An Analysis of Potential Capacity Enhancements Through Wind Dependent Wake Turbulence Procedures

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### Timeline:

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>Near-term CSPR Procedures: SOIA, 2500 ft rule (FAA)</td>
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<tr>
<td>2006</td>
<td>Mid-term: Wind-Dependent CSPR Departures (FAA/NASA)</td>
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<tr>
<td>2010</td>
<td>Long-term: Active Wake Avoidance Solution (Primarily NASA)</td>
</tr>
<tr>
<td>2020</td>
<td>International Coordination: European/FAA/NASA Action Plan</td>
</tr>
<tr>
<td></td>
<td>Wake Alleviation (NASA Only)</td>
</tr>
</tbody>
</table>
Problem Description
Example: STL Departures

Wind Direction

<table>
<thead>
<tr>
<th>Condition</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good VMC (3500ft and above)</td>
<td>66.88%</td>
</tr>
<tr>
<td>Low VMC with Dual Arrivals</td>
<td>21.42%</td>
</tr>
<tr>
<td>Low VMC with Single Arrivals</td>
<td>2.50%</td>
</tr>
<tr>
<td>IMC (below 1000 ft)</td>
<td>9.20%</td>
</tr>
</tbody>
</table>

90.8% of the time, just a wake constraint
Guidelines for the Initial Concept of Use

• Provide a measurable benefit based on
  – Hours of operation for various ceilings
  – Current separations for those ceilings
  – Current arrival/departure rates for those ceilings

• Keep proposed operational changes small
  – Same separation rule for all aircraft when reduced separation is possible
  – Simple indication (red/green) for the controller
  – No change in pilot procedures

• Use existing NAS wind sensors

• Facilitate a stable ATC procedure
  – Stable wind criteria
  – Extended periods of wind persistence

• Host any DST on existing ATCT displays
Integrated Design and Decision Making Process

- Initial Concepts
- Decision Support Tool
- Wind Forecast Algorithm
- Benefit Assessment
- Cost Assessment
- Implement / Don’t Implement
Concept Provides Initial Requirements for Wind Forecast Algorithm

Local controller planning horizon defines forecast requirement of about ten minutes

1) Type of aircraft in front
2) Type of aircraft just departing the parallel runway
3) Aircraft positions on final

Local controller may develop plan for 2nd or 3rd aircraft in queue. Considerations include:
Introduction

We went through a series of questions:

• Question 1: Is the wind favorable often enough to get benefit?

• Question 2: Is the surface wind predictable?

• Question 3: Is the wind aloft predictable?

The answers to these questions led to starting a prototype development effort
RUC/ASOS Climatology

Hours per year RUC/ASOS winds favorable by altitude

12R/30L

Threshold (kts)

12L/30R

Threshold (kts)

Altitude (ft)
Prediction of Surface Crosswind

- Need to predict when 2-minute mean crosswind will stay above threshold

- Time horizon much shorter for departures than arrivals
  - 20 minutes for planning
  - 5 minutes for safety

- Approach: Predict the range of future crosswinds. When the range of crosswinds are all above threshold, reduced spacing allowed.
Prediction of Surface Crosswind

- Predict mean crosswind and variability (std dev) separately
- Predicted range of crosswind = mean + n*standard deviations
- Take advantage of trends
- Take advantage of current variability
- Use a mix of time scales
- Use linear regression to build models
Surface Crosswind Prediction Performance

- 4 kt crosswind threshold
Type 1 Errors
By Magnitude And Timing

-4 kt crosswind threshold
Prediction Of Winds Aloft

- If blue crosswind profiles have crosswinds greater than threshold + buffer: Predict wind aloft favorable
- Validate against Lidar profile (red profile)
Crosswinds Aloft Results

- Surface to 1000 ft
- 1437 samples, over 8 months
- 1 error scales to 4 hours per year
Prototype Wind Prediction System

ASOS

surface wind prediction

RUC
NEXRAD VAD

wind aloft prediction

NEXRAD storm track

weather-type analysis

profile prediction

Crosswind favorable?
Yes/No
Summary

- There are many time periods with favorable crosswinds aloft at St Louis

- The crosswind prediction results to date are very promising

- Prototype development is under way for St Louis
Capacity Benefit Analysis Process

TOTAL CURRENT CAPACITY

Forecast & Data (ASOS/ASPM) → Favorable Weather? → Additional Capacity

Baseline Capacity

New Demand

Demand Data (ASPM)

TOTAL CURRENT DEMAND

Excess Demand

+ → Quantity and Length Delayed

-
Impact of Excess Demand on Benefits

Existence of Conditions

% Hrs Meeting
- Xwind Conditions
- Xwind & Dmd
- BOS
- DTW
- STL
- Actual
- Forecasted

Crosswind Threshold
Impact of Excess Demand on Benefits

Existence of Conditions

Crosswind Threshold

% Hrs Meeting Xwind Conditions
% Hrs Meeting Xwind & Dmd
BOS
DTW
STL
Actual
Forecasted
Impact of Excess Demand on Benefits

Existence of Conditions

- % Hrs Meeting Xwind Conditions
- % Hrs Meeting Xwind & Dmd
- BOS
- DTW
- STL
- Actual
- Forecasted

Crosswind Threshold

0  -2  -4  -6  -8  -10
# Capacity Enhancements

## Percentage Improvement Over Baseline Departure Capacity

<table>
<thead>
<tr>
<th>Airport/Runway Pair</th>
<th>Percentage Heavies and B757s</th>
<th>Wind-Based Departure Procedure</th>
<th>Wind-Based Departure Procedure with Heavies/B757s Departing From Downwind Runway</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLE 5 W/R</td>
<td>1%</td>
<td>1%</td>
<td>3%</td>
</tr>
<tr>
<td>STL 12 L/R</td>
<td>7%</td>
<td>3%</td>
<td>14%</td>
</tr>
<tr>
<td>PHL 9 L/R</td>
<td>9%</td>
<td>5%</td>
<td>16%</td>
</tr>
<tr>
<td>SEA 16 L/R</td>
<td>12%</td>
<td>7%</td>
<td>11%</td>
</tr>
<tr>
<td>DTW 21 C/L</td>
<td>13%</td>
<td>19%</td>
<td>23%</td>
</tr>
<tr>
<td>DFW 35 C/L</td>
<td>14%</td>
<td>8%</td>
<td>12%</td>
</tr>
<tr>
<td>BOS 22 L/R</td>
<td>15%</td>
<td>8%</td>
<td>13%</td>
</tr>
<tr>
<td>EWR 22 L/R</td>
<td>18%</td>
<td>9%</td>
<td>14%</td>
</tr>
<tr>
<td>SFO 28 L/R</td>
<td>27%</td>
<td>14%</td>
<td>19%</td>
</tr>
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</table>
Sample Local Control Position CHI on ACE-IDS

Cannot use color as sole indicator.

Need alarm if wake-free indication changes while controller is viewing another page
Simulation Facility