



# ***Turbulence Prediction and Warning Systems***

Weather Accident Prevention Project Review 2004

Las Vegas, NV

June 2-4, 2004

James F. Watson  
NASA-Langley Research Center



# Aviation Safety & Security Program Office

George Finelli, Director  
John White, Deputy Director  
Gin Marks, Sr. Prog Analyst

Brian Smith, Dep Prog Mgr (ARC)

Ron Colantonio, Dep Prog Mgr (Acting, GRC)

**Technical Integration**  
Frank Jones (LaRC)

**Program Integration**  
Michael Basehore (FAA)  
Carrie Walker (HQ)

Thrust Areas

**1.3 Vehicle Safety Technology**

**1.4 Weather Safety Technology**

**1.5 Systems Safety Technology**

Projects

**2.3 Single Aircraft Accident Prevention**  
John White (LaRC)

**2.6 Synthetic Vision**  
Daniel Baize  
Cheryl Allen (LaRC)

**2.5 Accident Mitigation**  
Robert McKnight (GRC)

**2.4 Weather Accident Prevention**  
K. Martzaklis (GRC)

**2.7 Aircraft Icing**  
Mary Wadel (GRC)

**2.1 Aviation System Monitoring & Modeling**  
Irving Statler (ARC)

**2.2 System-Wide Accident Prevention**  
Tina Beard (ARC)

**2.8 Search and Rescue**  
David Affens (GSFC)

Elements

**Aviation Weather Information (AWIN)**  
Paul Stough (LaRC)

**Weather Information Communications (WINCOMM)**  
Mike Jarrell (GRC)

**Turbulence Prediction & Warning Systems (TPAWS)**  
Jim Watson (LaRC)  
Rod Bogue, Dep (DFRC)

# Goals & Objectives



- **Weather Accident Prevention Goal:** Develop enabling technologies to reduce weather-related accident causal factors by 25-50% and turbulence-related injuries by 25-50% by year 2007.
- **WxAP Objective Number 3:** Develop turbulence prediction technologies, hazard metric methods, and mitigation procedures to enable a 25-50% reduction in turbulence-related injuries.
- **TPAWS Goal:** *Develop and augment knowledge of both the turbulence phenomena and the effects of turbulence on aircraft, and develop technologies to detect convective and clear air turbulence and mitigate the effects on aircraft passengers*
- Turbulence is the predominant weather threat for airborne tactical decision making relating to safety of cabin passengers and crew; also has significant operational costs impact

# TPAWS Priority Areas



*Weather Accident Prevention Project*

*Turbulence Prediction and Warning Systems*



- **Systems-Oriented Process**
  - Get the right turbulence information to/from the right aircraft with sufficient time for necessary decision making; focus on airborne tactical decisions
- **Enhanced Turbulence Radar**
  - Utilization of PWS hardware/architecture
  - Aircraft dependent hazard metric
  - Validated technology with LaRC 757
  - In service evaluation of single unit on revenue aircraft, with significant in-kind resource sharing
- **Certification Methods & Tools**
  - Turbulence Modeling and Simulation
  - Final formulation of turbulence safety hazard metric based upon aircraft dependent attributes
  - End-to-end analytical studies for scoring criteria/rules, validation boundaries

# TPAWS Priority Areas



*Weather Accident Prevention Project*

*Turbulence Prediction and Warning Systems*



- **Turbulence AutoPIREP System**
  - Aircraft dependent hazard metric, same as Turb-Radar
  - Aircraft-to-ground technology validation with LaRC 757
  - Aircraft-to-aircraft 757/Learjet flight experiments planned
  - In Service Evaluation on limited fleet of revenue aircraft
  
- **End User/Customer Collaboration**
  - WxAP Annual Reviews, NASA-FAA-Industry Certification Workshops
  - One-to-one workshops, MOUs, MOAs for transitioning TPAWS items
  - TPAWS website for dissemination of technology status/flight results
  - Significant in-kind resource sharing/partnering

# TPAWS Priority Areas



*Weather Accident Prevention Project*

*Turbulence Prediction and Warning Systems*



- **Flight Deck Integration**
  - Clean sheet focus
  - Joint TPAWS-AWIN simulation experiment for evaluation of conceptual cockpit displays of turbulence
- **Enhanced Autopilot for Aircraft Ride Smoothing**
  - Studies, simulations, and analyses of enhanced autopilot control laws for aircraft ride smoothing during turbulence encounters
- **Airborne Lidar Sensor for Turbulence**
  - Equipment capabilities and sensing performance
  - Flight experiments with analyses/conclusions

