Wake Vortex Avoidance System (WakeVAS)
Capacity Gains and Delay Reduction
as a Function of Weather

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Wake Vortex Separation Standards Background

• Current wake separation rules are static, based on empirical measurements, and represent a response to worst-case persistence of wake hazard

• Over 30 years of wake research and the technologies demonstrated in AVOSS (Aircraft VOrtex Spacing System) have produced the potential for a dramatic increase in knowledge about the persistence of wake hazard

• Introduction of systems and procedures that utilize this improved knowledge of wake hazard durations will allow for increases in capacity
NASA Aircraft VOrtex Spacing System (AVOSS)

• Goal:
  – Demonstrate an integration of technologies to provide weather-dependent, dynamic aircraft spacing for wake avoidance
  – Operate real-time in a relevant environment

• System demonstrated at Dallas Fort-Worth Airport in July 2000; Represented the culmination of six years of field testing, data collection, and technology development
Products of the AVOSS Program

- AVOSS effort represented the most comprehensive wake and weather data collection effort to date
  - Over 10,000 wakes measured with relevant ambient weather parameters captured
  - Measurements collected at Dallas Fort Worth, Memphis, Denver over the course of six years
- AVOSS provided platform for subsystem development & integration
  - Major progress made in wake modeling and sensing
  - Weather subsystems were integrated in new ways and data fusing algorithms were developed
- Demonstration of concept for system integration
  - Example guides future operational concept development
WakeVAS Concept Development

Real-Time Wake Hazard Knowledge
- Weather sensing and prediction
- Wake hazard predictions
- Wake sensing

Procedures/Rules Interfaces

- Controller Tools
  - Course – wake is/ is not a factor
  - Fine – integrate into approach spacing tool
- Flight Deck
  - Intuitive Displays (increase situational awareness)
  - NAV/Guidance Integration

- Ground System
- Airborne System
- Hybrid System
- Change Rules
WakeVAS Concept Architecture

- Airport weather system augmented with wake and weather sensors and prediction algorithms
  - Wake algorithm provides probabilistic wake behavior output
  - Fusing algorithm combines sensor data and closes a feedback loop between wake and weather predictions and measurements
  - Closed-Loop prediction system senses current conditions diverging from predictions and adjusts to more conservative spacing and changes prediction of duration appropriately
  - Output is time-varying, weather dependent wake-safe aircraft spacing
Airport Capacity Gains

• Analyzed data for 6 different weather days at 30 minute intervals for 12 selected airports\(^2\)
  – Spacing data for each aircraft class was used along with data from simulation (RAMS Plus\(^3\)) to determine runway arrival rates under IMC
  – Wake model also generates reduced departure time separations
• Airports selected for analysis have significant percentage of heavy/B757 traffic, capacity constraints under IMC
## Airports for WakeVAS Capacity Gains Analysis

<table>
<thead>
<tr>
<th></th>
<th>ATL</th>
<th>BOS</th>
<th>CLT</th>
<th>DFW</th>
<th>EWR</th>
<th>JFK</th>
<th>LAX</th>
<th>LGA</th>
<th>MIA</th>
<th>ORD</th>
<th>SFO</th>
<th>STL</th>
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<tbody>
<tr>
<td><strong>Config.</strong></td>
<td>2 pair</td>
<td>CSPR</td>
<td>INDEP</td>
<td>2 pair</td>
<td>CSPR</td>
<td>INDEP</td>
<td>2 pair</td>
<td>CSPR</td>
<td>2 pair</td>
<td>CSPR</td>
<td>INT</td>
<td>1 pair</td>
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<tr>
<td>% B757 + Heavy</td>
<td>25</td>
<td>14</td>
<td>5.5</td>
<td>14</td>
<td>19</td>
<td>41</td>
<td>21</td>
<td>9</td>
<td>26</td>
<td>15</td>
<td>30</td>
<td>7</td>
</tr>
<tr>
<td>% Time IFR</td>
<td>23</td>
<td>18</td>
<td>18</td>
<td>17</td>
<td>19</td>
<td>14</td>
<td>18</td>
<td>20</td>
<td>3</td>
<td>15</td>
<td>26</td>
<td>23</td>
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</table>

CSPR - Closely spaced parallel runways  
INT – Intersecting runways  
INDEP – Independent runways
Initial Benefits Analysis for WakeVAS Reduced In-Trail Separation of Arrivals under IMC

WakeVAS Improvement in Runway Arrival Rate

Mean Improvement % = 10.16
Example of Arrival Capacity Gains (ATL, best case)

ATL RW 8L/9R Arrivals
01/23/1999 - greatest improvement

Mean Improvement = 10 arrivals per hr
Example of Arrival Capacity Gains (ATL, worst case)

ATL RW 8L/9R Arrivals
05/08/1999 - least improvement

Mean Improvement = 4 arrivals per hr
NAS Wide Delay Reductions

- LMINET$^4$ Queuing network model of NAS used to investigate delay reduction for estimated 2010 demand
- Delays recorded:
  - Departure Queue
  - Arrival Queue
  - Departure Taxi Queue
  - Arrival Taxi Queue
  - Ground Hold
  - Wait for Aircraft (aircraft not available for departure)
  - Total Delay (sum of the above)
- 64 U.S. airports modeled at runway level of detail, included FAA Operational Evolution Plan (OEP) improvements expected by 2010
- Investigated Wake VAS deployment at 12, 30, 64 airports
- Wake VAS used for arrivals only and arrivals + departures
- Assumed 5% departure rate improvement
Demand Data Set for LMINET NAS Delay Reduction Assessment

