# Aircraft Weather Mitigation Team

September 12, 2005

**"Friends/Partners in Aviation Weather" Vision Forum**

# Outline

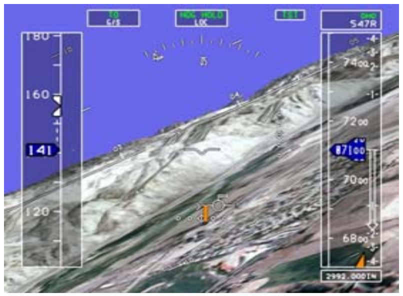
- Aircraft Weather Mitigation Team Emphasis
- Team Progress
- Turbulence Aircraft Mitigation Plan
- Synthetic/Enhanced Vision Plan
- Aircraft Environmental Icing Plan
- Near Term Priorities
- Summary

# Aircraft Weather Mitigation Team Emphasis

Captures systems and concepts that permit the aircraft (in the air or at the airport) to be less susceptible to the hazard and operational effects of encountered weather conditions.

Includes aircraft, propulsion, avionic and control concept changes for weather suppression as well as closed-loop (aircraft contained capability) systems for real-time weather avoidance and aircraft preparations.

# Typical Products

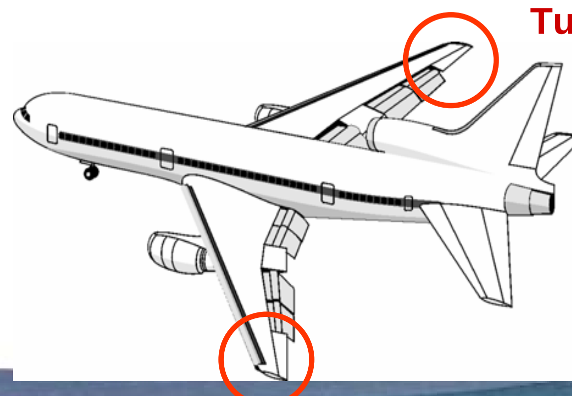


Real-time Synthetic Vision Display w/ Advanced Guidance

Advanced Aircraft Icing Mitigation Systems

Gust Alleviation and Wake Vortex Suppression Systems


Forward Looking Turbulence Radar



Turbulence Suppression Systems

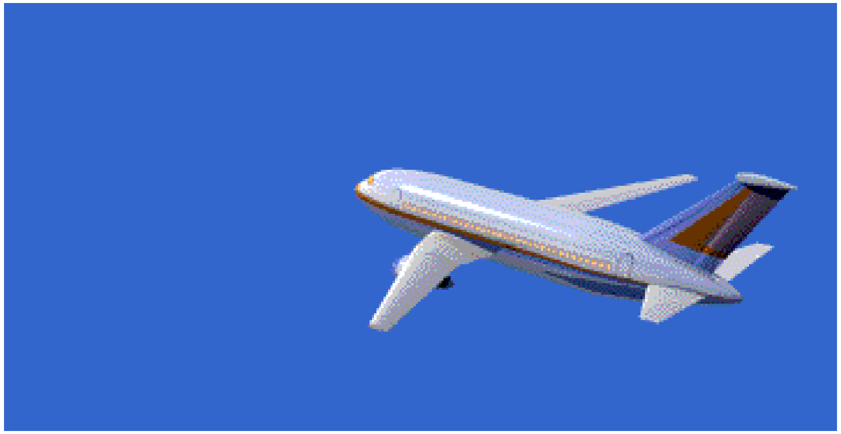
# Sub-Group Progress

- Core Team has formed in March 2005
  - Ron Colantonio/NASA Glenn (temporary lead)
  - Paul Stough/NASA LaRC
  - Guy French/DoD AFRL
  - Lou Cantrell/DoD AFRL
  - Gene Hill/FAA
  - Mary Wadel/NASA Glenn
  - Jim Watson/NASA Langley
- Actions plans developed for turbulence, synthetic and enhanced vision, and aircraft icing mitigation concepts

# Forward Looking Airborne Turbulence Radar/LIDAR Systems

Desired 2025 Outcome: Sensor suite integrated into an airborne systems that eliminates the threat of turbulence.

Current Capability: Airborne weather radars currently available to pick up only precipitation levels.



