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Air Transportation System (ATS) Analysis:

Dynamic System Model of the ATS

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12/2005

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- George Donohue, John Shortle, C.H. Chen, Sasha Klein, Jonathan Drexler, Danyi Wang (GMU)

Summary

- U.S. Domestic Air Transportation System (ATS):
  - amazing success story over last century
  - significant contributor to the U.S. economy
- ATS is faced with (9) major challenges
- Use Dynamic System Model of ATS to understand:
  - cause-effect of challenges ?
  - can system “self-heal” ?

Summary

- Results of analysis:
  1. ATS exhibits *Time Constants* and *Equilibrium Points* that should be taken into account in strategic plans
     - Key metrics: (1) effective capacity, (2) demand
     - 75% of capacity rule
  2. Sustainability in a future ATS (e.g. NGATS) can be attained by "designing" mechanisms to:
     a) balance capacity and demand
     b) signal need for capacity enhancement
     c) incentivize innovation

Organization

1. Success & Challenges
2. Air Transportation System Model
3. Results of Analysis
4. Opportunities

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1. Successes, Challenges

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Air Transportation Faces Challenges

New United, Ready to Emerge from Chapter 11, Faces Final Legal Tests
By James Ott
01/08/2006 04:19:20 PM

GRAND EXIT

Can a trimmed-down U
domestic arena and in
super carriers? That

Northwest Pilots Will Strike If Newco Subsidiar
By Steven Lott
01/10/2006 08:45:42 AM

essentially elimin
seats (DAILY, O
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Executive Coun
strategy.

EU: Airlines Must Compensate Passengers

By AOIFE WHITE
The Associated Press
Tuesday, January 10, 2006; 8:34 AM

BRUSSELS, Belgium -- European airlines lost a legal bid Tuesday that aimed to strike down new EU rules guaranteeing passengers c for flight delays or cancellations.

The European Court of First Instance said t were a fai didn't discriminat ing the air breach

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Los Angeles World Airports to Undertake Historic Noise Studies That May Lead to Future Noise Restrictions at Los Angeles and Van Nuys Airports

Monday March 21, 2005 7:19 pm ET

Actions May Lead to Ban on Easterly Departures from LAX During Over-Ocean Operations; VNY Study is First Attempt in U.S. to Implement Multiple Noise and Access Restrictions

LOS ANGELES, March 21, 2005 (PRIMEZONE) -- The Los Angeles Board of Airport Commissioners today awarded a $6,482,085 contract to Harris Miller Miller and Hanson, Inc., of Burlington, Mass., for noise studies at Los Angeles International (LAX) and Van Nuys (VNY) Airports. The studies will support efforts to seek restrictions from the federal government on future noise generation and aircraft operations. Los Angeles World Airports (LAWA) is the first airport authority in the United States to embark on two simultaneous Part 161 studies at separate airports. In addition, the VNY study is the first in the U.S. to attempt to implement multiple proposed noise and access restrictions.

FAA: Atlanta Airport Is Busiest in U.S.

Press
y 3, 2006; 4:56 PM

artsfield-Jackson Atlanta International Airport has topped
International Airport as the nation's busies
ngs, the Federal Avia

MWAA Bonds Get Solid Ratings Despite Independence Air Exodus
By Kimberly Johnson
01/10/2006 08:55:27 AM

thority (MWAA) has received solid marks from
MWAA's issuance of

In Announcing Increases, FAA Chief Says Tops of Pay Bands Will Be Raised

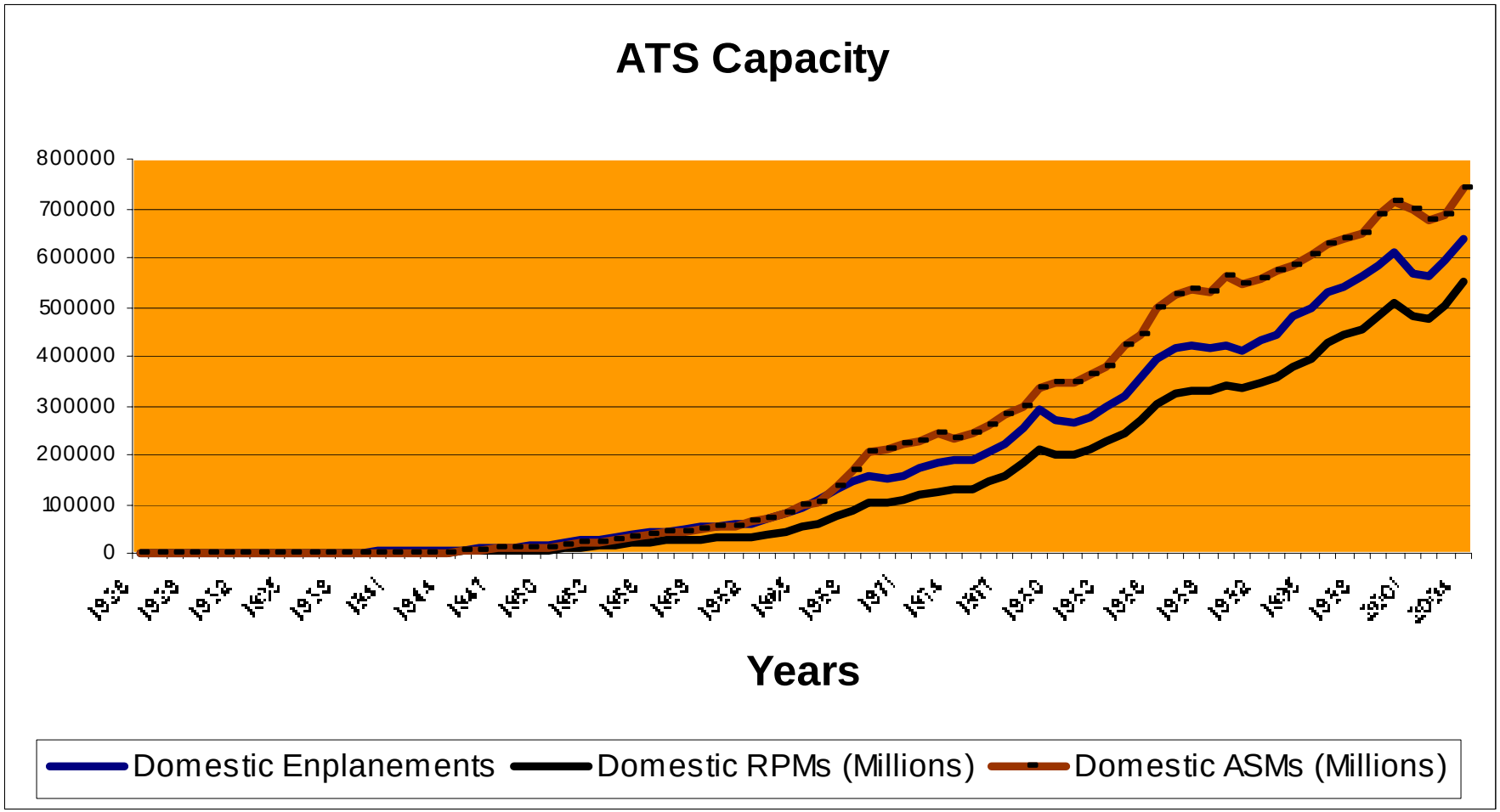
By Stephen Barr

Friday, January 6, 2006; Page B02

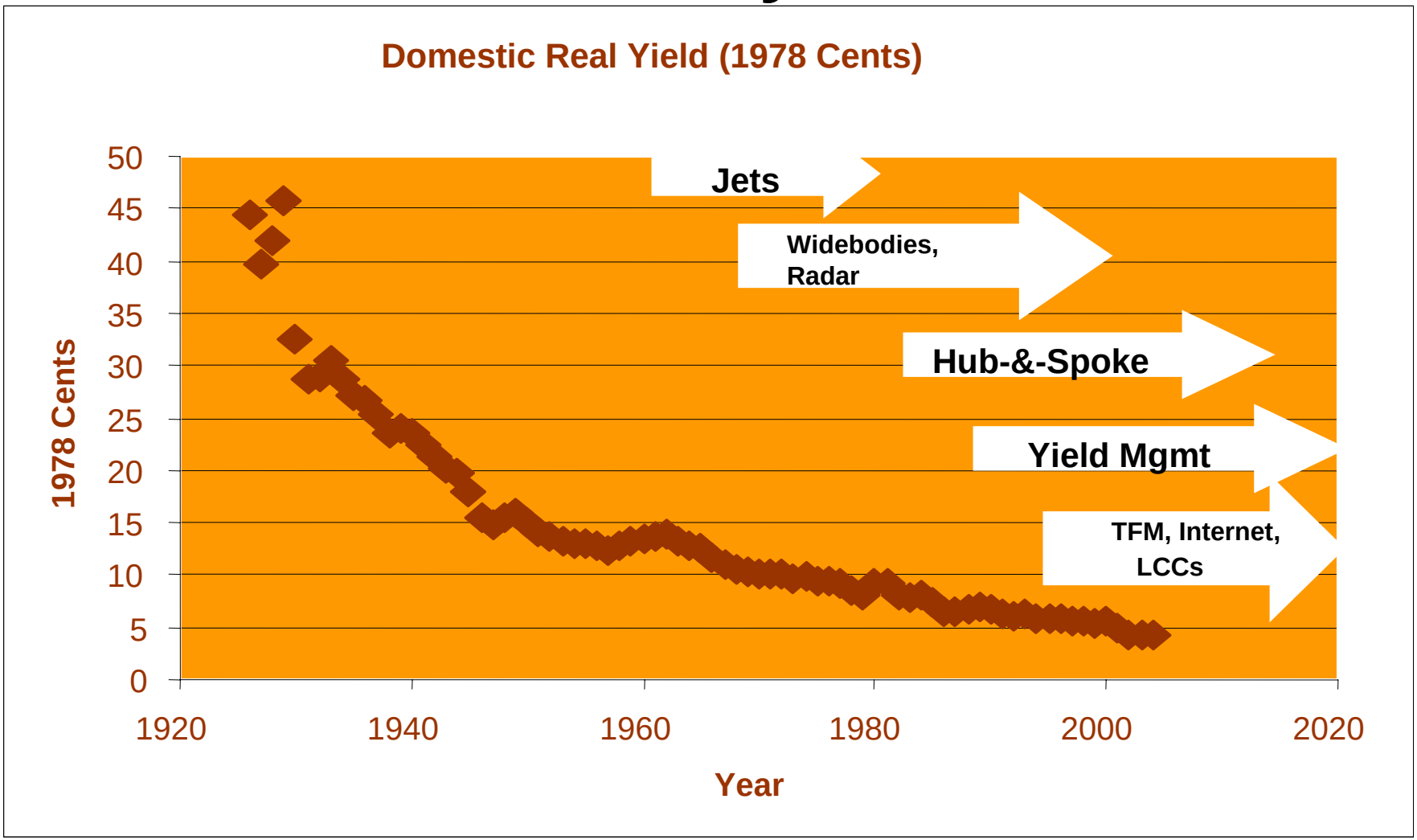
The Federal Aviation Administration, one of the few agencies to link pay to performance, announced yesterday that most FAA employees will receive a 3.1 percent salary increase and an additional 1 percent, on average, in a locality pay raise.

