Demand Modeling for NextGen

NEXTOR Research Symposium 2008

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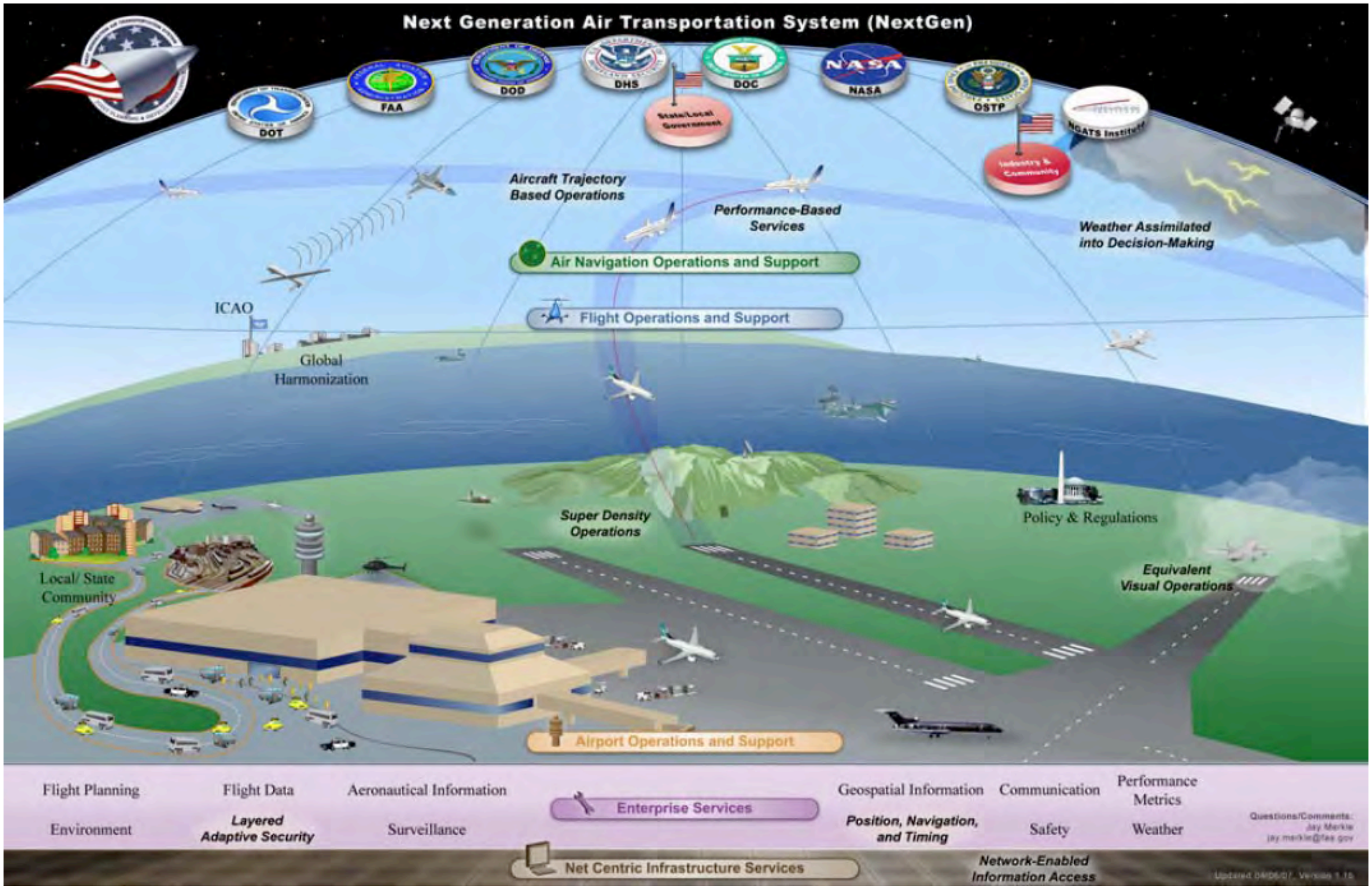
Presentation Overview

- Challenges to predict NAS demand behavior under NextGen
- Supply and demand relationships in modeling
- Examples of demand modeling for NextGen

NextGen Components



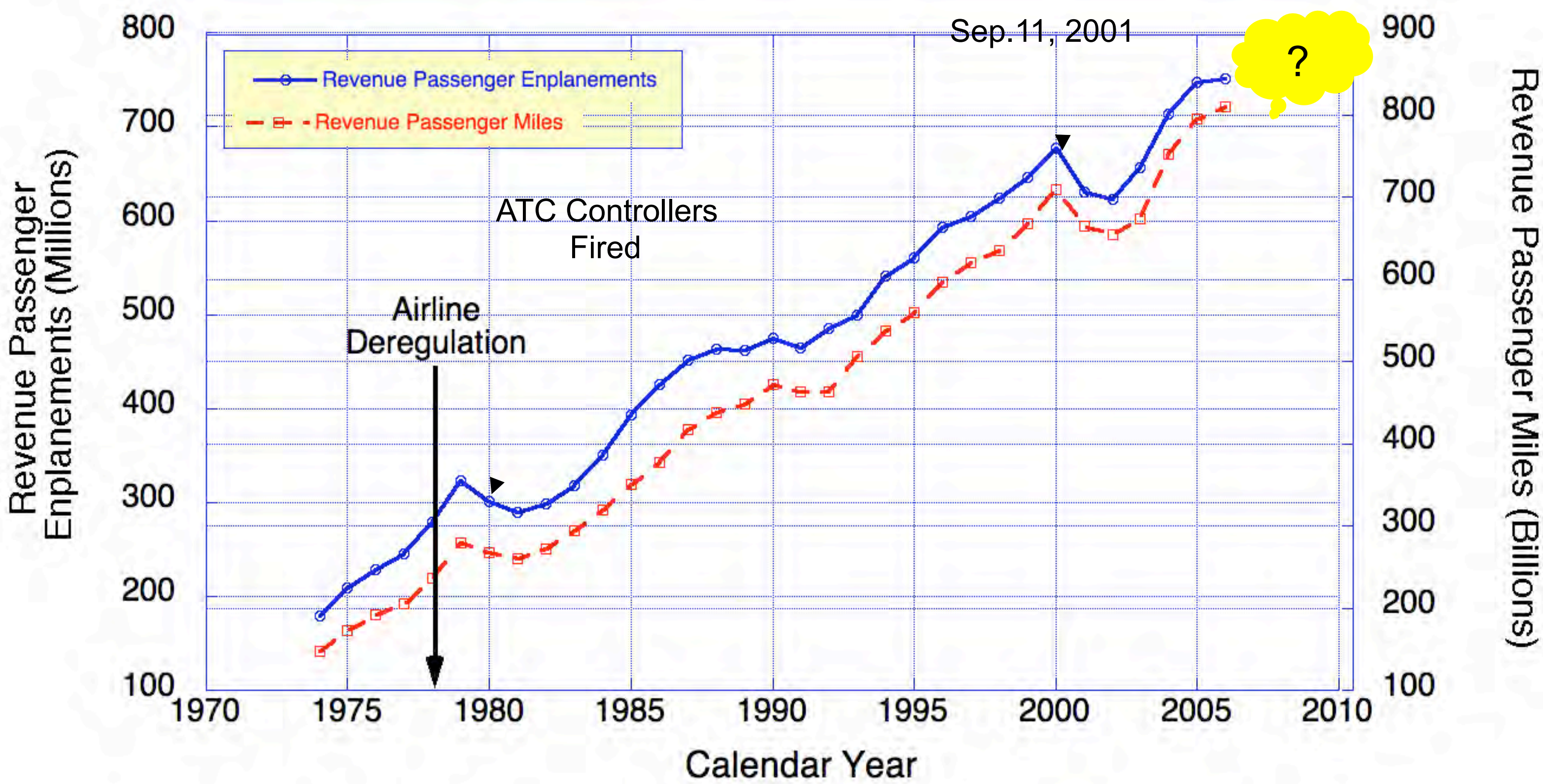
Source: JPDO NextGen CONOPS v.2

NextGen Basic Goals (per JPDO)

- Air transportation system transformation motivated by the need for aviation to grow
- Over the next decades, demand will increase, requiring a system that:
  - Provides two to three times the current air vehicle operations
  - Agile enough to accommodate a changing fleet that includes very light jets (VLJs), unmanned aircraft systems (UASs), and space vehicles (RLVs)
  - Addresses security and national defense requirements
  - Ensures that aviation remains an economically viable industry

