Future ATM Concepts & Technology

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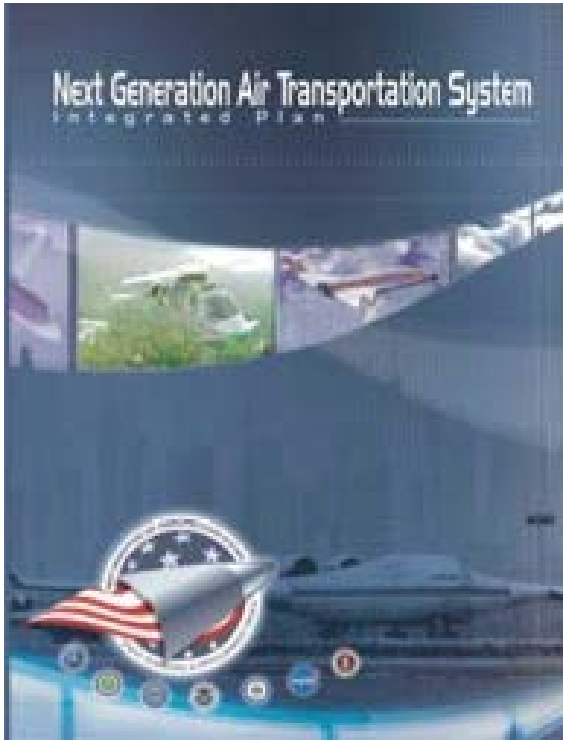
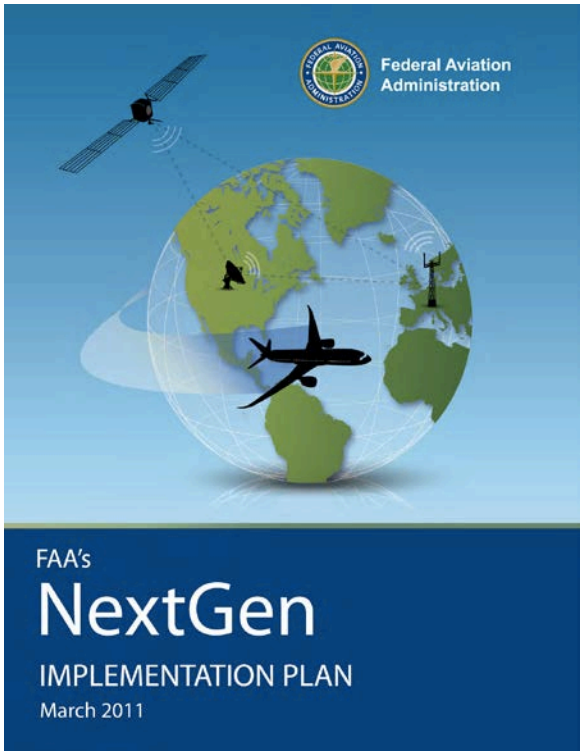
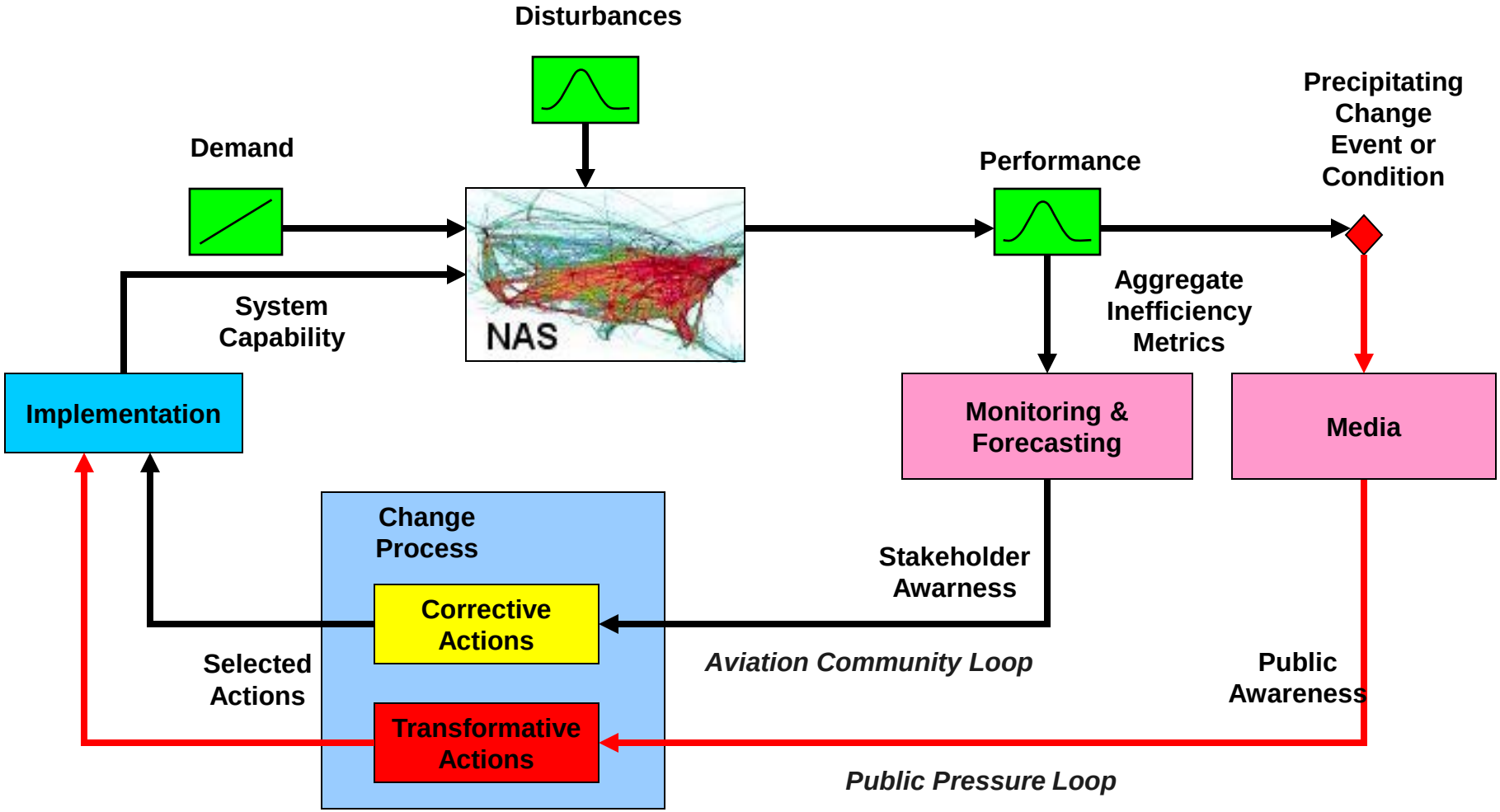
Future = Post NextGen & SESAR Initial Implementation





Simple Feedback Model of System Adaptation

Predictive, Reactive, Catalytic Transitions

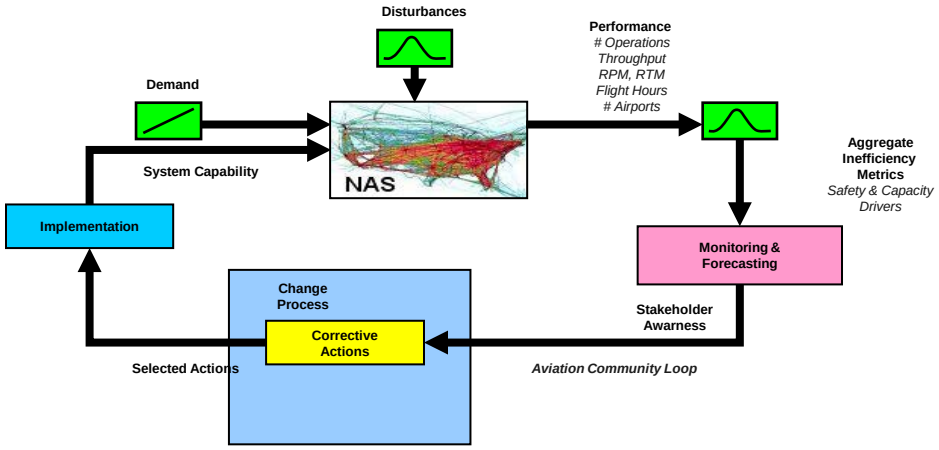


Catalytic Example
MH370 - Global Aircraft Tracking

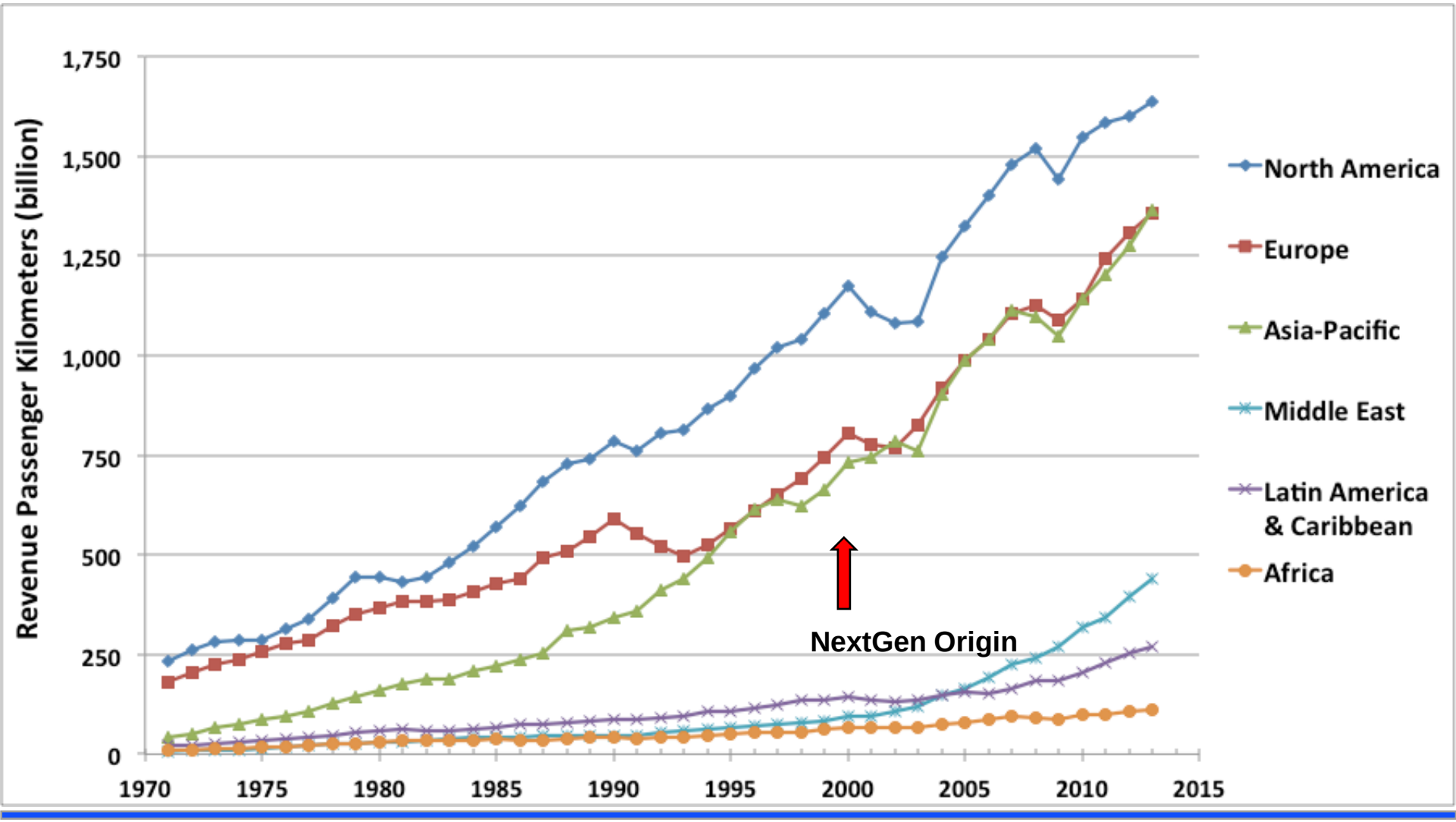
- **ICAO Proposal for 15 min reporting in remote areas and ICAO Global Aeronautical Distress and Safety System (GADSS)**
  - Technology Independent
- **Multiple Potential Technologies**
  - Existing FANS 1A CPDLC Packages
  - Satellite ACARS
  - Satellite Based ADS-B (Inmarrsat/NavCanada)
- **Satellite Orbit Configurations**
  - Geocentric (Inmarrsat)
    - High orbit, broad coverage per sat, issue at high latitudes
  - Polar (Iridium)
    - Low orbit, limited coverage per sat, good high latitude coverage
- **Operational Benefits Unclear**
  - Potential to leverage tracking for ATM Benefits

