgradable
  - G-1000 becoming WAAS upgradeable
- **Flight Management System Interface more complicated, hence slower to the market**
  - **Rockwell-Collins**: Providing both TSO WAAS enabled multimode receivers and WAAS FMS sensors. Expecting CRJ/Canadair 604 STC approval in FY'08
  - **CMC**: FAA Tech Center's Global 5000 is contracted to integrate CMC WAAS sensor into Honeywell Primus 2000 FMS; expected in 2008. CMC WAAS sensor open architecture targets retro-fit aircraft
  - **Universal Avionics**: WAAS-enabled capability in dual thread UNS-1 FMS TSO. Supports: Helicopters, Turboprops, Business jets, regional aircraft, air transport aircraft retrofits, FAA's two Citations XLs
  - **Honeywell/Bendix King** just announced their product line

WAAS Avionics Status (con't)

- **Air Carrier & Cargo Aircraft**
  - **Southwest Airlines**
    - Equipping 200 Boeing 737 with Rockwell Collins' GPS-4000S for Required Navigational Performance (RNP) operations
  - **Federal Express (FEDEX)**
    - Equipped 253 Cessna Caravan Aircraft with Garmin GNS-530W WAAS avionics and GMX-200 multi-function displays
  - **Horizon Airlines**
    - Has begun to equip their Bombardier Q400 fleet for WAAS LPV capability
- **Helicopter Aircraft Implementing WAAS**
  - Sikorsky, Bell/Textron and Agusta all recently signed commitments to develop a WAAS STC for their Airframes
  - Agusta
    - Submitted their STC application to the New York ACO for implementation of Garmin GNS 480
  - Sikorsky
    - Working on Certification plan
    - Expected to submit to their ACO next week
  - Bell/Textron
    - Bell 429 expected to be certified in 2009


WAAS LPV Coverage Contours -
10/17/07
Latitude
Longitude
65
60
55
50
45
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30
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−120
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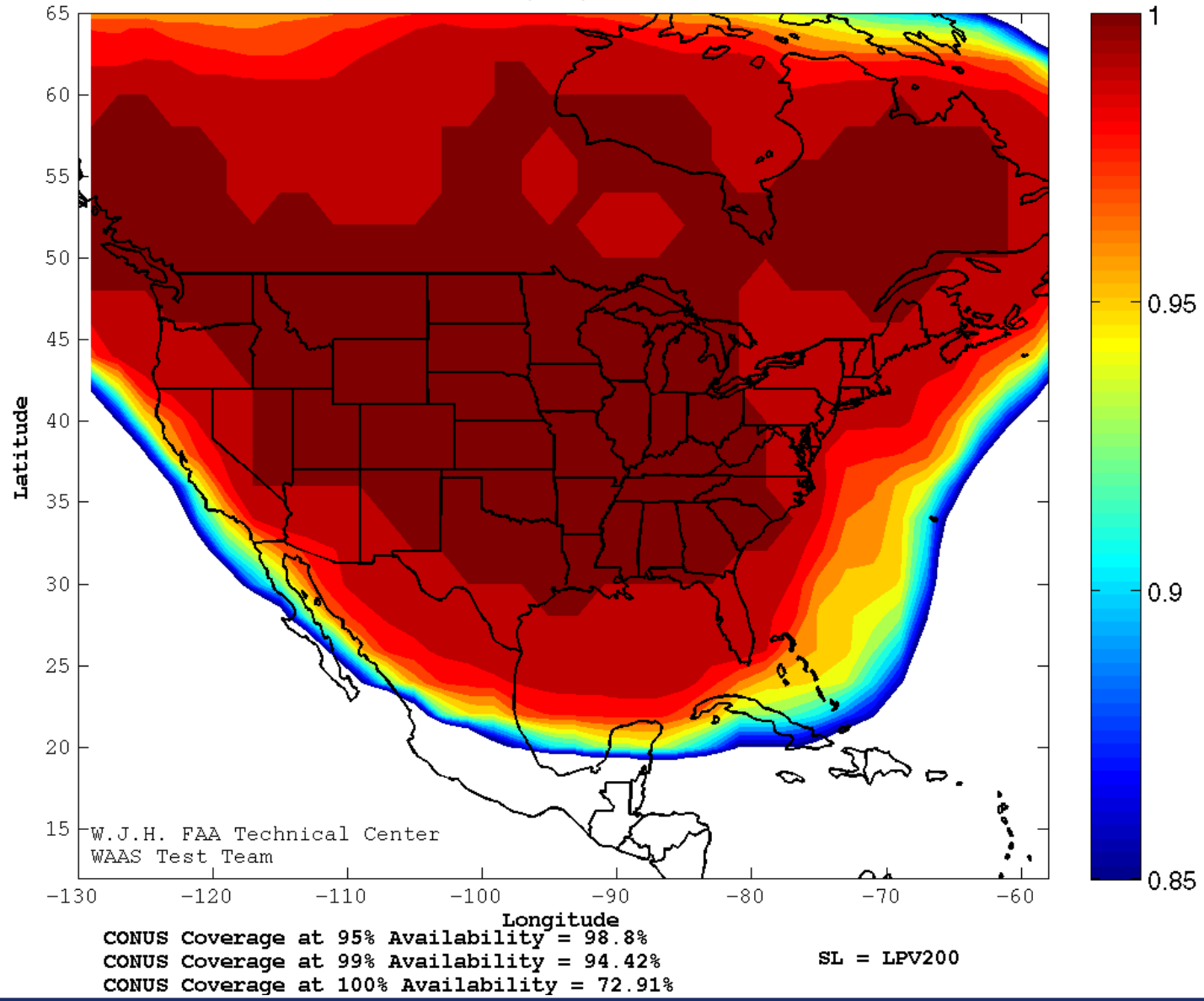
1
0.95
0.9
0.85
W.J.H. FAA Technical Center
WAAS Test Team
CONUS Coverage at 95% Availability = 100%
CONUS Coverage at 99% Availability = 100%
CONUS Coverage at 100% Availability = 97.21%
SL = LPV


