



# ***Turbulence Prediction and Warning Systems Overview and Status***

Weather Accident Prevention  
Third Annual Review  
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# Presentation Outline



- Programmatic Organization
- Background
- Goals & Objectives
- FY02 Technical Focus Areas
- FY02 Summary



# Programmatic Organization

**Aviation Safety Program Office**  
 Ruth Martin, Acting Director  
 George Finelli, Deputy Director  
 Glenn Bond, Senior Prog Analyst  
 Connie Smith, Secretary  
 Brian Smith, Dep Prog Mgr (ARC) Doug Rohn, 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)**  
 Rod Bogue (DFRC)  
 Jim Watson, Dep (LaRC)

# Background



- **Turbulence Impacts**
  - **Leading Cause of In-Flight Injuries**
  - **Cost estimated at >\$100M/yr. for airlines**
  
- **Turbulence Initiators**
  - **Convective Induced (within and as far as 40 miles away from visible clouds)**
  - **Jet Stream (at confluence of multiple streams and near boundaries)**
  - **Mountain Wave (upward propagating from disturbances near the surface)**

# 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*
- **TPAWS Objectives:** 23 Milestones for specific activities over a 6 year schedule.

# FY02 Technical Focus Areas



*Weather Accident Prevention Project*

*Turbulence Prediction and Warning Systems*



- TPAWS transition from TDAM
- Turbulence Modeling & Simulation
- Airborne Turbulence Sensors
  - Enhanced Radar
  - Conceptual Lidar
- Turbulence Prediction Algorithms & Hazard Metrics
- Turbulence Auto-PIREP Systems
- Flight Deck Integration
- Enhanced autopilot concepts for turbulence ride smoothing
- Certification Methodology & Tools

