



Wake Vortex Avoidance Solutions

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Neil O'Connor
Crew Systems & Aviation Operations Branch
NASA Langley Research Center
Hampton, VA 23681-2199
c.j.oconnor@nasa.gov (757) 864-4662



- **Problem statement**
- **Potential for solution**
- **End goal**
- **Recent work**
- **Solution concepts proposed for research**
- **Research steps**
- **Near, Mid, and Far term research**
- **Additional research considerations**
- **Summary**

Wake Vortices



Limitations Due to Wake Vortices



- **Wake vortices limit capacity**
 - Data indicate that current spacing standards are often very conservative
 - Not weather dependent, but worst-case
 - Loss of airport capacity in poor weather operations
 - Loss of visual approaches
 - Loss of full use of many parallel runways
- **This conservative spacing limits efficiency and capacity now as well as limits benefits expected from advanced NextGen super density concepts**
- **Wake sensors and prediction models are immature**



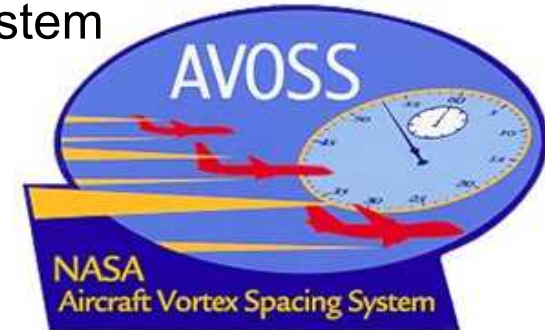
The Potential for a Solution



- **Accurate predictions/modeling of Wake ‘position and trajectory’ and ‘strength and decay’ could be used to:**
 - Safely reduce spacing
 - Enhance throughput and capacity
 - Enable full implementation of NextGen Concepts
 - Enable development of a dynamic wake-based spacing system
 - Optimize spacing and therefore capacity based on weather conditions
- **NASA’s wake vortex models show capability of predicting ‘position and trajectory’ and ‘strength and decay’**

- **Wake-optimized operations throughout the NAS**
 - Dynamic spacing system to maximize capacity
 - Weather dependent
 - Wake behavior forecasting capability
 - Applicable across the NAS
 - Arrivals
 - Departures
 - Enroute
 - Integrated with other efficiency and capacity enhancing concepts and technologies such as:
 - Interval Management for the terminal area
 - Trajectory based operations
 - Autonomous Flight Rules (AFR) and Separation Assurance
- **Wake encounter hazard defined**
 - Government / industry accepted standard of threshold for encounter
 - Threshold definition is a critical enabler for an optimized dynamic system

- **Wake Turbulence Mitigation for Departures (WTMD) – 2000s**
 - FAA project for crosswind based wake avoidance system for parallel runways
 - NASA heavily involved in research; we developed and built the prototype system
- **Aircraft VORtex Spacing System (AVOSS) – 1990s**
 - Wake spacing criteria based on actual weather conditions
 - Development and evaluation of
 - Weather sensors
 - Wake prediction models
 - Wake sensing technologies
 - Demonstration of integrated proof-of-concept system
 - DFW July 2000
 - Collection of wake data
 - DFW 1997, 1999, 2000
 - MEM 1994, 1995
 - JFK 1997



These projects demonstrated that wake solutions are feasible!

Airport Environment

- **Enable one or more alternative separation matrices**

- Based on meteorological-centric wake behavior prediction: could predict no wake issue for next x hours, use runway occupancy time to set following distance
- Early solution