WAAS LPV 200 Coverage Contours -
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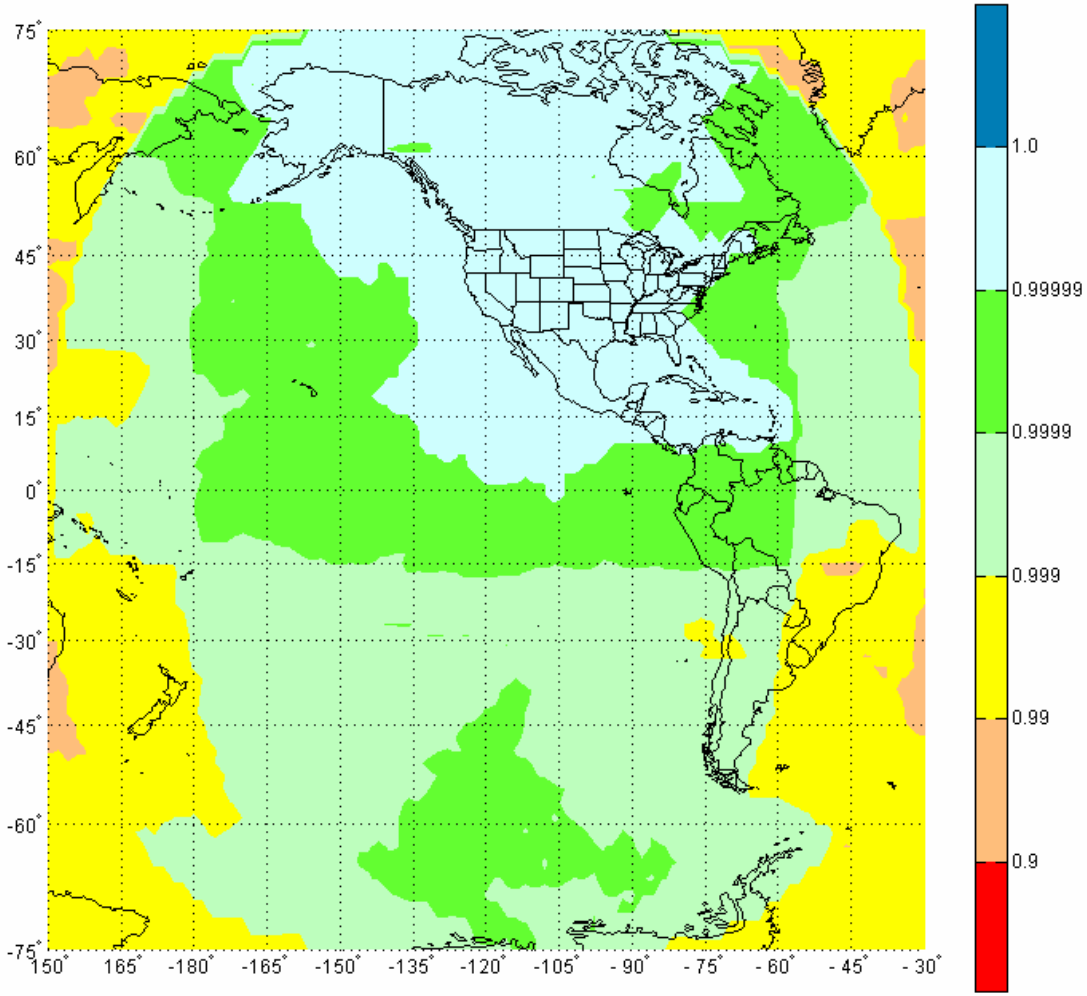
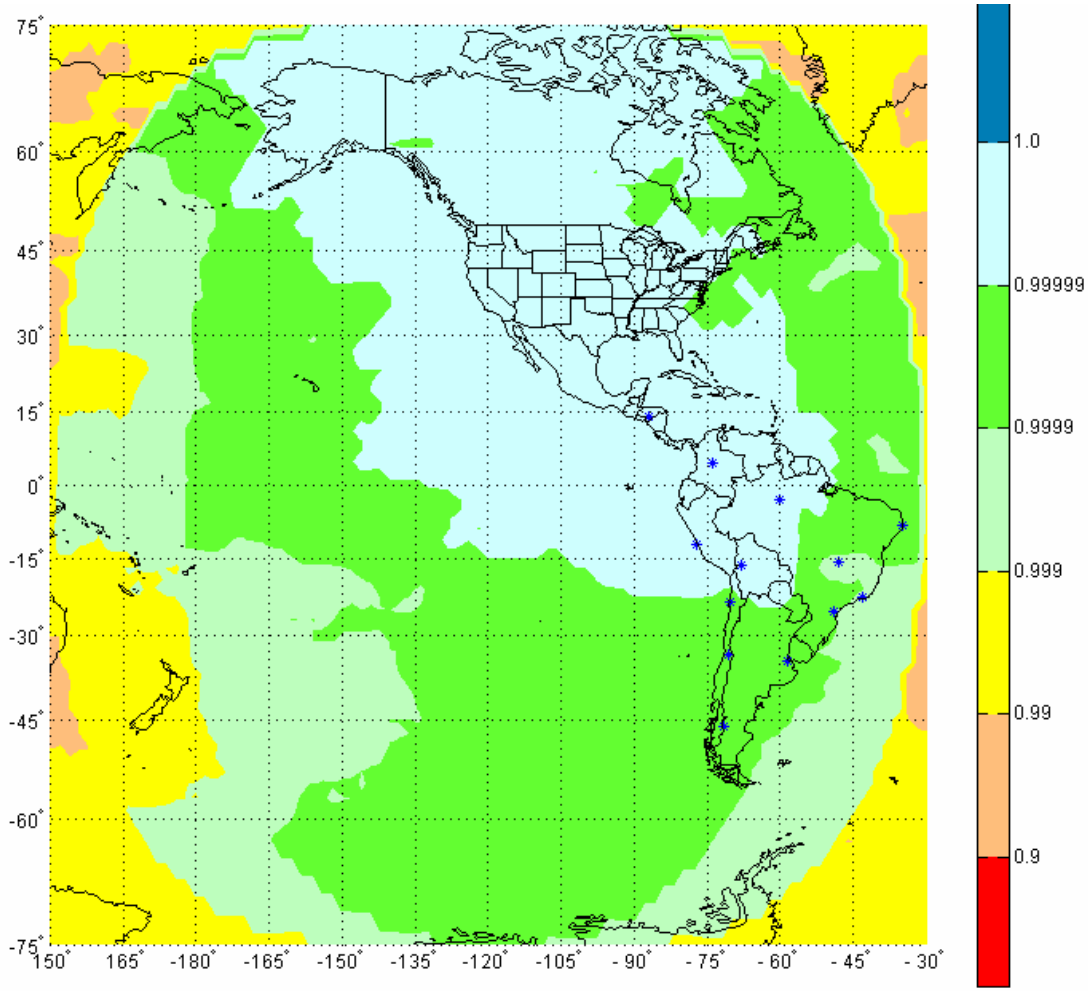
−60
1
0.95
0.9
0.85
W.J.H. FAA Technical Center
WAAS Test Team
CONUS Coverage at 95% Availability = 98.8%
CONUS Coverage at 99% Availability = 94.42%
CONUS Coverage at 100% Availability = 72.91%
SL = LPV200