# TPAWS Airborne Centric Concept

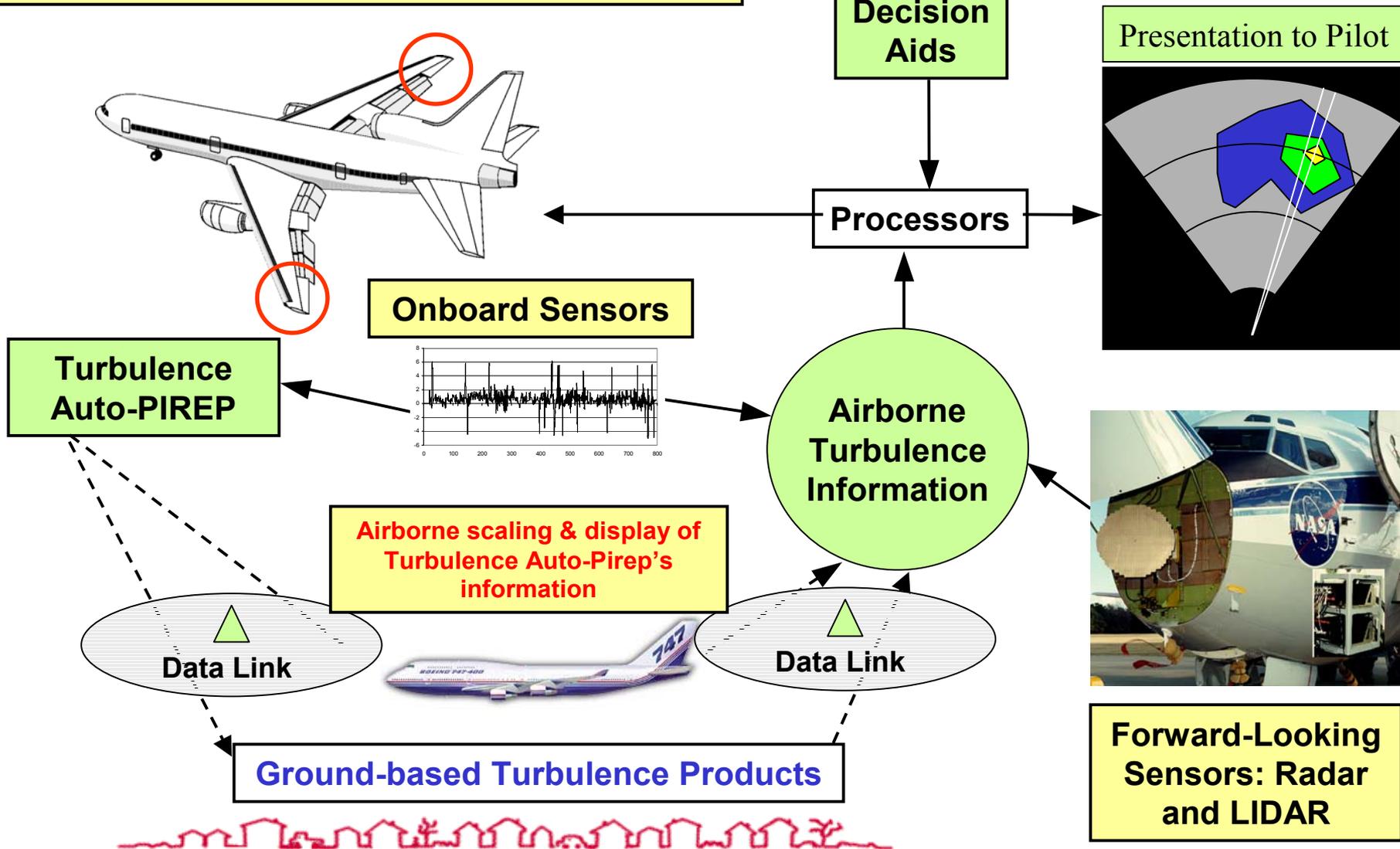


Weather Accident Prevention Project

Turbulence Prediction and Warning Systems



Flight Management System A/C Controls/Mitigation Schemes



# FY02 Overview



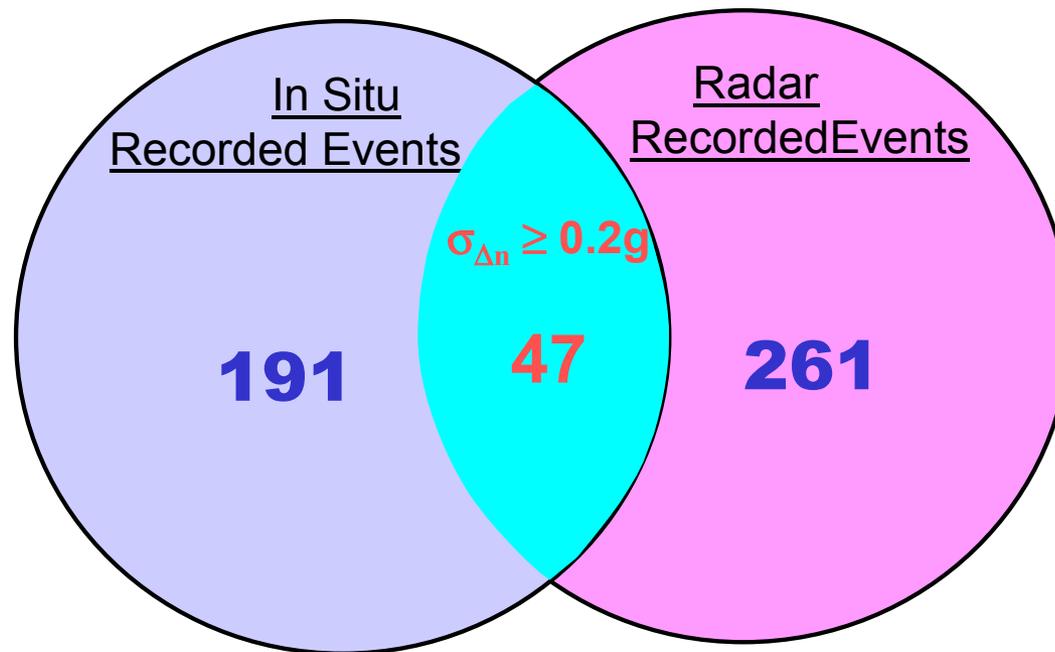
