GNSS Innovations and Implementations in Aviation

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Research and Innovative Technology Administration

Volpe National Transportation Systems Center

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Federal Aviation Administration

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

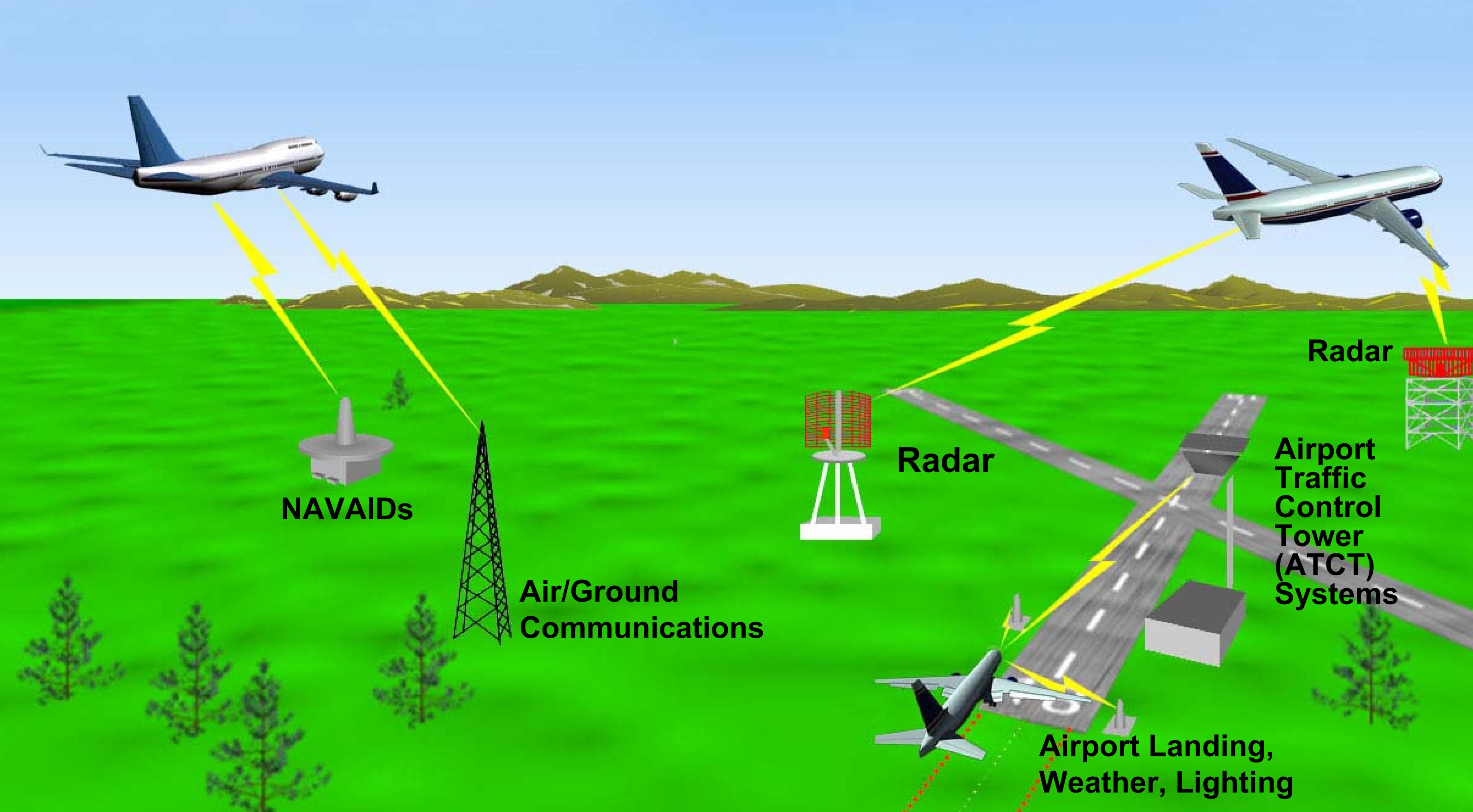
Air Traffic Organization

ATO

Safety. Service. Value.

Leading Aviation Services into the Future

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



NextGen is multi-agency cooperation and investment to transform U.S. air transportation to a system that will meet future needs, domestically as well as internationally.

The NextGen Vision

- A system that is based on satellite navigation and control, digital non-voice communication and advanced networking, and a sharing of decision making between the ground and the cockpit.
- A strong commitment to provide a systematic, well-informed and performance-based approach to transitioning to satellite based systems and to tackling aviation emissions and other environmental issues

NextGen: Improving Service Delivery

From Today's NAS…		…To the NextGen System
Ground-based navigation and surveillance	→	Satellite-based navigation and surveillance
ATC communications by voice	→	Routine information sent digitally
Disconnected information systems	→	Information more readily accessible
Air traffic "control"	→	Air traffic "management"
Fragmented weather forecasting	→	Forecasts embedded into decisions
Airport operations limited by visibility conditions	→	Operations continue into lower visibility conditions

"Greening Aviation" with NextGen

- **Win-win strategies reducing noise, emissions, flight time and fuel burn**
  - Accelerating the development and deployment of RNAV navigation procedures
  - SBAS (WAAS)
    - Direct Routes and precision approach
  - GBAS (LAAS)
    - Cat II/III approaches on non ILS airports
  - Continuous Decent Arrival (CDA)
    - Elimination of step down procedures for specific airframes and airports

Navigation Services Vision

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

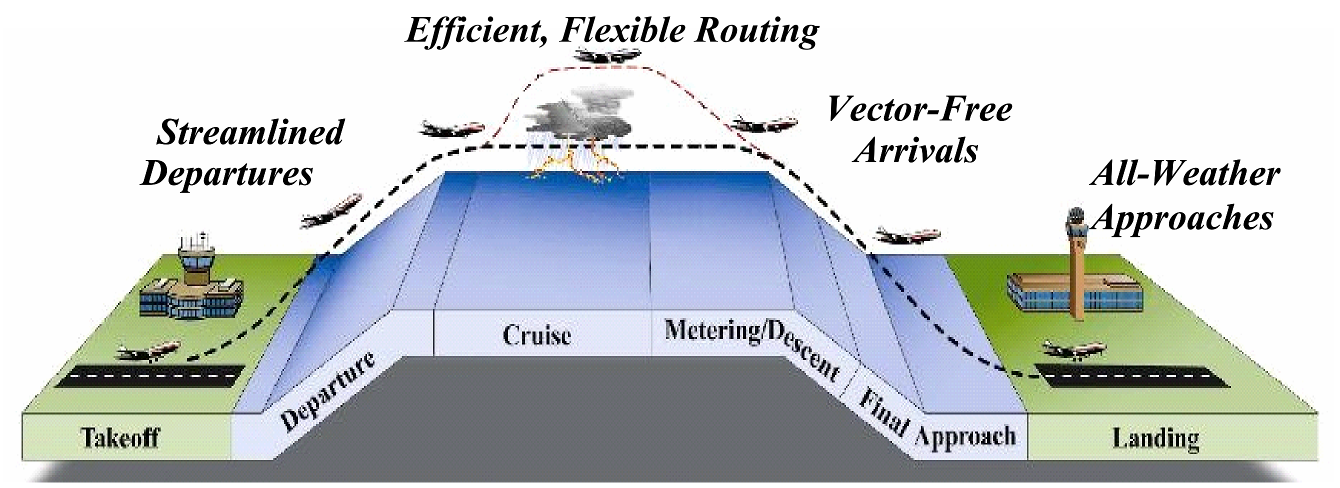
Note – Navigation services vision serves the FAA Mission and ATO Corporate Principles

