



ATIE Integrated (AWIN/TPAWS) Turbulence Cockpit Display Experiment

Weather Accident Prevention Project Review
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Steve Williams
NASA Langley



Acronyms and Abbreviations Used



| | |
|---------|---|
| AHAS | Aviation Hazard Awareness System |
| ANOVA | Analysis of Variance |
| ARIES | Airborne Research Integrated Experiments System |
| ARINC | Aeronautical Radio, Inc. |
| ATIE | AWIN TPAWS Integration Experiment |
| AvSP | Aviation Safety Program |
| AWIN | Aviation Weather Information |
| CG | Center of Gravity |
| CRA | Cooperative Research Agreement |
| CVMRF | Crew Vehicle Motion Research Facility |
| DSP | Digital Signal Processor |
| FER | Final Experimental Review |
| FL | Flight Level |
| FMS | Flight Management System |
| GTG | Graphical Turbulence Guidance |
| IRB | Institutional Review Board |
| METAR | Aviation Routine Weather Report |
| NAV | Navigation Display |
| NCWD | National Convective Weather Diagnostic |
| NCWF | National Convective Weather Forecast |
| NEXRAD | Next Generation Radar |
| PFD | Primary Flight Display |
| PIREP | Pilot Weather Report |
| PWS | Predictive Wind-Shear |
| RMS | Root Mean Square |
| SIGMET | Significant Meteorological Information |
| TAF | Aerodrome Forecast |
| TPAWS | Turbulence Prediction and Warning System |
| WINCOMM | Weather Information Communication |
| WxAP | Weather Accident Prevention Project |
| WXR | Weather Radar |



Outline



- Background
- Objectives
- Hypotheses
- Approach

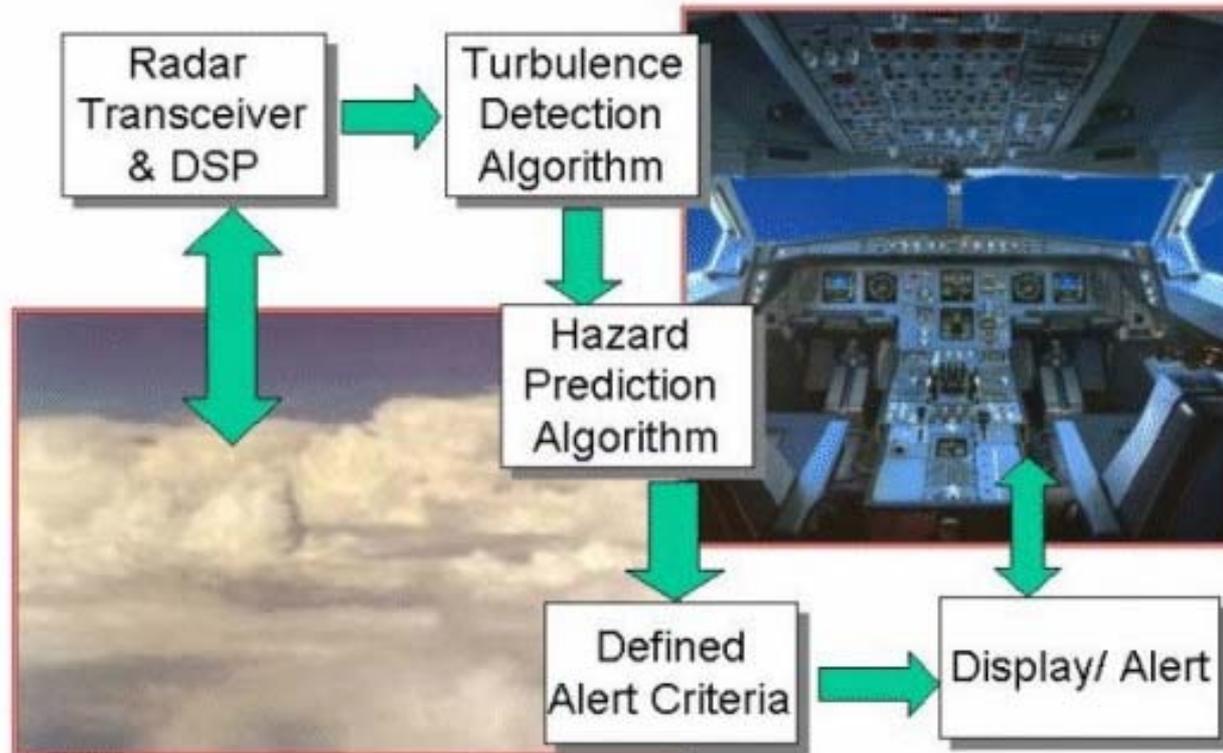


Background



- 2000 TPAWS goal set to be the mitigation of turbulence effects on aircraft and passengers. Initial focus on short range “sit down and hang on” system.
- 2001 AWIN Concept of Operations Document.
- 2001 Developed turbulence hazard metric that relates radar observables to severity of turbulence encounter.
- 2002 Prototype Airborne Hazard Advisory System (AHAS) flown on ARIES without cockpit display.
- 2002 Prototype radar based turbulence detection and prediction system flown on ARIES. Flight campaign demonstrates validity of system.