Emergent Drivers for ATM Modernization

- **Demand**
  - Economic Growth
  - Access to Air Transportation
- **Safety**
  - Catalytic Events (Grand Canyon, Los Ceritos, MH370)
- **Capacity**
  - Delays
- **Cost**
- **Fuel Efficiency**
- **Environmental Impact**

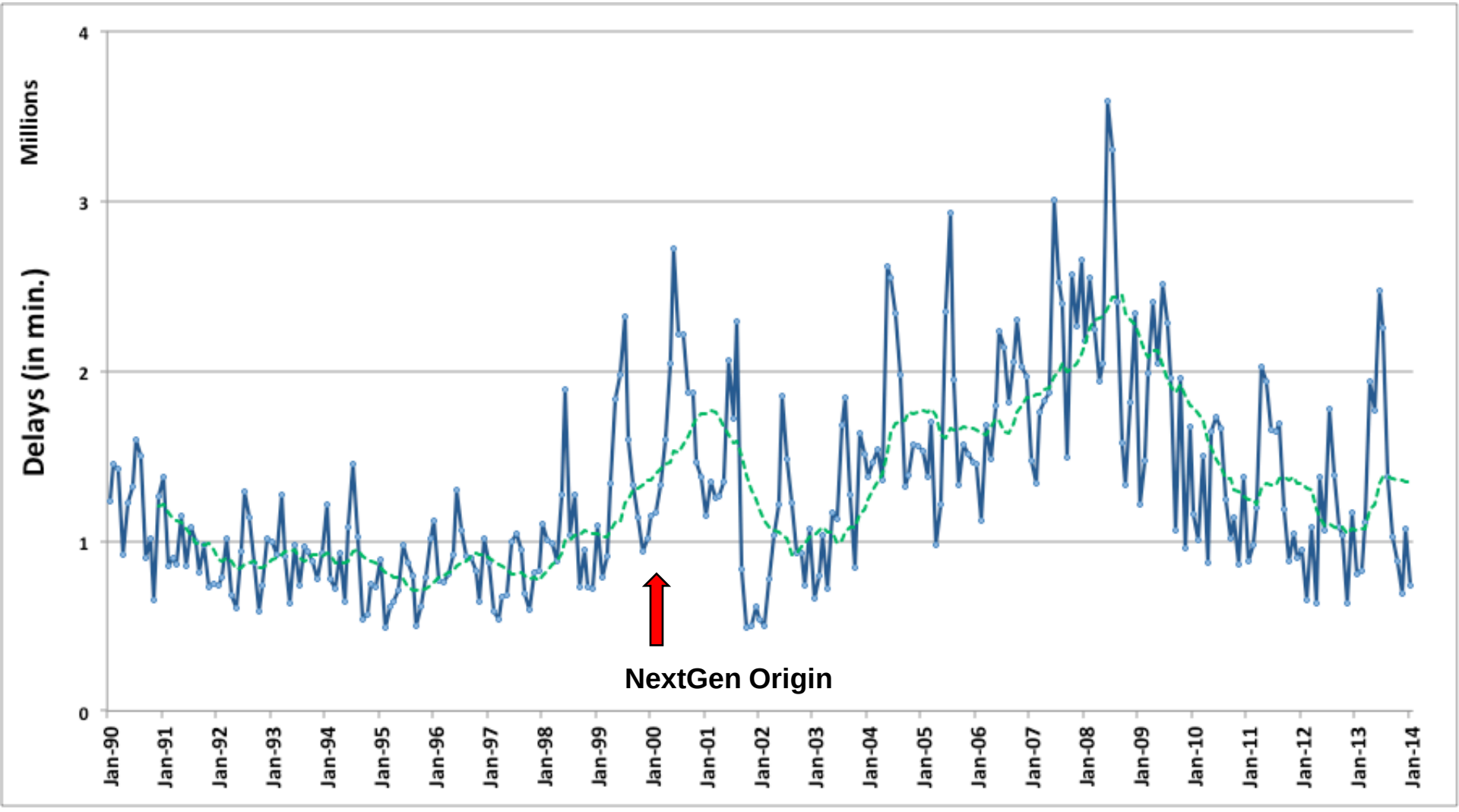


Revenue Passenger Kilometers (RPK)
by World Region



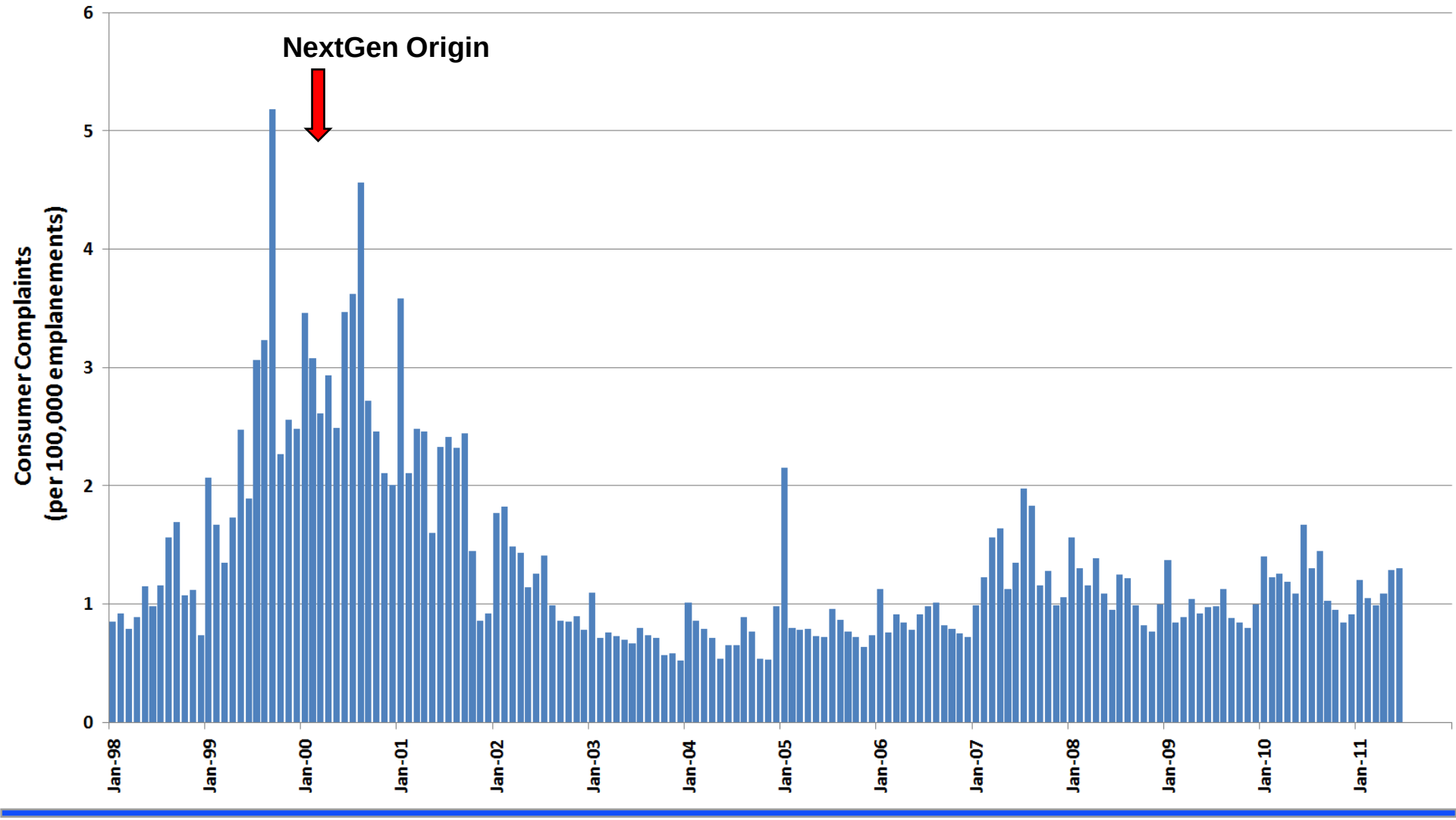
Data source: ICAO/IATA

Flight Delay Trends
US Data



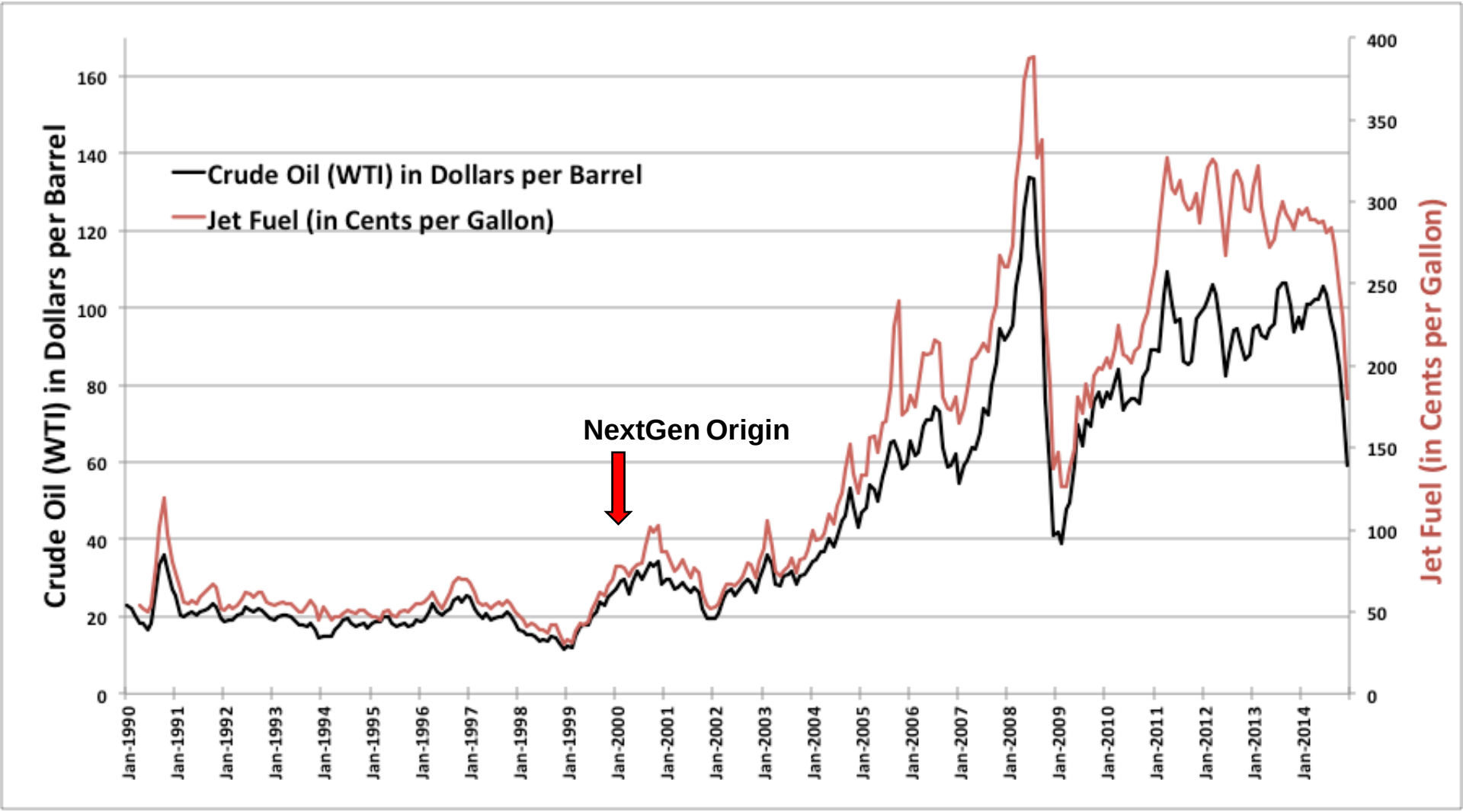
Data source: FAA Operational Network (OPSNET) (data through Jan'14)

