

***Air Transportation
The Next 100 Years
Challenges and Opportunities***

Prof. R. John Hansman

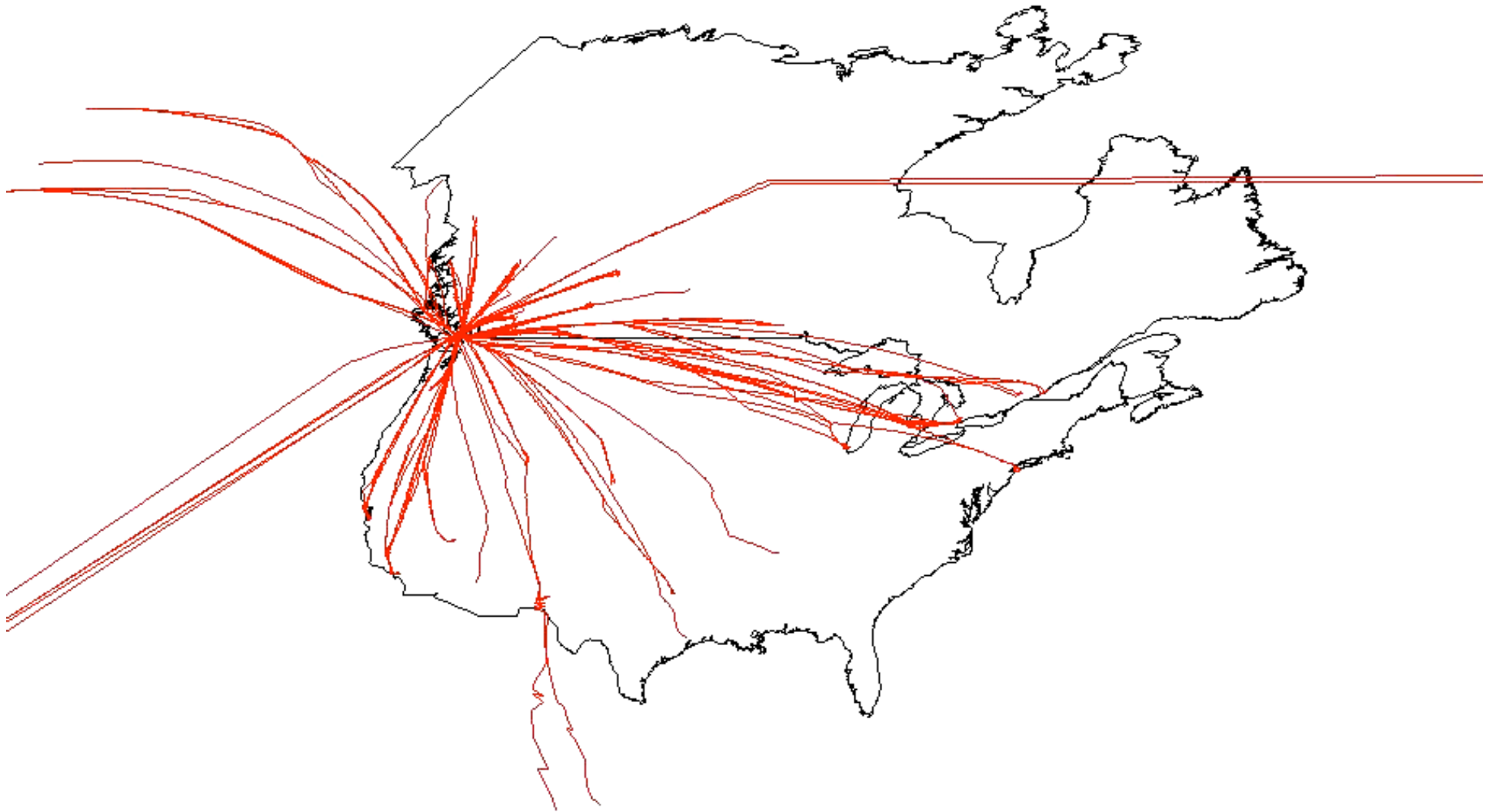
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Aeronautics and Astronautics***

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Flight Trajectories Departing YVR

January 9th 2003



**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**

H3A H2A FAE





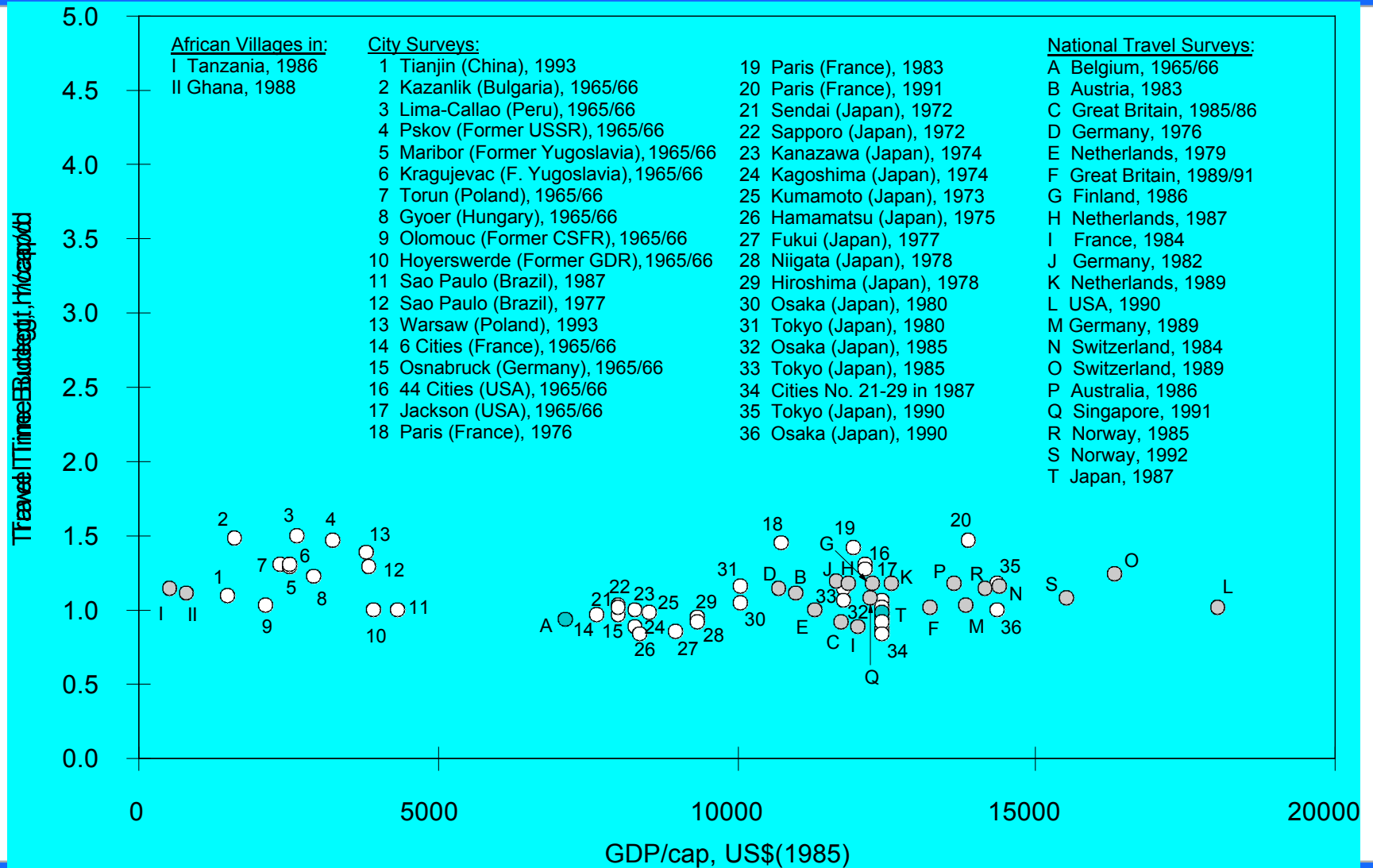
Overview

- **Trends**
 - **Challenges**
 - **Possibilities**
-



Fundamental Need for Travel

Global Travel Time Budget

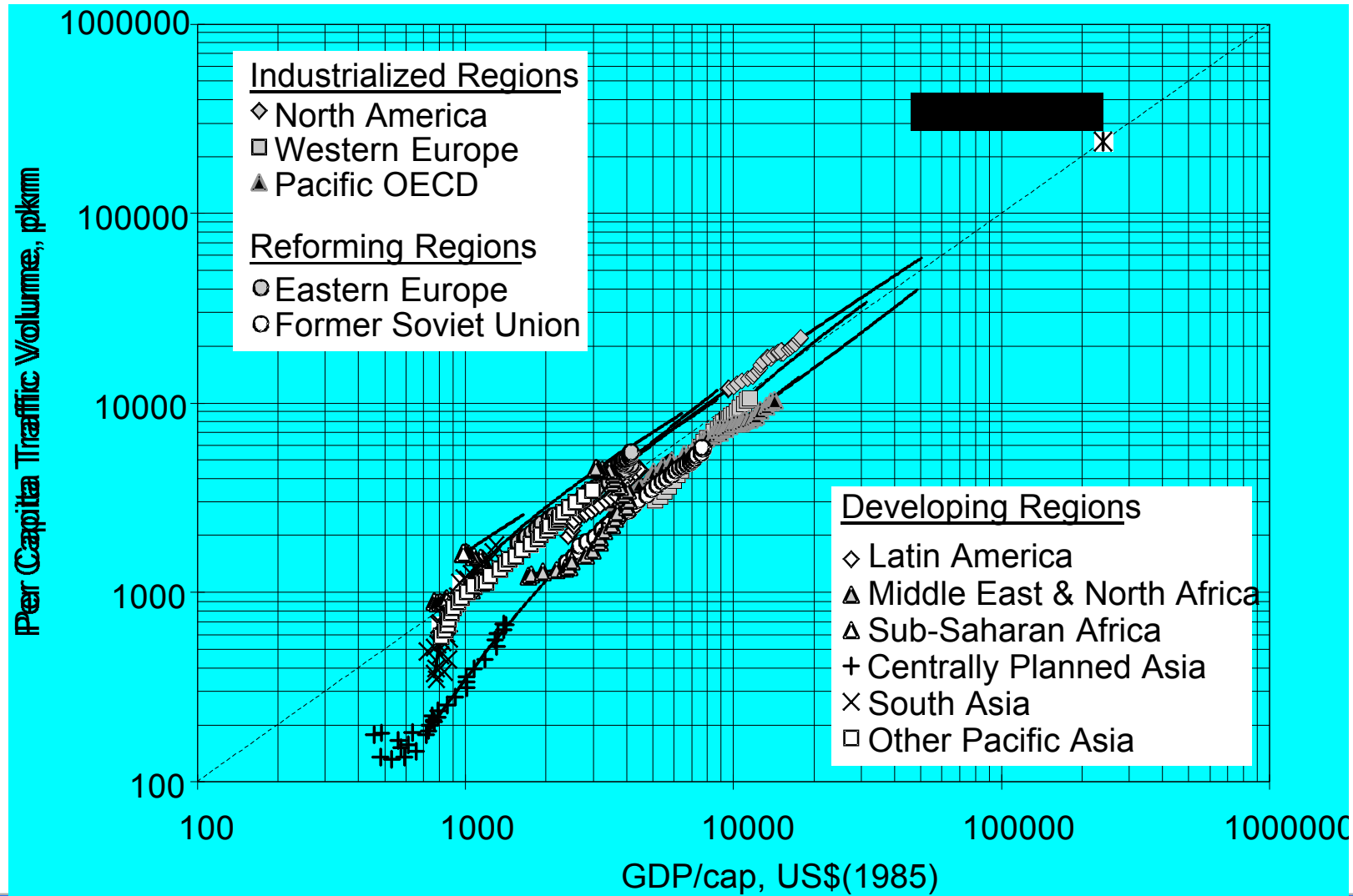


Source: Schafer and Victor (2000)



Fundamental Need for Travel

Global Total Mobility

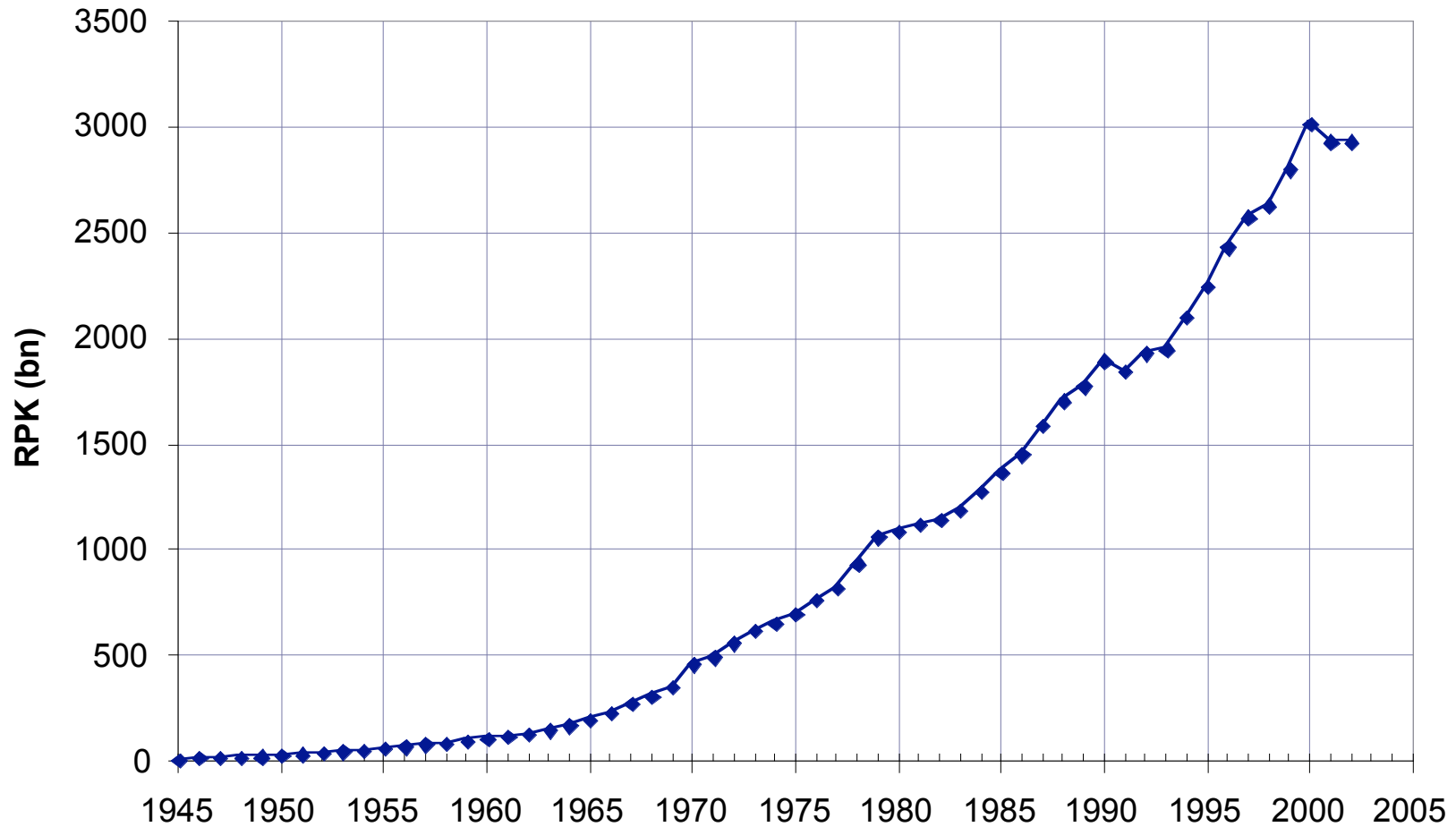


Source: Schafer and Victor (2000)