Looking at the Evolution of the System

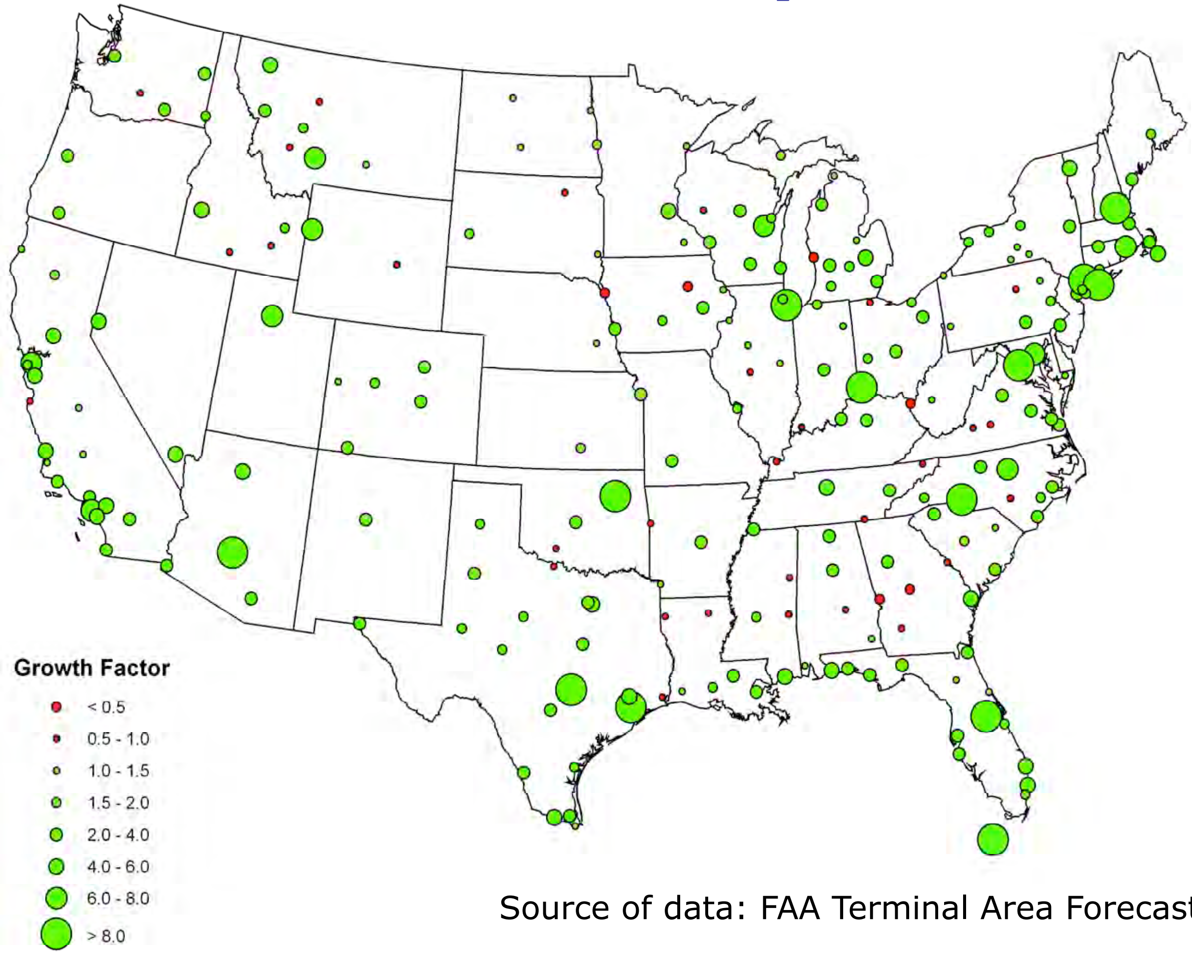
- The evolution of air transportation demand is driven by socio-economic growth and many externalities



Source of data: Bureau of Transportation Statistics

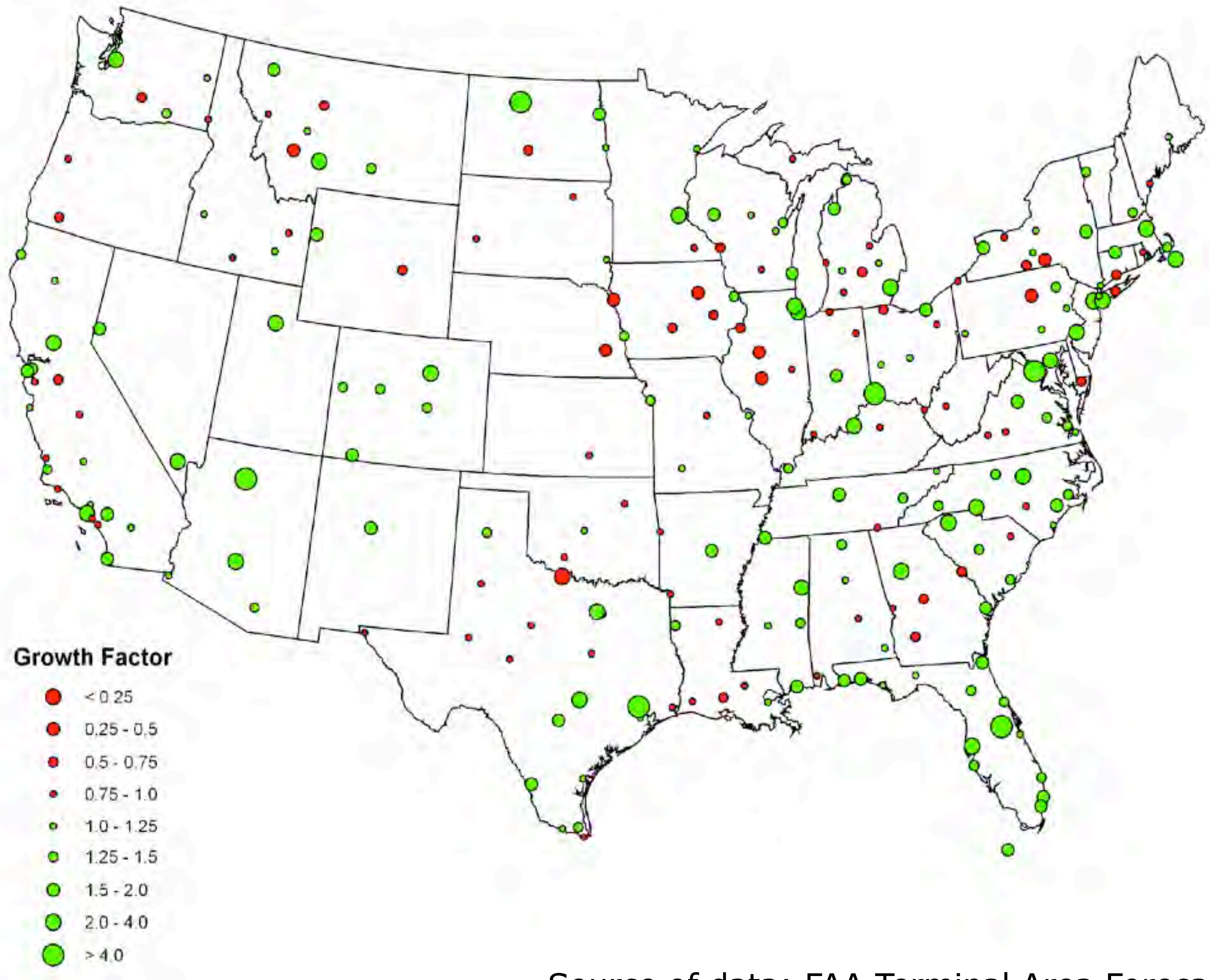
The total passenger enplanements tripled between 1976 and 2006

The System Grows Responding to Local and Regional Effects (Enplanement Growth 1976-2007)



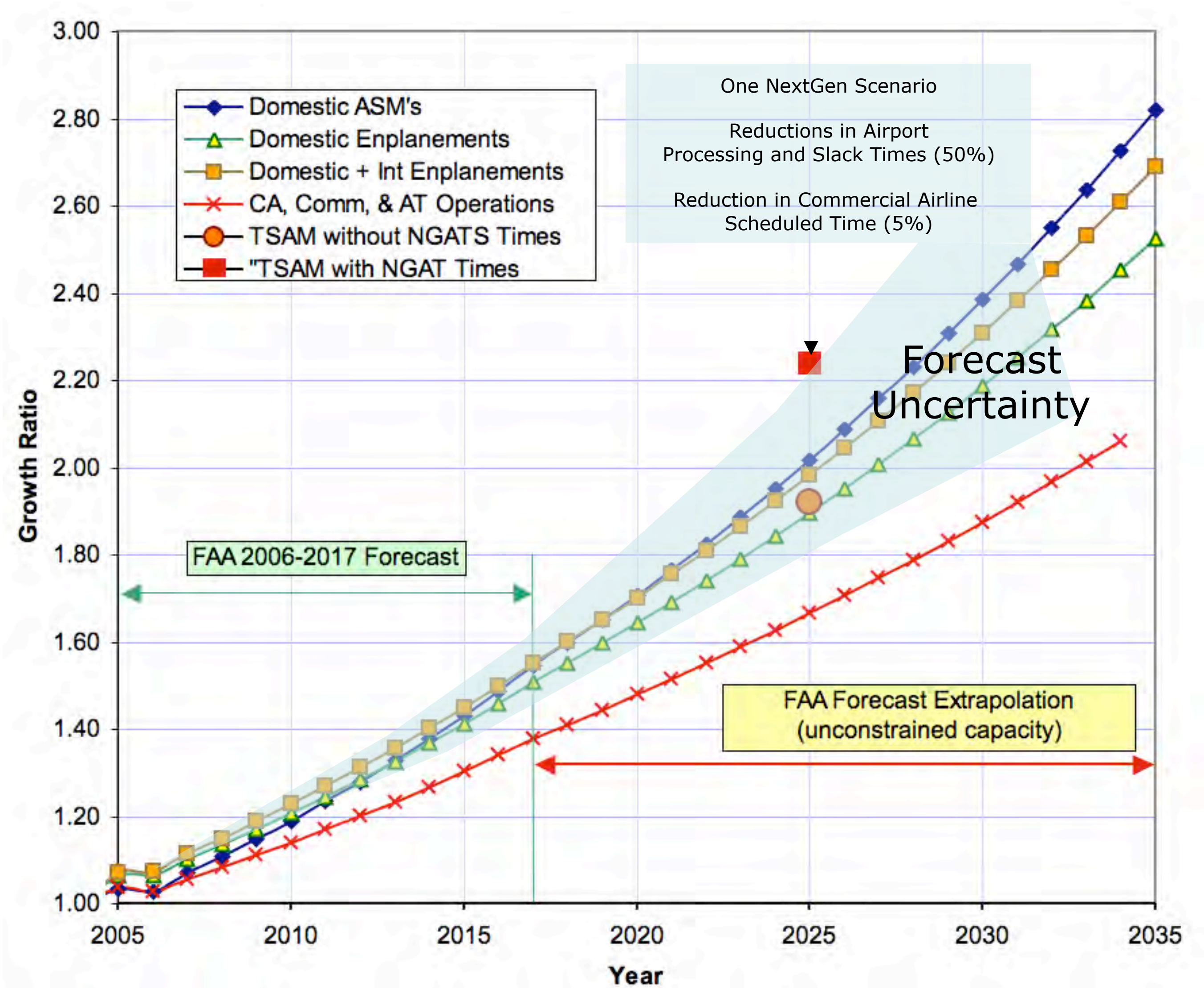
Source of data: FAA Terminal Area Forecast