The performance raise, known as an "organizational success increase," hinged on whether the FAA met a series of business and air traffic goals. Among those eligible for the raise are 19,000 employees covered by the FAA's Core Compensation Plan and about 18,000 employees involved in air traffic control.

Success Story – Capacity



Success Story - Airfares



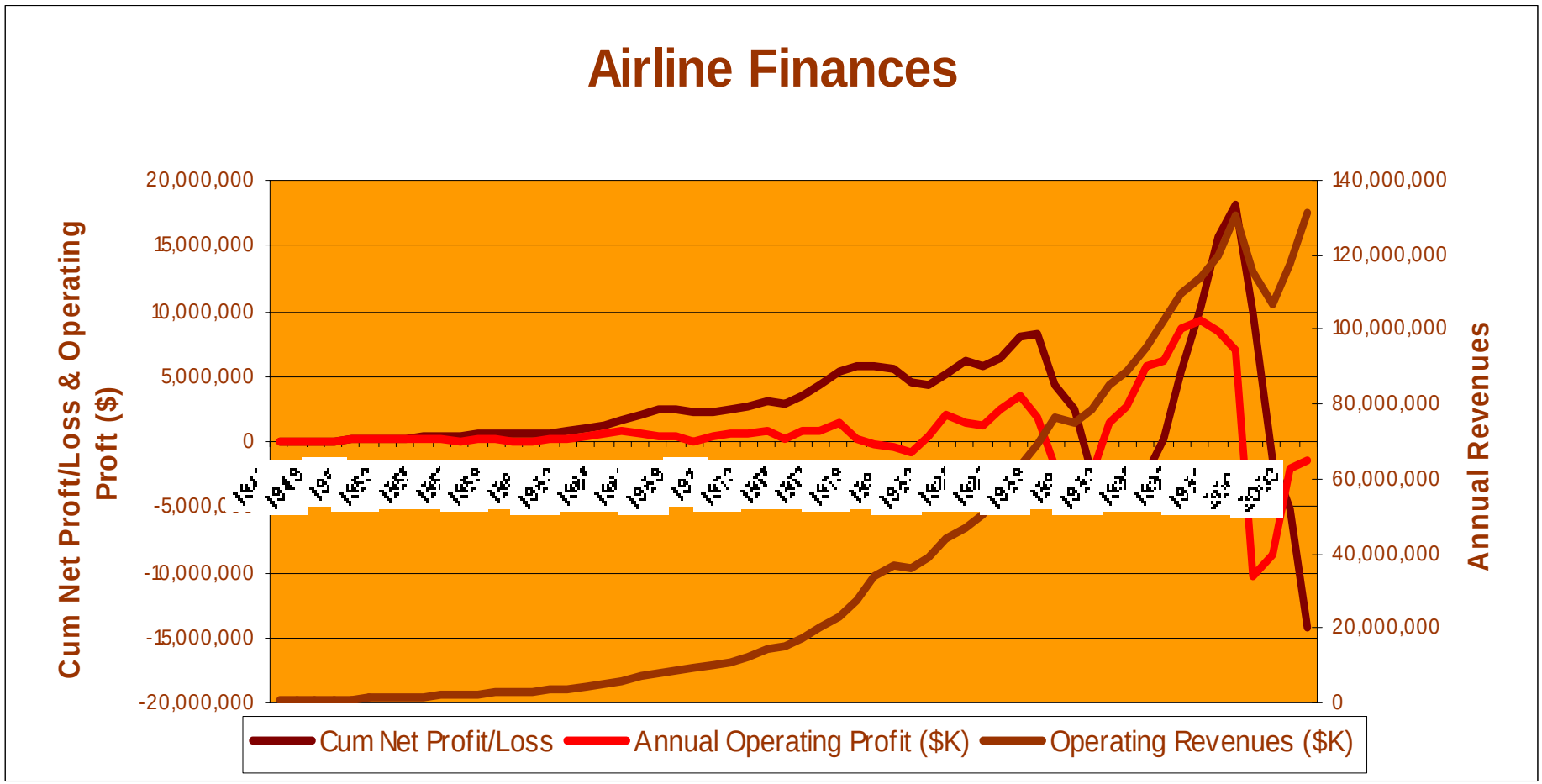
Source: ATA (2005)

Yield = Before Tax Revenue per Seat-Mile

Challenges ?

1. **Airline Profit/Loss Cycles**
   - Finding economic equilibrium?
2. **Equal Access**
   - Airlines consolidating service to high socio-economic metro areas
   - Eroding access from small communities (Essential Air Service subsidies)
3. **Passenger Experience**
   - delays and cancellations
4. Congestion
   - wasted resources and low predictability
5. **Environmental issues** (emmissions, noise)
6. **Airport & Airspace Trust Fund eroding**
7. **Airport & Airspace innovation cycle is dormant**
8. **ATC innovation cycle is dormant**
   - Modernization efforts effectively stalled
9. **ATC labor issues (salary, staffing)**

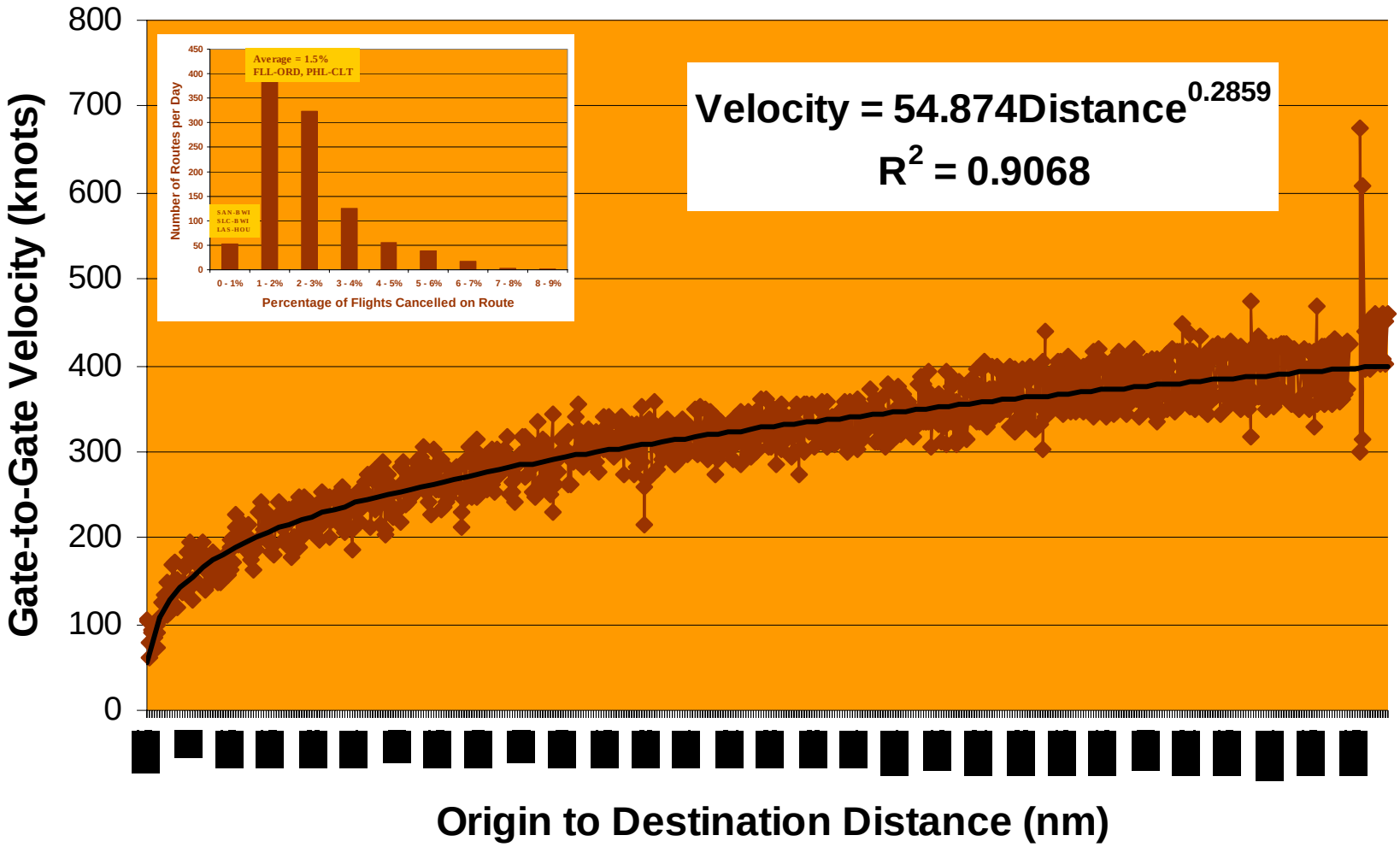
Challenges ? – Airline Finances



Source: ATA (2005)