- **WxAP Flight Campaign, LaRC 757**

- April-May 02 over 7 weeks, originally 12 weeks
- Turbulence Experiments were priority, some WINCOMM, some AWIN
- About 10 separate flights with 1-2 hr of turbulence encounters; lots of recorded data; aircraft “repairs”
- TPAWS radar algorithms & safety hazard metric were validated
- Turbulence Auto-PIREP algorithms enhanced, and aircraft-to-ground communication link demonstrated

# FY02 Flight Campaign Summary



## FY02 757 TPAWS Flight Experiment Data Summary



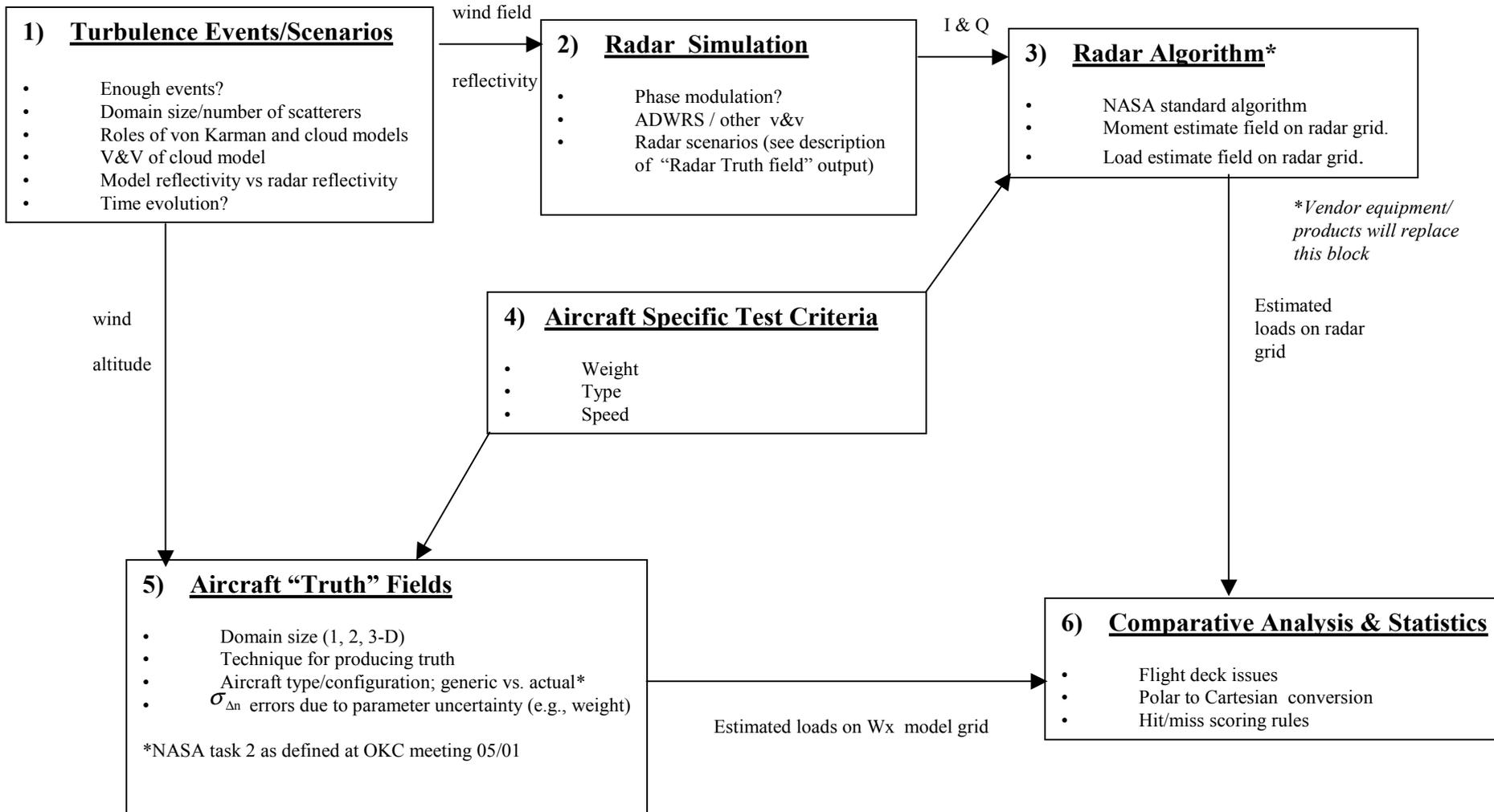
*15 flights total; 10 flights encountering significant events*

