Vortex Spacing Measurements Updates

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Volpe The National Transportation Systems Center
Advancing transportation innovation for the public good

U.S. Department of Transportation
Research and Innovative Technology Administration
John A. Volpe National Transportation Systems Center

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

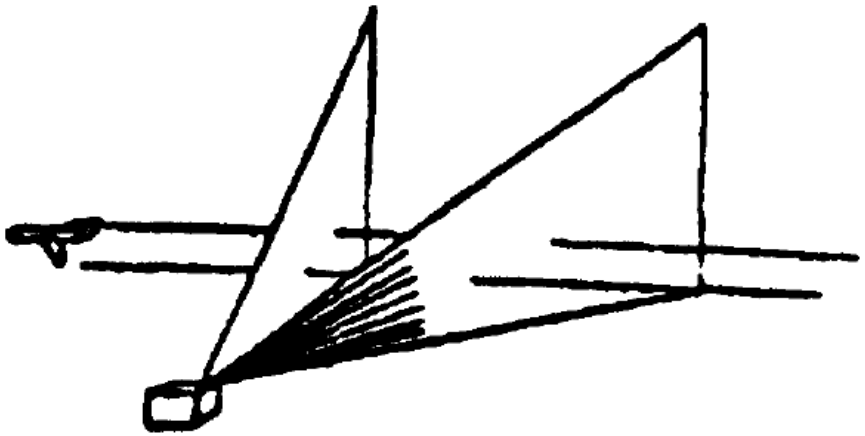
- Historically, “bo” Parameter is Difficult to Measure
- Advent of Measurement Technology Enables a Renewal Effort/Interest to Examine this Quantity in a Systematic Way
- In addition, In Collaboration with EUROCONTROL and NASA NRA* Related Efforts, FAA Invested Some Resources to Characterize the Vortex 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)

