Vortex Spacing Measurements Updates

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Acknowledgement

- Federal Aviation Administration
- NWRA
Background and Motivation

- Vortex Spacing, Commonly Denoted as “bo”, is a Fundamental Parameter Affecting Wake Turbulence Descent and Decay
  - This is Known Since Early Days of Wake Turbulence Research
- The Ability to Meaningfully Characterize bo is an Integral Part of the FAA NextGen Effort to Migrate from a “Weight Based” Wake Vortex Separation Minima to a “Wake Based” Standard
  - If Two Aircraft Having the Same Wingspan and Weight, the Aircraft with the Smaller bo/Wingspan is Expected to Decay Quicker
- Theoretical Value of bo/Wingspan is $\pi/4$
Vortex Spacing Illustration

Mikoyan-Gurevich MiG-29UB by Maciek Wolanski
Minsk Mazowiecki Airport (EPMM), Poland, May 20, 2009
http://www.airliners.net/photo/Poland---Air/Mikoyan-Gurevich-MiG-29UB-(9-51)/1535348/L/
Background and Motivation

- Historically, “bo” Parameter is Difficult to Measure
- Advent of Measurement Technology Enables a Renewal Effort/Interest to Examine this Quantity in a Systematic Way
- In addition, In Collaboration with EUROCONTROL and NASA NRA* Related Efforts, FAA Invested Some Resources to Characterize the Vortex Spacing Statistics
- Descriptions from Two of the Methodologies Are Discussed Herein, Respectively Termed as
  - Inferred Method
  - Direct Method

*NRA = NASA Research Announcement
Inferred Method
Inferred Method

- Pulsed Lidars such as the LMCT WindTracers (Not Restricted to the WindTracers) Have Much Higher Angular Resolution than Range Resolution
- Fine Angular Resolution Translates Fine Wake Descent Measurements in the Typical Scan Geometry (“Side Viewing” with a Long Standoff Distance)

Inferred Method

- It Can be Shown that bo can be Inferred from Wake Descent

- AIAA-2013-0365 in Addition Described Environmental Parameters that Can Affect the bo Estimates

- The Volpe Analysis is Essentially the Same as AIAA-2013-0365, and Only Differs in
  - Data Source
  - Data QA and Selection Process
Data Source - SFO

Data Source for Inferring Vortex Spacing
For Aircraft Types that Have At Least 100 Tracks Satisfying the QA Criteria from SFO:

- 16 Aircraft Types (Based on Type Designators)
- The Range of bo/Wingspan can be up to 20 Percent Different from $\pi/4$
Direct Method
Direct Method

- The Smaller / Compact Pulsed Lidars (Marketed Primarily for Wind Energy Sector) Recently Procured by FAA Have Attributes that Can be Deployed Almost Like a Traditional CW LIDAR Upward View Mode
  - Specific Example/Experience Reported Here is Based on the Galion Lidar from SgurrEnergy/Halo Photonics
  - Has a Programmable Scanner
  - Has Very Short Pulse Width and Minimum Standoff Distance Relative to LMCT Type of Hardware
  - Does Not Have the Range as LMCT Lidars (But Not an Issue for This Application)
  - Implication – Allows Vortex Spacing Measurements Directly
Measurement Equipment
Direct Method – Expected Pattern

- If Measurements Were Made with
  - Upward Scanning Lidar
  - Aircraft Passing Directly Above
  - No Crosswind
  - After Rollup ... and
  - Before Wake “Gets Old”

Vertical Velocity Distribution of Wake Vortices

Ref: *Journal of Fluid Science and Technology, Vol. 3, No. 4, 2008*
Interpretation of the Mean LOS Wind Data

Simulated Lidar Spectra for a Horizontal line across the 2 wakes

Simulations showing that using mean wind does not bias $b_0$. 

Black Line = Vortex Profile from Mean LOS Winds
Status of the Direct bo Measurements

- **BOS Phase (Fall 2012)**
  - Proof of Concept Established
  - Proof of Concept Version of the Processing and Analysis Code Developed
  - Staffed Test: Procedure to Acquire Data with Rotating Staff Developed

- **JFK Phase (Starting Winter 2013 and Ongoing)**
  - Focusing on *Heavy* Aircraft (Or RECAT B and C)
  - JFK’s Daily Heavy or CAT B/C Traffic is 7 Times Those of BOS
  - Additional Processing Software Automation Developed (Almost Beta Version)
  - Data Collection Will Continue as Resources Permit
    - Currently the Effort is Considered Supporting FAA’s Farther Term Objectives
Direct Method – Two Examples

An FAA Large
41_20120531_175309.csm

An FAA Heavy
41_20120601_150236.csm

Two Examples Are Not on the Same Scale
- Blue is the Wind Corrected First Scan
- Red is the Wind Corrected Second Scan
- Green is the Average of the Two Scans
An Example of Ongoing Improvement
Direct Method – Additional Technical Information

Overall Ongoing Efforts

- Continue the SFO OGE Data Collection and the Associated Inferred bo Effort
- Continue the Software Enhancement Towards V1.0 for the Direct Method Data
- Continue the Direct Method Data Collection at JFK
  - Weather and Resource Permitting
- Will Compare with Inferred Method When the Aircraft Counts on Specific Airplanes of Interest Become Large Enough
Closing Comments

- Vortex Spacing is One of the Key Parameters that Will Enable the Migration from a “Weight Based” Wake Separation Minima Standard to that of a “Wake Based”
- Advances in Remote Sensor Technology Enabled the Current Efforts to Better Quantify Vortex Spacing
  - LMCT or Similar COTS Hardware: Late 1990s/Early 2000s
  - Galion or Similar COTS Hardware: Late 2000s/Early 2010s
- Input/Feedback/Comparison Opportunity from Airframe Manufactures’ Data Would be Very Valuable
Questions?