World Scheduled Passenger Traffic

World Revenue Passenger-Kilometers of Scheduled Service

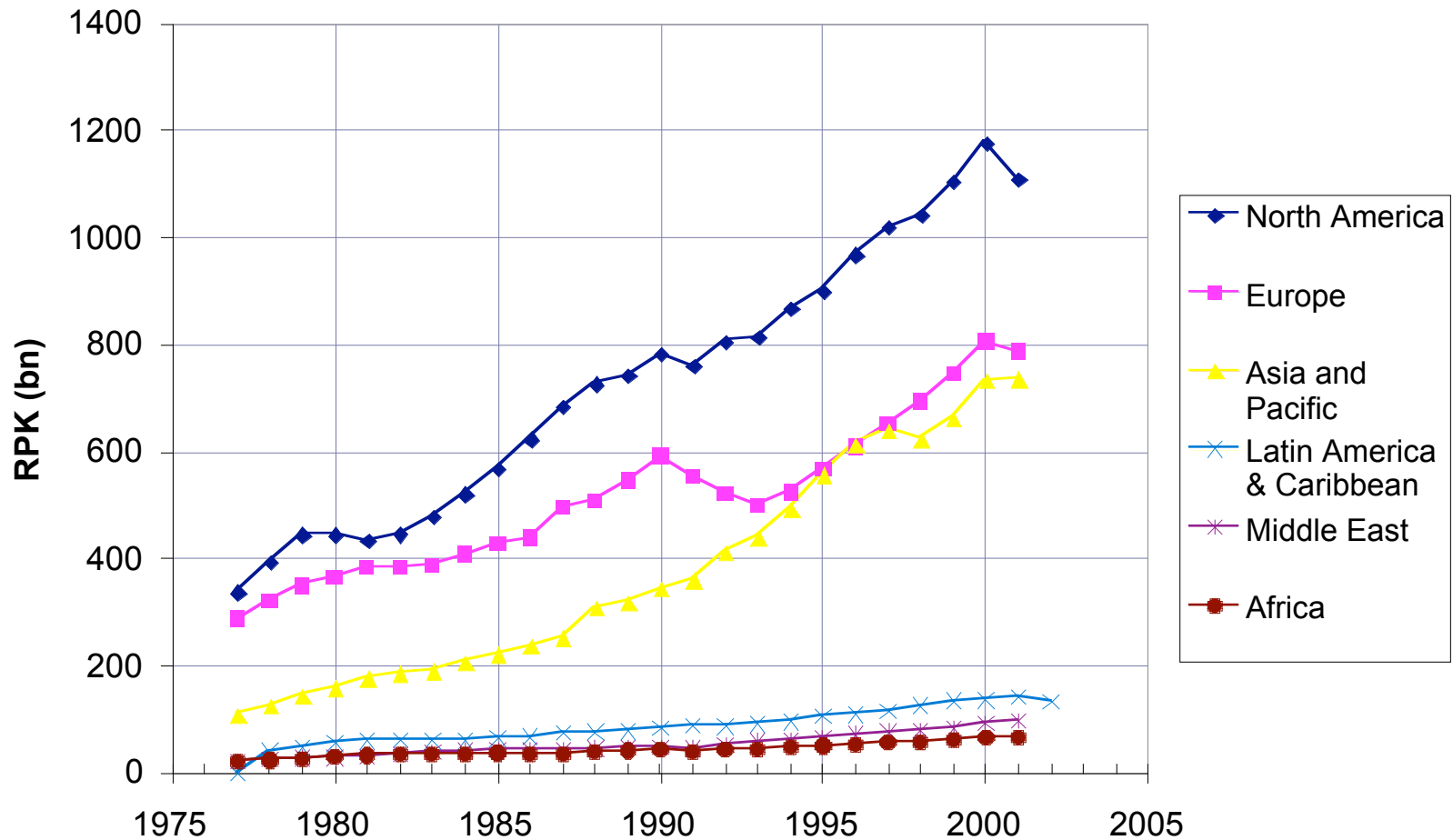


Source: ICAO



Passenger Traffic by Region

Scheduled Revenue Passenger-Kilometers by Region

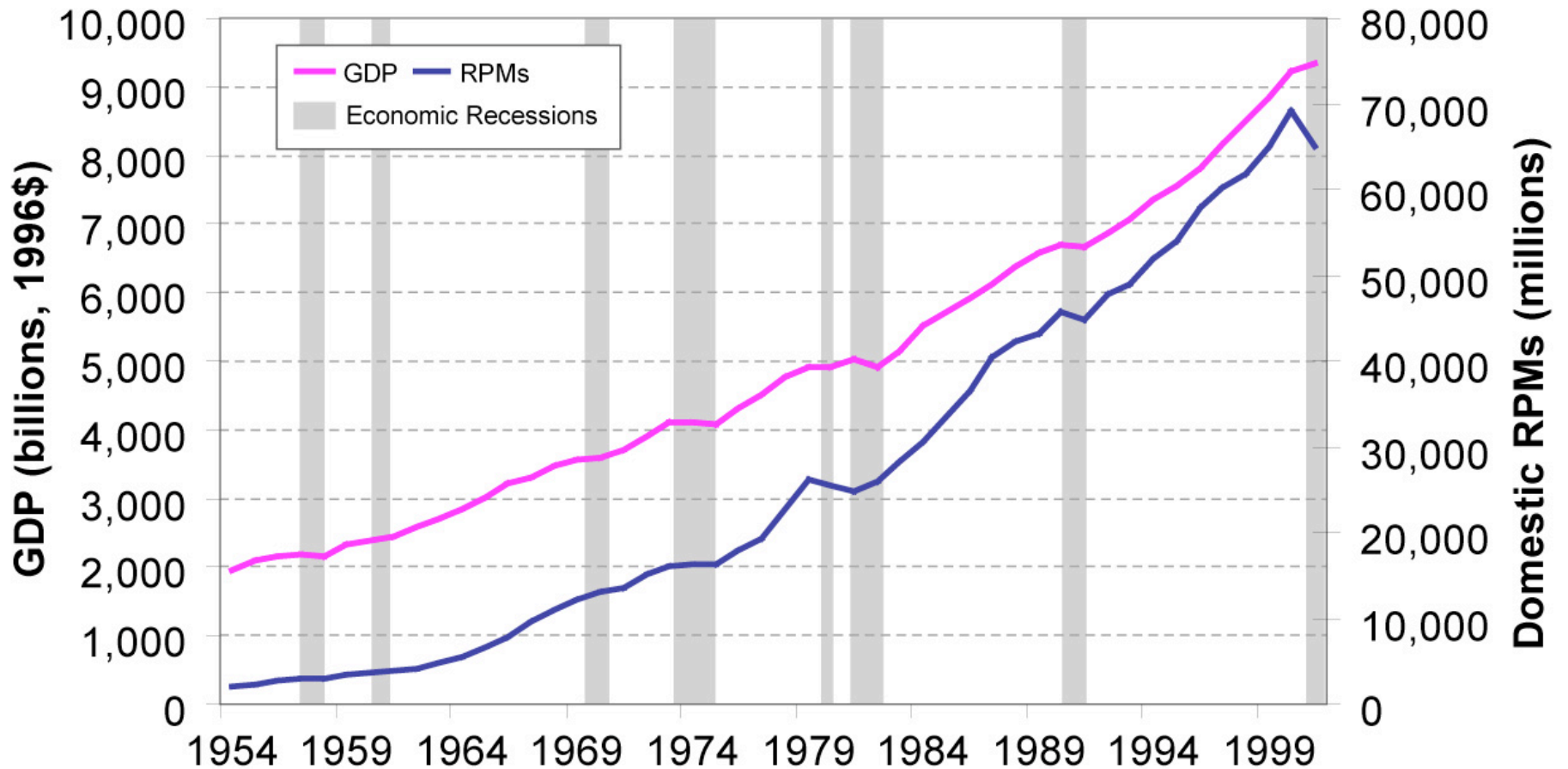


Source: ICAO



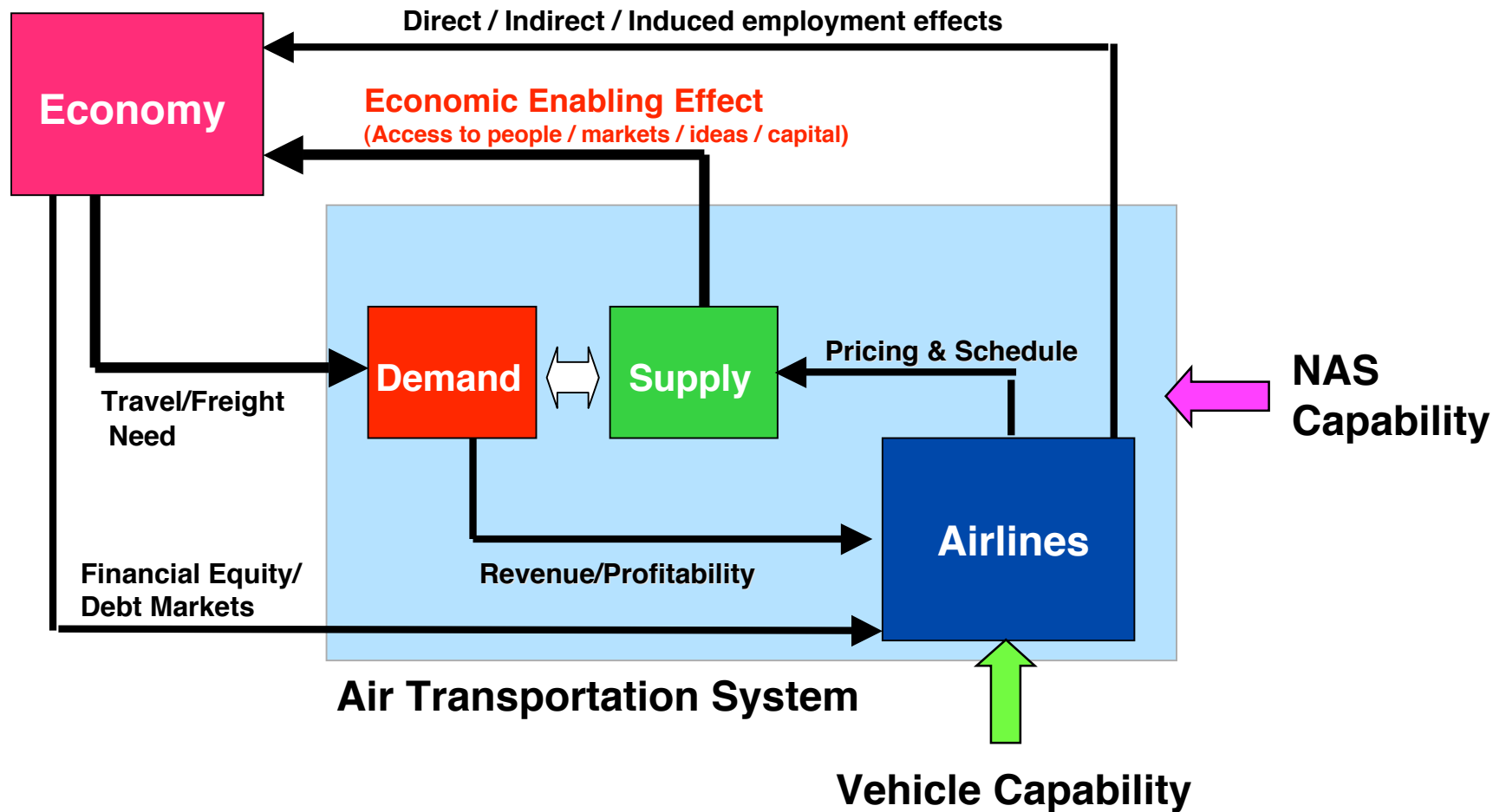
Historical Demand Trends with Economy

US GDP vs. RPMs: 1954-2001





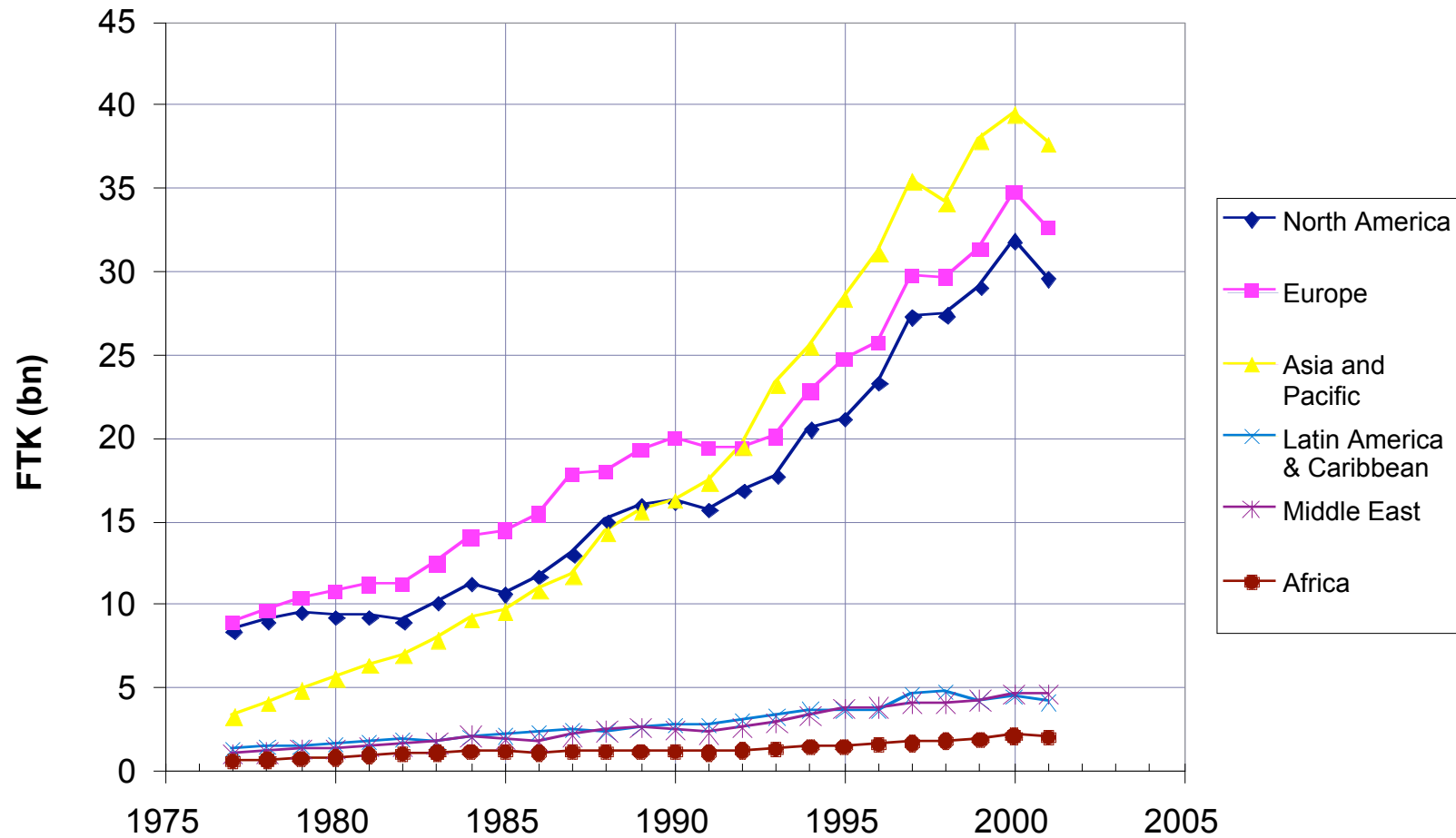
Conceptual Model





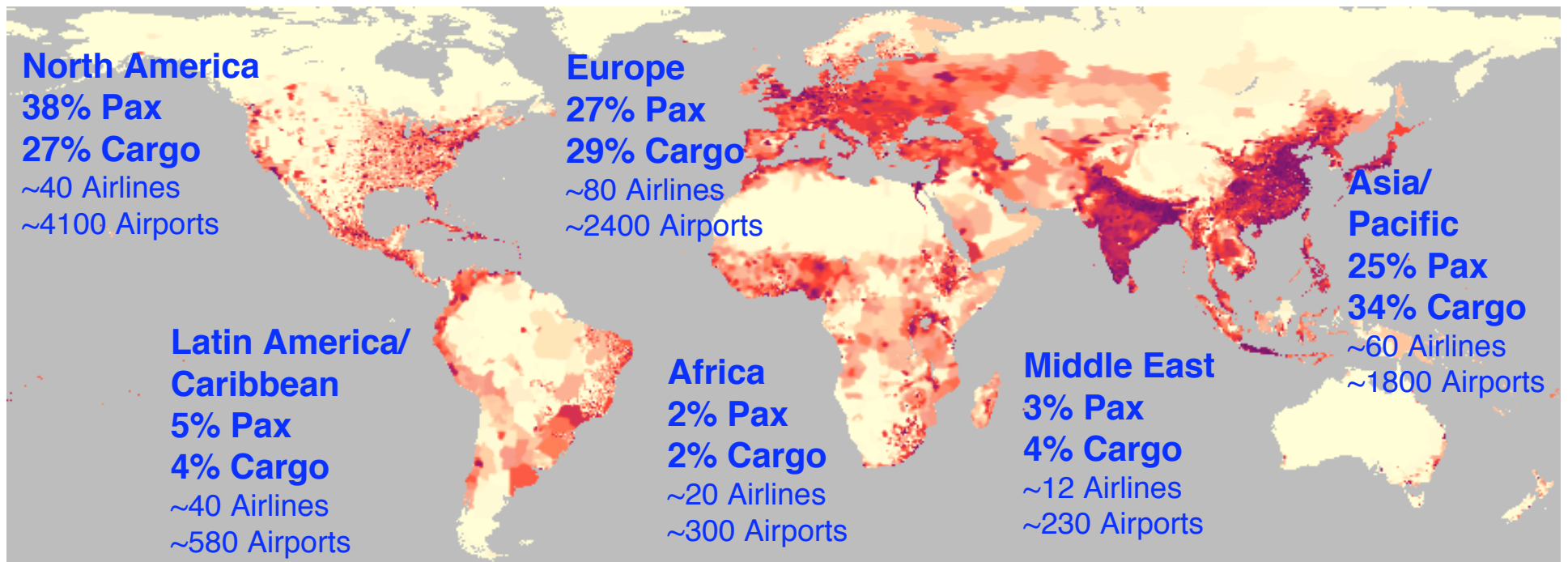
Air Freight by Region

Freight Tonne-Kilometers by Region





World Population Distribution and Air Transportation Activity

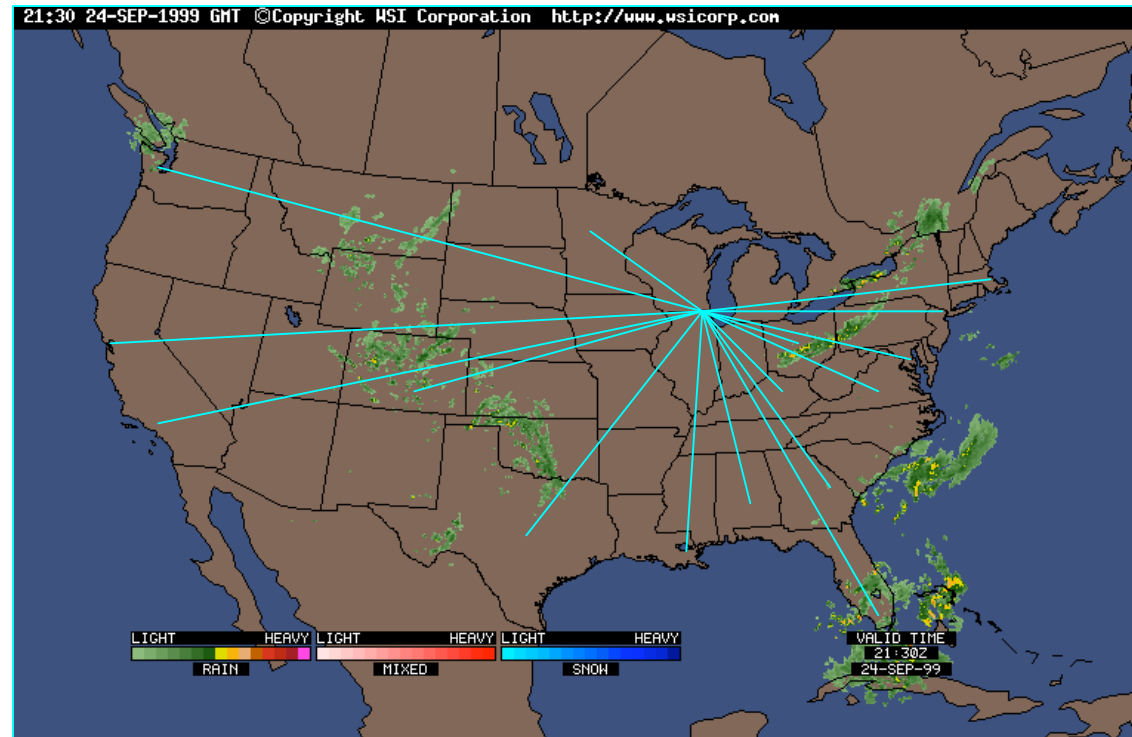


Population Source: <http://www.ciesin.org/datasets/gpw/globldem.doc.html>

Air Transport Source: ICAO, R. Schild/Airbus



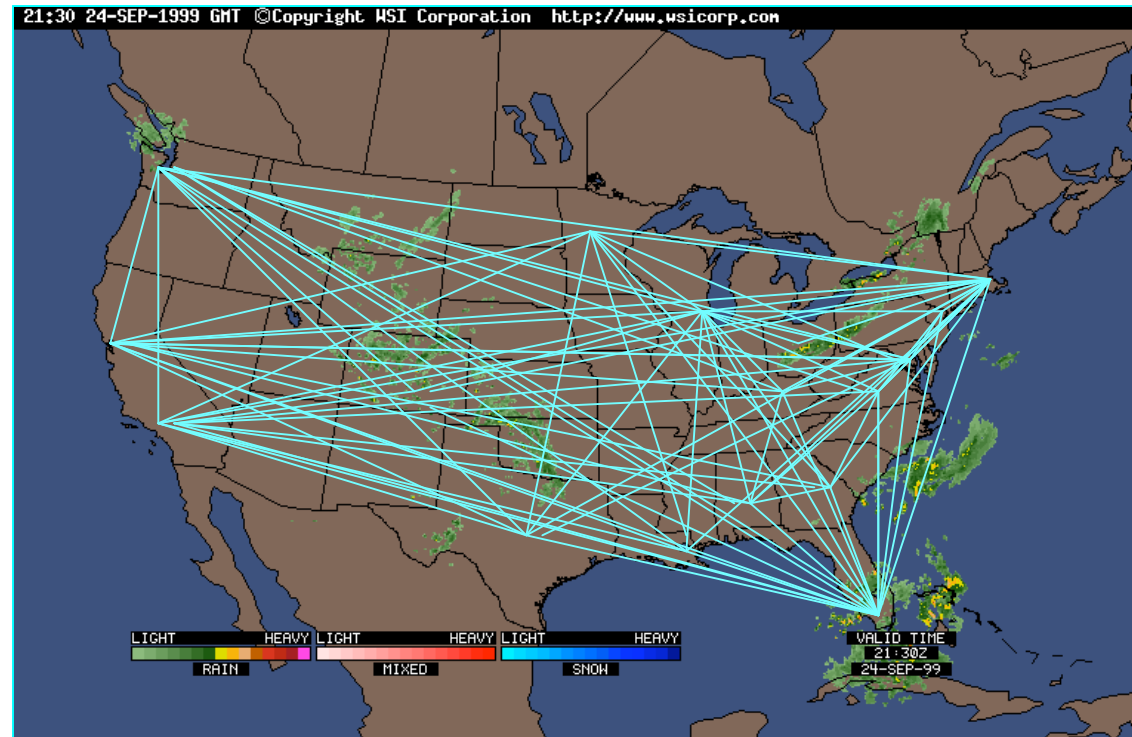
Hub and Spoke vs Direct Networks



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



Fully Connected Network

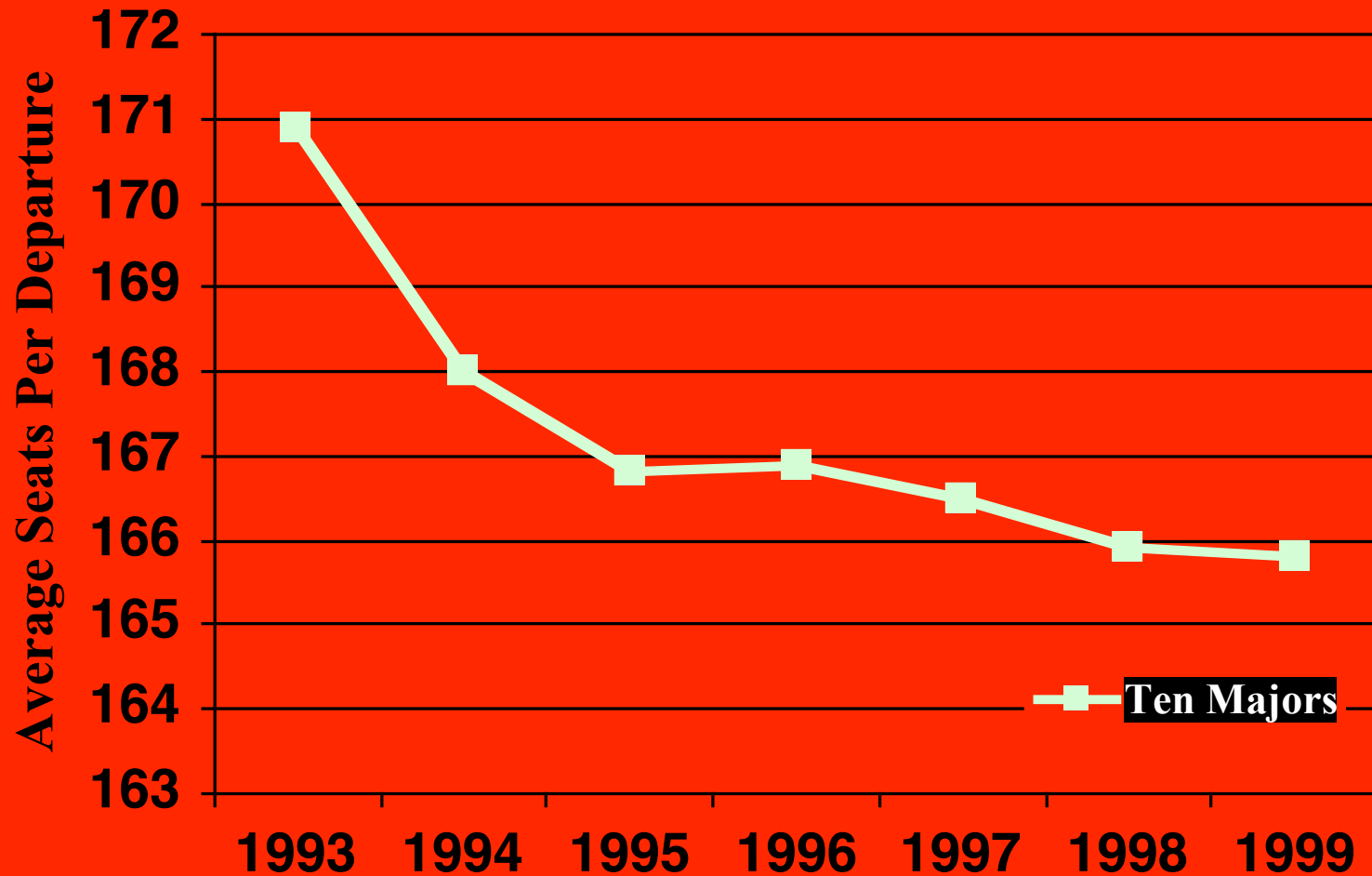


Completely Connected Network = $N(N-1)$
(eg., 50 Airports, 2450 Flights)



Demand Drives Frequency Decreasing Aircraft Size

Ten Major US Carriers - Excludes Regional Jets



Source: DOT Form 41 Data



Emergence of Regional Jets

ERJ 145 (50 seats)

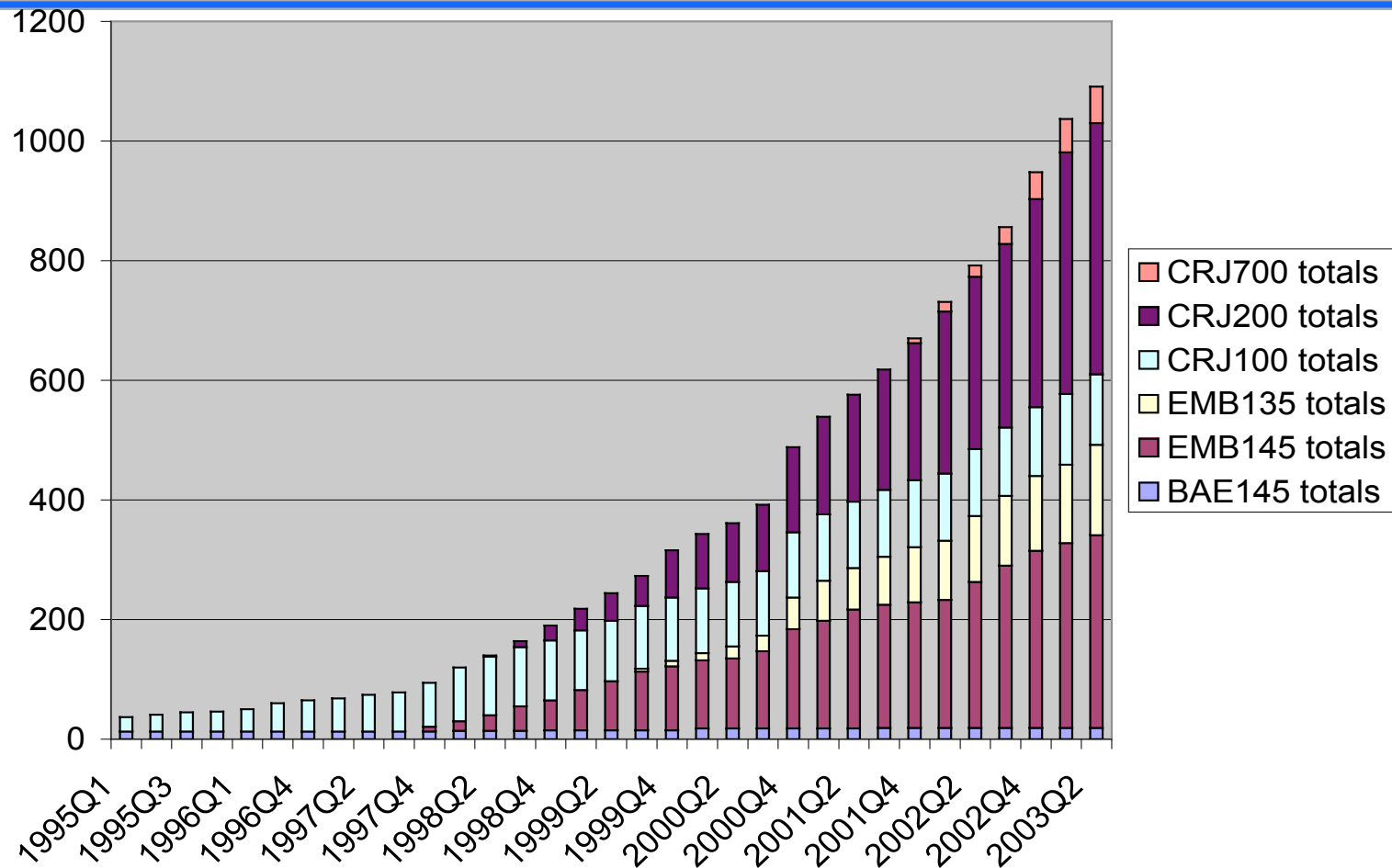


CRJ 200 (50 seats)





