Systems Models for the NAS Strategy Simulator
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NEXTOR Research Seminar
FAA Headquarters

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Organization

• Brief statements about the NAS Strategy Simulator
• Transportation Systems Analysis Model (TSAM)
• Connections to NAS Strategy Simulator
• Applications
  – Very light jet demand analysis
  – NGATS benefits
  – FAA taxes
• Conclusions
Brief Statements About the NAS Strategy
Simulator (NSS)
NAS Strategy Simulator (NSS)

• A strategic decision tool to study the effects of macro-level policies
• Developed by FAA and Ventana
• NEXTOR universities have participated in the effort developing sub-models and providing background information to justify causal relationships
• NSS requires detailed analyses to understand cause-effect relationships
NAS Strategy Simulator

VLJ Aircraft Production Constraint Model

Source: Tran, & Bala, (2006).
Transportation Systems Analysis Model (TSAM)
Transportation Systems Analysis Model (TSAM) Framework

Standard TSAM Interface

Airport Travel Time from ROA - Roanoke Regional / Woodrum Field
Background of the Model

- A strategic planning tool to predict all intercity transportation demand (auto, airline, GA and SATS) and national level impacts (county-to-county)
- Employs socio-economics and demographics of the country
- County-to-county spatial model (complements NSS)
- Multi-modal in scope (commercial air, auto, and new technologies). Predicts how people make choices and decisions for intercity travel
- Accepts any user-defined airport sets
- While TSAM was created to predict the impact of SATS, the framework predicts auto and airline trips as well
- Runs in a standard Windows XP system
- Use of GIS technology to present results (70+ screens)
- **Contact:** Mr. Stuart Cooke (NASA), TSAA Technical Lead (757-864-7087 at NASA Langley Research Center) or Jeff Viken, NASA Systems Analysis Branch (757-864-2875)
Transportation Systems Analysis Model (TSAM)

Model Outputs:
- Annual trips (airport-to-airport)
- Annual trips (county-to-county)
- Mobility Benefits
- Flight Trajectories
- Energy and Fuel Impacts
- Airport Operations

Transportation Systems Analysis Model

Aerospace Technology

Airport Set
- 443 Commercial Airports
- 688 ILS Airports
- 3415 SATS Airports
- User-defined Airports

Model Inputs:
- American Travel Survey
- Woods & Poole Economic Database
- FAA Airport Airspace Database

Flowchart:
- Trip Generation → Trip Distribution → Mode Choice → Transportation Network Analysis
- DOT Commercial Airline Database
- Official Airline Guide
- Eurocontrol BADA Database
- BCA Aircraft Cost Database
- FAA Airport Database

Simulators and Models:
- NAS Strategy Simulator
- ACES Model
- RAMS Model
- INM/NIRS Models
- TAAM Model
- EDMS Model
Trip Generation

Total Intercity Trips Generated by County (Business + Non-Business Trips)
Changes in the U.S. Population
(>Years 2000 to 2025<)

Woods and Poole Demographic Data Implemented in the Transportation Systems Analysis Model

Population Growth
- < -15%
- -15% to -10%
- -10% to -5%
- -5% to 0%
- 0% to +10%
- +10% to +25%
- +25% to +50%
- > +50%

Woods and Poole Demographic Data Implemented in the Transportation Systems Analysis Model
Distribution of Trips (LA County to all)

**Annual Trips**

Legend
- 0 - 10
- 501 - 1,000
- 25,001 - 50,000
- 500,001 - 1,000,000

Gravity Model

\[ T_{ij} = \frac{P_i A_j F_{ij} K_{ij}}{\sum_j A_j F_{ij} K_{ij}} \]
Mode Split Analysis

Factors considered in mode split:
• Travel time
• Travel cost
• Value of time
• Route convenience
• Trip type
• Mode reliability

TSAM employs a Nested Multinomial Logit Model
Consider a Business Trip from Blacksburg, VA to Cleveland, OH

• Suppose three possible travel alternatives are:
  – Auto
  – Commercial Air
  – On-demand service using VLJ aircraft (future NAS)

• To make a mode selection a user might consider:
  – Travel time
  – Travel cost (including lodging and rentals)
  – Duration of stay
  – Value of time
Multi-route Mode Choice Model

TSAM Uses the Official Airline Guide (OAG) to estimate airport-to-airport travel times.
Multi-mode Choice Model
(Door-to-Door Commercial Air Travel Time)

TSAM considers airport processing times and airport egress and access times.