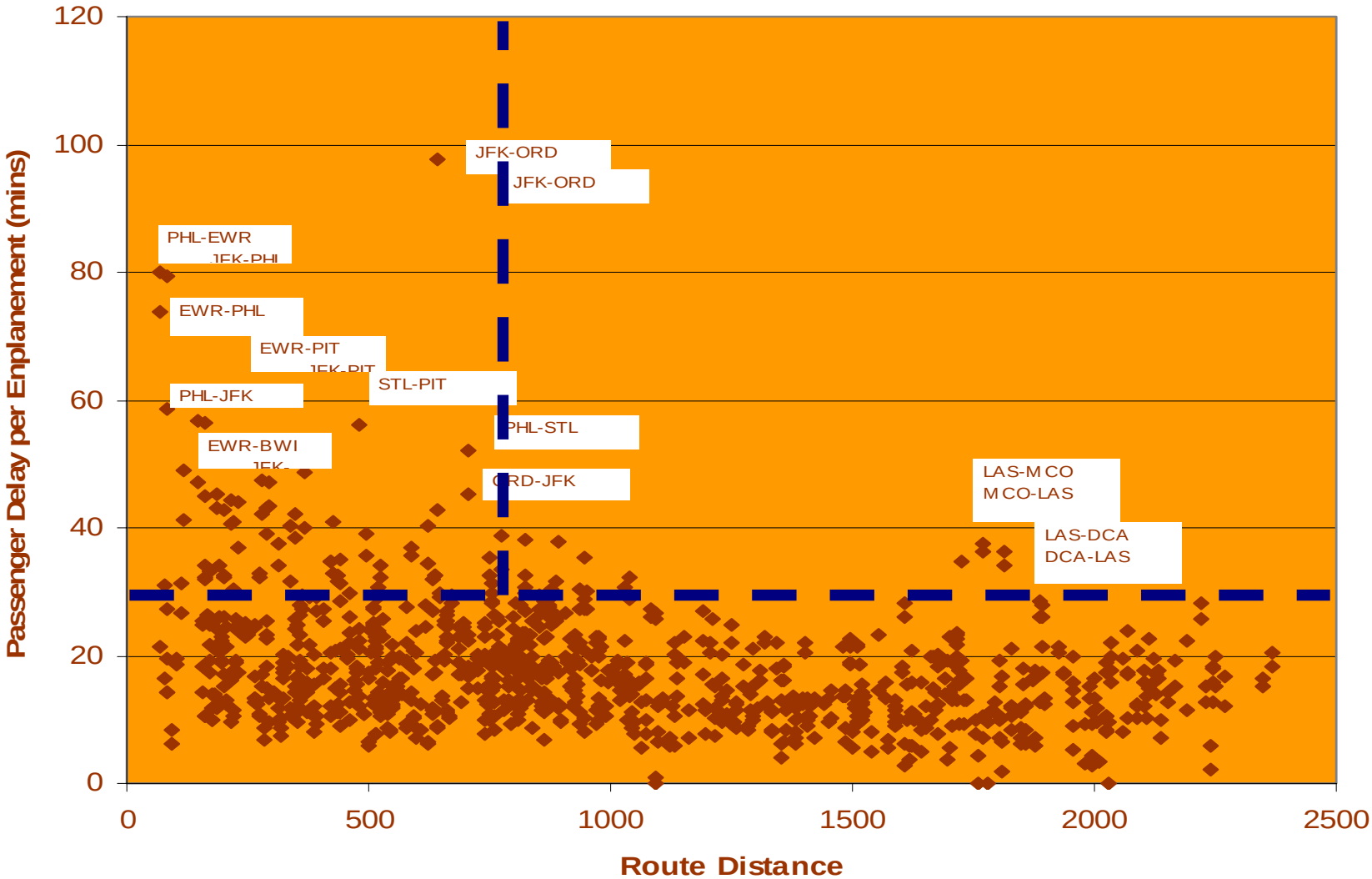
Symptom, not a cause

Challenges – Passenger Experience?