Evolution of Flight Operations 1976-2007



Source of data: FAA Terminal Area Forecast

Demand Forecast Uncertainties

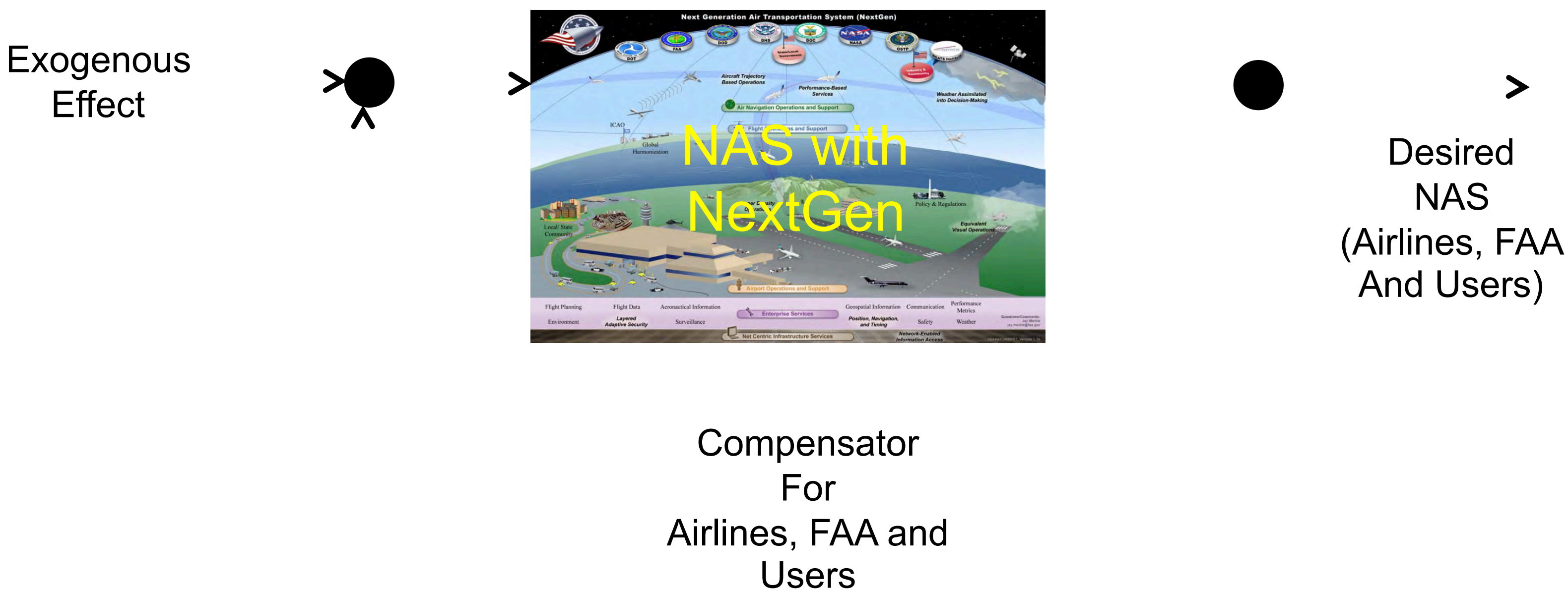


Some Challenges in Predicting Aviation Demand

- Demand is uncertain
- Depends on many exogenous parameters that in general cannot be controlled by the aviation agents:
  - State of the economy
  - Fuel prices
  - Wars
  - Disease
  - Political agreements
- Many of the demand forecasts deviate by 50% or more in 10 years

How to Proceed?

- Design the NextGen system so that it can accommodate a wide variety of demand scenarios at a reasonable investment
- Similar to designing a multi-attribute control system to reject exogenous conditions



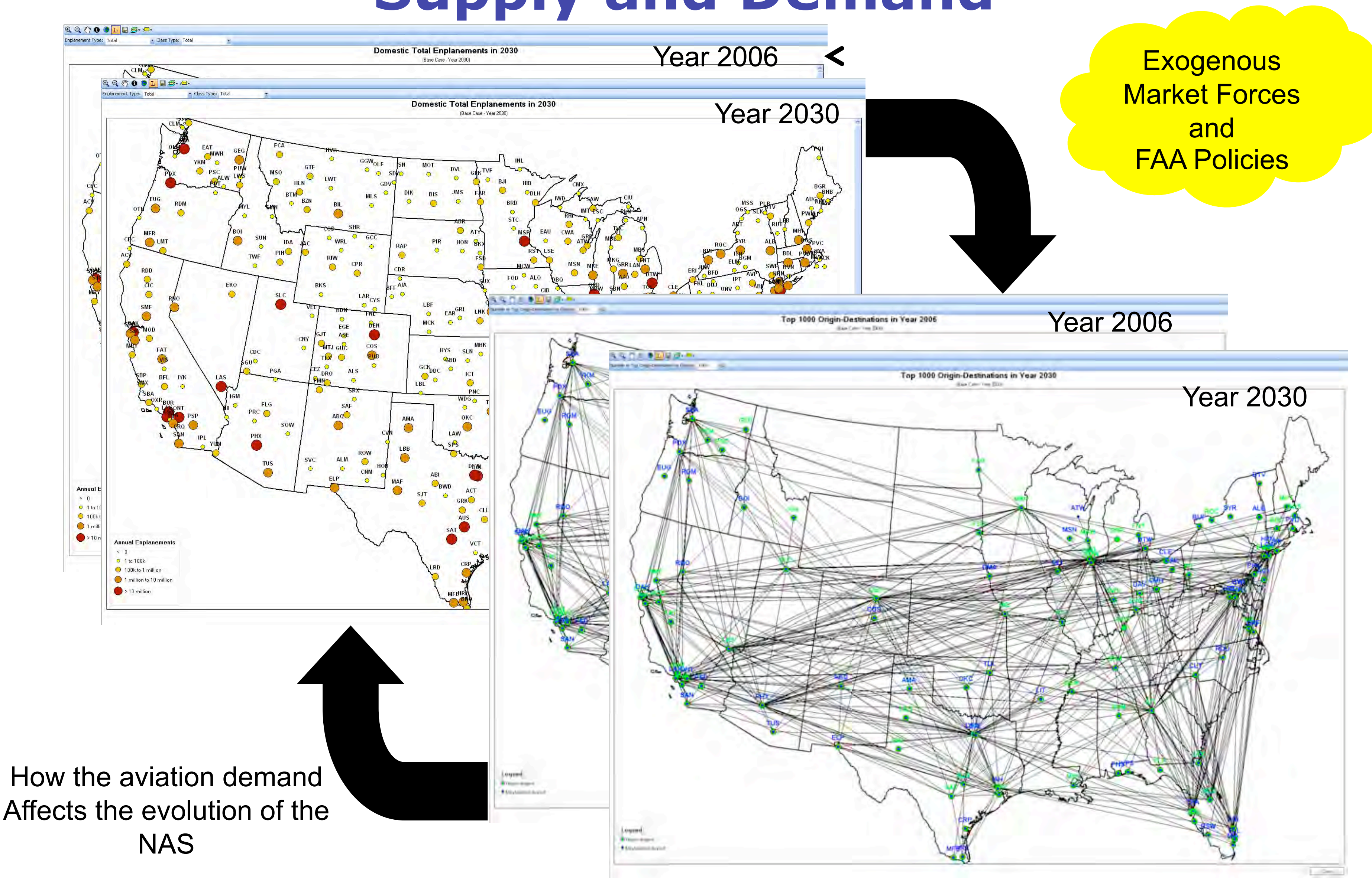
Measuring Demand Responses to NextGen Benefits

- **Indirect Method** - Measure flights that cannot be conducted in future years by trimming schedules
  - Delays drive trimmed flights
  - Airport capacity used as surrogate to trim flights
  - Requires adjustment of airline practices (de-peaking, changes in aircraft size, OD pairs served)
- **Direct Method** - Measure explicitly the air transportation demand loss using a mode choice/demand elasticity formulation
  - Passenger schedule delay drives mode choice behavior
  - Airport capacity constrains airline supply
  - Requires adjustment of airline practices (de-peaking, changes in aircraft size, OD pairs served)