Consumer Complaints
from 1998 to 2011



Data source: DOT Aviation Consumer Protection Division (Data through Jun-11)

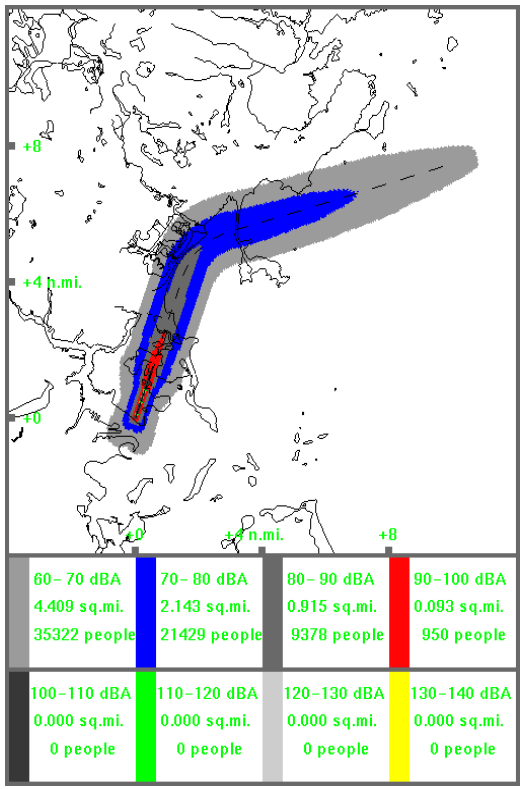
Crude Oil and Jet Fuel Price Trends



Data sources: EIA Independent Statistics & Analysis (Data through December 2014)

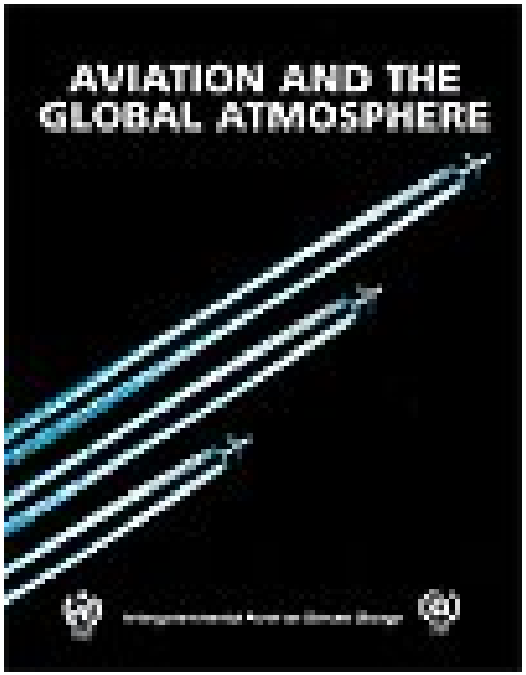
Additional Drivers for Modernization: Environmental Concerns

Noise



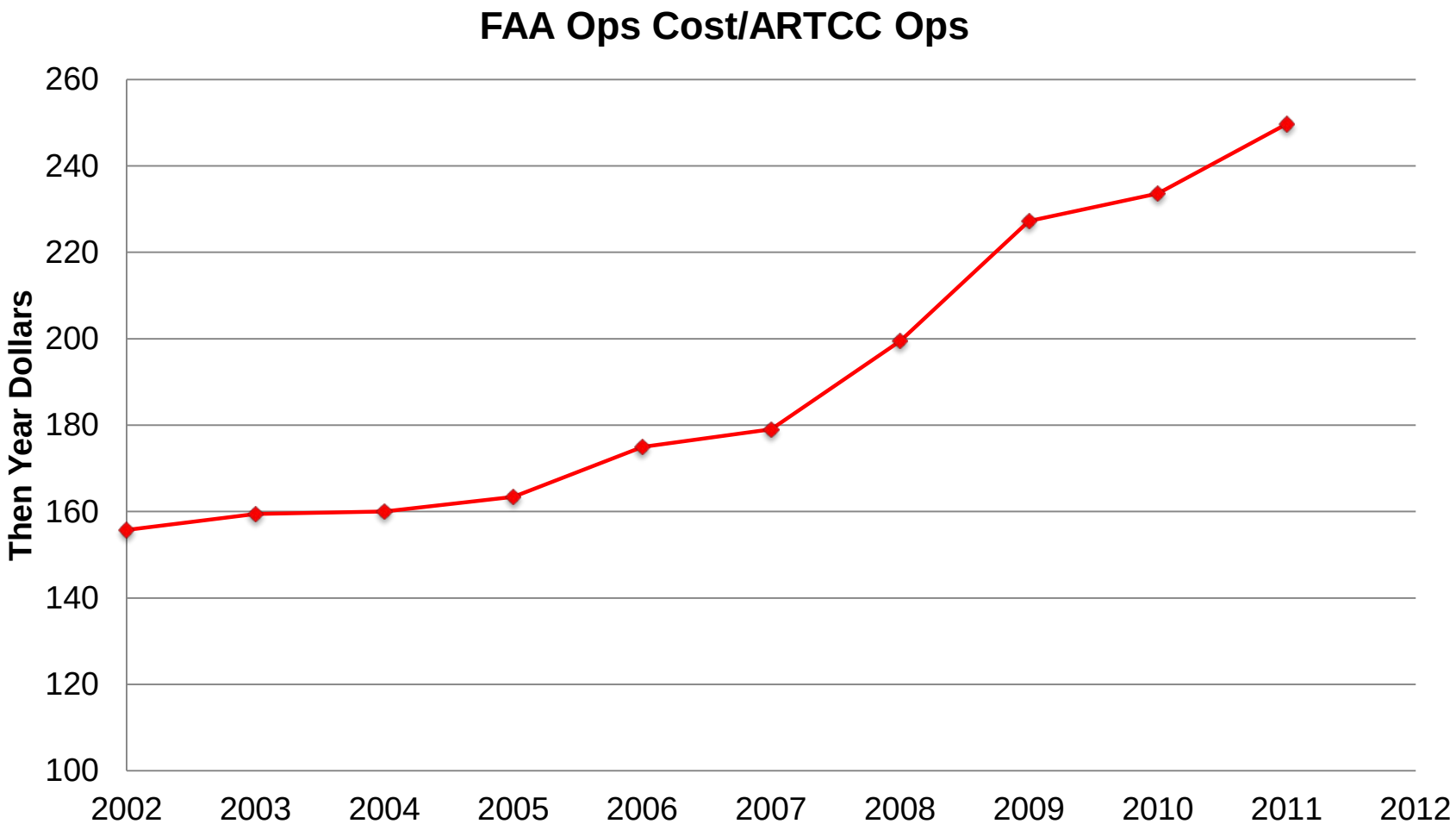
- Stage 4 (Equipment)
- Airports (Capacity)

Emissions



Intergovernmental Panel on Climate Change

Costs



Data source: FAA Budget and Administrators Fact Book

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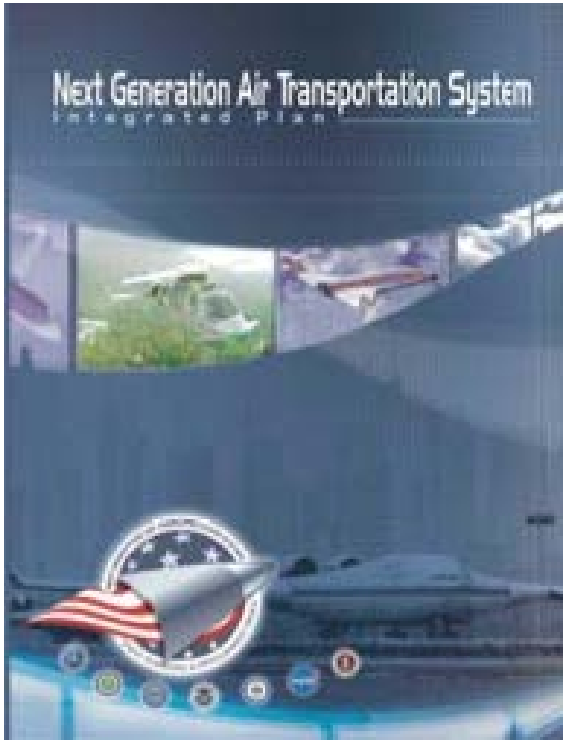
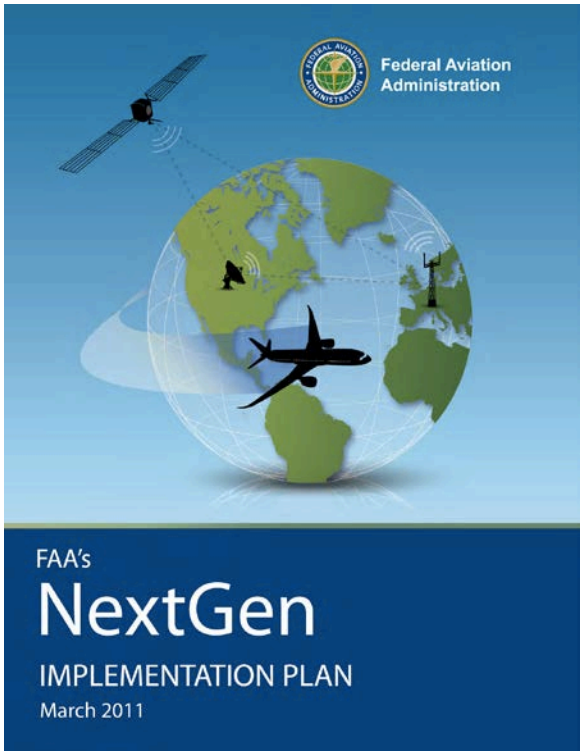
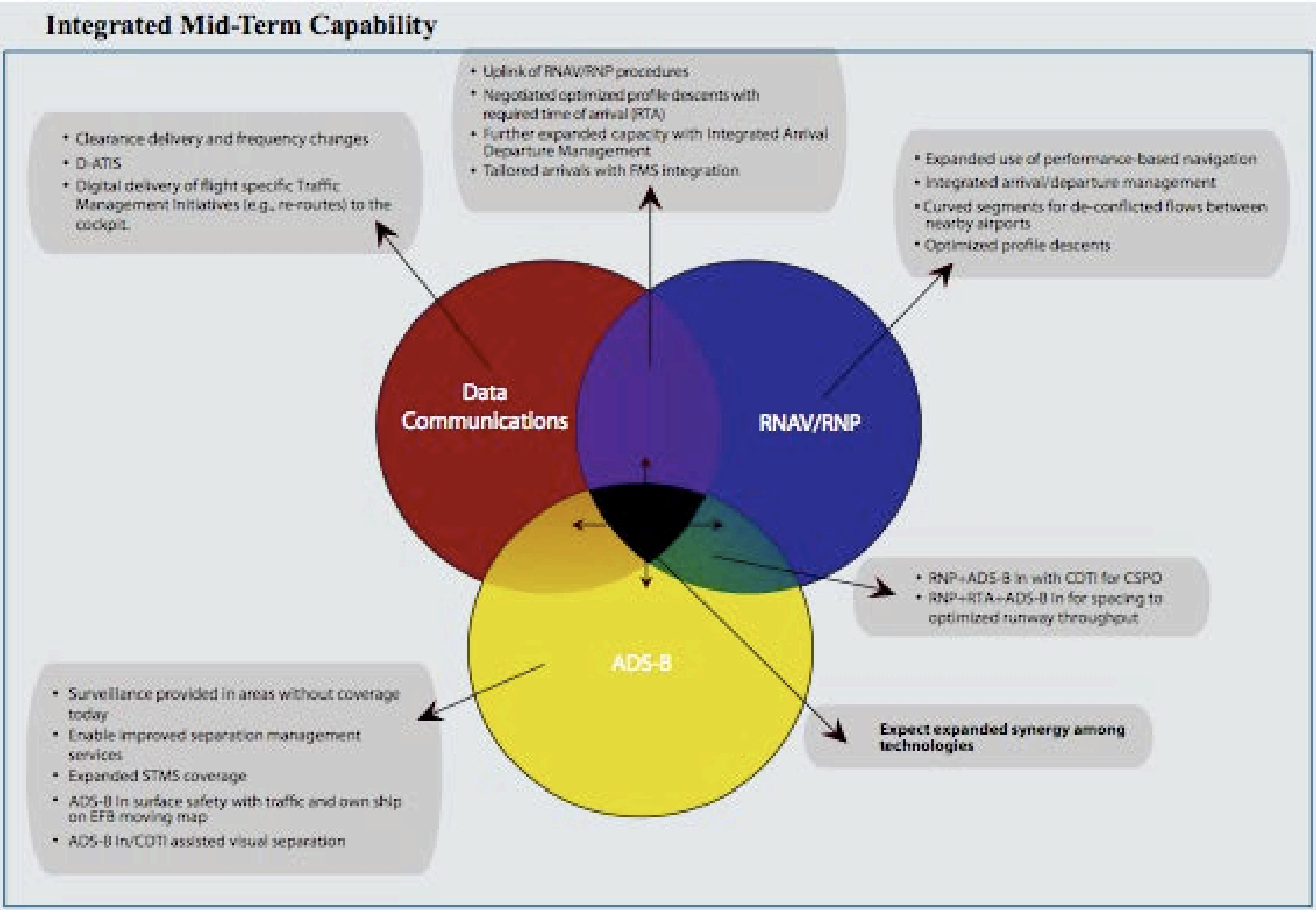