Door-to-Door Travel Time
6.6 Hours by Airline
Multi-mode Choice Model (Auto)

TSAM uses Mappoint to estimate auto travel times.

Travel Time = 6.6 Hours by Automobile
Multi-mode Choice Model (SATS)
# Summary Trip Information

From Blacksburg, VA To Cleveland, OH (391 miles)

Roundtrip Travel Time Savings Using:
- SATS: 7 hrs 2 min + 2 extra nights compared to automobile
- 7 hrs 16 min + 1 extra night compared to fastest airline route

## SATS Trip Details

<table>
<thead>
<tr>
<th></th>
<th>Origin Airport</th>
<th>Destination Airport</th>
<th>Travel Time (Outbound)</th>
<th>Travel Time (Return)</th>
<th>Travel Cost (Roundtrip)</th>
<th>Average Travel Speed</th>
<th>Cost for Speed</th>
<th>Nights Away</th>
</tr>
</thead>
<tbody>
<tr>
<td>SATS</td>
<td>BCB, Virginia Tech / Montgomery Executive, Blacksburg, VA</td>
<td>BKL, Burke Lakefront, Cleveland, OH</td>
<td>2 hrs 59 min</td>
<td>2 hrs 59 min</td>
<td>$1,083</td>
<td>131 mph</td>
<td>$8.33/mph</td>
<td>0</td>
</tr>
</tbody>
</table>

## Car Trip Details

<table>
<thead>
<tr>
<th></th>
<th>Origin</th>
<th>Destination</th>
<th>Travel Time (Outbound)</th>
<th>Travel Time (Return)</th>
<th>Travel Cost</th>
<th>Average Speed</th>
<th>Cost for Speed</th>
<th>Nights Away</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>Blacksburg, VA</td>
<td>Cleveland, OH</td>
<td>6 hrs 30 min</td>
<td>6 hrs 30 min</td>
<td>$493</td>
<td>60 mph</td>
<td>$5.20/mph</td>
<td>2</td>
</tr>
</tbody>
</table>

## Commercial Air Trip Details

<table>
<thead>
<tr>
<th>Route</th>
<th>Origin Airport</th>
<th>Destination Airport</th>
<th>Travel Time (Outbound)</th>
<th>Travel Time (Return)</th>
<th>Travel Cost</th>
<th>Average Travel Speed</th>
<th>Cost for Speed</th>
<th>Nights Away</th>
</tr>
</thead>
<tbody>
<tr>
<td>Route 1</td>
<td>ROA, Roanoke, VA</td>
<td>CLE, Cleveland, OH</td>
<td>6 hrs 37 min</td>
<td>6 hrs 36 min</td>
<td>$526</td>
<td>59 mph</td>
<td>$7.39/mph</td>
<td>1</td>
</tr>
<tr>
<td>Route 2</td>
<td>ROA, Roanoke, VA</td>
<td>CAK, Akron, OH</td>
<td>6 hrs 50 min</td>
<td>7 hrs 15 min</td>
<td>$528</td>
<td>57 mph</td>
<td>$7.65/mph</td>
<td>1</td>
</tr>
<tr>
<td>Route 3</td>
<td>CLT, Charlotte, NC</td>
<td>CLE, Cleveland, OH</td>
<td>7 hrs 38 min</td>
<td>7 hrs 12 min</td>
<td>$638</td>
<td>51 mph</td>
<td>$10.71/mph</td>
<td>1</td>
</tr>
</tbody>
</table>

## Market Share Details*

<table>
<thead>
<tr>
<th>Household Income Group</th>
<th>&lt;$30K</th>
<th>$30K-$60K</th>
<th>$60K-$100K</th>
<th>$100K-$150K</th>
<th>&gt;$150K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto</td>
<td>82 %</td>
<td>76 %</td>
<td>64 %</td>
<td>53 %</td>
<td>51 %</td>
</tr>
<tr>
<td>Airline</td>
<td>18 %</td>
<td>24 %</td>
<td>30 %</td>
<td>32 %</td>
<td>31 %</td>
</tr>
<tr>
<td>SATS</td>
<td>0 %</td>
<td>0 %</td>
<td>5 %</td>
<td>16 %</td>
<td>18 %</td>
</tr>
</tbody>
</table>