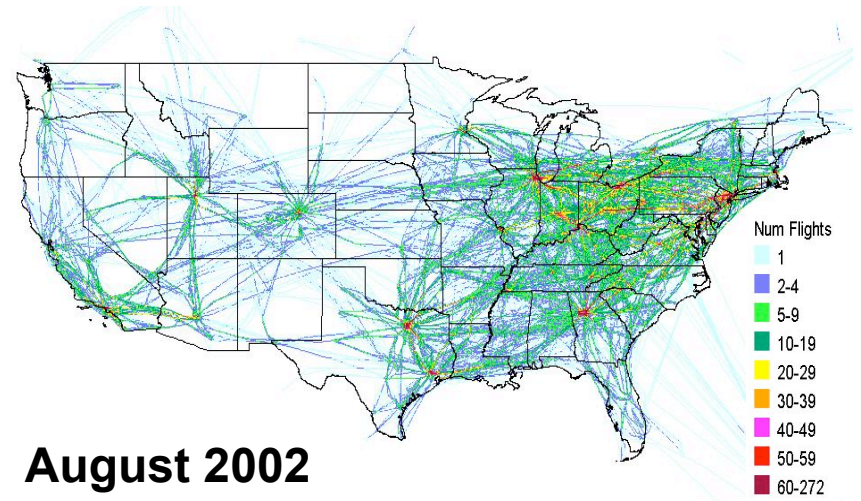
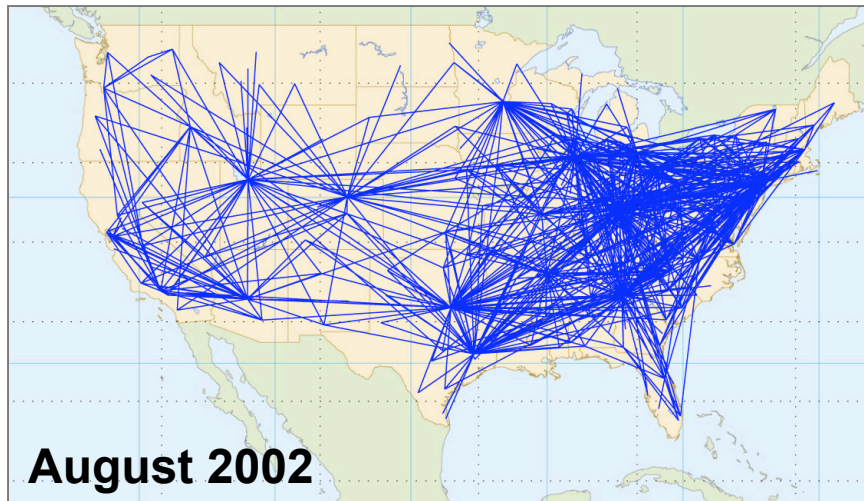
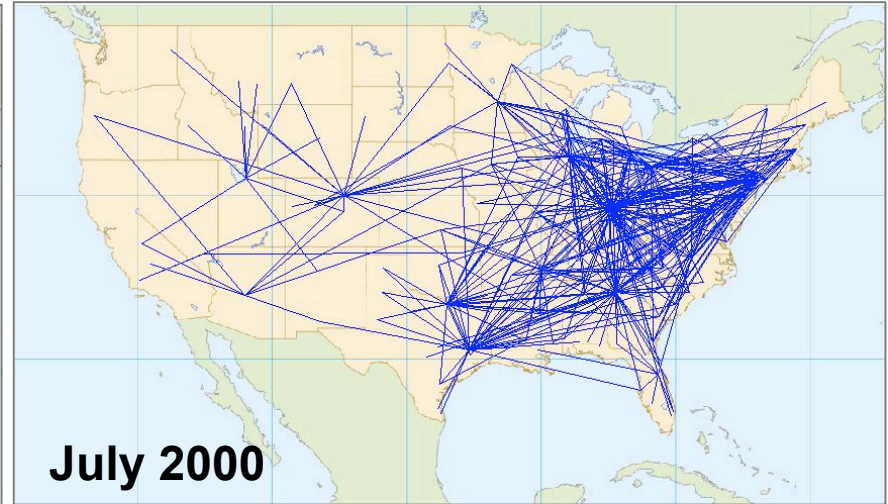
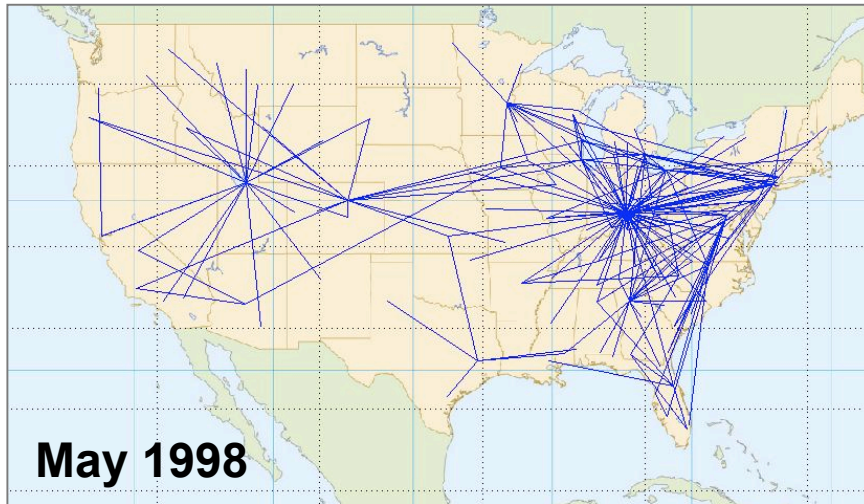
U.S. Regional Jet Growth



Source: FAA registration data from 1995 until the present

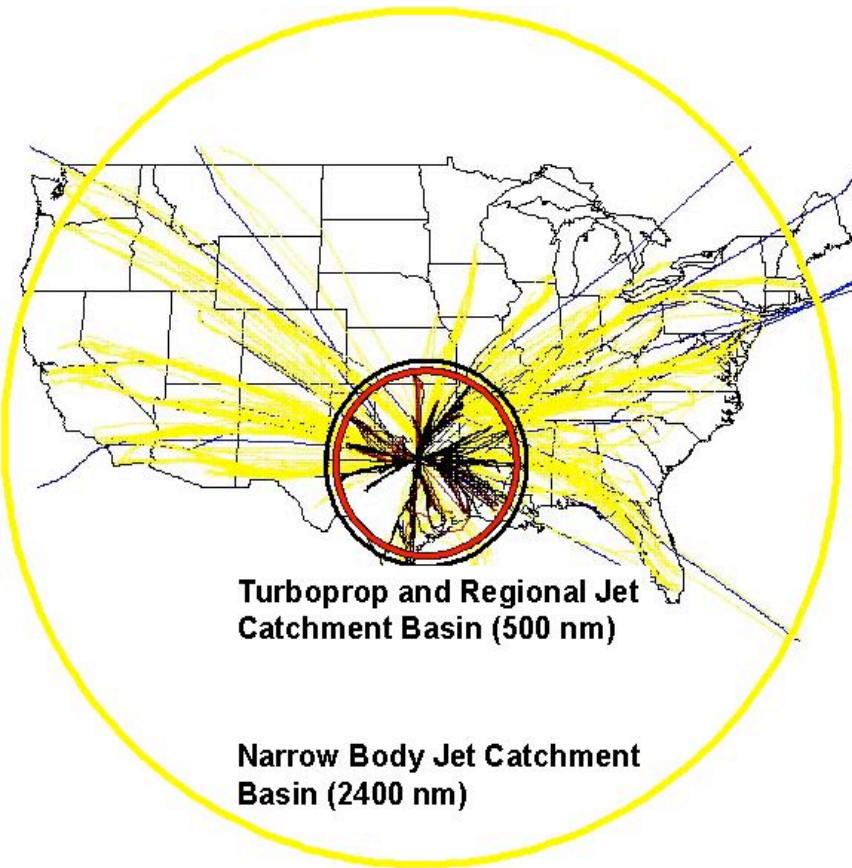


Regional Jet Deployments

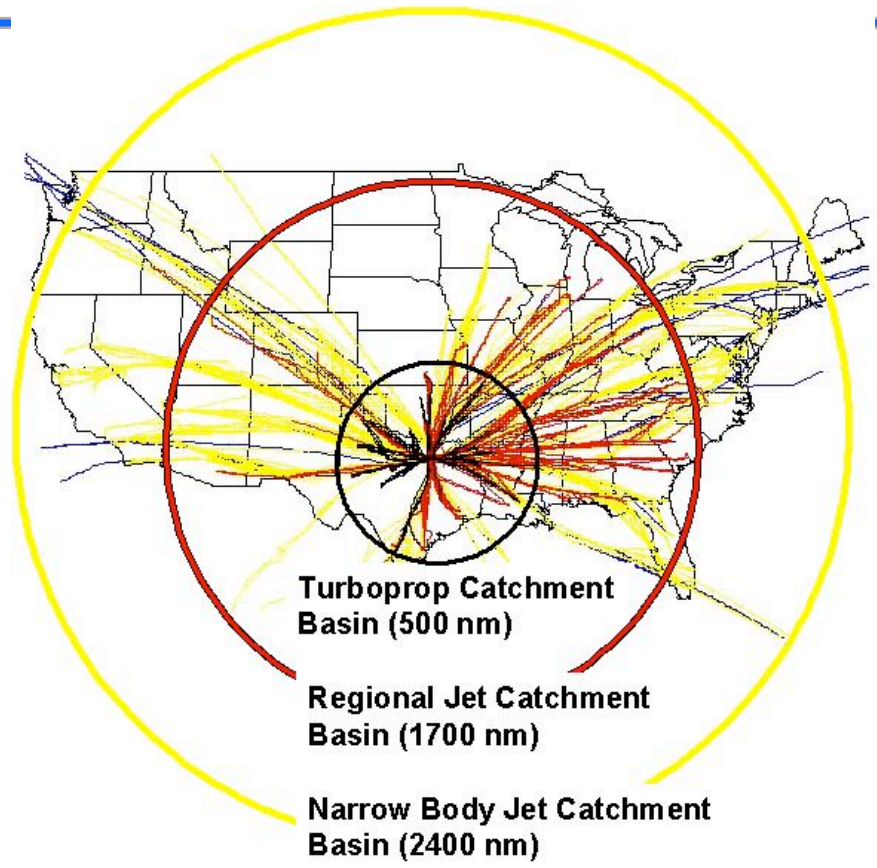




DFW Departures



January 1998



January 2003



Proposed - Small Turbofan Passenger Aircraft



Eclipse Jet



Cessna Mustang

Proposed New Aircraft will Extend the Size Spectrum of the Air Transportation Fleet



Proposed Large Efficient Transport



Proposed New Aircraft will Extend the Size Spectrum of the Air Transportation Fleet



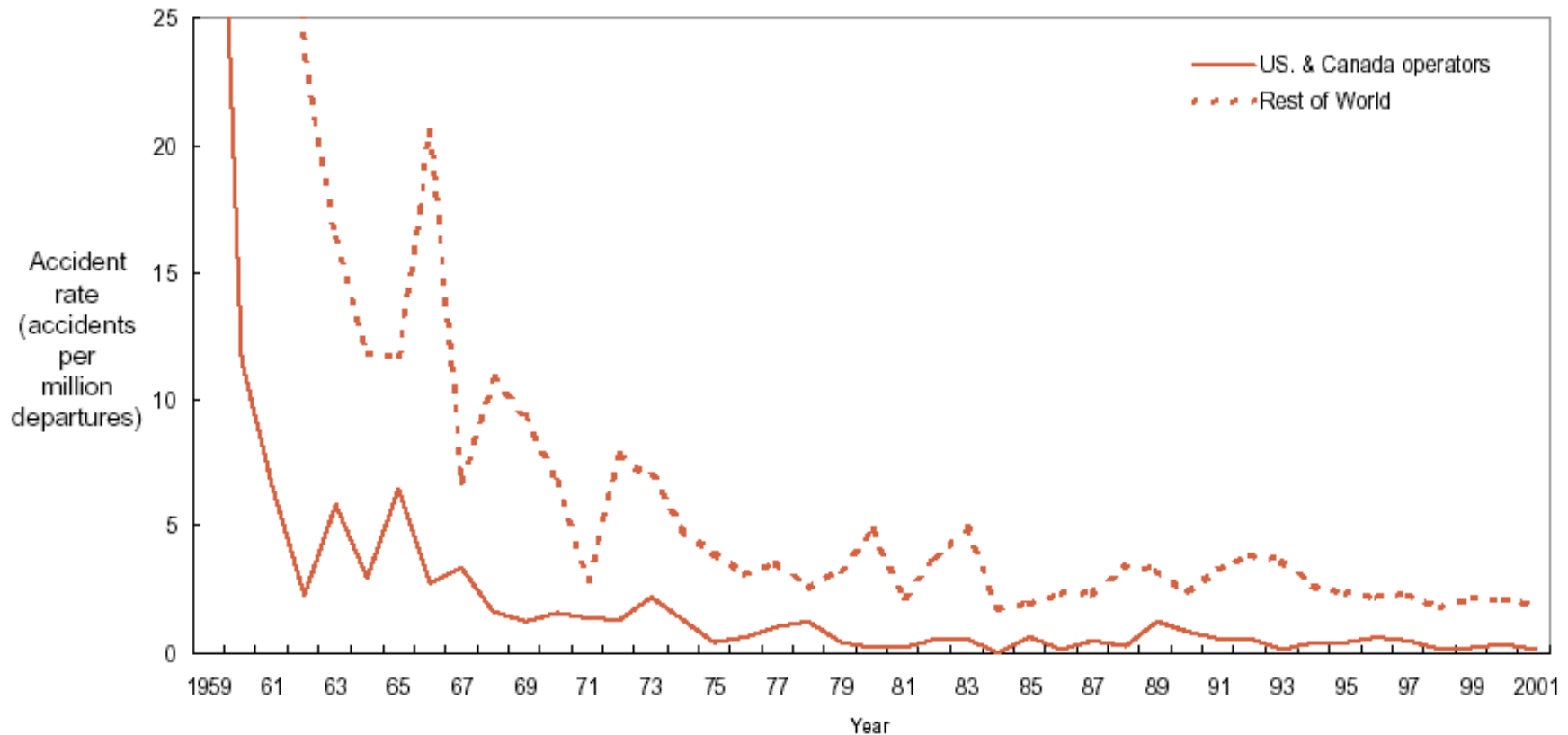
New Operational Class - Unmanned Air Vehicles





Safety Trends

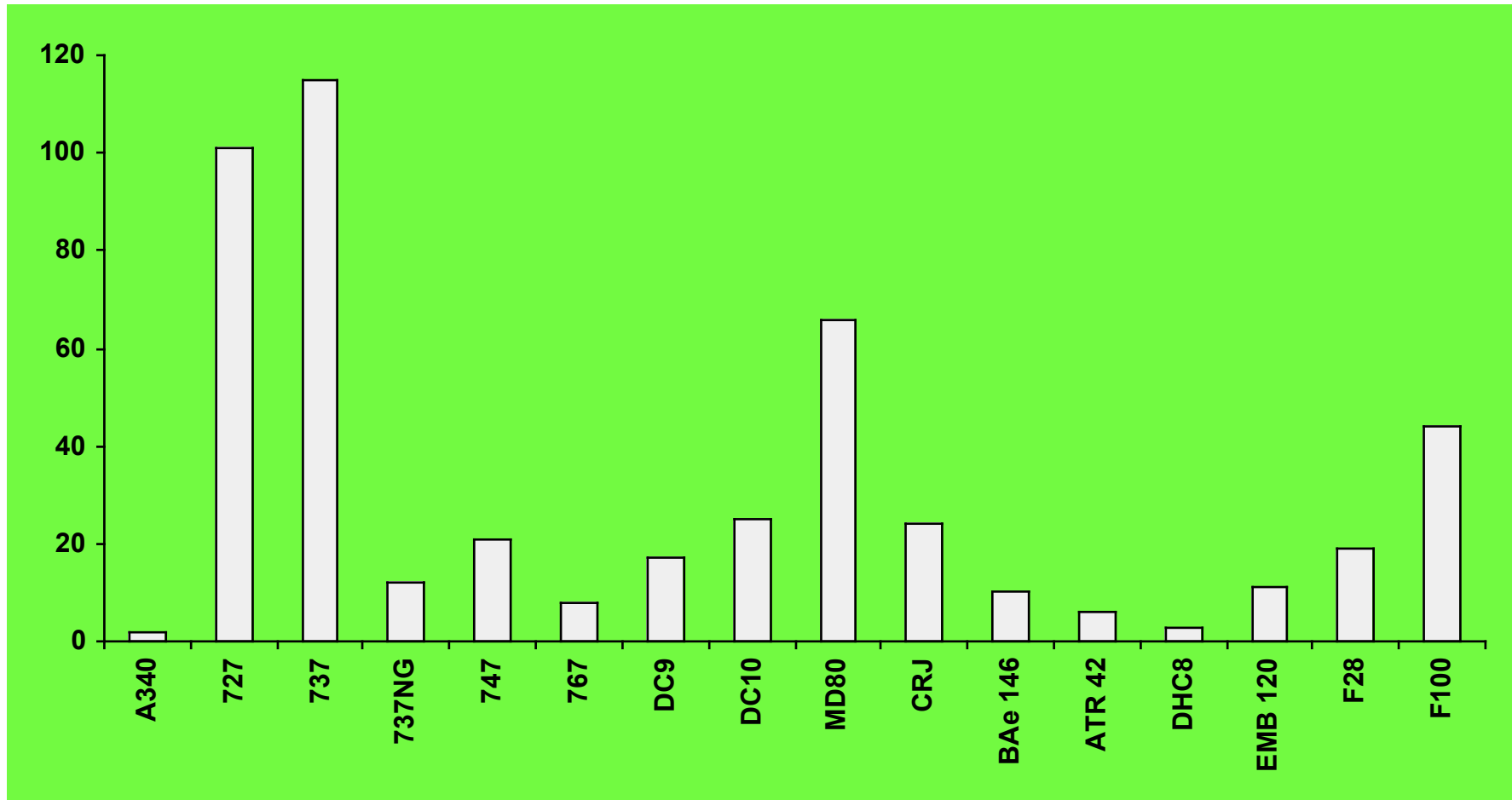
Hull Loss and/or Fatal accidents - Worldwide Commercial Jet Fleet - 1959 through 2001



Source: Boeing 2001 Statistical Abstract



Estimated 484 Aircraft Parked/Retired Worldwide Effective Modernization of the Fleet

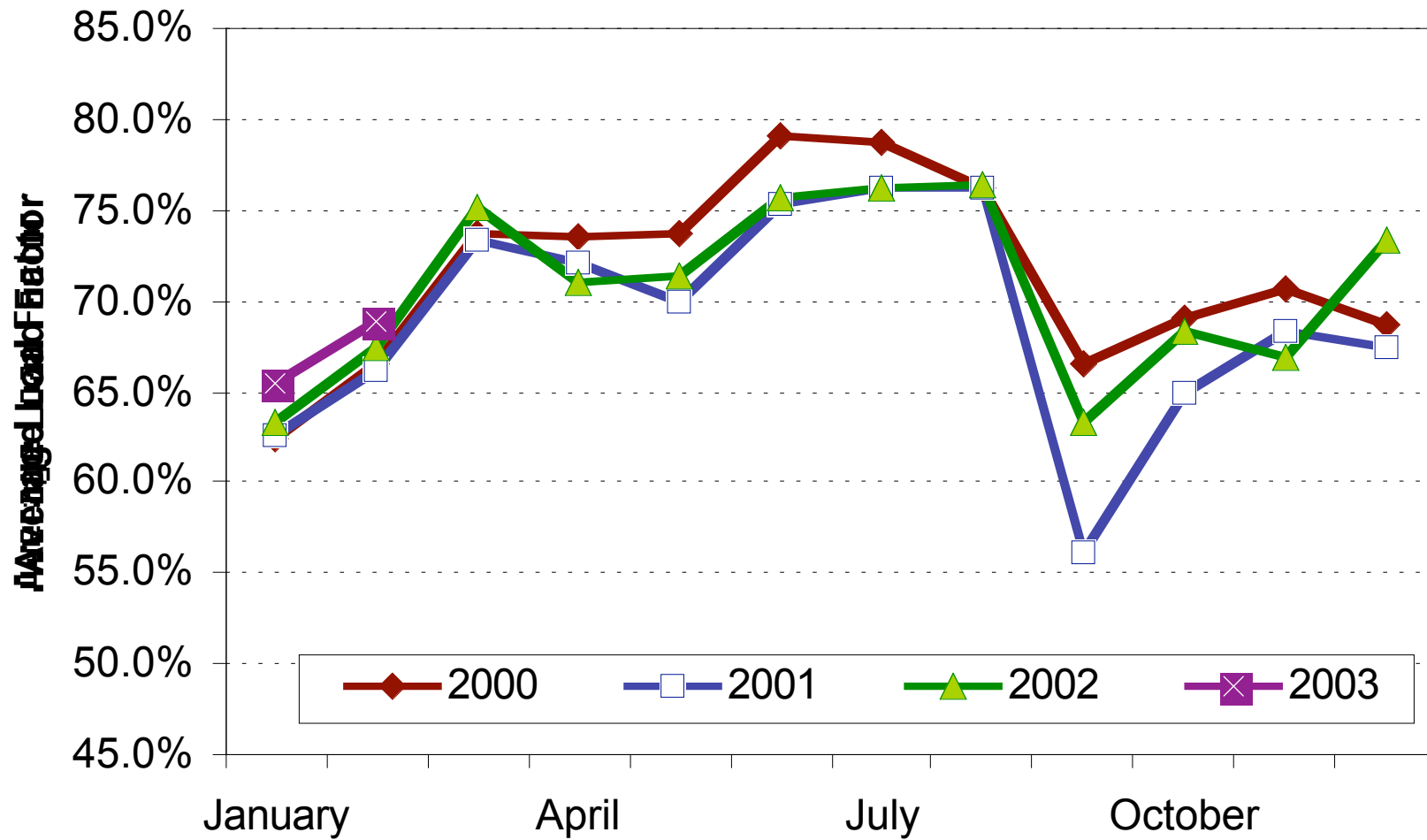


(Source: Avsoft)