Future Technologies

- **After the NextGen/SESAR investment there will be limited interest in another round of air/ground technology investment**
  - We will be constrained by the performance levels incorporated in the Standards and equipment defined by NextGen/SESAR
- **Most technological changes will come from exogenous technical development**
  - Cloud based systems
  - Wireless systems
  - Optimization

NextGen-SESAR CNS Technologies



Performance Based Navigation
RNAV and RNP

NEXT GEN Components: RNAV/RNP

Moving to Performance-Based Navigation

Conventional Routes

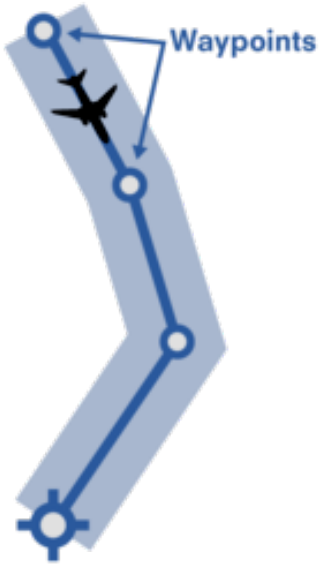
Today's airways connect ground-based navigation aids

Limited Design Flexibility

RNAV

Area Navigation (RNAV) routes follow defined "waypoints"

>90% air carrier fleet

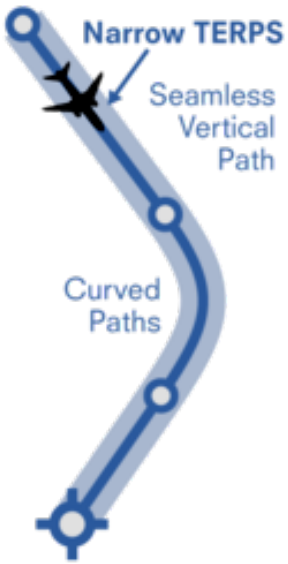


Increased Airspace Efficiency

RNP

Required Navigation Performance (RNP) routes within specified "containment area"

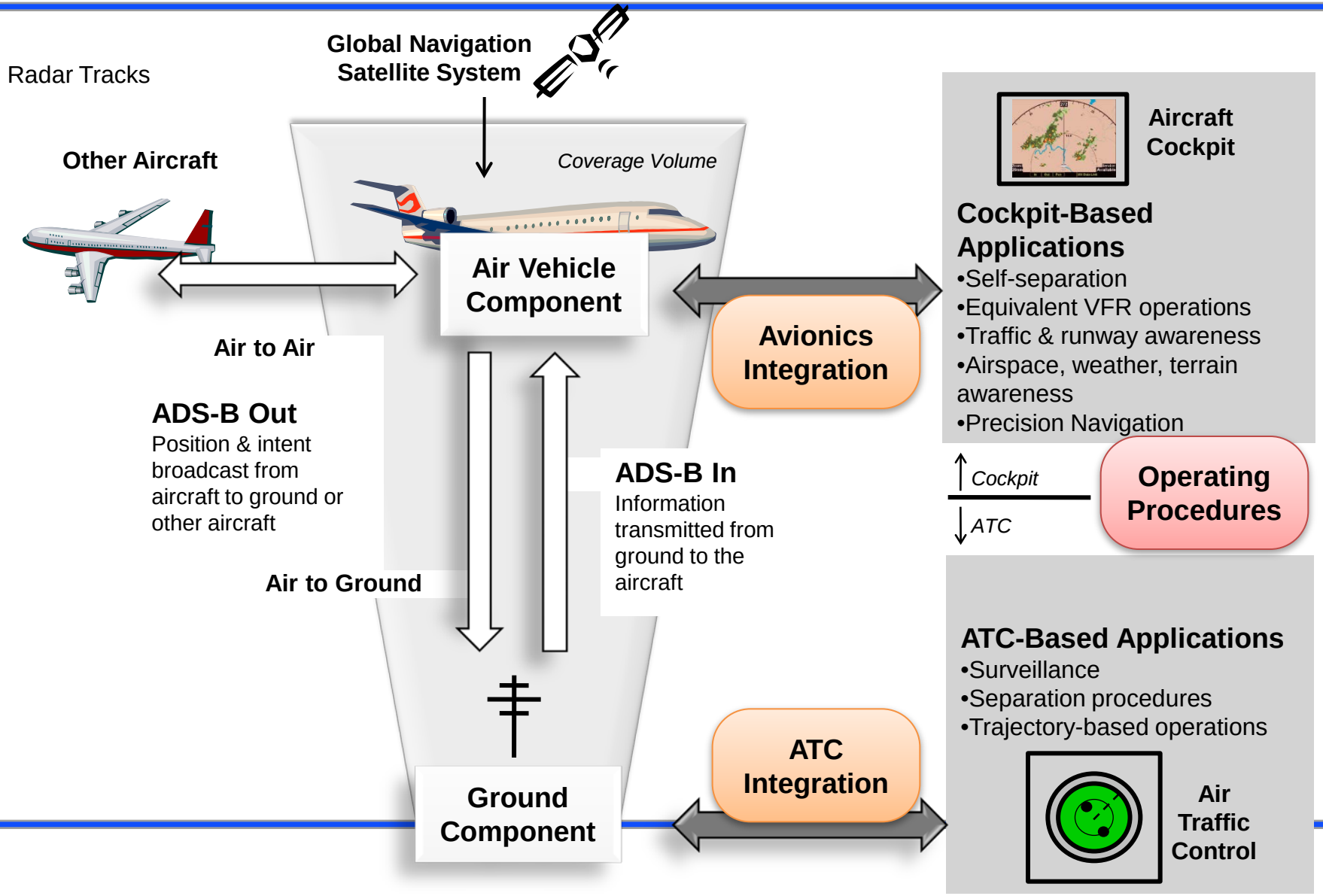
>30% air carrier fleet



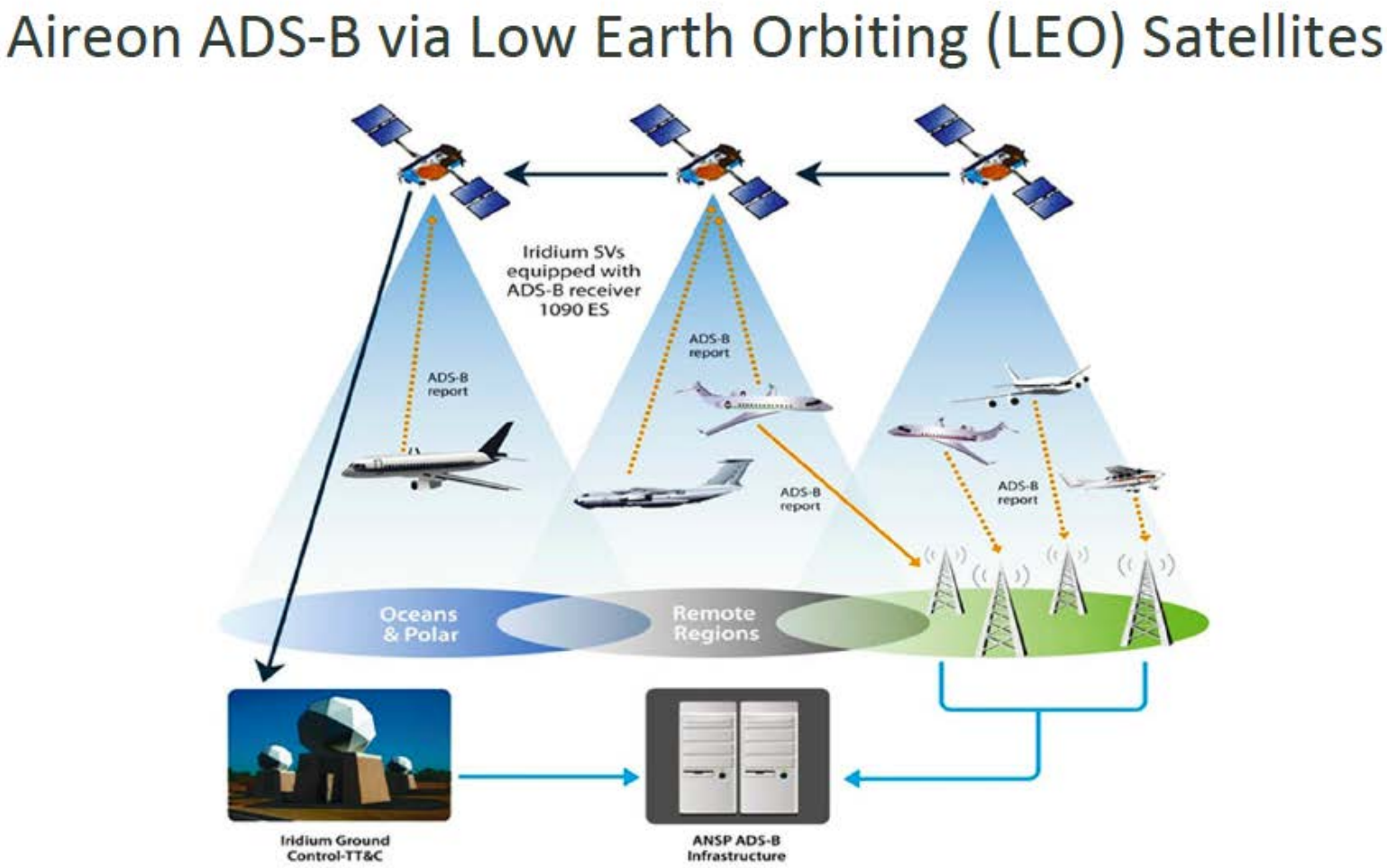
Optimize Use of Airspace

Source: Federal Aviation Administration

ADS-B (1 sec update)