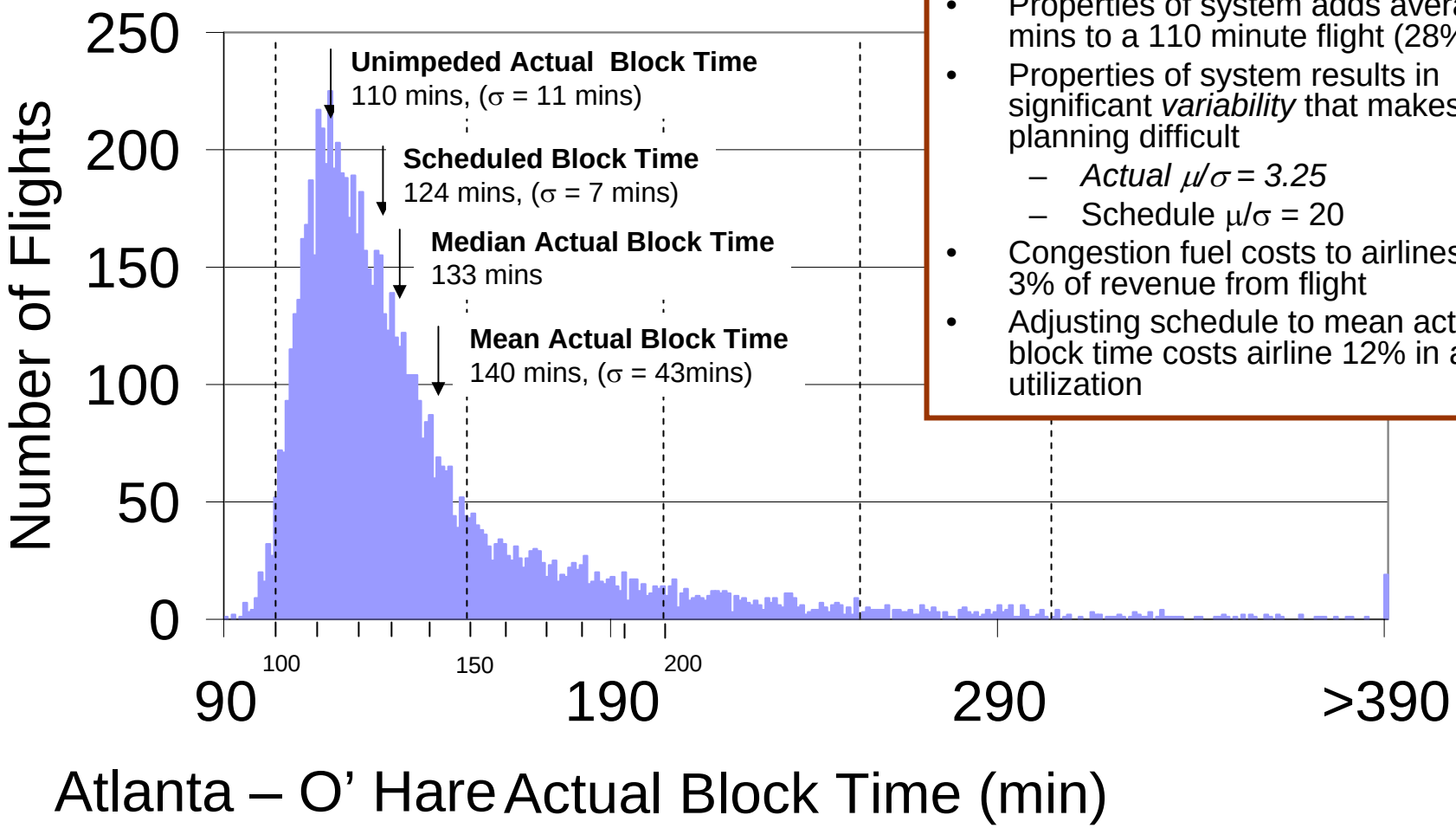


Data Prepared By: Danyi Wang

Challenges – Passenger Experience



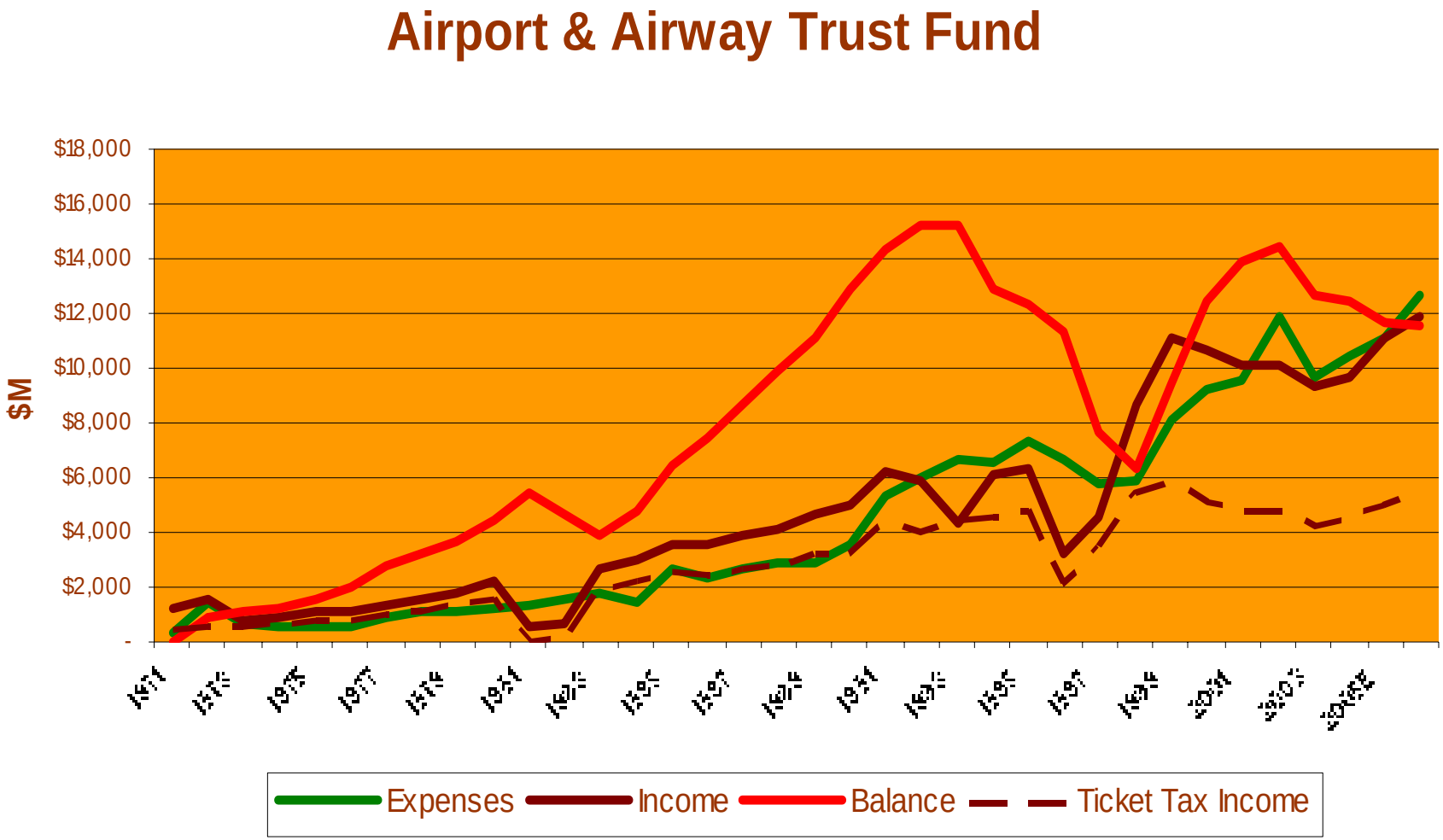
Challenges ? - Congestion



- Properties of system adds average 30 mins to a 110 minute flight (28%)
- Properties of system results in significant *variability* that makes planning difficult
  - *Actual $\mu/\sigma = 3.25$*
  - Schedule $\mu/\sigma = 20$
- Congestion fuel costs to airlines = 2-3% of revenue from flight
- Adjusting schedule to mean actual block time costs airline 12% in aircraft utilization

Schaar, Drexler, Sherry (2005)

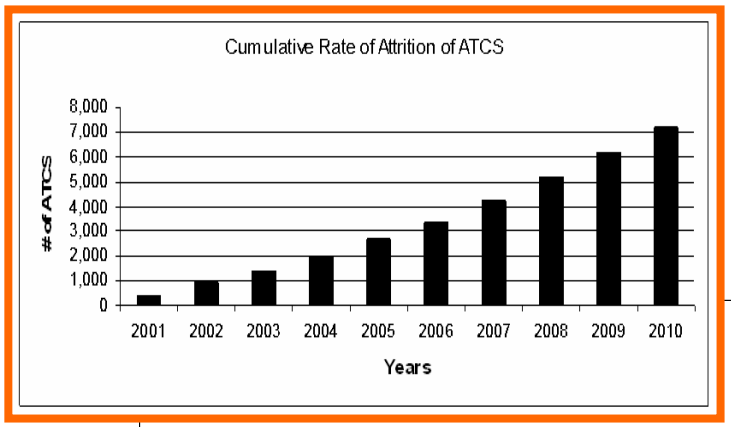
Challenges ? – A&ATF

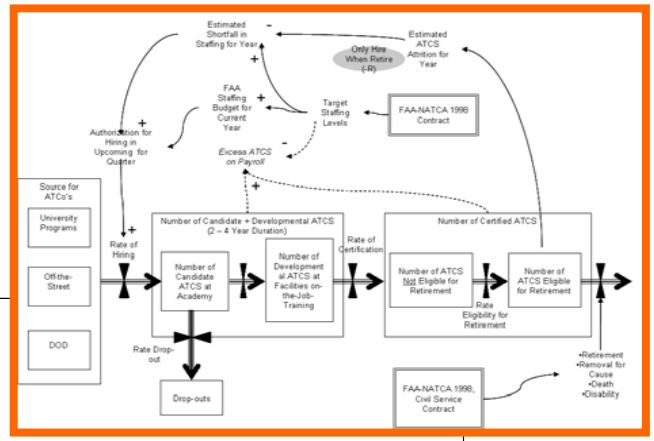


Source: ATA (2005)

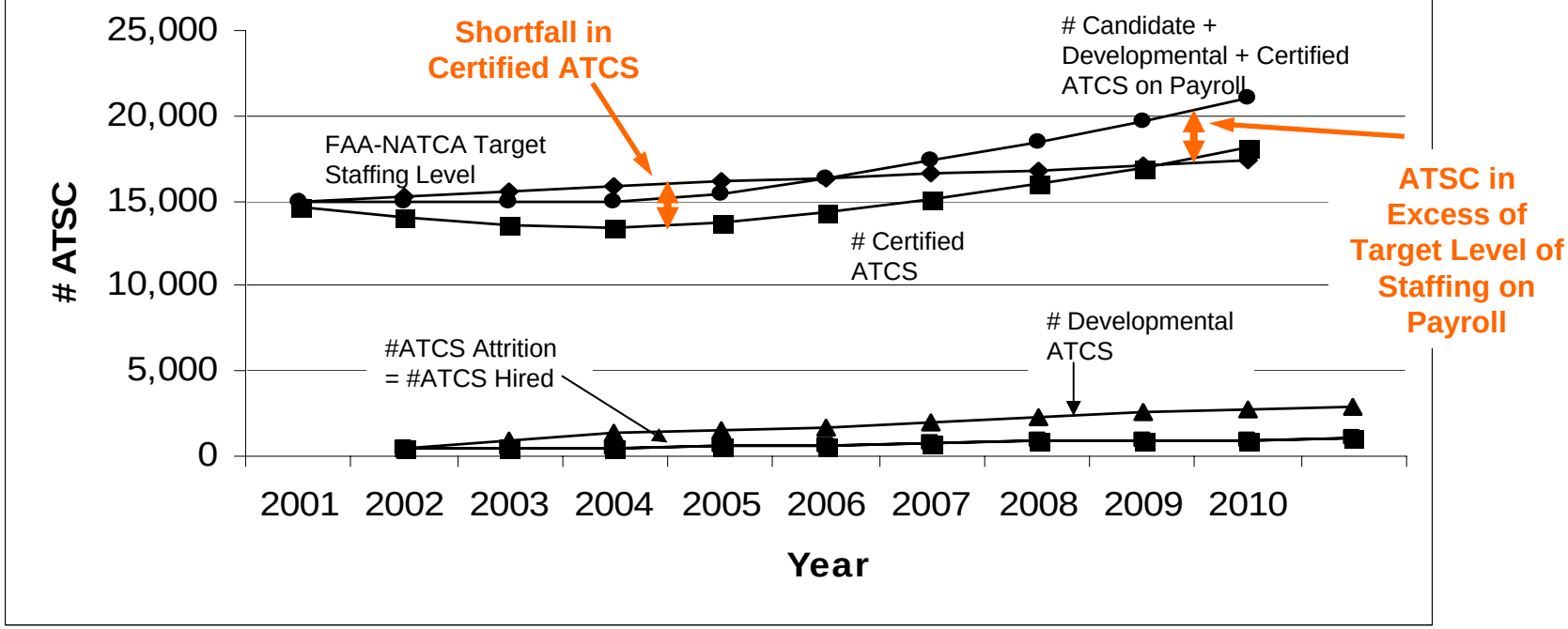
Shift to RJs, results in more ATC operations, A&TFless revenue

Challenges ? – ATC Labor





ATSC Hiring



Addressing the Challenges ?