Path to Performance-based NAS

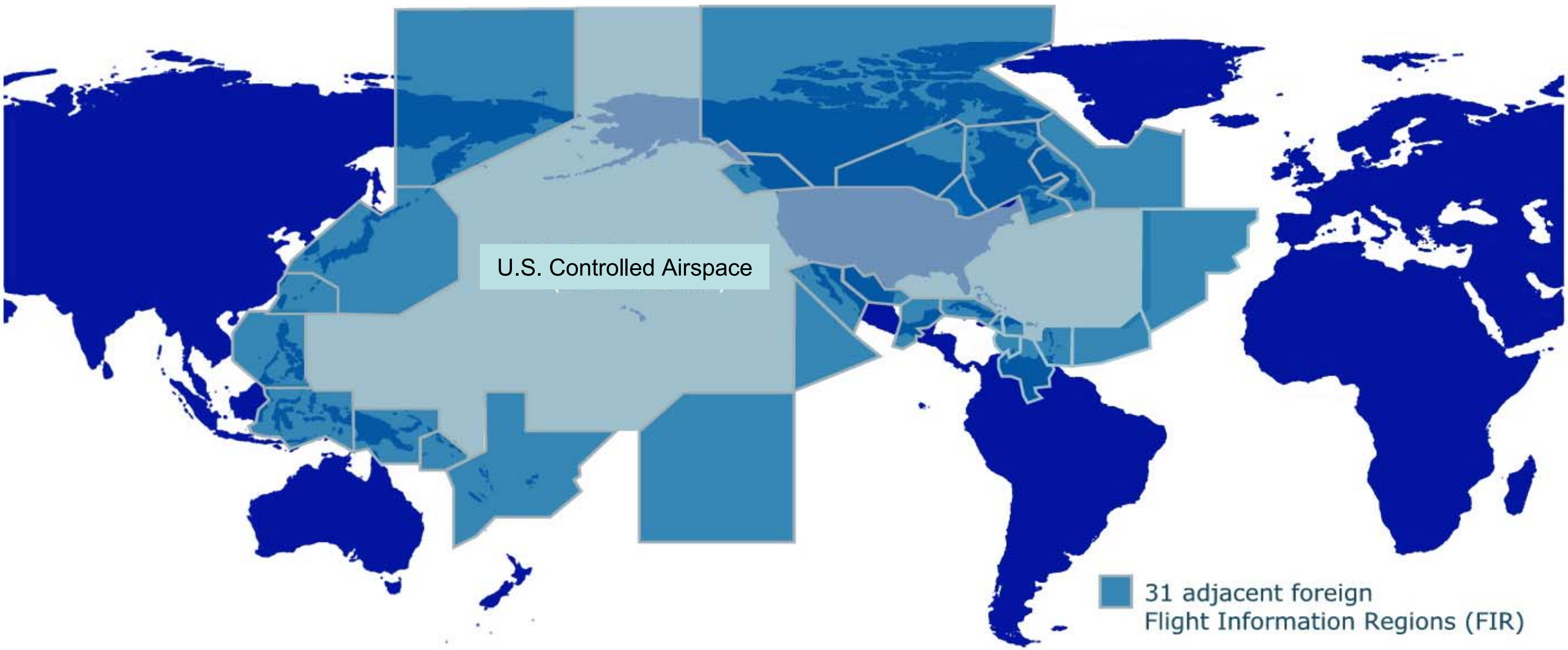
- **The Next Generation Air Transportation System (NextGen) Plan Defines A System That Can Meet Demands For The 21st Century**
  - Precision Navigation is one of the 9 Key capabilities
  - http://www.jpdo.gov
- **The Roadmap for Performance-Based Navigation v2 was published in 2006**
  - http://www.faa.gov/about/office_org/headquarters_offices/avs/offices/afs/afs400/rnp/media/RNProadmap.pdf
- **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**
  - Draft – in coordination with industry before FAA Administrator will sign.

Performance-Based Navigation in the United States

- 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



Int'l Cooperation… A Necessity



- **U.S. Assigned Airspace Equals 77 Million Square Kilometers**

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

Possible Systems:
GNSS, DME/DME, DME/DME/IRU, …

NAVAID INFRASTRUCTURE

+

NAVIGATION SPECIFICATION

Airworthiness & Operator Requirements

=

NAVIGATION APPLICATION

Air Traffic System Airspace, Routes and Instrument Procedures

Atlanta (ATL) Departure Procedures Before RNAV

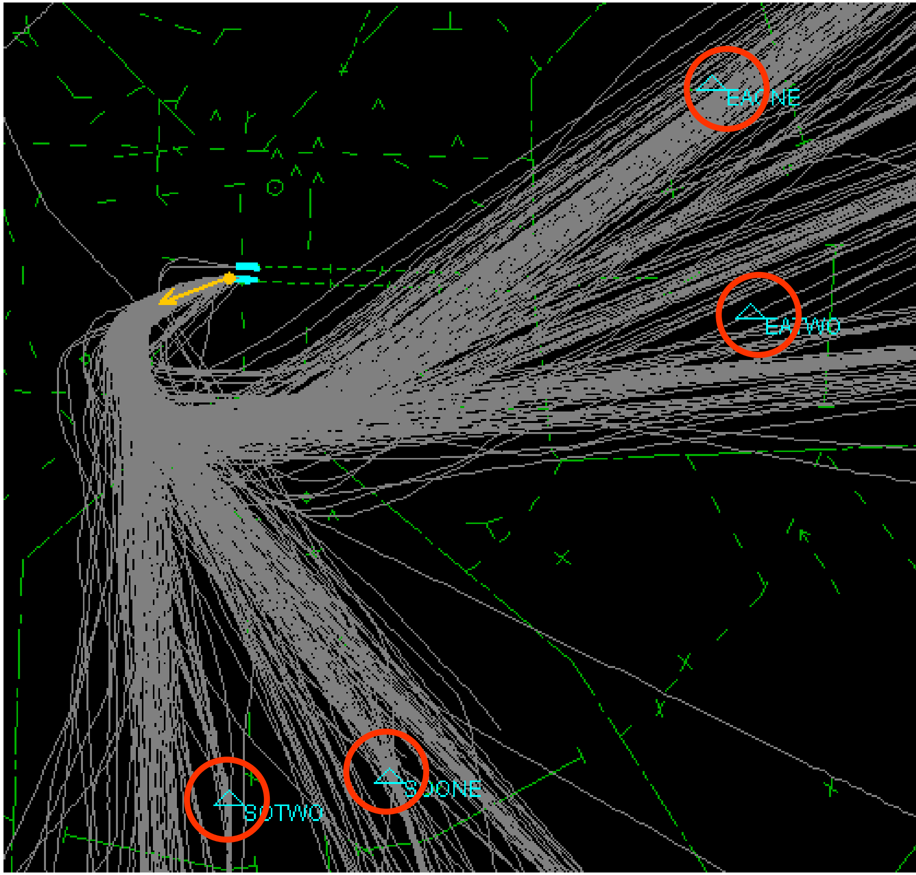
Departures are vectored

- Headings, altitudes and speeds issued by controllers
- Large number of voice transmissions required