*Numbers rounded to nearest percent.
Converting Trips to Flights (On-demand VLJ)

**TSAM Model**

- **Model Outputs**
  - Airport catches (airport to airport)
  - Origin catch distribution
  - Trend analysis
  - Weather, industry, and economic effects
  - Demand, benefit, and cost analysis
  - Economic impacts
  - Energy and fuel impacts
  - Airport operations

- **Model Inputs**
  - Network and aviation data
  - Market data
  - Social and economic data
  - Operational data

- **Model Components**
  - Trip Generation
  - Trip Distribution
  - Mode Choice
  - Aircraft Performance
  - Taxi/Runway Time
  - Traffic Demand
  - Airport Operations
  - Trajectory Analysis
  - Transportation Systems
  - Analysis Model
  - Aerospace Technology

**Annual Person Trips**
- By mode
- (Airport-Airport)
- (County-County)

**Seasonal Travel Effects (ATS)**

**Daily Trip Analysis**
- (Hourly Passenger Demand)

**Flight Trajectory Analysis**

**On-demand VLJ ACES Output**

**ETMS Business Aircraft Flight Distribution**

- Observations
- Departure Time (hrs)
Airline Flights and Legacy GA

Annual Person Trips By mode (Airport-Airport)

Initial Base Schedule

Commercial Airline Schedule (Fratar Model)

Flight Trajectory Analysis

Legacy GA Monte Carlo Demand Model

Legacy GA Airline Flights ACES Output

NASA Langley / Swales
Traffic Assignment (Sample Flight)

- Estimates the number of flights across the National Airspace System (NAS)
- Aircraft performance model (Eurocontrol BADA Model)
- Estimates fuel consumption

Jacksonville

Miami
Closing the TSAM Loop with Airspace/Delay Models

TSAM can measure directly the effect of system delays in the demand for air transportation.

**TSAM Model**

- Transportation Systems Analysis Model
- Aircraft Flights
- NAS Components
- Adjusted Travel Time/Cost

**Flight Trajectory Analysis**

- Aircraft Flights
- ACES Output

**System Induced Delays**

- ACES, RAMS, TAAM, LMINet or NASPAC

**Airline Schedules And Network Changes**

- NSS Simulator

**NAS Component Capacities**

- Model Outputs:
  1. Air travel time (airport-airport)
  2. Airport delays (airport-airport)
  3. System delays (airport-network)
  4. Energy and fuel impacts
  5. Airport Operations

**Adjusted Travel Time/Cost**

- Airline Schedules
- Network Changes
TSAM Implementation Scheme

**Time = Base Year**

- National Mobility

**Time = 1**

- Trip Generation
- FAA Airport Airspace Database

**Time = 2**

- Mode Choice
- FAA Airport Airspace Database

**Time = Horizon Year**

- Mode Choice
- FAA Airport Airspace Database

**Model Outputs**

- Annual trips (airport-to-airport)
- Annual trips (county-to-county)
- Mobility Benefits
- Flight Trajectories
- Energy and Fuel Impacts
- Airport Operations

**National Mobility And Impact Metrics**
Transportation Systems Analysis Model (TSAM) Demand

- TSAM can make future projections (to 2030) for the following:
  - Commercial airline demand and operations
  - Legacy General Aviation operations
  - SATS / VLJ / Air-Taxi both demand and operations (Emergent travel mode)
  - International Commercial Airline demand and operations
Applications
Impact of VLJ Operations in the NAS
Very Lights Jets

• General purpose category of jet-powered aircraft weighting less than 10,000 lbs

• Aircraft in flight testing phase
  – Eclipse Aviation 500 (April 2006)
  – Cessna Mustang (April 2006)
  – Adam 700 (End of 2006)
  – Grob SP (Unknown)

• Aircraft in the design stage
  – Embraer Phenom 100 (2008)
  – Diamond Jet (unknown)
Typical Very Light Jet Vehicle Modeled