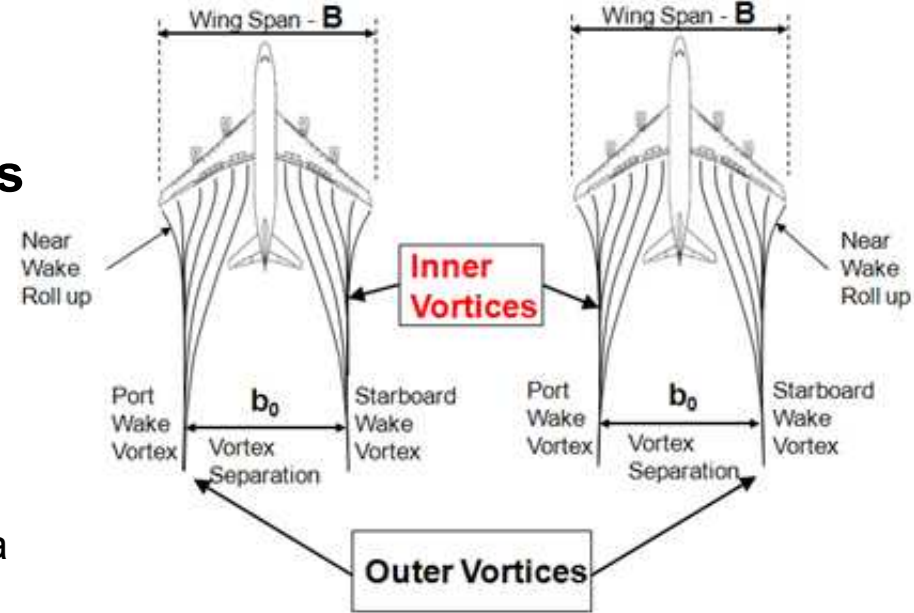
		Trailing Aircraft			
		Super	Heavy	Large/B757	Small
Leading Aircraft	Super	2.5	6	7	8
	Heavy	2.5	4	5	6
	B757	2.5	4	4	5
	Large	2.5	2.5	2.5	2.5
	Small	2.5	2.5	2.5	2.5

- **Dynamic Wake Spacing System**

- Weather-dependent, wake-free airport operations
- Tactical system—Up to 30 minutes for local poor weather recovery or demand surges
- Strategic system—Up to 3-4 hours needed for effective integration into the NAS
- Applicable to Re-Cat Phase III: Dynamic Pair-Wise Separation

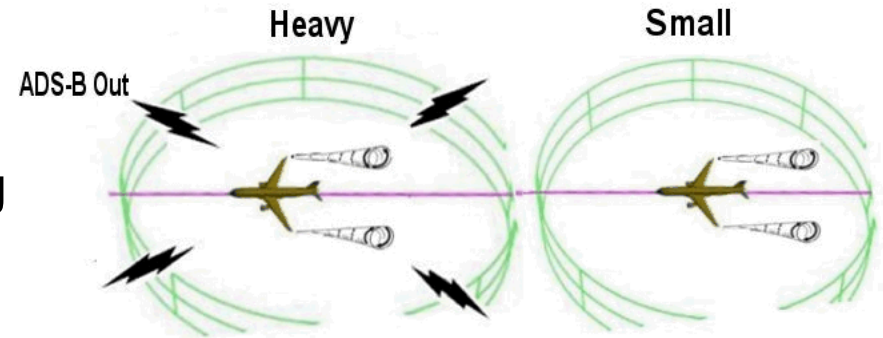
Airport Environment

- **Wake-independent operations for very closely spaced parallel runways**
 - Supports FAA's CSPO
 - Wake interactions are a key challenge
 - How close can we operate 'wake-independent'?
 - Interaction behavior changes as wakes get close together
 - Significant unknowns, no available flight data
- **Runway intersection “Clearzone”**
 - Intersecting runway solution
 - Extra minute added to R31 departure after heavy R22 landing for wake vortex dissipation
 - LGA uses this configuration 20% of time
 - 2002 Lincoln Lab report attributed 4000 hours of delay annually to this restriction
 - Model-based solution to optimize based upon weather conditions
 - Can start now, swap in validated models as they become available