# TPAWS Airborne Centric Concept

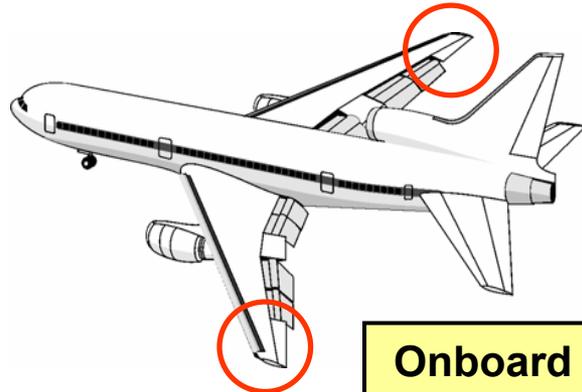


Weather Accident Prevention Project

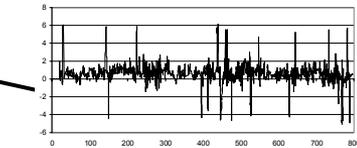
Turbulence Prediction and Warning Systems



Flight Management System A/C Controls/Mitigation Schemes



Onboard Sensors



Turbulence Auto-PIREP

Airborne scaling & display of Turbulence Auto-Pirep's information

Data Link

Ground-based Turbulence Products

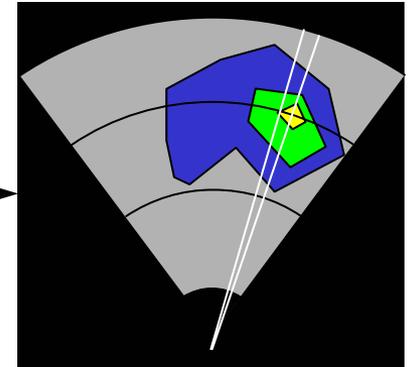
Data Link

Airborne Turbulence Information

Processors

Decision Aids

Presentation to Pilot



Forward-Looking Sensors: Radar and LIDAR



# TPAWS Turbulence Hazard Synopsis



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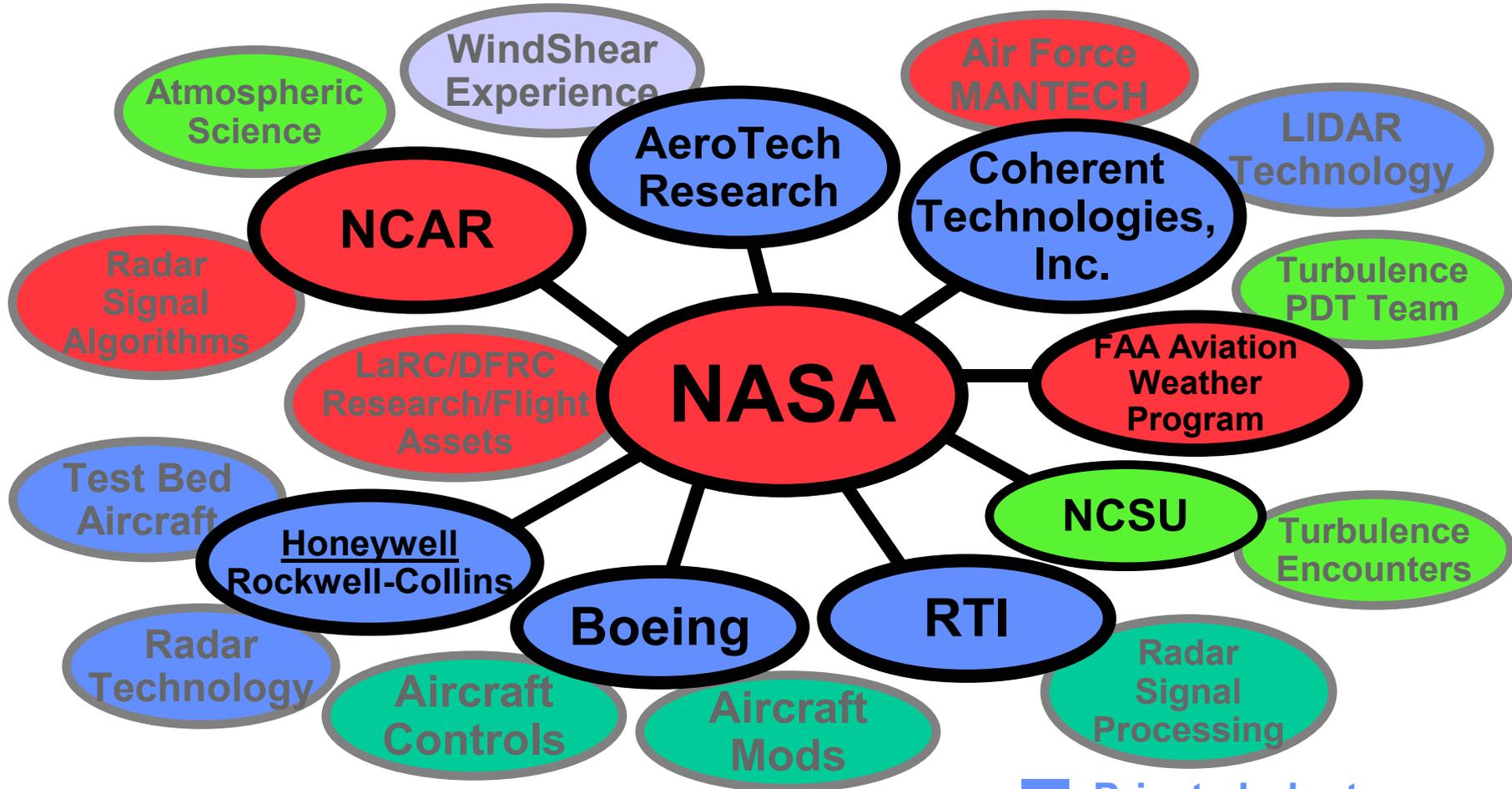
- **Accidents/Injuries**
  - All aviation accidents are being perceived as random events
  - Leading cause of injuries to passengers and crew/flight attendants
- **Operational Cost**
  - Analyses by Volpe estimates the turbulence related/induced TOTAL operational costs to US airlines at about \$750M/year
- **Oversight Organizations**
  - CAST, NRC, IIR, OFCM have all advocated for and endorsed the TPAWS research activities to date, and the need for long term airborne turbulence safety research
- **Airlines**
  - Major airlines have initiated specific activities for turbulence injury and operational cost reduction objectives
  - Significant objectives relating to flight safety, operations routing and aircraft inspections, and overall customer satisfaction
- **Future**
  - NASA-TPAWS technologies are being recognized for applicability in reducing turbulence related accidents and injuries
  - An integrated research activity with aviation operations focus is needed to expand the capabilities and transfer turbulence technologies for maximum utilization and effectiveness