Source: Katherine Andrus, Air Transport Association

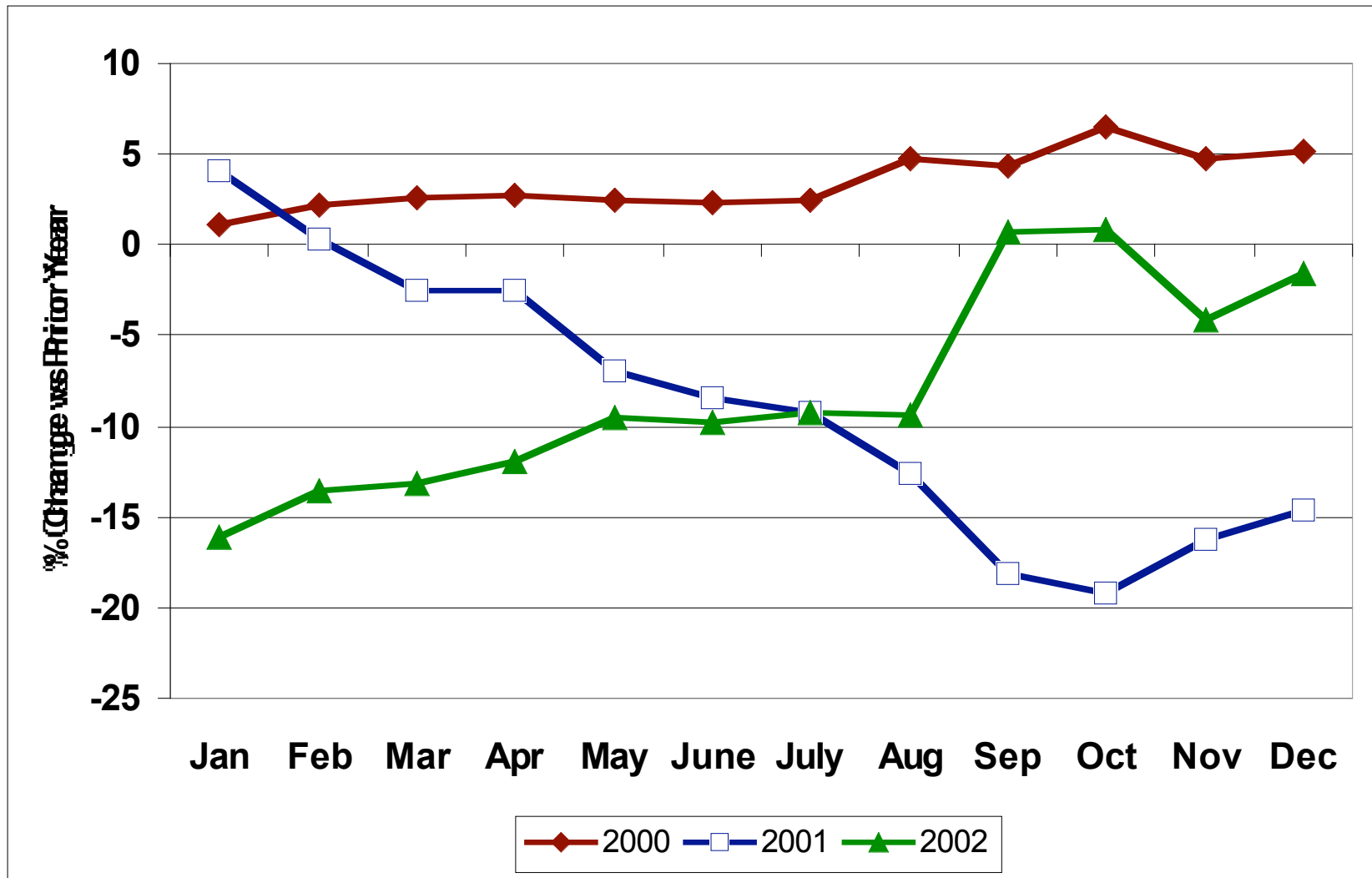


US Airline Load Factors 2000-2003



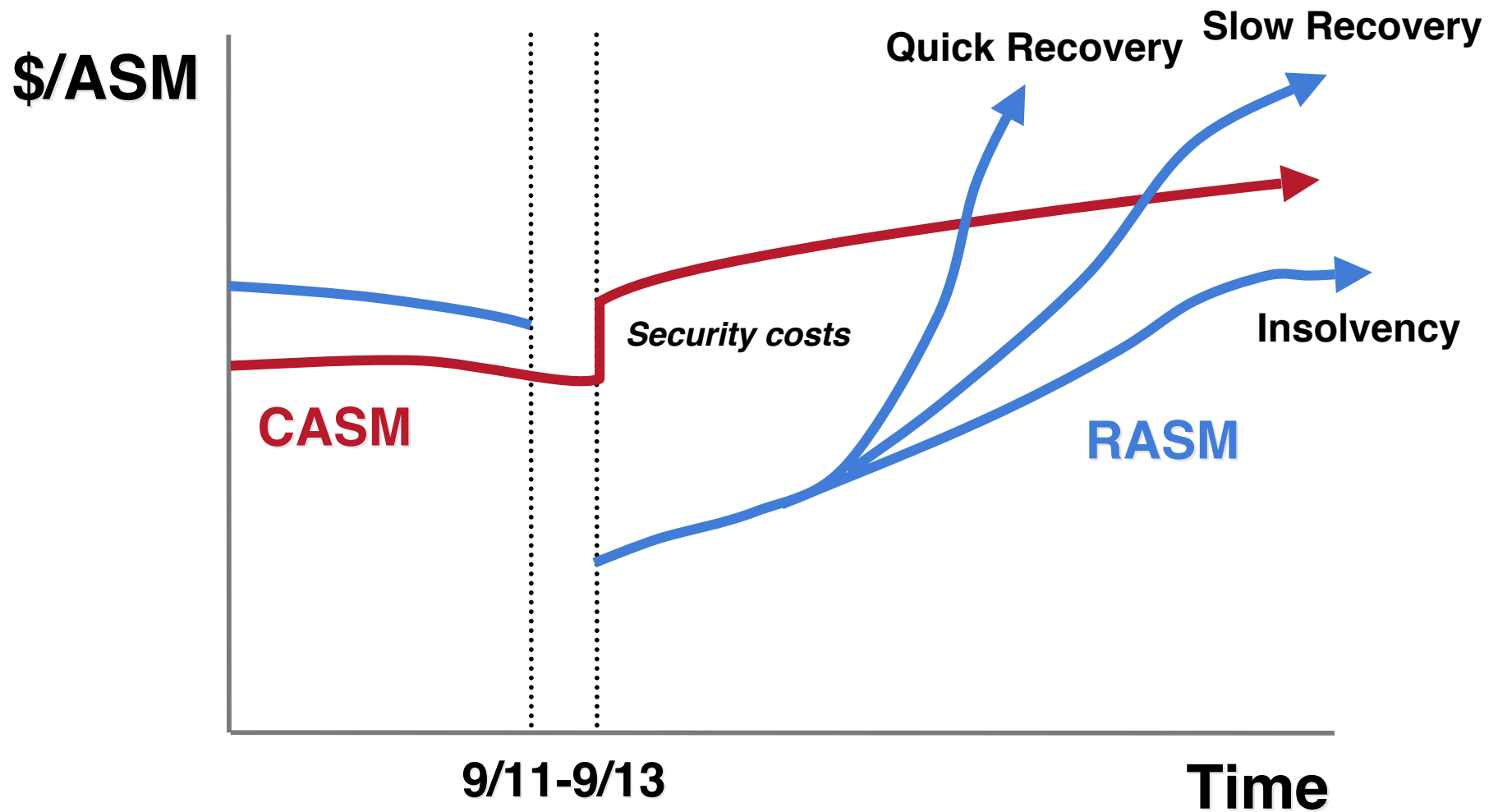


Annual Change in Average Domestic Fare



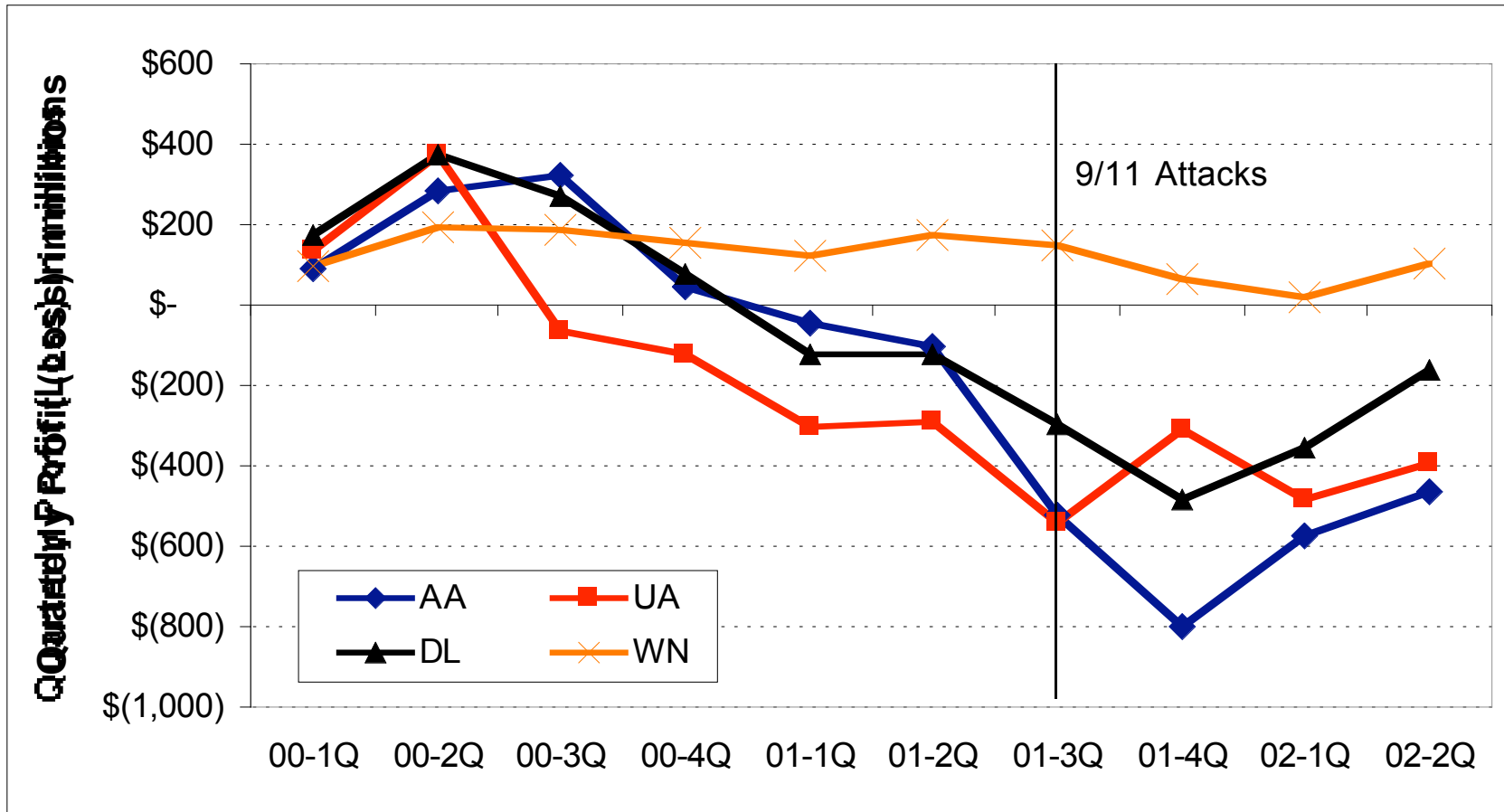


Airline Profitability Impact





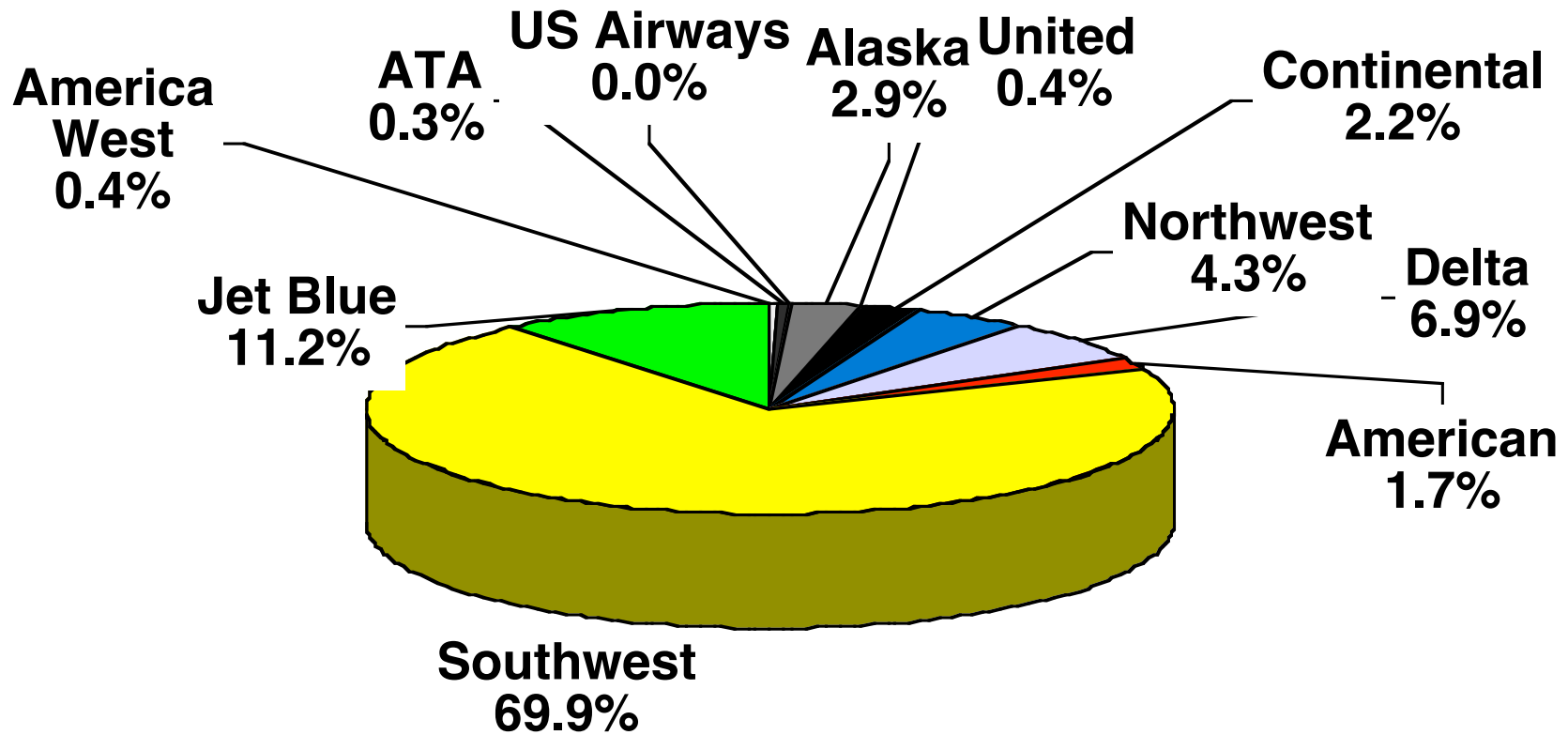
All Major Carriers On “Slow Recovery” Trajectory Except Southwest