- Pressurized aircraft
- All weather vehicle
- Four revenue seats
- 365 mph cruise speed
- Certified to fly into known icing conditions
- 700 nm practical with 2 passengers (4 seats total + pilots)
- Cost per passenger-mile ($1.75 nominal based on life-cycle cost analysis)
- 1.2 million dollars (cost)
- 3,415 public airports (> 3,000 ft. paved runways)
- Low Landing Minima capability provided to all airports using SATS LLM hardware (WAAS-aided)
- **Airport Design Group = A-I**
- **Wake Vortex Classification = Small**
On-demand VLJ Fleet Size vs. Cost for Service

Fleet Size (Aircraft) vs. SATS Cost ($/passenger-mile)

Cost Metrics:
- Total Cost Per Hour: $2,412.61
- Cost Per Mile: $0.93
- Fuel Expense: $22,004.81

Annual Costs:
- Annual Tape Cost: $17,591.21
- Annual Maintenance & C.m.: $4,411.11
- Annual Friction Cost: $2,006.25
- Annual Hangar and Ops.: $48,403.54
- Annual Fuel and L. Cost: $87,203
- Annual Personnel Cost: $8,000
- Annual Training Cost: $2,200.60
- Total Annual Cost: $125,401.00

Total Annual Person Trips: 23,000
Aircraft Speed: 300.2
Load Factor: 0.80
Profit Margin: 0.30
Avg. Reserving Rate: 0.50
VLJ Aircraft Fleet Size Projections (with Capacity Constraints)

- FAA 2005 Forecast
- Honeywell Forecast
- Embraer Forecast

Assumes a fixed demographic and socio-economic (WP 2004)

**Interpretation**

In 2015 there could be 4,200-5,000 VLJ aircraft flying in the NAS
Spatial Distribution of SATS (VLJ) Operations (2014)

TSAM Output
VLJ Traffic in 2025 with OEP Airports

Daily VLJ Demand (# of Flights)
- < 25
- 25 - 50
- 50 - 100
- 100 - 250
- > 250
Legacy GA Operations
(Swales GA Analysis Module)
Year 2015 Analysis (VFR + IFR Traffic)

69,879 flights per day
45,649 VFR flights
24,230 IFR flights
VLJ Traffic Will Fly Below Regular Airline Traffic due to Shorter Stage Lengths

Average Cruise VLJ Flight Level = 230*

Average Cruise FL Cessna CitationJet I = 240**

Average Jet Cruise Flight Level = 320**

* TSAM Analysis
** FAA ETMS Data
2014 VLJ Air-Taxi NAS Impacts

Airspace Impacts (Year 2014)

Enroute Center

Daily Aircraft Operations (IFR)
Connections Between TSAM and NSS Strategy Simulator
Implementation into Vensim by Ventana

VLJ Aircraft Production Constraint Model

Fleet Constrained by Production Capacity

Flights Constrained by Production Capacity

Source: Trani & Balg (2005), jsoo_vlij_modelling_v7.0
Note: Comments and units have been added by
and have not been reviewed by VT for accuracy.

cf. Trani & Balg side 15

cf. Trani & Balg side 17
Predicted FAA Revenue for Various GA Fuel Tax Schemes

VLJ traffic is included in this analysis.

For Jet and Avgas users, 21.8 and 19.3 cents/gallon is predicted.
Impact of Ticket Taxes and Airline Fare Yields in Air Transportation Demand
Airline Demand as a Function of Ticket Taxes

TSAM Demand for Segment Tax = $3.10/leg

Projected Ticket Prices in 2025
(at 85% of Ticket Cost in 2000)

Projected Ticket Prices in 2025
(62% of Ticket Cost in 2000)

Lost trips ~ 80 million round air trips

Stephanie Chung’s M.S. Thesis (Virginia Tech 2005)
Demand Analysis to Support JPDO
Future NAS Demand Predictions
Modeling NGATS in TSAM

- **Airport capacity improvements**
  - Airport landside improvements
    - Reduced travel times from access point to aircraft gate
  - Airside improvements
    - Improved airport capacity (reduces scheduled delay in system)