# TPAWS Research-Development Team



Weather Accident Prevention Project

Turbulence Prediction and Warning Systems



- Private Industry
- Academia
- Government

# NASA TGIR *Revolutionize Aviation* Award



Weather Accident Prevention Project

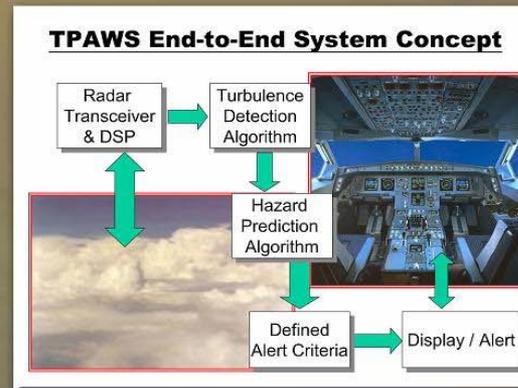
Turbulence Prediction and Warning Systems



## Aviation Safety Turbulence Prediction and Warning Systems (TPAWS) Team

Team Members: NASA Langley Research Center, NASA Glenn Research Center, NASA Dryden Flight Research Center, Federal Aviation Administration, AeroTech Research (USA), Research Triangle Institute, National Center for Atmospheric Research, North Carolina State University, Aviation Cabin Safety Specialists Incorporated

NASA and its partners are developing advanced airborne systems to predict and provide cockpit alerting for inflight turbulence--the leading cause of injuries in airline incidents. These innovative technologies greatly enhance the capabilities of existing windshear radars and have been successfully flight-tested aboard the NASA 757 research aircraft. Results indicate important advancements to predicting turbulence ahead of aircraft that adversely affect scheduled commercial operations. This early warning will allow pilots enough time to advise flight attendants and passengers to buckle up resulting in significantly reduced turbulence-related injuries.



TGIR 2003  
Williamsburg, VA



Goal One

# Web Sites



- <http://tpaws.larc.nasa.gov>

- TPAWS related research papers, articles
- Certification Workshops #1-6 presentations
- LaRC-757 turbulence flight data/results <r>
- Distribution of turbulence data sets and tools for certification <r>

- <http://wxap.grc.nasa.gov>

- Presentations of WxAP Annual Reviews #1-3, including specific session presentations of all TPAWS research activities
- WxAP CONOPS document

# Meeting Success Criteria for TPAWS



*Weather Accident Prevention Project*

*Turbulence Prediction and Warning Systems*



- Contribute, in a collaborative manner, to the effective transfer of NASA aviation safety turbulence technologies to the airline end user community for the benefit of the general flying public.