Gaps and Challenges:

1. CAT degree of detection unanswered
2. Financial business case not well understood

# Forward Looking Airborne Turbulence Radar/LIDAR Systems

Critical Items/Products/Deliverables

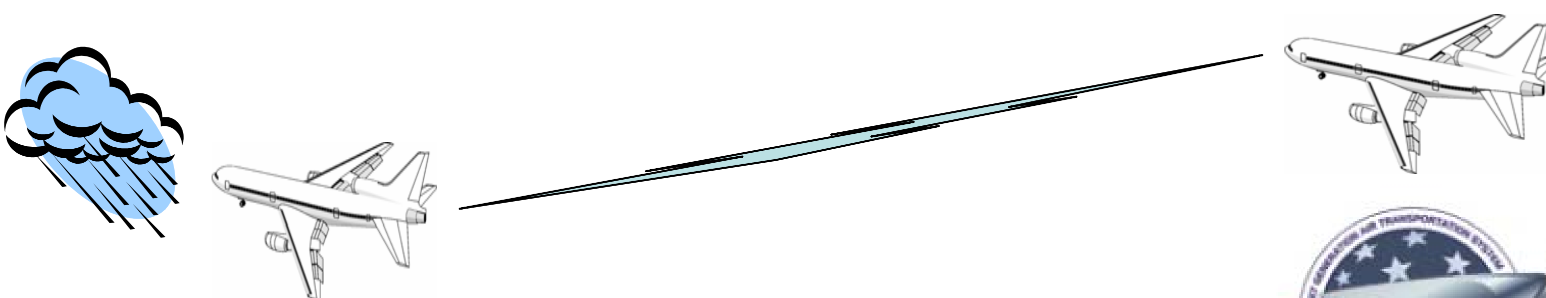
- Short Term (2007-2010)
  - Radar (E-turb) unit production started for aircraft implementation for new aircraft (e.g. 777, 737-800…)
  - Develop retro-fit capability for predictive windshear radars (currently mandated for about 8000 aircraft)
- Mid-Term (2011-2015)
  - Retro-fit radar units fully implemented in US 121 fleet
  - In-service evaluation of LIDAR (other sensors) for detection of CAT
- Long Term (2016-2025)
  - In-service evaluation and initial development of complete sensor suite capable of detecting convective induced and clear air turbulence.
  - Full implementation of sensor suite in all 121 aircraft, RJs, and bizjets.

# Turbulence Reporting Aircraft-to-Aircraft/Ground System

<u>Desired 2025 Outcome:</u> Every aircraft that is flying will be a node in a network ensuring turbulence information dissemination to the ground and <u>other potentially impacted aircraft</u>

<u>Current Capability:</u> Encountered turbulence reporting to the ground airline operations centers; limited information to other flying aircraft

<u>Gaps and Challenges:</u> Financial business case not well understood



# Turbulence Reporting Aircraft-to-Aircraft/Ground System

Critical Items/Products/Deliverables

- Short Term (2007-2010)
  - Total (including oceanic) air-to-air/ground capability demonstrated for 121 aircraft with other airlines
  - Integration analysis/design into the NAS (including airborne cockpit environment)
  - Alternate communication (other than ARINC) studies
- Mid-Term (2011-2015)
  - Implementation of turbulence encounter reporting system in the 121 fleet
- Long Term (2016-2025)
  - N/A

# Gust Alleviation (GA) and Wake Vortex Suppression (WVS)

Desired 2025 Outcome:

- Aircraft systems (sensors, control, and structural) having the capability to reduce the effects of turbulence (natural and wake) on the aircraft and passengers.
- Ability to safely fly through turbulence regions presently considered hazardous.
- Weaken the initial wake vortex, increase its rate of decay, and track its path to allow closer aircraft take-off/landing distances

Current Capability:

- Current aircraft autopilot control laws do not compensate for vertical turbulence effects except as a by-product of increased pitch damping. Almost all airplanes have yaw dampers that mitigate the effects of lateral gusts to some degree.
- Limited winglet and tracking capabilities with unchanged FAA defined take-off/landing spacing. Some work in the prediction of wake vortex generation, transport, and decay.

# Gust Alleviation (GA) and Wake Vortex Suppression (WVS)

Gaps and Challenges:

- Acceptance of flying through previously classified convective hazards
- Operational/policy changes to current FAA spacing requirements
- Technical breakthrough not well understood for advanced gust alleviation and wake vortex suppression configurations/approaches
- Certifiable look-ahead and distributed turbulence sensors.

# Gust Alleviation (GA) and Wake Vortex Suppression (WVS)

## Critical Items/Products/Deliverables

- Short Term (2007-2010)
  - Aircraft flight validation of modified auto-pilot control laws (without look-ahead sensor)
- Mid-Term (2011-2015)
  - Aircraft flight validation of modified auto-pilot control laws (with look-ahead sensor)
  - Sub-scale wind tunnel and/or RC model tests of advanced aircraft control and distributed sensor/effector systems
- Long Term (2016-2025)
  - Full fleet implementation of FMS-Ride Smoothing Capabilities with forward looking sensor
  - Flight experiments of advanced full scale wing/control configuration

# Synthetic/Enhance Vision

Desired 2025 Outcome: A system that optimizes aircrew situation awareness of aircraft state, geo-location, and surrounding environments in all weather conditions, such that visibility is removed as a factor affecting civil and military air operations.