Market Cap: US Majors, 3/18/03

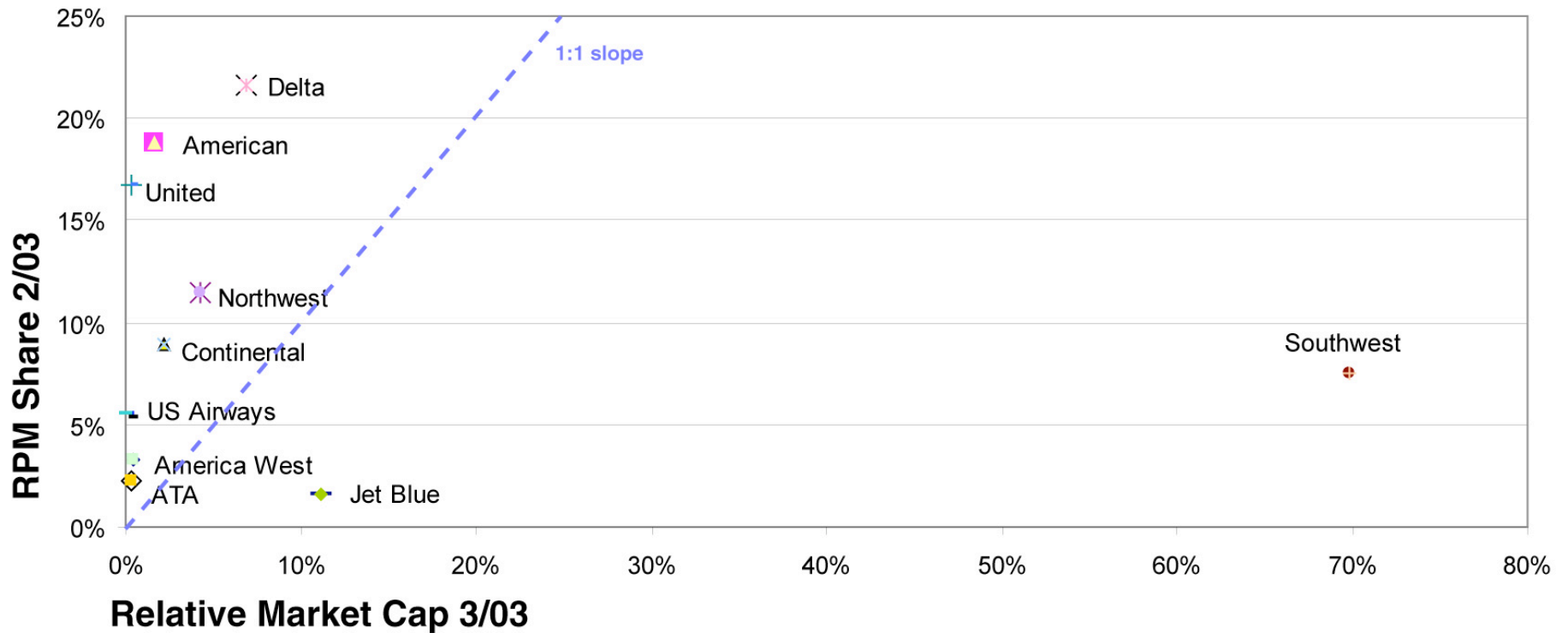
With Jet Blue



Total Market: \$15.7 billion



Current Market Cap vs. RPM Share US Majors and ATA



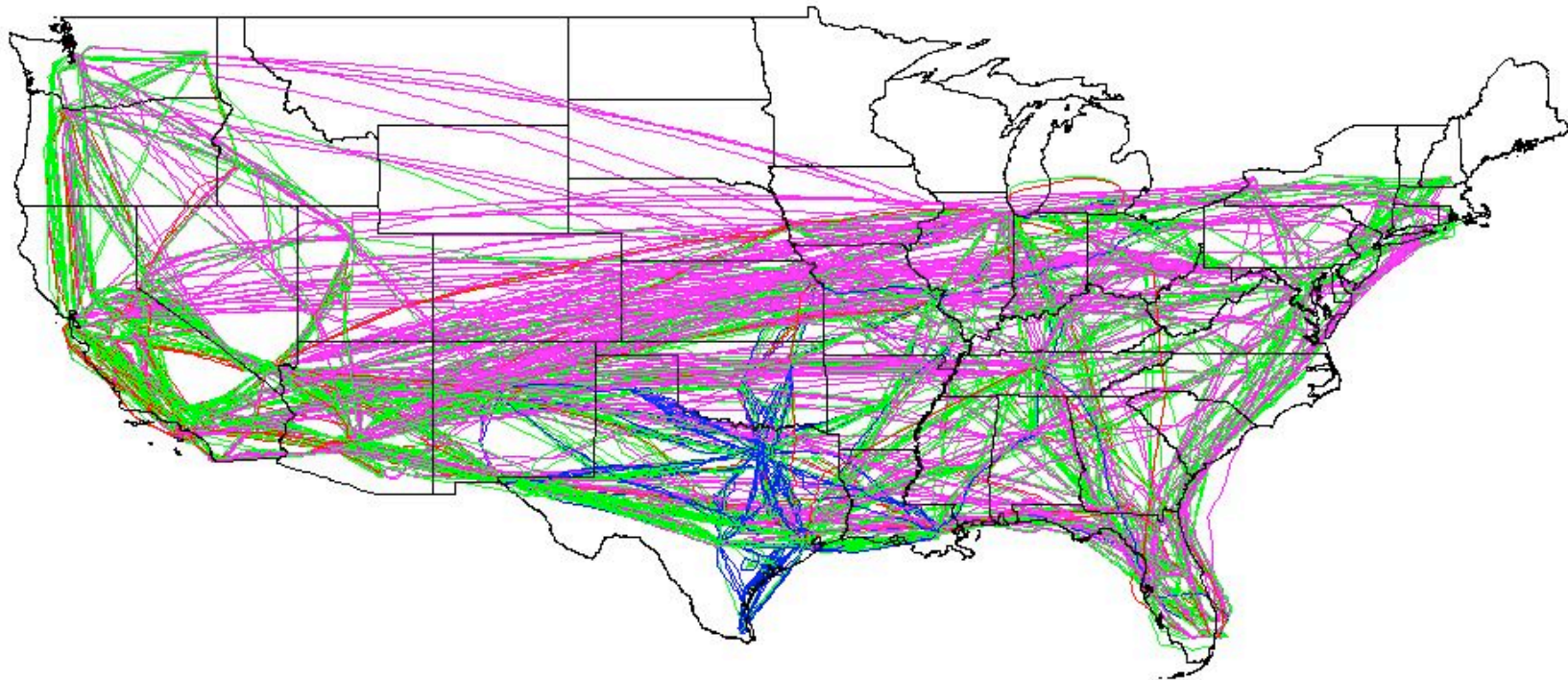
Network vs Cost Efficiency Questions

Source: Yahoo! Finance and airline traffic reports



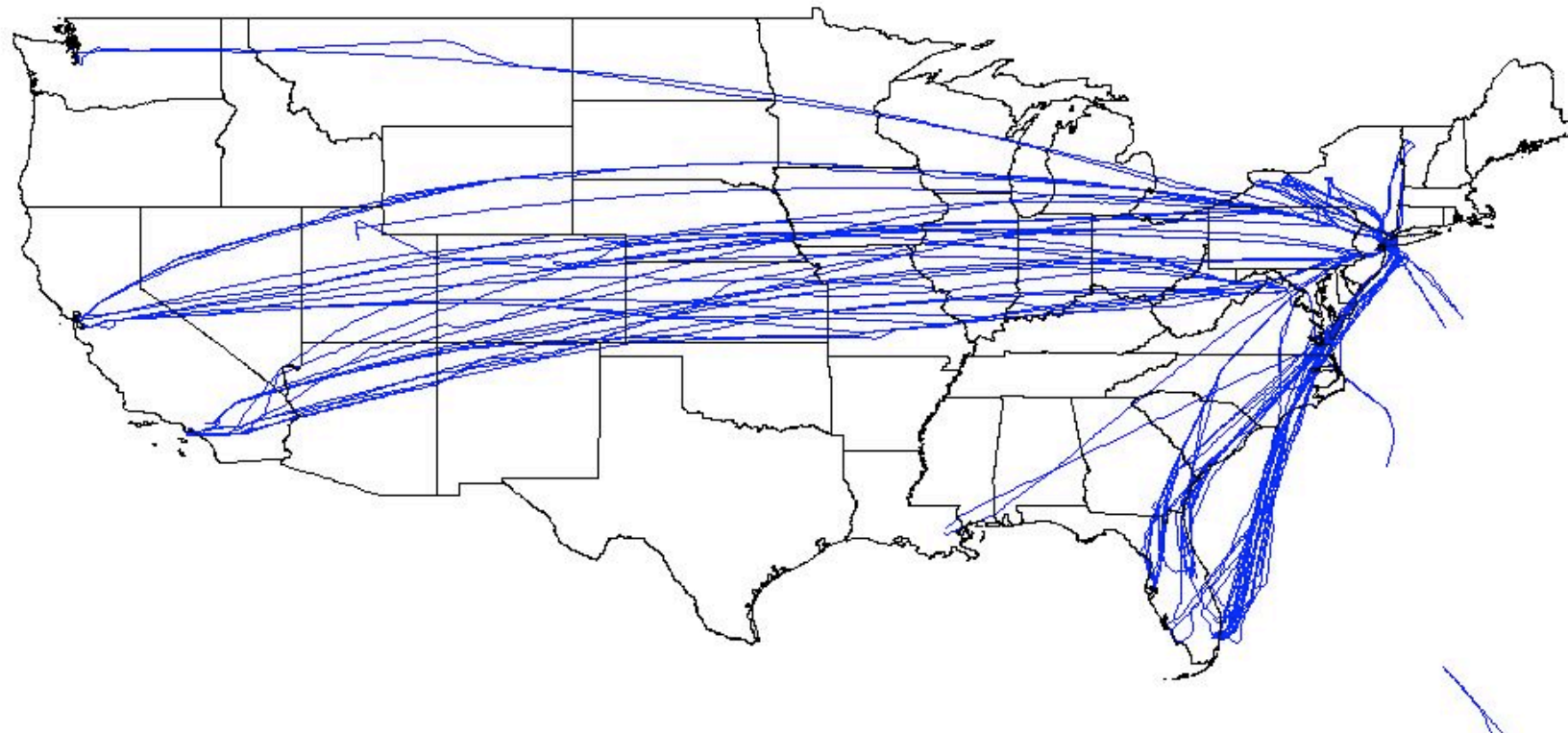
Southwest SWA Flights (8/7/02)

Acft
■ B733 (1554)
■ B737 (708)
■ B73Q (271)
■ B735 (217)





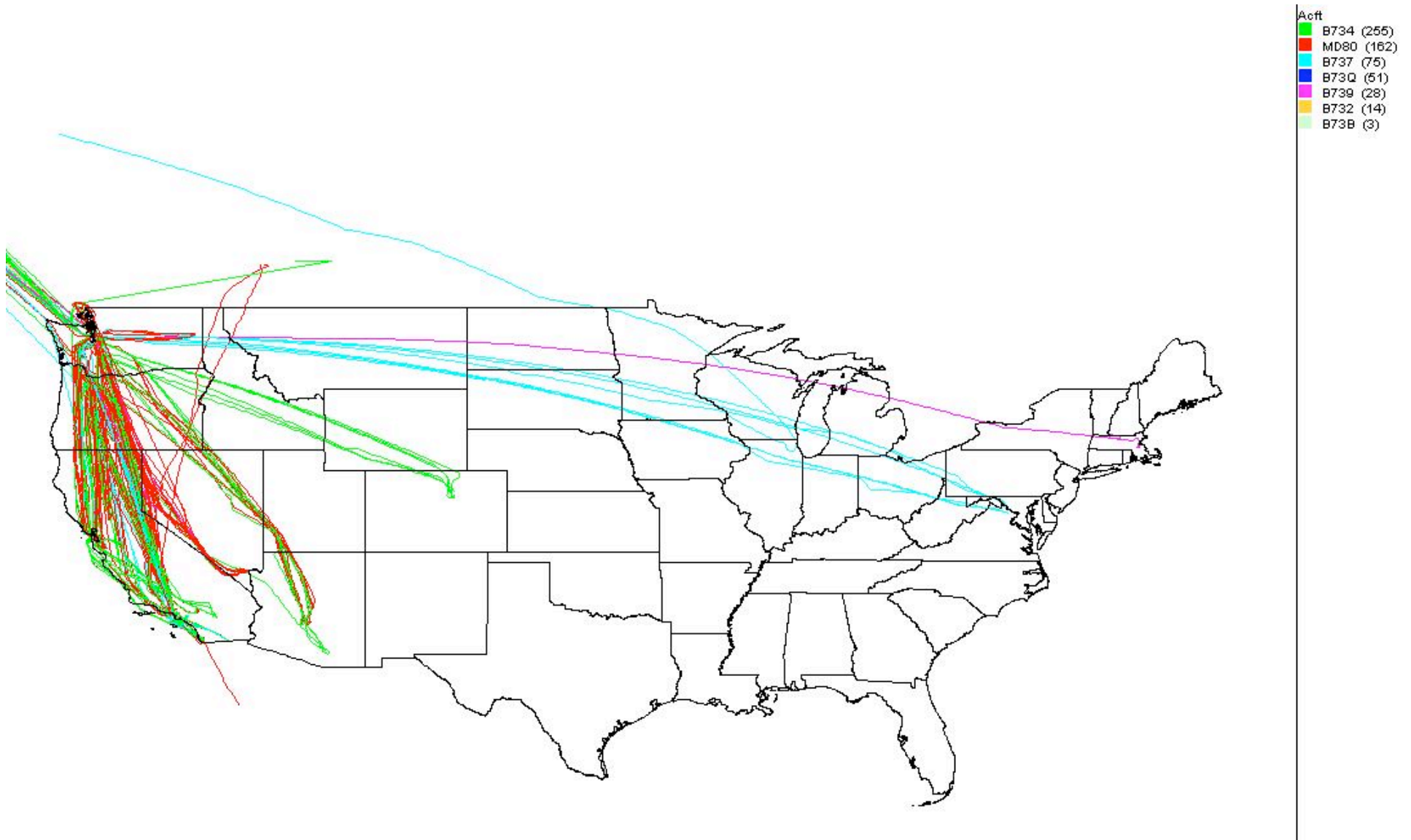
Jet Blue Flights (8/7/02)



Acft
■ A320 (130)

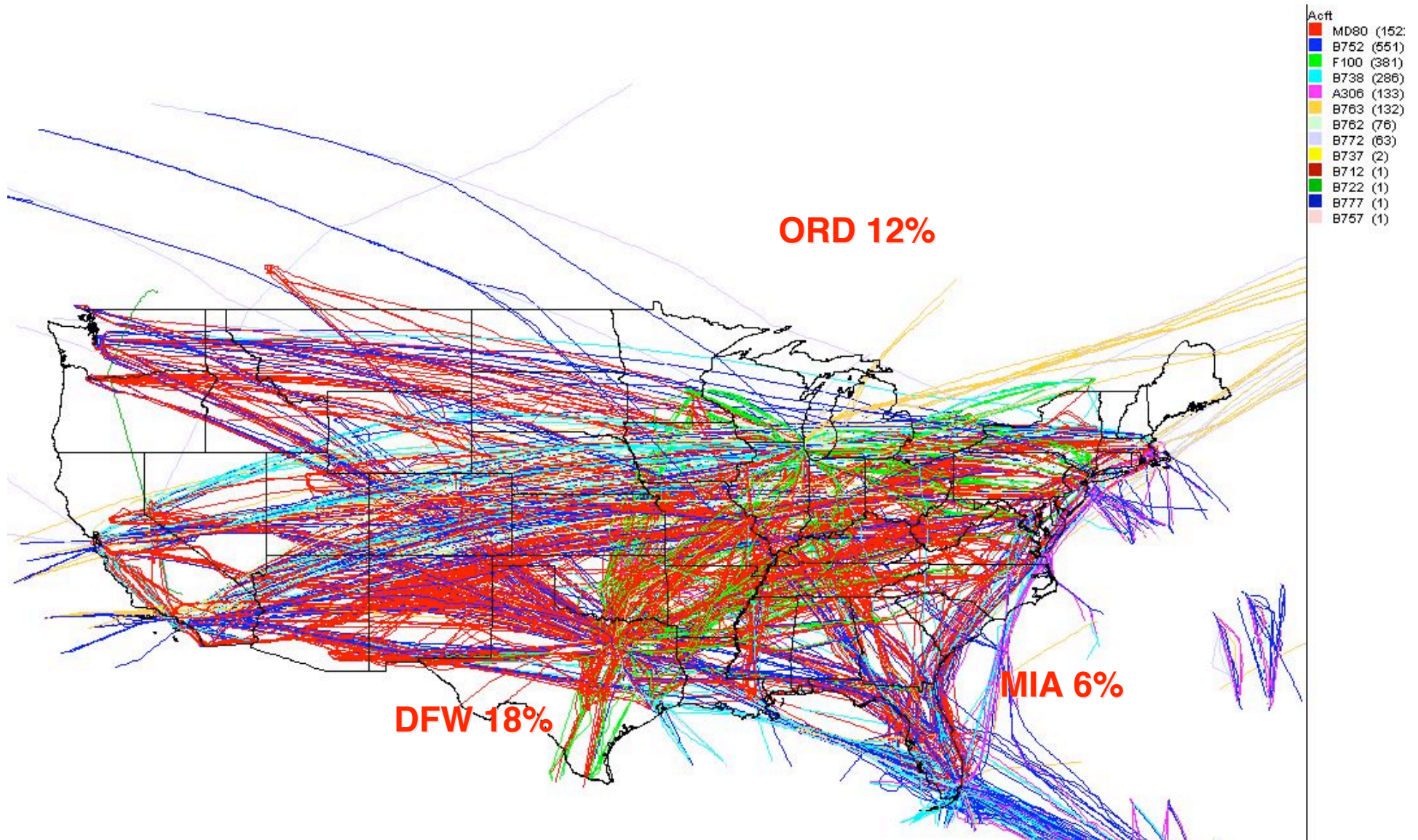


Alaska Flights (8/7/02)



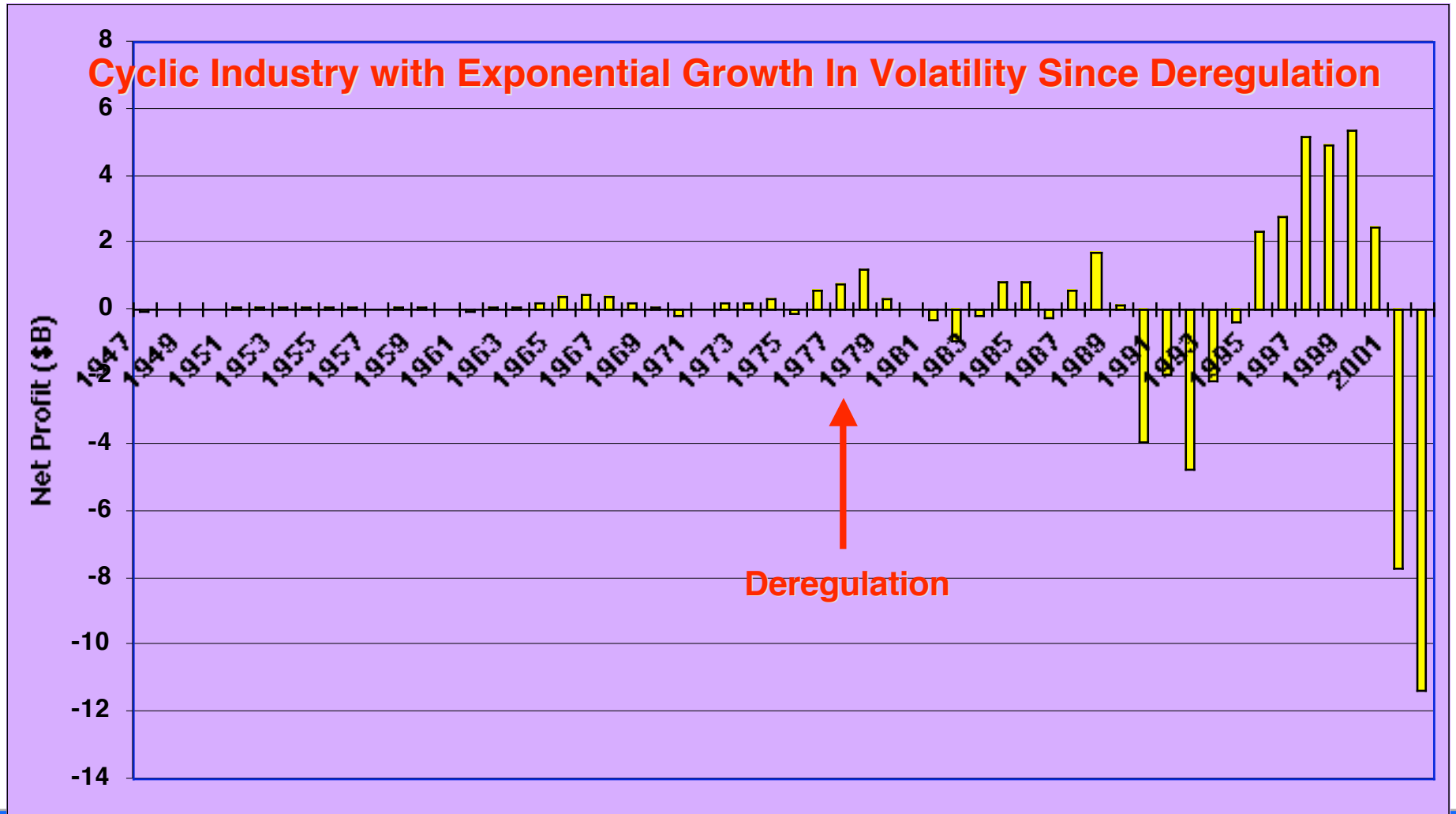


American AAL Flights (8/7/02)





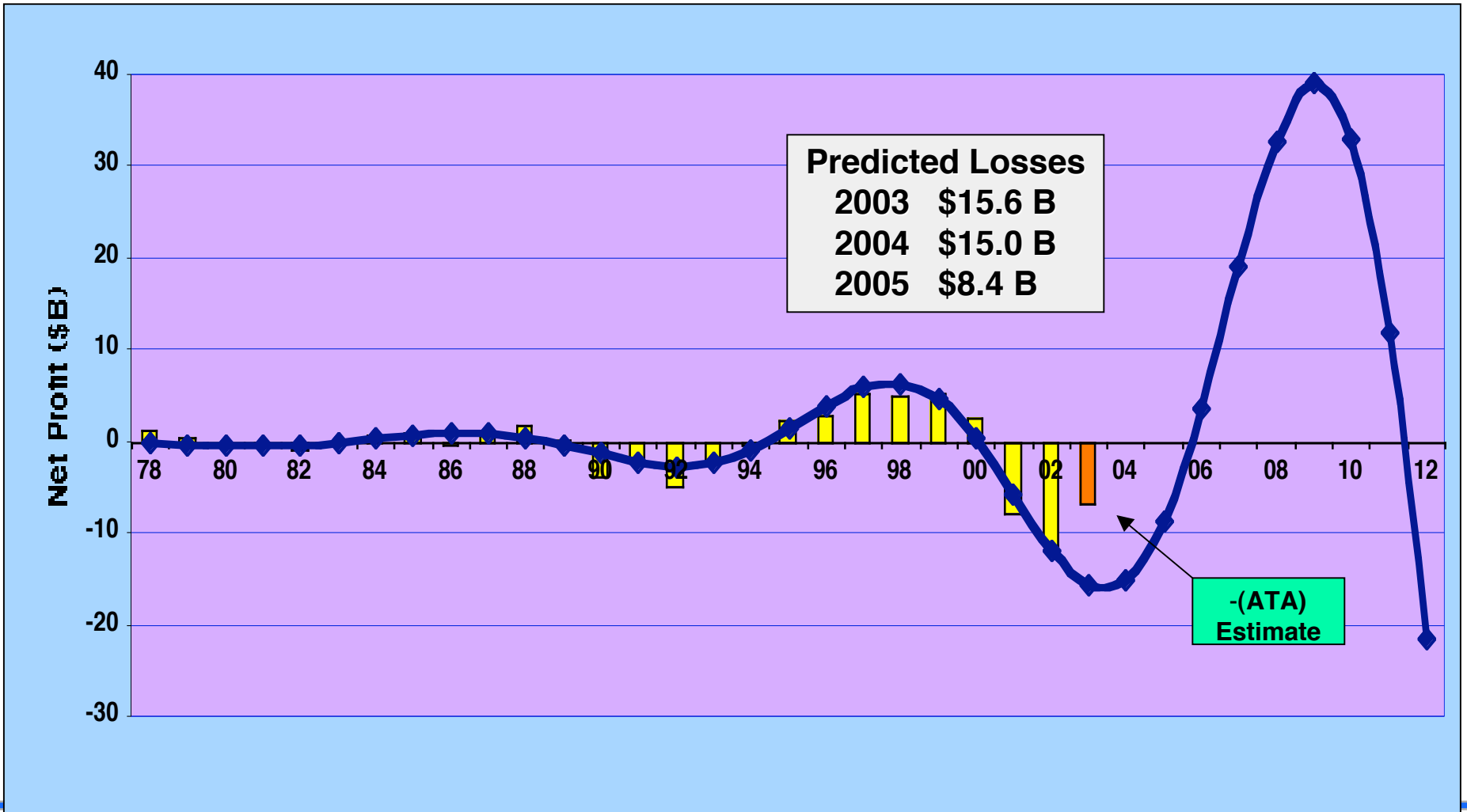
Macro Scale Drivers US Airline Net Profit





US Airlines Net Profit Model

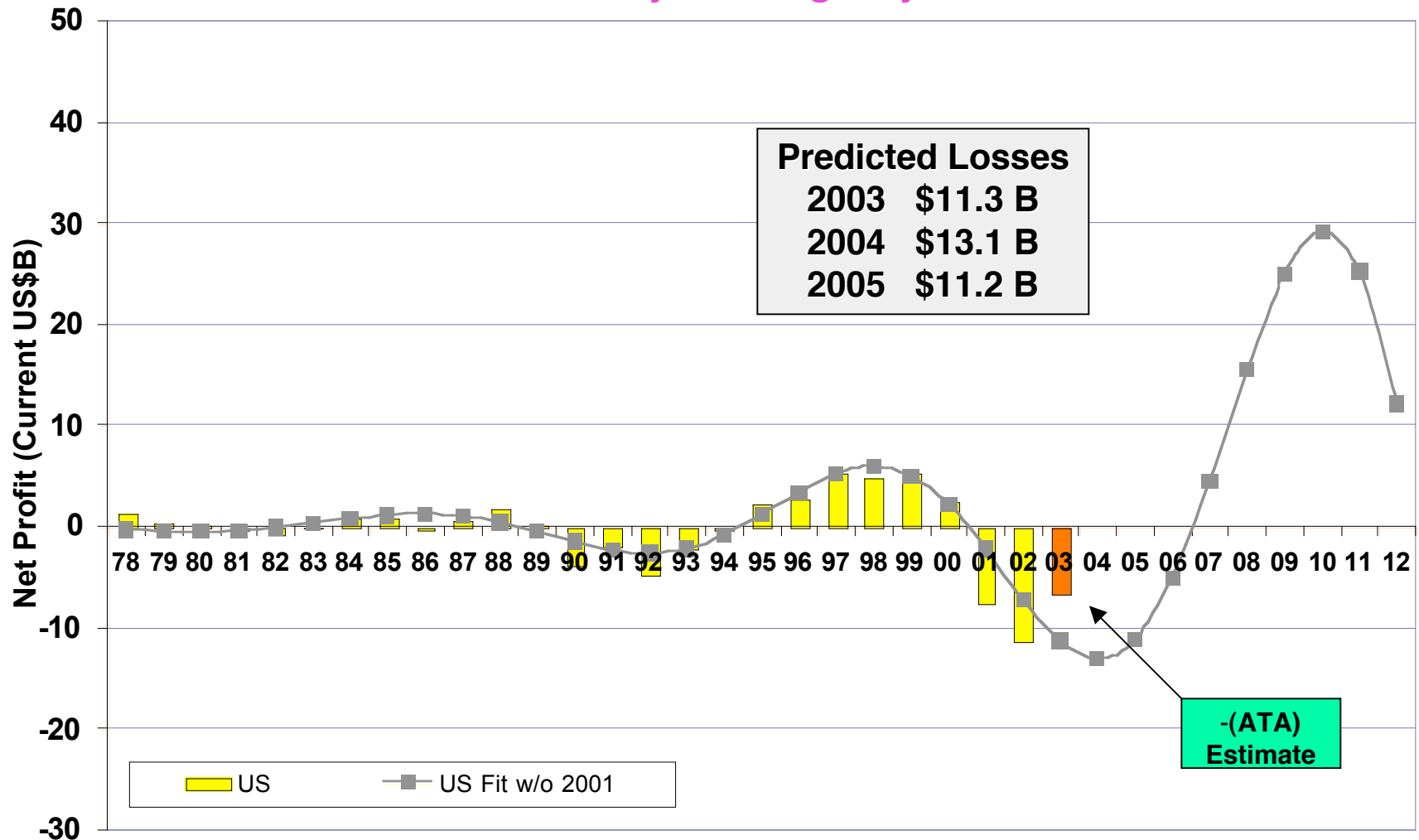
Best Fit of Undamped Oscillation
Cycle Period = 11.3 yr eFolding Time = 6.3 yr