- Are Challenges symptoms or causes?
  - What are cause-effect relationships?
- What is the systemic structure of the industry?
  - Can this knowledge explain behavior?
  - Can this knowledge focus R&D?
  - How do policies, regulations, and procedures affect the system
  - How does NGATS affect these success and challenges

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2. Air Transportation System

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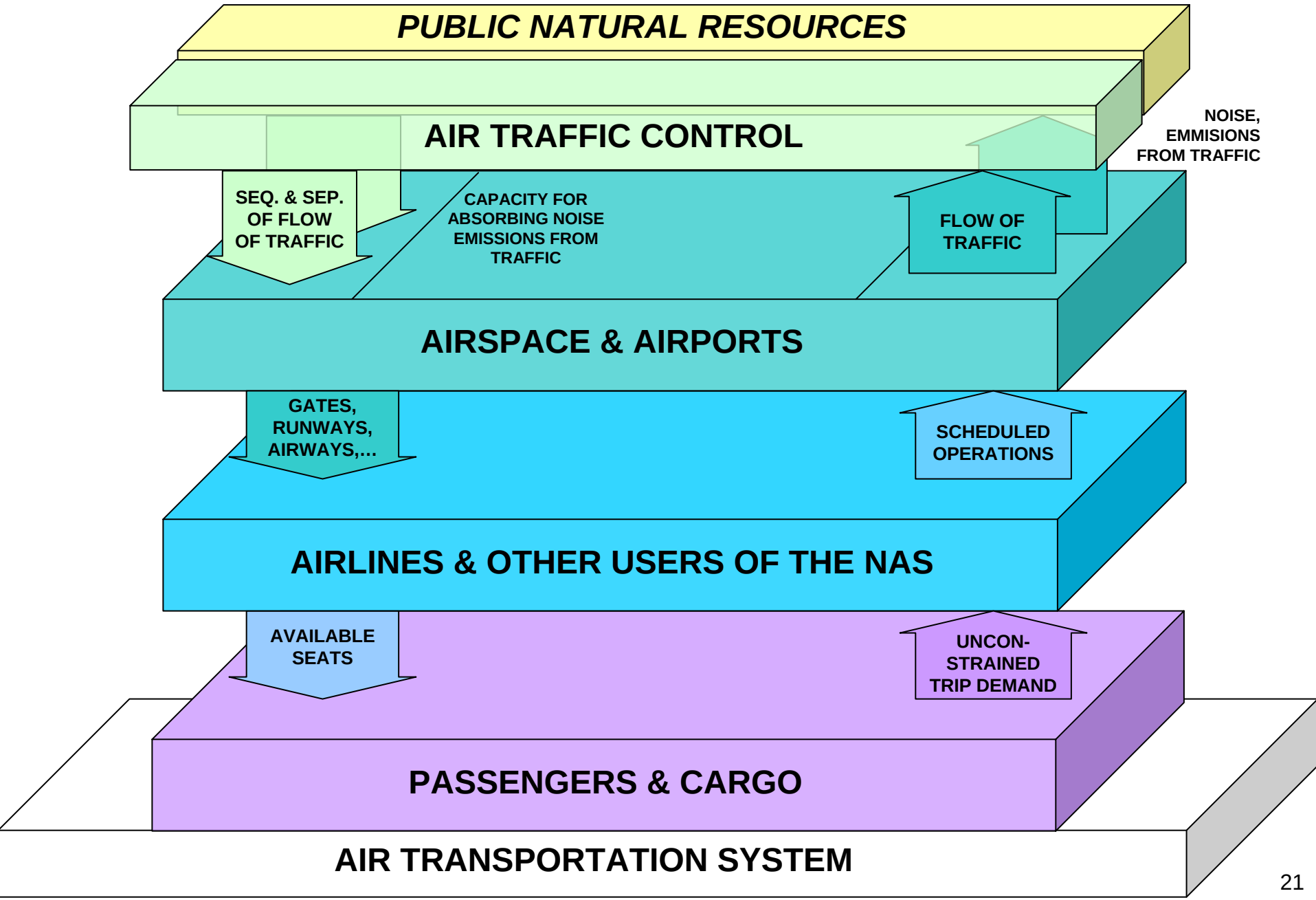
Air Transportation System

- Air Transportation System is …
  - Layers of networks
  - Networks composed of agents
  - Agents:
    - Distributed
    - Autonomous
- Networks and agents operating with own objective functions
  - Reinforce/Undermine each other
- Networks exhibit:
  - stochastic behavior
  - operate in non-equilibrium state
    - Economically
    - System Performance

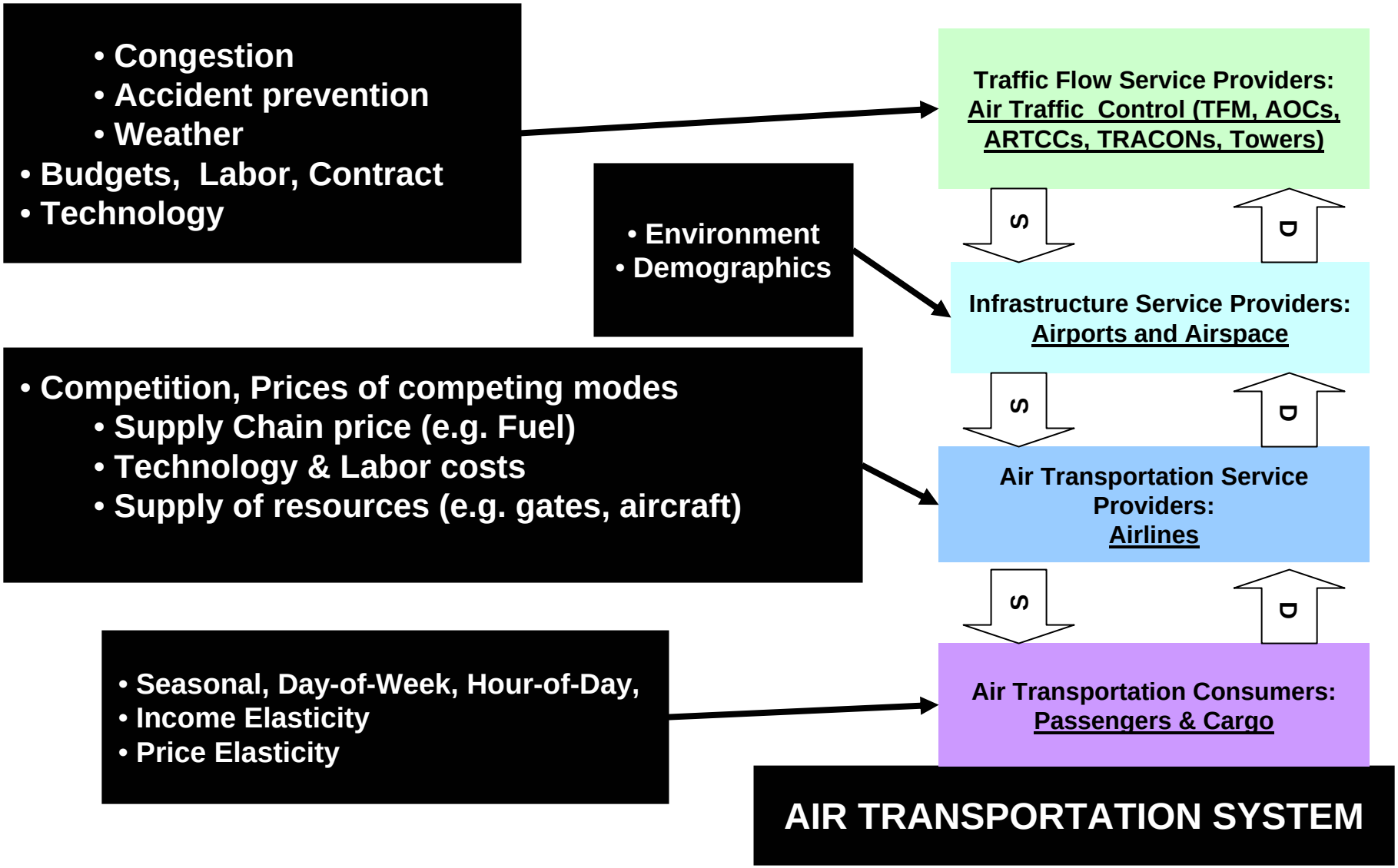
ATS Stakeholders

STAKEHOLDERS	OBJECTIVE FUNCTIONS
Passengers and Cargo • Purchase air transportation services	Optimize costs, time and reliability
Airlines • Provide capacity for air transportation of passengers and cargo • Scheduled Flights (routes, frequency and aircraft)	Profit Marketshare in competitive marketplace Maximize economies of scope and scale
Airports & Airways • Provide capacity for Airline's Scheduled Flights • Airways and their navigational aids, Flightlevels, Runways, Gates, …etc.	Regional Economy Effective Capacity Congestion
Air Traffic Control • Provide sequencing and separation of air traffic (flow)	Throughput (Delays) Airports & Airspace Utilization Accidents/Incidents Workload
Public Natural Resources • Provides "natural resources" consumed by air transportation	Capacity Rate of Utilization Rate of Replenishment

Relationship between Stakeholders



Variability in Demand



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3. ATS Dynamics

3-1) Time Constants
3-2) Demand and Capacity Balancing Feedback Loops
3-3) System Equilibrium