En-route Environment

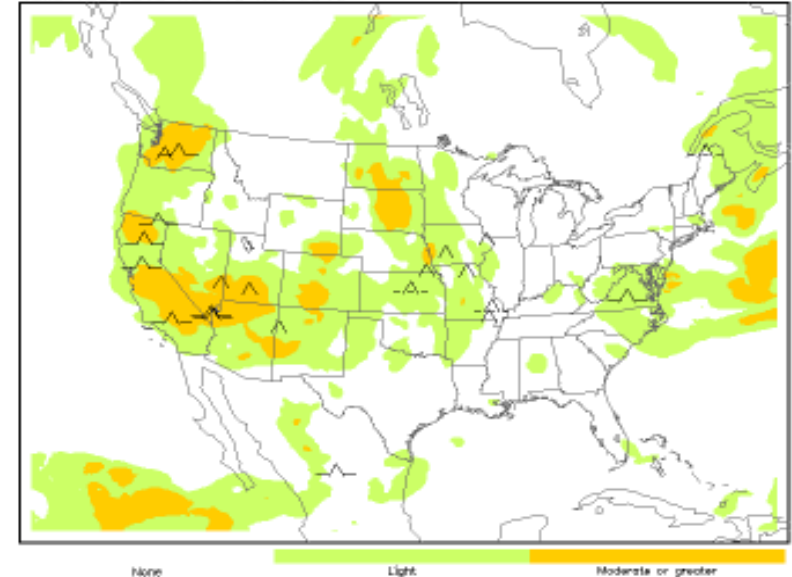
- **Wake-dependent Super Dense Operations**
 - Dynamic, wake-informed spacing
 - Applicable to AFR concept
 - Model validation required, no flight data available
- **Regional wake forecast for strategic operations planning**
 - Integrate wake models into large-scale weather prediction products
 - Produce forecasts similar to current turbulence products
 - Regions of higher or lower risk of wake persistence



GTG2 - Maximum turbulence intensity (10000 ft. MSL to FL450)