<table>
<thead>
<tr>
<th>Traffic Type</th>
<th>17 May 2002 Baseline Flights</th>
<th>2010 Flights*</th>
<th>% Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial + Cargo from OAG</td>
<td>30853</td>
<td>37163</td>
<td>20%</td>
</tr>
<tr>
<td>GA from FAA reported data</td>
<td>21294</td>
<td>27533</td>
<td>29%</td>
</tr>
<tr>
<td>Total</td>
<td>52147</td>
<td>64696</td>
<td>24%</td>
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</table>

* Generated using models references 5, 6
Weather data for NAS Delay Analysis

- 3 Representative days in the NAS
- Annualized delay calculated as weighted average of each weather day according to probability of occurrence APR (0.13), JUN (0.8), NOV (0.07)

<table>
<thead>
<tr>
<th>Weather Set</th>
<th>%VMC</th>
<th>%MVMC</th>
<th>%IMC</th>
<th>#Airports IMC/MVMC</th>
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<tr>
<td>April</td>
<td>77.0</td>
<td>16.9</td>
<td>6.1</td>
<td>33</td>
</tr>
<tr>
<td>June</td>
<td>67.1</td>
<td>26.8</td>
<td>6.1</td>
<td>40</td>
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<tr>
<td>November</td>
<td>72.0</td>
<td>14.4</td>
<td>13.6</td>
<td>28</td>
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</table>
Total Hours of Delay for 24 hours of Operations with 2010 Demand

<table>
<thead>
<tr>
<th></th>
<th>Default</th>
<th>WakeVAS for Arrivals and Departures at 12 Airports</th>
<th>WakeVAS for Arrivals and Departures at 30 FAA Benchmark Airports</th>
<th>WakeVAS for Arrivals and Departures at 64 LMINET Airports</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delay (hrs)</td>
<td>Delay (hrs)</td>
<td>%Reduction</td>
<td>Delay (hrs)</td>
</tr>
<tr>
<td>April</td>
<td>3780</td>
<td>3591</td>
<td>5.00</td>
<td>3574</td>
</tr>
<tr>
<td>June</td>
<td>4035</td>
<td>3877</td>
<td>3.92</td>
<td>3841</td>
</tr>
<tr>
<td>November</td>
<td>14120</td>
<td>13641</td>
<td>3.39</td>
<td>12950</td>
</tr>
</tbody>
</table>
Estimated Annual Reduction in Delay for 2010 Demand

2010 Estimated Annual Percentage Reduction in Total Delay due to WakeVAS

- 12 WakeVAS Apts
- 30 FAA Benchmark Apts (excluding HNL)
- 64 LMINET Apts

WakeVAS for Arrivals
WakeVAS for Arrivals & Departures
Estimated Annual Air Carrier Cost Savings for 2010 Demand

2010 Estimated Annual Air Carrier Cost Savings due to WakeVAS

- 12 WakeVAS Apts
- 30 FAA Benchmark Apts (excluding HNL)
- 64 LMINET Apts

[Bar chart showing cost savings for different scenarios]
Annualized Delay Reduction and Cost Savings Calculation

• Use $2209 in the air, $1702 on ground, $853 in ground hold (engines off) per hour in 2004 $ average air carrier variable operating cost calculated from FAA data\textsuperscript{7}
• Weight weather days according to probability of occurrence
• Weighted annual hours of delay saved for WakeVAS at 12 study airports for arrivals only = 46563 hrs saving approximately $75 million
• Weighted annual hours of delay saved for WakeVAS at 64 LMINET airports for arrivals and departures = 108481 hrs saving approximately $165 million
• Detailed results presented in reference 8
References

1) **Multivariable Regression Models for Prediction of Eddy Dissipation Rate from Available Meteorological Data**
   Gerald E. Plassman, Gerald H. Mall, and John R. Quagliano
   1 - Raytheon Technical Services Company, Hampton, Virginia
   2 - Analytical Services and Materials, Hampton, Virginia
   3 - NCI Information Systems, Hampton, Virginia
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2) **Systems Analysis for a Wake Vortex Advisory System (WakeVAS) at Selected U.S. Airports**
   Appendix – Parametric Model for the Performance of a Wake Vortex Advisory System
   Gary D. Millsaps, Jeremy C. Smith, Swales Aerospace, Hampton, VA, David Rutishauser, AST, David Hamilton, AST, LaRC Airborne Systems Competency, Hampton, VA
   NASA/CR (in publication)


4) **Modeling Air Traffic Management Technologies with a Queuing Network Model of the National Airspace System**

5) **Integrated Mode Choice, Small Aircraft Demand and Airport Operations Model**

6) **Future Air Traffic Growth and Schedule Model**

7) **Economic Values for Evaluation of FAA Investment and Regulatory Decisions**
   GRA Incorporated, DTFA 01-02-C0020, May 2004

8) **Wake Vortex Advisory System (WakeVAS) Evaluation of Impacts on the National Airspace System**
   Jeremy C. Smith, Swales Aerospace, Hampton, VA
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