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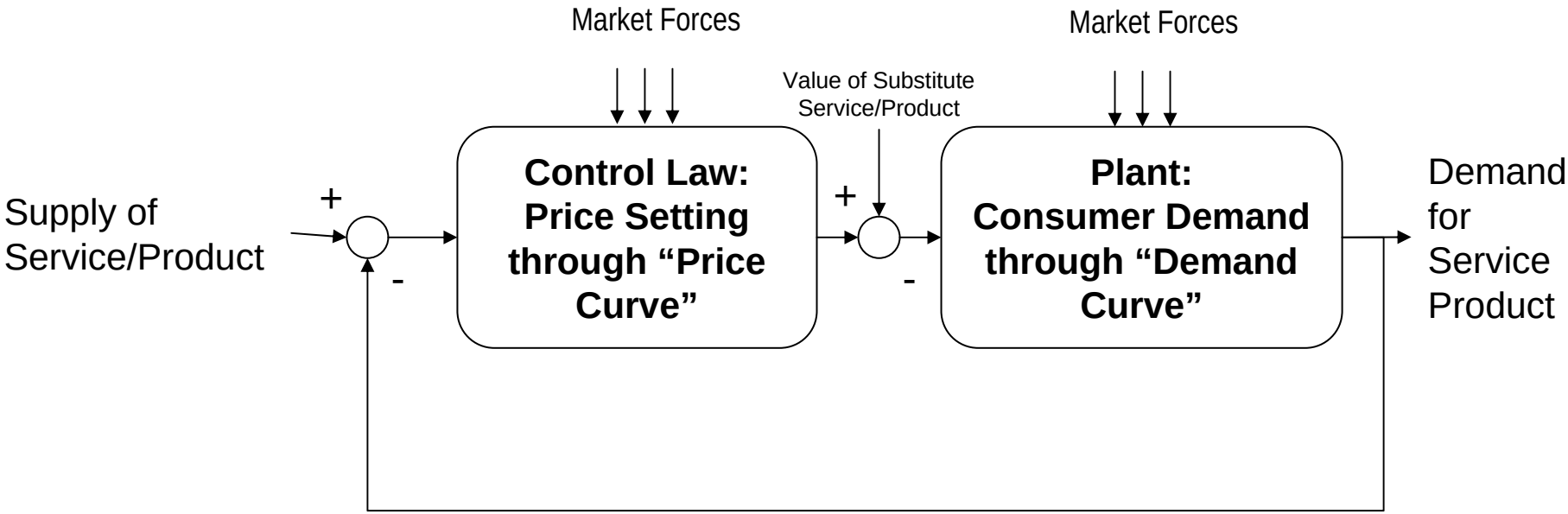
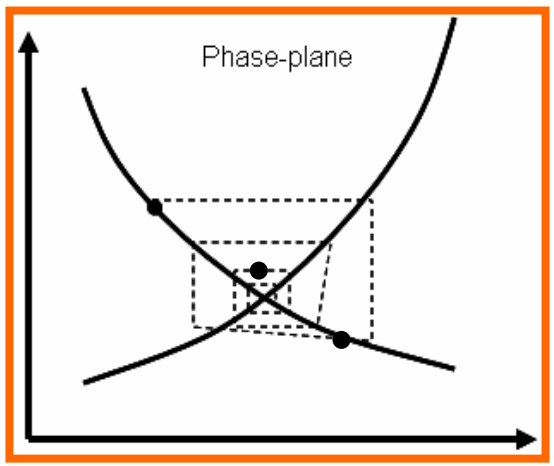
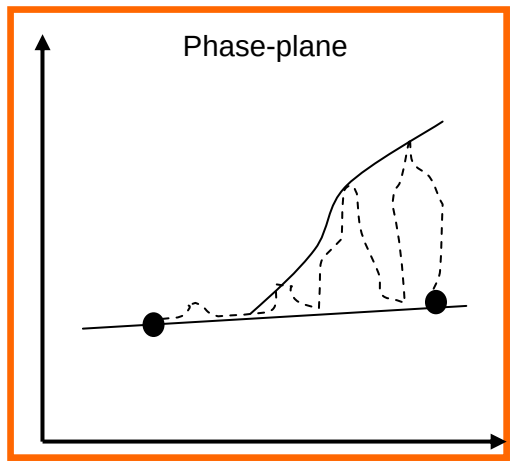
Dynamical System Model



Plant exhibits non-linear dynamics (e.g. price elasticity)



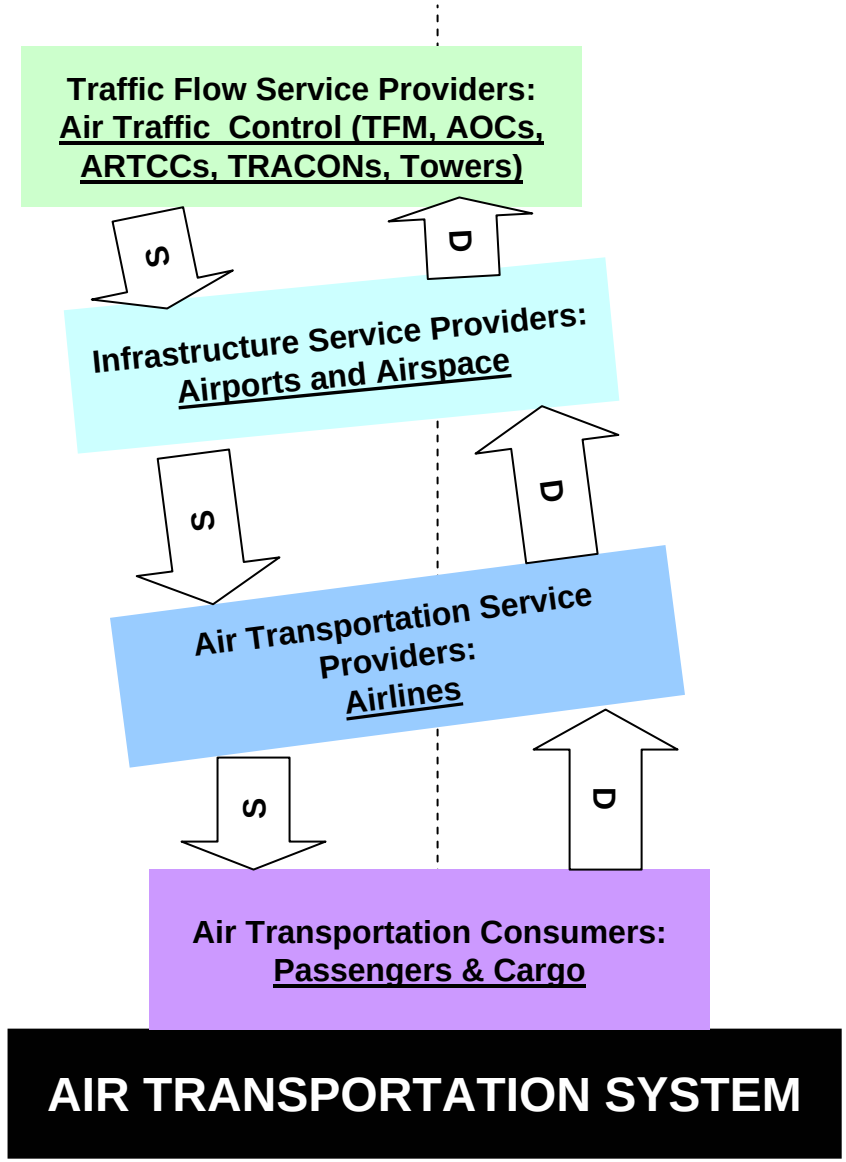
Equilibrium



No-equilibrium

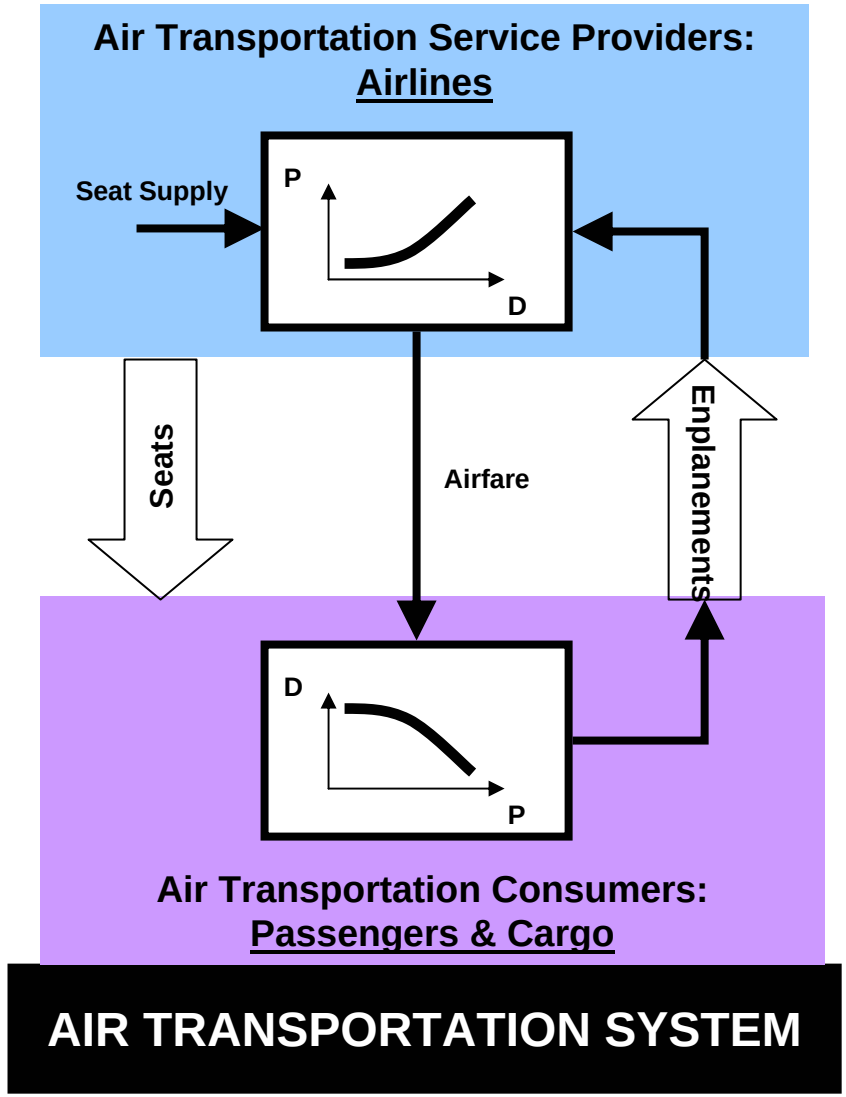
Time Constants ?