Expected RNP .3 Performance at the end of WAAS Phase II Development (Sept 2008)



Theoretical Coverage of RNP .3 with 13 South American Reference Stations



Instrument Flight Procedures Panel

- **FAA adopted ICAO point-in-space (PinS) criteria**
  - Pilot Information and Procedures Design
- **March 2008**
  - Coordinate Route departure criteria
  - Discuss the standardization of manuals between ICAO and FAA
  - Address further ICAO/FAA joint satellite based initiatives

Instrument Flight Procedures Panel Presentations, March 2008

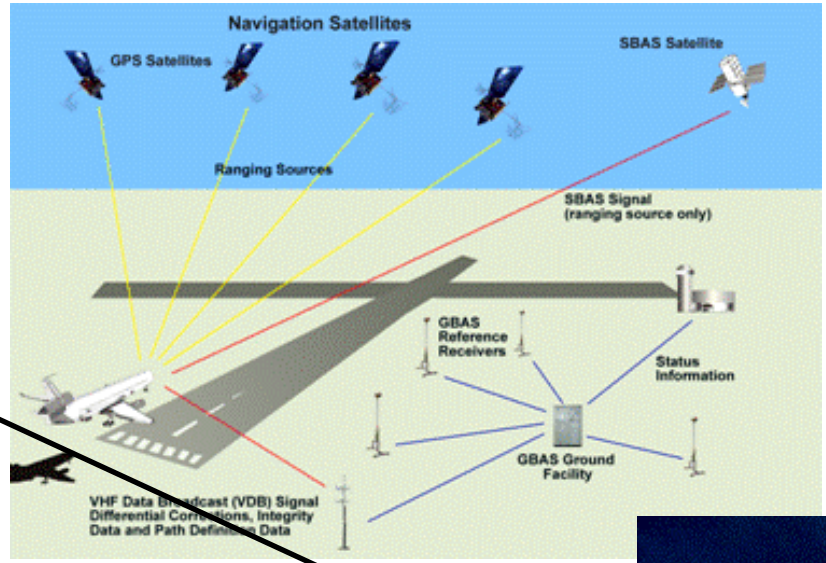
- Doc 8168 Volume II proposals for PinS Route Departure criteria
- Doc 8168 Volume I proposals for PinS Route Departure criteria
- Standardization in Annex 4 and Charting manual of charting of PinS procedures
- Recognition of the Need for a Helicopter supplement to the ICAO Performance Based Navigation Manual
- Need for Navigation specification for reverse PinS Departure (consistent with Order 8260.42B Special Departure criteria)
- Reduction in existing Terminal Area Semi-widths to Meet Helicopter Reduced Flight Technical Error