A Direct Demand Modeling Approach

- Multimodal analysis (commercial air is not the only travel alternative considered)
- Door-to-Door travel time considerations (to measure how the system works under NextGen)
- Consideration of time-space relationships in the NAS
- Consideration of airline strategies (evolution of the airline network)
- Explicit consideration of airport capacity
- Tie of commercial air demand and supply feedback loops

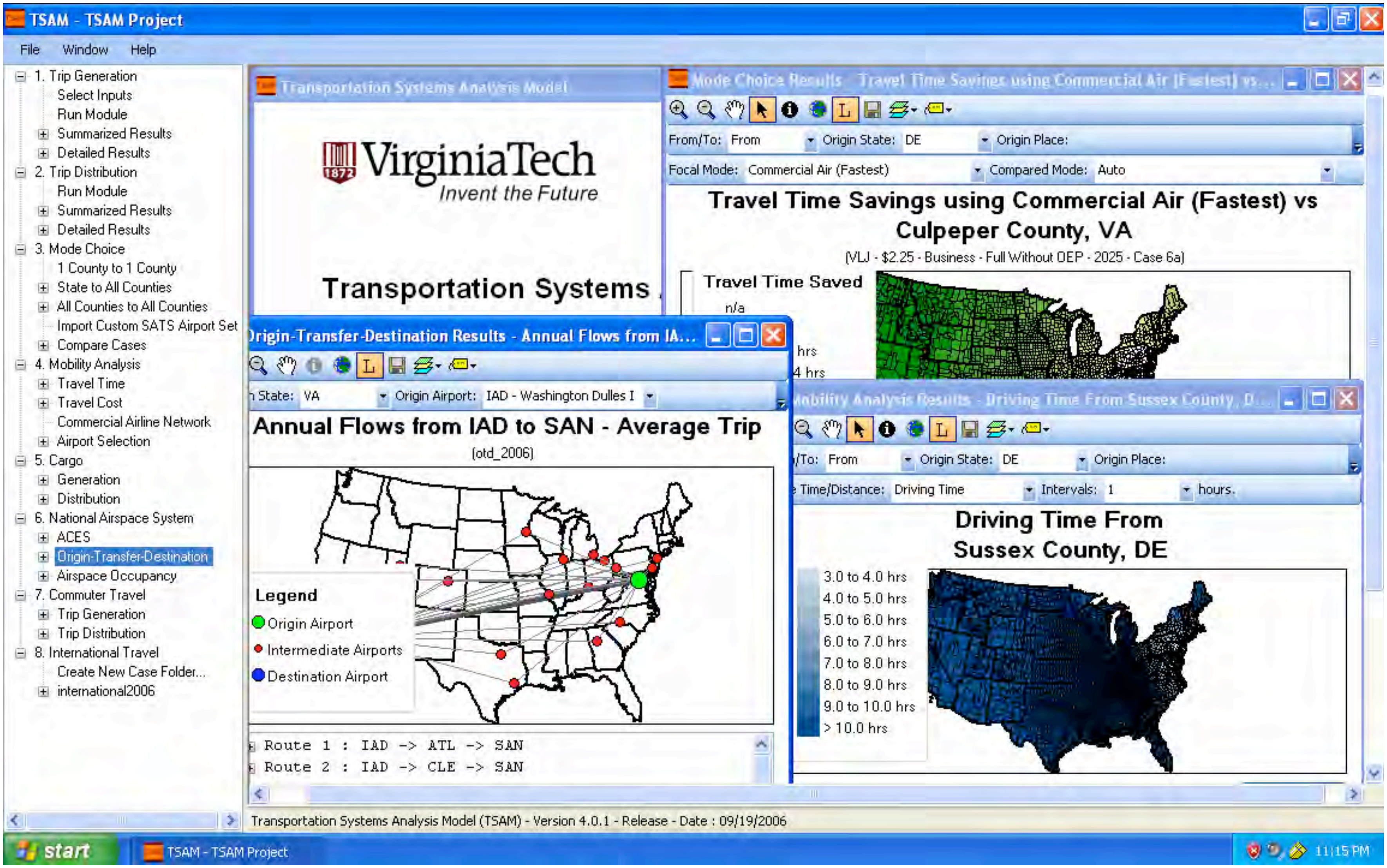
Feedback Effects Between Supply and Demand



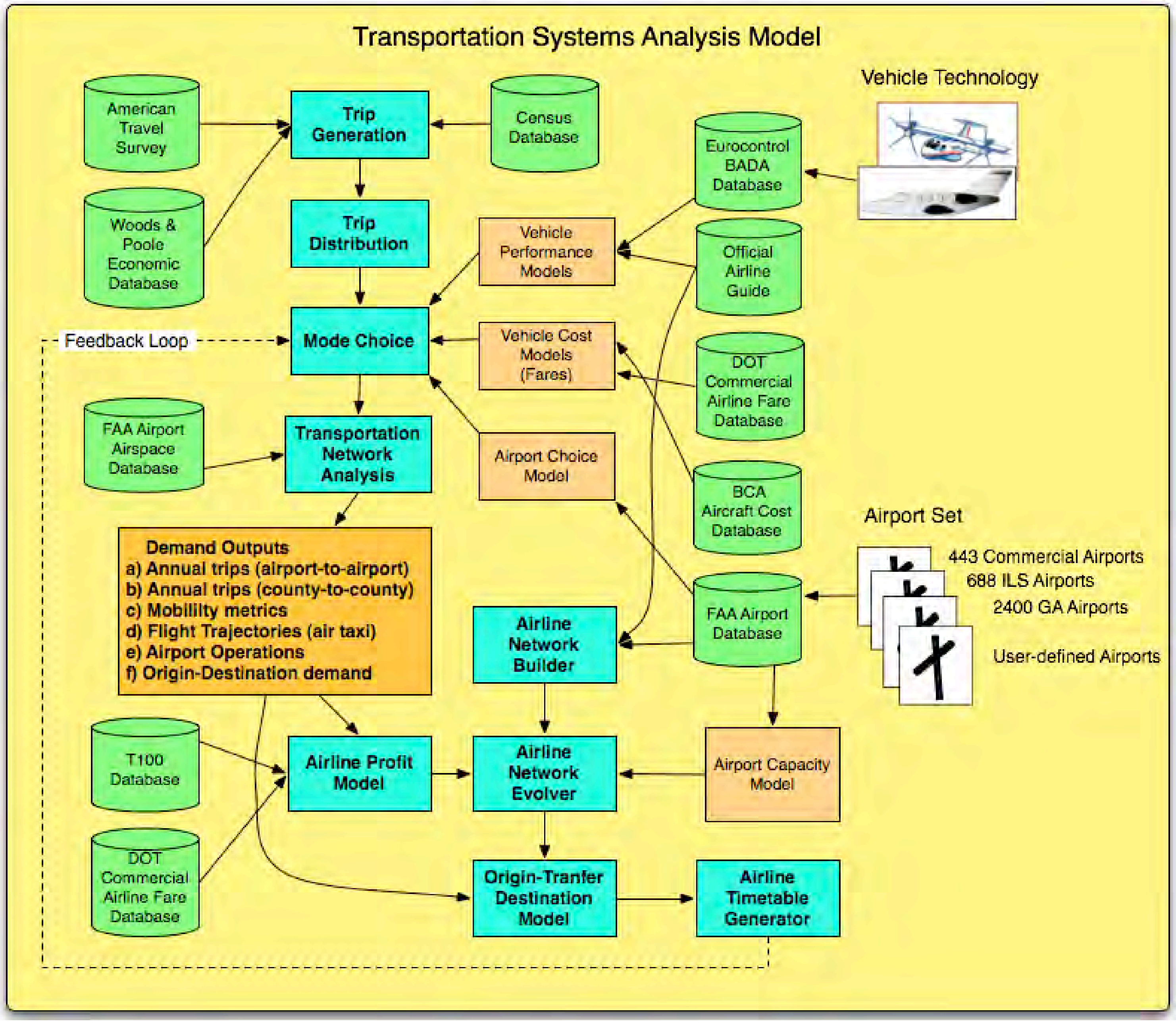
Methodology (TSAM Model)

- A multi-mode intercity trip demand model that predicts long distance travel (one-way route distance greater that 100 miles) in the continental U.S.
- Employs a multi-step, multi-modal transportation planning framework where trips are:
  - produced,
  - distributed,
  - split into modes, and
  - assigned to routes
- TSAM model can predict intercity travel in the presence of multi-mode alternatives (auto, commercial air, and new aviation modes)
- Mode choice of travelers based on trip characteristics (business and noon-business) and traveler demographics (income level)
- Mode choice is sensitive to vehicle performance, level of service and supply cost characteristics
- Produces an incremental flight schedule for commercial airlines
- Accepts any user-defined airport sets

