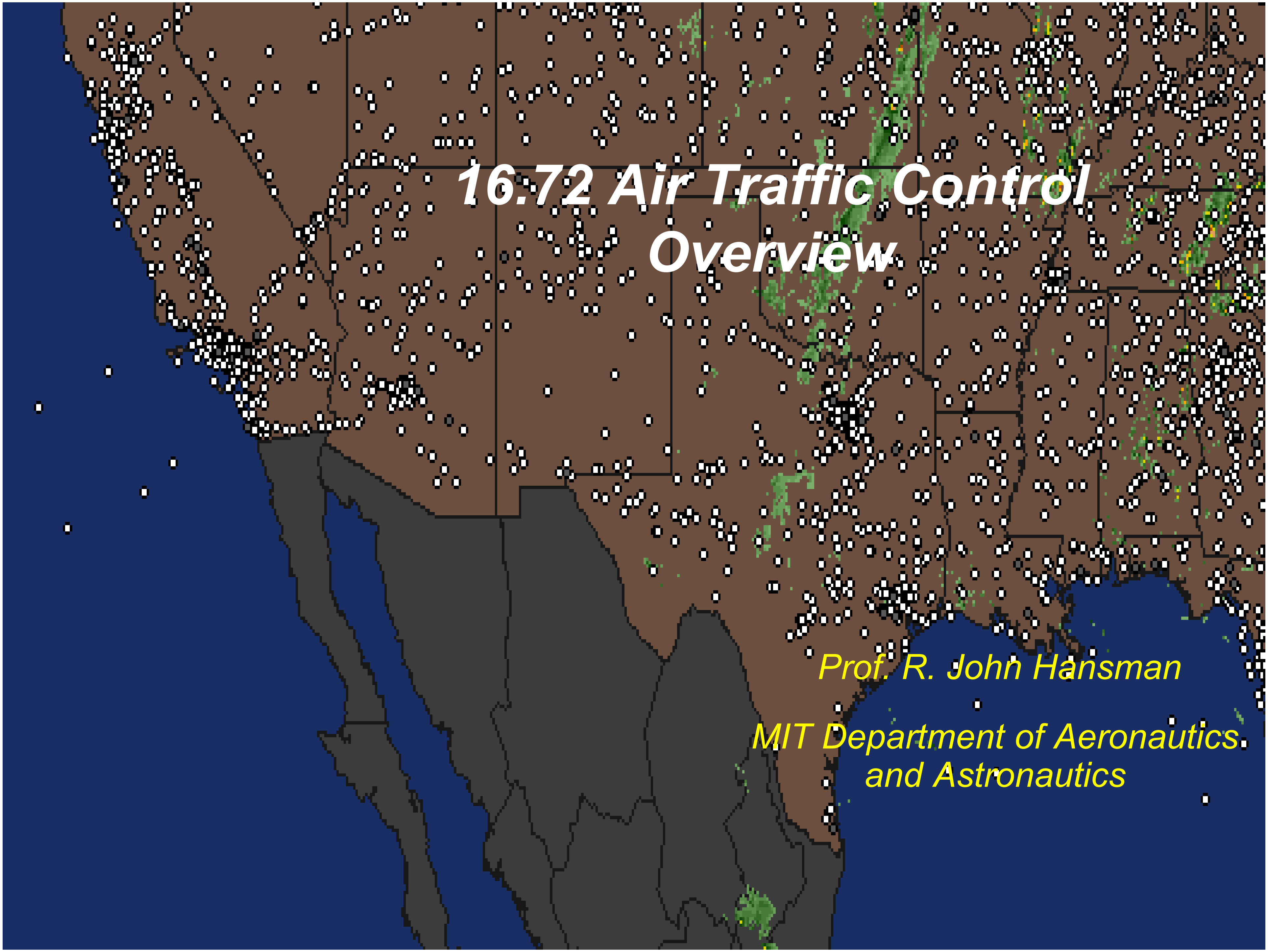


16.72 Air Traffic Control Overview

Prof. R. John Hansman

MIT Department of Aeronautics and Astronautics

US Capacity Issue

- **Prior to 9/11 the US Air Transportation system is approaching a critical saturation threshold where nominal interruptions (e.g. weather) resulted in a nonlinear amplification of delay**
- **US and Regional Economies highly dependant on Air Transportation**
  - ❑ Business travel (stimulated by info technology)
  - ❑ Air Freight
  - ❑ Personal travel
- **System is highly complex and interdependent**
- **Need better understanding of system dynamics and real constraints to guide and justify efforts to upgrade NAS**
- **Current efforts will not provide capacity to meet demand which will re-emerge when the economy cycles up**
- **Impact of upcoming capacity crisis is not well understood**
  - ❑ Operational Impact
  - ❑ Economic Impact
- **Similar Issues in Europe**
- **Different Issues in Emerging Regions (eg China, India)**

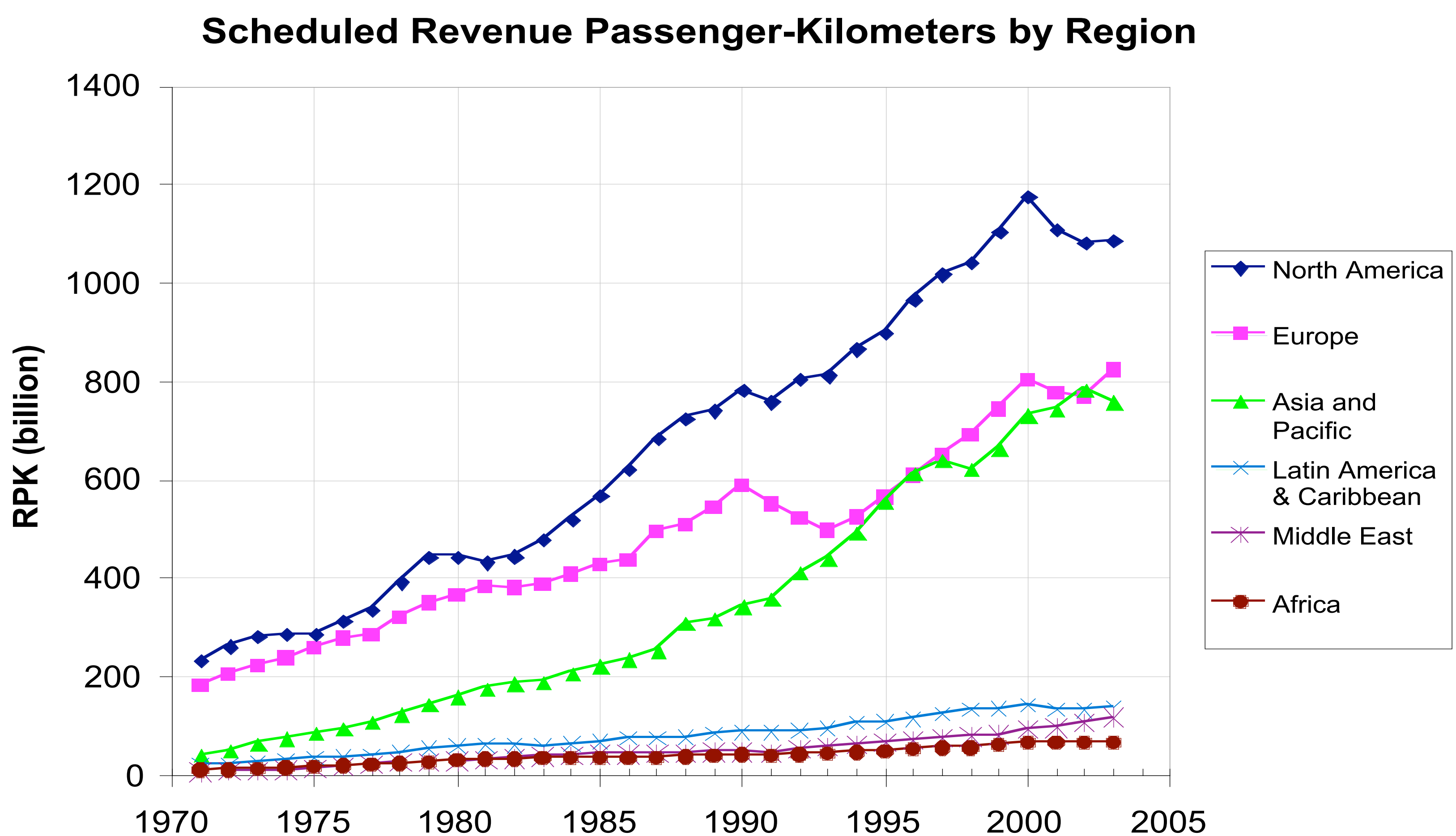
A DAY IN THE LIFE OF
AIR TRAFFIC OVER
THE CONTINENTAL U. S.

ANIMATION CREATED USING

FUTURE ATM CONCEPTS
EVALUATION TOOL
(FACET)

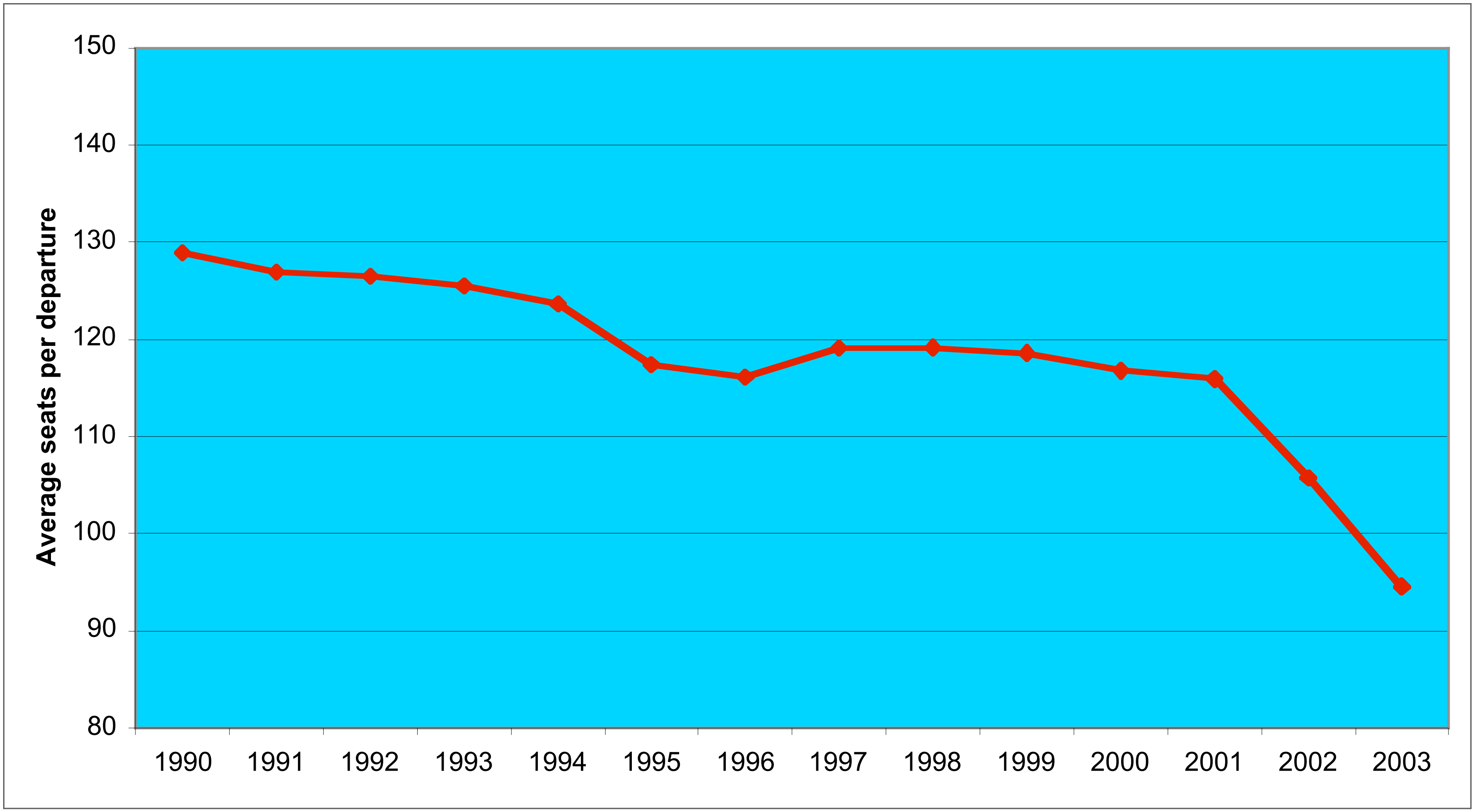
FOR
AVIATION SYSTEMS DIVISION
(AF)
NASA AMES RESEARCH CENTER

Passenger Traffic by Region



Source: ICAO, scheduled services of commercial air carriers

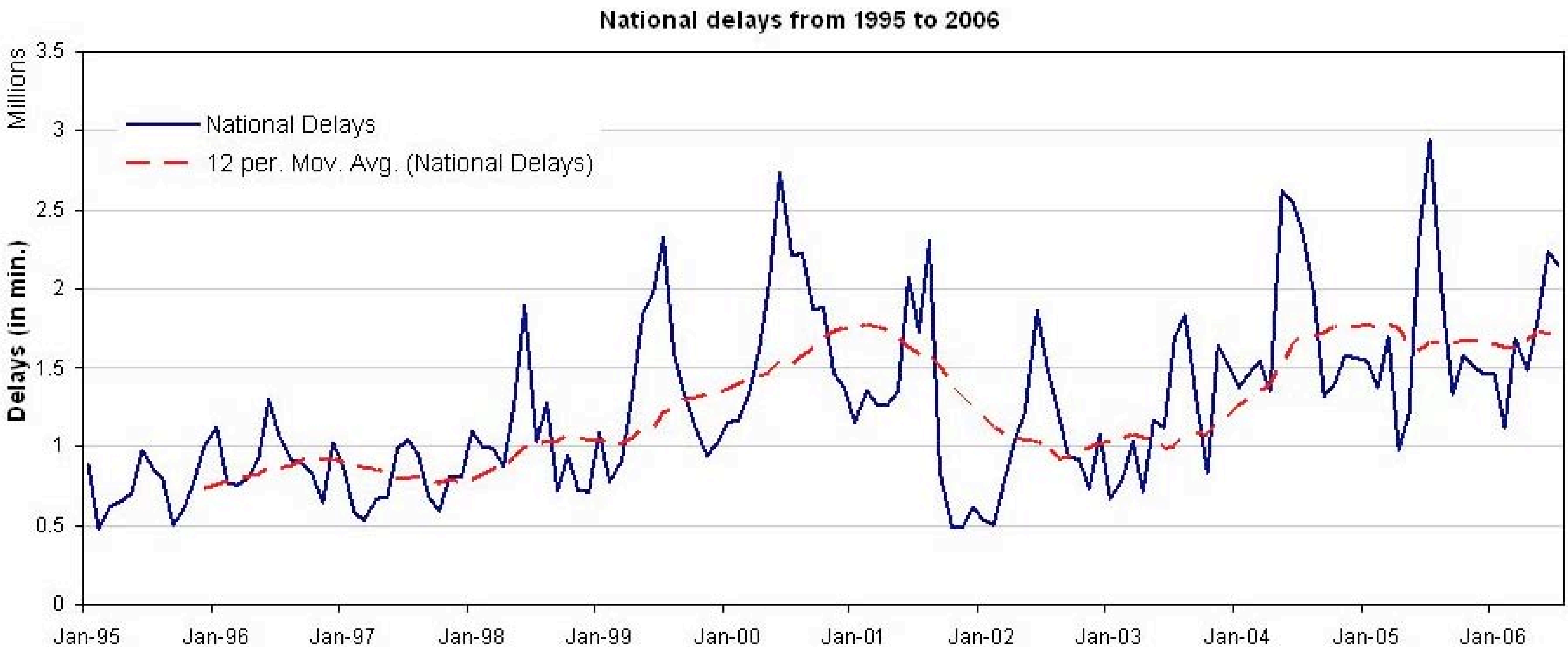
Trends in Aircraft Size



Source: DOT Form 41 data (including Regional Jets and Turboprops)

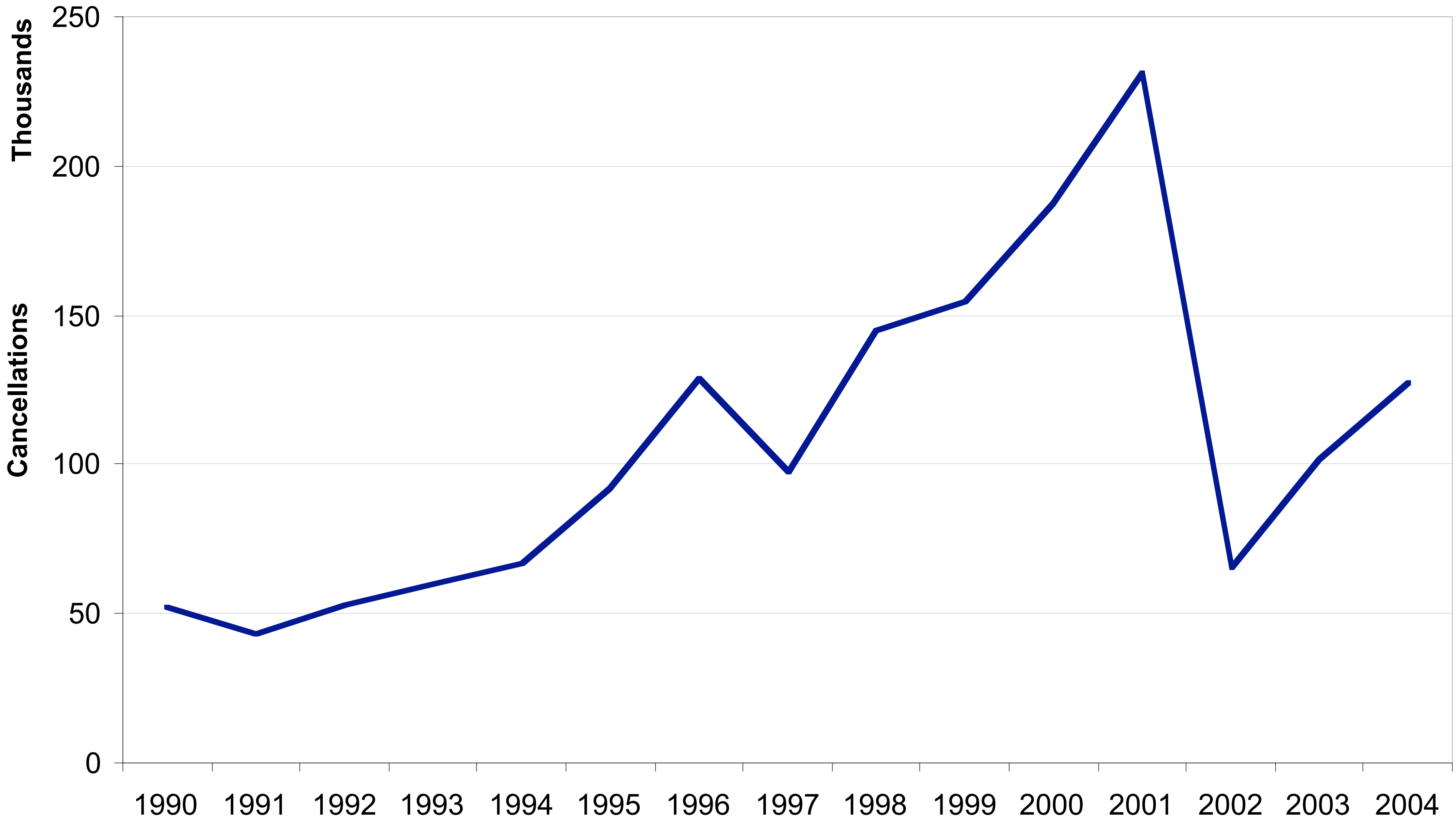
US Flight Delays

from 1995 to 2006



Data source: FAA Operational Network (OPSNET)