Valid 1900 UTC Wed 10 Nov 2010

00-hr forecast from 1900 UTC 10 Nov

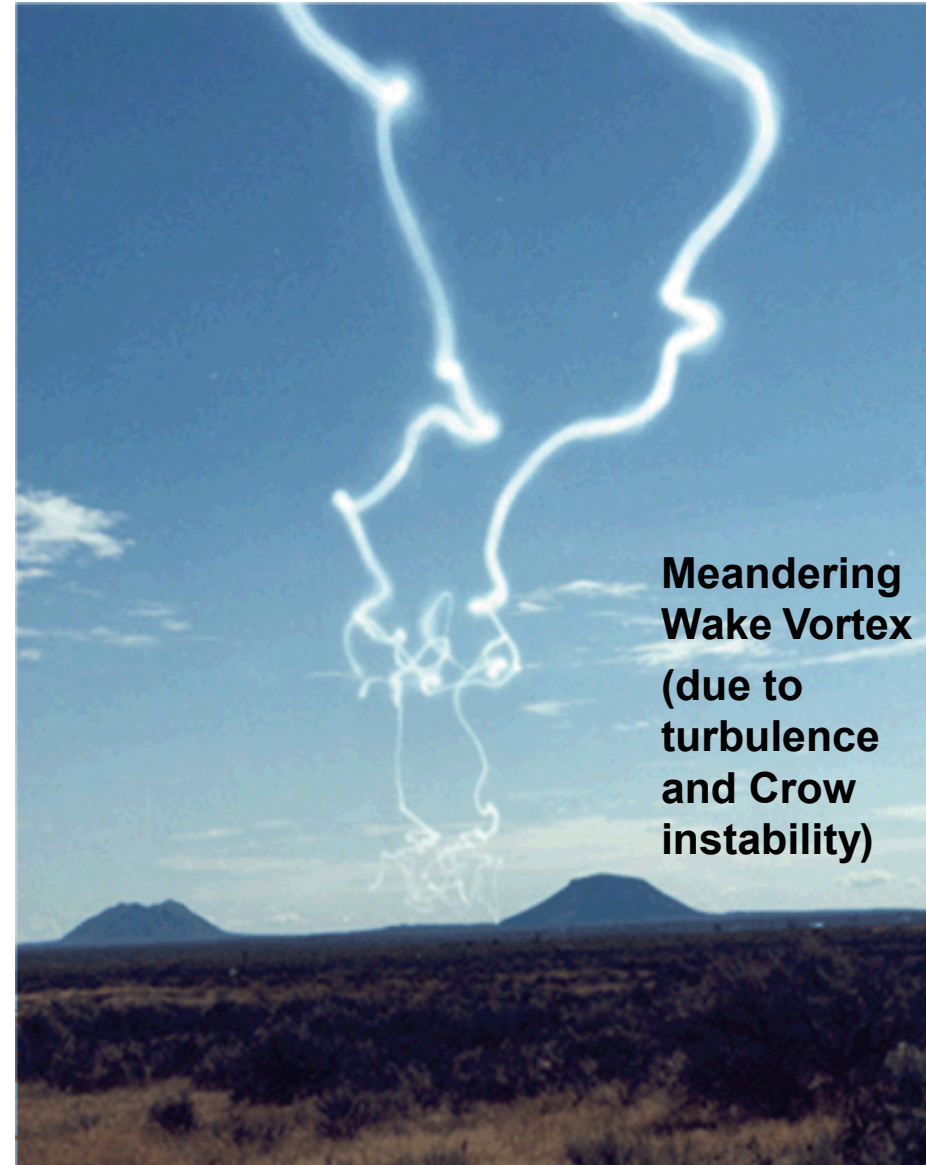


How Do We Get There?



Current NASA Wake Vortex Research

- **Characterization of the Wake Vortex structure:**
 - Velocity, pressure, and temperature
 - As influenced by meteorology, ground effects, and interaction with other wakes
- **Development of wake prediction tools (models) for operational use:**
 - Real-time operations
 - ‘Position and trajectory’ and ‘strength and decay’ prediction
 - Applicable in a wide range of meteorological conditions for all transport aircraft
 - Includes data collection and validation
- **Initial development of Dynamic Spacing System and Wake Operational Procedures Concepts**
- **Assessment efforts focused on:**
 - Prediction tools
 - Wake and meteorological sensors
 - Benefits
- **Support to FAA Wake Vortex Office, including tech transfer of:**
 - Fast-time models
 - Lidar post-processing algorithms



**Meandering
Wake Vortex
(due to
turbulence
and Crow
instability)**

Research Plans—Near Term



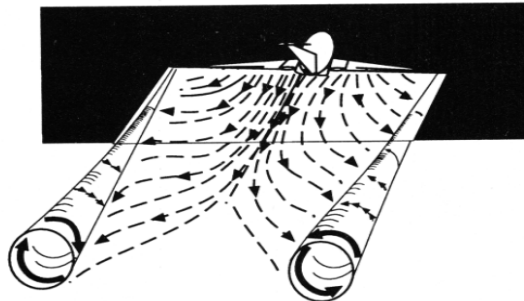
- **Robust validation of fast-time models in terminal environment**

- Models will be a core application of a dynamic system
- Validation requires large database
- Data acquisition activity just starting
 - Airport environment
 - Concurrent meteorological and wake vortex strength and position data
- Validation of lidar and other wake sensors
 - Required to raise confidence in data
 - Continued development of lidar post-processing algorithms
 - Tech transfer to FAA

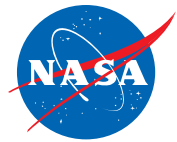


- **Study of the near-aircraft environment, prior to development of a 'rolled-up' wake**