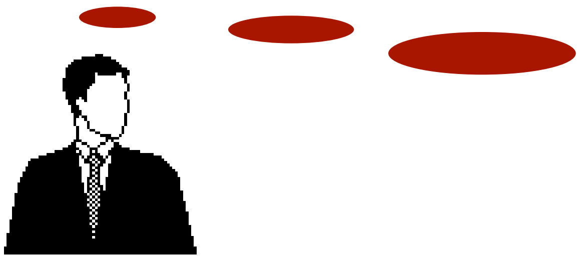
TSAM Model


TSAM - TSAM Project
File
Window
Help
1. Trip Generation
Select Inputs
Run Module
Summarized Results
Detailed Results
2. Trip Distribution
Run Module
Summarized Results
Detailed Results
3. Mode Choice
1 County to 1 County
State to All Counties
All Counties to All Counties
Import Custom SATS Airport Set
Compare Cases
4. Mobility Analysis
Travel Time
Travel Cost
Commercial Airline Network
Airport Selection
5. Cargo
Generation
Distribution
6. National Airspace System
ACES
Origin-Transfer-Destination
Airspace Occupancy
7. Commuter Travel
Trip Generation
Trip Distribution
8. International Travel
Create New Case Folder...
international2006
Transportation Systems Analysis Model
VirginiaTech
Invent the Future
Transportation Systems
Travel Time Savings using Commercial Air (Fastest) vs Culpeper County, VA
(VLJ - $2.25 - Business - Full Without OEP - 2025 - Case 6a)
From/To: From
Origin State: DE
Origin Place:
Focal Mode: Commercial Air (Fastest)
Compared Mode: Auto
Travel Time Saved
n/a
Annual Flows from IAD to SAN - Average Trip
(otd_2006)
Origin Airport: IAD - Washington Dulles I
Legend
Origin Airport
Intermediate Airports
Destination Airport
Route 1 : IAD -> ATL -> SAN
Route 2 : IAD -> CLE -> SAN
Driving Time From Sussex County, DE
Time/Distance: Driving Time
Intervals: 1
hours.
3.0 to 4.0 hrs
4.0 to 5.0 hrs
5.0 to 6.0 hrs
6.0 to 7.0 hrs
7.0 to 8.0 hrs
8.0 to 9.0 hrs
9.0 to 10.0 hrs
> 10.0 hrs
Transportation Systems Analysis Model (TSAM) - Version 4.0.1 - Release - Date : 09/19/2006
start
TSAM - TSAM Project
11:15 PM

The TSAM Model



People Have Choices When They Travel



Auto | **GA/Air Taxi** | **Commercial Aviation**

Factors considered in mode split:

- **Travel time**
- **Travel cost**
- **Value of time**
- **Route convenience**
- **Trip type**

Airport Choice

Route 1 | Route 2... | Route n

A Multinomial Logit Model is Used to Capture Individual Travel Behavior

Commercial Airline Evolution Model

- Given OD airport pair demand,

- Predict the segment demand and enplanements at all major airports
  - Estimate a model that predicts the route choice of passengers in a particular O-D pair
- Predict the evolution of the airline network
  - Estimate a model that predicts new potential markets served by an airline
- Build a revised airline schedule given the demand and a baseline schedule
- Predict the evolution of how airports might be used in the system (in the future)

Commercial Airline Frequency Generator Basic Idea

- Decision Variables
  - Flight frequency between OD pairs with vehicle k
- Objective
  - Minimize Cost, Maximize frequency or a combination of the two
- Constraints
  - Segment Seat Capacity
  - Load Factor (Max and Min)
  - Airport Capacity
  - Runway Length
  - Payload Range
  - Fleet utilization
  - Minimum Frequency
  - Airline Market Niches
  - Flow Conservation

Minimize

$$\sum_i \sum_j \sum_k C_k T_{ij} \Delta N_{ijk}$$

Subject to

- 1) Seat Capacity

$$\Delta D_{ij} \leq \sum_k \Delta N_{ijk} S_k (LF_k)_{\max}$$

- 2) Minimum Load Factor

$$\Delta D_{ij} \geq \sum_k \Delta N_{ijk} S_k (LF_k)_{\min}$$

- 3) Airport Capacity

$$\sum_j \sum_k \Delta N_{ijk} + \sum_j \sum_k \Delta N_{jik} \leq C_i - \sum_j \sum_k N_{ijk}$$

- 4) Fleet utilization

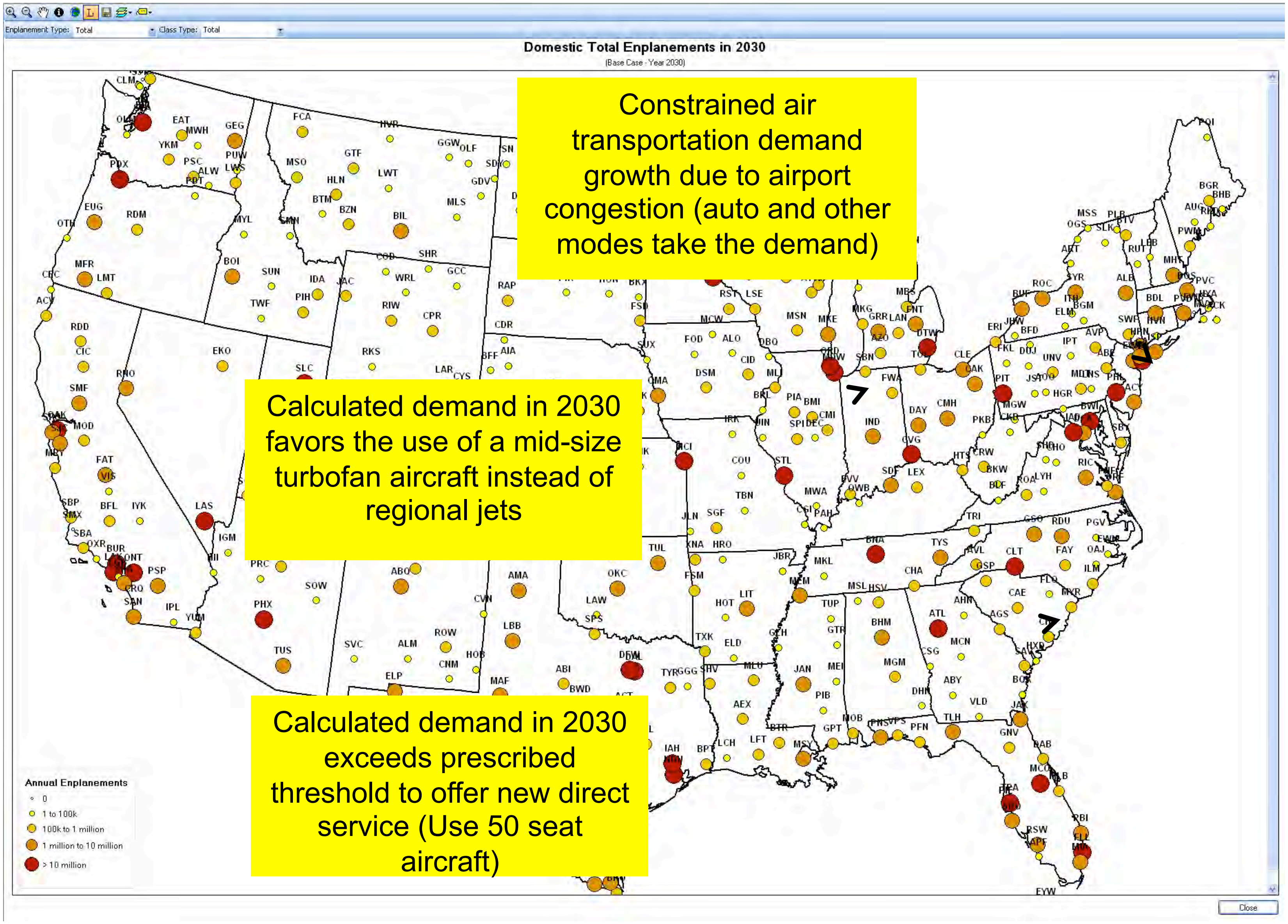
$$\sum_i \sum_j \Delta N_{ijk} \leq \Delta(F_k H_k)$$

and many more

Make the Airline World "Simple"

- Start with a known schedule (say the year 2006)
- One mega-carrier operates all flights in the U.S.
- 10 groups of aircraft (based on seating capacity) are operated at any time in the system
- The mega-carrier grows its schedule according to needs in dement predicted by the TSAM demand model across the country
- Airline assets (i.e., aircraft) are employed in the same "rational" (or perhaps irrational) way as today
- The airline fleet growth is predicated on new markets predicted by TSAM and heuristic rules added in the model