# FY02 Overview



- **Certification Methodology and Related Tools**
  - Process definition developed and finalized (6-box chart)
  - Released weather sets for LaRC 191-06 and Dickinson encounters
  - Released enhanced radar simulator for turbulence (ADWRS 5.1)
  - Preliminary evaluation of hazard metric on six classes of aircraft
  - Preliminary development of conceptual flight deck display of turbulence information
  - Initiated study for development of criteria for scoring & evaluation of turbulence detections

# Certification Methodology



# Milestones Accomplished in FY02



## • Level III TPAWS

MS #18: Flight Demonstrate Conceptual Lidar-based Turbulence System (completed 1Q02 via DC-8)

MS #12: Flight Demonstrate Conceptual In-Situ based Algorithms (scheduled for 2Q02; completed 3Q02 due to B-757 AvSec delay)

MS #15: Flight Demonstrate Radar-based Turbulence System (scheduled for 2Q02; completed 3Q02 due to B-757 AvSec delay)

## • Level II WxAP

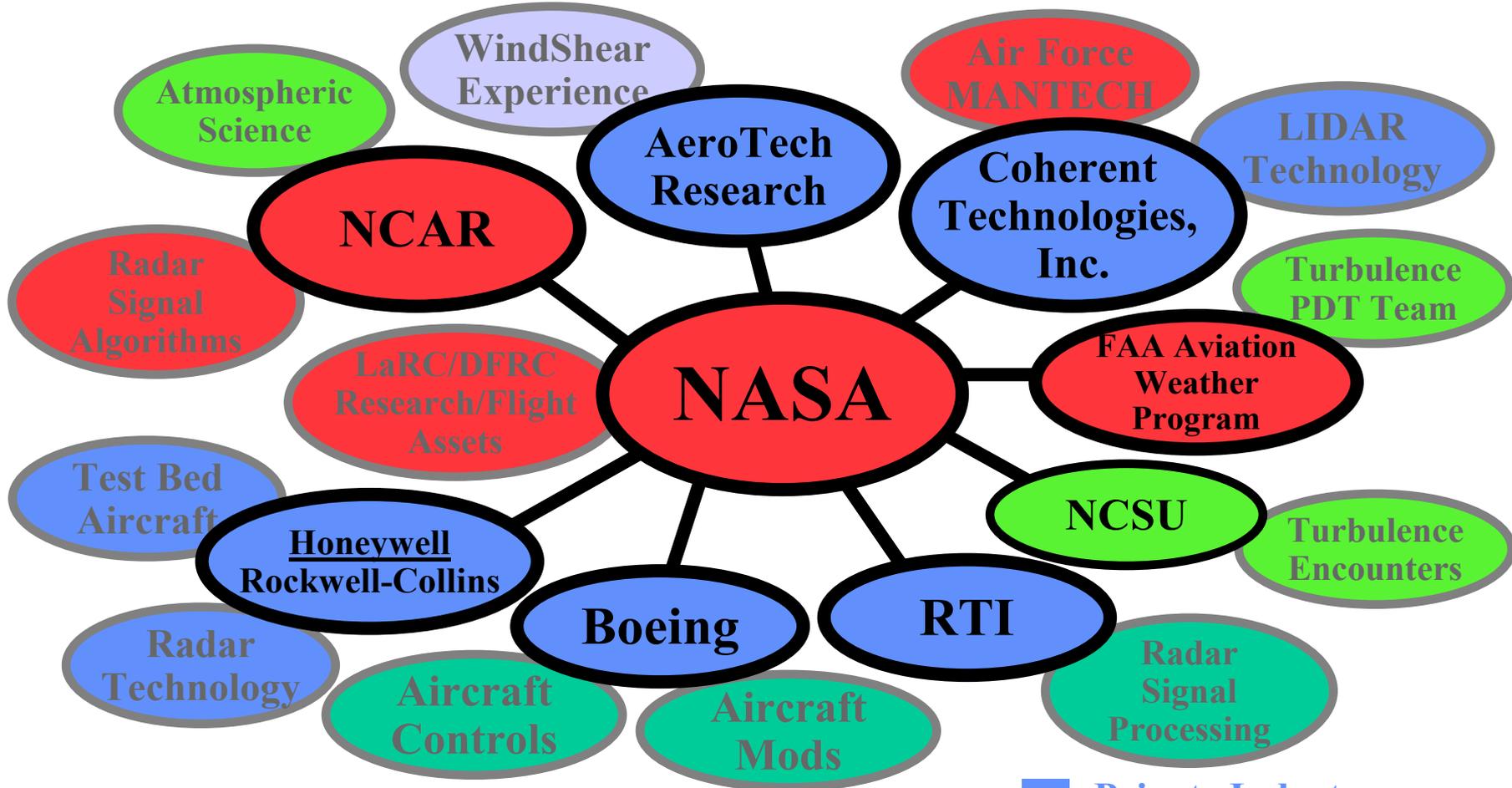
MS #2: Flight Demonstration of Forward-Looking Turbulence Warning System (scheduled for and completed, 4Q02)

# TPAWS Development Team



Weather Accident Prevention Project

Turbulence Prediction and Warning Systems



- Private Industry
- Academia
- Government

# Key TPAWS Research Facilities



*Weather Accident Prevention Project*

*Turbulence Prediction and Warning Systems*



Langley B-757



Glenn Lear Jet



Dryden DC-8

- Langley G/A and transport category simulators
- Ames transport simulator
- Delta simulators
- United simulators



Simulators

# FY02 Summary



- Significant results in enhanced radar turbulence technology including prediction algorithm and hazard metric validation
- Significant results in AutoPIREP turbulence reporting including algorithms and communications links
- Significant results in turbulence certification methodology and related tools including weather data sets, radar simulations, end-to-end concept validation, preliminary scoring/evaluation criteria
- Quantitative results from cabin turbulence warning experiments to determine time durations for “securing passengers” based upon flight phases
- Preliminary results of capabilities and systems criteria for Lidar as a airborne turbulence sensor

# FY02 Summary



- Quantitative results from study of autopilot enhancements for ride smoothing based upon turbulence encounters
- Flight Deck Integration efforts were initiated, then suspended; re-plan in FY03
- Two highly successful, collaborative workshops of NASA-FAA-Industry Turbulence Detection Certification Team
  - Feb-02 at NASA-LaRC
  - Sept-02 at FAA-Long Beach
- Significant results in developing several TPAWS technologies. Some are near TRL/IRL of 6/4, and will be very effective in reducing turbulence related injuries, thus meeting WxAP goal in both quantity and timeframe.