Significant dispersion

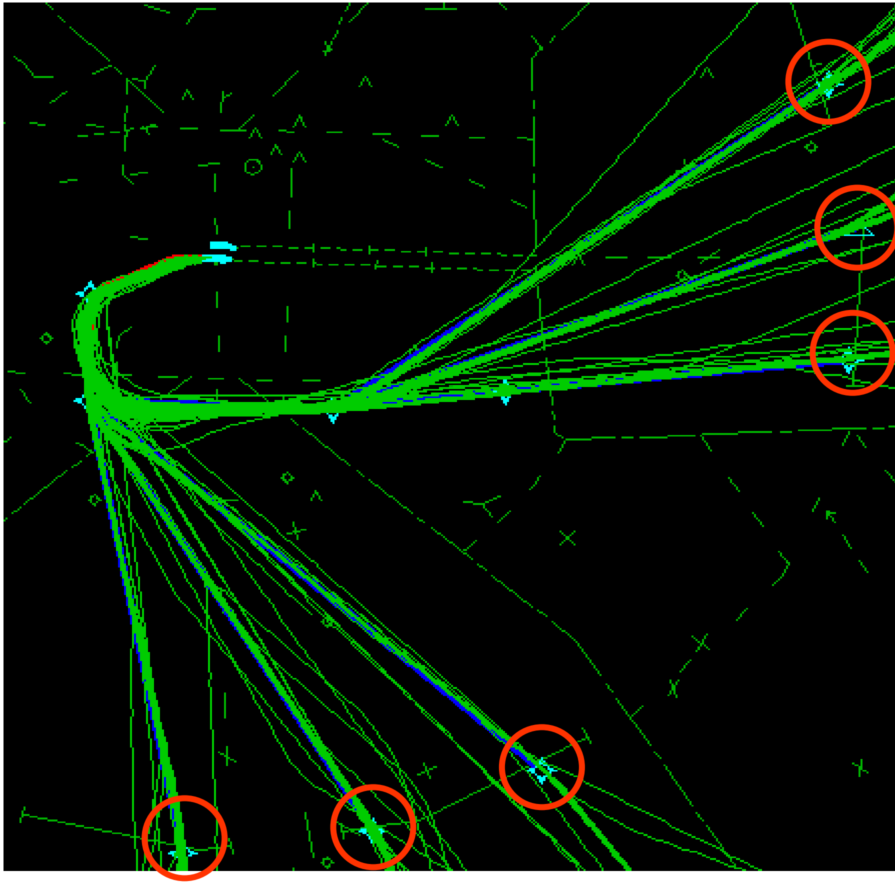
- Tracks are inconsistent and inefficient

Limited exit points

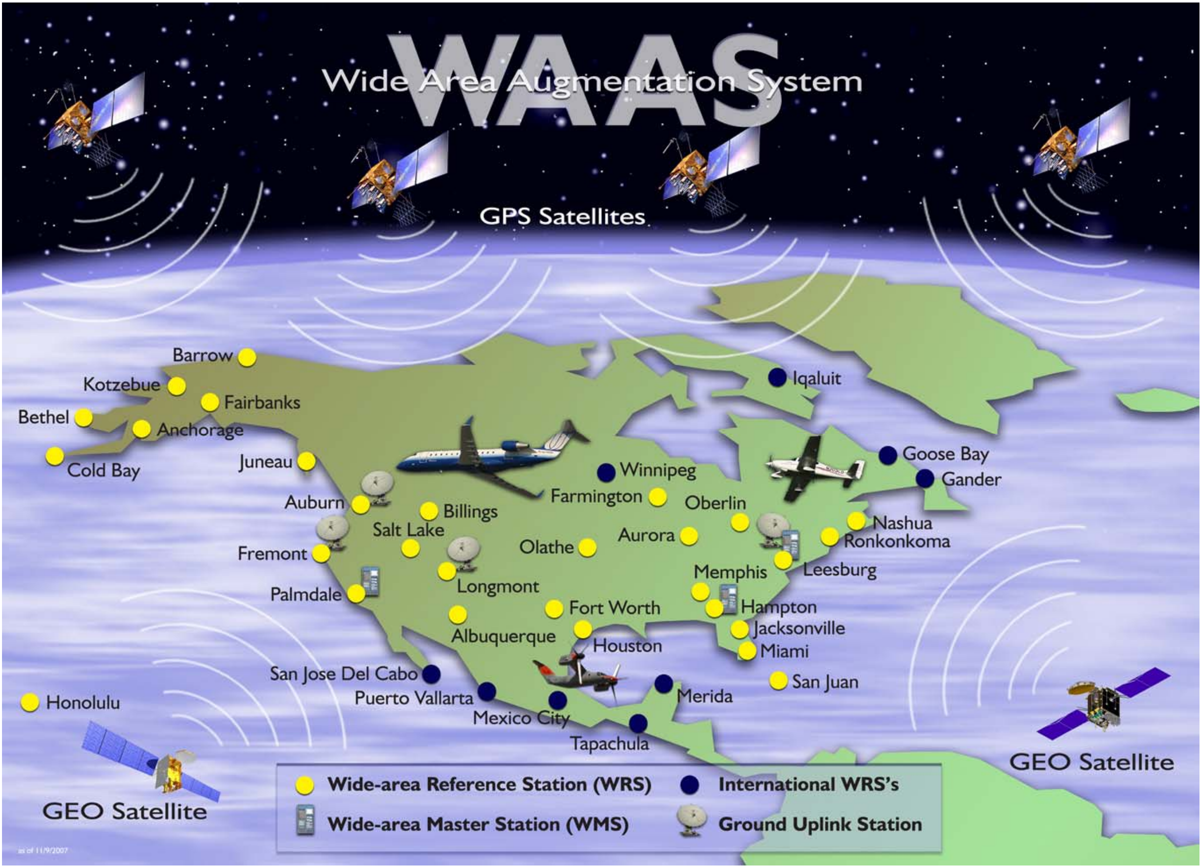


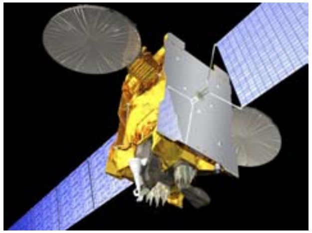
Atlanta (ATL) Departure Procedures After RNAV

- Departures fly RNAV tracks (not vectored)
  - **Headings, altitudes and speeds are automated (via avionics)**
  - **Voice transmissions reduced (30-50%)**
- Dispersions reduced
  - **Tracks are more consistent and more efficient**
- Additional exit points available