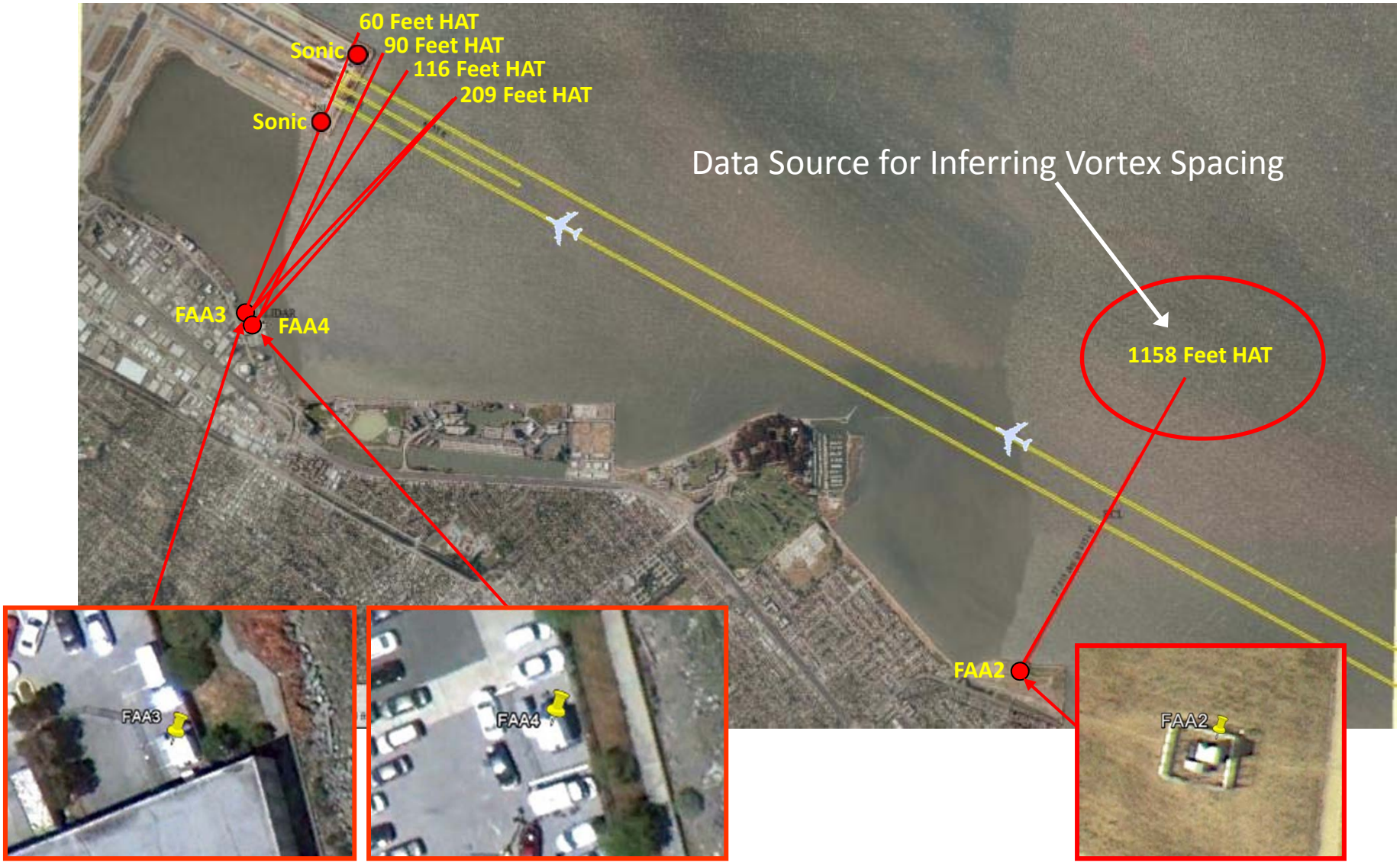


Depiction of the Typical Lidar Side View Scan Geometry. Ref: Thomson and Hannon, "Wake Vortex Modeling for Airborne and Ground-Based Measurements Using a Coherent Lidar", SPIE Vol. 2464/63, 1995.

Inferred Method

- It Can be Shown that bo can be Inferred from Wake Descent
  - A Recent Ref: Delisi, et al., "Estimates of the Initial Vortex Separation Distance, bo, of Commercial Aircraft from Pulsed Lidar Data", AIAA-2013-0365, 2013
- 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 Trend - PRELIMINARY