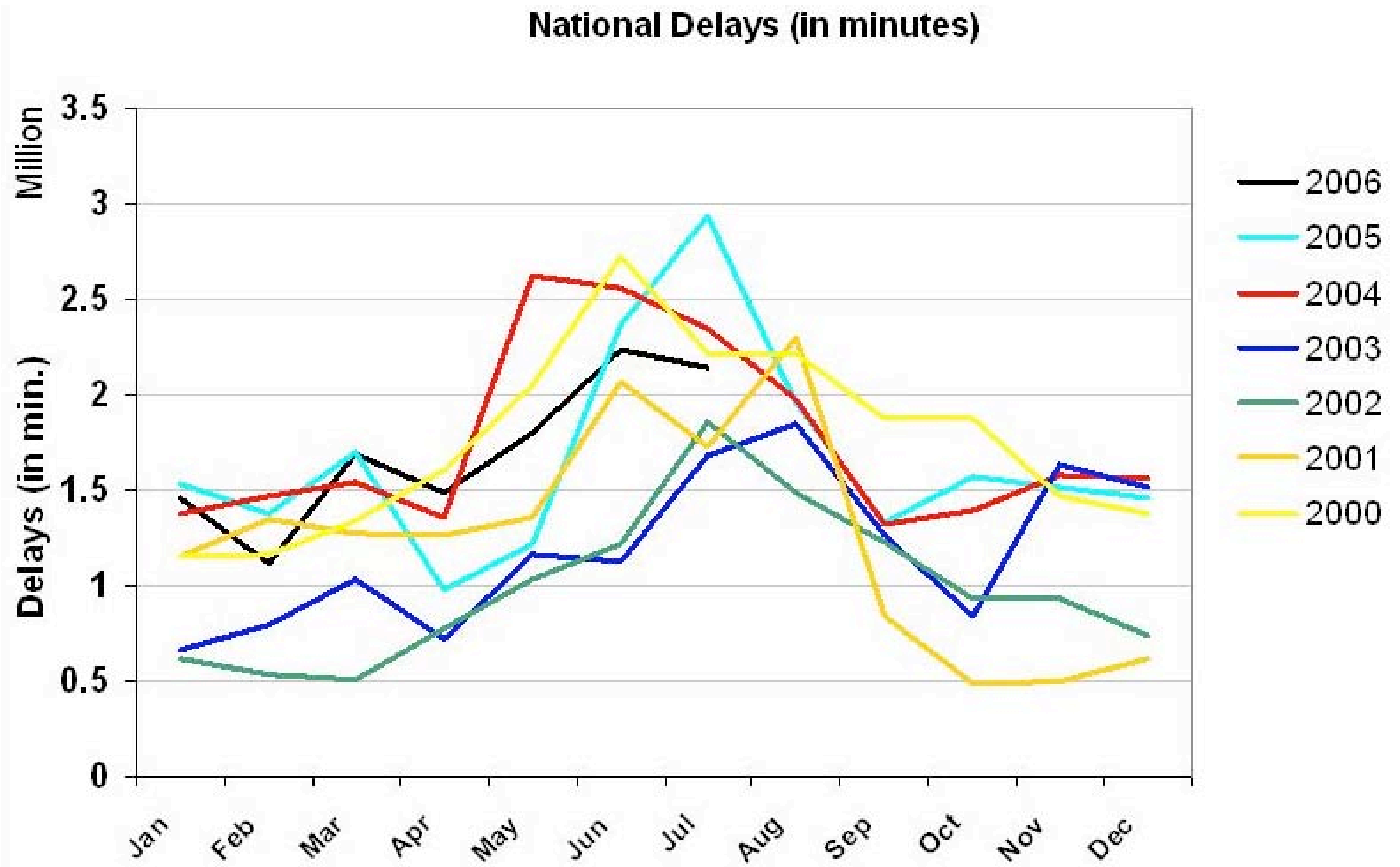
Flight Cancellations



Source: BTS, Airline On Time Performance data

US Flight Delays

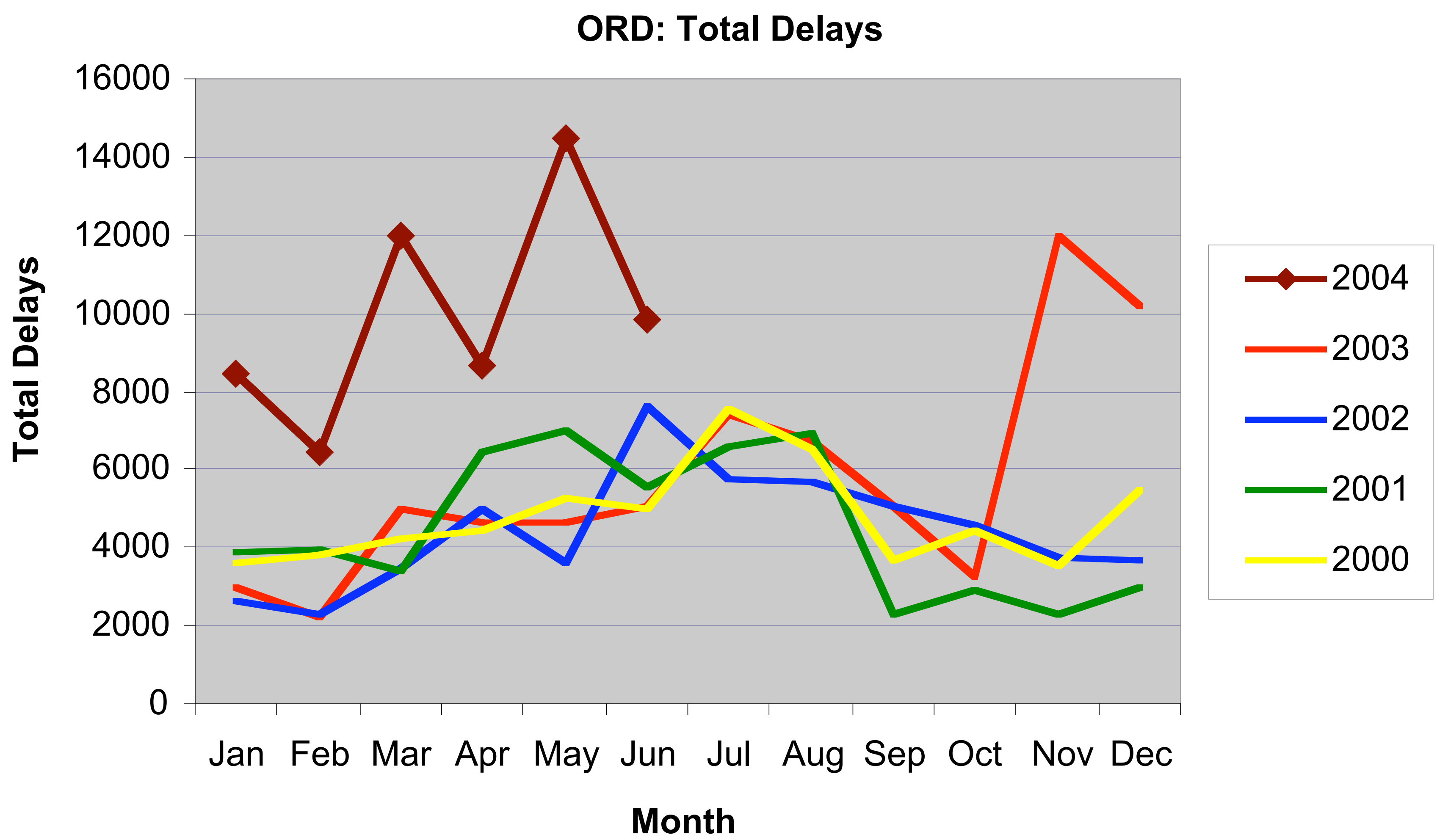
from 2000 to 2006



Source: FAA OPSNET data

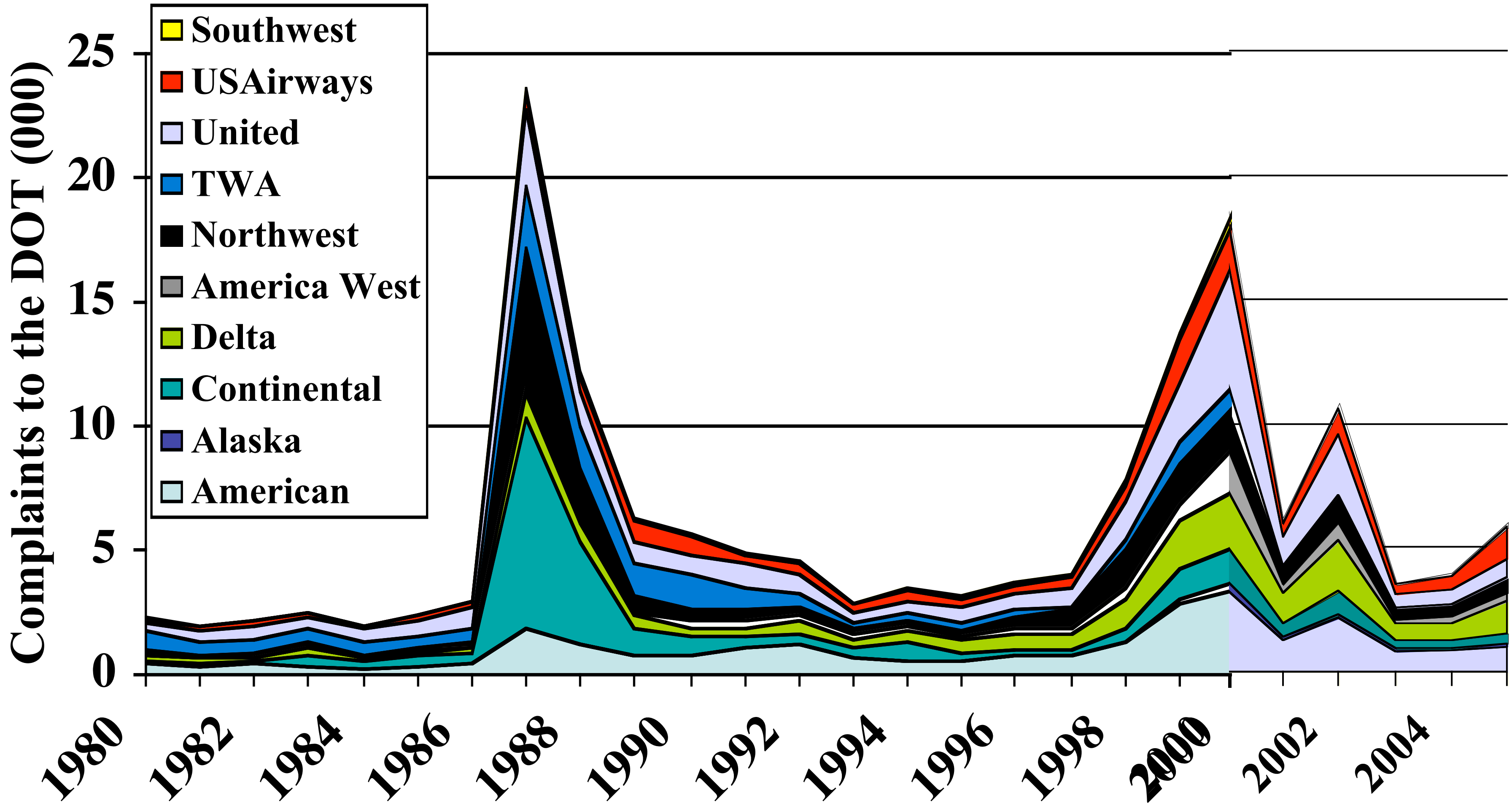
Delays at Chicago O'Hare

Pressure for Demand Managment



Source: FAA OPSNET data

Consumer complaints



Note: Year 2005 consumer complaints is an extrapolation using data from Jan-Mar 2005

Data source: DOT Aviation Consumer Protection Division, available at: http://airconsumer.ost.dot.gov/

Air Traffic Control Functions

- Aircraft Separation Assurance
- Traffic Congestion Management
- Flight Information
- Search and Rescue

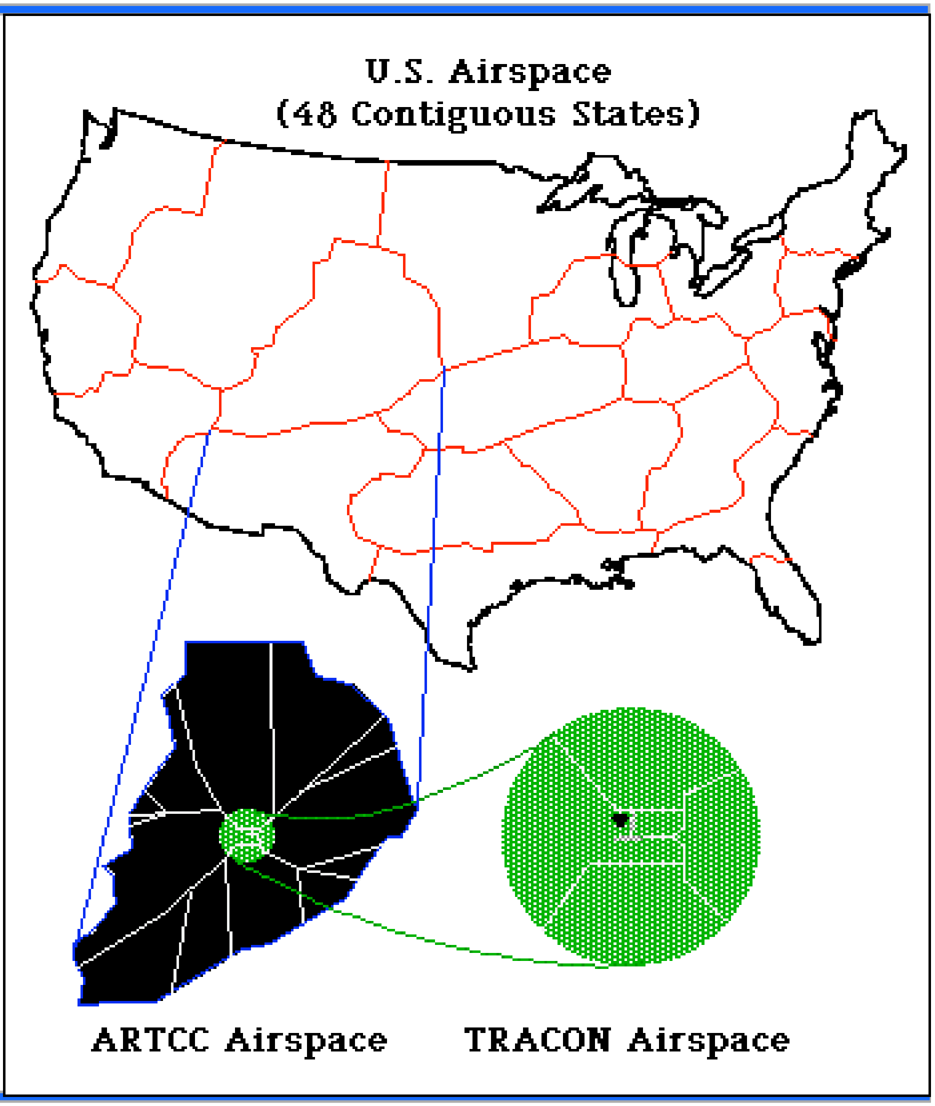
- Example of a Command, Control and Information System

COMPONENTS OF AIR TRANSPORTATION INFRASTRUCTURE

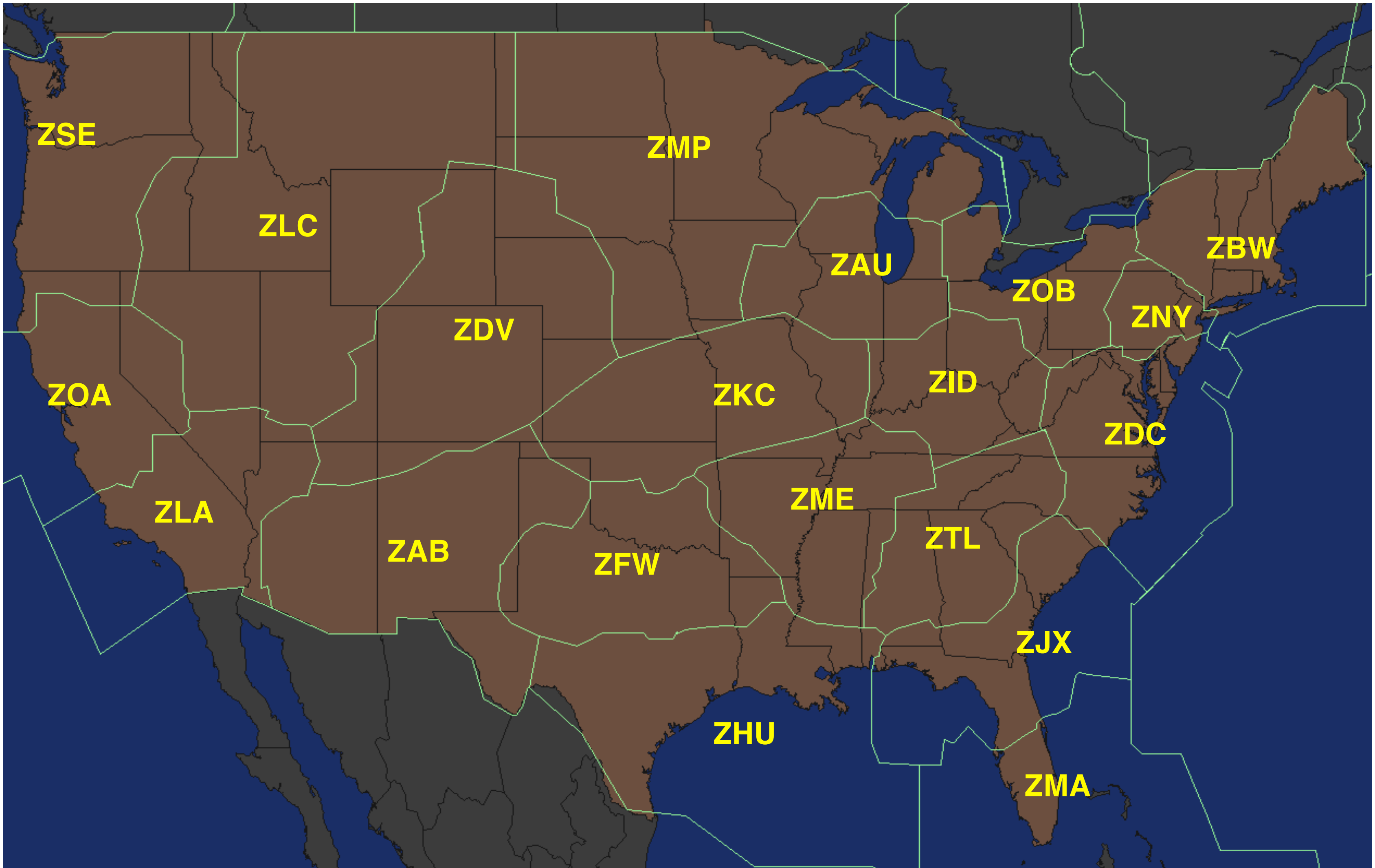
- **Airports**
  - ❑ Runways
  - ❑ Terminals
  - ❑ Ground transport interface
  - ❑ Servicing
  - ❑ Maintenance
- **Air traffic management**
  - ❑ Communications
  - ❑ Navigation
  - ❑ Surveillance
  - ❑ Control
- **Weather**
  - ❑ Observation
  - ❑ Forecasting
  - ❑ Dissemination
- **Skilled personnel**
- **Cost recovery mechanism**