- Changes in Pax & Cargo demand
  - τ = Weeks to Months
- Changes in Airlines supply
  - Routes, Frequency, Gauge
    - τ = Weeks to 3 -6 Months
  - Increased Fleet
    - τ = 3 years
- Changes in A&A supply
  - Sector changes
    - τ = 3-6 months, 2 years
  - Runways, gates, routes, Crz FLs
    - τ = 10 – 30 years
- Changes in ATC
  - Staffing, Sectors
    - τ = 7 – 10 years



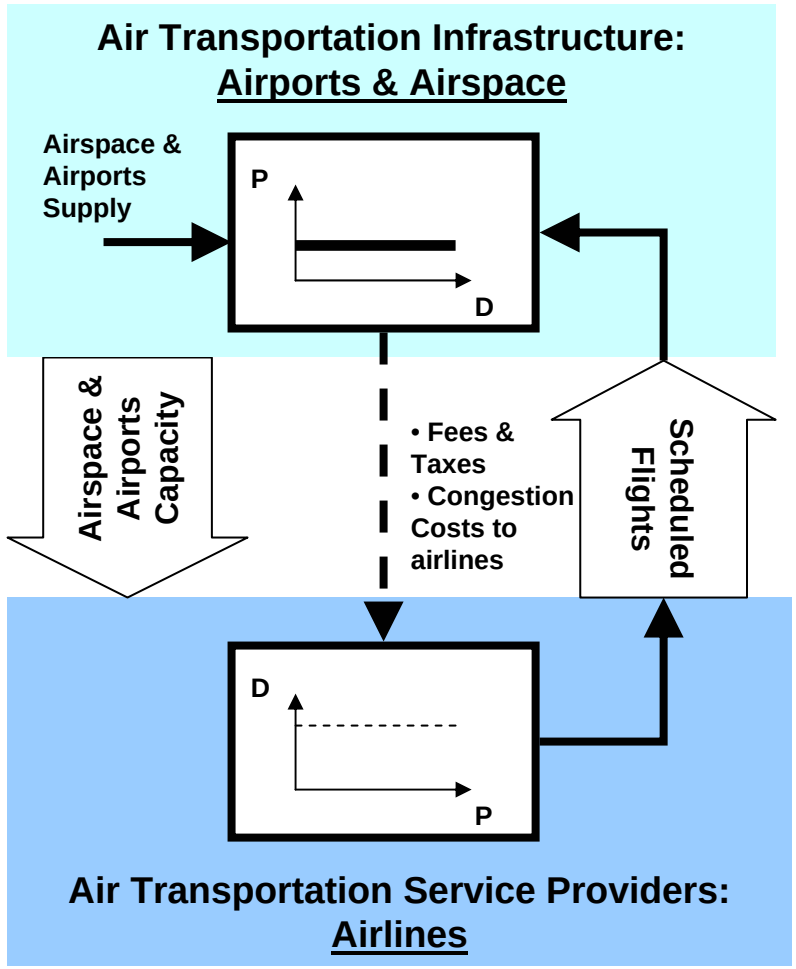
Pax v. Seats Feedback Loop (1)

- Strong feedback-loop
  - Airfares set by airlines based on demand for available seats
  - Scarce resources (seats) result in higher prices
    - Revenue Management
  - Loop has no external costs
- Feedback distorted by:
  - Hyper-competition for marketshare
  - Monopolies on given routes
  - Bankruptcy protection
  - Network integrity
  - Use-it-or-Lose it rules
- Innovation Rate
  - Very high



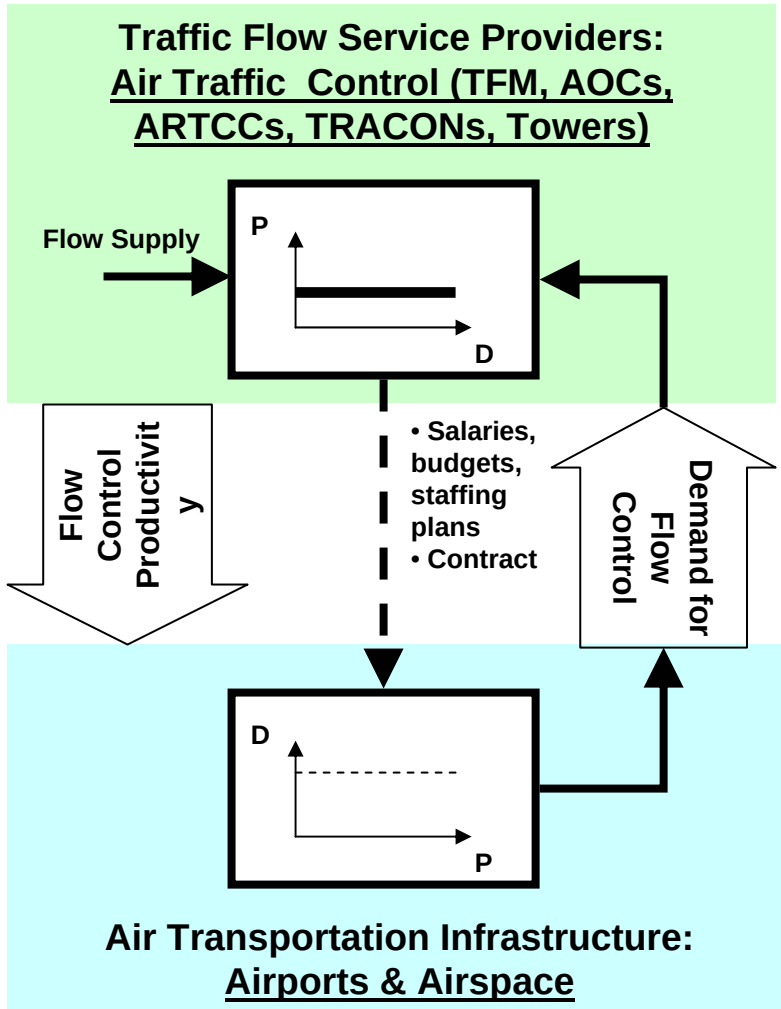
Flights v. Slots - Feedback Loop (2)

- Weak feedback-loop
  - Fees and Taxes based on:
    - Revenue-neutrality
    - Congestion (delay) costs
      - Weak
  - FAA F&E Budget
  - Costs borne by (third party) passengers
  - Administrative measures (slots, uni-laterals)
    - not responsive to market
- Feedback distorted by:
  - Absence of *value* of scarce resource
- Innovation Rate
  - Slow
  - Negligible productivity improvements at chokepoints



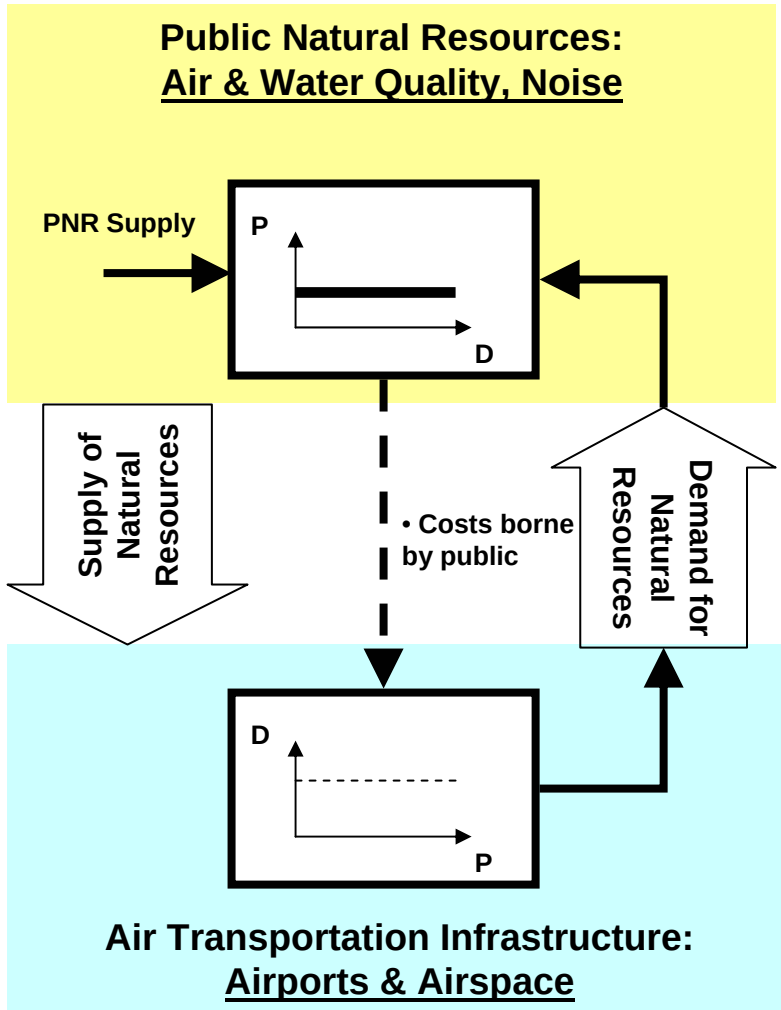
Slots v. Sep. - Feedback Loop (3)

- Weak feedback-loop
  - Contract, budget & staffing plans determine staffing levels based on forecasts
  - Costs borne by (*third party*) passengers (& taxpayers)
- Feedback distorted by:
  - Absence of *value* of scarce resource
- Innovation Rate
  - Slow
  - Negligible productivity improvements
    - # aircraft per sector in 15 mins