- 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

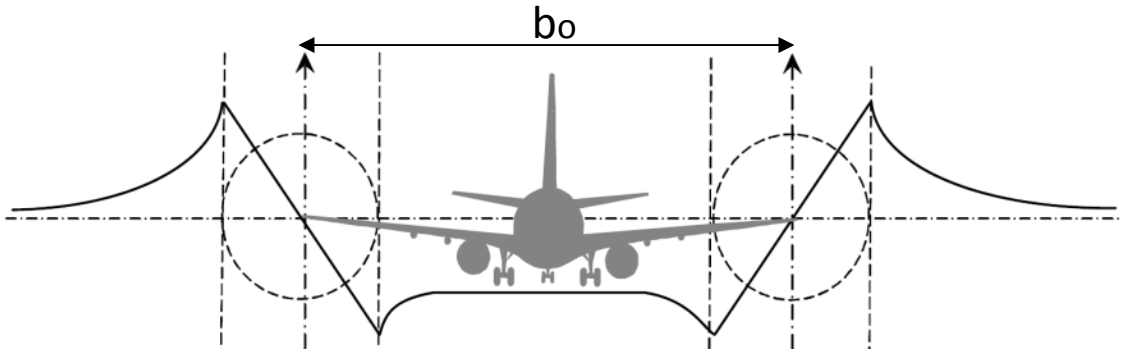
Direct Method

- 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

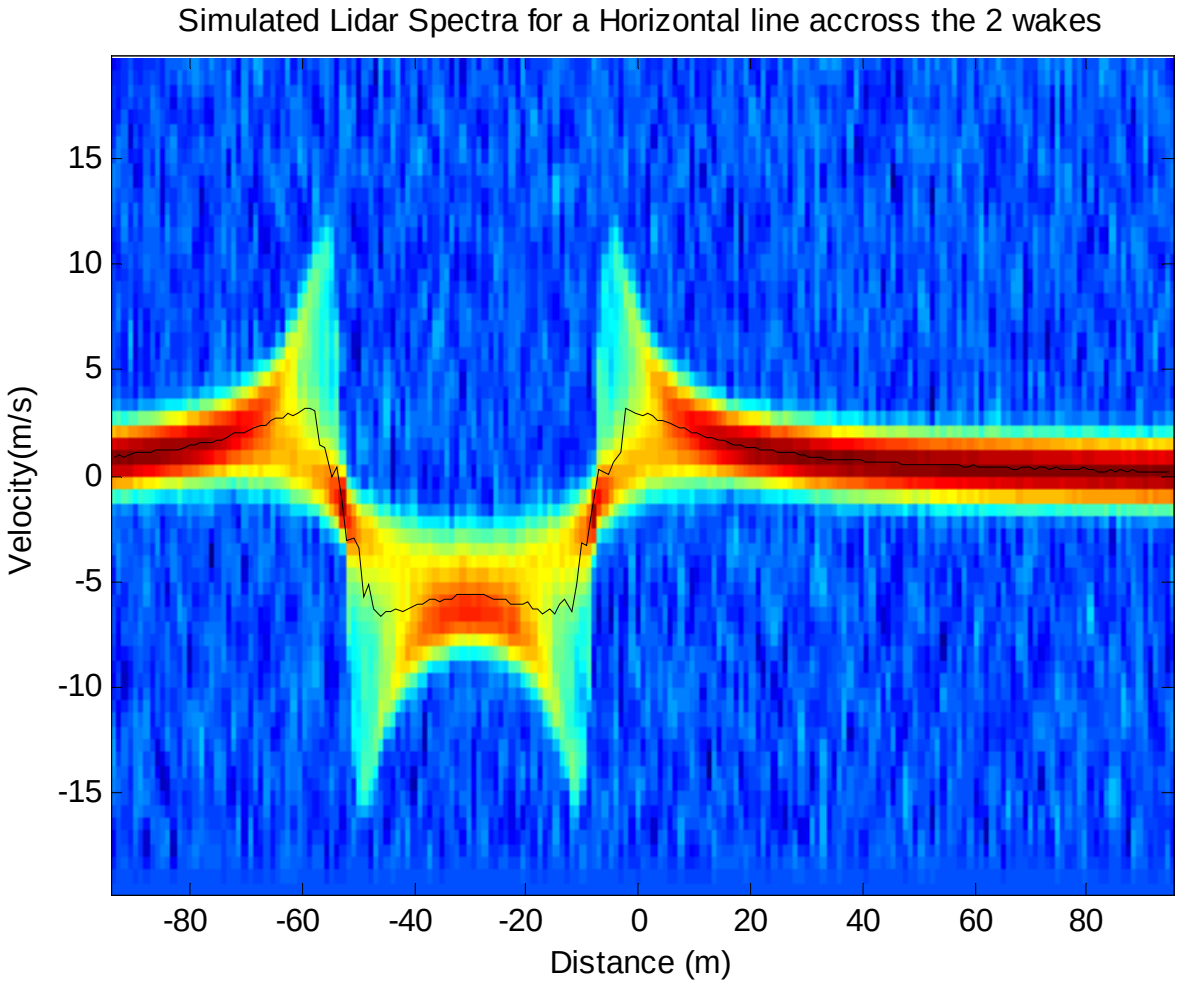
- If Measurements Were Made with
  - Upward Scanning Lidar
  - Aircraft Passing Directly Above
  - No Crosswind
  - After Rollup … and
  - Before Wake "Gets Old"