Sample Model Outcomes

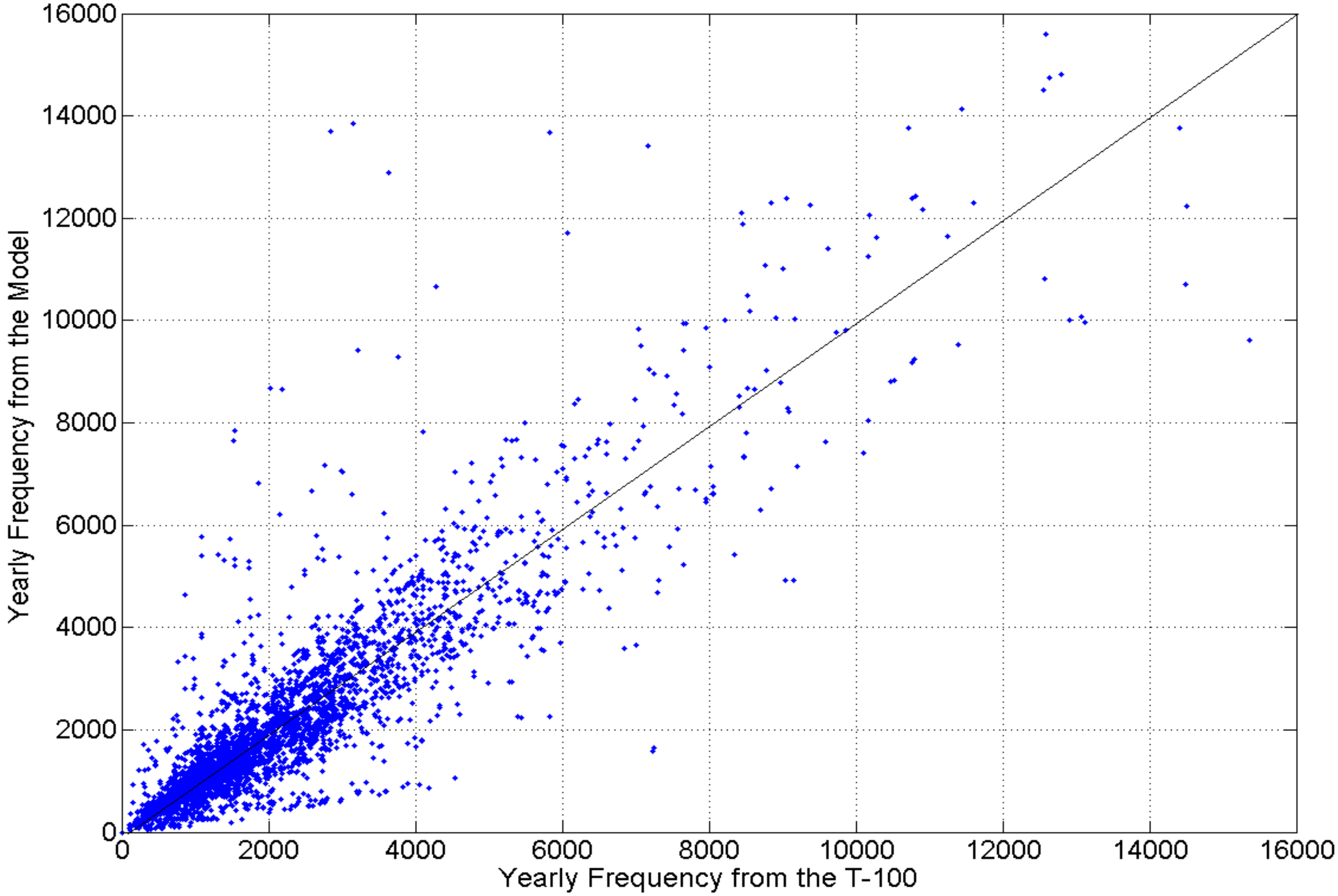


Constrained air transportation demand growth due to airport congestion (auto and other modes take the demand)

Calculated demand in 2030 favors the use of a mid-size turbofan aircraft instead of regional jets

Calculated demand in 2030 exceeds prescribed threshold to offer new direct service (Use 50 seat aircraft)

Validation (Frequency Generator)



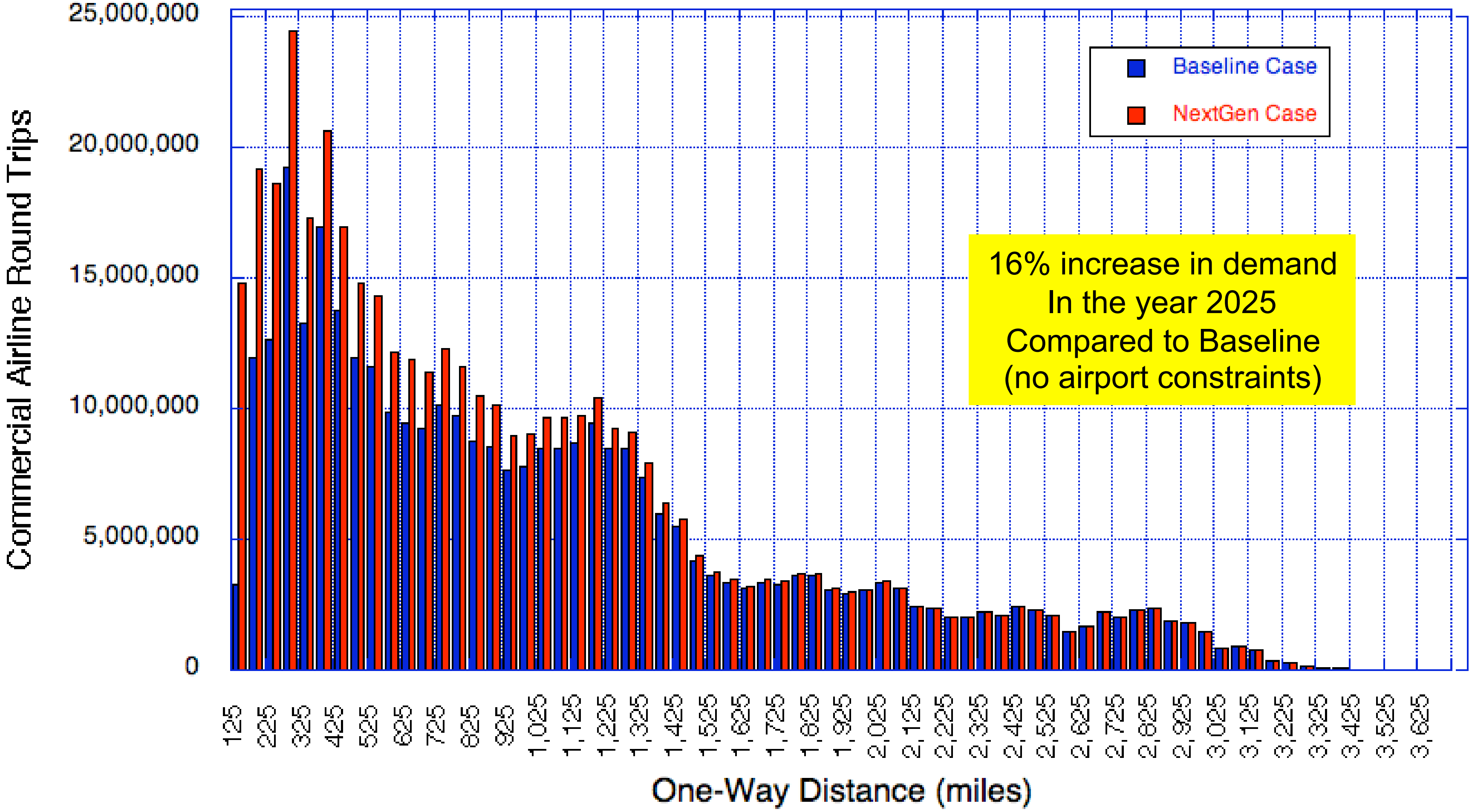
Example 1

Effect of NextGen on Commercial Airline Travel

NextGen Deployment Example

- Suppose a new NextGen technology deployed in the NAS provides the following quantifiable benefits:
  - 5% reduction in travel time between airports (say a combination of Air Traffic Management and Air Portal Flow Management Technologies)
  - A 50% reduction in airport processing times (required to achieve the 30% JPDO goal of reducing curb-to-curb time)
  - A 2% reduction in airline fares in the future (due to savings in block time)
- Question: How would the air transportation system demand be affected?

Potential Benefits of a NextGen (Modeling the Year 2025)



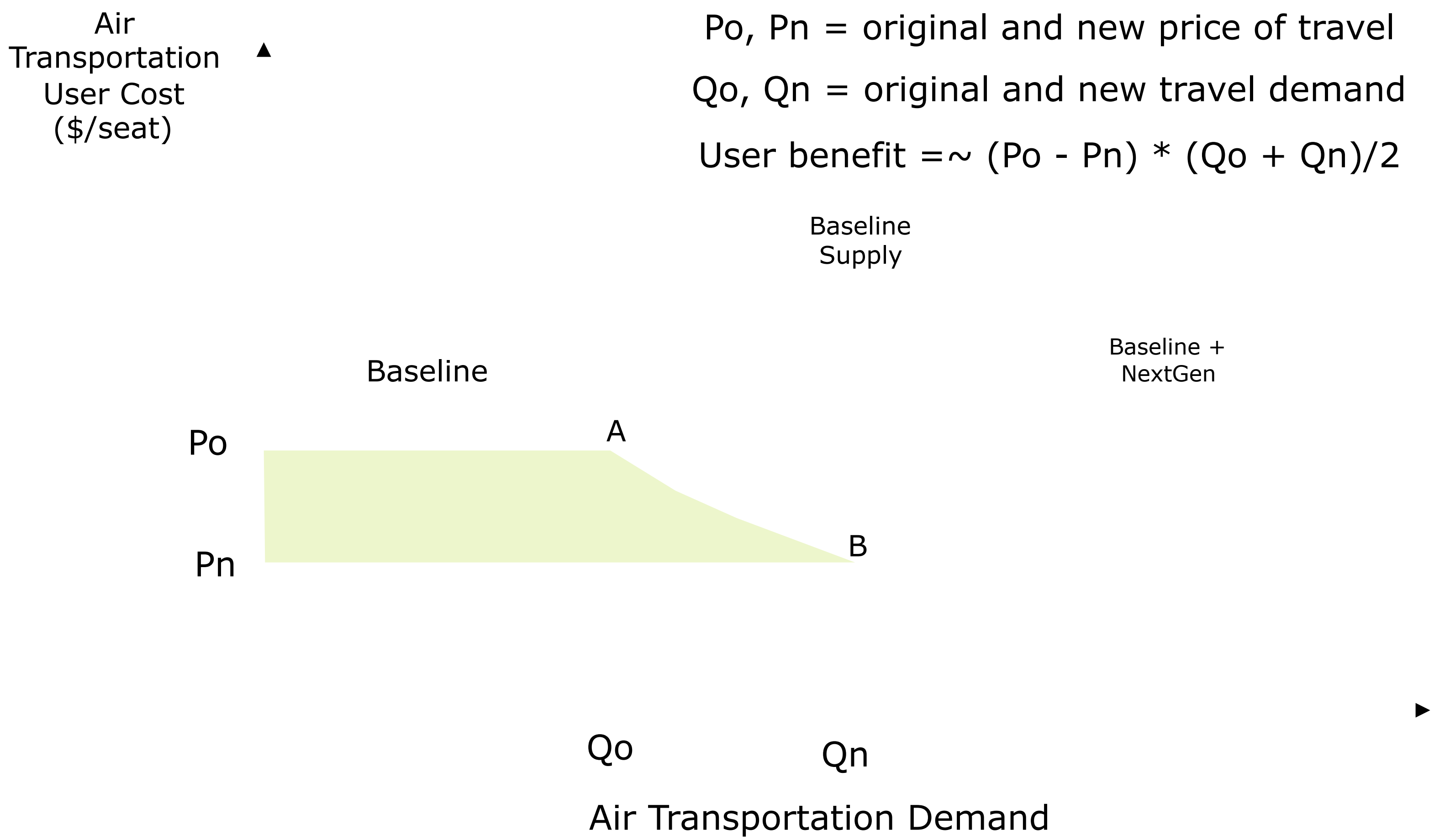
Results Obtained with the Transportation Systems Analysis Model version 4.7