WAAS Architecture





2 Geostationary Satellite Links

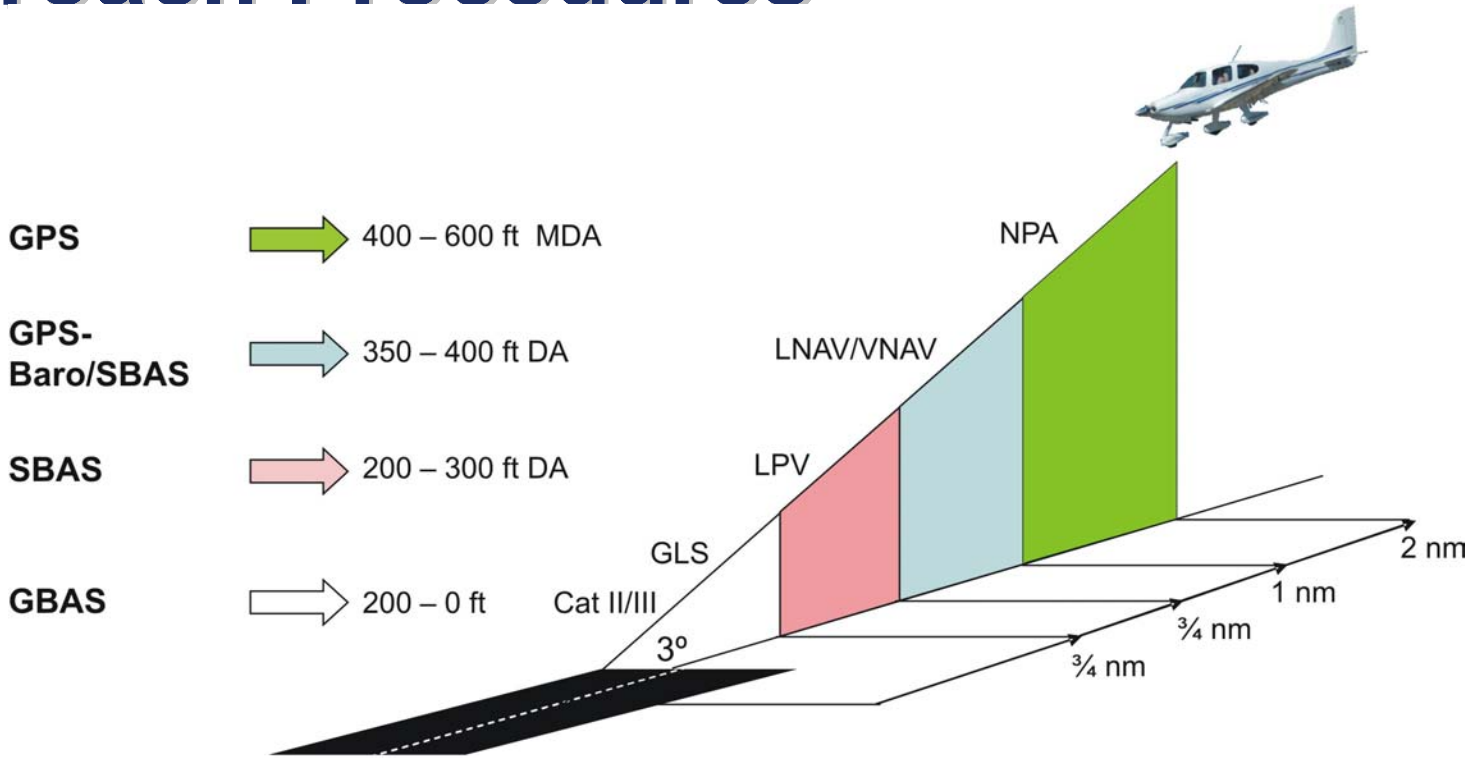
3 Master Stations

4 Signal Generator System/ Ground Earth Stations

38 Referenc Stations

2 Operational Control Centers

Approach Procedures

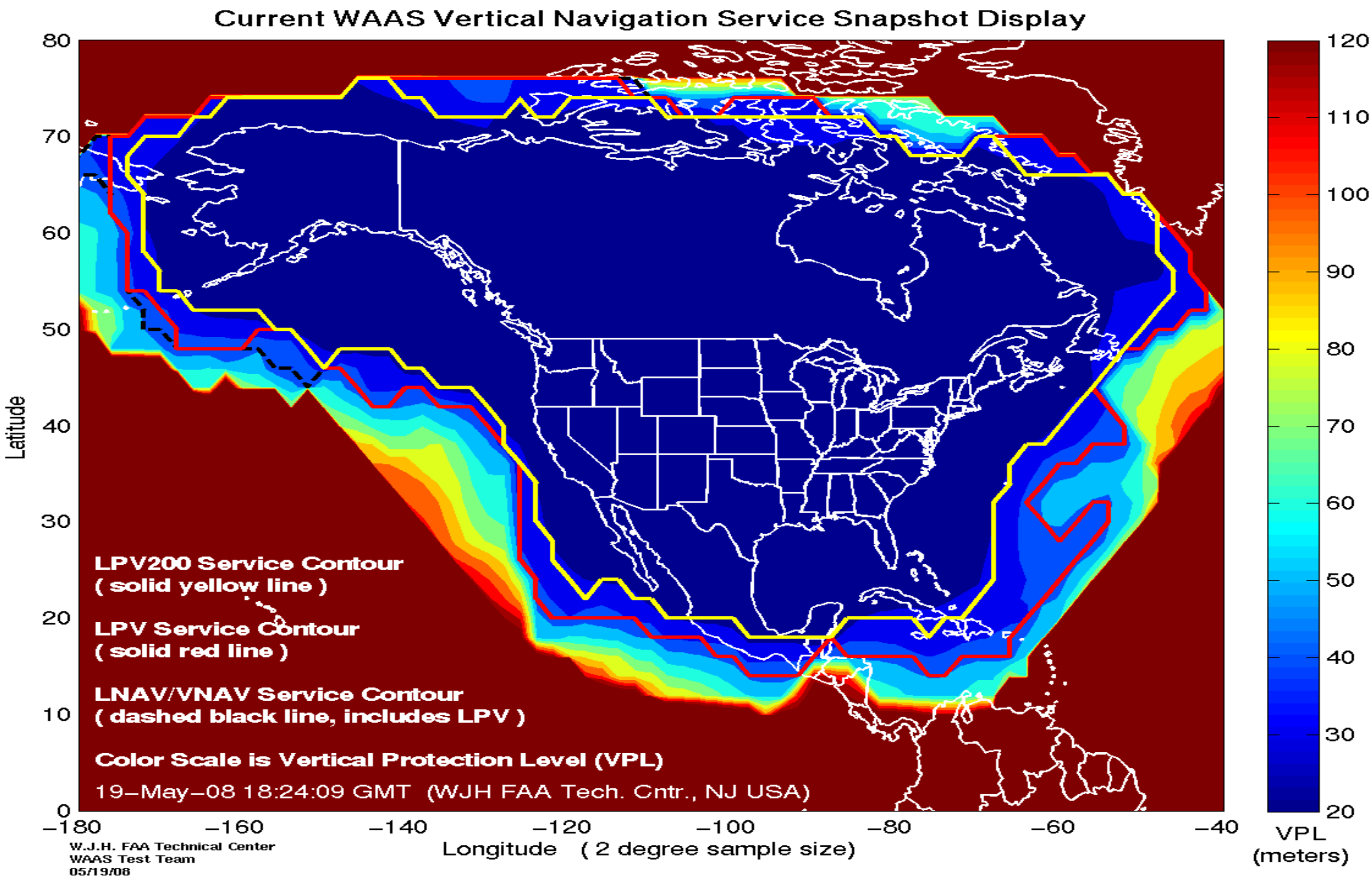


- **Existing Procedures (as of 4/10/08 publication cycle):**
  - 4,461 GPS NPA (LNAV)
  - 1,294 LNAV/VNAV
  - 1051 LPVs (14 of which are below 250')

