Impact of Very Light Jet (VLJ) Flights on Airport Terminal Area

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Outline

• Future Flights (Demand)
  – Airline Flights
  – VLJ Flights
  – Legacy GA Flights

• Airside Facilities (Supply)
  – Runway
  – Terminal Area
  – En-route

• Impact on the Terminal Area
  – Any Congestion/Delays?
  – Any Environmental Issues?

• Suggestions
What is Very Light Jet (VLJ)?
Very Lights Jets (VLJ)

- 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)
  - Spectrum 33 (2008)
  - Diamond Jet (unknown)
VLJ Engine Manufacturers

• Pratt and Whitney Canada
  – PW 610 (Eclipse 500)
  – PW 615 (Cessna Mustang)
  – PW 617 (Embraer Phenom 100)

• Williams International
  – FJ44 (Adam 700)
  – FJ33 (Spectrum 33)
Typical Very Light Jet Vehicle

- Pressurized aircraft
- All weather vehicle
- Four revenue seats
- 365 mph cruise speed
- Certified to fly into known icing conditions
- 1,100 nm range (maximum). 700 nm practical with 2 passengers
- 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
Future Flights* Estimation

*Flights =
Airline Flights
+ VLJ flights
+ Legacy GA Flights
Transportation Systems Analysis Model (TSAM)

Travel Time Analyses

Demand

Transportation Systems Analysis Model for the Small Aircraft Transportation System (SATS)

Version 3.45 - Release - Date: 05/18/2005

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Transportation Systems Analysis Model (TSAM)

Model Outputs:
- a) Annual trips (airport-to-airport)
- b) Annual trips (county-to-county)
- c) Mobility Benefits
- d) Flight Trajectories
- e) Energy and Fuel Impacts
- f) 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
- DOT Commercial Airline Database
- Official Airline Guide
- Eurocontrol BADA Database
- BCA Aircraft Cost Database
- FAA Airport Database

Model Components:
- Trip Generation
- Trip Distribution
- Mode Choice
- Transportation Network Analysis

Simulation Tools:
- 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 (TSAM)

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 (TSAM)
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 Choice Analysis

Factors considered in mode choice:
- Travel time
- Travel cost
- Value of time
- Trip purpose
- Travel party size
- Route convenience
- 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
  - Party size
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 (VLJ)

Door-to-Door Travel Time
3.0 Hours by On-demand VLJ
Summary Trip Information
From Blacksburg, VA To Cleveland, OH (391 miles)

Roundtrip Travel Time Savings Using
- 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>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 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>$1,093</td>
<td>131 mph</td>
<td>$8.33/mph</td>
<td>0</td>
</tr>
</tbody>
</table>

### Car Trip Details

<table>
<thead>
<tr>
<th>Origin</th>
<th>Destination</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>Auto</td>
<td>Blacksburg, VA</td>
<td>6 hrs 30 min</td>
<td>5 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></th>
<th>&lt;$30K</th>
<th>&lt;$60K</th>
<th>&lt;$100K</th>
<th>&lt;$150K</th>
<th>&gt;$150K</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Auto</strong></td>
<td>82%</td>
<td>76%</td>
<td>65%</td>
<td>52%</td>
<td>51%</td>
</tr>
<tr>
<td><strong>Airline</strong></td>
<td>18%</td>
<td>24%</td>
<td>30%</td>
<td>32%</td>
<td>31%</td>
</tr>
<tr>
<td><strong>VLJ</strong></td>
<td>0%</td>
<td>0%</td>
<td>5%</td>
<td>16%</td>
<td>18%</td>
</tr>
</tbody>
</table>
### Intercity Travelers by Mode (from LA County)

<table>
<thead>
<tr>
<th>Year</th>
<th>Case</th>
<th>NGATS</th>
<th>Total Trips</th>
<th>Business Trip</th>
<th>Non-Business Trip</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>2a</td>
<td>No</td>
<td>3.4 million</td>
<td>3.4 million</td>
<td>0.13 million</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(53.7%)</td>
<td>(53.7%)</td>
<td>(2.1%)</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>NGATS</td>
<td>2.8 million</td>
<td>16.6 million</td>
<td>0.02 million</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(44.2%)</td>
<td>(65.0%)</td>
<td>(0.1%)</td>
</tr>
</tbody>
</table>

#### 2015 Case 2a: No NGATS
- Existing commercial airport set (443 nationwide)
- **Airline Fare Scale Factor = 0.720**
- **VLJ**
- **Auto cost = $0.37 vehicle-mile**
- Processing times at airports remain the same

#### 2015 Case 4: NGATS
- Existing commercial airport set (443 nationwide)
- **Airline Fare Scale Factor = 0.720**
- **VLJ**
- **Auto cost = $0.37 vehicle-mile**
- **Processing Times Scaling Factor = 0.75**

(Captured from Virginia Tech Transportation System Analysis Model (TSAM))
Mode Choice Window in TSAM
Travel Time Saving
(Case 2a minus Case 4)

137 mil. hr Time Saving
(Business Trip)
Convert Air Demand to Flights

Daily Passengers

Seasonal and Daily Variation

Daily Passengers
Create Flight Trajectories

Daily Flights

Performance Metrics:
- Flight Time,
- Fuel Consumption
Spatial Distribution of VLJ Flights (year 2015)
TSAM is ...