Future Rotary Aircraft Actions

- **Charting of Heliport Departure Procedures**
- **Special "En Route" Criteria with WAAS Equipage (Consistent with Appendix I to Order 8260.42B)**
- **LP PinS Procedure criteria**
- **LPV PinS Procedure criteria**

LAAS

DATALINK



Antenna

GPS

Base Station Computes Differential Corrections, Provides Integrity Check & Provides Approach Coordinates

Transmitter Encoder

Broadcast Information

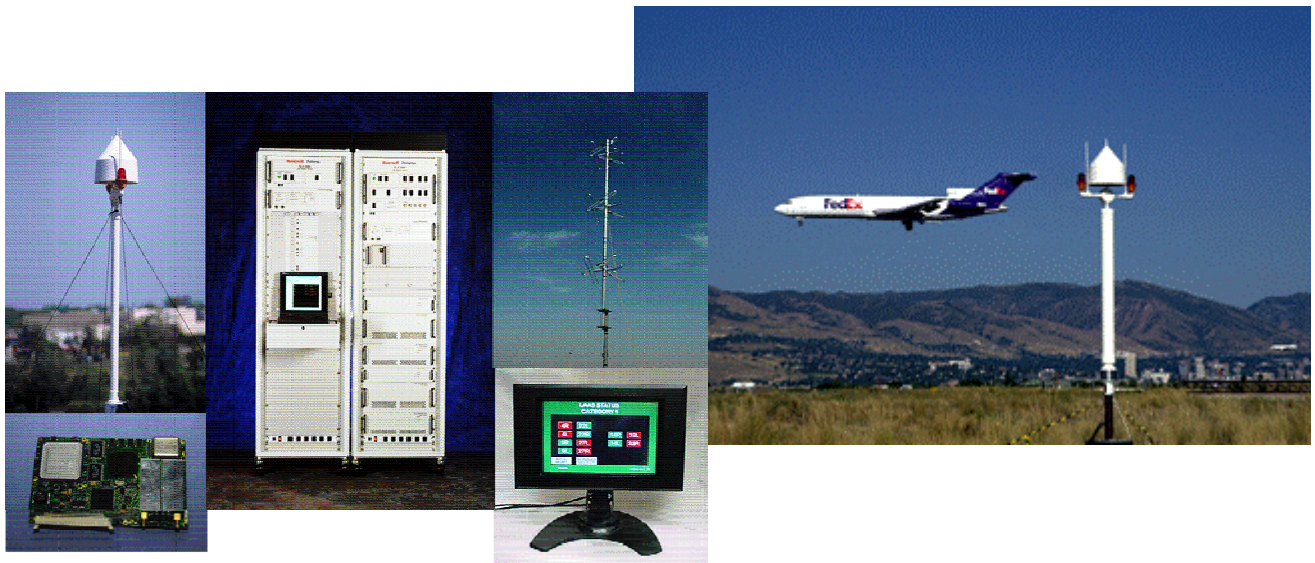
Differential Corrections, Integrity Status and Approach Coordinates

LAAS Capabilities

- The Local Area Augmentation System (LAAS) Represents the U.S. Approach to the International Goal of an Interoperable GBAS Capability
- LAAS Provides a Navigation Signal That Supports the Most Demanding RNP Requirements
- LAAS is complementary to SBAS
- One LAAS Can Cover the Entire Terminal Area and Enables Precision Guidance
  - Precision approach for Category I, II, & III
  - Multiple runway coverage
  - Complex procedures Guided missed approaches and departure procedures
  - Aircraft surface navigation

Current Activities

- Integrity Analysis and Prototype Development
- GBAS Approval Process
- GBAS/LAAS Operational implementation
- International Cooperation
- CAT-III Research & Development Activities