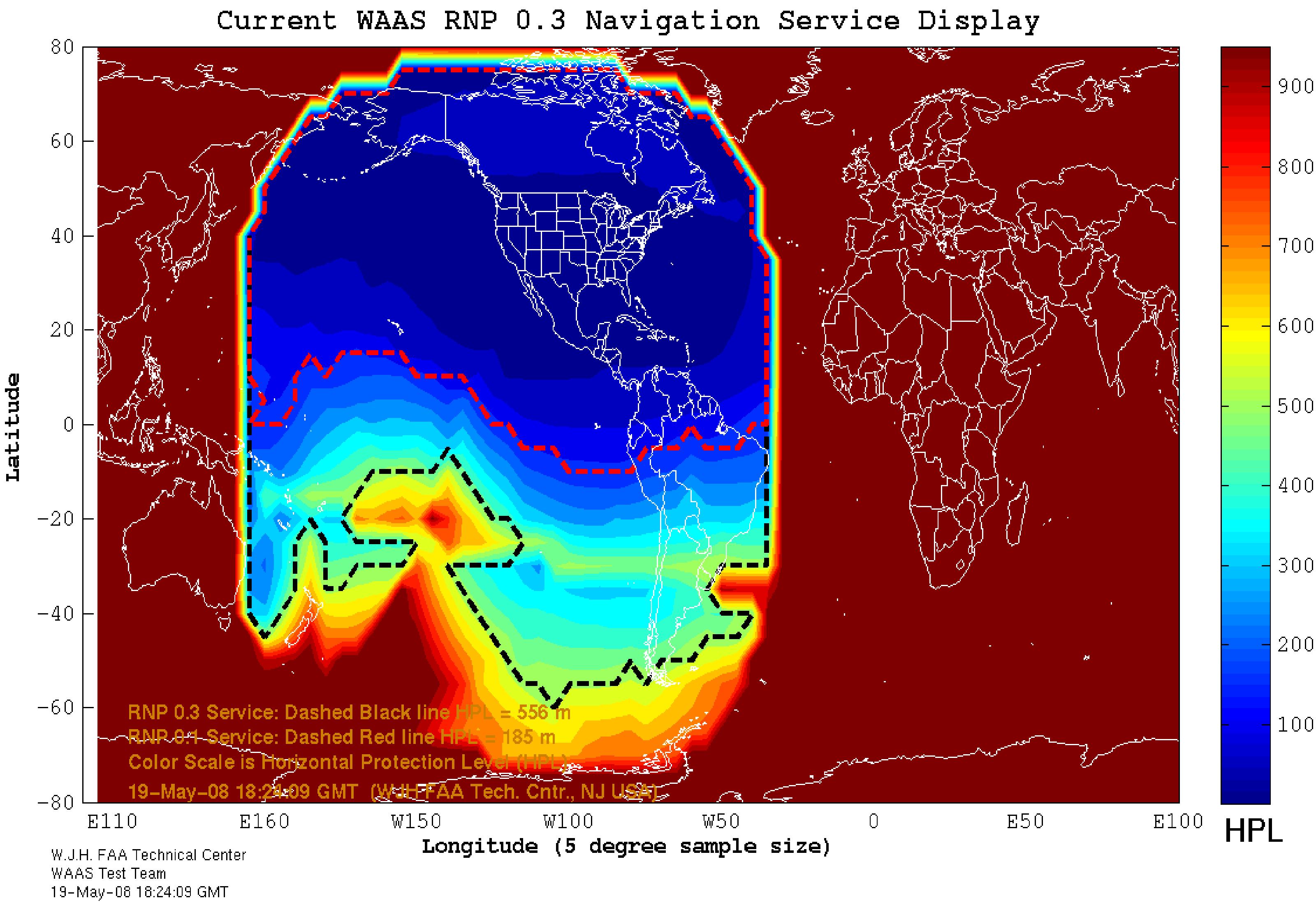
New WAAS Procedures

- **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

WAAS LPV Coverage



WAAS RNP Coverage



WAAS Performance

	GPS Standard	GPS Actual	WAAS LPV-200 Standard	WAAS LPV-200 Actual
Horizontal 95%	36 m	2.74 m	16 m	1.08 m
Vertical 95%	77 m	*3.89 m	4 m	1.26 m

** Use of GPS vertical not authorized for aviation without augmentation (SBAS or GBAS)*

WAAS Performance evaluated based on a total of 1,761 million samples (or 20,389 user days)

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

GNSS Evolutionary Architecture Study (GEAS)

- **Chartered under the FAA to investigate future directions for GNSS architectures**
  - Recognized that integrity provision is one of the most challenging aspects
  - Develop Architectural Alternatives to provide Worldwide LPV-200 Service in the ~2020-2030 Timeframe
  - Support for multiple modes of transportation and multiple user communities
- **Strategic planning for:**
  - GPS modernization
  - L5 standards development
  - Near-term WAAS development
  - Long-term provision of navigation

GEAS Architecture Options

- **Architectures Under Investigation by the GEAS**
  - GPS Integrity Channel (GIC)
  - Relative RAIM (RRAIM)
  - Absolute RAIM (ARAIM)
- **Meeting the 6 Second Time to Alarm (TTA) Requirement is a Significant Challenge for Any Architecture Providing a Global Service for Aviation**
- **All Three Alternatives Tradeoff the Degree of Aircraft Based Augmentation (ABAS), Constellation Size, User Range Accuracy, and Corrections/Integrity Augmentation**

Preliminary Results

	[illegible]					
Architecture	**24 minus 1**	**24**	**27 minus 1**	**27**	**30 minus 1**	**30**
GIC	**86.6%**	**100%**	**97.8%**	**100%**	**100%**	**100%**
RRAIM with 30 s coasting	**81.2%**	**99.4%**	**96.8%**	**100%**	**100%**	**100%**
RRAIM with 60 s coasting	**74.4%**	**98.5%**	**92.8%**	**100%**	**100%**	**100%**
RRAIM with 300 s coasting	**28.0%**	**76.1%**	**52.3%**	**99.6%**	**93.9%**	**100%**
ARAIM	**7.80%**	**44.7%**	**30.6%**	**94.1%**	**90.5%**	**100%**