• A strategic planning tool to estimate the intercity transportation demand that
  – Employs socio-economics and demographics of the country,
  – County-to-county spatial model (complements NSS),
  – Multi-modal in scope (auto, airline, GA and VLJ),
  – Includes domestic and international trips
  – Accepts any user-defined scenarios: airport sets, fare, processing time, new technologies, etc.
  – Runs in a standard Windows XP system, and
  – Use of GIS technology to present results (70+ maps)

• The current TSAM is an unconstrained model.
  – It assumes that there is no capacity constraints in runway, terminal area and en route.

• We need “credible capacity-delay analysis” to obtain the steady-state solution.
Impact of VLJ Flights in the Airport Terminal Area
Question 1:

Can VLJ/GA operations at TEB, FRG, and HPN grow at the predicted growth rate with interacting LGA, JFK and EWR?

TEB, FRG, HPN, LGA, JFK and EWR share substantial flights through the same departure/arrival fixes.
Interactions....

- TEB Departures
- TEB Arrivals
- EWR Departures
- EWR Arrivals
- LGA Departures
- LGA Arrivals

Eliot
Lanna
White

20 nm
50 nm

Long Island
**New York Area Terminal Operations**

- **In 2004**, there are **2.3 million operations** at 10 New York terminal area airports.

- **In 2015**, there could be **2.8 million operations** at the same airports (21% increase).
  - With VLJ operations, the total number of operations could go as high as **3.1 million** in 2015 (34% increase).

**Q:** What will be terminal area delays for TEB, FRG, HPN flights?
Terminal Areas of Interest

- San Francisco
- Los Angeles
- Dallas--Forth Worth
- Chicago
- New York
- Miami
- Atlanta
- Denver
- DC/Philadelphia
- Central Florida
- Las Vegas
- Pittsburgh
- Seattle
- Houston
- Boston
- New York
TEB Airport Runway Capacity Envelopes

(Analysis with Airport Capacity Model)
Teterboro Future Hourly Demands

<Without NGATS>

Optimum VMC Hourly Capacity
Optimum IMC Hourly Capacity

<With NGATS>

Optimum VMC Hourly Capacity
Optimum IMC Hourly Capacity

Time of Day (GMT)
Q2: What will be runway delays for TEB flights?
Impact of VLJ Flights in the Airport Terminal Area (Environmental)
Teterboro Airport
(Noise Analysis using INM)

- 180 VLJ operations per year in 2014
- 6-7% increase in the noise contour area when VLJ operations are added to the airport base operations

Q3: Will the noise restrict VLJ operations?

SATS Program Study sponsored by S. A. Cooke (NASA)
Emission (CO) Analysis using EDMS 4.2

Q4: Will the emission restrict VLJ operations?

CO Emissions (tons)

- 0 - 100000
- 100001 - 250000
- 250001 - 500000
- 500001 - 1000000
- 1000001 - 2700000

SATS Program Study sponsored by S. A. Cooke (NASA)
Suggestions
Suggestions

• What if we add one hour delay to all the TEB flights,

• TEB VLJ passengers in 2005 with no delay: 62,650 pax/yr.

• TEB VLJ passengers with 1 hr extra delay: 44,993 pax/yr.

We need the more in-depth analysis in
– Terminal area delay using simulation tools such as ACES, RAMS, TAAM, or LMI-Net,
– Runway delay,
– En route delay, and
– Environmental constraints.

Flight Trajectory Generator

Adjusted Travel Time/Cost

System Induced Delays

Simulation (ACES, RAMS, TAAM, LMINET)

NAS Component Capacities

NSS Simulator

TSAM Model
Questions?
Supplements
(TSAM)
Mode Choice = f(Travel Time, Travel Cost, Income, Trip Purpose)

Legacy GA (Exogenous)

Travelers

Current TSAM

Cargo

Future TSAM
Convert Air Demand to Flights

Daily Demand

Seasonal and Daily Variation

Daily Demand
Converting Trips to Flights (On-demand VLJ)

**TSAM Model**

- Trip Generation
- Hotel Travel
- Airport-Airport Database
- Final Trip Distribution
- Hourly Passenger Demand
- Transportation Systems Analysis Model