GBAS Integrity

- Integrity Analysis and Prototype Development
  - FAA GBAS prototype work under Honeywell Contract
  - Hazardous Misleading Information (HMI) Analysis underway to validate GBAS architecture/design
  - **Responsibility for GBAS Integrity resides in the Ground Facility**
    - The user (aircraft) receives a set of integrity parameters from the LGF and applies those in a set of standardized equations to determine protection levels
    - The user must check the calculated result against the requirement
  - **The Service Provider is responsible for ensuring that the uplink integrity parameters are accurate and that they provide the required function**
    - When used in the specified equations, the protection level must always bound the user error

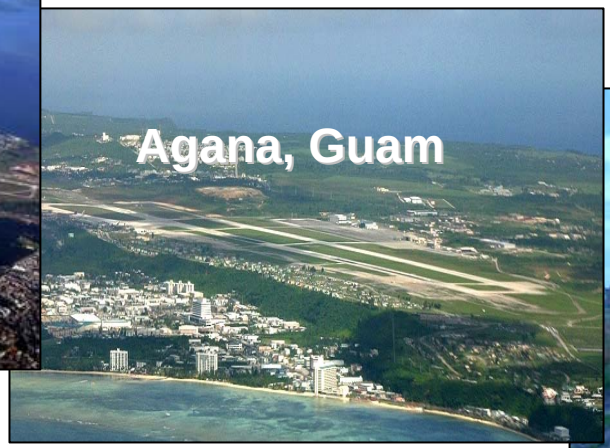
CAT II/III GBAS

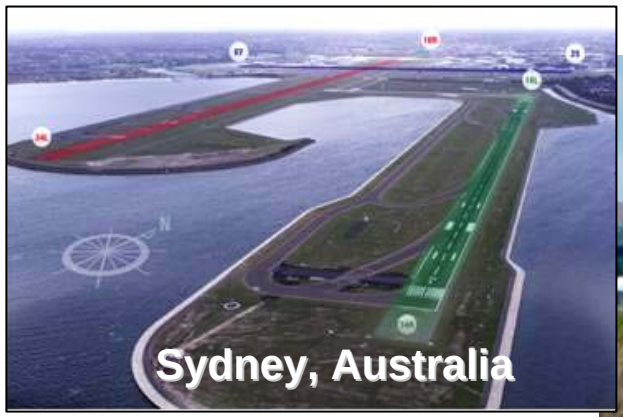
- Requirements development underway in coordination with Boeing and FAA
  - Regular briefings to ICAO/NSP and RTCA/WG-4
- Target milestones
  - Draft MOPS and Non-fed Ground Facility (GF) specification September 2007
    - Ground rule: minimal changes to ground facility and transfer of some requirement responsibility to the aircraft
    - Develop requirements in line with current ILS auto-land criteria
  - Published MOPS and GF specification by Dec. 2008
  - SDA, airworthiness, and OPS approval to follow with close coordination to ensure success

LAAS Operational Implementation

- GBAS Implementation Activities in Memphis
  - Drafted GBAS Procedures for Memphis Airport (MEM)
  - Developed LAAS straight in procedures for all runway ends
  - Coordination with MEM Air Traffic Control
  - Developed GBAS Terminal Area Path (TAP) procedures
  - Developed new traffic flow concept based on GBAS terminal area capability
  - Performing flight test with FAA Technical Center Aircraft and FedEx B727 aircraft

LAAS International Efforts





GBAS International Activities

- FAA Memorandum of Cooperation (MOC for GBAS) established with multiple countries
  - Australia, Brazil
  - Spain, Germany

- **MOC**
  - Scope
    - Engage in cooperative technical activities to support development and operational approval of GBAS capable of providing Category I approach services.
      - Technical Interchange of Local Area Augmentation System (LAAS) Data
      - Access to LAAS Information.
      - Type Acceptance and Commissioning Information.
      - Test and Evaluation Support.

Summary

- The U.S. is transitioning to a performance based CNS/ATM system
- GNSS is one of the cornerstones of NextGen
- RNAV/RNP is being implemented throughout the U.S. National Airspace
- SBAS (WAAS) will complete LPV development in September 2008
- GBAS (LAAS) will complete Cat-I development in December 2008
- The United States will continue its multilateral and bilateral efforts

Questions