Potential Use of Aircraft Derived Meteorological Data for Wake Turbulence Applications

Wake Vortex & Wind Monitoring Sensors Workshop

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Outline

- Background
- Phasing of Wake Vortex Applications
- Basic Questions to Answer
- Data Elements
- Suggested Data Priorities for Wake Application
- Broadcast Data Link Requirement
- ADS-B Data Links Advantages
- Proposed Initial Wake Turbulence Applications
- Criticality of Data
- Next Steps

Existing Systems Provide Aircraft Met Data to Improve Weather Forecasts

- **AMDAR Program in Europe**
  - E-AMDAR a program under the auspices of EUMETNET
  - 26 European countries participating
  - Participating airlines are Air France KLM, British Airways, Lufthansa and SAS,ThomasCook, Novair, Blue1 and SASNorway
  - ~450 aircraft report daily. (~ 900 atmospheric profiles - 3 hr profiles at 38 airports)
  - E-AMDAR has a set annual budget – to fund management, development and data procurement from the airlines

- **MDCRS (Meteorological Data Collection and Reporting Service)**
  - Commenced operations in 1991
  - Participating airlines are American, Delta, FedEx, Northwest, United, UPS, Southwest
  - 1500 aircraft report Winds and Temps
  - 100 UAL a/c report Turbulence (EDR)
  - 16 UPS 757s report Water Vapor
  - >100,000 observations per day, >3M per month

- **TAMDAR**
  - Continuous operation since 2004 on regional airliners
  - Dedicated sensor suite providing temperature, pressure, and winds aloft measurements, humidity, icing, and turbulence
  - More than 400 participating aircraft (coverage areas - continental United States and Alaska)
  - “Case studies and statistical analyses show that the inclusion of TAMDAR data yields dramatic improvements in the accuracy of forecast models, particularly in dynamic atmospheric conditions.” ref AirDAT LLC

Aircraft as Weather Sensor Platforms

- **Discussion on use of aircraft as real-time weather sensor platforms ongoing for approximately 20 years**
- **Currently have multiple operational systems collecting and reporting aircraft derived weather data**
  - Proven increases in forecast skill using these data
  - Business cases for these operational systems very favorable
  - Coverage areas and participating airlines continue to expand
  - Weather products using these data already used in air traffic control and flight information services applications
- **Difficult for the deployed systems to meet requirements for envisioned long-term real-time NextGen & SESAR wake vortex applications due to:**
  - Ground-based communications & data processing network architecture
  - Data collection & reporting strategies optimized for weather applications & efficient use of data link hardware
  - Data latencies
  - Up link & down link bandwidth limitations

Some Envisioned Wake Vortex Applications

Near-term: (Weather dependent concepts -- no real-time data link of meteorological data required)

- Wake Turbulence Mitigation for Departures (WTMD)
- Crosswind Reduced Separations for Departure Operations (CREDOS)
- 2nd generation systems could potentially utilize real-time weather data to enhance benefits by reducing wind uncertainty buffers

Mid-term: (Weather dependent concepts -- real-time data link of meteorological data could significantly improve benefits)

- Time-Based Separations (TBS)
- Wake Turbulence Mitigation for Arrivals (WTMA)
- Crosswind Reduced Operations (CROPS)
- Typically envision Air-to-Ground data link of meteorological and aircraft specific parameters
- Ground-based decision support systems permit ATC to operate reduced wake vortex separation distances (atmospheric conditions permitting)
- Concepts do not typically require up link of wake vortex data to aircraft or cross link of data between participating aircraft

Far-term: (Dynamic wake vortex separations between aircraft -- real time data link of meteorological and aircraft parameters air-to-ground and/or air-to-air is required)

- Reduced wake vortex separationss & self separation from wakes based on depiction of wake safe flight regions to flight crews
  - NASA flight prototype (2002)
  - GosNIIAS - Wake Vortex Safety System including air-air interaction – (ongoing)
  - FlySafe Wake Vortex Prediction & Alerting Proposal – Airbus Sept 2007
- Dynamic depiction/calculation of wake safe trajectories for trajectory based operations (TBO) and air traffic controllers
- Automated wake vortex conflict detection and alerting for controllers and pilots