Note: Predictions Valid for WAAS-Like Integrity Assured URA's of 1 Meter or Less

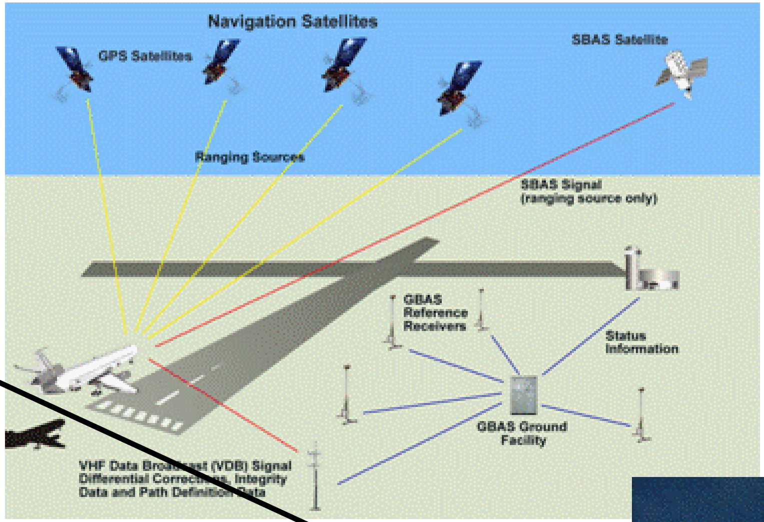
GEAS Next Steps

- **Phase 1 Report – Completed**
- **Future Work Plan**
  - WAAS RRAIM Architecture
    - Detailed Analysis and Design Leading to Implementation of the RRAIM Architecture as the Dual Frequency Architecture for WAAS
  - Support to GPS-III/OCX Integrity & Continuity Assurance Activities
    - Provide Assistance to GPS Wing Program Office Team

FAA Satellite Navigation Vision

LAAS

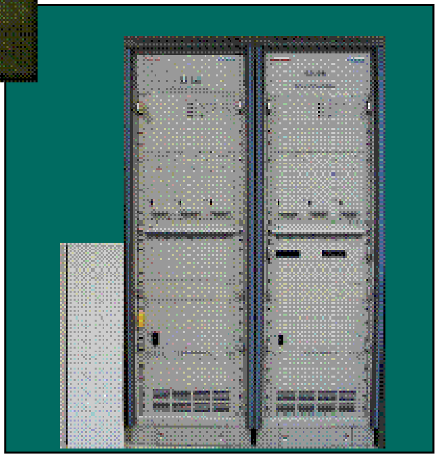
DATALINK



Antenna

GPS

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



Transmitter

Encoder

Broadcast Information

Differential Corrections, Integrity Status and Approach Coordinates

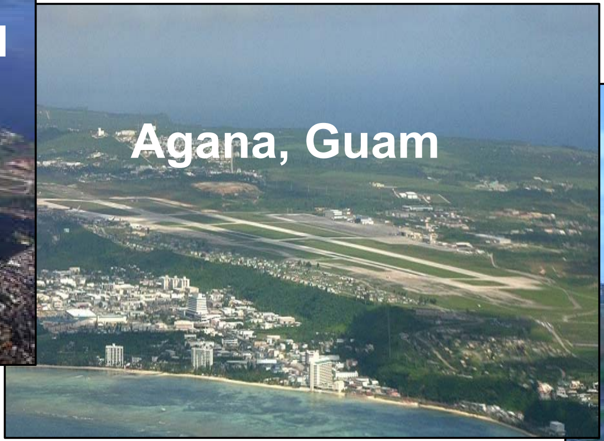
LAAS Capabilities

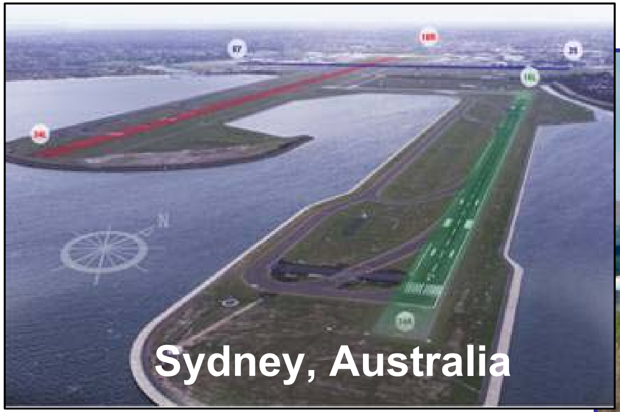
- The Local Area Augmentation System (LAAS) Represents the U.S. Approach to the International Goal of an Interoperable GBAS Capability
- LAAS Provides a Navigation Signal That Supports the Most Demanding RNP Requirements
- LAAS is complementary to SBAS
- One LAAS Can Cover the Entire Terminal Area and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

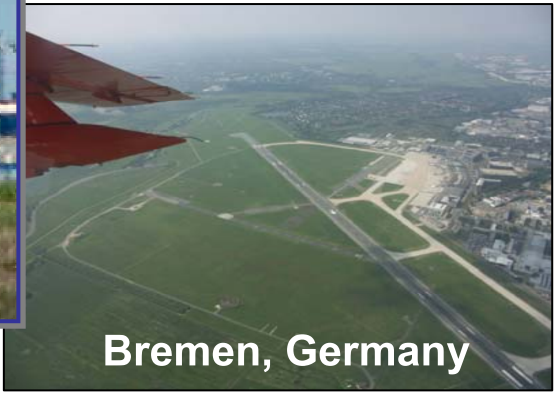
GBAS Status

- HMI analysis to validate that the CAT I system meets integrity design requirements
- Continuation of regulatory approval for the HI LAAS at Memphis, TN in 2008
- Facility and Service Approval at Memphis in early 2009
- Continued data collection/flight test to validate operational benefits (national/international)
- Coordination of development and approval activities with International community
- R&D to develop and validate CAT II/III requirements to support a 2008 CAT II/III decision point