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



Black Line = Vortex Profile from Mean LOS Winds

Simulations showing that using mean wind does not bias b_o

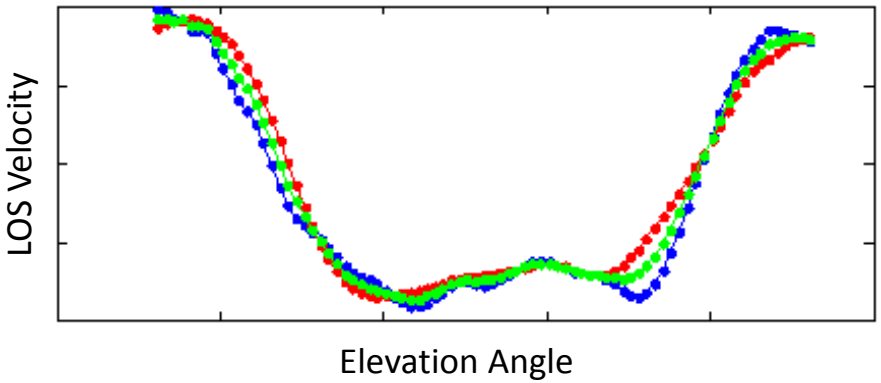
Status of the Direct bo Measurements

- 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

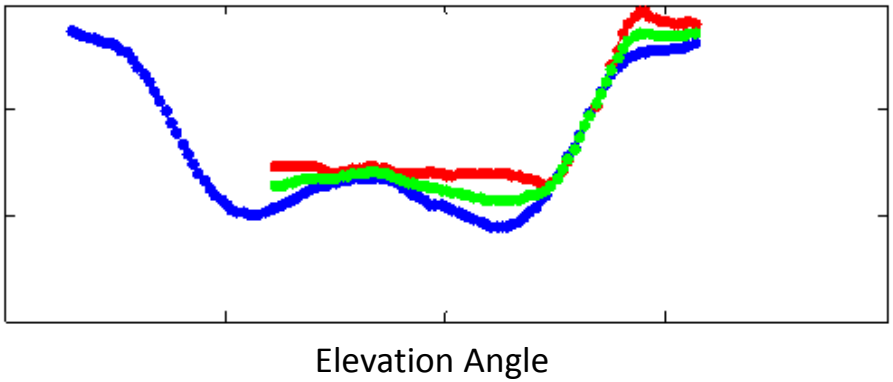
An FAA *Large*

41_20120531_175309.csm



An FAA *Heavy*

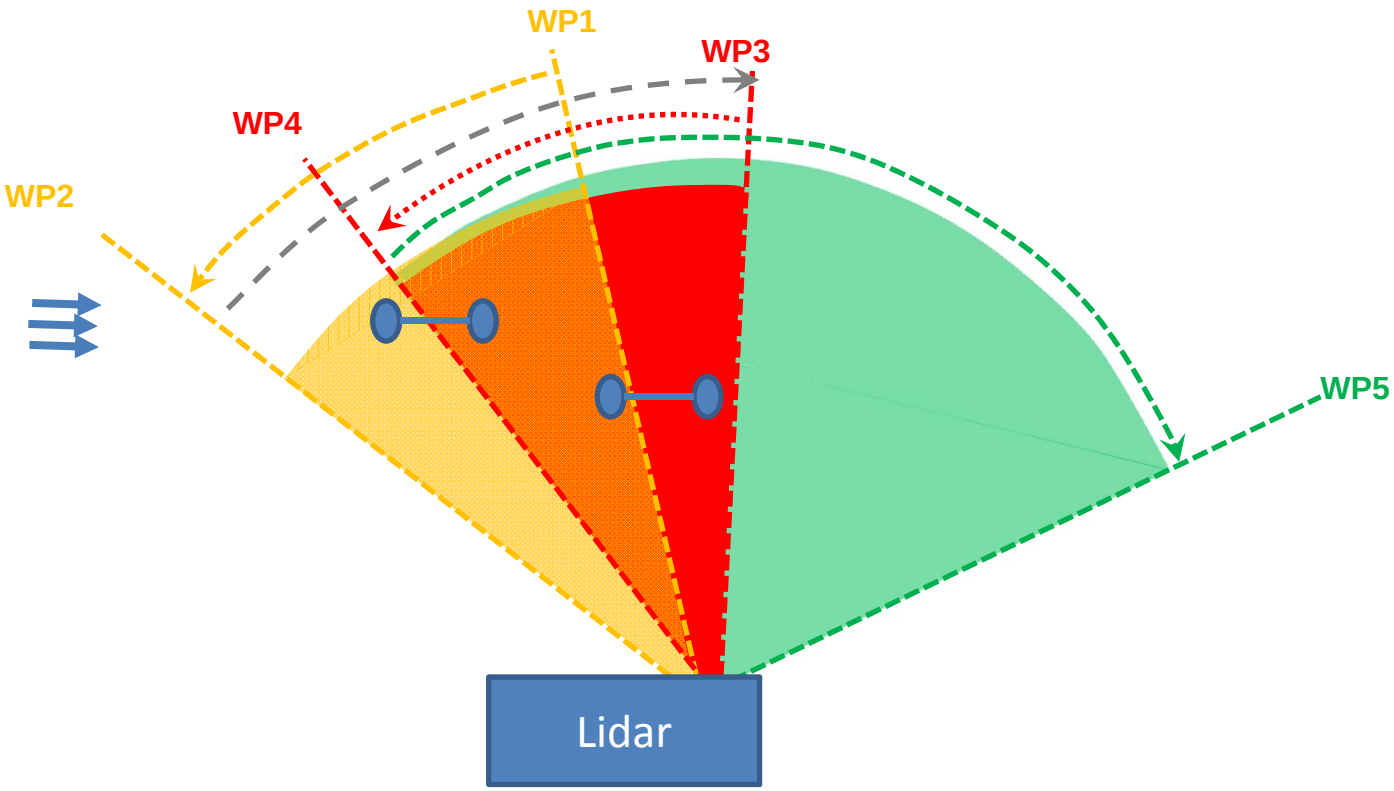
41_20120601_150236.csm



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

Wassaf, H. S., et al., "Direct Measurement of Initial Wake Separation (b_o) Using Pulsed Lidars", 17th Coherent Laser Radar Conference (CLRC), June 17-20, 2013

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?

Boeing MD-10-10F by Jonathan Derden – Jetwash Images
Tampa International Airport, April 2, 2006
http://www.airliners.net/photo/FedEx---Federal/Boeing-MD-10-10F/1032068/L/