Basic Questions Include:

- Can we define a minimum set of data elements today that will support envisioned near-term, mid-term, and far-term wake turbulence applications? ✓
- Can these data be obtained from aircraft acting as meteorological sensors or other data sources? ✓
- Is the meteorological sensor data and aircraft data accessible via current and/or future aircraft data bus networks? ✓
- Will current & future data link communication systems support wake turbulence concepts requiring air-to-ground and air-to-air data links? ✓
- For each concept, what data and what rate of data transmission is required? ✓
- Will current & future data links communications systems support these required data transmission rates? ✓
- What is the extent of the data coverage area that can be obtained from aircraft derived meteorological measurements? ✓
- How are safety risk management topics (if any) addressed for each proposed usage of the data? ?

Data Elements

- **Real-time predictions of the movement and decay of aircraft wake vortices can be developed from a list of data elements that includes:**
  - Wind speed
  - Wind direction
  - Static temperature
  - Static pressure
  - Pressure altitude
  - Aircraft type
  - Aircraft position
  - Aircraft speed and heading
  - Aircraft weight (previous results based on percentage of max landing weight)
  - Local atmospheric turbulence (normally eddy dissipation rate but total kinetic energy has also been used)

Eight data elements currently available on aircraft data bus or provisioned in RTCA documents

Atmospheric turbulence (edr) currently reported by some aircraft – standardization required

Weight & configuration available on some aircraft – standardization required

- **Additional utility for potential future applications may be gained if the list above is supplemented with:**
  - Aircraft configuration data (e.g. landing gear & flap setting)

Availability of Data from Onboard Systems

For most parameters standard ARINC labels exist & required data is available from multiple onboard systems

Parameter Name	Onboard System	Units	Range (Scale)	Resolution
Aircraft Type (not ICAO) Aircraft Position Pressure Altitude Aircraft Speed Aircraft Heading	Data is already provided to ADS-B Transmit Subsystem for broadcast. Standards published in DO-260B (ADS-B MOPS)/ED-102A and DO-282B (UAT MOPS). Approved applications include surveillance and air traffic control.			
Wind Speed	Flight Management Computer & ADIRS & Inertial Ref Sys	Knots	256	1.0
Wind Direction (True)	Flight Management Computer & ADIRS & Inertial Ref Sys	Degrees	+/-1 180	0.05
Static Temperature	Flight Management Computer & ADIRS & Air Data System	Deg C	512	0.25
Aircraft Weight	Flight Management Computer & Thrust Control Computer	Lbs.	1310720	40 (Using proposed encoding scheme)
Aircraft Configuration (landing gear & flaps)	Landing gear and flap configuration is currently available on some aircraft but there is no uniform standard ARINC label assigned for all aircraft. Standardization required.			
Atmospheric Turbulence (edr or TKE)	Some aircraft currently report edr through MDCRS. International agreement on standards required.			

Suggested Data Priorities for Wake Applications

Cumulative Capabilities

Data Elements

- Wind speed
- Wind direction
- Static temperature
- Static barometric pressure
- Aircraft position
- Aircraft speed & heading
- Pressure altitude

1st Priority

Ground-based system extracts aircraft type & weight estimates from ground-based networks (based on Mode S Ident). Generates safe trajectories for ATC DSTs

- Aircraft type
- Aircraft weight
- Atmos.turbulence

2nd Priority

Provides improved ground-based capabilities & enables airborne applications. Provides data for calculation of wake decay and more precise prediction of wake vortex movement. Provides data to enhance meteorological forecasts

- Aircraft configuration data (e.g. flap setting)

3rd Priority

Provides aircraft data specific to phase of flight for highly dynamic NextGen & SESAR operational concepts. Supports precise determination of aircraft trajectory changes. Enables advanced aircraft specific prediction of wake vortex movement & decay,

