NASA Wake Encounter Flight Test Database

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Hampton, Virginia
Presentation Outline

- Background
  - Test Objective
  - Approach
- What was accomplished
  - Wake-Encounter Flight Tests
  - Wake Measurement Database Content
  - Obtaining Database
- Lessons learned
- Summary
From 1995-97 NASA conducted a series of flight tests to develop a dataset to validate wake encounter simulation models. Flights supported the “Hazard Metric” element of NASA’s Aircraft Vortex Spacing System (AVOSS).
Wake Hazard Metric

- Establish a metric to quantify the upset potential of a wake
- Establish a candidate boundary for an “acceptable” wake encounter

The Hazard Metric element of the AVOSS program was eliminated in 1998 due to funding constraints
Wake Encounter Model Validation

What you need to know:

- The wake velocity flow field
- The airplane’s position relative to wake
- Airplane’s rates, accelerations and control positions
- Accurate airplane model
Flight Test Setup

Wake & Atmospheric Measurement
OV-10

Wake Generator
C-130

Wake Encounter
B-737-100
C-130 Wake Generator

- Wgt 95,000 to 113,000 lbs
- Span 132’ 7”
- Clean configuration (flaps up, gear up)
B737 Wake Encounter

- Wgt 90,400 to 79,200 lbs
- Span 93’
- Flaps 15, 30
B737 Wake Encounter Maneuvers

- **Steady**
  - Nose
  - Nacelle
  - Wing tip

- **Dynamic**
  - Out-to-in
  - Down-to-up
  - Up-to-down
  - In-to-out
OV-10 Experimental System

- Cockpit Displays
- Air Data Computers
- INU / GPS

- 5-hole Probe
- NACA $\alpha$, $\beta$ & Pitot-static
- Dew-Point Sensor
- Air Temp. Sensor
- Stereo Wing Video Cameras (left & right)
- Tail Video Camera
OV-10 Wake Measurement
Wake Axis System

- Interpolated C-130 position at $t_{\text{ref}}$
- Orientation of wake axis system
- C-130 ground track
- OV-10 ground track
- Wind
- OV-10 position at wake encounter ($t_{\text{ref}}$)
- Origin of wake axis system
- C-130 position when wake generated ($t_0$)
- $X_w$
- $Y_w$
Wake Velocity Measurement

Ground Track - Flight 558

14:48:09.8 - 14:48:16.3, $\Delta t = 32.8$ sec, $\psi_w = 30.6^\circ$, Wind 257/36 (262/38)
Wake Velocity Measurement

Ground Track - Flight 558
14:48: 9.8 - 14:48:16.3, ∆t = 31.8 sec, $\psi_w = 30.5^\circ$, Wind 268/38 (268/35)

Altitude Profile - Flight 558
14:48: 9.8 - 14:48:16.3, ∆t = 31.8 sec, $\psi_w = 30.5^\circ$, Wind 268/38 (268/35)
Wake Velocity Measurement

Flight 558, Run 26, Event 1

Wake Vertical Velocity - Flight 558

Wake Lateral Velocity - Flight 558

Wake Axial Velocity - Flight 558
Atmospheric Data

Temperature & Dewpoint Profiles

Turbulence Measurements
- Turbulent Kinetic Energy
- Turbulent Dissipation Rate

<table>
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<tr>
<th>Flight No.</th>
<th>Range of Turbulent Dissipation Rate (ft²/s³)</th>
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Wind Profiles

WFF Weather Balloon Data
Wake Descent Profile

Flight 558, Run 26

\[ \Delta h = b_\ast (\Delta t / t_\ast) \]

\( t_\ast = 39.8 \) seconds
Wake Database Content

<table>
<thead>
<tr>
<th>Flight Number</th>
<th>Wake Runs</th>
<th>Wake Measurements</th>
<th>Weather Runs</th>
<th>Wake Images</th>
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The database stored on CD-ROM can be obtained through:

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(757) 864-2022  
d.d.vicroy@larc.nasa.gov
±2 pixels = ±22 feet in depth at 500 ft separation
### C-130 / B737 Wake Encounter Data

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<tr>
<th>Separation</th>
<th>B-737 Flaps</th>
<th>C-130 Speed</th>
<th>Flight</th>
<th>Run</th>
<th>Number of Steady Encounters</th>
<th>Number of Dynamic Encounters</th>
<th>Dyn. Enc. with Stereo Video</th>
<th>Wake Dynamics</th>
<th>Vortex Marked</th>
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</table>

| Total       | 295         | 180         | 72     |
Lesson’s Learned

- Straight, parallel vortices are hard to come by
- Encounters were very dynamic
  - Difficult to separate maneuvering loads from wake induced effects (requires accurate airplane model)
- Resolution of wing tip video cameras was not sufficient to resolve wake location to desired accuracy
- Video tracking task was difficult and fatiguing
Summary

- A comprehensive dataset of C-130 wake measurements is currently available.
- Considerable effort remains to reduce B737 wake encounter flight data into a usable database.
  - Further processing required of wake encounter stereo video to "accurately" resolve wake location relative to B737.