**VLJ Annual Person Trips (Airport-Airport) (County-County)**

**Seasonal Variation (ATS)**

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

**Flight Trajectory Generator**

**ETMS Business Aircraft Flight Distribution**

**On-demand VLJ ACES Output**

**ACES Output**

- on-demand VLJ
NAS Daily Flights

Baseline NAS: 2004 ETMS
Projections:
2014 - NAS Flights + VLJ
2025 - NAS Flights + VLJ

Baseline and Projected NAS Daily Traffic
Supplements
(NGATS Scenarios)
## Scenarios Modeled
*(Same as the Gulf of Mexico Study)*

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2005</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Case 1</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Airline Fare Scale Factor = 0.800</td>
</tr>
<tr>
<td></td>
<td>Current airline network structure</td>
</tr>
<tr>
<td></td>
<td>Auto cost ($0.37 / veh-mile)</td>
</tr>
<tr>
<td></td>
<td>No VLJ</td>
</tr>
<tr>
<td><strong>2015</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Case 2a</strong></td>
<td></td>
</tr>
<tr>
<td><strong>No NGATS</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Existing commercial airport set (443 nationwide)</td>
</tr>
<tr>
<td></td>
<td>Airline Fare Scale Factor = 0.720</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td></td>
<td>Auto cost = $0.37 vehicle-mile</td>
</tr>
<tr>
<td></td>
<td>Processing times at airports remain the same</td>
</tr>
<tr>
<td><strong>2025</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Case 3a</strong></td>
<td></td>
</tr>
<tr>
<td><strong>No NGATS</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Existing commercial airport set (443 nationwide)</td>
</tr>
<tr>
<td></td>
<td>Airline Fare Scale Factor = 0.650</td>
</tr>
<tr>
<td></td>
<td>VLJ</td>
</tr>
<tr>
<td></td>
<td>Auto cost = $0.37 vehicle-mile</td>
</tr>
<tr>
<td></td>
<td>Processing times at airports remain the same</td>
</tr>
</tbody>
</table>
## Scenarios Explored
### (NGATS Solutions with VLJ)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2015</strong></td>
<td><strong>Case 4</strong> NGATS: Existing commercial airport set (443 nationwide) Airline Fare Scale Factor = 0.720 VLJ on-demand services at $1.75 / pass-mile Auto cost = $0.37 vehicle-mile Processing Times Scaling Factor = 0.75</td>
</tr>
<tr>
<td><strong>2025</strong></td>
<td><strong>Case 6a</strong> NGATS: Existing commercial airport set (443 nationwide) Airline Fare Scale Factor = 0.650 VLJ on-demand services at $1.75 / pass-mile Auto cost = $0.37 vehicle-mile Processing Times Scaling Factor = 0.50 Airline Travel Times Scaling Factor = 0.95</td>
</tr>
</tbody>
</table>
VLJ Daily Airport Traffic in 2015 with OEP Airports (NGATS System)

Daily Operations
- <= 25
- 26 - 50
- 51 - 100
- 101 - 250
- > 250
VLJ Daily Airport Traffic in 2025 with OEP Airports (NGATS System)
Another GA Airport Growth Consideration
Constrained Analysis (Noise Impact)

TSAM Model

Integrated Noise Model

Airport Demand Function

Noise Impacts to Population

SATS Program Study sponsored by S. A. Cooke (NASA)
Supplements
(VLJ)
VLJ Traffic Will Fly Below Regular Airline Traffic due to Shorter Stage Lengths

Median Cruise VLJ Flight Level = 230*

Median Cruise FL Cessna CitationJet I = 240**

Median Jet Cruise Flight Level = 320**

* TSAM Analysis
** FAA ETMS Data
VLJ fares by Region

• From MCATS Study
VLJ Aircraft Fleet Size Projections (with Production Capacity Constraints)

**FAA 2005 Forecast**

**Honeywell Forecast**

**Embraer Forecast**

- Assumes a fixed demographic and socio-economic (WP 2004) Interpretation
- In 2014 there could be 4,200-5,000 VLJ aircraft flying in the NAS
Summary of VLJ Forecast Results (TSAM)

Notes:
1) Results for year 2047 require large extrapolations of demographic model
2) High production capacity scenario
3) VLJ = $1.75 per passenger-mile, optimistic airline fares, auto = 37 cents/veh-mile
2014 VLJ Air-Taxi NAS Impacts

Airspace Impacts (Year 2014)

Enroute Center

Daily Aircraft Operations (IFR)


FAA Center Projections (2014)

VLJ Traffic (2014)
VLJ Fleet Size vs. Cost for Service

SATS Cost ($/passenger-mile)

Fleet Size (Aircraft)

- 1200 hours / year
- 800 hours / year
APO View of the VLJ World (March 2005)