Note: Can develop successful wake turbulence applications even if some data elements are not available (e.g. aircraft weight)

Broadcast Data Link Requirement

- **Broadcast link of relevant atmospheric and aircraft data is required to accommodate the wide range of temporal and spatial scales associated with hazardous wake turbulence.**
- **To provide data when wake vortices are short-lived and during ascent and descent flight operations, a data broadcast frequency on the order of 15 seconds is desired.**
  - Terminal environment, 15 second update frequency provides a high likelihood of receiving broadcast data:
    - Every 1-2 miles traveled by the generating aircraft
    - Every 1000 ft or less during departure and arrival phases of flight
    - Less than 1000 ft vertically on approach where wake turbulence encounters can be most hazardous
  - Represents a report once every 2 miles typical at cruise speeds
    - High likelihood of receiving broadcast data on temporal and spatial scales consistent with the current separation en route separation standards (5 miles and +- 1000 ft)
- **Addressed data links may be inappropriate for transmission of data to multiple aircraft and ground stations at this frequency**
- **Previous RTCA and FAA studies produced recommendations for a broadcast data link of meteorological and aircraft data**

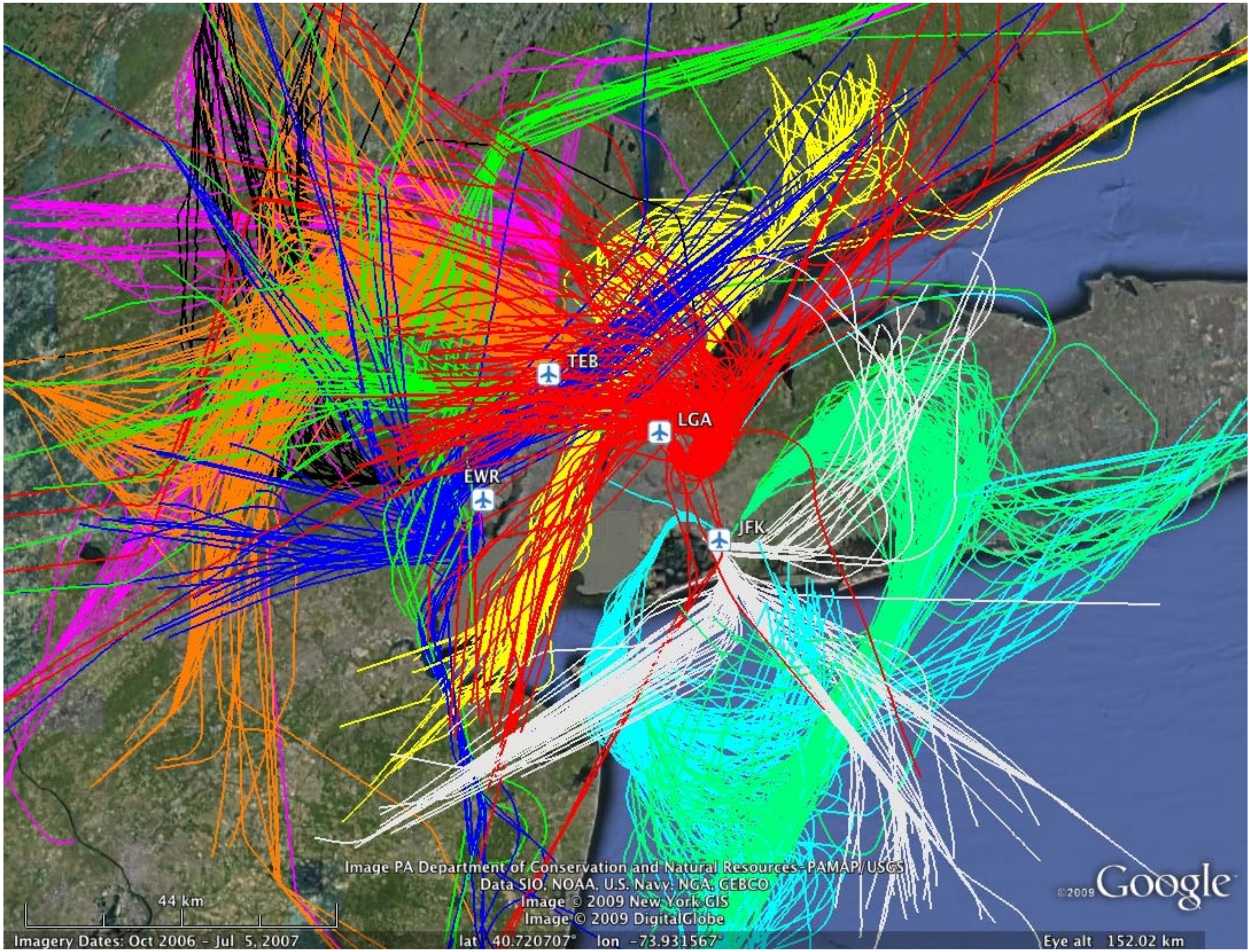
ADS-B Data Link Advantages

- **ADS-B equipped aircraft have the potential to measure and report meteorological data at a high resolution, under all weather conditions, over regions of operational interest**
  - Aircraft fly where observations are needed
  - Data availability meets temporal and spatial needs
  - Much of required infrastructure already available onboard
  - Existing message sets include most of the required data elements
  - Network infrastructure providing coverage at major international airports being deployed for surveillance applications

- **FAA Wake Turbulence Program collaborating with RTCA SC-186 Working Group 1 and international partners to develop system documentation:**
  - Subgroup formed to develop OSED document
  - Hardware foundation based on 1090 MHz Extended Squitter & UAT Minimum Operational Performance Standards (MOPS)

Potential Data Coverage in Dense Airspace Operations

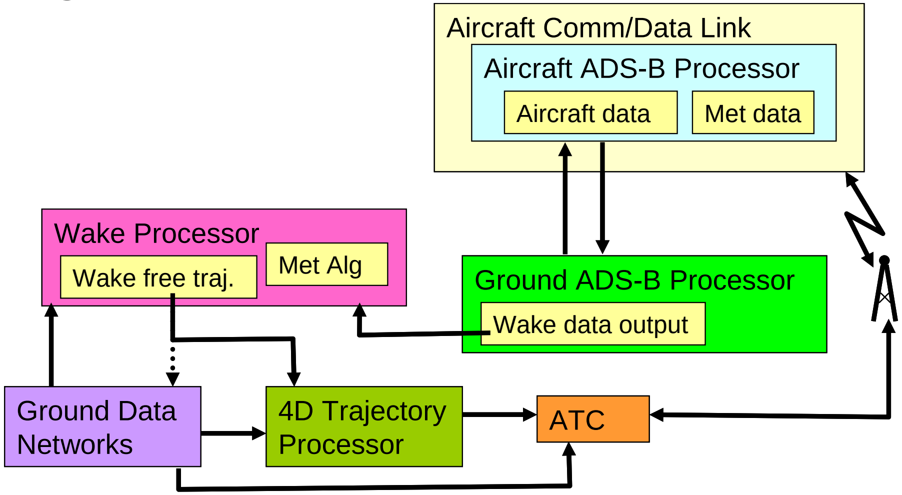
EWR 11 Arr.
EWR 22L Arr.
EWR 22R Dep.
JFK 22L Arr.
JFK 13L Arr.
JFK 13R Dep.
LGA 22 Arr.
LGA 13 Dep.
TEB 19 Arr.
TEB 24 Dep.