Current Control Structure

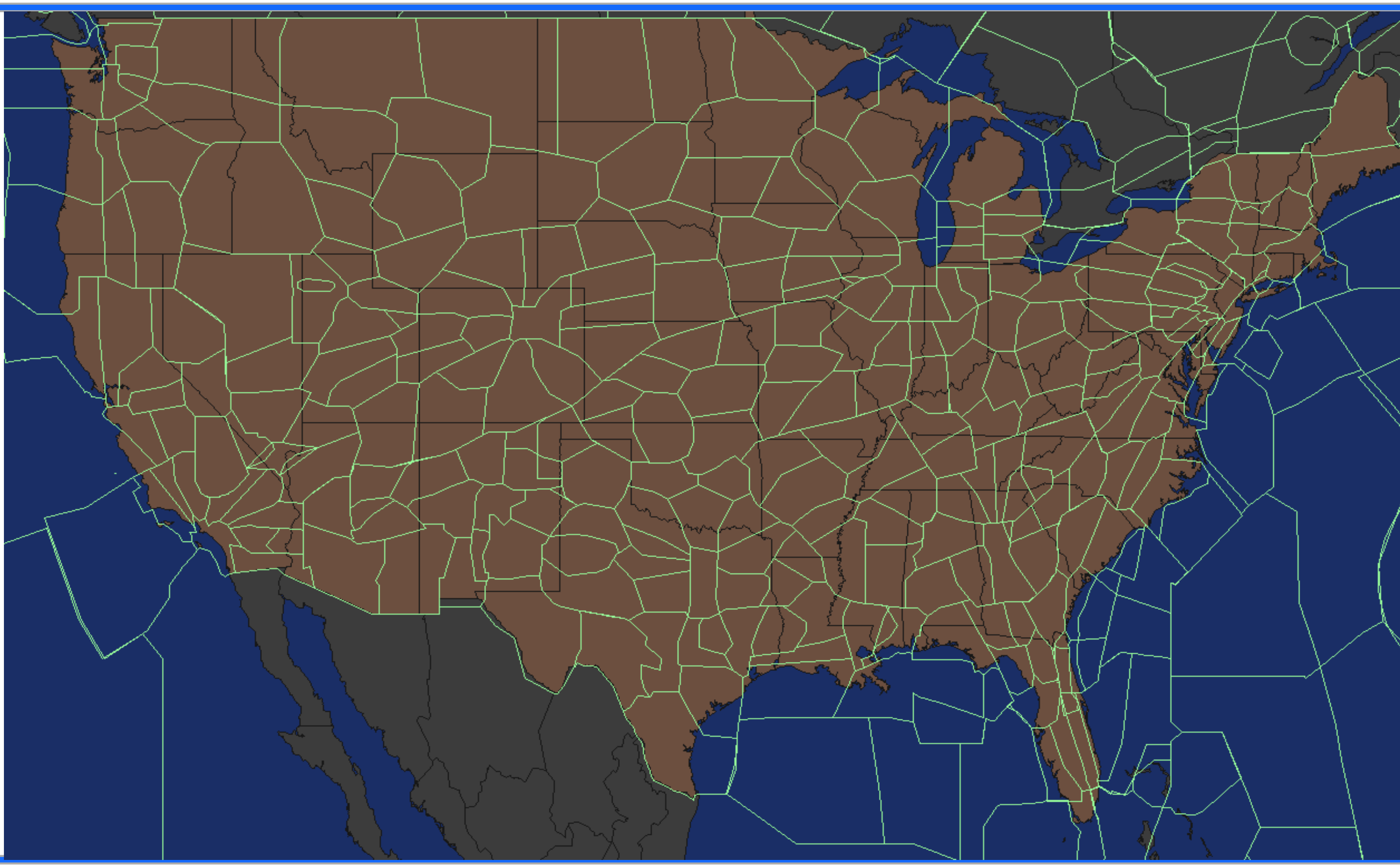
- **Surface Control**
  - ❑ "Ground"
- **Local Control**
  - ❑ "Tower"
- **Terminal Area Control (TRACON)**
  - ❑ "Approach and "Departure"
- **Enroute Control (ARTCC)**
  - ❑ "Center"
- **Oceanic Control (FIR)**
  - ❑ "Oceanic"
- **Flow Control (ATCSCC)**
  - ❑ "Central Flow"



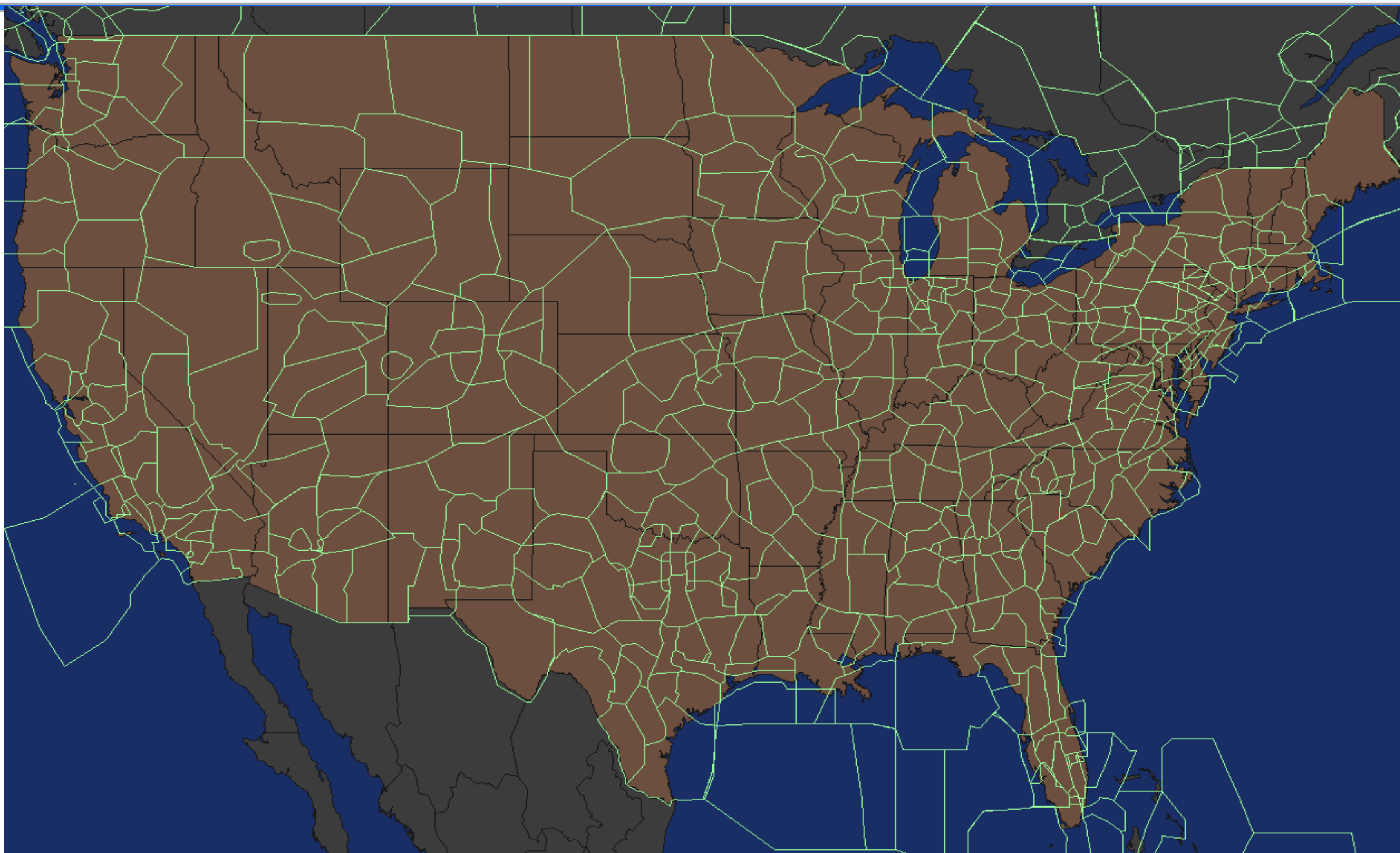
US Air Route Traffic Control Center (ATRCC) Airspace - 20 Centers