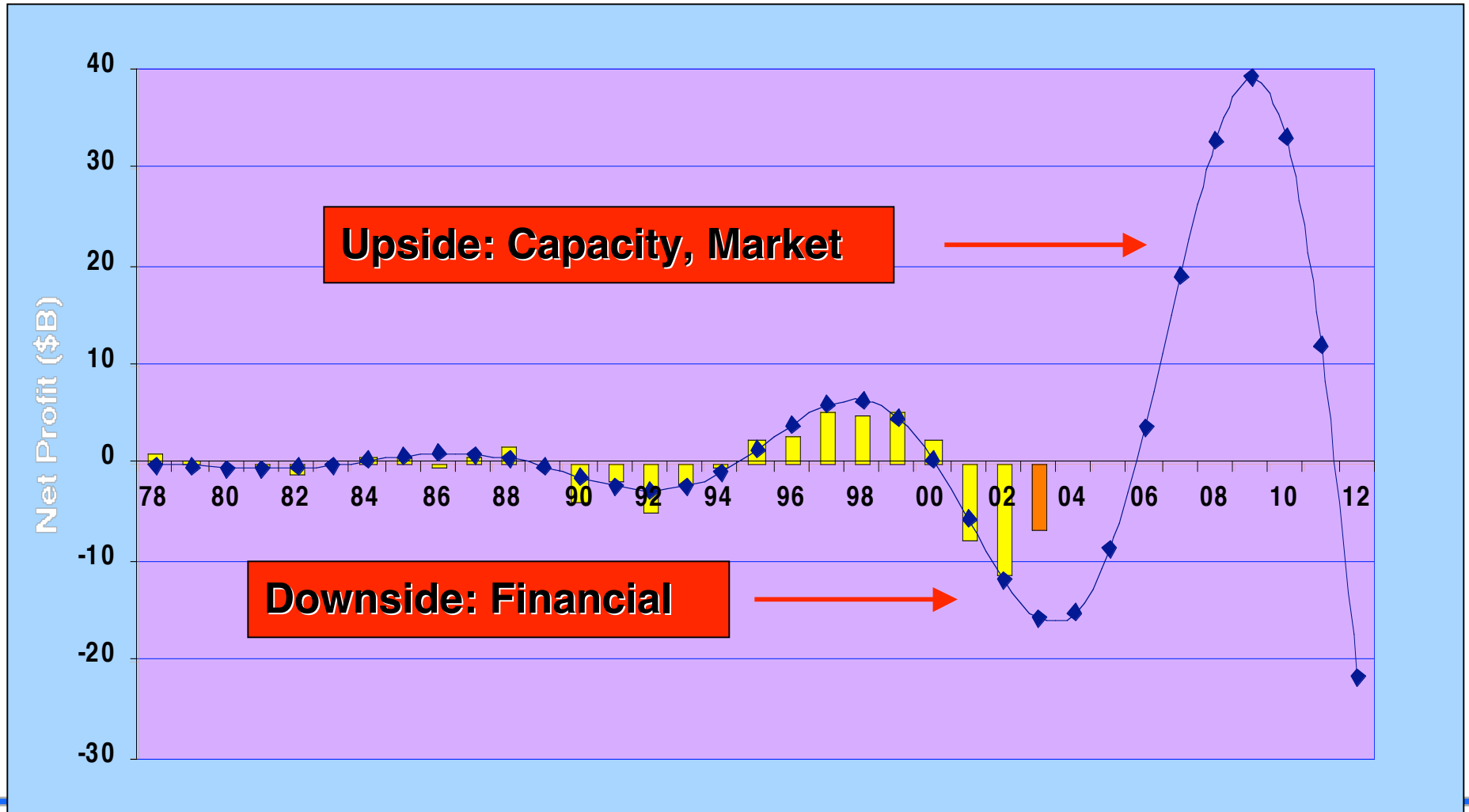
September 11 Does not Significantly Change Trend

Cycle Period = 12.1 yr eFolding Time = 7.6 yr
Analysis using only data before 2001





Growth Limits Constraints vs Damping



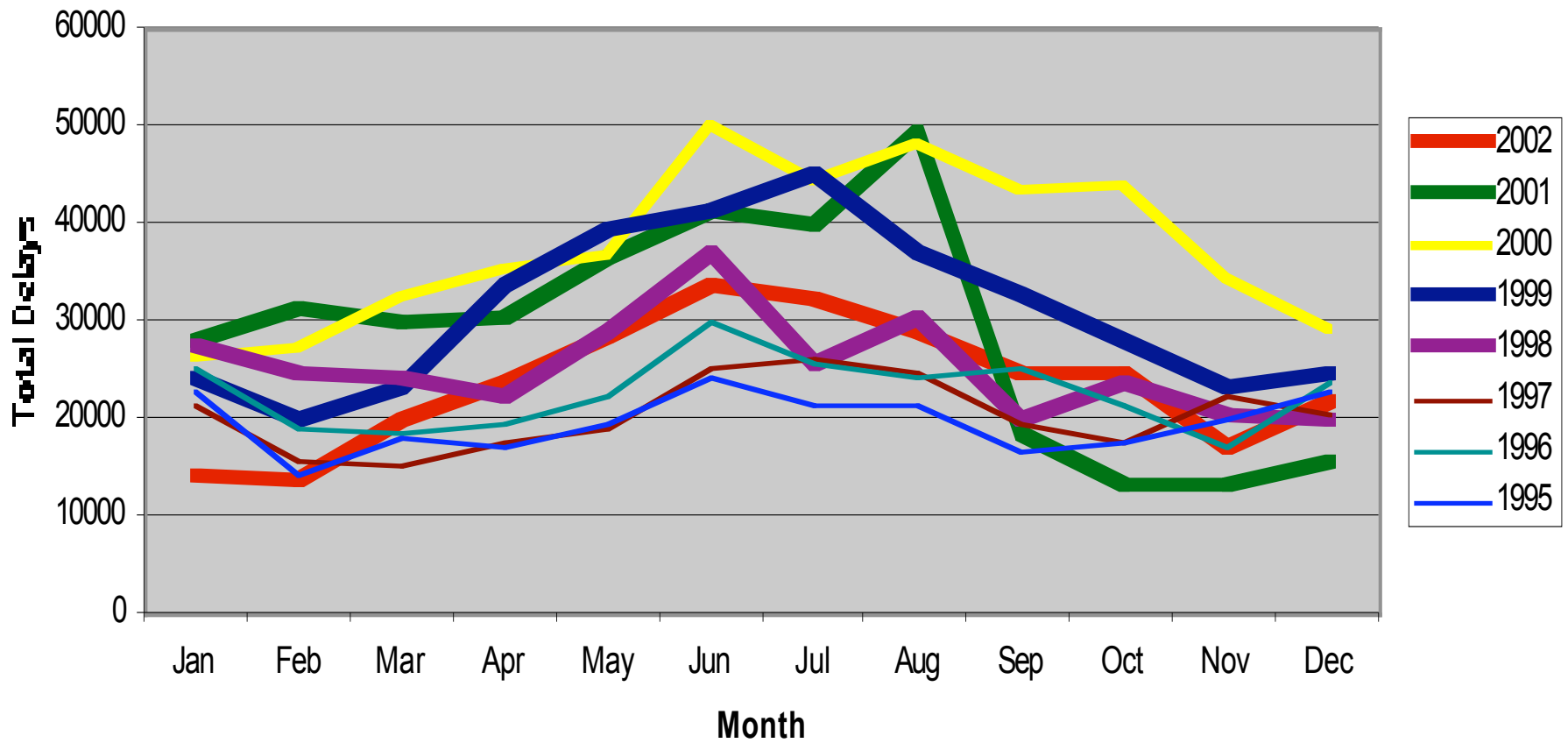


Issues



Capacity Issues US Flight Delays

OPSNET National Delays





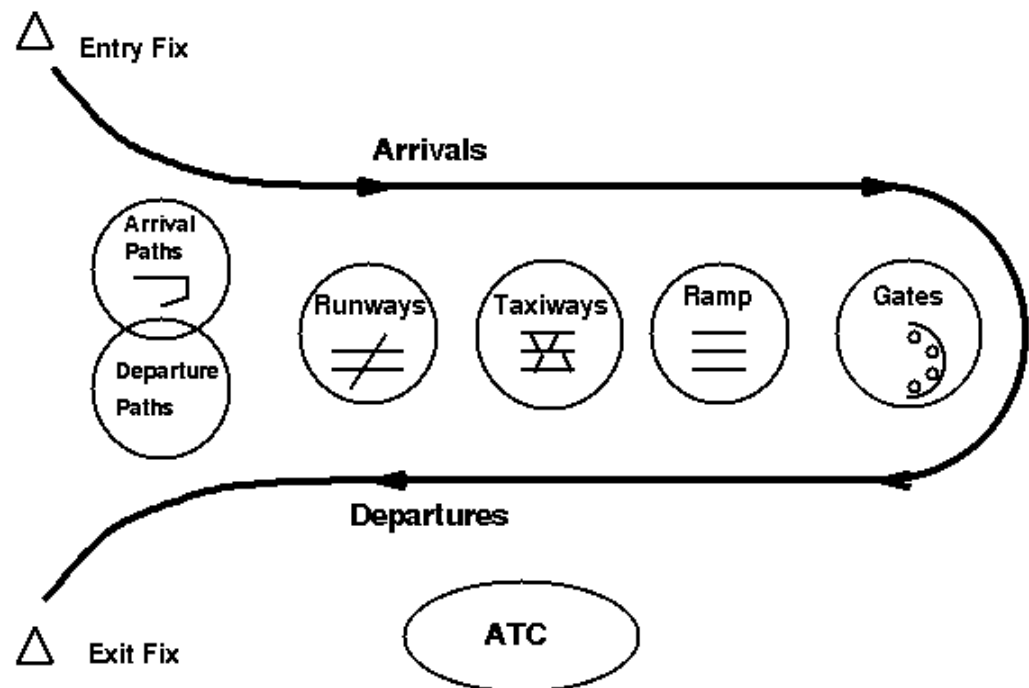
Capacity Limit Factors

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



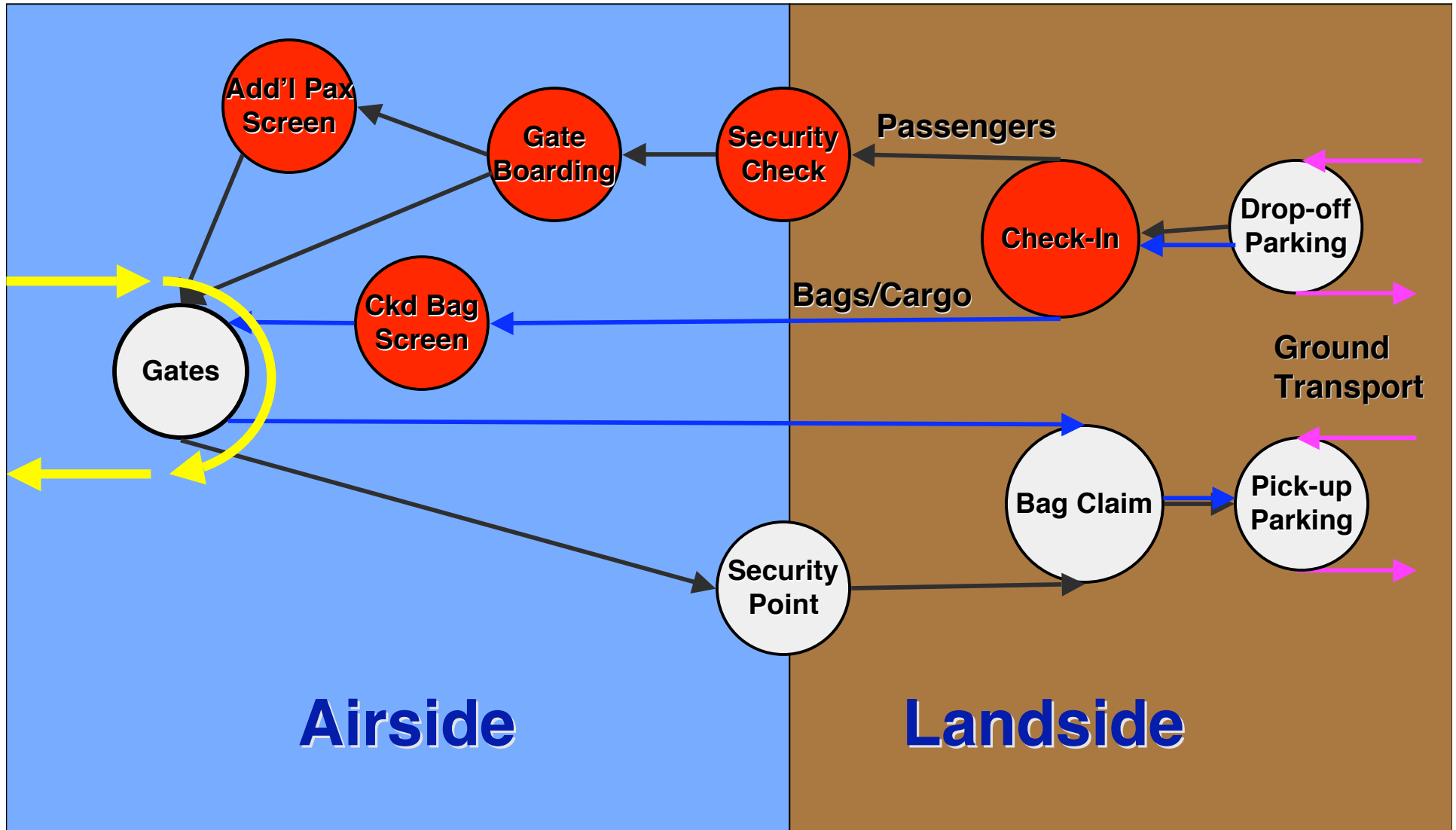
Airport System Capacity Limit Factors

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





Key Terminal System Flows (adaptive system - impedance matching)





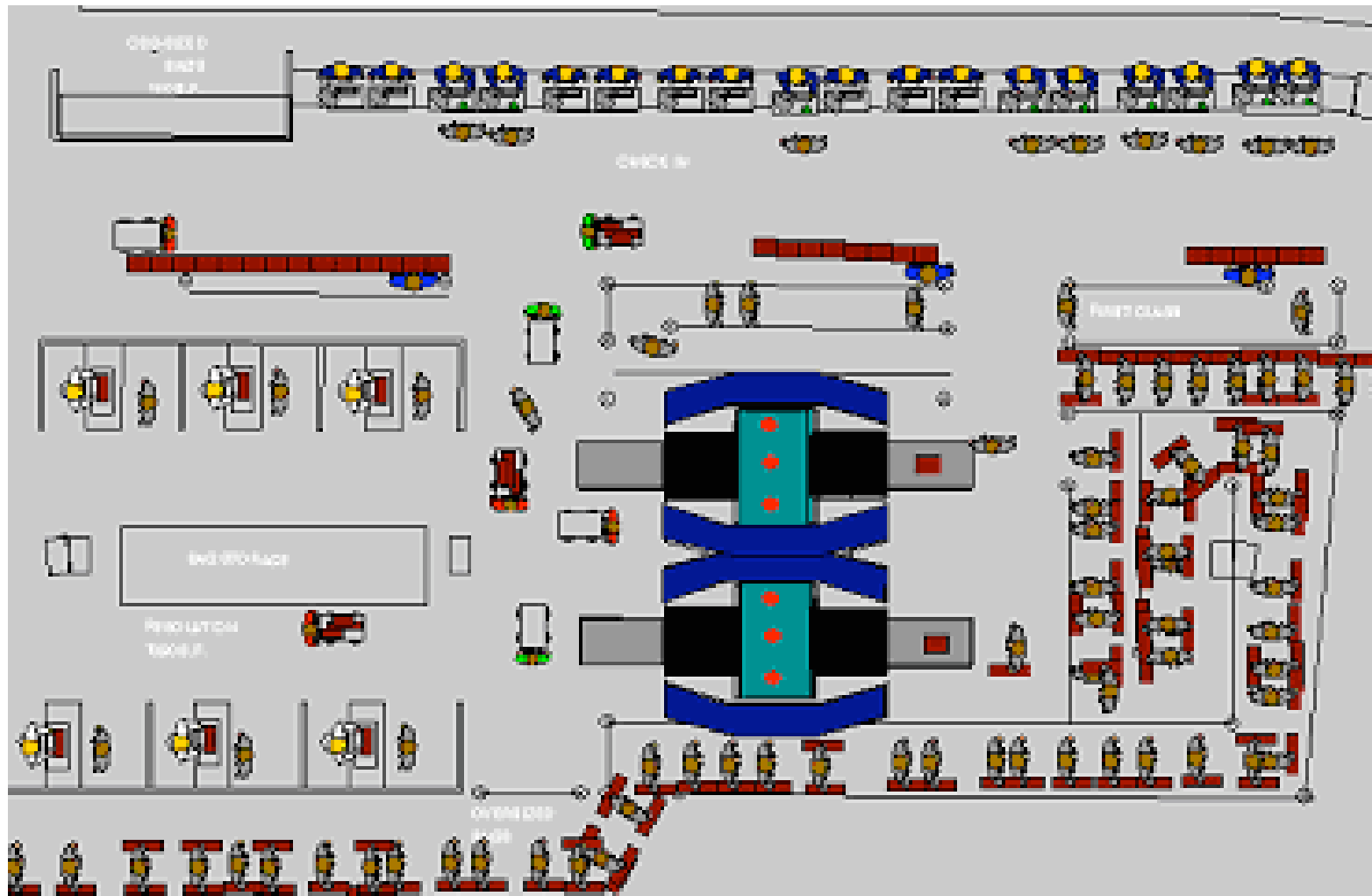
CTX 9000 Explosive Detector



500 Bags/hr



Example EDS Before Ticketing Check In



Source: Transsolutions Website



Other Threats

Portable SAMs

SAM-7 Fired at Arkia Airlines B757-300 Mombassa Kenya, Nov 2002





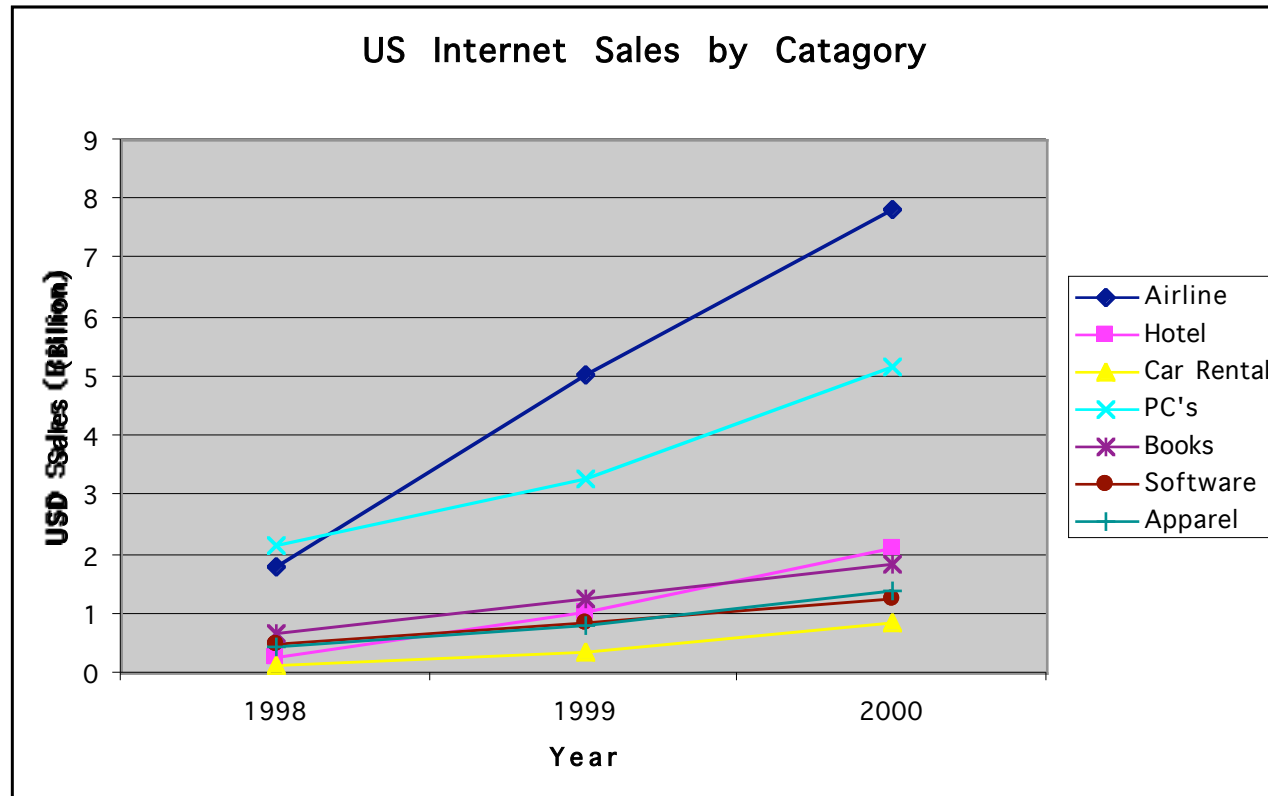
Electronic Processing

- **Airline Tickets #1 Web Product by Value**
 - ❑ Browser 1st page effect on marketing
- **Increase in e-Tickets**
 - ❑ Interlining of e-Tickets
- **Kiosk check-in**
- **CAPPS II**





Distribution

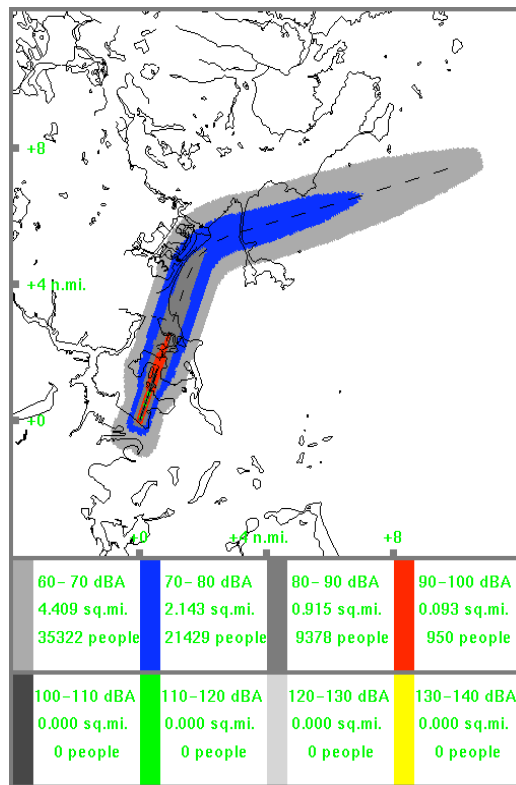


- - Reduction in commissions to travel agents
- - Shift to e-tickets (additional charges for paper tickets)
- - Increased restrictions on low fares (USAir charges)