- Critical for CSPR ops 'blunder' risk evaluation

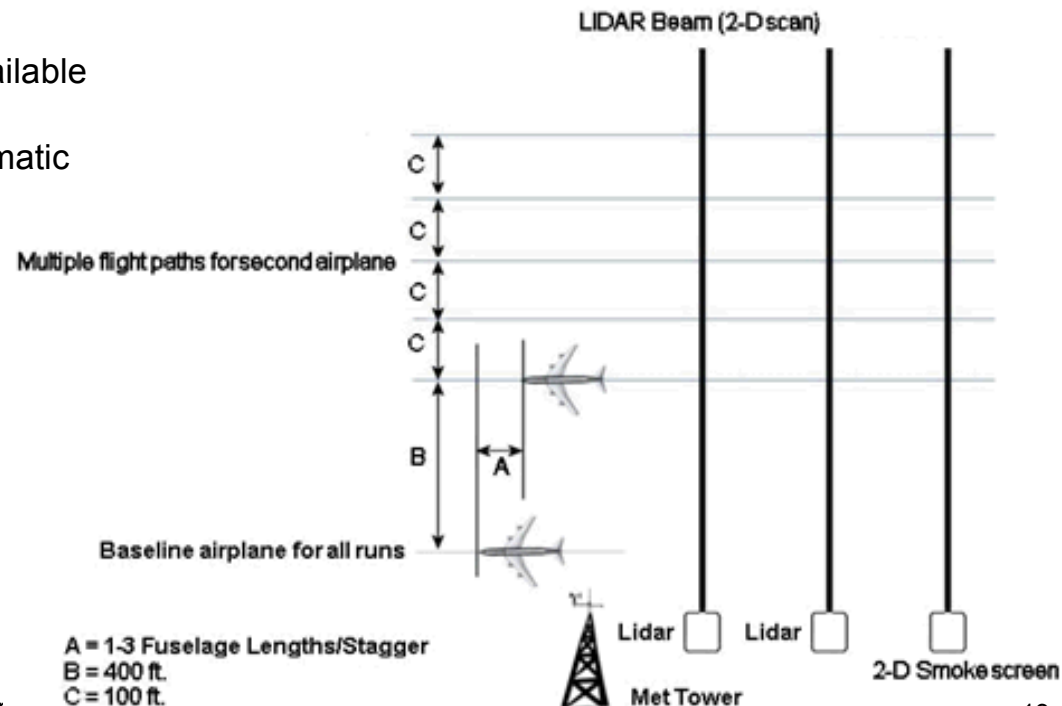


Research Plans—Mid and Far Term



Concept development, research, and data acquisition

- **Integration of wake modeling/prediction and wake spacing concepts with other advanced NextGen concepts and proposed solutions**
 - Terminal Area IM
 - AFR/Separation Assurance
 - SORM
- **Dynamic Wake Spacing System**
 - Development and prototype testing
- **Data acquisition**
 - Collect enroute flight data
 - Limited high-speed, high-altitude data available
 - Collect CSMR data
 - Wake interaction research, see test schematic
 - Validate prediction models
- **Encounter research**
 - Develop concepts and validate methods for diagnosing aircraft upsets from wake encounters
 - Development of hazard definition, encounter metric and validation
 - What is an acceptable encounter?
 - What is a hazard?
 - Automated reporting for evaluation and tuning of a real-time system



Additional Research Considerations



- **Determination of safe and efficient spacing for new aircraft**
 - Support FAA and industry with NASA as the 'Honest Broker'
- **Development of aircraft optimized for reduced wake characteristics**
- **Evaluation of wake vortex characteristics for advanced aircraft concepts**
 - Aircraft with non-classical wing loadings may produce wakes with significantly different characteristics
 - Wake encounters by advanced aircraft may also be different



- **There is a solution path – NASA has viable wake vortex solution concepts**
- **We are working on model validation and achieving success (*more information in next presentation*)**
- **Tech Transfer of wake knowledge and algorithms are near term benefits, as NASA provides guidance to industry and FAA for:**
 - Wake modeling
 - Sensor validation
 - Wake categorization of newly designed aircraft
- **We are beginning development of advanced Dynamic Spacing System concepts based on new model capabilities**
 - Accurate and validated wake models incorporated into Dynamic Systems can lead to safe capacity improvements

Questions