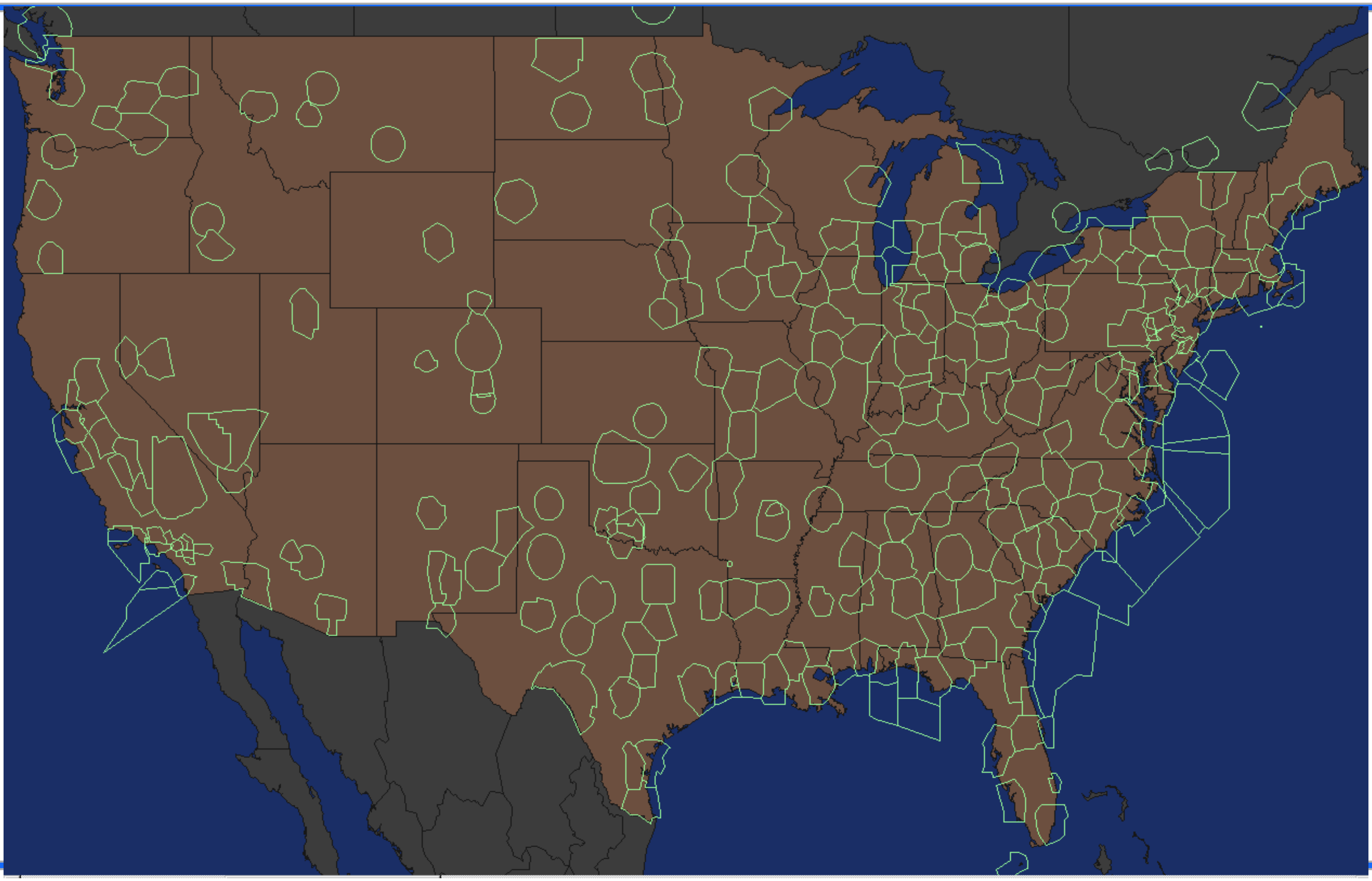
High Level Sectors
257



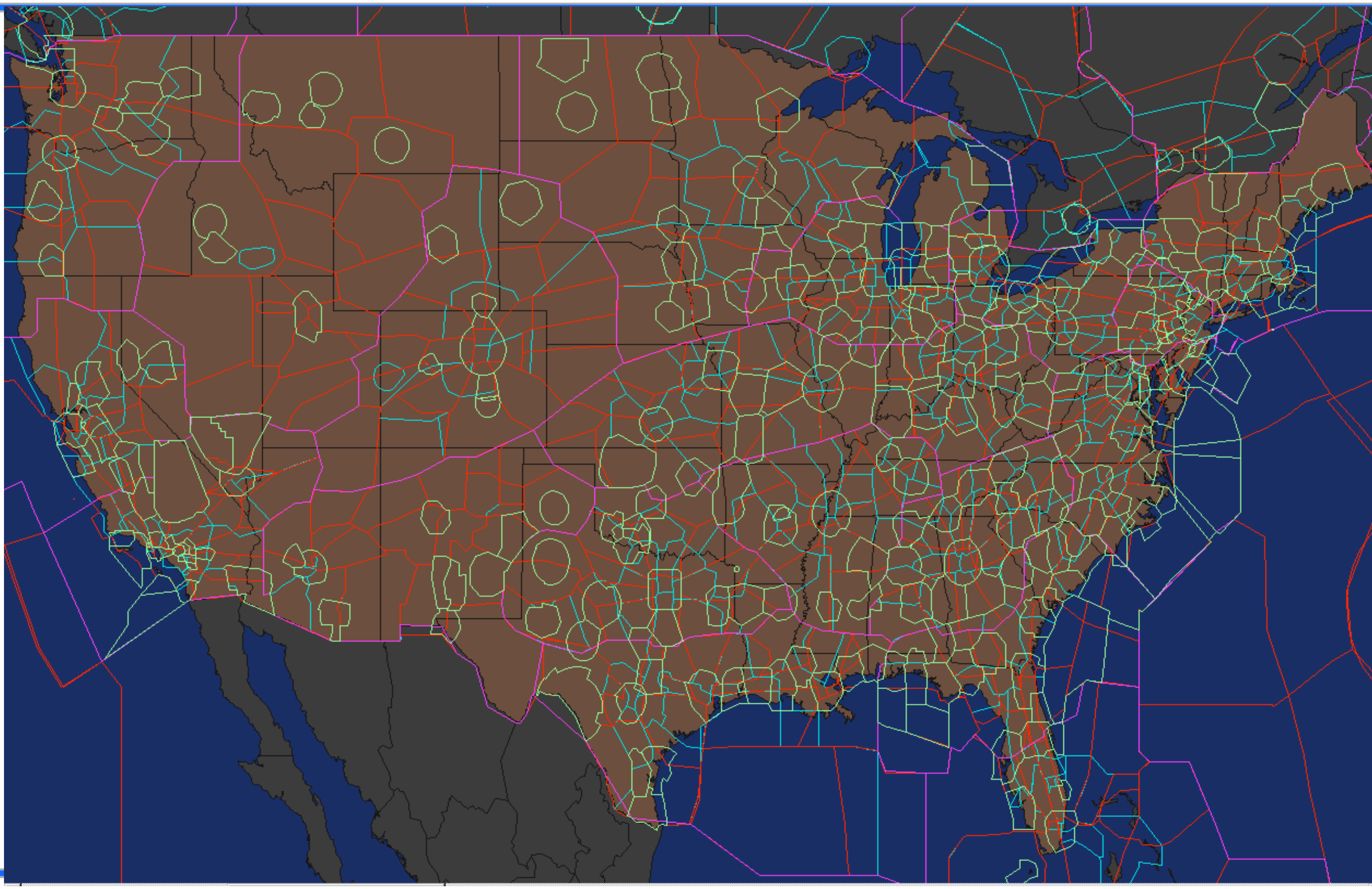
Low Level Sectors
378



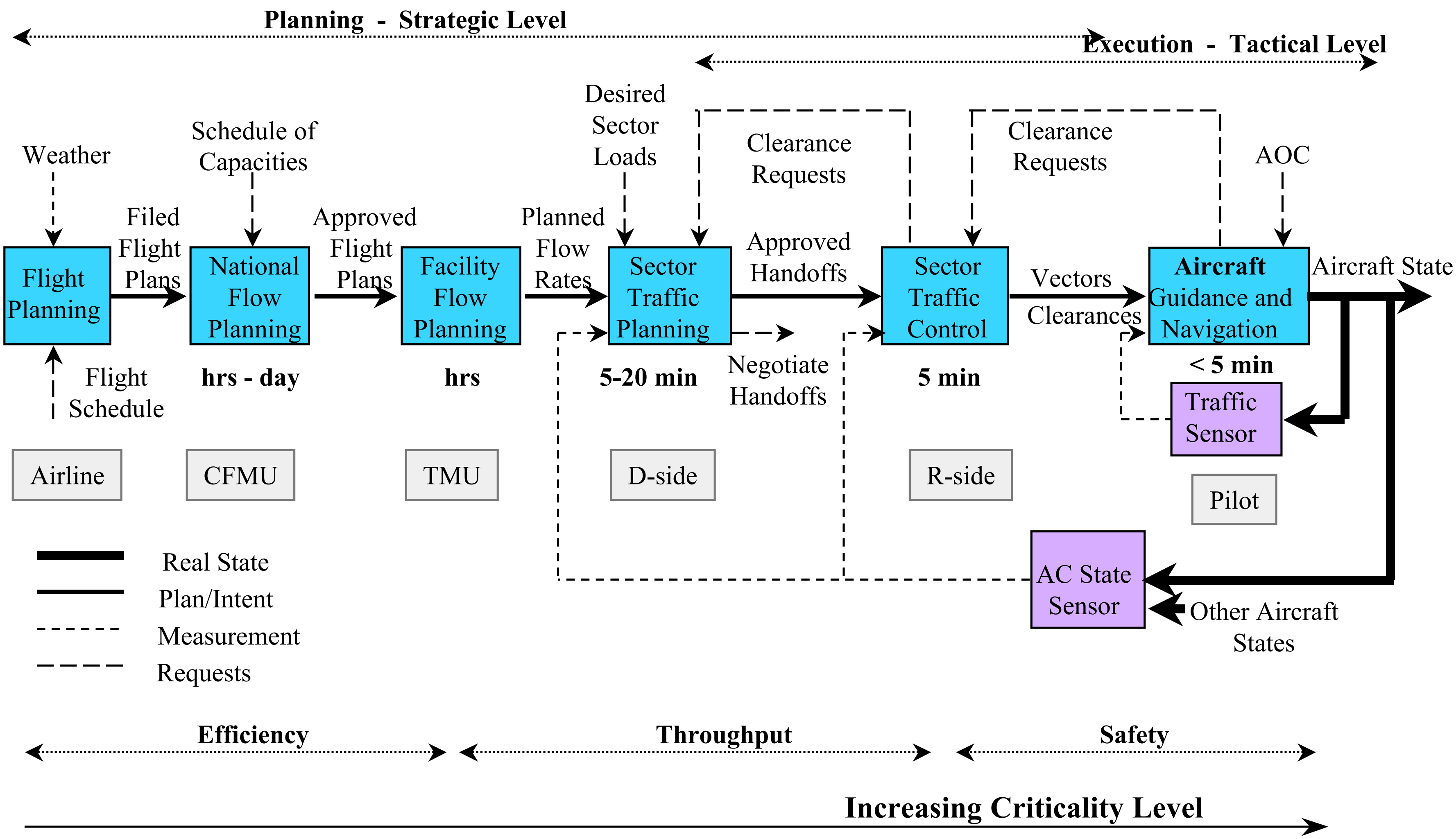
TRACONS



Overall Structure

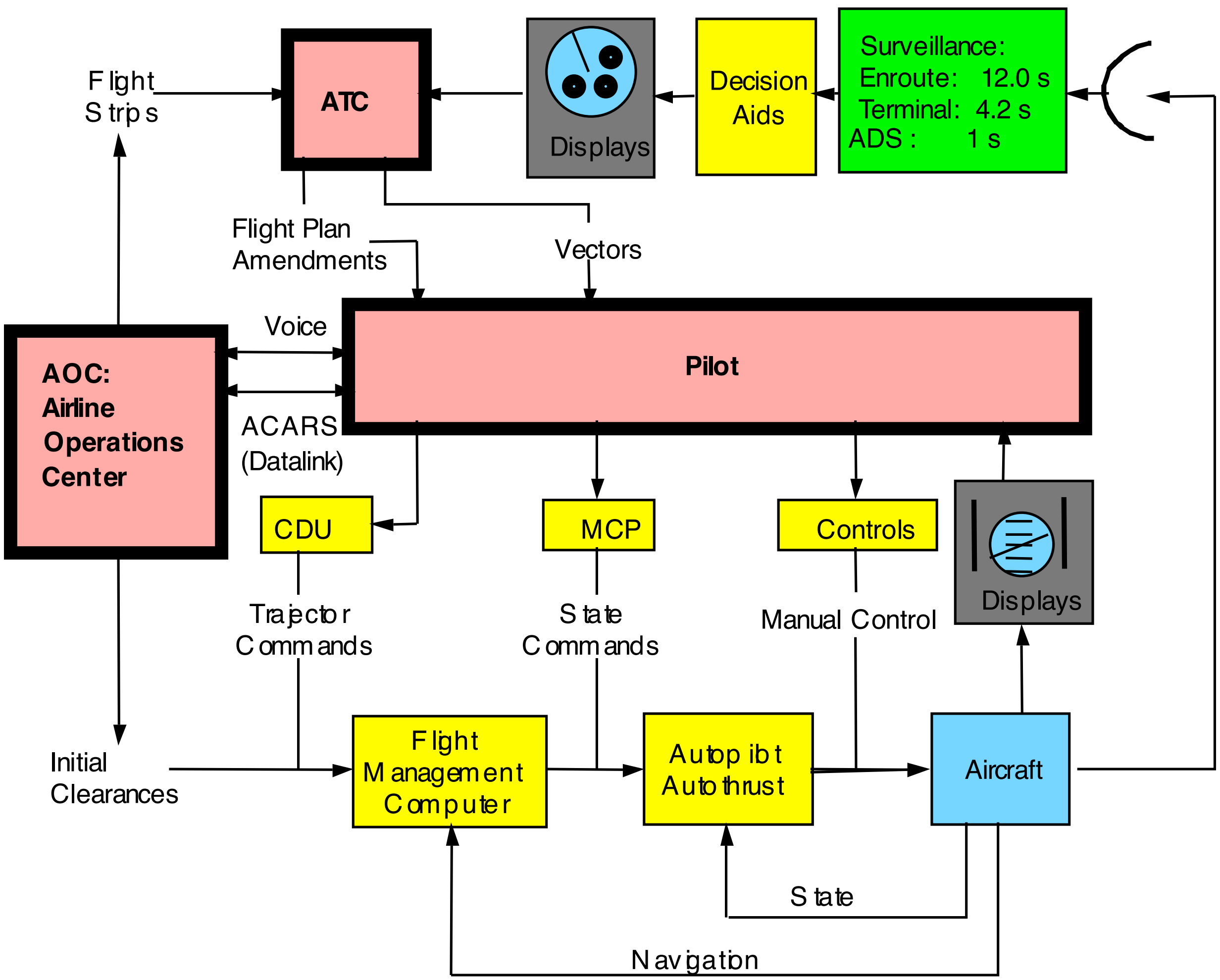


ATM System Current Functional Structure



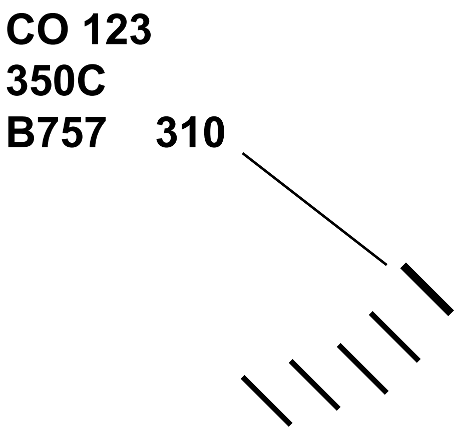
Source: A. Haraldsdottir Boeing

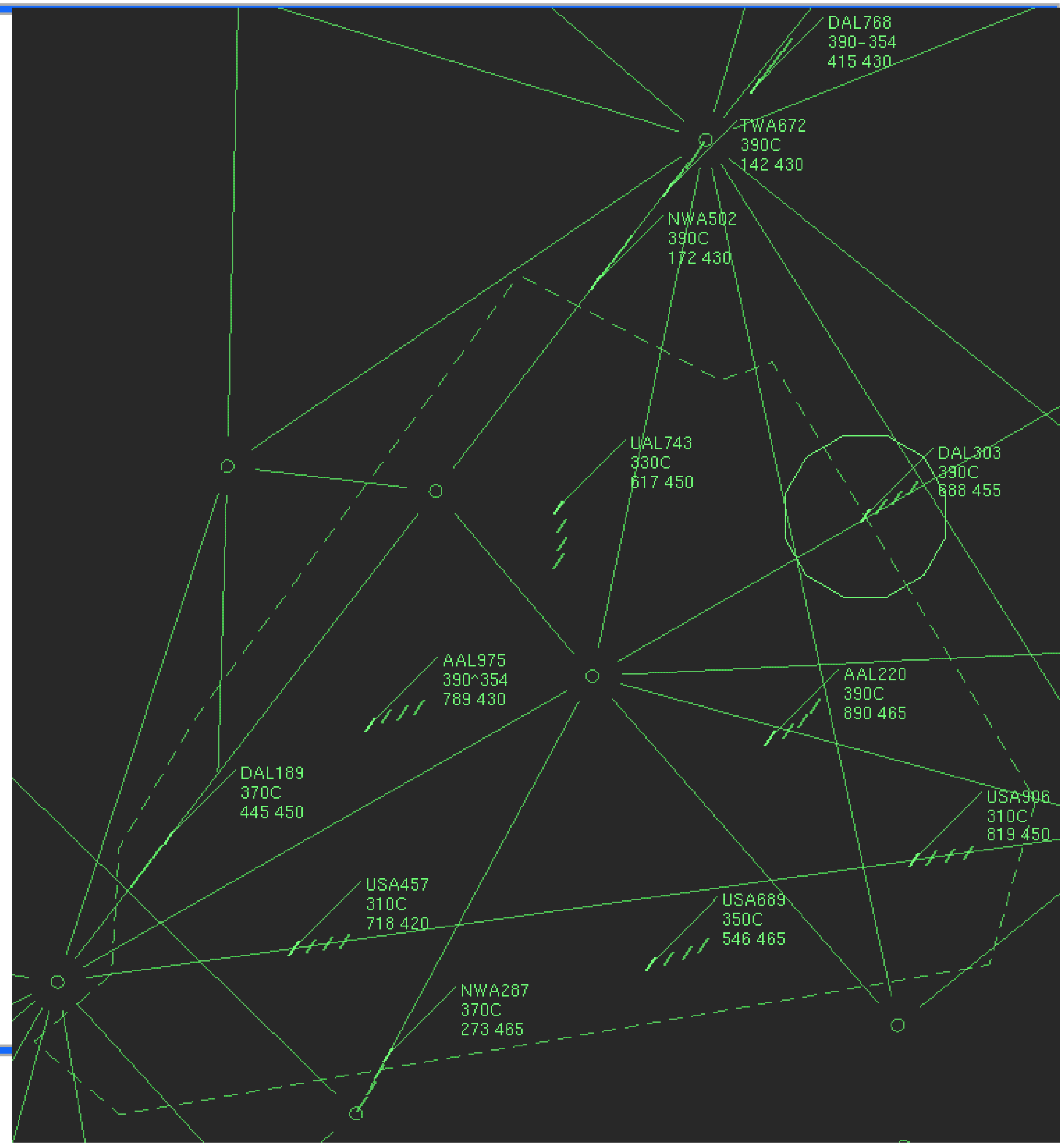
ATC Control Loo
Radar Surveillance Limits



Emerging Approaches: ADS-B and Multi-Lateration

Radar Display Example

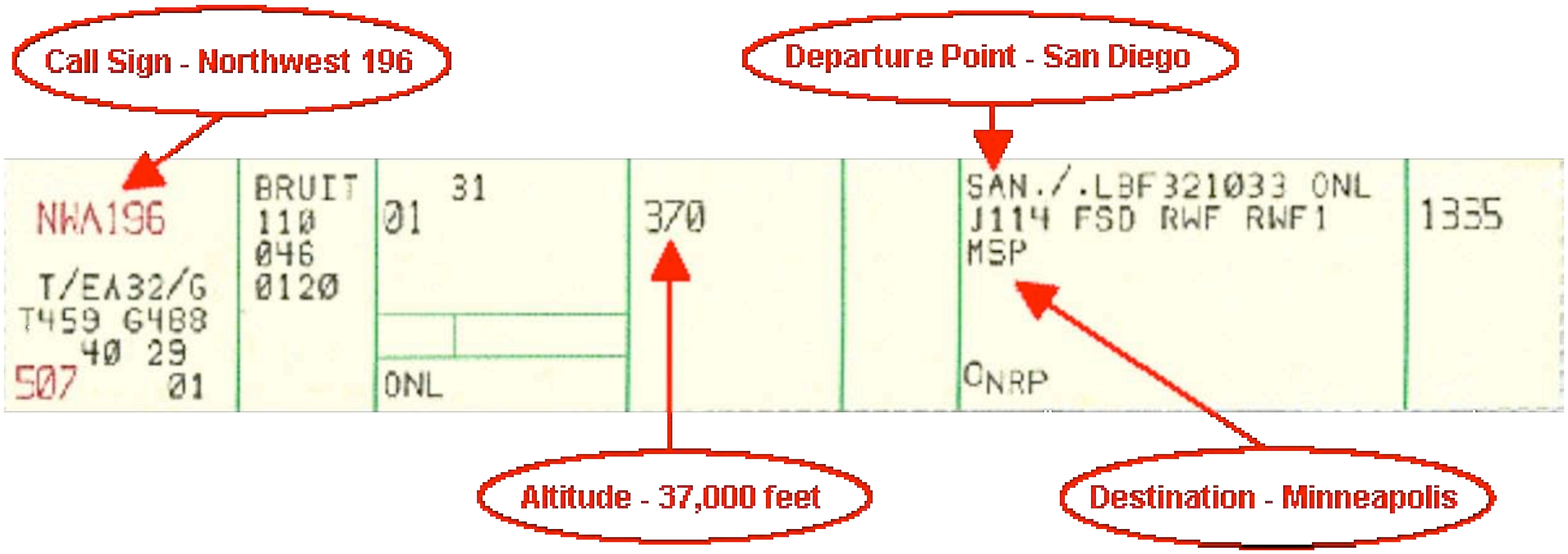




ATM is a Human Centered Process

- **Contract process**
  - Negotiation
  - Execution
  - Monitoring
  - Re-negotiation/amendment
- **Agents**
  - Controllers
    - Strategic
    - Tactical
  - Pilots
  - Airlines
    - Dispatchers
    - ATC coordinators
  - Airports
- **Resources**
  - Airspace
  - Runway
  - Airport surfaces

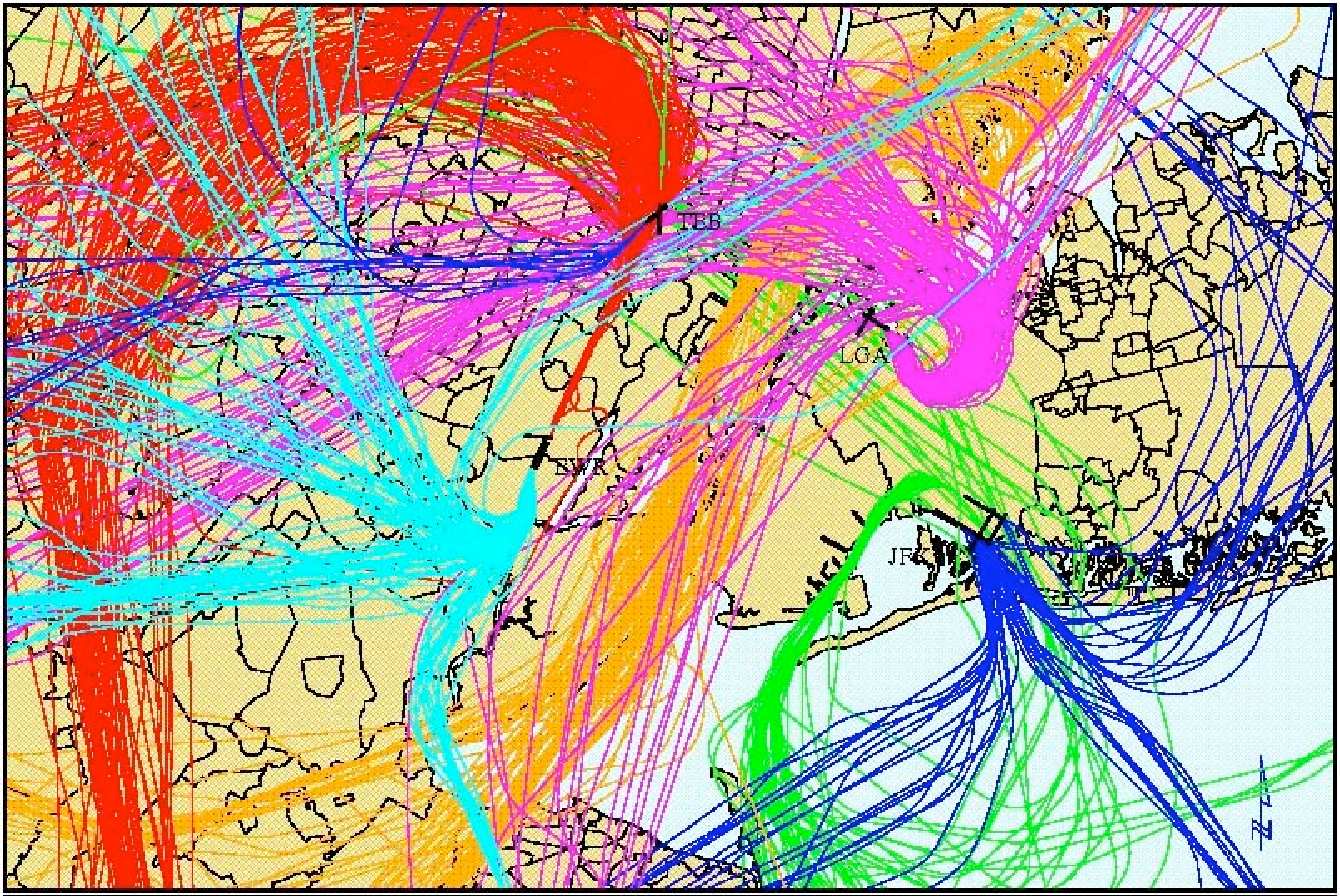
Flight Progress Strip



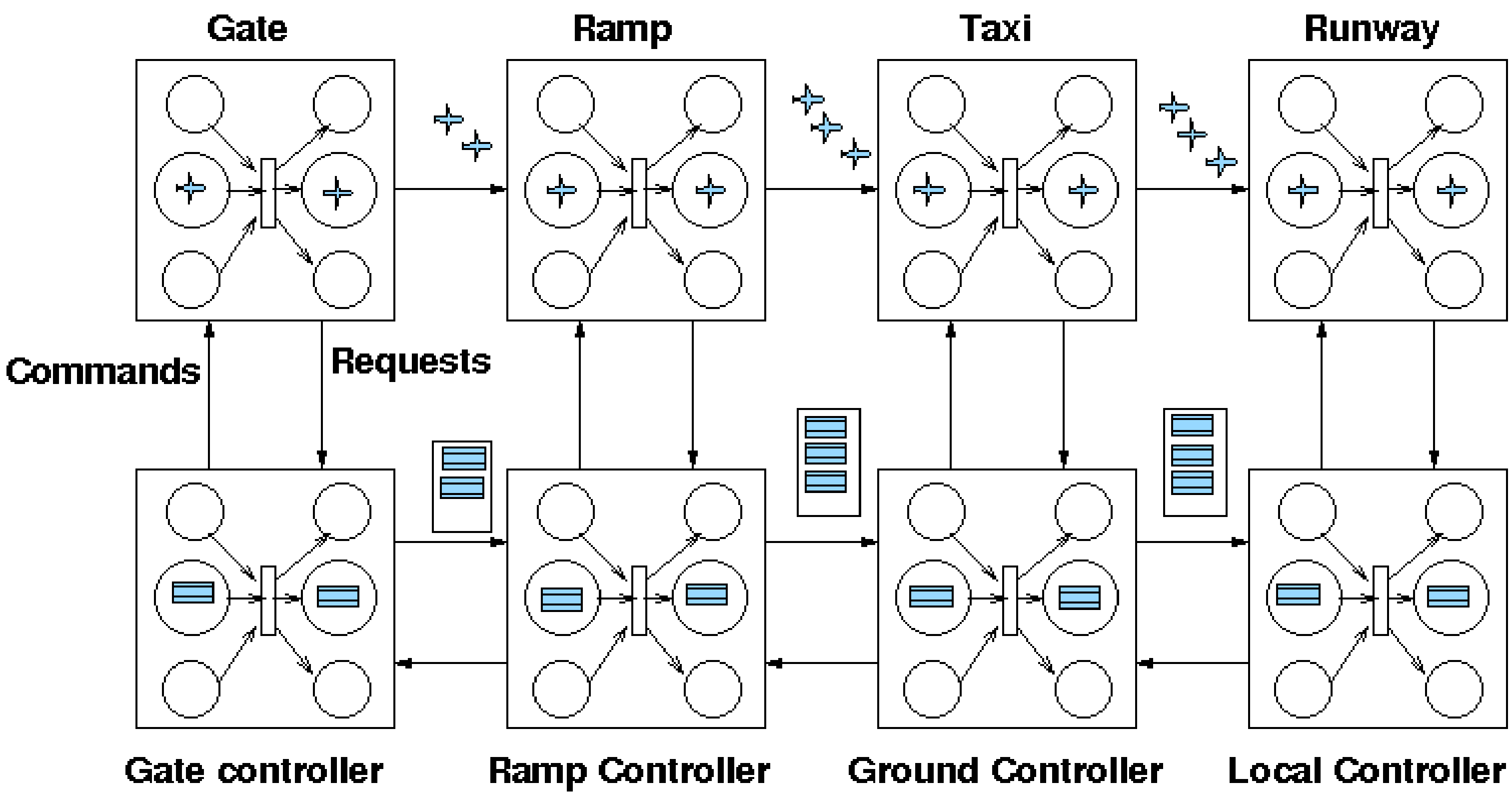
Human Factors and Adaptation

- **ATM is a human centered contract process for the allocation of airspace and airport surface resources.**
- **Current NAS has evolved over 60 years**
- **The system has significant local adaptations resulting in nonhomogeneity**
  - ❏ Airspace design
  - ❏ Local procedures
  - ❏ Letters of agreement
  - ❏ Noise restrictions
  - ❏ Site specific training (FPL = 3-5 years)
- **Major operational changes were event driven, enabled b technical capability**
  - ❏ Positive radar control - Grand Canyon 1956
  - ❏ TCAS - Los Cerritos 1982