- FAA APO assumes microjets (or VLJs) will be used as standard corporate jets (300-342 hours per year) based on historical trends
  - 4,000 microjets in 2016
  - Low use rate (< ~ 400 hours per vehicle)
- This results in small number of total hours flown since VLJs are assumed to be used in traditional low use roles
Comparison with Virginia Tech Projections

• We have projected that 70-75% of the fleet will go to on-demand services (today Eclipse Aviation claims 67% of the orders are for air taxi services)
  – 4,800 to 5,400 VLJs in 2016
  – High use rates (800-1,200 hours per year)
  – On-demand air taxi services
  – Fractional ownership

• Conclusion:
  – APO forecast has substantially fewer hours flown per year for the fleet
  – For NGATS planning we recommend a more “optimistic” view of VLJ demand to be ready for a VLJ wave if it happens
Supplements
(Non-towered Airport)
Impact of VLJ Operations at Non-Towered Airports (2025 scenario)
Non-towered Airport Capacity Gains

• The SATS Program successfully demonstrated capacity improvements at airports with no control towers
• Use of Airport Management Module (AMM)
• High-Volume Operations (HVO)
Future Airport Procedures (SATS Program)

- Example of technology implications for non-towered airports
- High-Volume-Operations (HVO) concept (NASA Langley)

Danville Demo (2005)

HVO technology has impact on airport capacity
Technology can Help but to what Extend?

- Conduct RNP 0.3 approaches to two distinct airports using PRM-aided ILS simultaneous spacing criteria

Supplements
(Future Airline Schedules)
Methodology to Create Future Airline Schedules

• TSAM provides airline demand estimates for 443 domestic airports
• Swales Aerospace has developed a Fratar-based module to predict the future flight schedules (from current schedules) produced by TSAM
• Airplanes are assumed to have an average 70% load factor

Direct Flights

• As demand increases between city pairs in the future, when demand justifies it, direct flights are introduced where non existed previously
• We model this by introducing 2 direct flights (each way) per day when passenger demand exceeds 25k trips per year
• Add 1 morning and 1 evening direct flight each way
• Remove shortest connecting route flights from future schedule (only flights of 2 legs considered)
• 2 direct flights replace 4 connecting flights
Methodology to Create Future Airline Schedules

Adding Frequency and Larger Aircraft

• Increased passenger demand between airports can be met with a combination of increased flight frequency and larger aircraft.
• Research by Airbus\(^1\)(next slide) indicates that airlines will satisfy increased demand by adding the following service (flights refer to all airlines combined):
  – Total round trip flights <= 6 - Increase frequency of flights between airports
  – Total round trip flights > 60 - Increase capacity (size) of aircraft
  – Total round trip flights in between: Use a combination of increased frequency and increased capacity.

Airbus Global Market Forecast Method

The GMF assumes liberal frequency development

Total daily flights (all airlines combined)

Capacity/frequency split

Capacity share

Capacity growth only

Frequency share

Frequency growth only

Maximum service levels

Satisfactory regional service levels (Europe-Asia shown)

Distance (km)
Supplements
(GA)
Legacy GA Flights*

• **Model:**
  
  – Uses baseline values for projected active aircraft and itinerant operations derived from TAF & FAA Airspace Forecasts FY 2004-2016.
  – Includes airports reporting 10 or more itinerant GA operations (per year) in the 2004.
  – Projects a flight “schedule” between 5243 public and private airports using Frata model.

• **Results:**

  – About **65,000** itinerant GA flight per day (average) in **2005**, and About **76,000** per day in **2025** (17% increase).
    • Growth mostly due to business jets which will be IFR flights (275% increase)
  – Flight sets:
    • Single-engine VFR, Single-engine IFR,
    • Multi-engine VFR, Multi-engine piston IFR, Multi-engine turbo
    • IFR, Jets (assumed to always be IFR)

*By Swales Aerospace.*
Legacy GA Operations (Swales Aerospace Module)

Year 2015 Analysis (VFR + IFR Traffic)

69,879 flights per day
45,649 VFR flights
24,230 IFR flights
Supplements
(International)
Future Airline Travelers: International

Annual Enplanements

Future Airline Travelers: International

Year

Annual Enplanements (Europe Only)

Annual Enplanements

Africa
- Middle East
Canada
Mexico
Asia
Oceania
South America
Caribbean
Europe

376 million passengers (total)

(Captured from Virginia Tech Transportation System Analysis Model (TSAM))
TSAM comparison with Domestic Enplanement Data

2004

**TSAM:** Business trips 86.7M  
Personal trips: 154.0M  
Total Commercial Airline Trips: 240.7M

How does this relate to enplanements?
Assumption: ~36% of trips have connection  
Each person trip has 2 trips - Depart and Return

TSAM Commercial Enplanements: 654.7M
ATA/FAA Reported Enplanements: 635.5M (3% difference)