Radar Track (PDARS) data for typical IFR operational day in NY airspace

Proposed Initial Wake Turbulence Application

- **FAA Wake Turbulence Program proposed an initial ground-based wake turbulence avoidance application**
  - Application will be crosswind-based and will not rely on any wake decay mechanisms
  - First step in the development of a series of ADS-B supported wake avoidance applications enabling the transition to long-term NextGen and SESAR operational concepts
- **Set of data elements proposed is sufficiently robust to support envisioned NextGen and SESAR ground-based and airborne wake avoidance applications**
- **High potential to produce early benefits for NAS users**
- **Follow on ground-based and airborne applications can use the same data elements**



Criticality of Data

- Criticality of the data and how to address any safety risk management issues are current topics of discussion
- The intended usage of the data will drive the requirements
- For initial ground-based wake vortex applications, data usage is similar to current weather forecast enhancement applications
  - Wake turbulence separations normally represent capacity constraints only at major airports with dense air traffic
  - Multiple aircraft will be reporting data simultaneously from several arrival and departure corridors plus over flight routes (No separation decisions based on reports from a single aircraft)
  - Ground-based systems will assemble composite atmospheric profiles utilizing both airborne and ground based data sources (data quality checks etc. will be included)
- Situational awareness applications (e.g cockpit display of predicted wake locations) may have no impact on standard wake separation distances or procedures
  - Flight operations & roles/responsibilities remain as today
  - Must prevent the display of incorrect or mis-leading data
- Air-to-air wake vortex self-separation applications are likely to have the most stringent data requirements
  - Air traffic density may be high or low
  - Greater reliance on data reported from fewer aircraft
  - May not be able to exclude operations involving as few as 2 aircraft
  - Procedural requirements for a minimum number of reporting aircraft may be needed

Next Steps

- **RTCA DO-260B (1090 ES) & DO-282B (UAT) Informative Appendices**
  - Informative appendices describing wake, air traffic management and weather published in Dec 2009
  - Goals of informative appendices were:
    - Advise aircraft operators on how they can provision their aircraft at present to support these potential ADS-B applications
    - Lay the groundwork for international agreement on the inclusion of these applications in a future revision of the MOPS
  - Informative appendices are advisory documents
    - Indicate formal intention to produces MOPS etc. and become RTCA standards under DO-260C and DO-282C
    - Final versions submitted for publication

- **RTCA sanctioned formation of new group within SC-186 WG 1 to develop:**
  - Operational Services and Environment Description (OSED)
  - Co-chaired by MITRE (Clark Lunsford) & the FAA (Ed Johnson)
  - Subgroup now has approx. 70 members and includes international participants.

  If approved to continue, the group will then develop:
  - Operational Safety Assessment (OSA)
  - Operational Performance Assessment (OPA)

- **RTCA activity will be internationally harmonized**

Questions?

Brief History of SC-186 WG-1 Activity

- **Ad Hoc Group developed:**
  - List of applications in wake, air traffic, and weather with strong business cases
  - Common set of data elements
  - Data message formats consistent with 1090 ES and UAT transponders
  - Messages and data rates consistent with ADS-B bandwidth limitations (no impact on surveillance functions)
  - Informative appendices to be included in DO-260B & DO-282-B