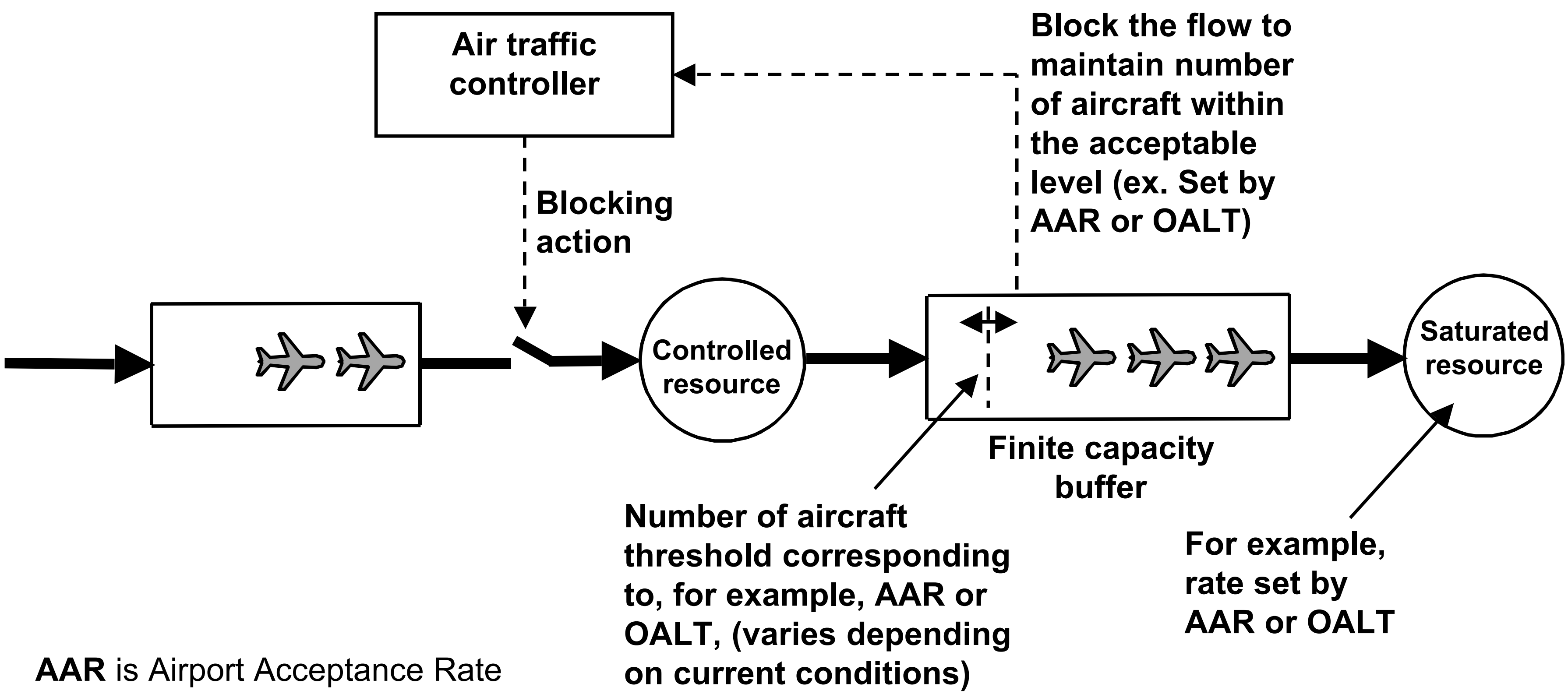
New York Arrival and Departure Tracks



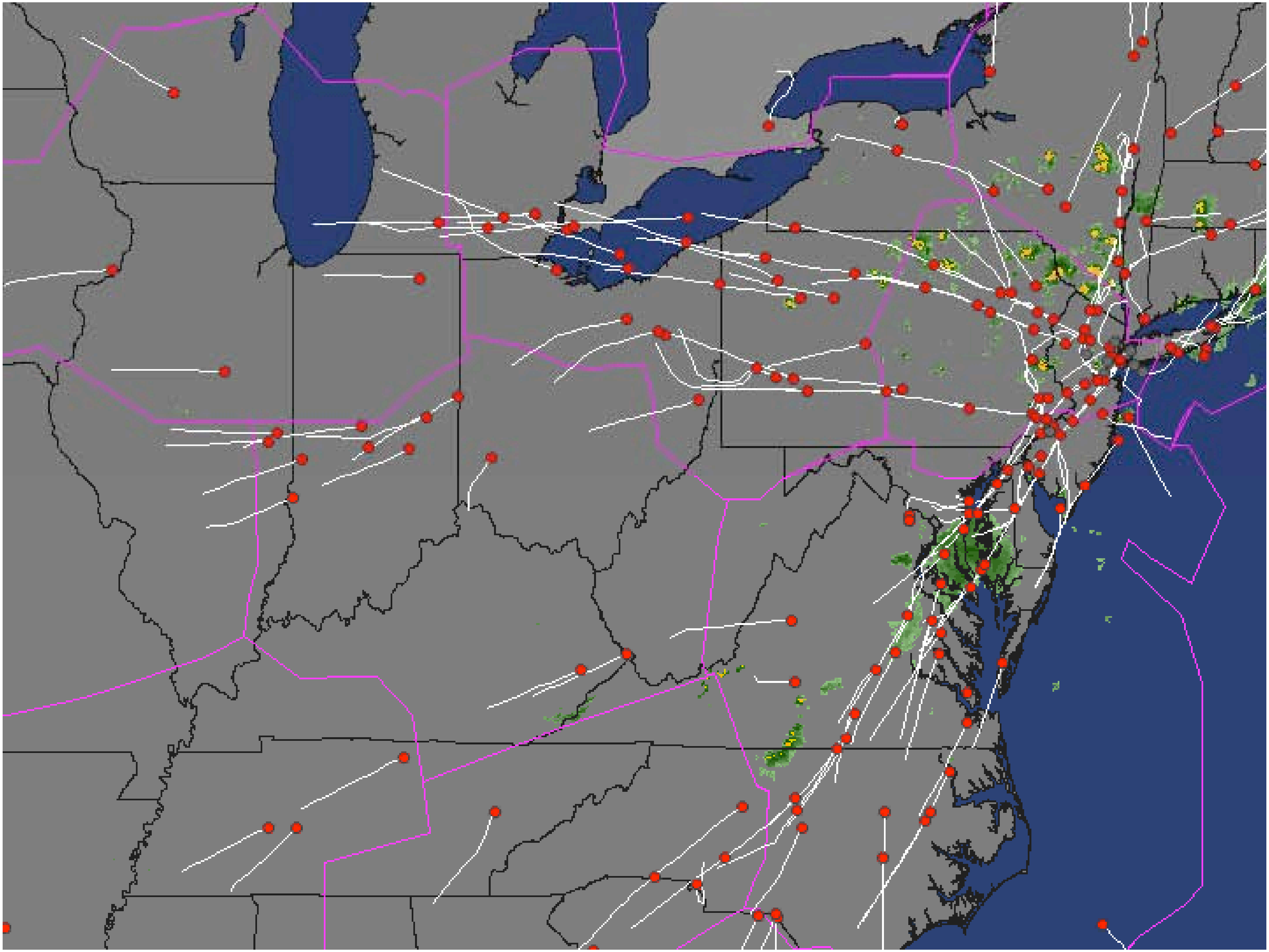
ATC Workload as a System Constraint



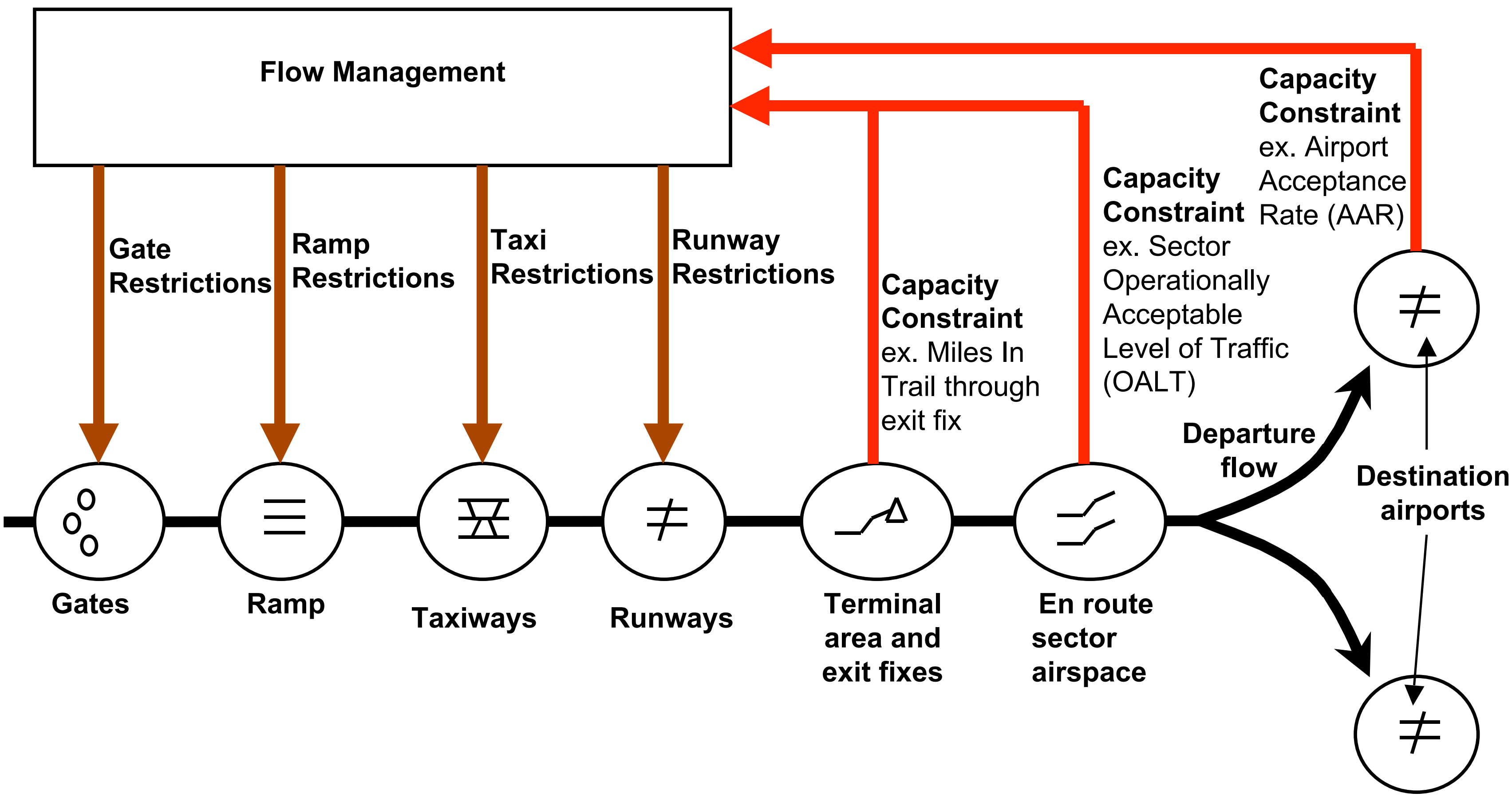
Blocking



AAR is Airport Acceptance Rate
OALT is sector Operationally Acceptable Level of Traffic

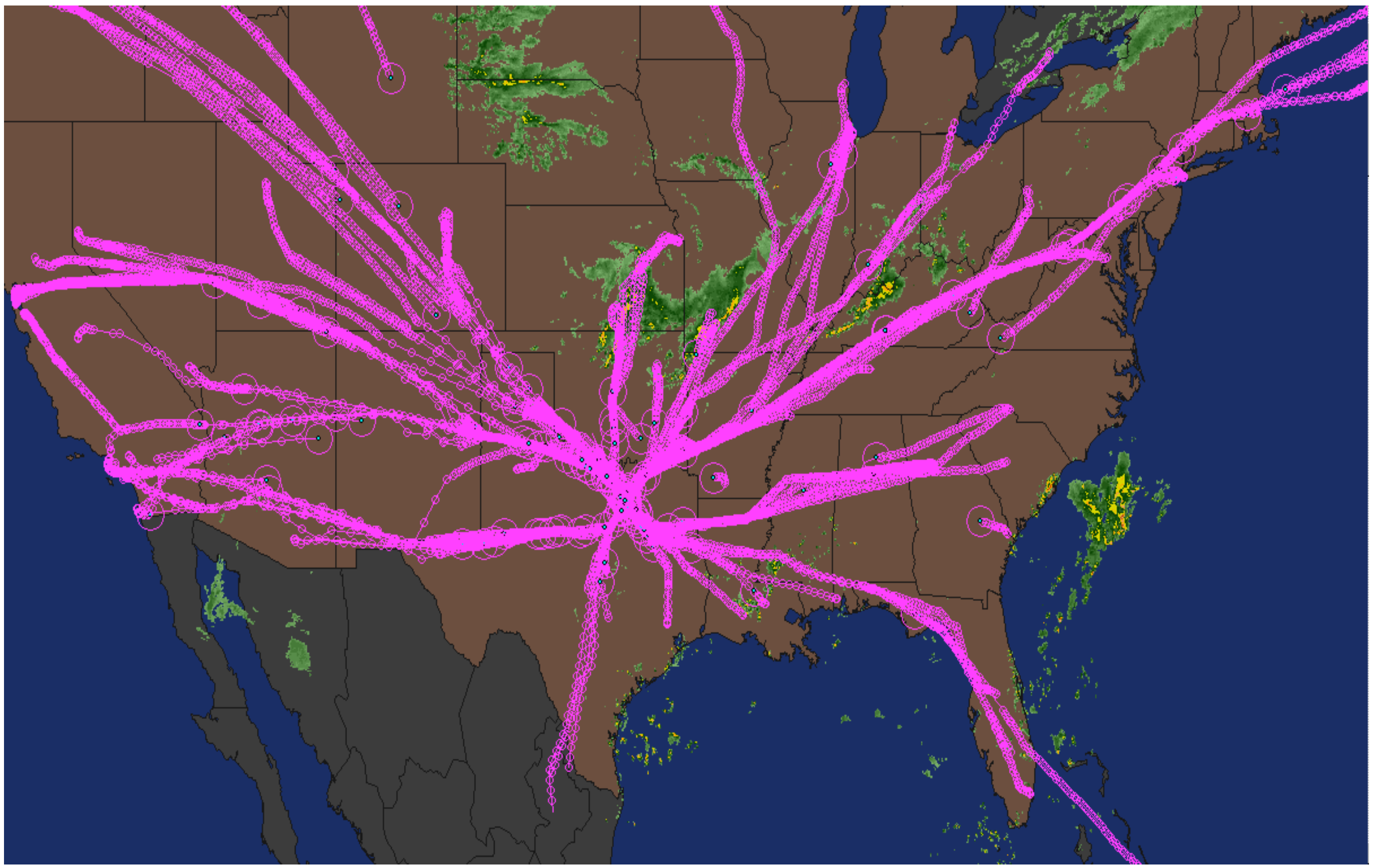


Downstream Flow Constraints



Dallas Fort-Worth

- **Aircraft are condensed into distinct flows feeding 4 arrival fixes.**



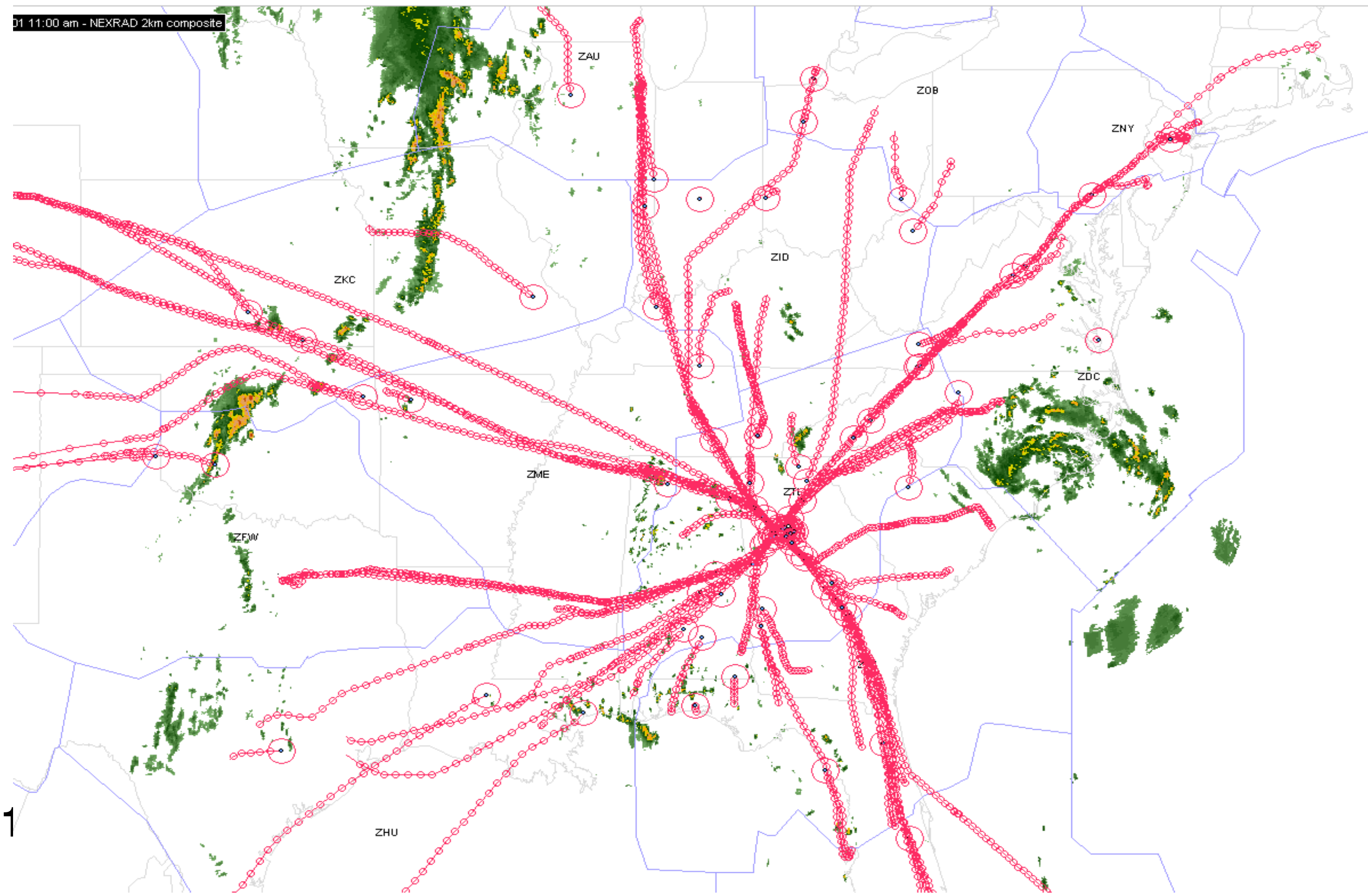
- **June**

Atlanta

- **Condensation and merges have reduced 116 trajectories at airport to 4**

ARTCC Boundaries

Route Flown



- **June 14, 2001** 1

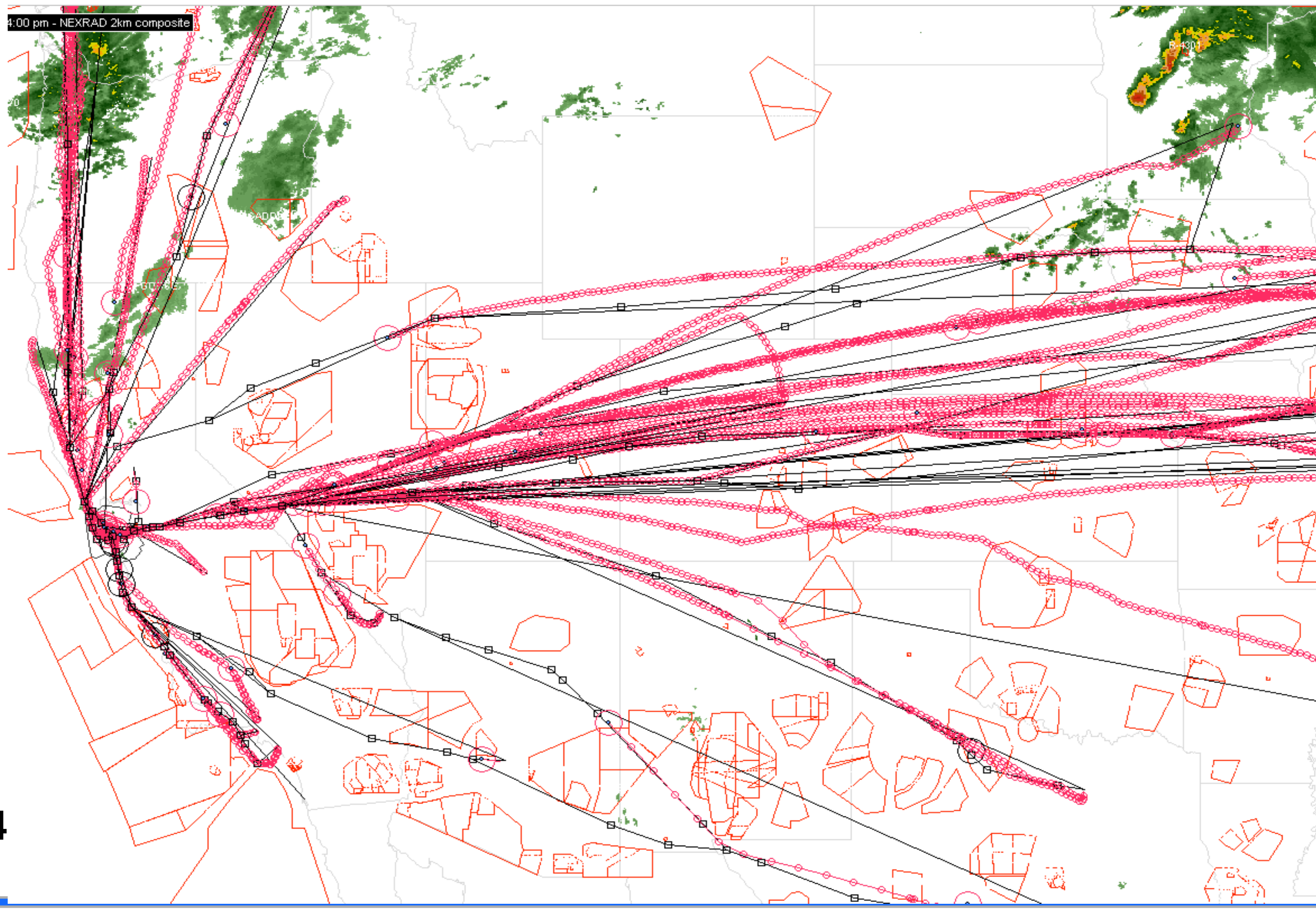
San Francisco

- Special use airspace provides additional constraints

Special Use Airspace

Route Flown

Flight Plan



- June 11, 2001

Projected % Developmental Controllers

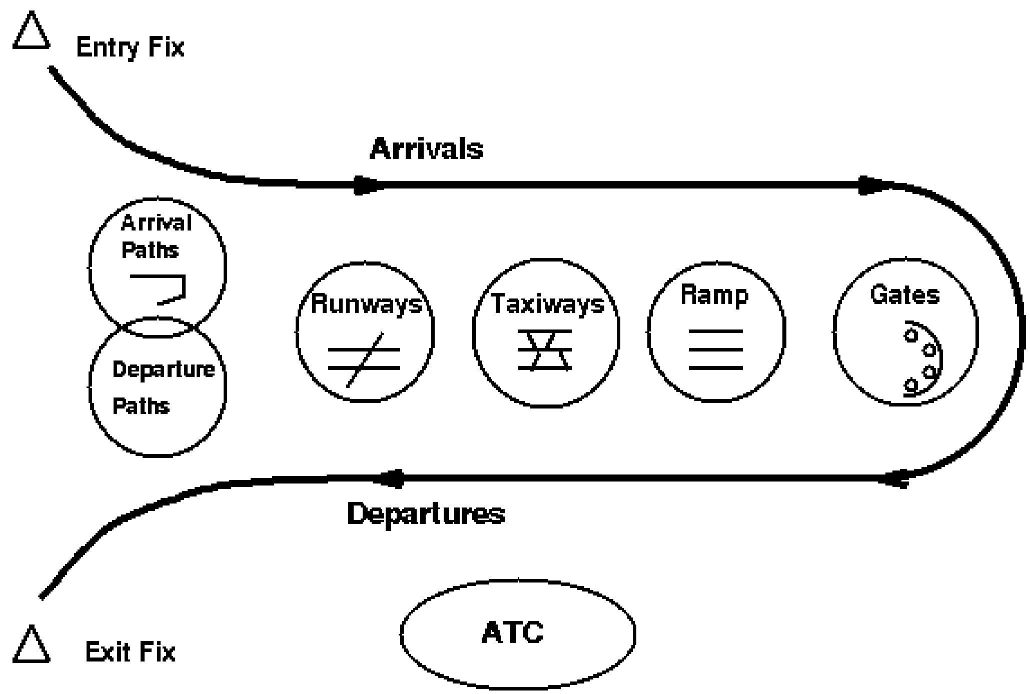
From: ATCS Workforce Plan Briefing

Capacity Limit Factors

- **Demand**
  - ❑ Peak Demand
  - ❑ Hub & Spoke Networks
- **Airspace Capacity**
  - ❑ Airspace Design
  - ❑ Controller Workload
  - ❑ Balkanization
- **Airport Capacity**
  - ❑ Runways
  - ❑ Gates
  - ❑ Landside Limits (including Security)
  - ❑ Weather
- **Environmental Limits**
  - ❑ Noise (relates to Airport)
  - ❑ Emissions (local, Ozone, NOX, CO2)