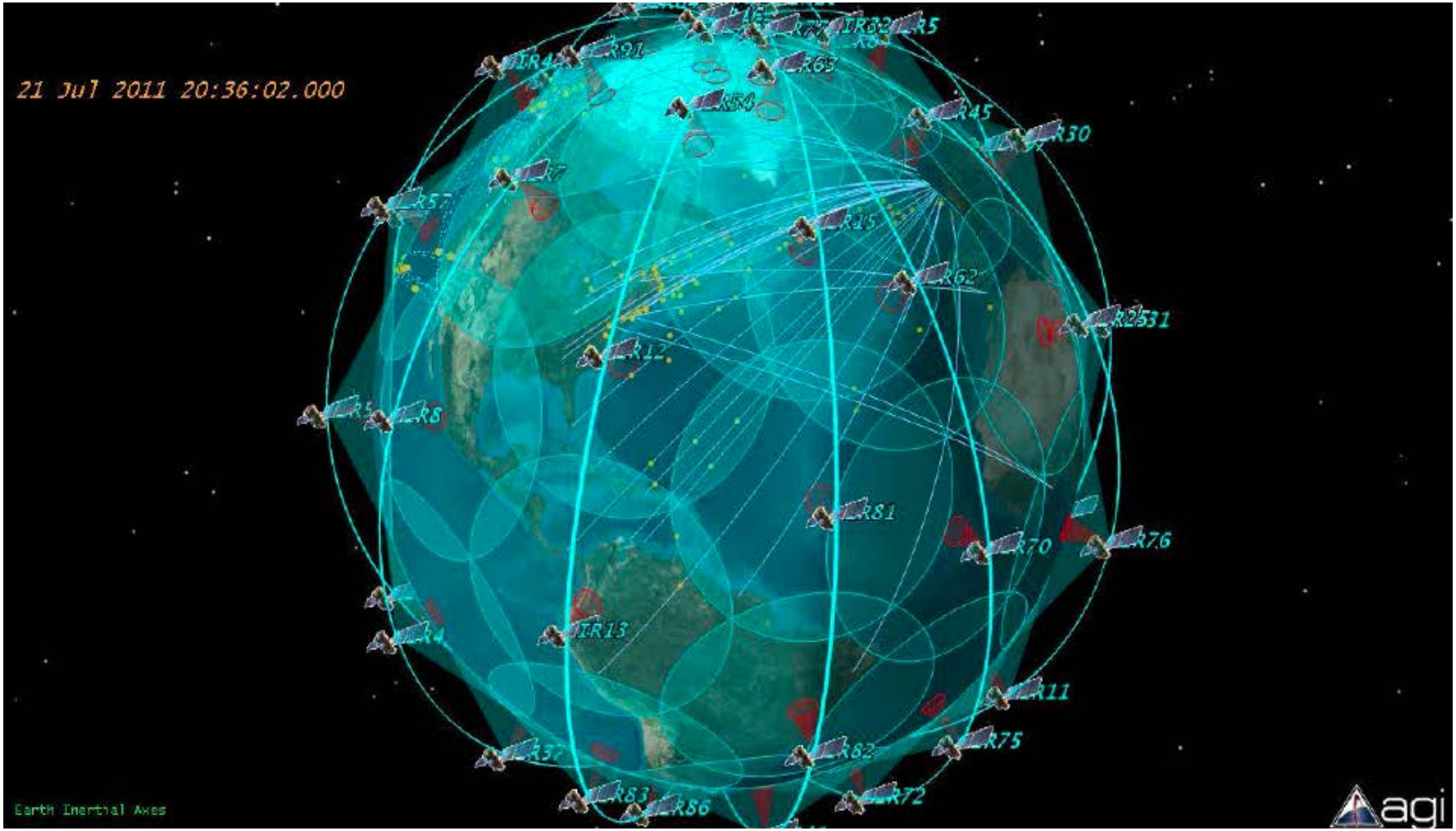


Satellite Based ADS-B
North Atlantic Application



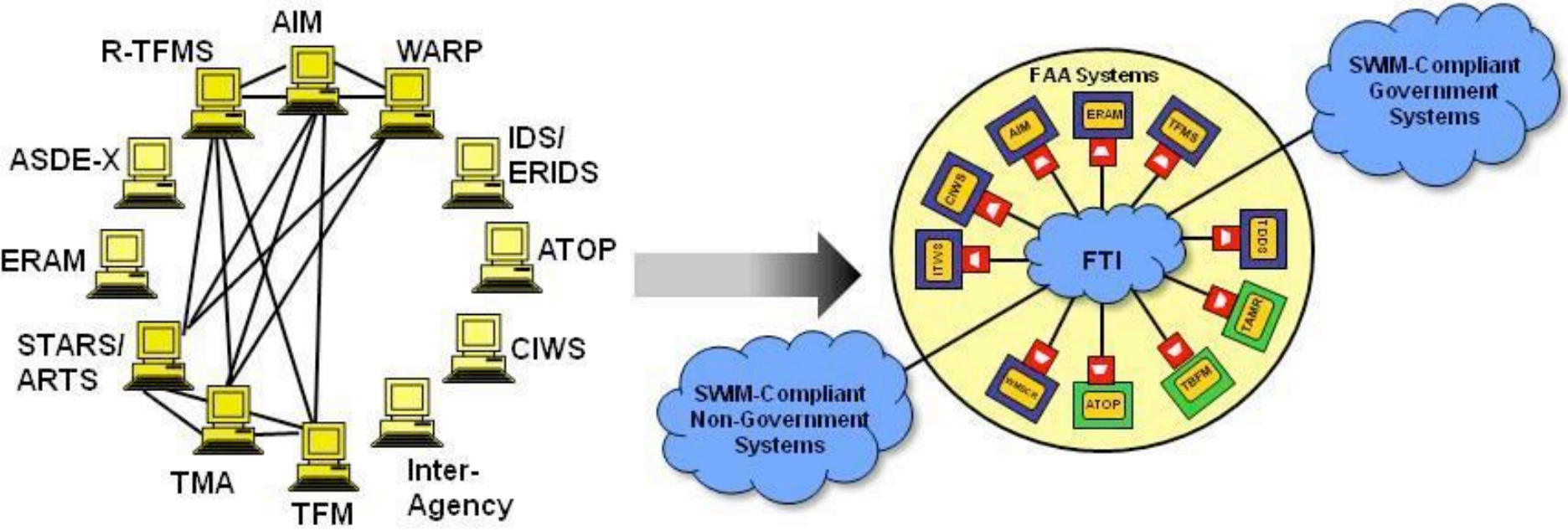
Source: NavCanada

ADS-B Iridium Orbital Constellation



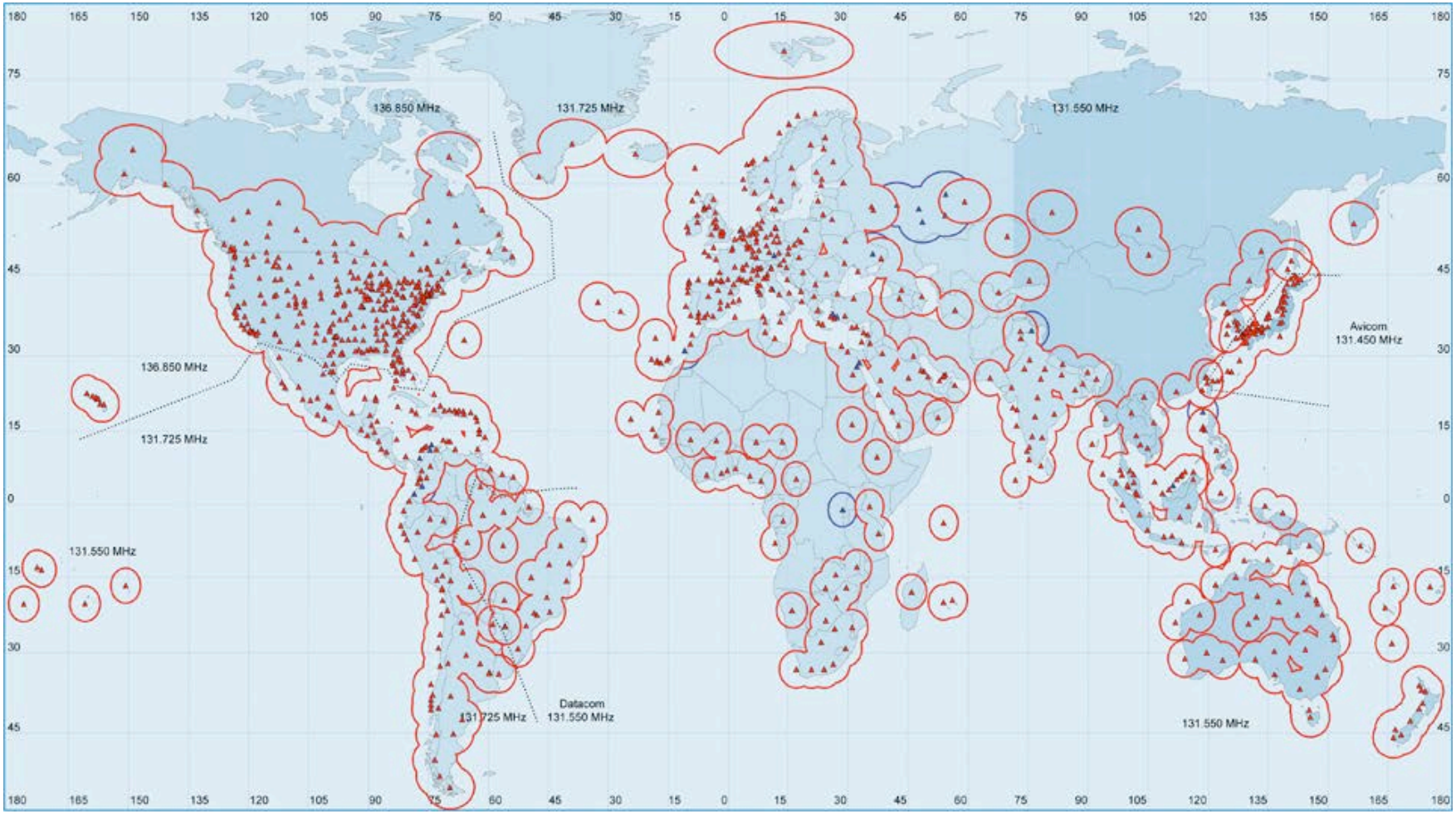
Source: NavCanada

System Wide Information Management



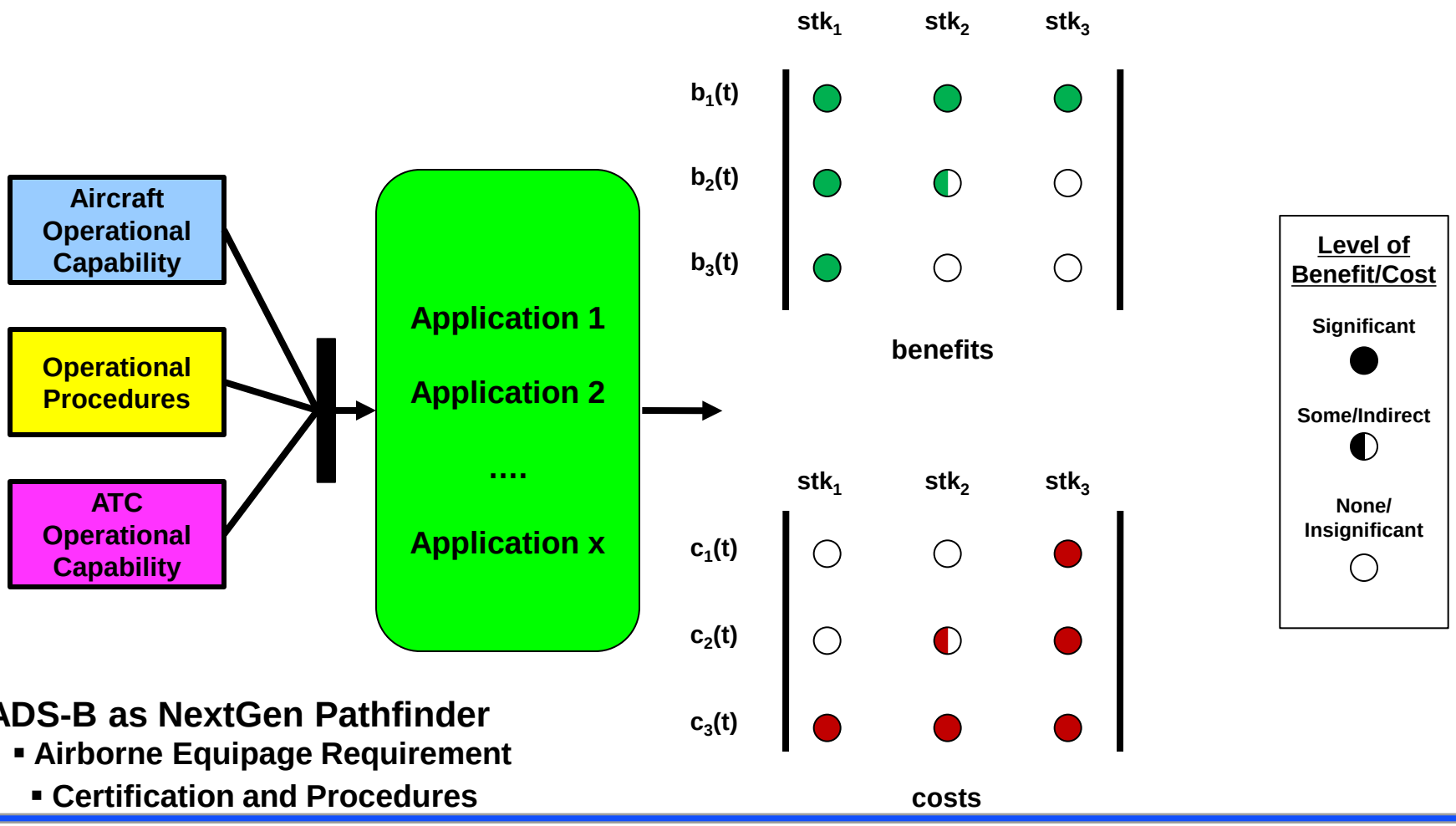
Source: FAA

Voice Datalink Mode 2 VHF Network



Source: SITA

NextGen User Benefits Dependent Upon Approved Applications and Operational Capabilities

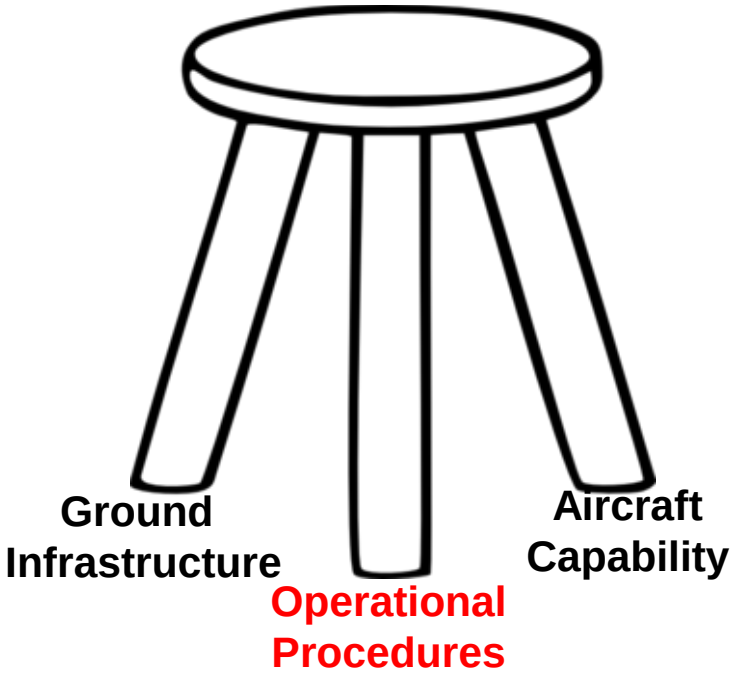


- ADS-B as NextGen Pathfinder