TPAWS Airborne System Concept





TPAWS Airborne System Concept

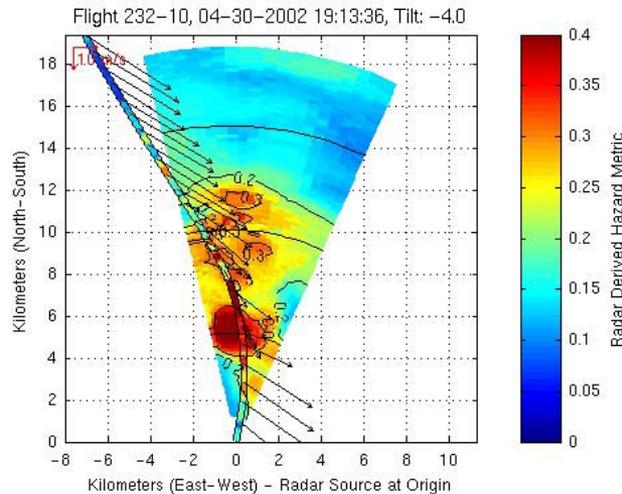
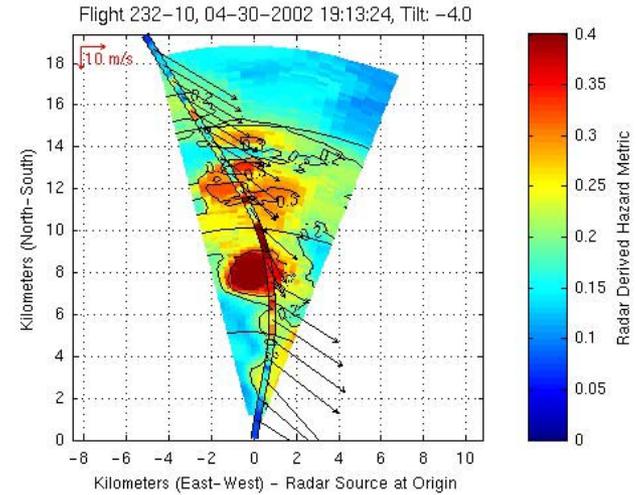
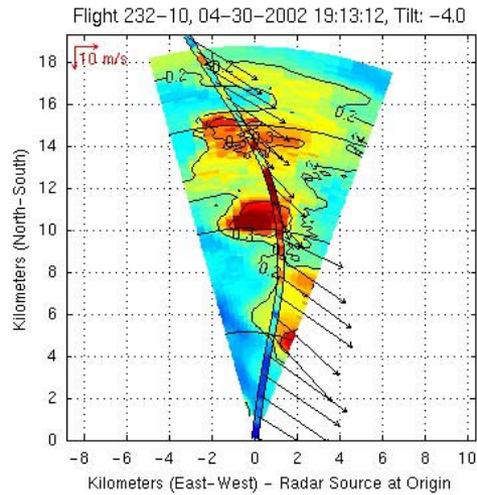


- Radar transceiver and DSP.
 - Uses current on-board predictive wind-shear radar (PWS).
- Turbulence detection algorithm.
 - Uses doppler second moment radar product to estimate amount of turbulence energy in atmosphere.
 - Short range, 30 to 120 second detection lead time.
- Hazard prediction algorithm.
 - Uses aircraft based hazard metric lookup table to convert radar observables into estimated RMS g-load at CG.
 - RMS g-load at CG has direct correlation to severity of turbulence event.
- Defined alert criteria.

| | | |
|--------------------------|---------------------|----------------|
| • RMS g-load < 0.2 | light turbulence | must not alert |
| • 0.2 < RMS g-load < 0.3 | moderate turbulence | may alert |
| • 0.3 < RMS g-load | severe turbulence | must alert |



Example Flight Test Turbulence Data





Objective



- Establish guidelines for:
 - Cockpit display of turbulence events and alerts.
 - Cockpit presentation of strategic and tactical weather information.
 - Crew procedures for response to turbulence events and alerts.