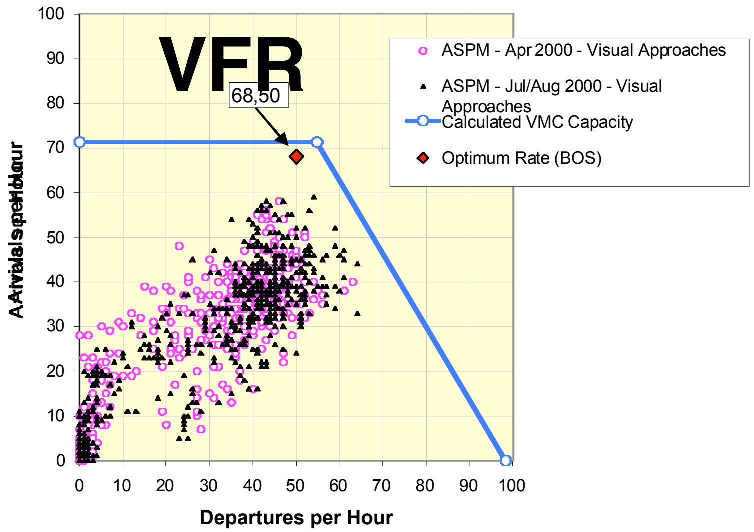
Airport Syste
Capacity Limit Factors

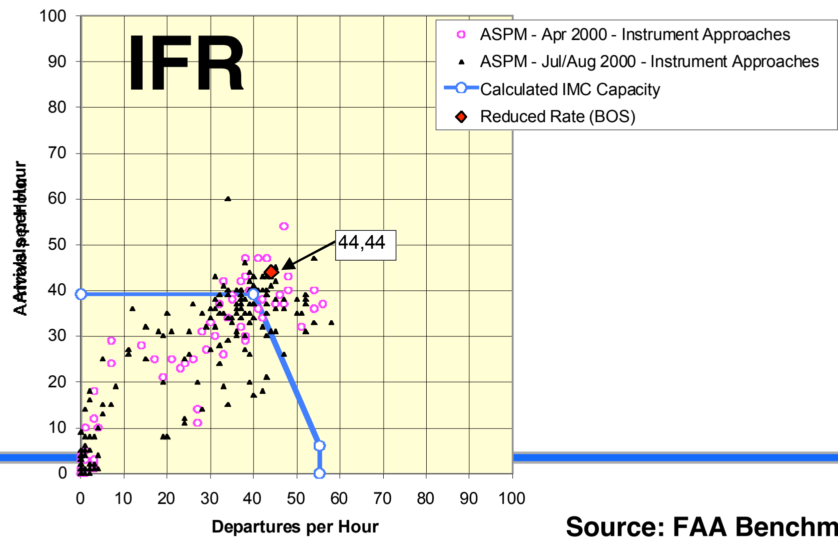
- **Runways**
- **Weather**
  - ❑ Capacity Variability
  - ❑ Convective Weather
- **Landside Limits**
  - ❑ Gates
  - ❑ Terminals & Security
  - ❑ Road Access
- **Downstream Constraints**
- **Controller Workload**
- **Environmental**
  - ❑ Community Noise
  - ❑ Emissions
- **Safety**



Airport Capacity Envelope

Boston (BOS)





Source: FAA Benchmark Data

Separation Requirements for Arrival (Same Runway)

- **Wake Turbulence Requirement**
  - ❑Radar Separation requirements

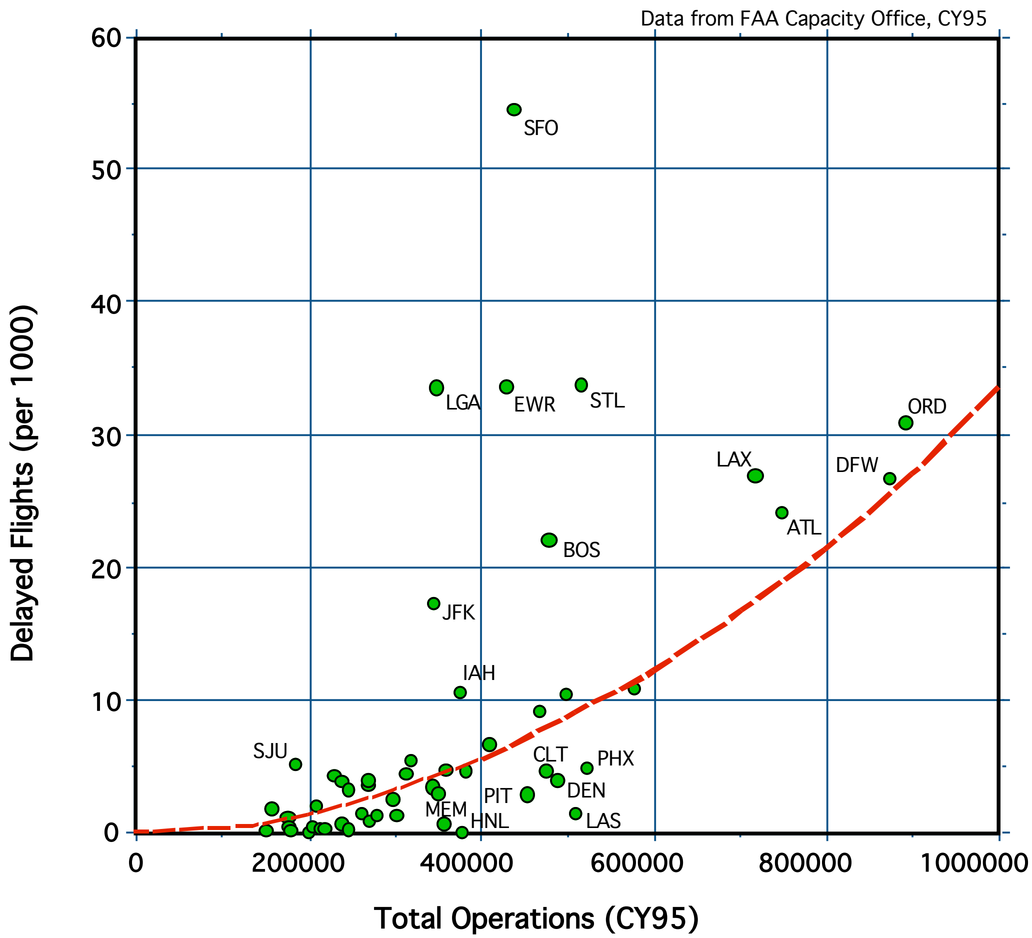
Trailing Aircraft (columns); **Leading Aircraft** (rows)

	Heavy	Large	Small
Heavy	4	5	5
B757	4	4	5
Large	3(2.5)	3(2.5)	4
Small	3(2.5)	3(2.5)	3(2.5)

  - ❑Visual Separation requirements
    - ◆ Pilots Discretion
- **Preceding arrival must be clear of runway at touchdown**
  - ❑Runway Occupancy time

Variable Capacity Effects

1995 Delays vs Operations



VISUALIZATION OF FLIGHT DELAYS IN THE NAS ON A BAD WEATHER DAY

ANIMATION CREATED USING

FUTURE ATM CONCEPTS
EVALUATION TOOL
(FACET)

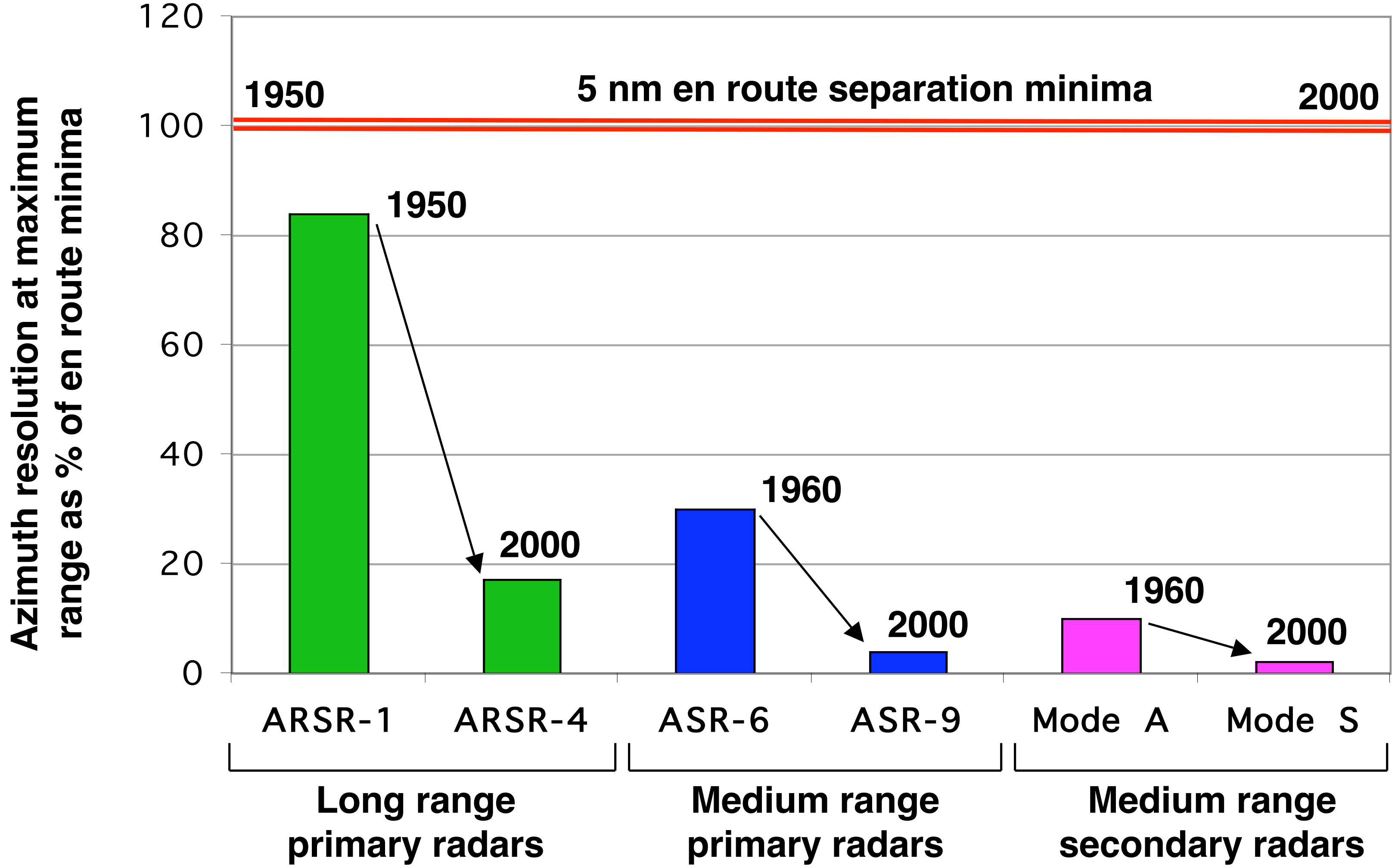
FOR

AVIATION SYSTEMS DIVISION (AF)

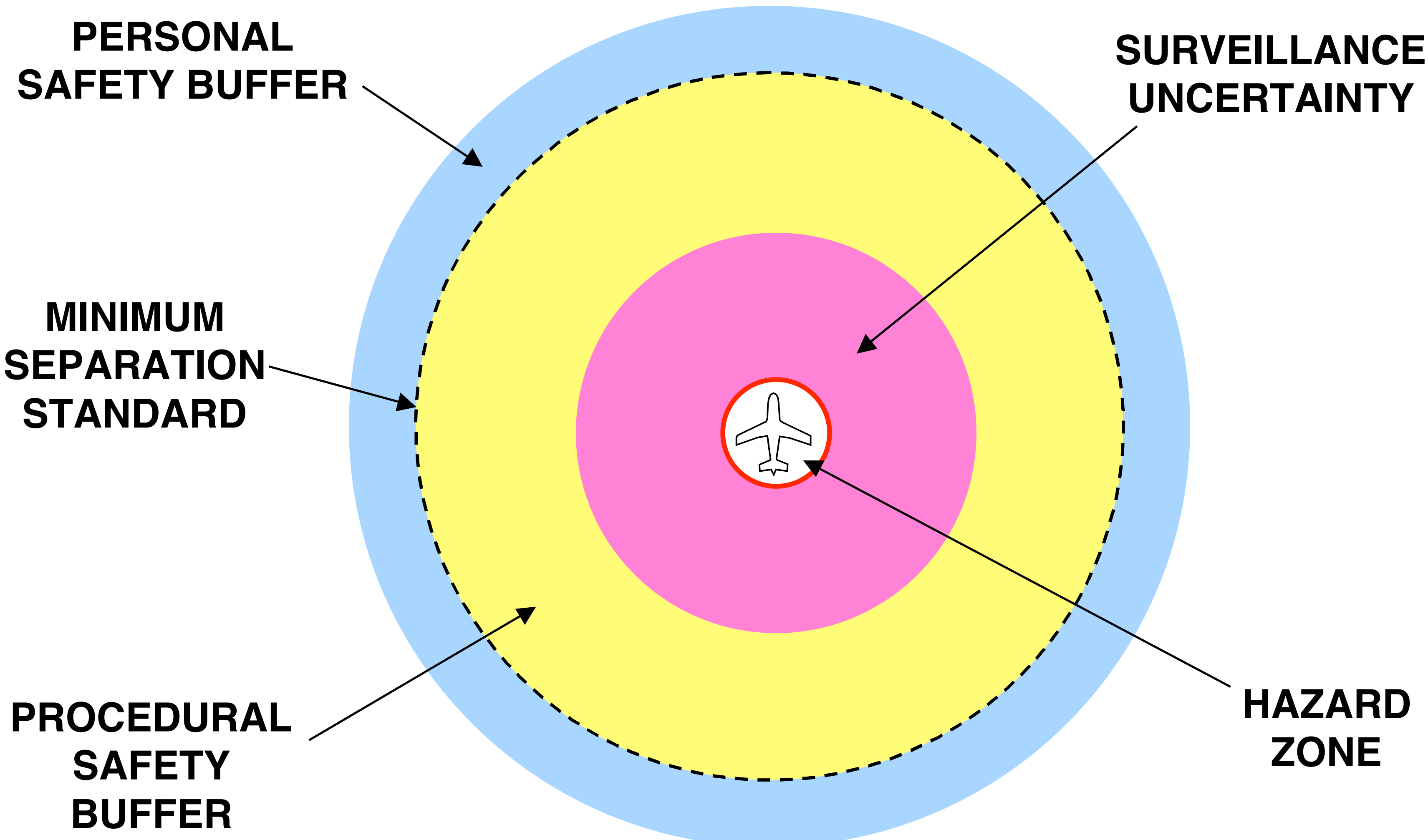
Safety vs Capacity

- **The current airborne system is extremely safe but conservative**
- **Increased capacity with current infrastructure implies Reduced Operational Separation**
  - ❑ Airborne Separation Standards
  - ❑ Runway Occupancy Times
  - ❑ Wake Vortex
  - ❑ Controller Personal Buffers
  - ❑ ...
- **How do you dependably predict the safety impact of changes in a complex interdependent system?**
  - ❑ Statistics of small numbers
  - ❑ Differential analysis limited to small or isolated changes
  - ❑ Models??
- **Safety Veto Effect**
- **Runway Incursions are an area of concern**

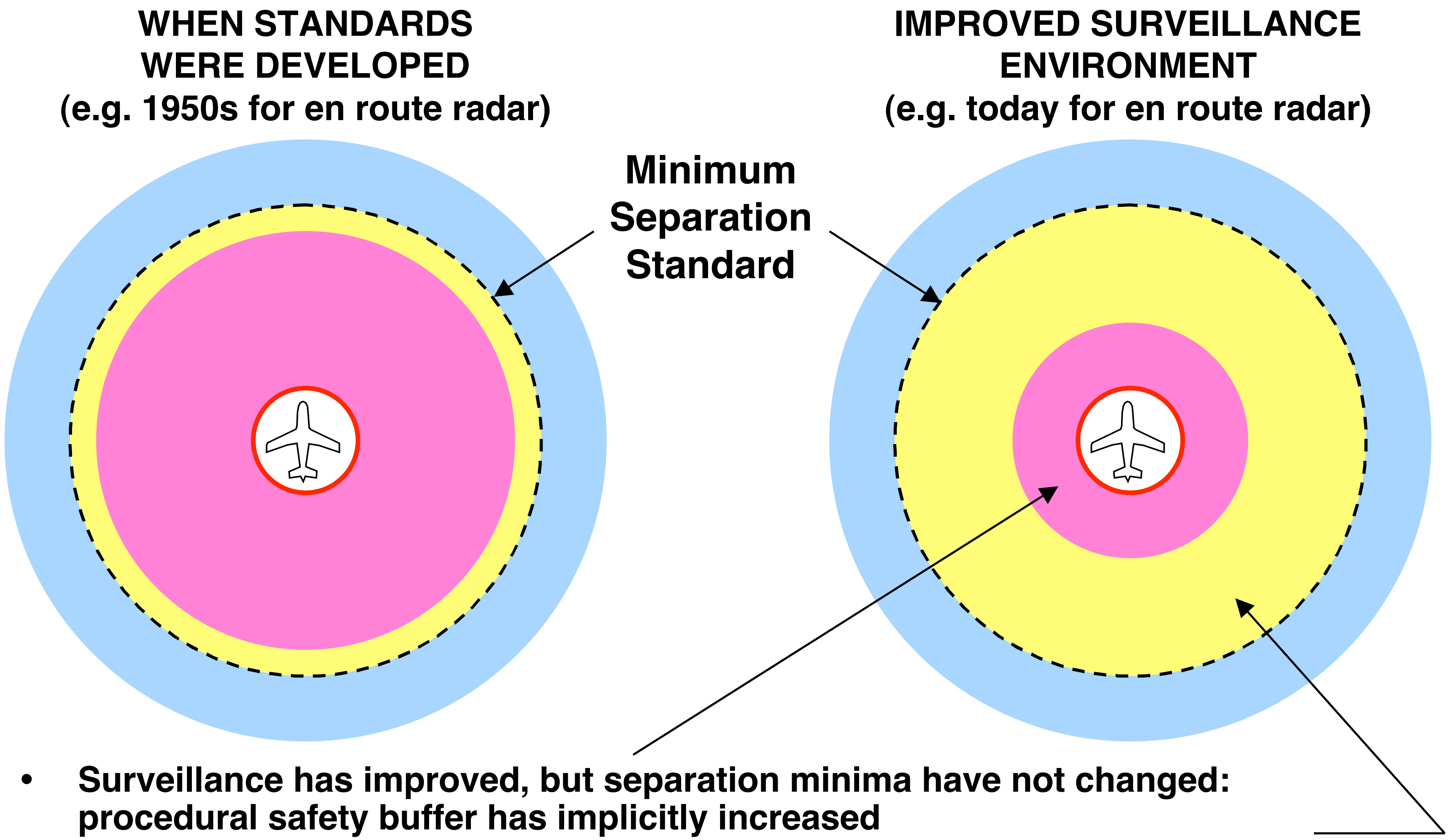
EN ROUTE MINIMA HAVE NOT CHANGED DESPITE 5 x IMRPOVEMENT IN RADAR PERFORMANCE



SEPARATION ASSURANCE CONSIDERATIONS



IMPROVED SURVEILLANCE HAS NOT LED TO REDUCED EN ROUTE MINIMA

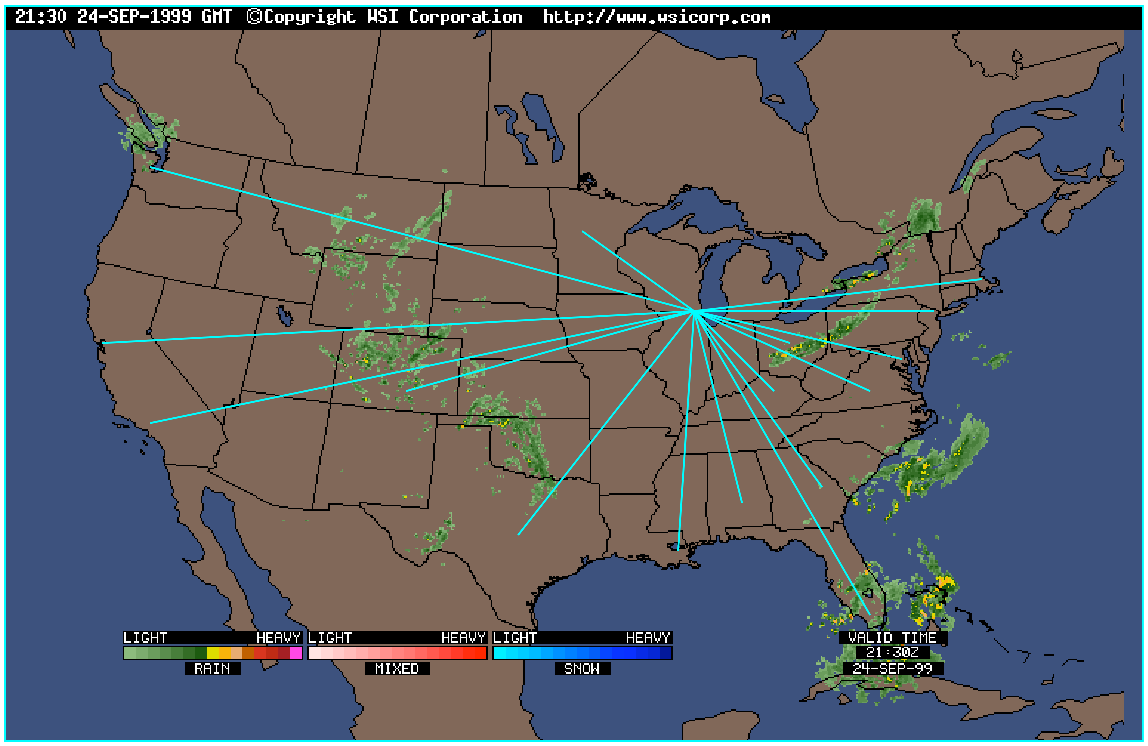


- Surveillance has improved, but separation minima have not changed: procedural safety buffer has implicitly increased