  - Airborne Equipage Requirement
  - Certification and Procedures

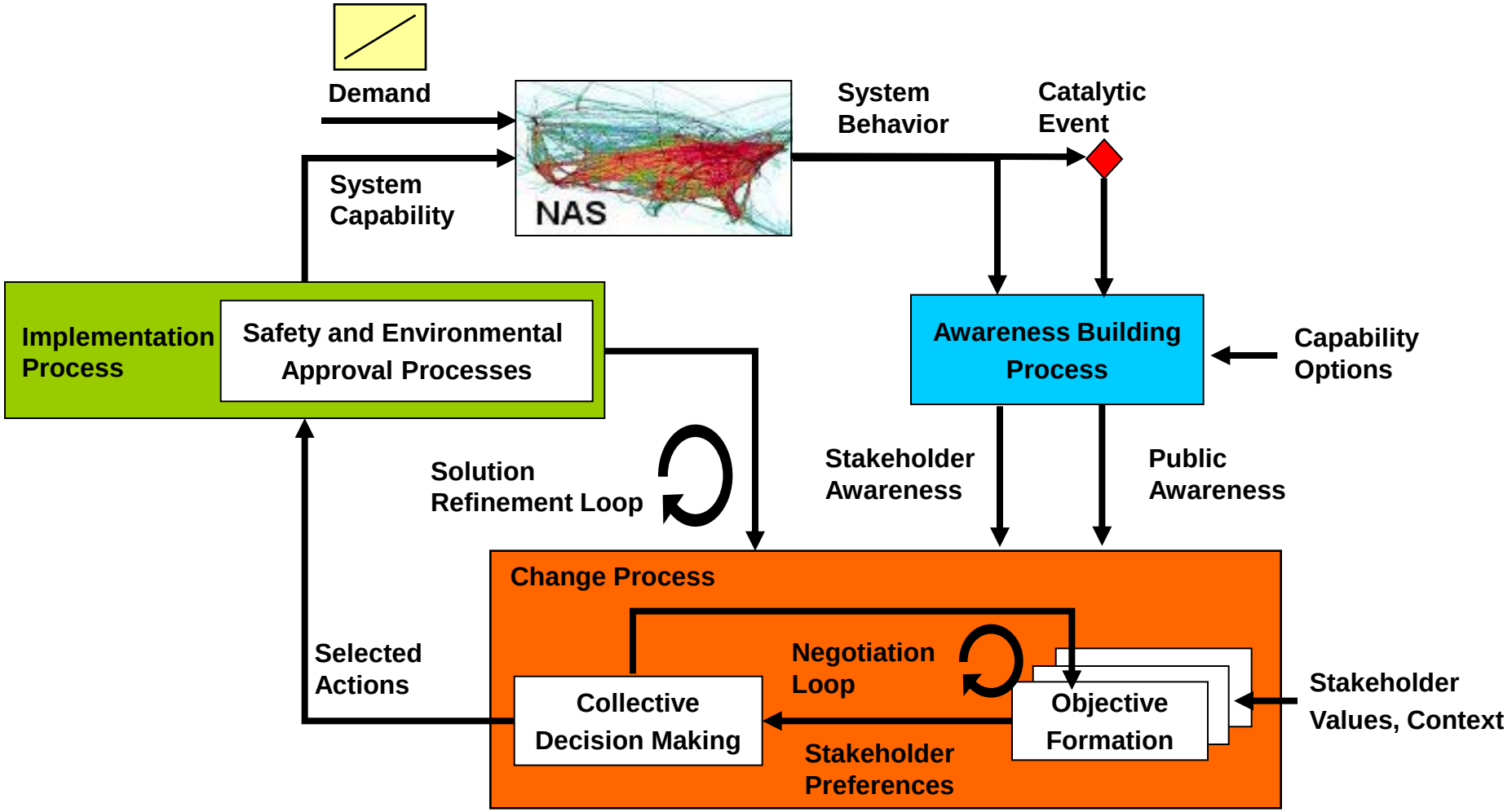
Disaggregate benefit/cost approach adapted from Marias and Weigel

Importance of NextGen Procedure Development

- Operating Procedures are the critical element in the integration triad
- If procedures are not updated to reflect that NextGen capabilities then there there is limited benefit and limited stakeholder buy-in
- NextGen and SESAR will provide the technical infrastructure. Need to develop processes to approve innovative operational procedures.