LAAS International Efforts

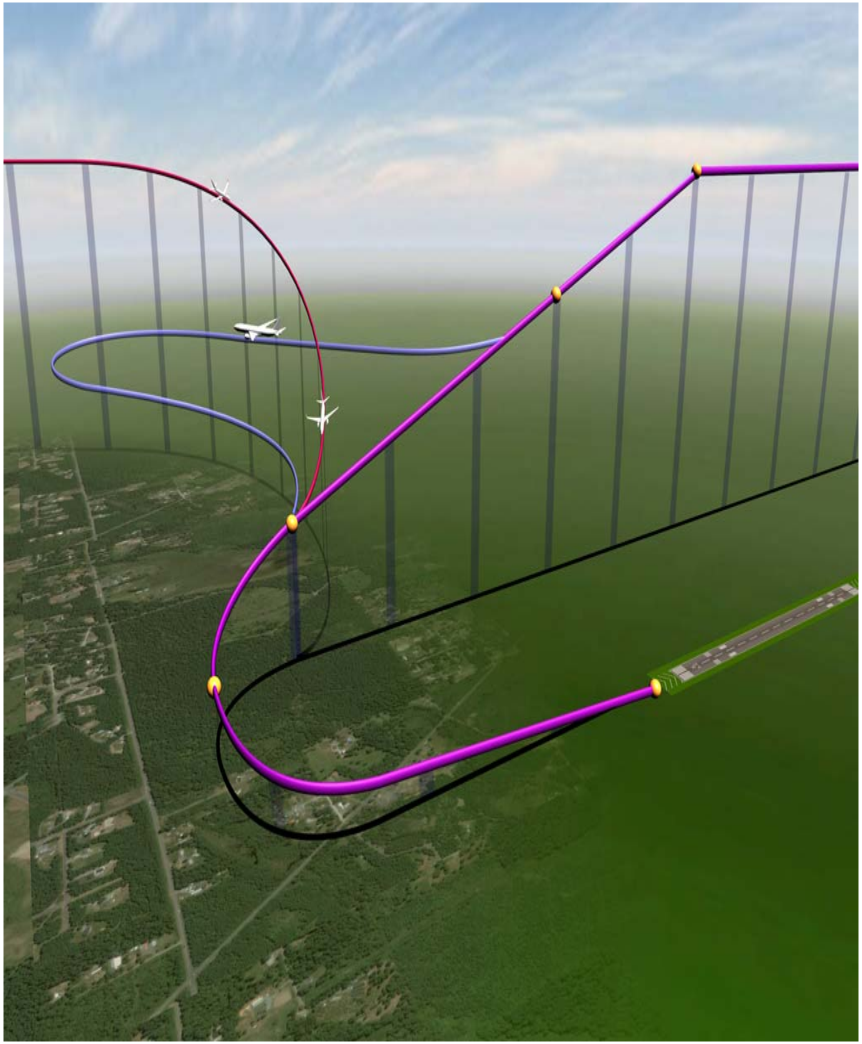






The Challenge of Controlled Descent

Continuous Descent Arrivals (CDA): *An arrival which flies a continuous decent path rather than the traditional step downs or intermediate flight operations.*



- **Use RNAV/RNP arrivals with optimized vertical profile**
- **Benefit to airlines: 200 – 400 LBS of fuel per arrival**
- **Benefit to airports: reduced emissions and reduced noise**

CDA Features

Key Features:

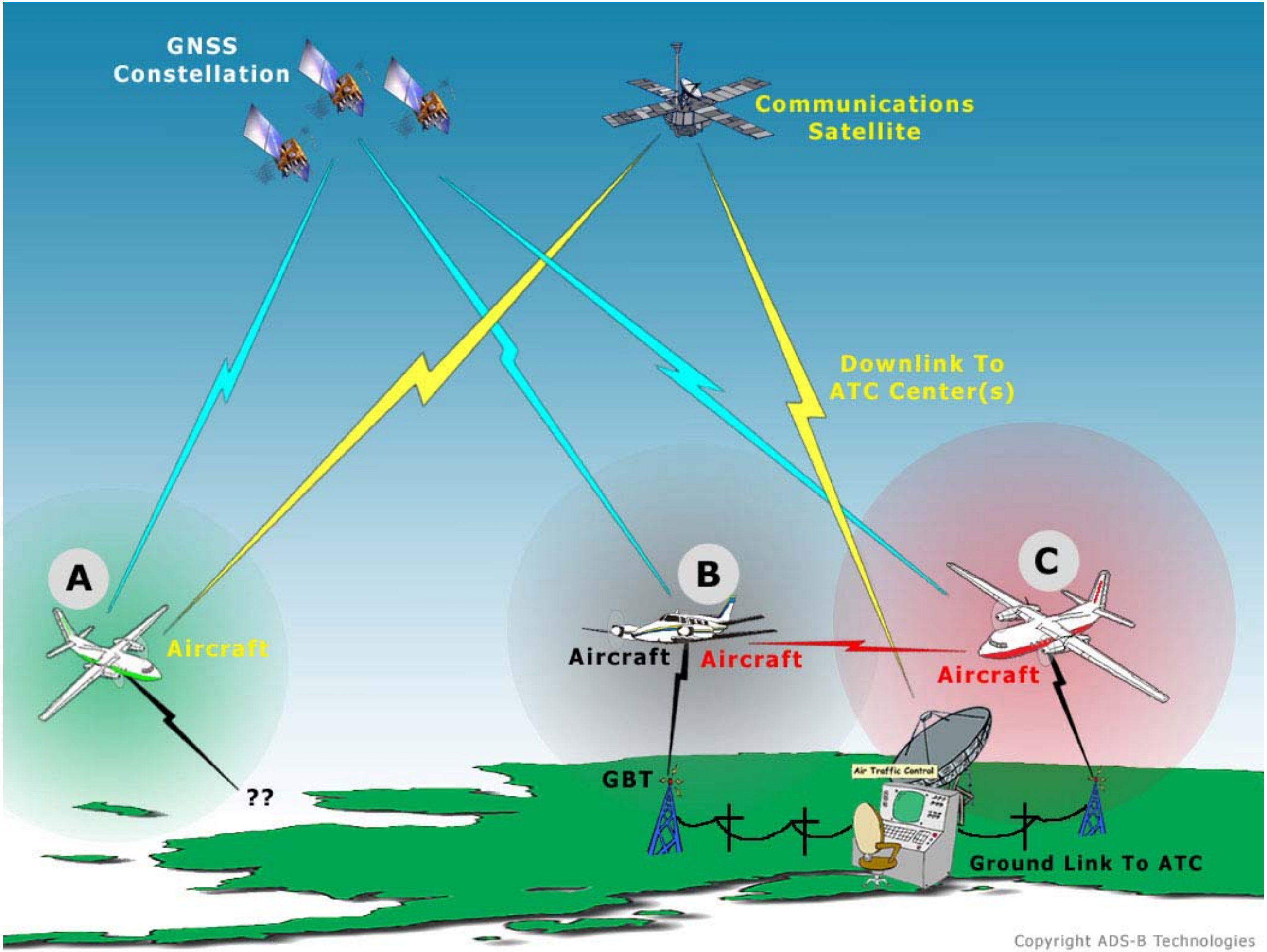
- **RNAV STAR**
  - Fixed lateral path
- **Optimized Vertical Profile**
  - Minimize level segments
  - Idle descent with minimal speed intervention
  - Uses existing Descend Via phraseology
- **Benefits**
  - Uses FMS capabilities to manage energy and reduce cockpit workload
  - Reduces pilot/controller communications
  - Fuel savings
  - Reduced noise
  - Reduced emissions
- **Inter-aircraft separations priority**
  - Evaluate metering scheme
  - Limit controller intervention below initiation altitude

GNSS 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
- WAAS LPV-200 will begin in FY09
- GBAS (LAAS) will complete System Design Assurance for Cat I in December 2008
- GBAS Develop and validate Cat II/III requirements in FY09
- Develop CAT-III prototype LAAS Ground Facility and user avionics by ~2010
- GNSS is an enabler for CDA

Backup

Automatic Dependent Surveillance (ADS-B)