Schedule Factors

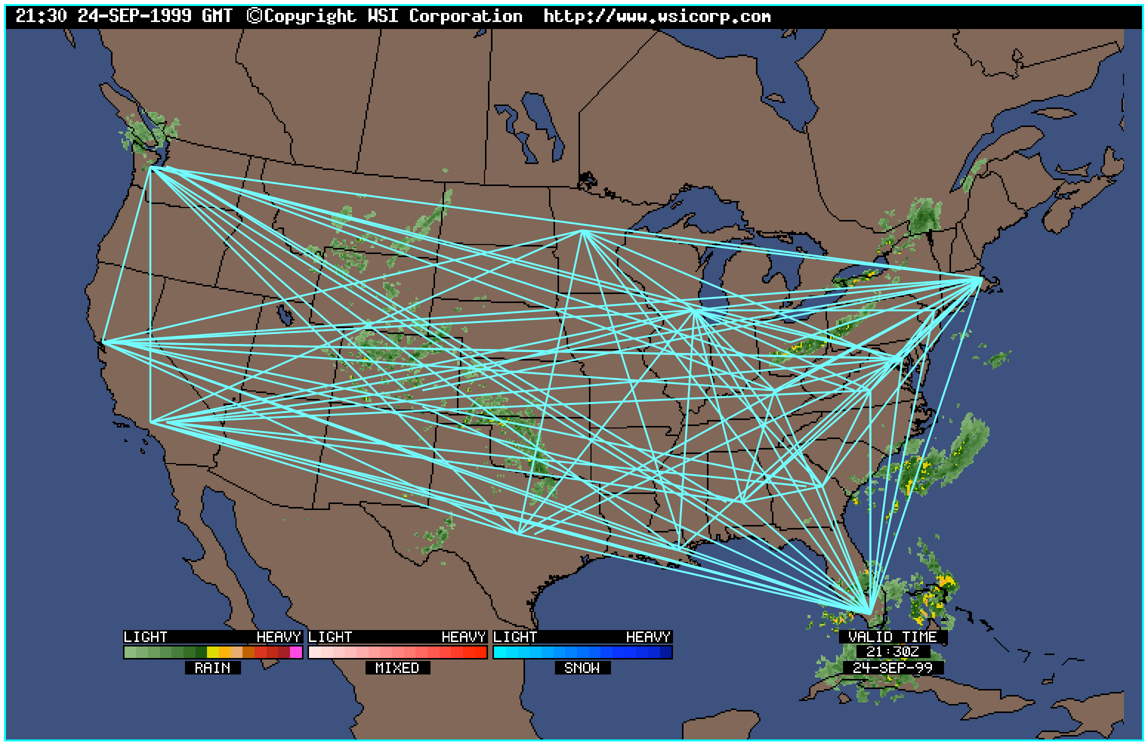
- **Peak Demand/Capacity issue driven (in part) by airline Hub and Spoke scheduling behavior**
  - ❑ Peak demand often exceeds airport IFR capacity (VFR/IFR Limits)
  - ❑ Depend on bank spreading and lulls to recover
  - ❑ Hub and Spoke amplifies delay
- **Hub and spoke is an efficient network**
  - ❑ Supports weak demand markets
- **Schedules driven by competitive/market factors**
  - ❑ Operations respond to marketing
  - ❑ Trend to more frequent services, smaller aircraft
  - ❑ Ratchet behavior
  - ❑ Impact of regional jets
- **Ultimately, airlines will schedule rationally**
  - ❑ To delay tolerance of the market (delay homeostasis)
- **Limited federal or local mechanisms to regulate schedule**

Hub and Spoke Network



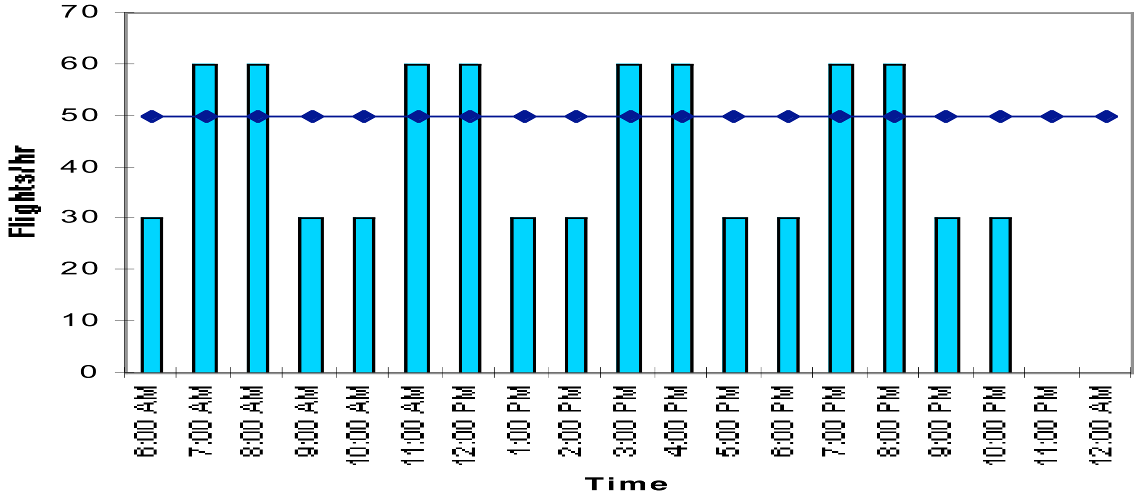
Completely Connected Network = 2(N-1) Flights
(eg., 50 Airports, 98 Flights)

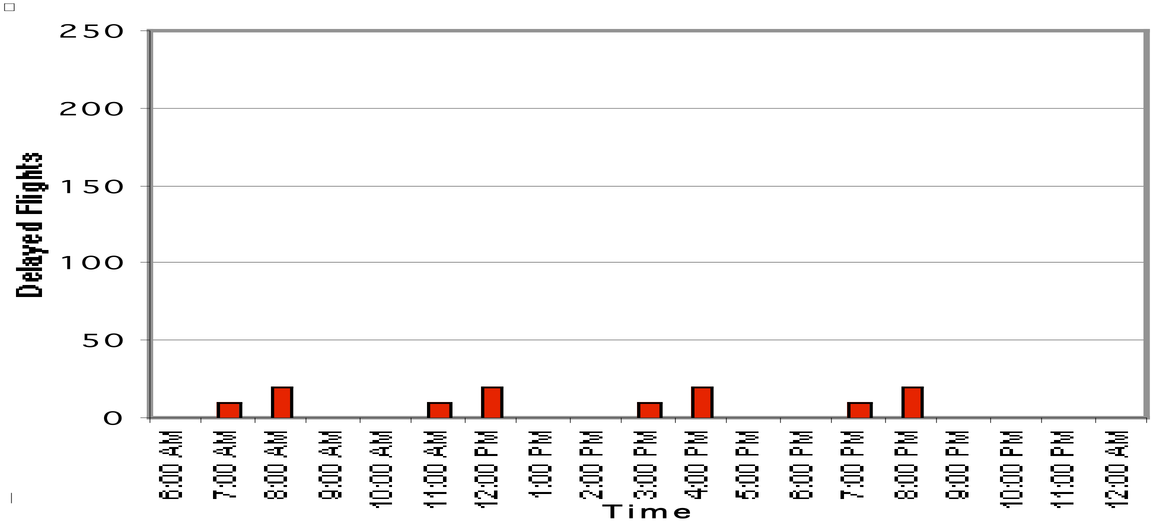
Fully Connected Network



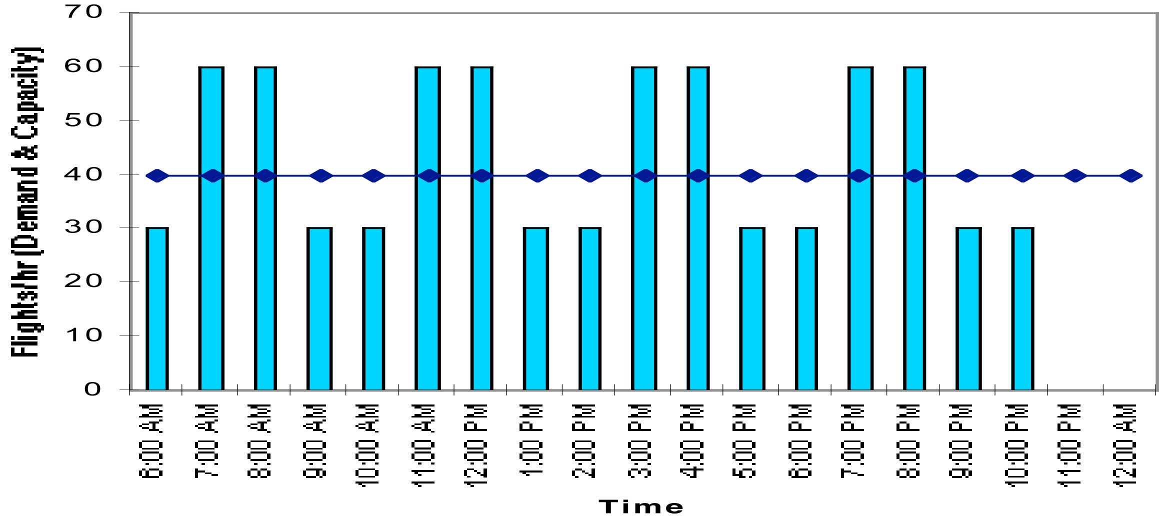
Completely Connected Network = N(N-1)
(eg., 50 Airports, 2450 Flights)

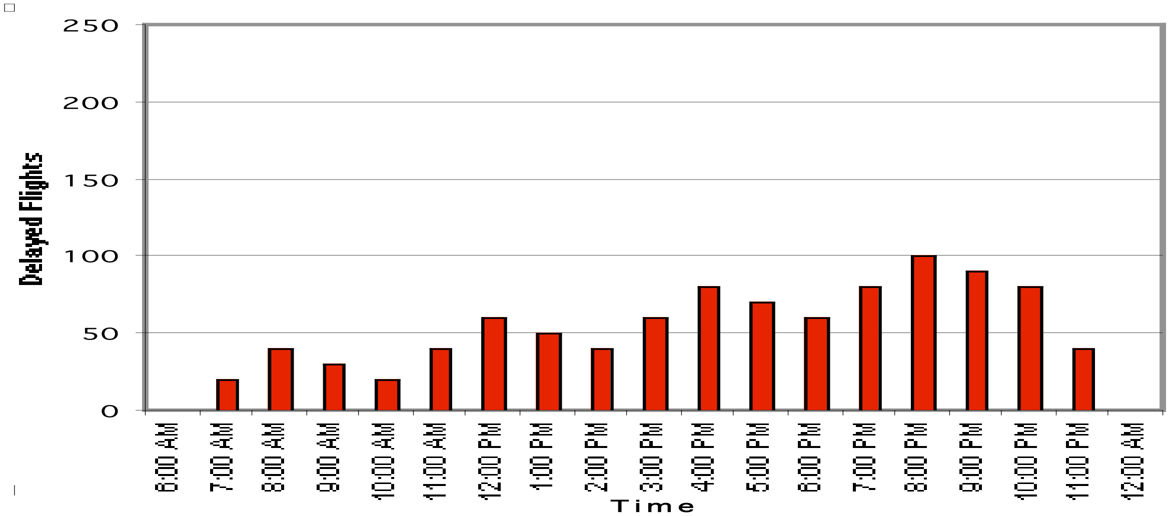
Capacity Exampl
(50 Flights/hr)



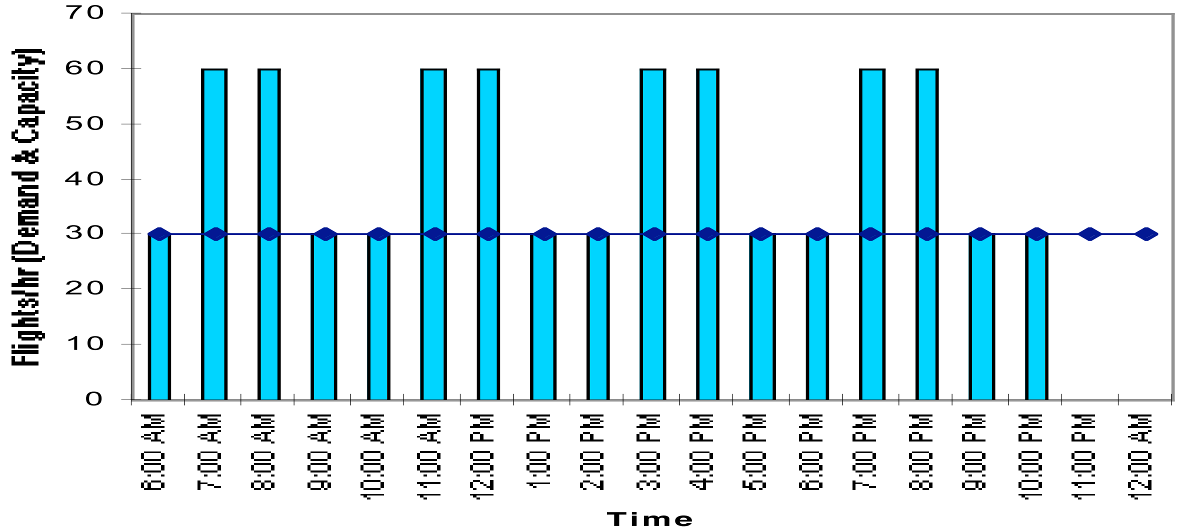


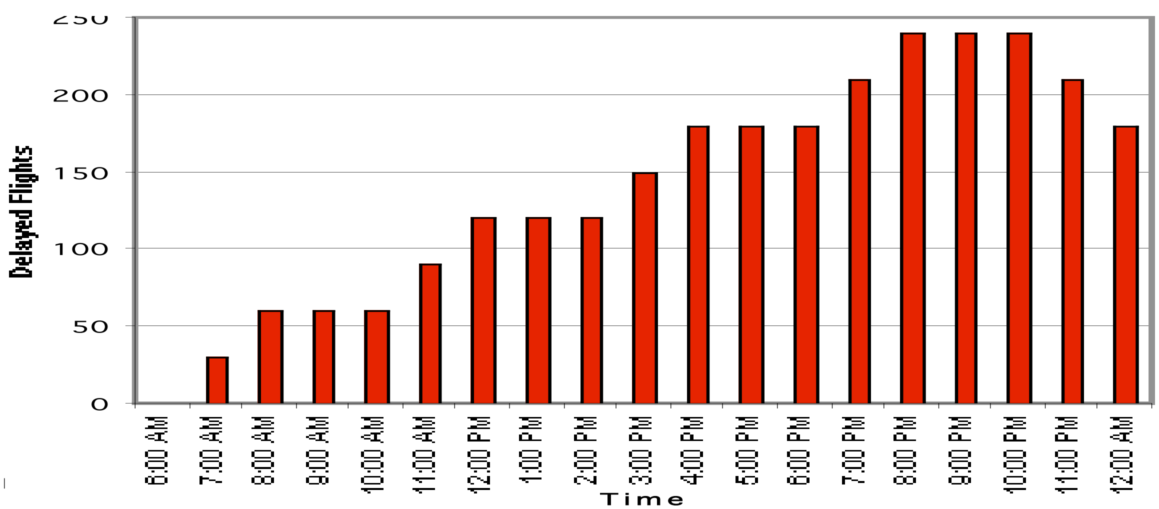
Capacity Exampl (40 Flights/hr)



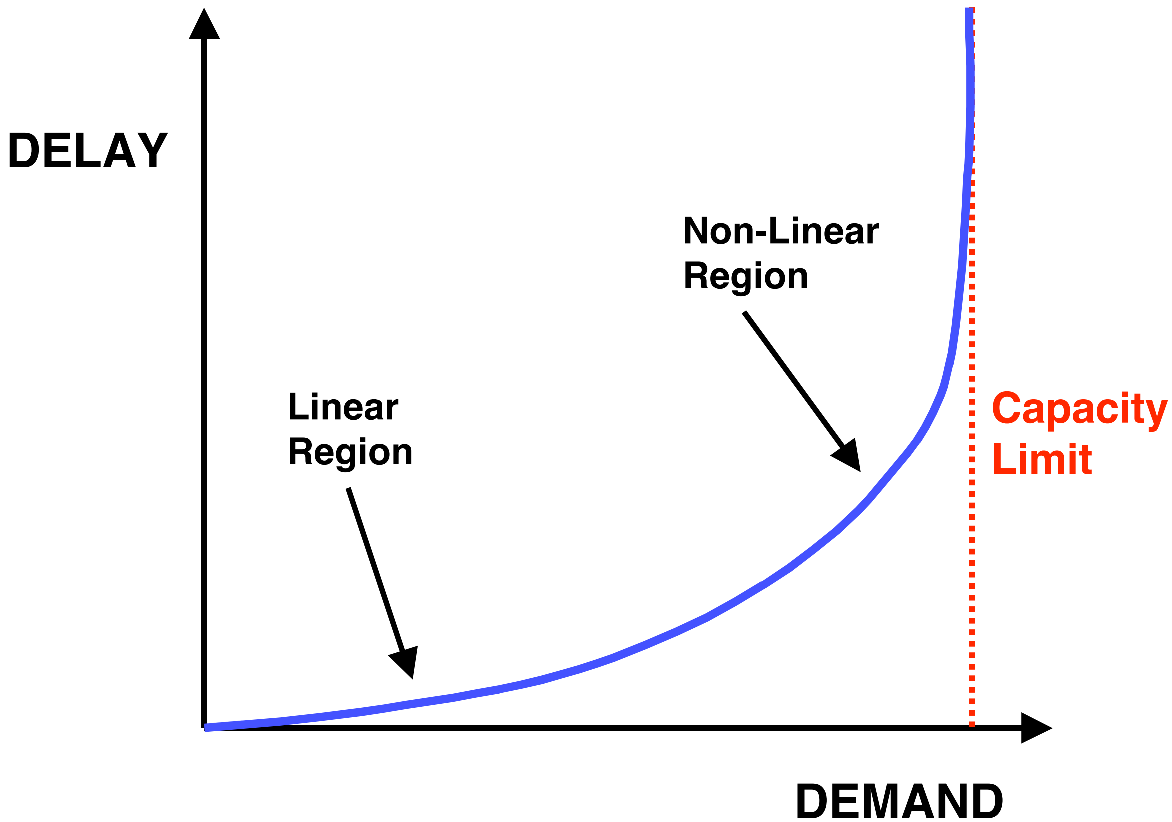


Capacity Exampl (30 Flights/hr)