Current Capability: Sensor capabilities vary from none to very little. Currently deployed systems may provide imagery that penetrates rain or fog or sand/dust. Due to the phenomenology of the various sensor technologies no one sensor is a silver bullet that can penetrate all of the restrictions to visibility that affect aviation. Current technologies include infrared/LLLTV cameras, millimeter wave radar, and X-band radar.

Database capabilities today are generally limited to moving map displays and collision alerting systems.

Gaps and Challenges: Business case for unhindered operations in weather understood, but few willing to invest in the technology to advance it to useful level.

# Synthetic/Enhance Vision

# Synthetic/Enhance Vision

Critical Items/Products/Deliverables

- Short Term (2007-2010)
  - Studies on other potential imaging sensors (e.g. LIDAR, terahertz band, passive imaging, panoramic)
  - Development of reliable image enhancement and fusion algorithms to process sensor data and improve the images provided to aircrew.
  - Create high-resolution terrain and obstacle databases for the highest traffic areas. (Assumes a process for maintaining and updating the databases on a short-cycle schedule).

- Mid-Term (2011-2015)
  - Development and testing of the most promising new imaging sensors.
  - Studies for evaluation of windowless flight deck and use of virtual environments to create full field of regard for the aircrew.

- Long Term (2016-2025)
  - In-service evaluation of new imaging sensors, image processing algorithms, databases, controls, and displays.
  - Full implementation of the synthetic and enhanced vision technology systems in commercial and military aircraft.

# Aircraft Environmental Icing

Desired 2025 Outcome:

- No aircraft accident or significant events in which environmental icing is a contributing cause.
- Free-flight of aircraft with minimum flight-path deviations for atmospheric icing considerations.
- Minimum flight delays and terminal capacity interference resulting from environmental icing considerations.

Current Capability:

- Fatal aircraft accidents continue to occur, despite the recognition of atmospheric icing as an aviation environmental hazard. However, hazardous atmospheric icing environments have not been fully characterized and methods of characterizing the hazards are unsatisfactory.
- Progress is being made in developing technologies to remotely detect and index icing conditions using multi-frequency and polarized radar and other sensors.
- Current and potential processes used to ensure safe aircraft operations in environmental icing are expensive, burden the industry, and the economics of these processes limit efforts to eliminate icing related accidents and events.

Gaps and Challenges:

- Business case development.
- Development of new and modified icing simulation facilities.
- Invention of highly effective, low energy ice protection provisions.

# Aircraft Environmental Icing

**Critical Items/Products/Deliverables**

**Short-term (2007-1010)**

- Development of tools to better characterize aircraft and engine icing
- Demonstrate an airborne system for remotely detecting and indexing icing conditions with sufficient range to allow tactical flight path decisions by flight crews.

**Mid-term (2011-2015)**

- Demonstration of a cost-effective system that ensures safe operations in icing with minimum pilot decision-making.
- Development of improved, low-energy ice protection systems that address high icing intensities.

**Long-term (2016-2025)**

- Implementation of highly effective, low-energy ice protection provision on all new aircraft approved for flight into icing conditions.
- Implementation of a cost-effective system that ensures safe operations in icing with minimum pilot decision-making on all new aircraft approved for flight in icing conditions.

# Top Priorities (FY06/FY07)

| Ranking | Study Title |
|---|---|
| 1 | Study to Determine the Cost-Benefit of Aircraft Mitigation Technologies as Compared to Avoidance Techologies (i.e. forecasting) |
| 2 | Complete icing related research recommended by the Commercial Aviation Safety Teams (3-year program) |
| 3 | Continued ISE of In-Situ Turbulence Reporting System and Metric Development |
| 4 | In-Service Evalautions (ISE) of NASA E-Turb Forward Looking Radar |
| 5 | Development of image enhancement and fusion algorithms to process sensor data and improve the images provided to aircrew |
| 6 | FAA Certification Support Towards Ensuring Turbulence Mitigation Technologies are Available to the B-787 aircraft |
| 7 | Sythethic Vision/Enhanced Vision Integration Studies |
| 8 | NASA S-3 Aircraft Accelerated Readiness and Equipage |
| 9 | In coordination with industry and the FAA establish an Engine Icing Road Map for understanding the physics and hazards of turbojet engine icing and for developing simulation methods for the design and approval of safe engine designs |
| 10 | In collaboration with industry, the Meteorological Services of Canada, NASA, FAA, and academia, continue development of capabilities to achieve the flight conditions and measuring methods to characterize mixed-phase–and glaciated conditions that affect turbojet engine operability (1.5-year program with icing wind tunnel and flight tests) |

# Summary

- Aircraft Weather Mitigation Team is working synergistically and effectively
- Team is looking at other mitigation areas including airports, lightning, EMI/Solar etc.
- There is a national need for an aircraft mitigation approach towards dealing with adverse weather
- There currently exist near-term opportunities to transform aircraft to be more weather resistant