ADS-B Program

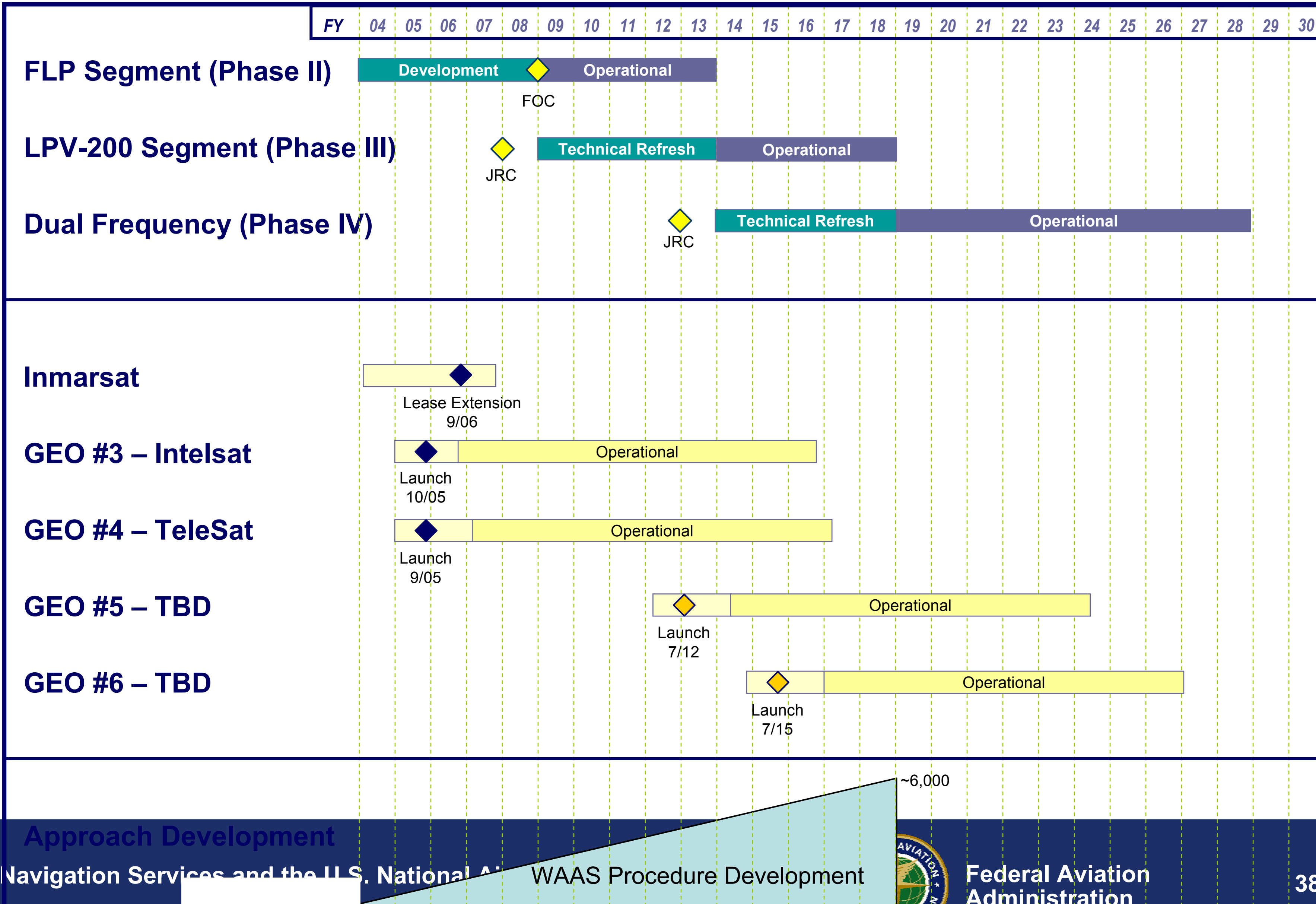
- **Benefits**
  - Safety Improvements By Increasing Situational Awareness Both In-flight And On The Ground
  - Increased Operational Efficiency Through Higher Air Traffic Throughput
- **Schedule**
  - Final Rulemaking Issued 2010
  - Avionics Implementation 2010-2020
  - Ground Infrastructure Completion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

ADS-B is a Primary Building Block for NextGen

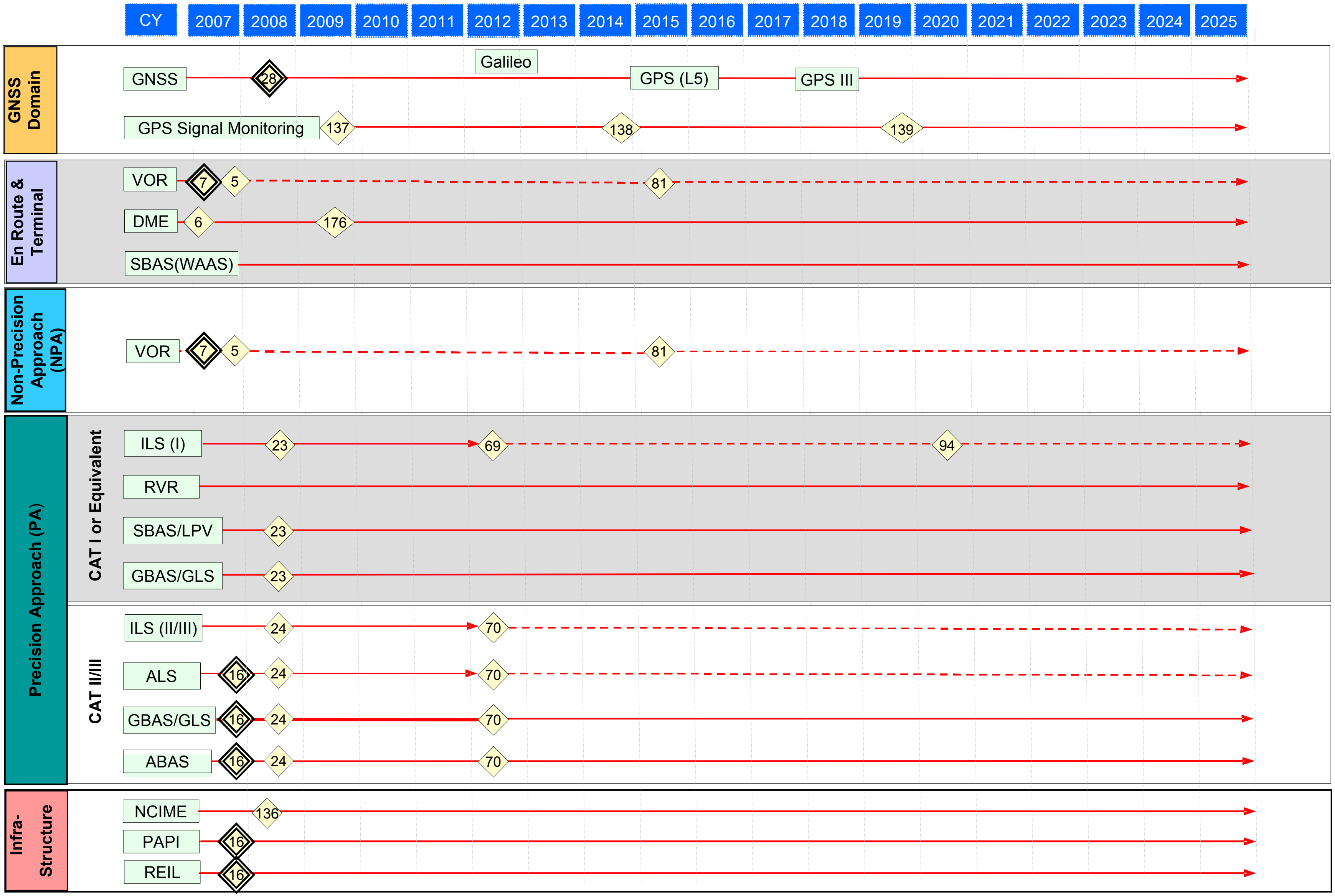
Navigation Service Roles & Responsibilities

- **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**

WAAS Enterprise Schedule



Navigation Roadmap



Navigation Roadmap Decisions

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