- **RTCA DO-260B (1090 ES) & DO-282B (UAT) Informative Appendices**
  - Informative appendices submitted to WG 3 (1090 ES) & WG 5 (UAT)
  - Goals of informative appendices were:
    - Advise aircraft operators on how they can provision their aircraft at present to support these potential ADS-B applications
    - Lay the groundwork for international agreement on the inclusion of these applications in a future revision of the MOPS
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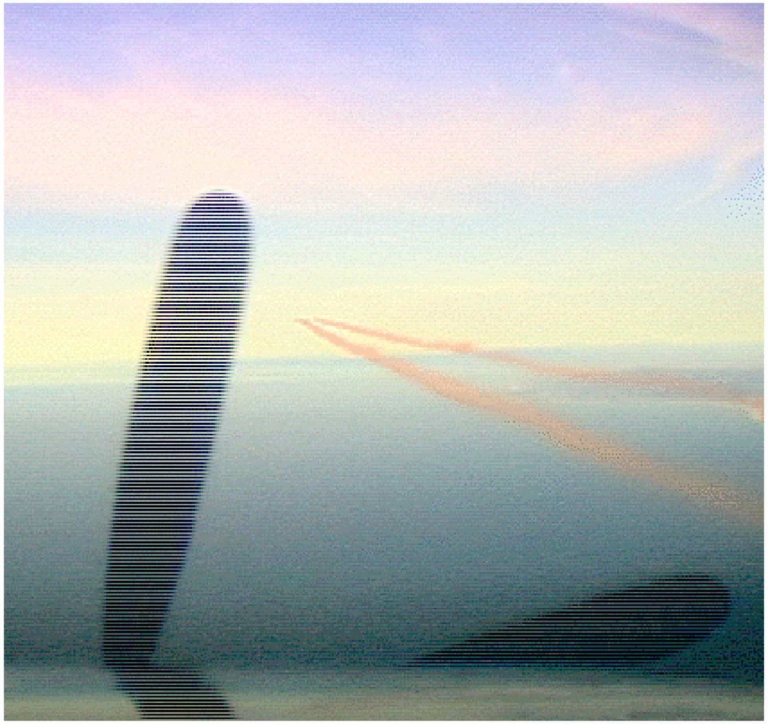
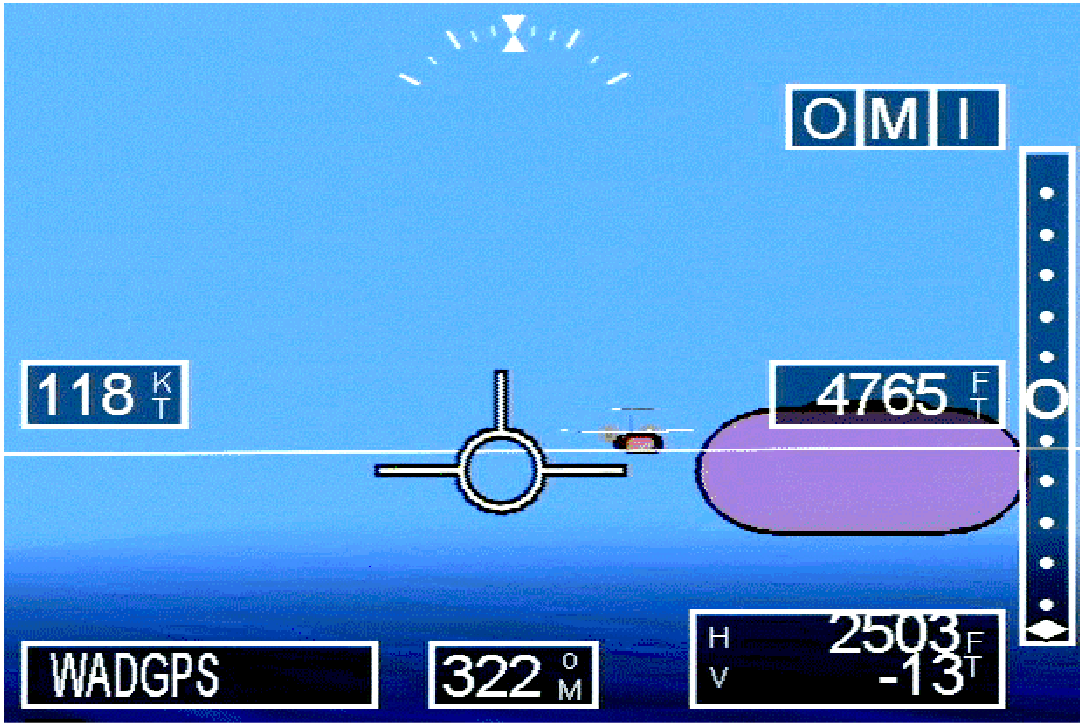
Stanford University Flight Test of Wake Cockpit Visualization 2002

Figure 6-6 Position of wake display between pilots.

In-trail – beside the wake

Wendy L Holforty
Ph.D. Dissertation
Stanford Univ. 2003





Graphics courtesy of Dr. J. David Powell, Stanford University