- **Airspace technology improvements**
  - Reduced flight times by virtue of improved ATM structure and more fuel optimal trajectories

- **Controlling parameters in the TSAM model**
  - **Airline Fare Scaling Factor (AFSF)**: Regulates fares charged by airlines to flying public
  - **Airport Processing Time Scaling Factor (PTSF)**: Controls the processing times at the airport
  - **Airline Travel Time Scaling Factor (ATTSF)**: Regulates flight time of every flight from an origin to a destination airport

  - These parameters are controlled through a user interface in the model
  - Parameters for competing modes (auto and GA) are left constant in this analysis since we are trying to understand the effect of NGATS in the unconstrained demand function
NGATS Objective

• Expand Capacity - Reduce transit time and increase predictability (domestic curb-to-curb time cut by 30%)

• This objective was approximated by reducing airport transit time by 50% and scheduled flight time by 5%

• Airport transit times:  
  - Origin Airport
  - Destination Airport
  - Large hubs: 2.0 hrs to 1.0 hrs, 45 min to 23 min
  - Medium hubs: 1.5 hrs to 45 min, 45 min to 23 min
  - Small hubs: 1.25 hrs to 38 min, 30 min to 15 min
  - Non-hubs: 1.0 hrs to 30 min, 30 min to 15 min

• A 5% reduction in scheduled flight time only partially removes the delay (padding) already built in today’s schedules
Airline Demand Will Benefit from NGATS

![Chart showing the impact of NGATS on airline demand](chart)

- **Lost Airline Demand Without NGATS**

  - **2025 with NGATS**
  - **2015 with NGATS**
  - **2025 no NGATS**
  - **2015 no NGATS**
  - **Current 2005**

Annual Person Trips (Millions of Round Trips)
Spatial Distribution of Travel Time Savings due to NGATS (2025)

- 398.3 million hours saved by business travelers
- 845.7 million hours saved by personal travelers
- 40.9 billion dollars (using FAA economic values)

Sam Dollyhigh (Swales) calculations using TSAM
Concluding Remarks

- TSAM is a flexible intercity transportation framework
- TSAM projects the national demand for **all forms of air travel** from socio-economic and population characteristics by county
- TSAM can compute the demand for a completely new mode of travel diverted from existing travel modes
- TSAM provides a foundation to conduct various types of studies:
  - Cost-benefit of FAA technology investments in NAS
  - Airport priority investments
  - Demand changes with airline and FAA policies
  - Noise and emission impacts
  - Impact of government policies in travel behavior
- Detailed systems analysis models like TSAM complement the FAA NAS Strategy Simulator
NASA LaRC Staff Contributing to Model Development/Analyses

- **Stuart Cooke** - SATS TSAA Level 2, Aeronautics Research Directorate
- **Jeff Viken** - SATS TSAA Level 3, ASAB
- **Sam Dollyhigh** - Swales Aerospace
- **John Callery** - Swales Aerospace
- **Jeremy Smith** - Swales Aerospace
Virginia Tech Air Transportation Systems Laboratory Staff

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- Mr. Howard Swingle
- Mr. Nick Hinze
- Graduate Research Assistants
  - S. Ashiabor
  - X. Yue
  - A. Seshadri
  - K. Murthy
Backup Slides
Measuring Environmental Impacts using TSAM and INM and EDMS
VLJ Noise Characteristics

- Low noise characteristics
- Low thrust engines (1,000 - 1,300 lb.)
- New technology engines
Noise Impact Analysis

Airport Demand Function

TSAM Model

Integrated Noise Model

Noise Areas Around Teterboro

Without SATS Operations

With SATS Operations

65 DNL Noise Areas (Significant Exposure)
Teterboro Airport (metropolitan airport)

- Up to 180 VLJ operations per day in 2014
- 5-7% increase in the noise contour area when VLJ operations are added to the airport base operations
Nationwide Emissions (with EDMS 4.2) Using TSAM

CO Emissions (tons)
- 0 - 100000
- 100001 - 250000
- 250001 - 500000
- 500001 - 1000000
- 1000001 - 2700000
Travel Time Savings ($40.9 Billion)
VLJ Daily Demand Map in TSAM
VLJ Flights from a single Airport in TSAM