Consumer Surplus Analysis (Explains how the Demand and Supply Functions Move from A to B)

Po, Pn = original and new price of travel

Qo, Qn = original and new travel demand

User benefit =~ (Po - Pn) * (Qo + Qn)/2



Example 2

Very Light Jet Demand

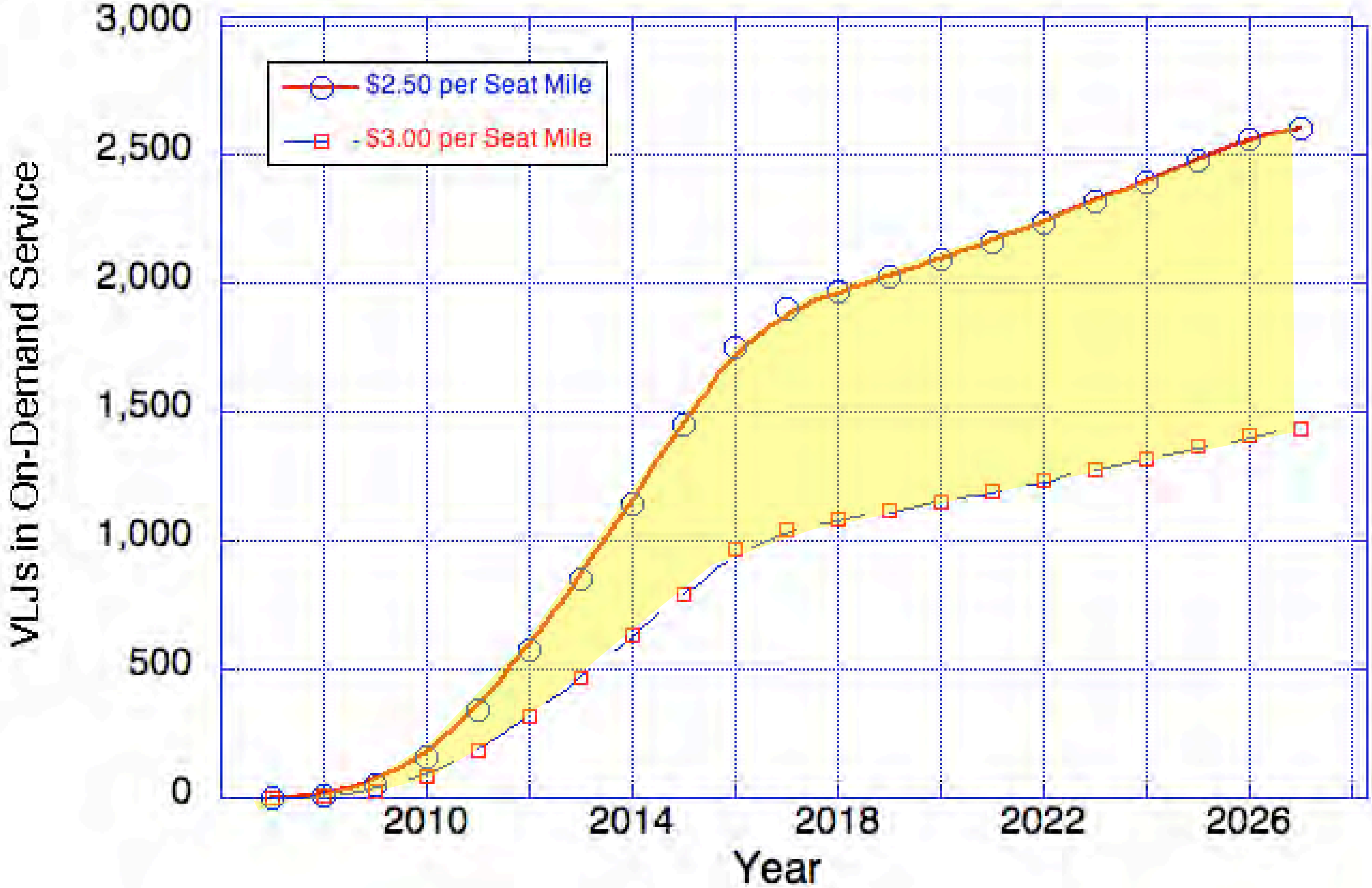
Very Lights Jets

- General purpose category of jet-powered aircraft weighting less than 10,000 lbs
- Flying Aircraft
  - Cessna Mustang (Certified 2006)
  - Eclipse Aviation 500 (Certified 2007)
- Aircraft in development
  - Embraer Phenom 100 (late 2008)
  - Diamond Jet (2009)
  - Honda Jet (2010)

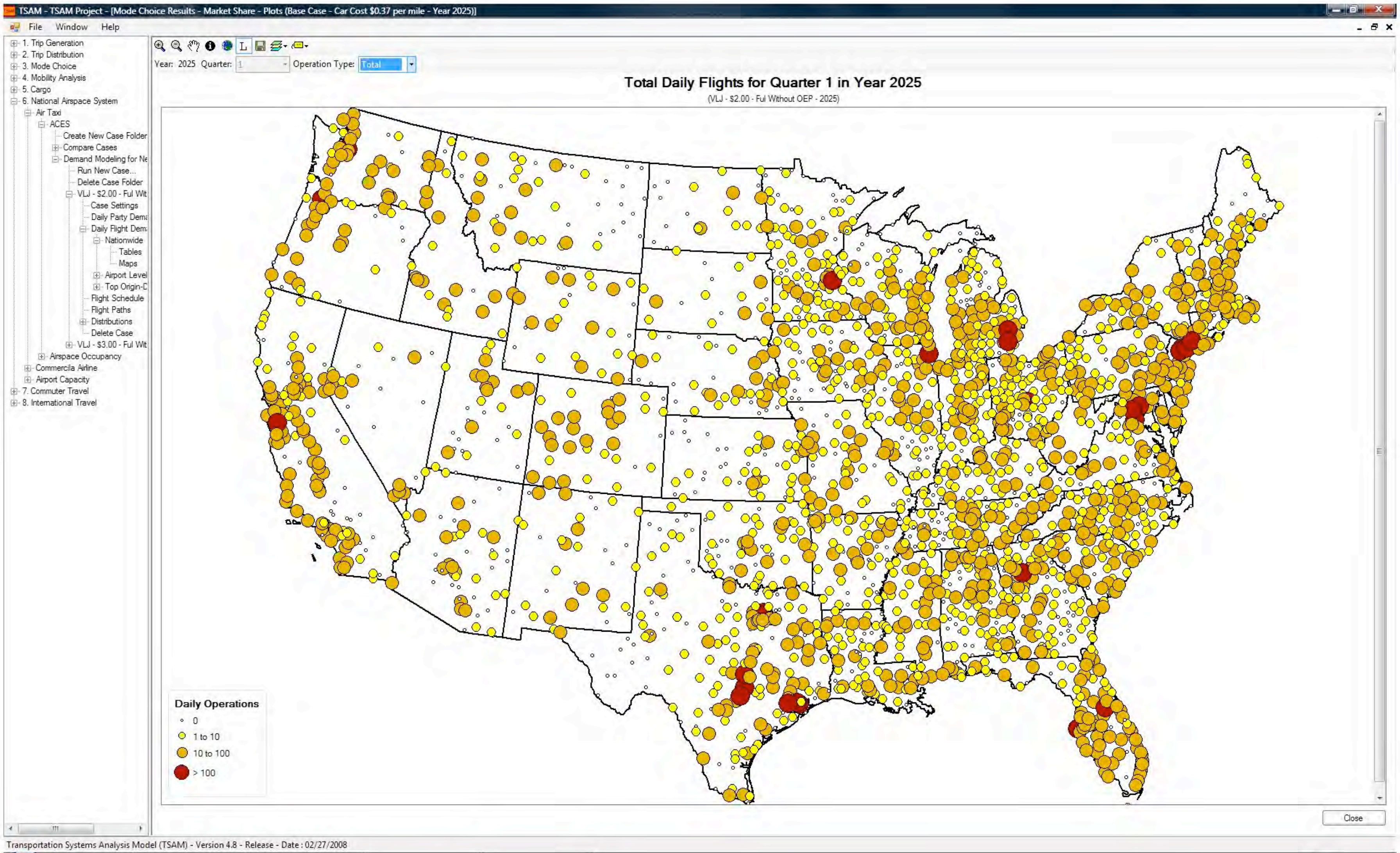
Cessna Mustang

Eclipse 500

Predicted VLJ On-Demand Response (650 aircraft/year Production Constraint) (2400 airports nationwide)