Airborne Hazard Awareness System (AHAS)



- Provides strategic and tactical weather information.
- Receives weather information from datalink.
 - FY2003: Hazard analysis now processed at ground station.
- **Strategic Display** provides “big picture” weather information.
 - NCWD, NCWF, NEXRAD, GTG, METARs, SIGMETs, TAFs, Winds Aloft.
- **Tactical Display** provides weather information in NAV display format.
 - On-board weather radar.
 - Datalinked NEXRAD, NCWD, NCWF.
 - Split product mode: on-board weather radar plus datalinked weather.
- Decision aiding capability.
- Display interface has panning, centering, zoom and active icons.



AHAS Decision Aiding Features



Strategic

- Performs a periodic automatic hazard assessment every two minutes, unless the flight plan changes.
- Filters which weather products are most relevant for display given aircraft position in space and time.
- Ranks hazards by proximity to flight path.
- Tests combinations of weather products against multiple thresholds such as the phase of flight and aircraft limitations.
- Generates alerts and shows relevant source reports.



AHAS Decision Aiding Features



Tactical

- Segments and tracks storms.
- Correlates tracked storms on WXR to tracked storms in NEXRAD or NCWD.
- Filters storm information by hazard level, such as maximum intensity and echo tops.
- Predicts Flight Plan Impact:

Projecting storm information into the future
+
Projecting aircraft location into the future



Determines if projected storm region will impact projected aircraft position. If so, provides pilot with graphical alerting representation.



AHAS Hazard Thresholds



- Fully selectable by pilot or policy.
- Current threshold values for enroute and destination weather.

Enroute Weather

| | |
|-------------------|-----------------------------|
| Headwinds | 70 kt |
| Distance to storm | 20 NM |
| SIGMETs | Alert by proximity |
| PIREPSs | Alert with icing/turbulence |

Destination Weather

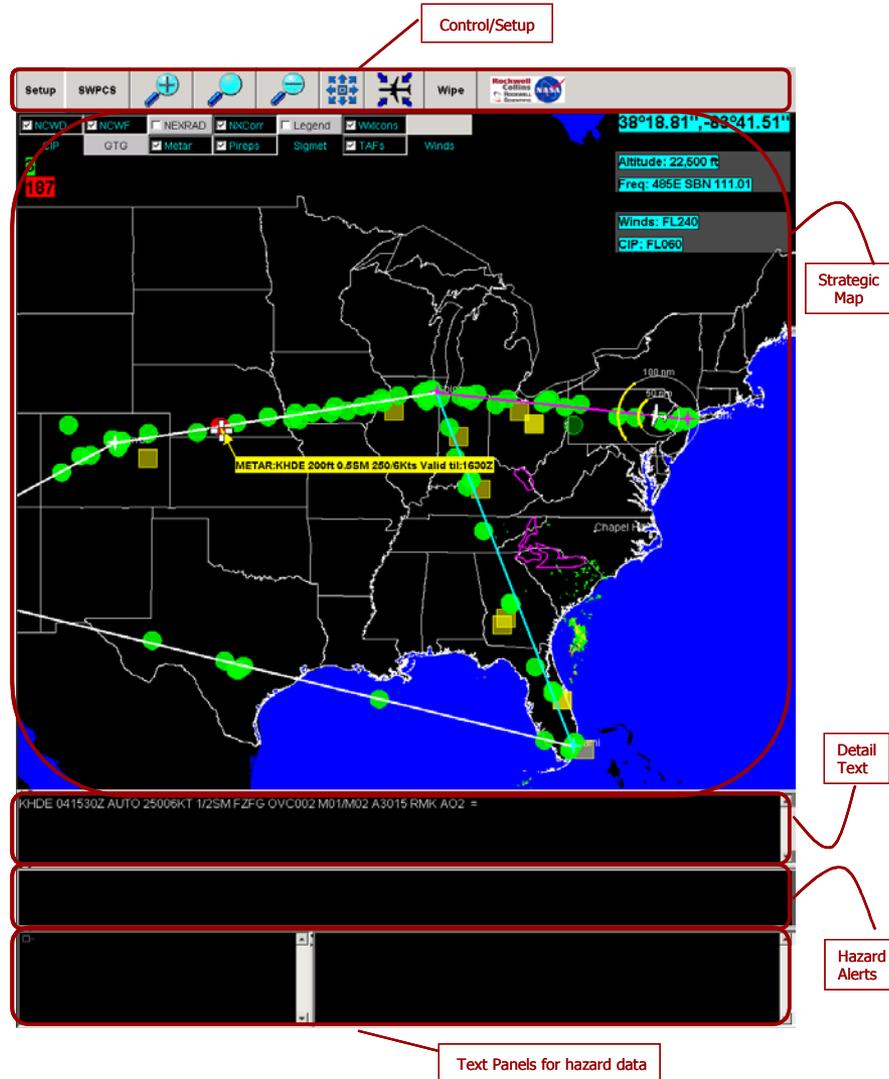
| | |
|--------------|------------------------|
| Crosswinds | >26 Kts |
| Tailwind | >10 Kts |
| Gusts | <=50 Kts |
| Ceiling | <=100 ft |
| Visibility | <=1200 ft |
| METARs, TAFs | Remarks on storms/snow |