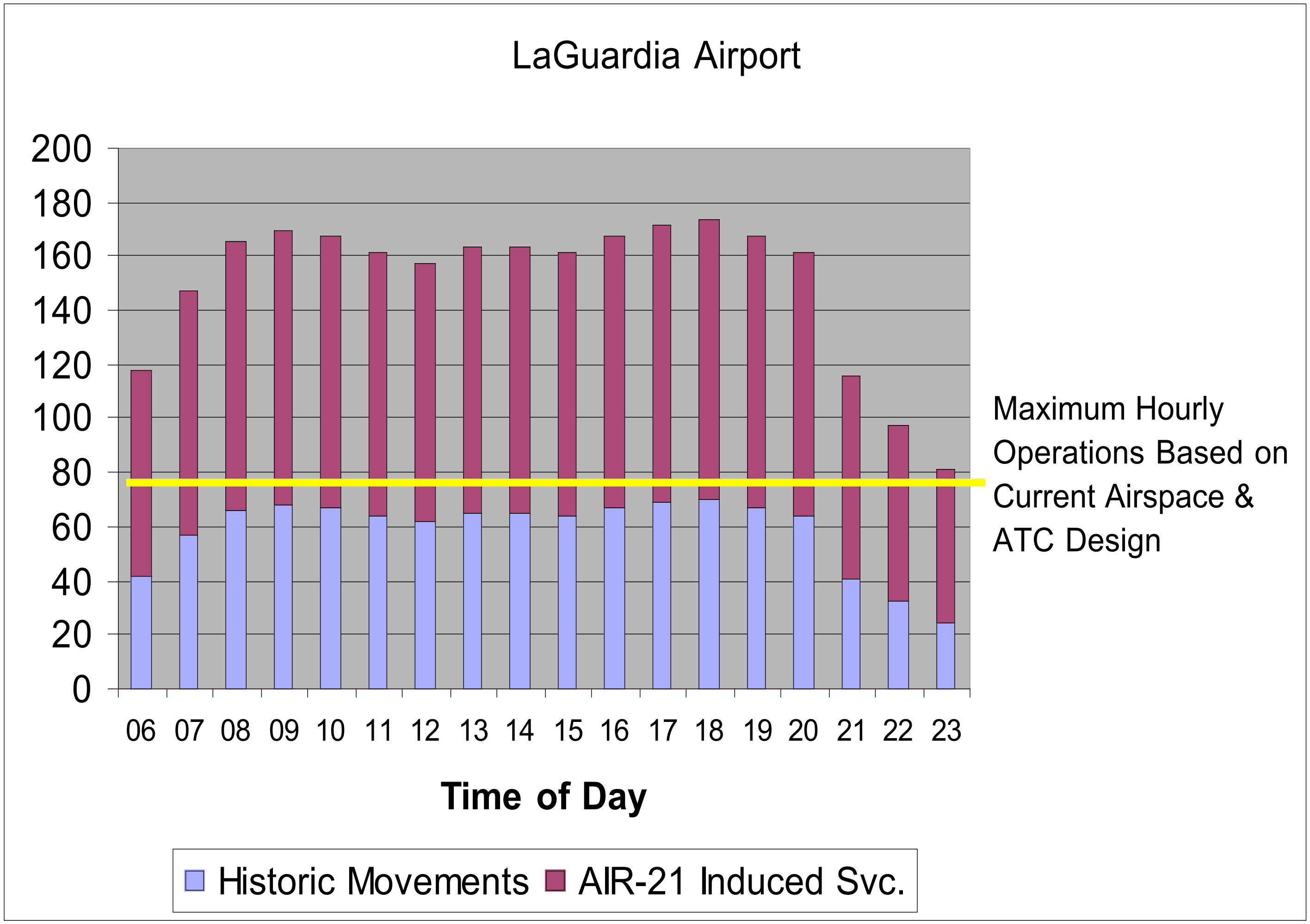




Classic Delay vs Demand Curve



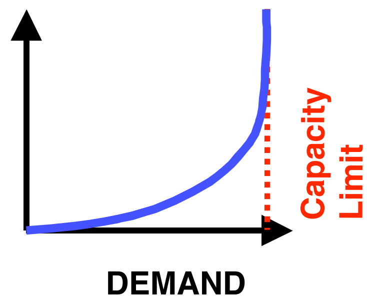
LGA Air 21 Impact

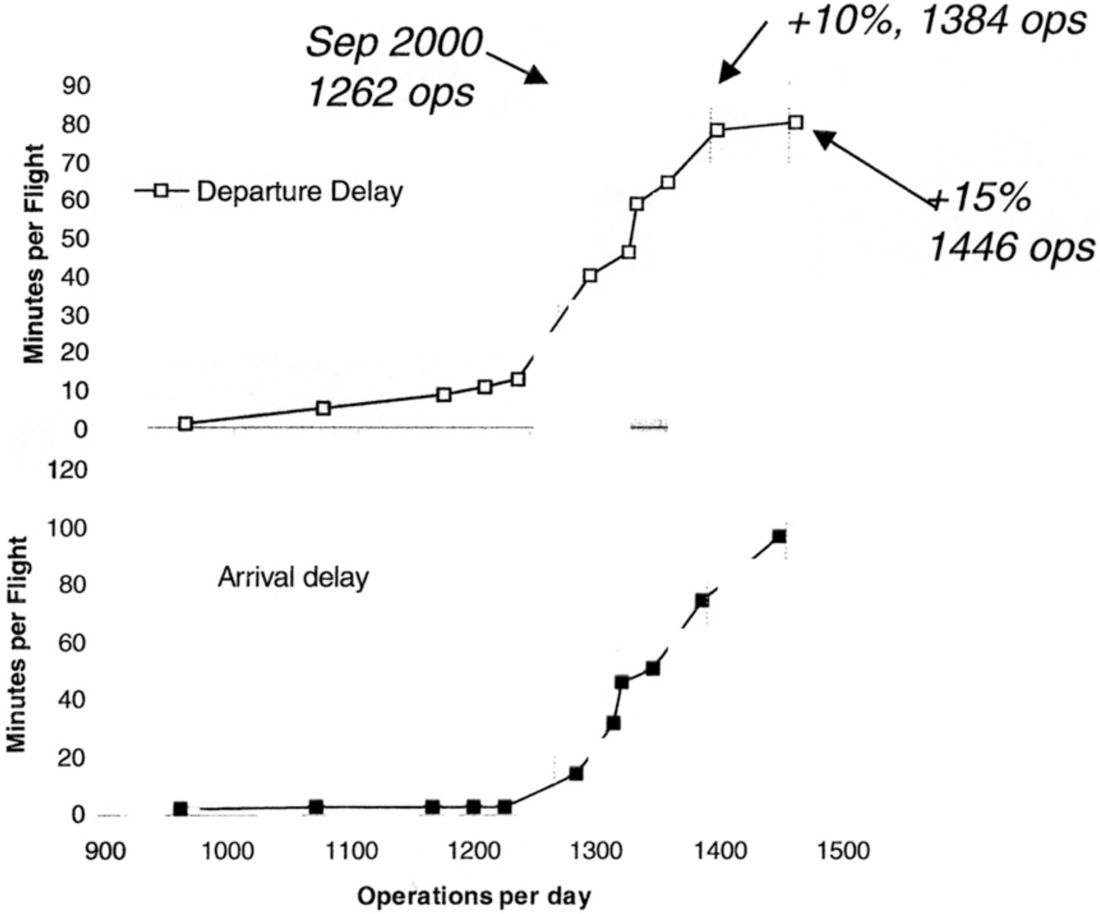


Source: William DeCota, Port Authority of New York

LGA

Average Arrival and Departure Delay





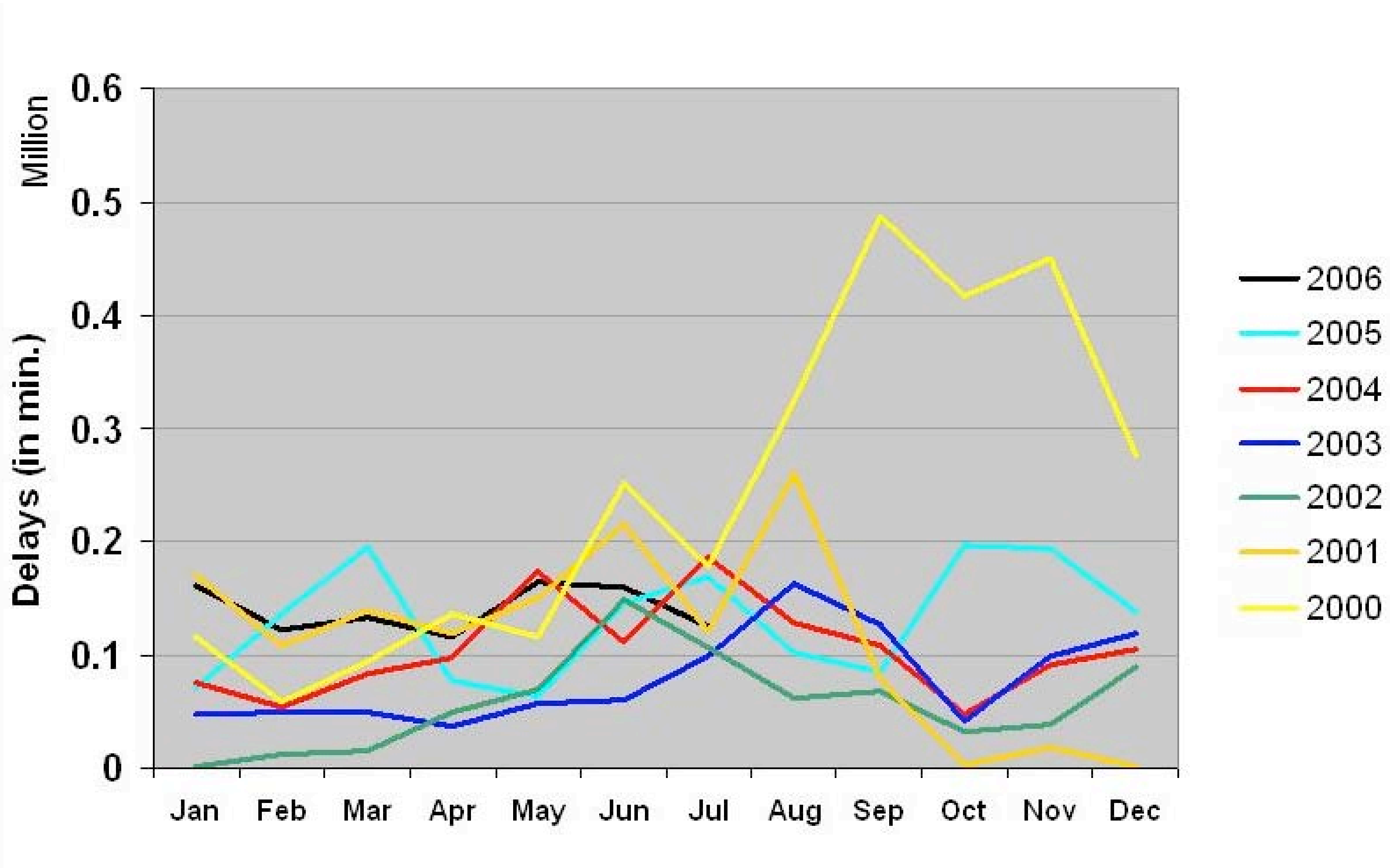
Departure Delay: (Actual - scheduled pushback time)+ (taxi-out time minus 10 minutes)

Arrival Delay: time spent waiting for proper separation from previous aircraft.

Source: William DeCota, Port Authority of New York

Flight Delays at LGA

from 2000 to 2006



Source: FAA OPSNET data

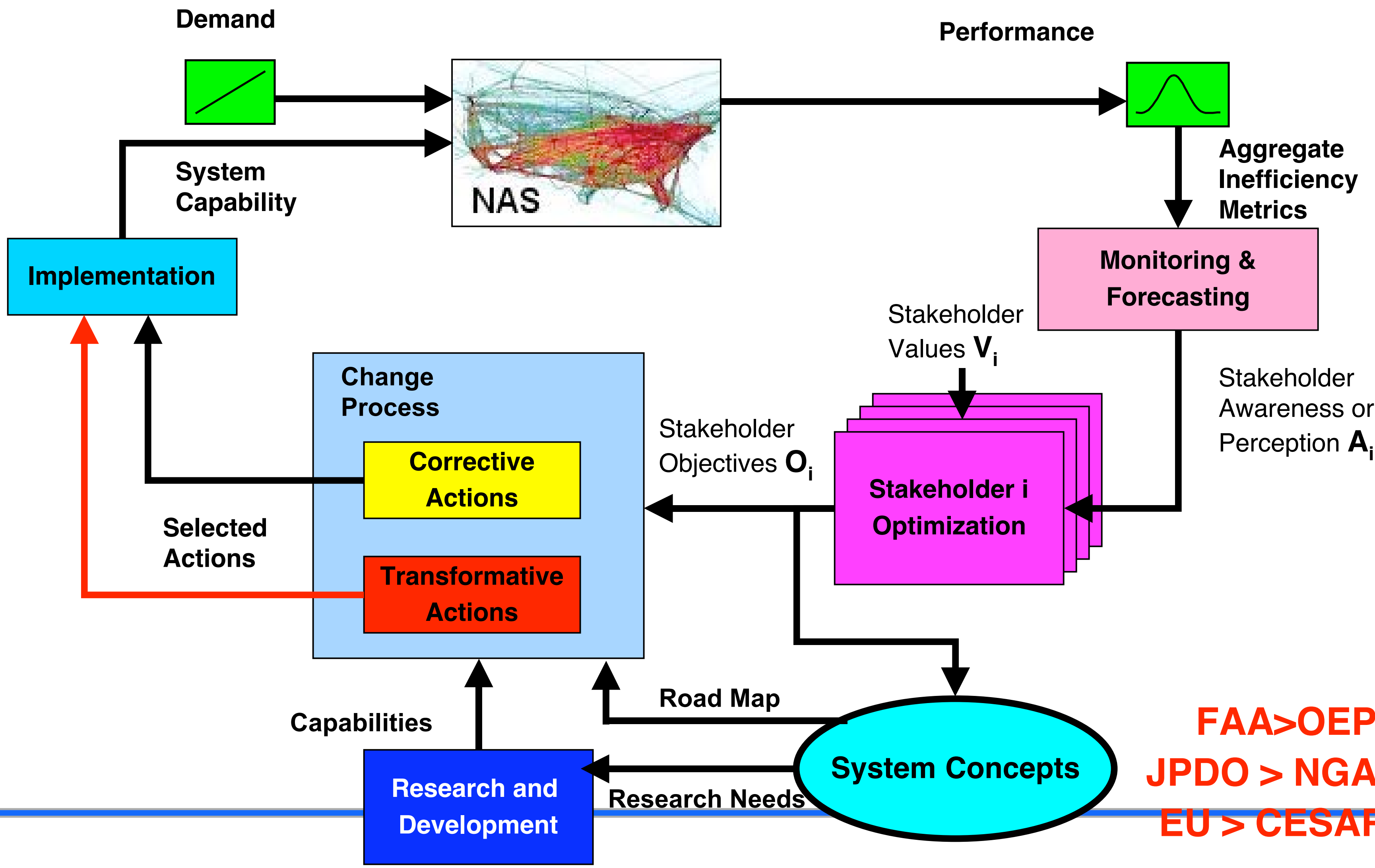
Suggested Political Solutions to Capacity Shortfall

- Full or Partial Privatization (eg AIR-21)
  - ❑ May improve modernization,costs and strategic management
  - ❑ Limited impact on capacity
- Re-regulation
  - ❑ Increased Costs to Consumer
- Demand Management (eg Peak Demand Pricing)
  - ❑ Reduced service to weak markets
  - ❑ Need to insure that revenues go to improved capacity
- Run System Tighter
  - ❑ Requires improved CNS
  - ❑ Safety vs Capacity Trade
- Build more capacity
  - ❑ Local community resistance
- Multi-modal transportation networks

Conclusion

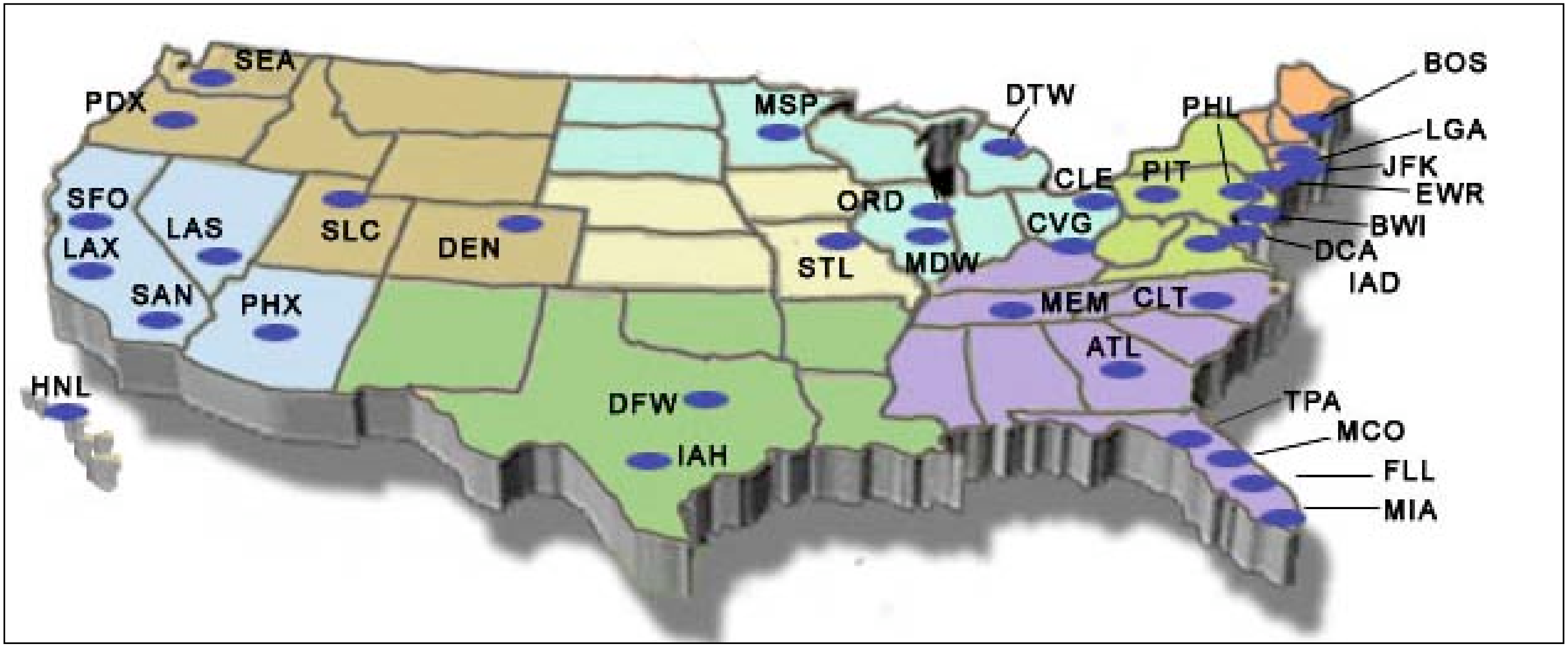
- **Technology in Pipeline will have limited impact on peak Capacity at Currently Stressed Airports**
  - ❑ 20% to 40% Optimistically
- **System will become (is) Capacity Restricted**
- **Airlines will Schedule in Response to Market Demand**
  - ❑ Delay Homeostasis (at Hubs)
  - ❑ Increased Traffic at Secondary Airports
  - ❑ High Frequency Service
  - ❑ Changing Value for Reliability
- **Overall system response is not clear**
- **Need**
  - ❑ Protection of Airport and Spectrum Resources
  - ❑ More runways in critical locations
  - ❑ **New ATM paradigms**
- **Need for leadership**

Multi-Stakeholder Considerations & Role of System Transition Plans



FAA>OEP
JPDO > NGATS
EU > CESARE

Focus is the OEP 35 airports



More? Oakland Burbank Long Beach John Wayne-Orange County Tucson Albuquerque San Antonio Houston Hobby Palm Beach

NGATS Operational Improvements and Benefits

1. Broad Area and Precision Navigation ► Access and capacity
2. Airspace Access and Management ► Capacity
3. 4D Trajectory Based ATM ► Capacity and efficiency
4. Reduced Separation between Aircraft ► Capacity
5. Flight Deck Situational Awareness and Delegation ► Capacity and safety
6. ATM Decision Support ► Capacity
7. Improved Weather Data and Dissemination ► Capacity and safety
8. Reduced Cost to Deliver ATM services ► Cost
9. Greatly Expanded Airport Network and Improved Terminals ► Capacity