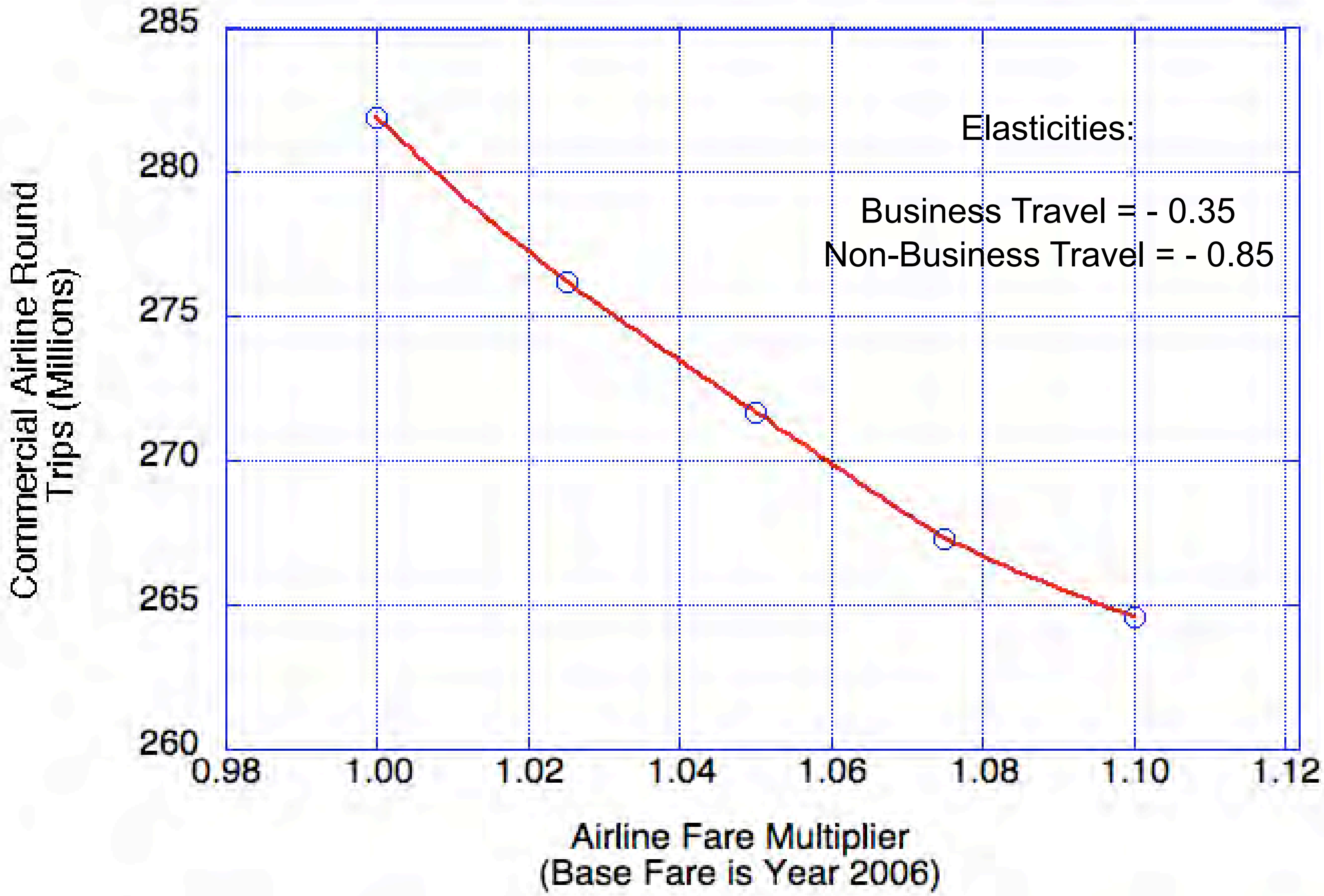
Projected VLJ Operations in 2025



Example 3

Air Transportation Demand Changes due to Air Fare Changes Driven by Fuel Cost

Increasing Commercial Air Fares (Year 2015 Scenario)



Further Model Development

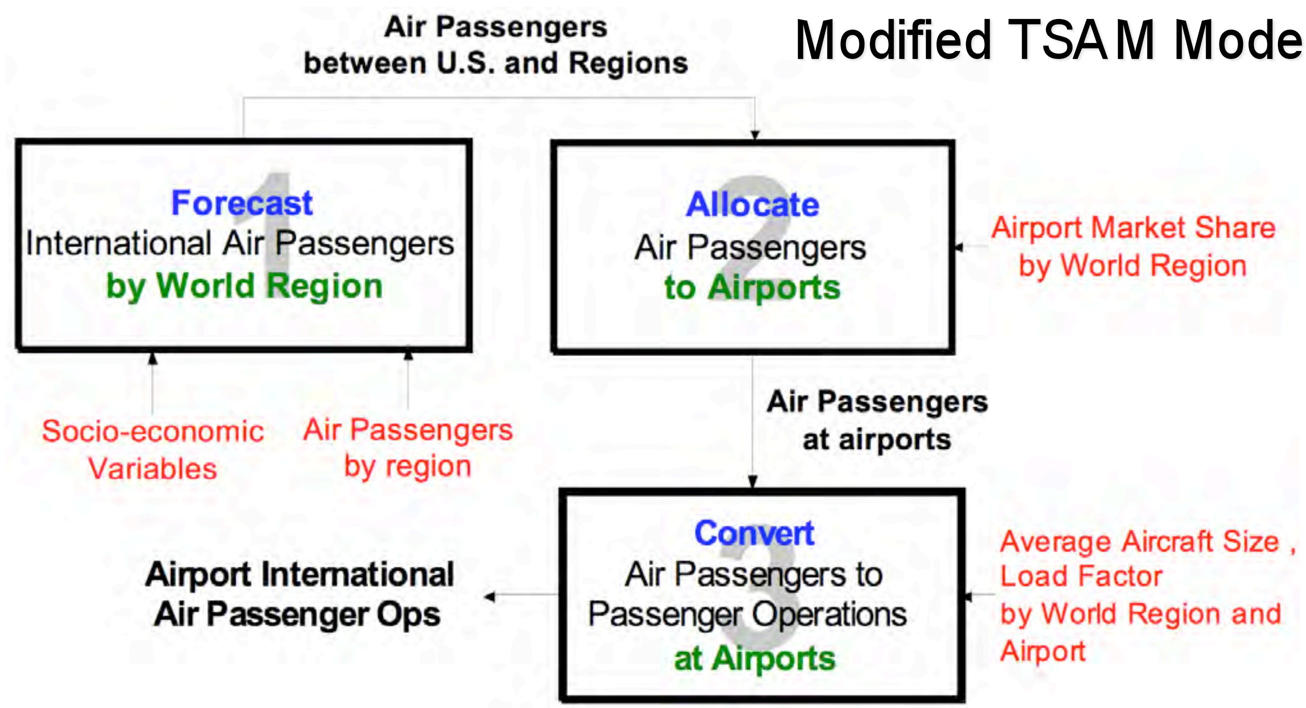
Modifications to TSAM to Study North Atlantic Open Skies Policies

Analysis to Support NAT Open Skies Policies

Open Skies Policies

GTAP Model

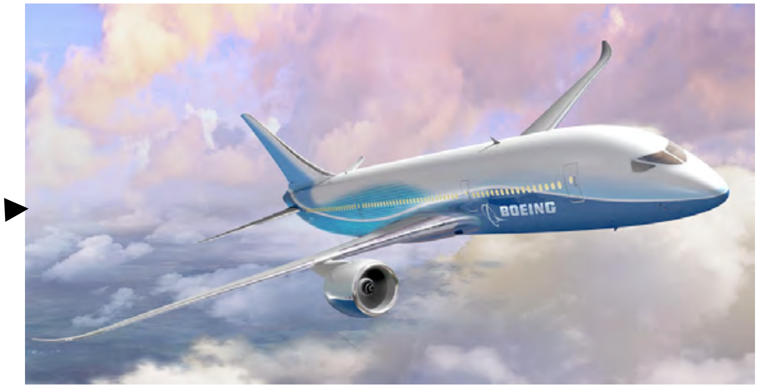
Modified TSAM Model



Open Skies Policies Being Studied

- Pricing effects on demand
- Cost effects to airlines (consolidation, entry of low-cost carriers in the North Atlantic market)
- Other savings (fees paid - Air Navigation Service Provider)
- Emission policies on aviation users
- Airport capacity constraints

Boeing 757 and Boeing 767



Boeing 787-8

Conclusions

- The National Aviation System is a very complex and adaptive system
- NextGen demand modeling requires new approaches to understand the dynamics between supply and demand in the presence of other modes of transportation
- Mathematical models developed require heuristics that attempt to mimic reality
- Our ability to model future demand is modest at best
- The work presented is just one example of the many efforts at NEXTOR universities to better understand the future NAS

Acknowledgements

- Many of the latest ideas in our modeling work have been influenced by many people at NASA and FAA
- We would like to thank the following individuals
- NASA Langley and ATK
  - Jeff Viken, Stuart Cooke, Sam Dollyhigh, Jerry Smith
- FAA ATO
  - Dave Knorr, Joe Post, Stephanie Chung, Thea Graham, Dan Murphy and David Chin