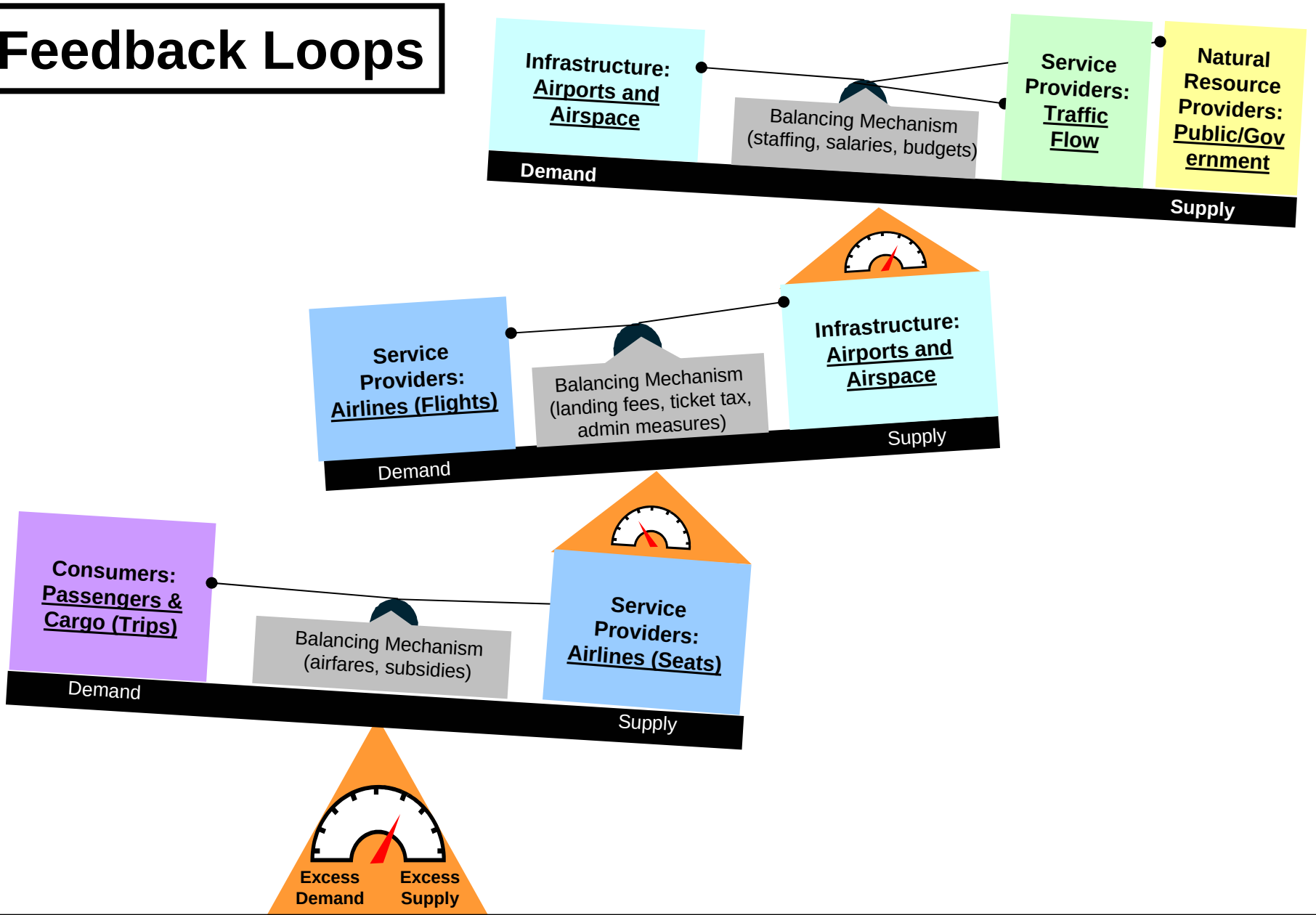


Slots v. NPR - Feedback Loop (4)

- Weak feedback-loop
  - Capacity and Rate-of-Replenishment is under debate
  - Costs borne by (*third party*) public
  - Regulations (noise abatement, engine upgrades)
- Feedback distorted by:
  - Absence of *value* of scarce resource
  - Global and local issue
- Innovation Rate
  - High in some areas
  - Driven by forces other than scarcity of resources



Feedback Loops



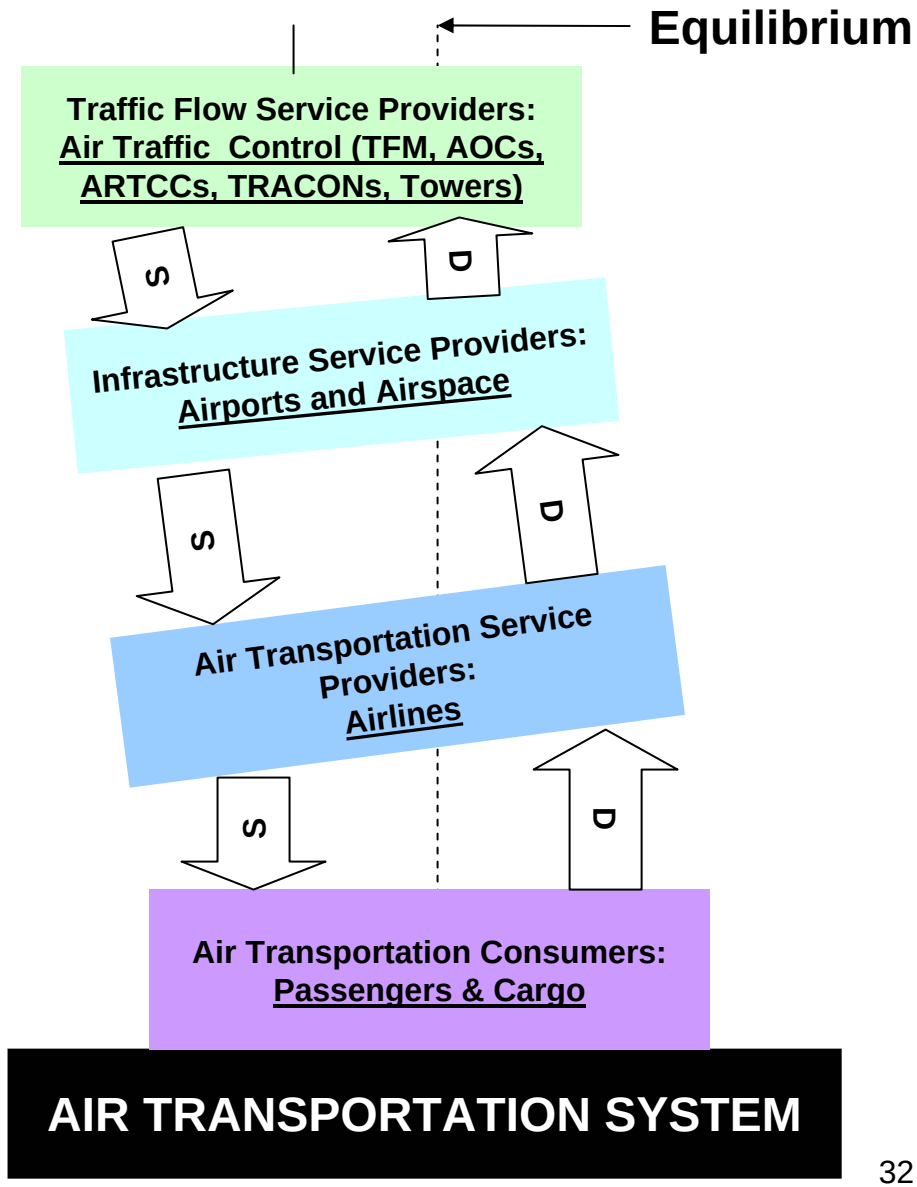
AIR TRANSPORTATION SYSTEM

Feedback Loops

- Absence of feedback loops prevents:
  1. **Maximizing use of scarce resources**
     - Exacts costs on third parties not part of loop (Golaszewski, 2005)
       - delays, workload, overtime, sick-leave, pollution
       - not a problem until resource becomes scarce
  2. **Signaling for improvement**
     - Crisis results in action
     - 75% of capacity rule (Miller and Clarke, 2005)
  3. **Innovation**
     - absence of value of resource (given demand) prevents return-on-investment (ROI)
     - absence of ROI prevents venture capital (VC)
     - absence of VC prevents best-minds from investing time & energy

Equilibrium ?

- Equilibrium:
  - supply = demand
    - No shortage/excess
  - *ability to anticipate changes*
- ATS is *unable* to reach and maintain equilibrium due to:
  - Time constants
  - Weak feedback loops
- Contributes to challenges to ATS



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4. Opportunities

Opportunities

1. Create awareness and educate decision-makers, media, and public
   - Gross mis-understandings exist, must be addressed
   - NAS Strategy Simulator
2. Plans & budgets should incorporate dynamics of model
   - time-constants, equilibrium points
     - Key metrics: (1) effective capacity, (2) demand
     - 75% of capacity rule

Opportunities

3) Sustainability in future ATS (e.g. NGATS) can be achieved by including in the specification of mechanisms to
   - **balance** existing supply with demand
     - Establish property rights and liability (Coase, 1988)
   - **signal** need for capacity enhancement
   - **incentivize** innovation, renewal, & expansion
     - Airports & Airspace, Air Traffic Control, Public Natural Resources

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Thank you

Questions?

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