Environmental Issues

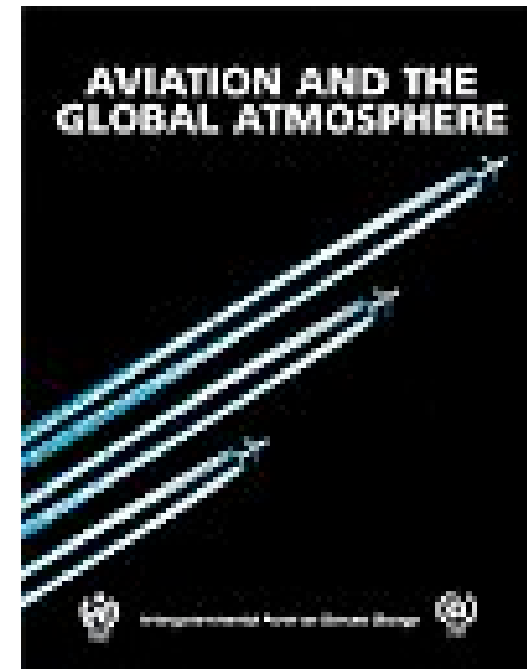
Noise



Stage 4 (Equipment)

Airports (Capacity)

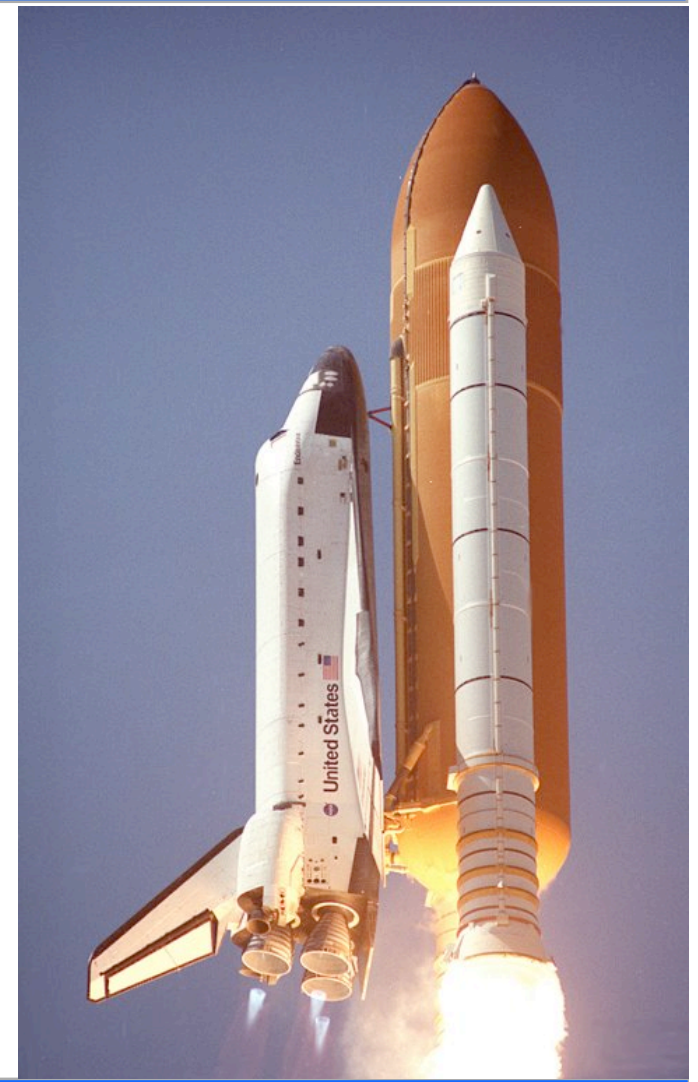
Emissions



Intergovernmental Panel on Climate Change



Replacement Vehicles





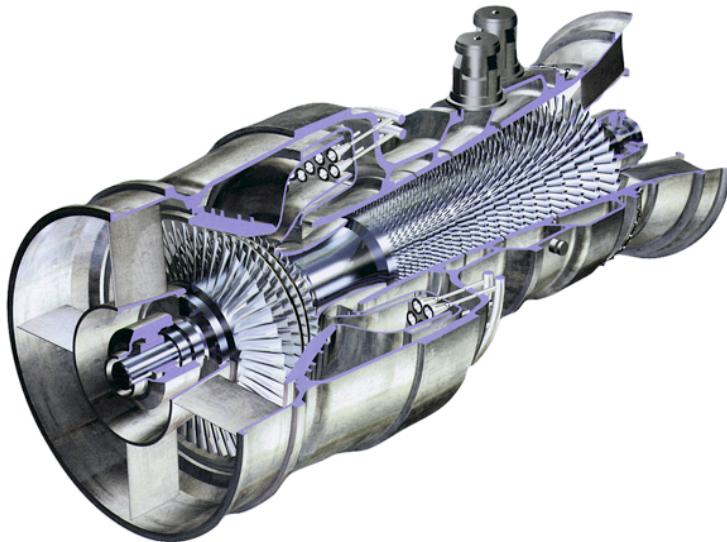
Possibilities

- **Technologies**
 - **New Operating Paradigms**
 - **New Airports**
 - **New Vehicles**
 - **New Markets**
-



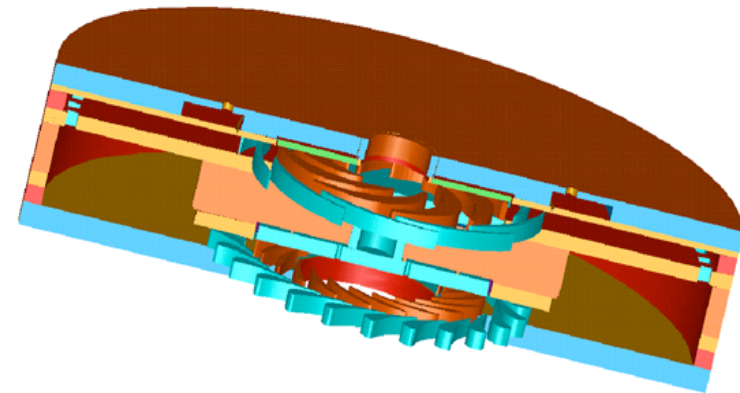
Nano-Technology Example “MICRO” Gas Turbines

“MACRO”



10,000 parts
Inlet dia = 2 meters
Airflow = 500 kg/sec
Weight = 400 tons
Power output = 150 MW

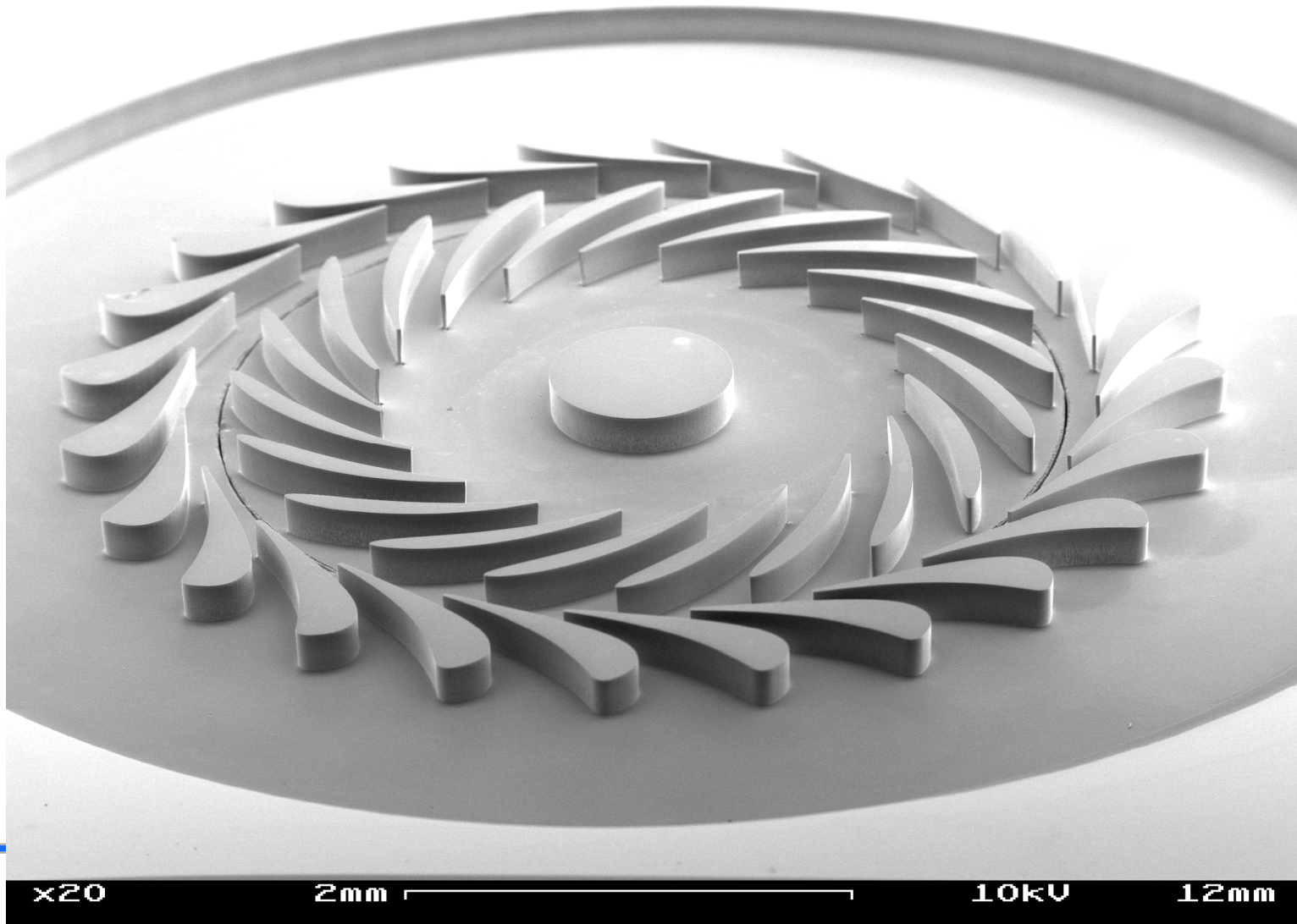
“MICRO”



2 parts
Inlet dia = 2 mm
Airflow = 0.25 g/sec
Weight = 1 gram
Power output = 10-50 watts



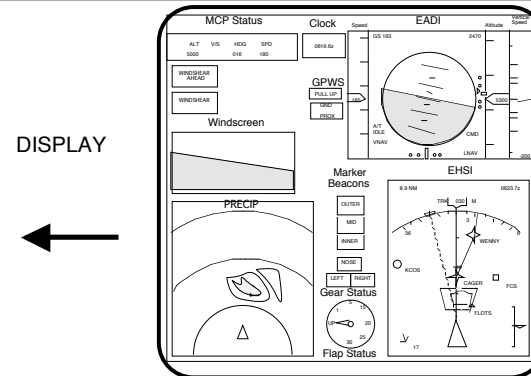
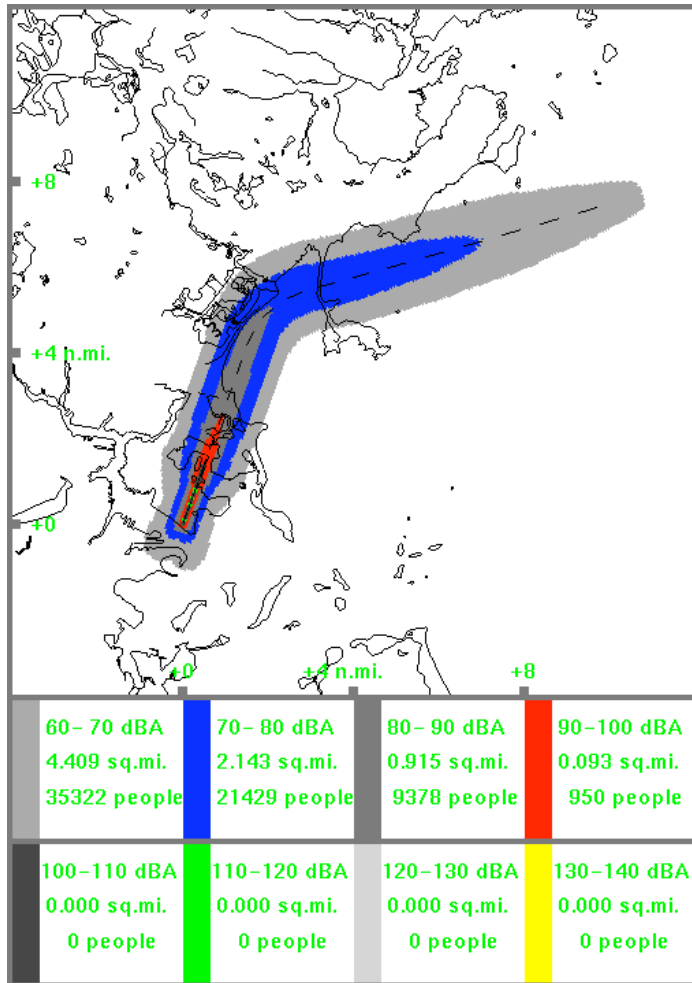
MIT-ARO MICROTURBINE





Example ATC Operating Paradigm

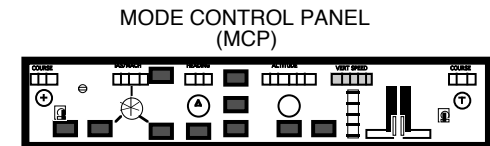
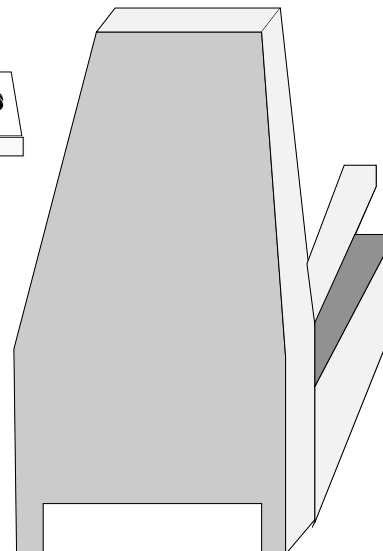
Minimal Noise Procedures



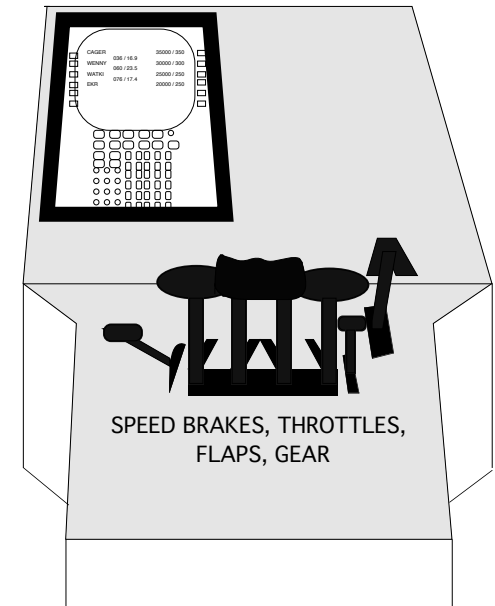
CONTROL STICK



PILOT'S CHAIR

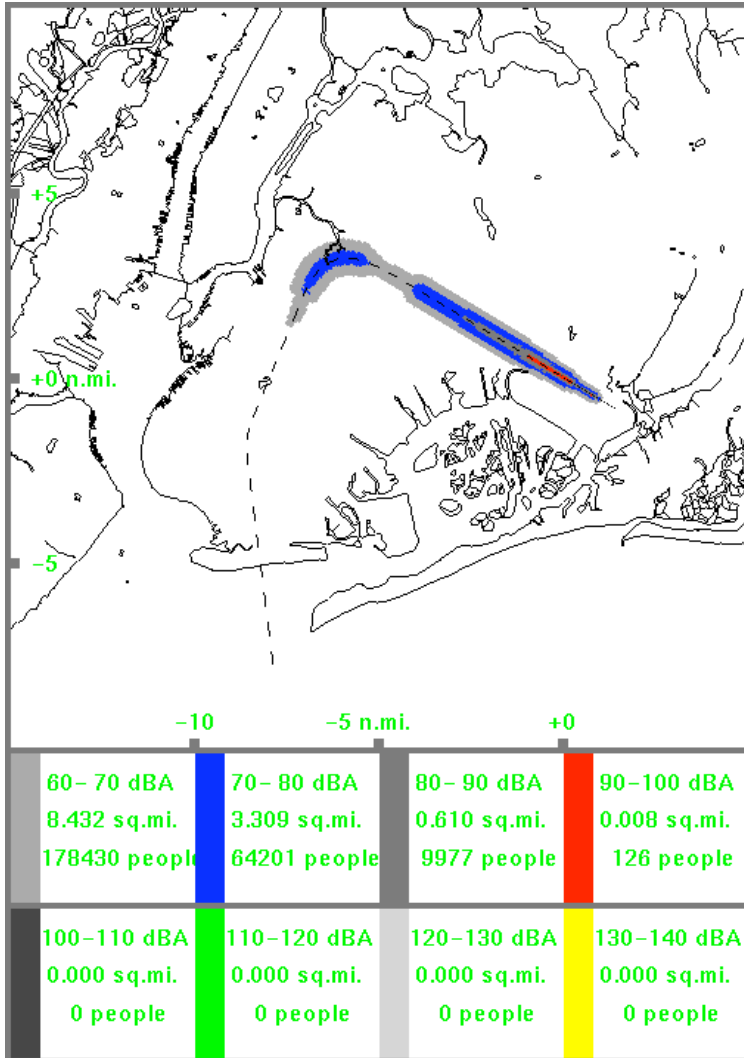


CONTROL DISPLAY UNIT

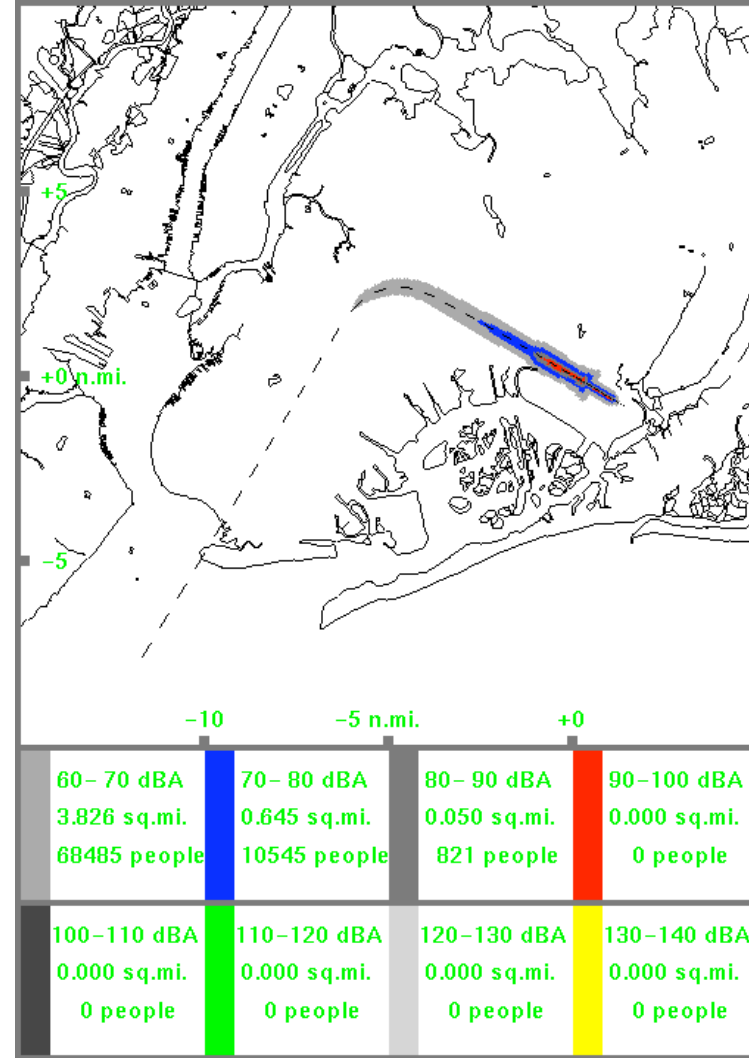




3° Decelerating Approach (JFK 13L)