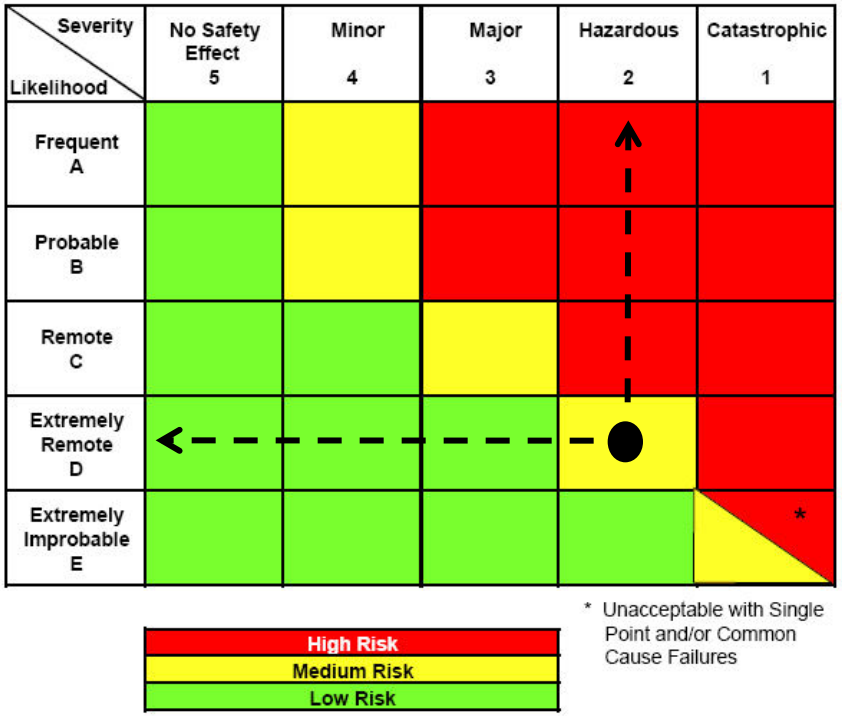
Feedback Model of System Transition



Transition Model : Alexandra Mozdznowska

Safety Management System (SMS)Classification of Severity & Likelihood

Extremely Remote = (quantitative) $1x10^{-7}$ to $1x10^{-9}$

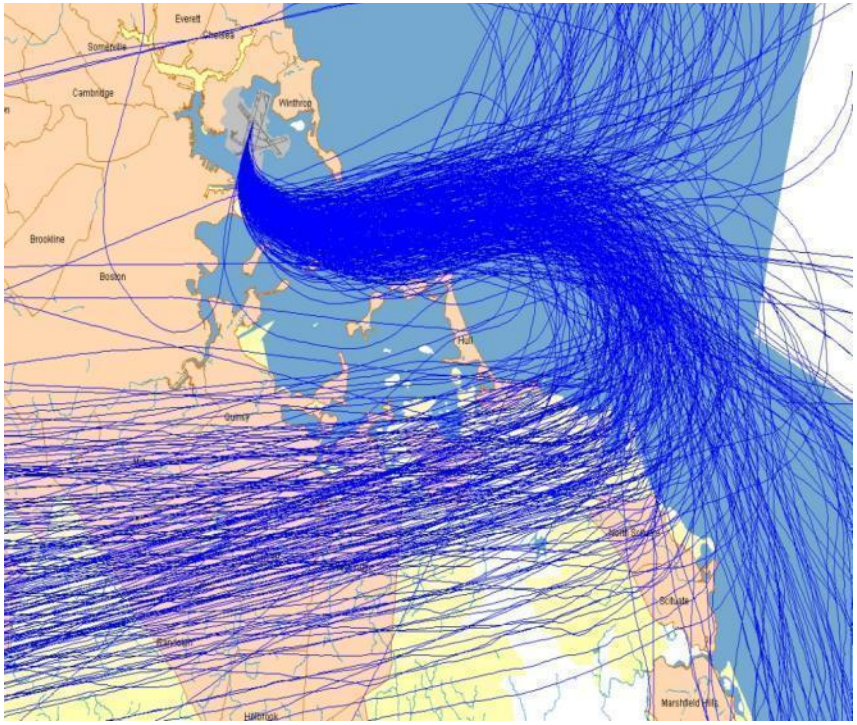


Hazardous = "Serious or fatal injury to small number of occupants or cabin crew"

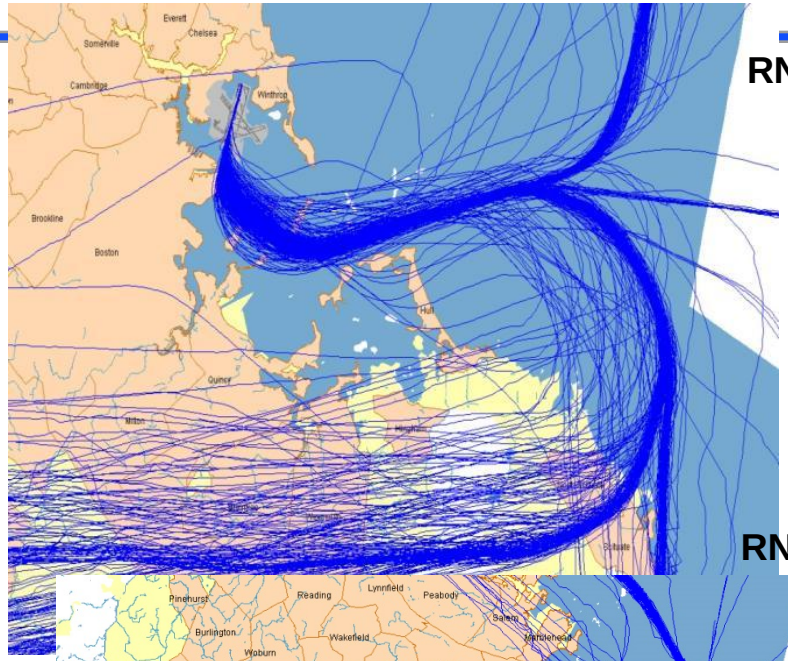
- **Target risk classified by ATO Safety Management System standards**
  - Hazardous assumption & 10^{-7} assumption
- **Risk also compared to ground fatality risk from commercial aviation**
  - Frequency approximately $1x10^{-7}$ fatalities/hr due to Part 91 ops

RNAV application at Boston Logan
R22R Departures

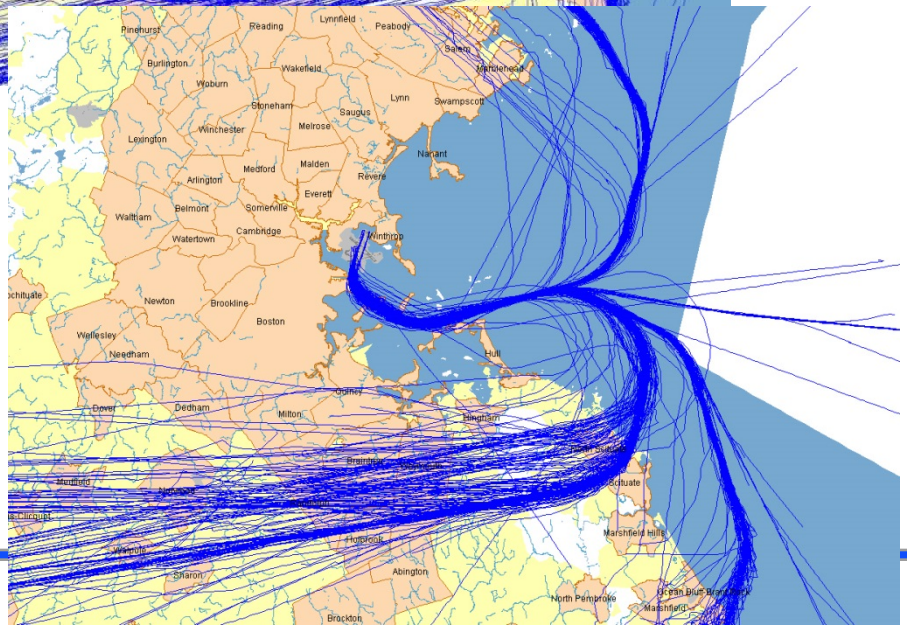
Pre-RNAV



RNAV - 2012

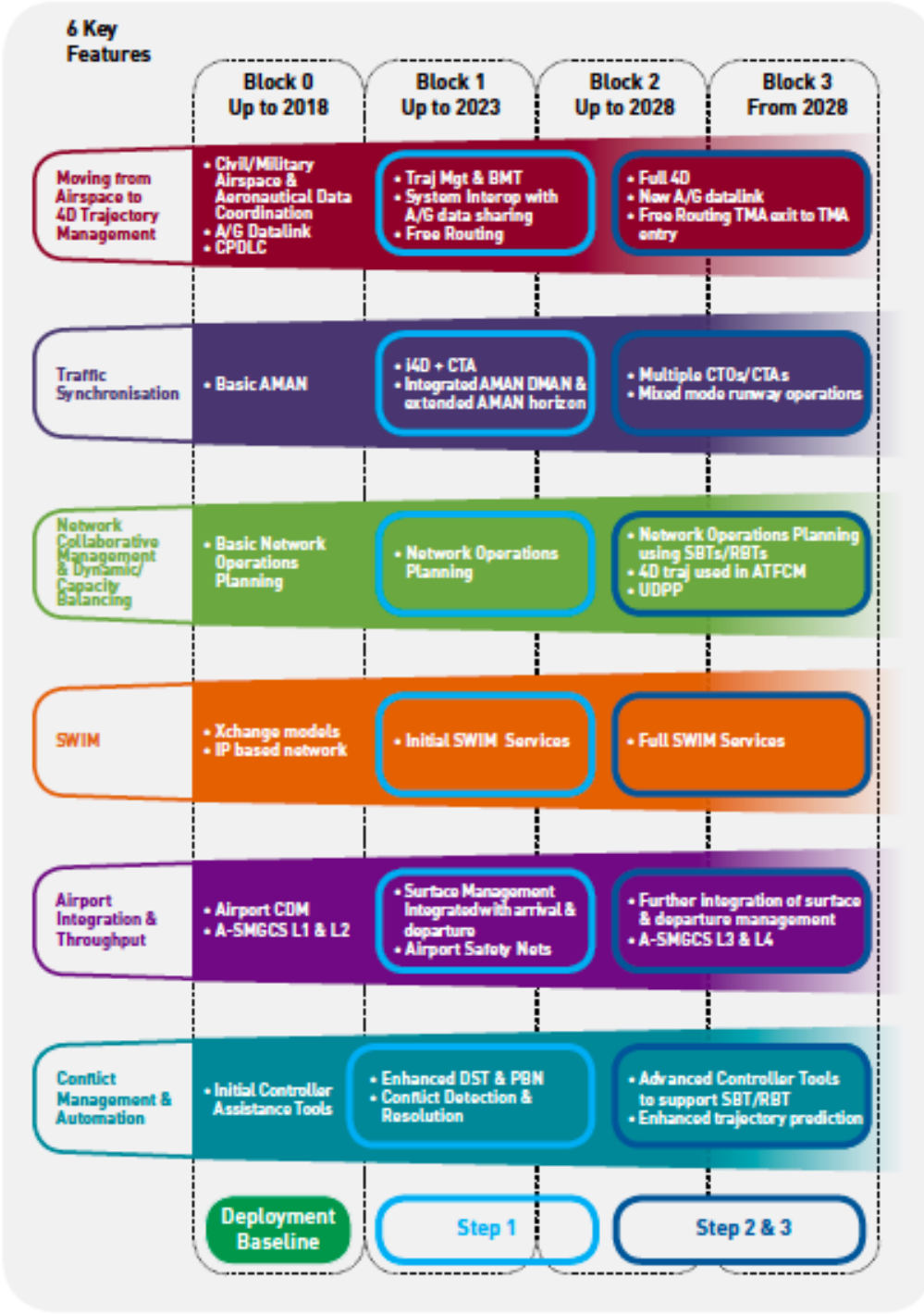


RNAV - 2014



Source: Massport

SESAR Essential Operational Changes



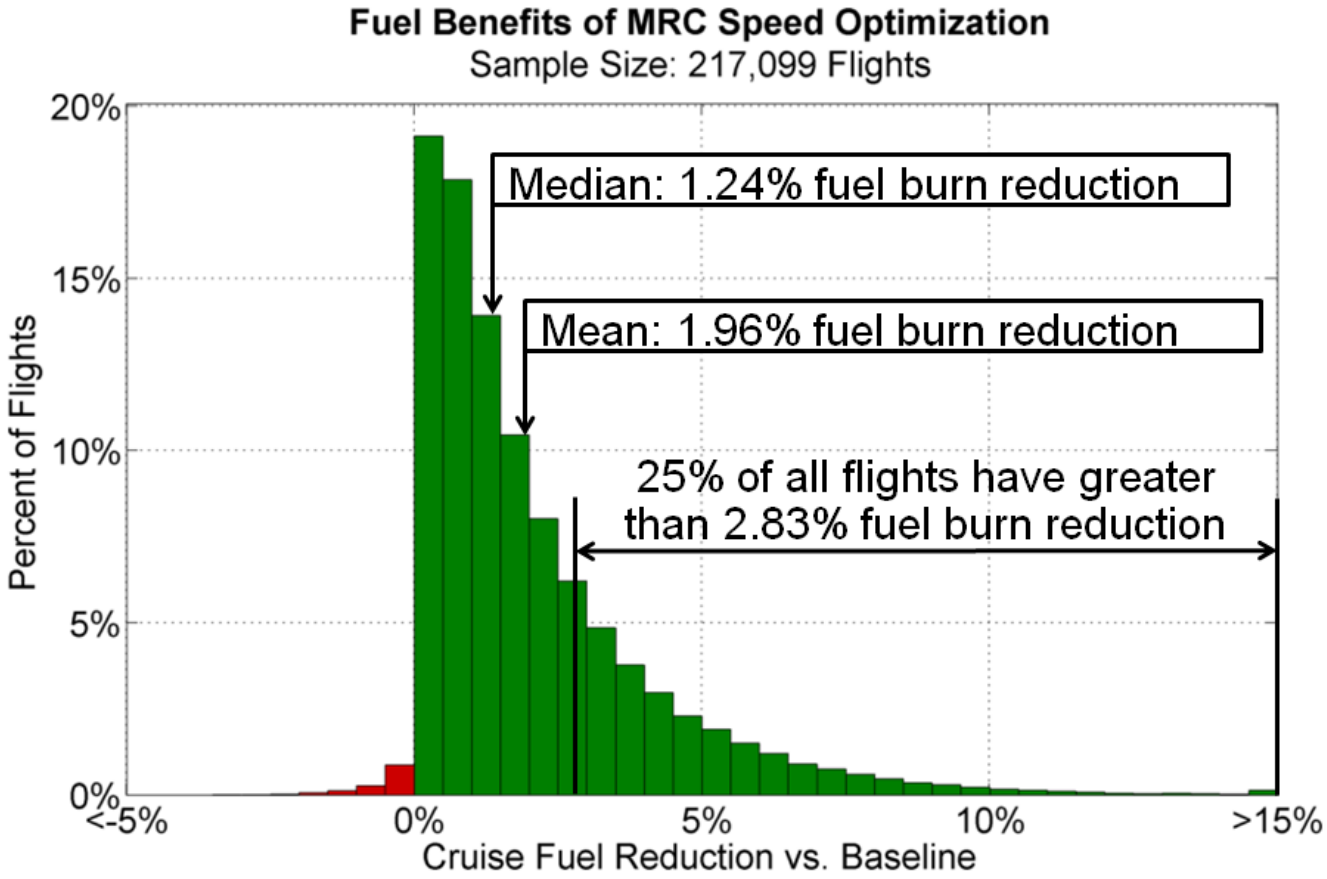
Future Concepts

- **Absent catalytic events the system will change by evolution and adaptation**
  - Adapt to NextGen/SESAR technologies
  - Strong NextGen/SESAR concepts will survive if they can be made operational
- **System will adapt to emerging drivers**
  - Point capacity limits
  - Environmental drivers (Noise, GHG)
  - Cost will emerge as key driver
- **Concept Types**
  - Evolutionary (e.g. Optimization and Refinement)
  - Obvious but Politically Difficult (e.g. Dynamic Facility Consolidation)
  - High Payoff, Out There (e.g. Formation Ops)

Meta Optimization

- **CDM-2 Evolution of CDM at both Tactical and Strategic level**
  - Enabled by
    - SWIM
    - Data Mining,
    - New Optimization Approaches
    - Communication Systems and Cloud
- **Increase Capacity and Improve Operational Efficiency**
- **ATM Service Providers**
  - Realtime and predictive capacities
  - Smoothed matched demand
  - Dynamic Airspace Reallocation
  - Stochastic vs.. Deterministic Approaches
  - Predictability and Robustness
- **Airlines**
  - Increased predictability and efficiency
  - Requires real time optimization and internal prioritization

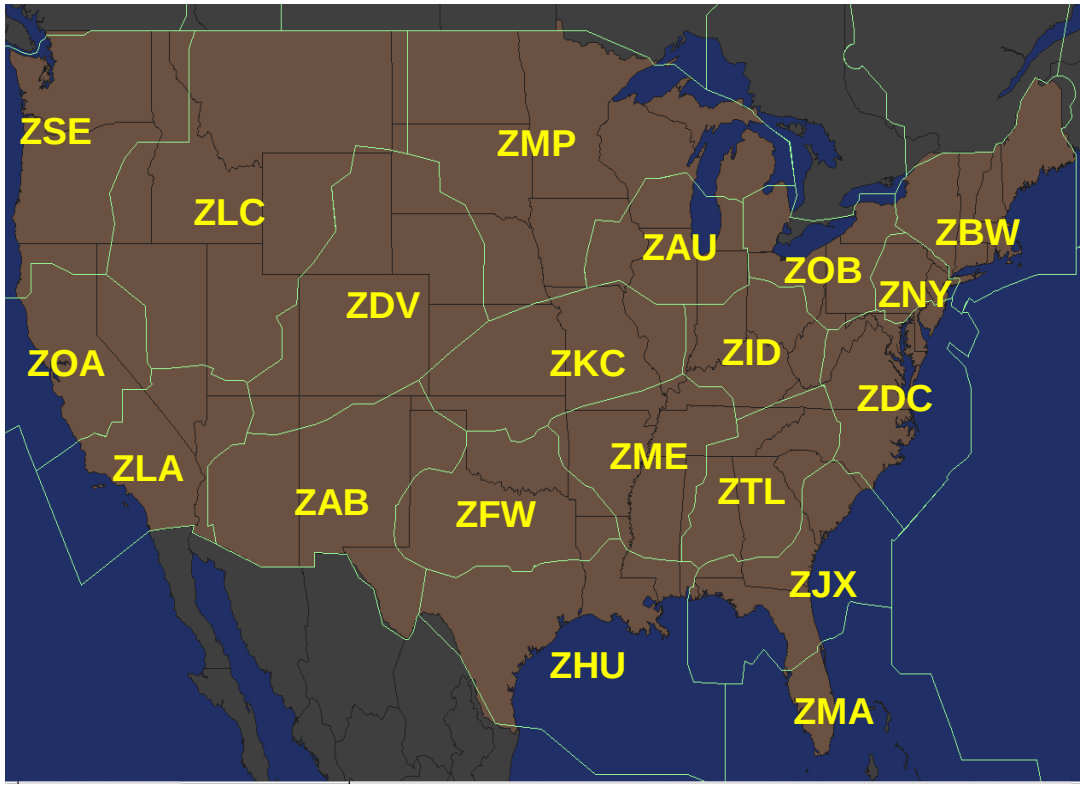
Speed Optimization Example



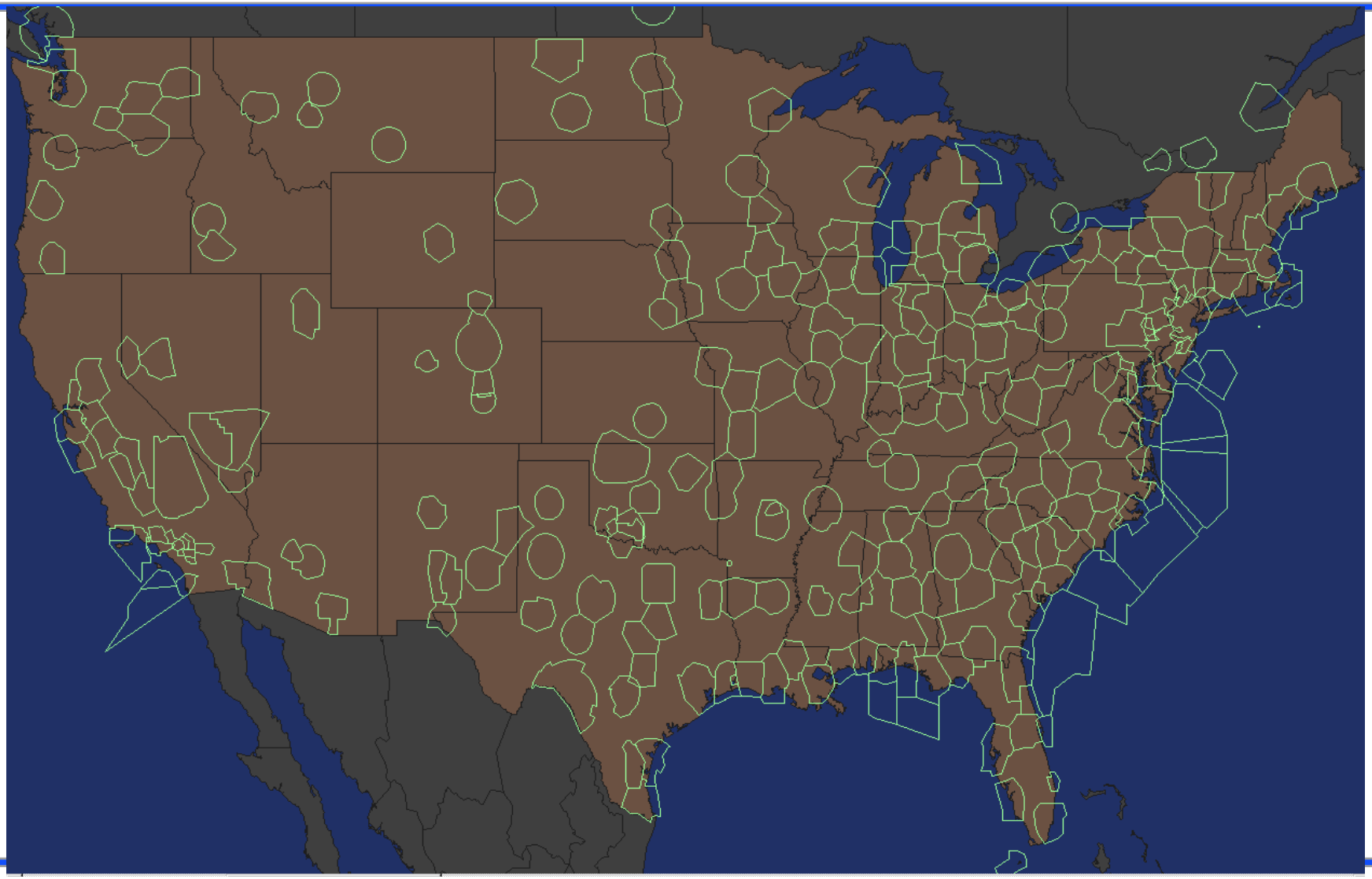
Max Range Cruise (MRC):

Dynamic Facility Consolidation

- **Obvious but Politically Difficulty**
- **Cost, Efficiency and Robustness Opportunity**
- **Technically Feasible**



TRACONS



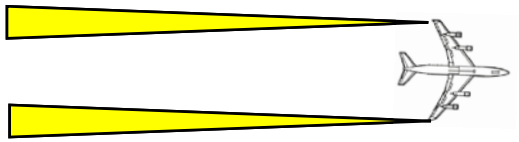
Out There Concepts

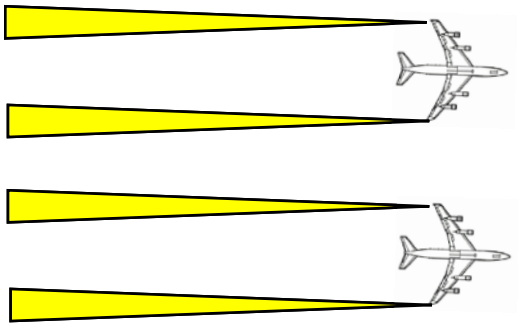
- **Enabling Advanced Formation Operations**
- **Enroute**
  - Fuel Efficiency, Reduced Costs/Labor
- **Terminal**
  - Runway Throughput
- **Need to work formation issues**
- **Need to work failure cases**
- **ADS-B performance standards not sufficient**
  - DO 260B

Formation Flight Feasibility Study

Formation Approaches

Lateral vs. Longitudinal Wake Vortex Separation





28L | 28R

- **Limited Reduction Possible in Longitudinal Separation due to Vortex Dynamics**
  - 20-30 % Throughput Improvement
- **Lateral Position of Wake well known close to aircraft**
- **Close Dependent Parallel Approaches or Formation Approaches enabled by accurate guidance technologies**
  - 100 - 200% Throughput Improvement

Comments?