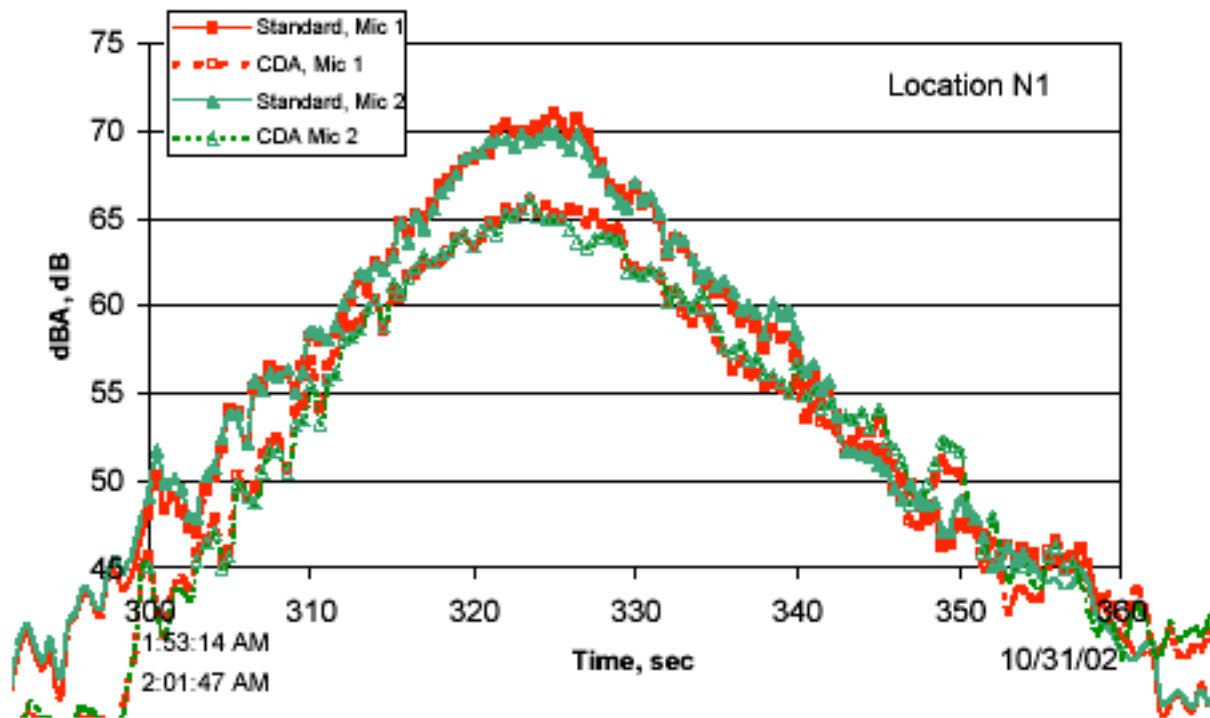
Existing ILS Approach



3° Decelerating Approach



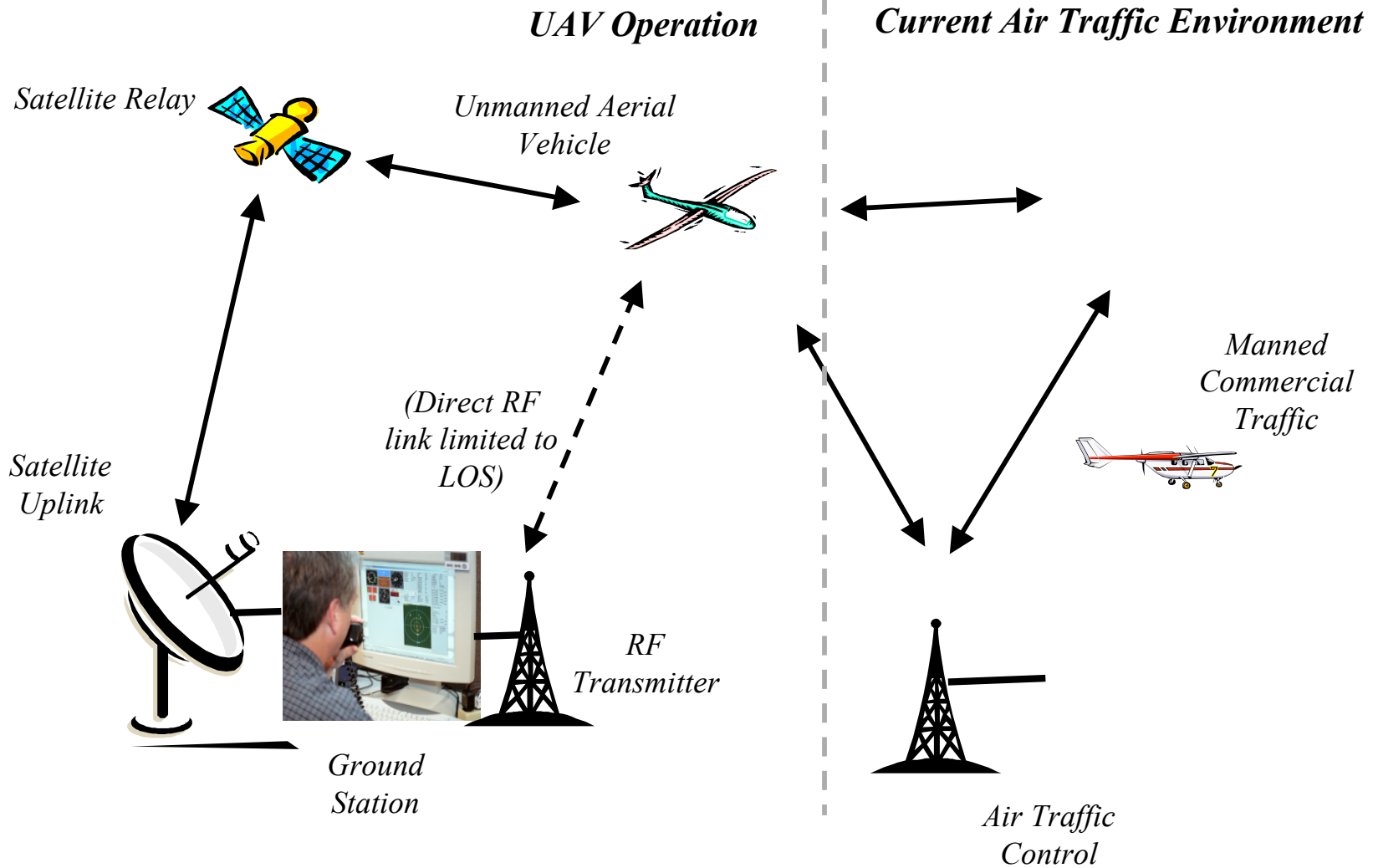
Continuous Descent Approach Louisville Flight Test



5 dBA Reduction Observed



Example ATC Operating Paradigm UAV Operation

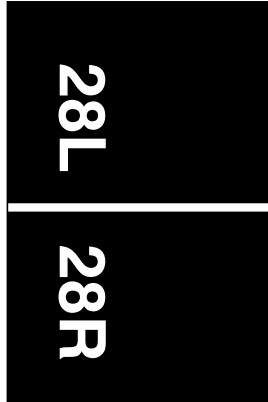
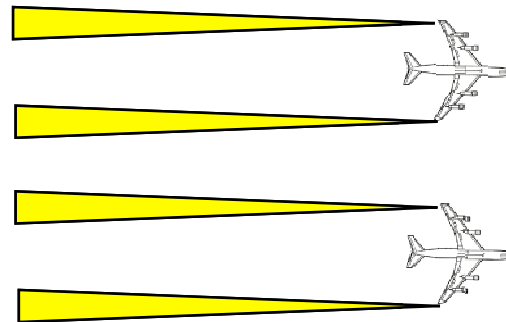
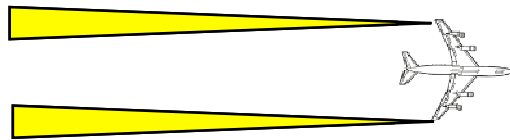




Example ATC Operating Paradigm

Formation Approaches

Lateral vs Longitudinal Wake Vortex Separation



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



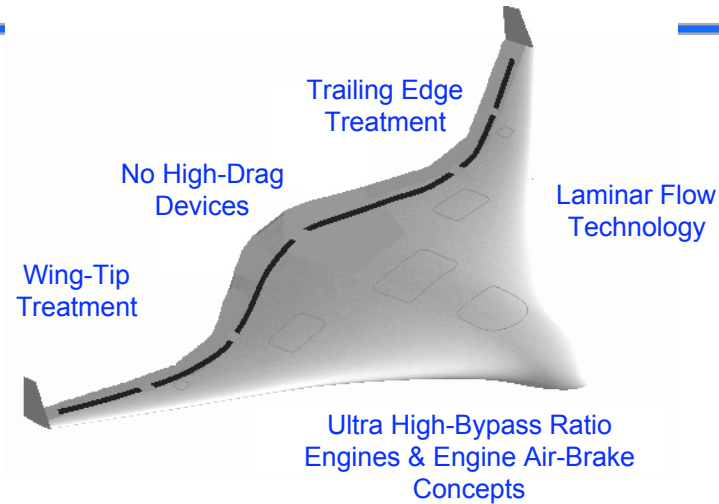
Example New Vehicle

Functionally Silent Commercial Aircraft



Noise signature conventional Aircraft:

- Sideline EPNL: 96.0 dB
- Cutback EPNL: 90.2 dB
- Approach EPNL: 98.5 dB



Silent Aircraft concepts are targeted to:

- Reduce airframe and propulsion noise by **20 to 30 dB**
- Improve quality of life near airports
- Reduce the operating and societal cost of noise
- Enable growth of commercial air transportation

What do we mean by “silent”?

- “Silent” means sufficiently quiet that aircraft noise is less than background noise in a well populated area

Heretofore unasked technical question - “what would an aircraft look like that had ...”

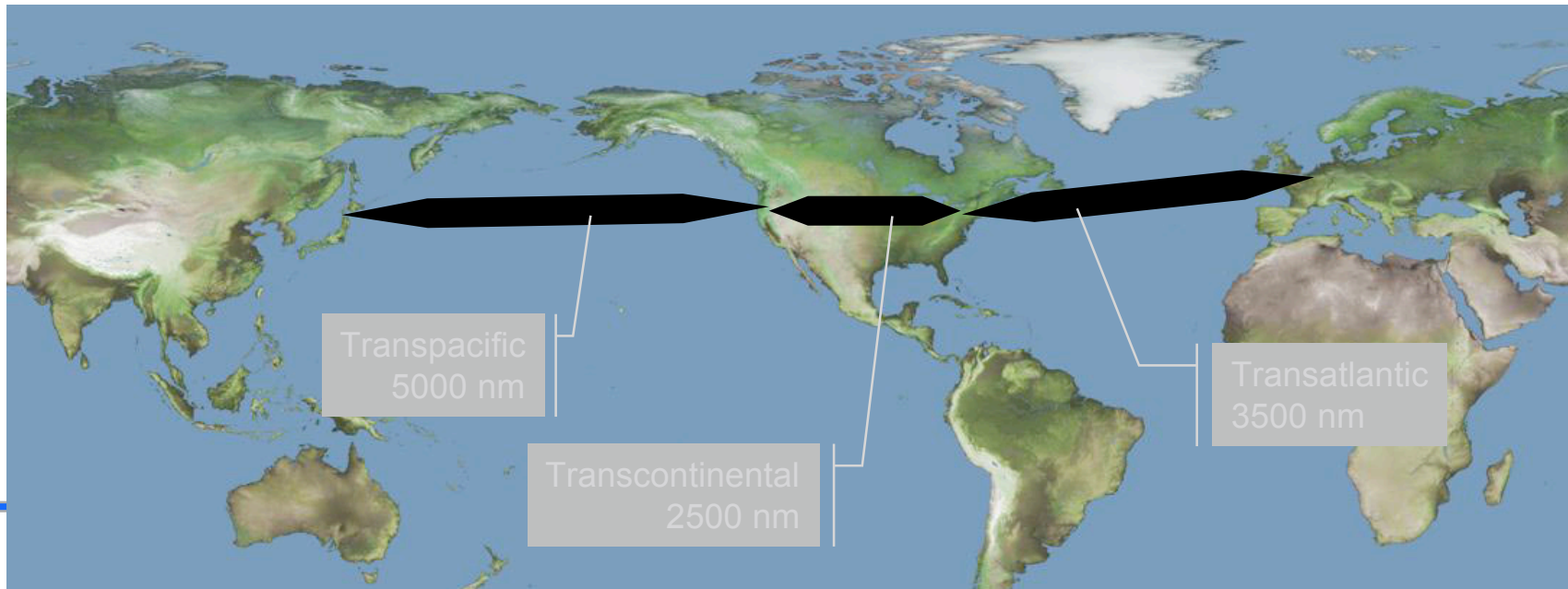
- Noise as a prime design variable?
- A design criterion which is a revolutionary step in noise reduction compared to present configurations?



Example New Vehicle

Quiet Super-Sonic Business Jet

- **Market Study**
 - ❑ Range
 - ◆ Trans-Atlantic (required), Trans-Pacific (desirable)
 - ❑ Supersonic over land highly desirable
- **Trans-Atlantic 8 - 15 passenger scheduled service viable**
- **15 Year Market**
 - ❑ 100 (Pessimistic) - 470+ (Optimistic)





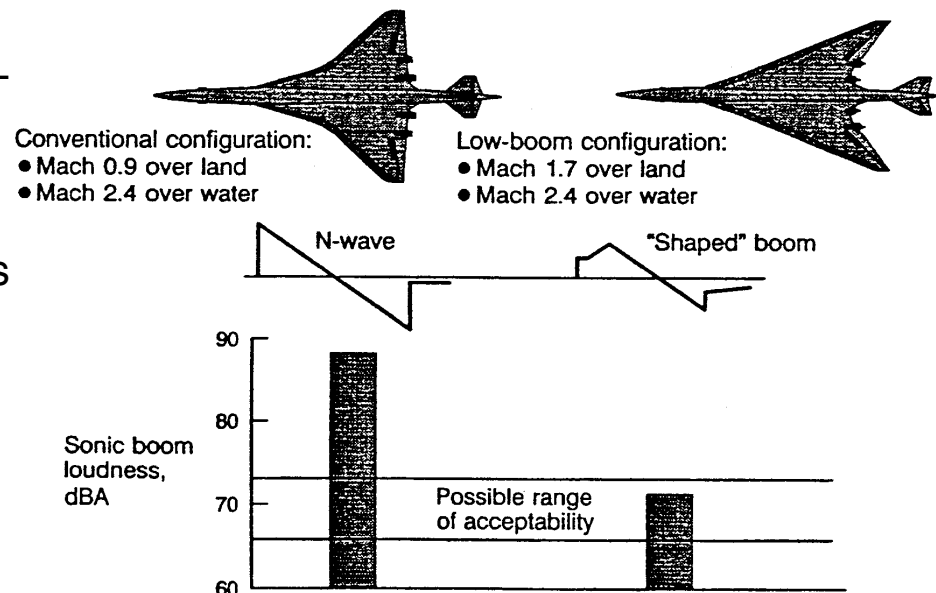
Aerodynamics - Sonic Boom

- **Boom shaping shows great promise**

- **Mitigate risk early with demonstrator**

- Boom shaping codes TRL 3-4 now*
- Bring up to 6-7 with demonstrator
- Define “acceptable” levels for boom
- Get FAA participation in tests

Figure 2. Conventional and Low-Boom Concepts Compared



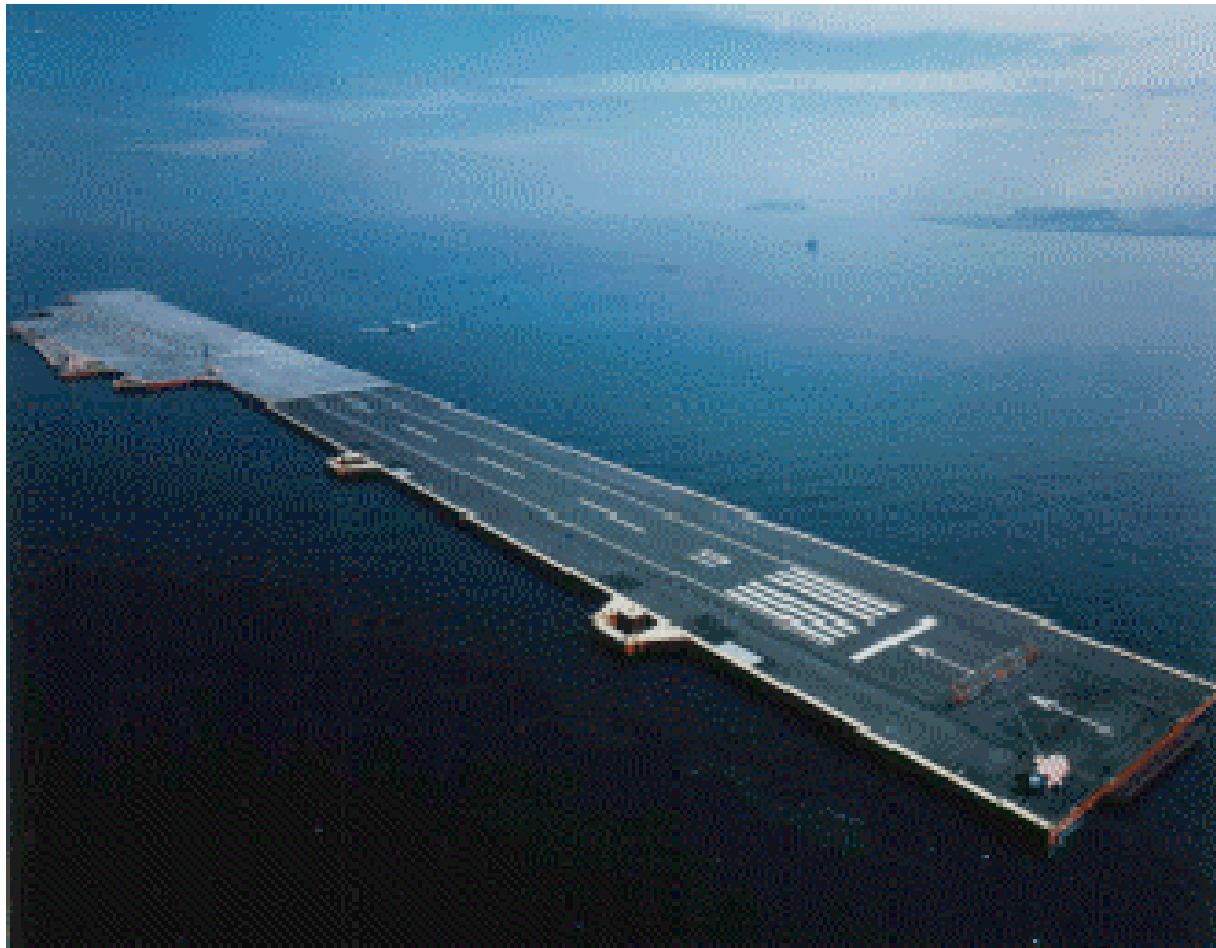
Source: Ruffin, MIT Presentation

* Peter Coen, MIT Presentation

Flight demonstrator reduces technological and regulatory risk



Example New Airports Mega-Float Concept

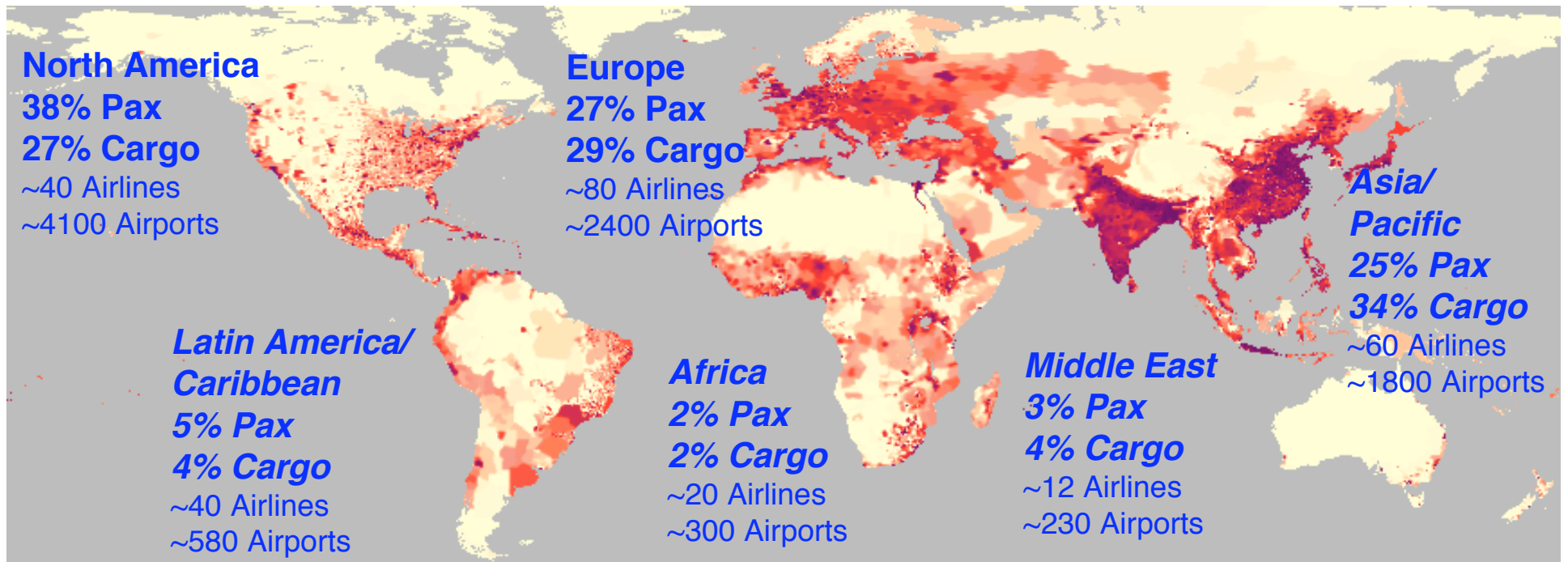


Tokyo Bay Experiment



Example New Markets

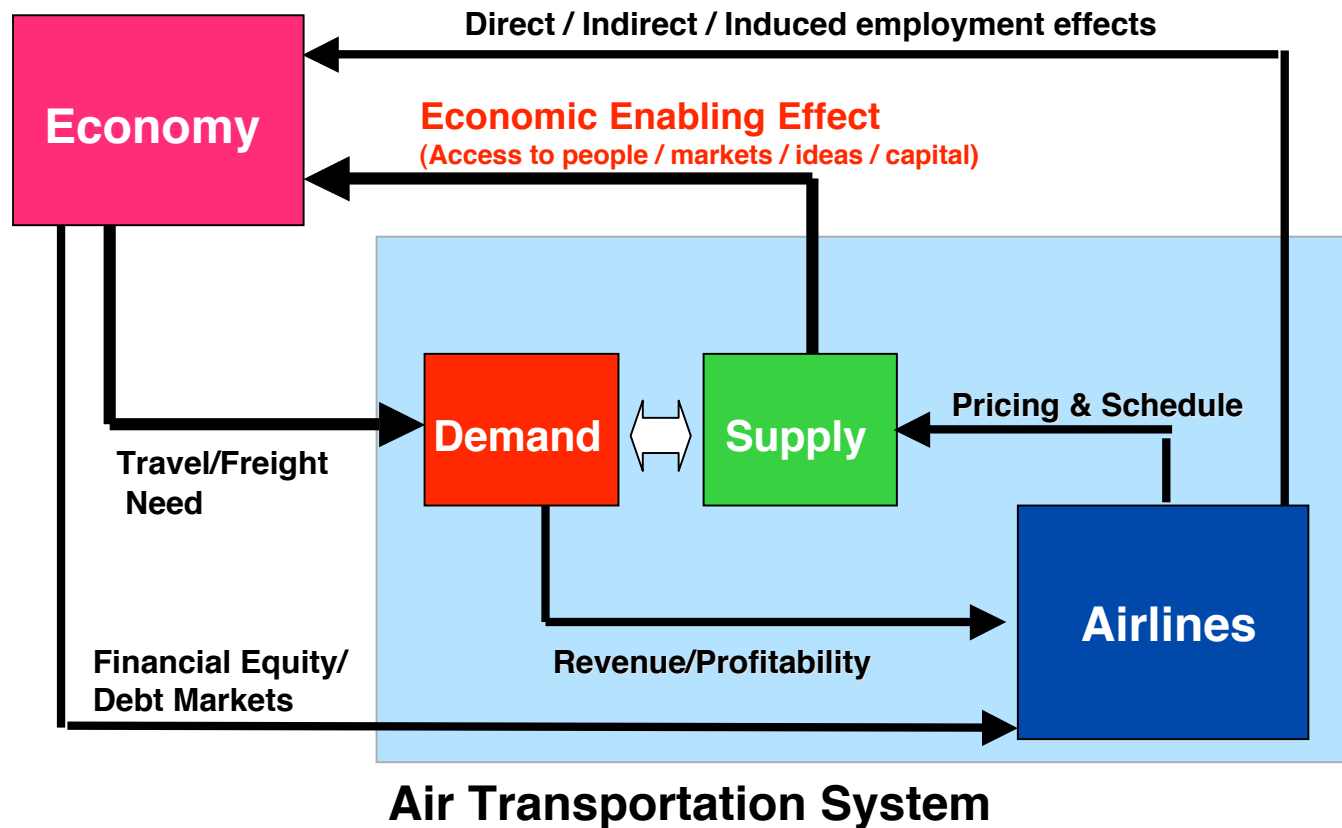
Air Transportation as Enabling Factor in Developing Regions



Infrastructure - Satellite Based Information Technologies have the potential to allow regions with immature air transportation infrastructure to rapidly reach parity with mature systems



Air Transportation as Enabling Factor in Developing Regions



- The Air Transportation Industry has an obligation to find economic models which support investment and economic development in these regions.