AHAS Strategic View



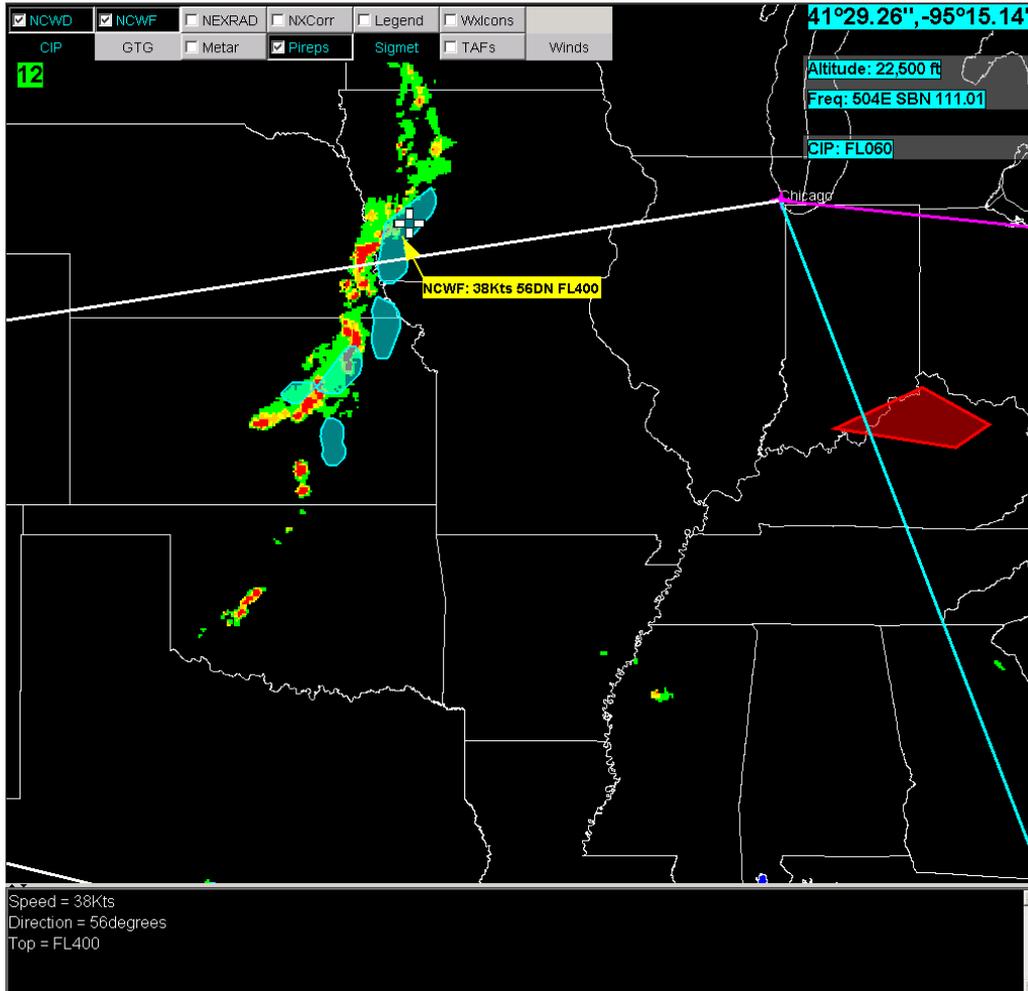
Interface



- Control setup.
- Text boxes at bottom.
- Flight path displayed.
- Weather options selected.
 - METARS
 - NCWD/NCWF
 - NxCORR
 - PIREPS
 - TAFs
- Note mouseover on METAR.



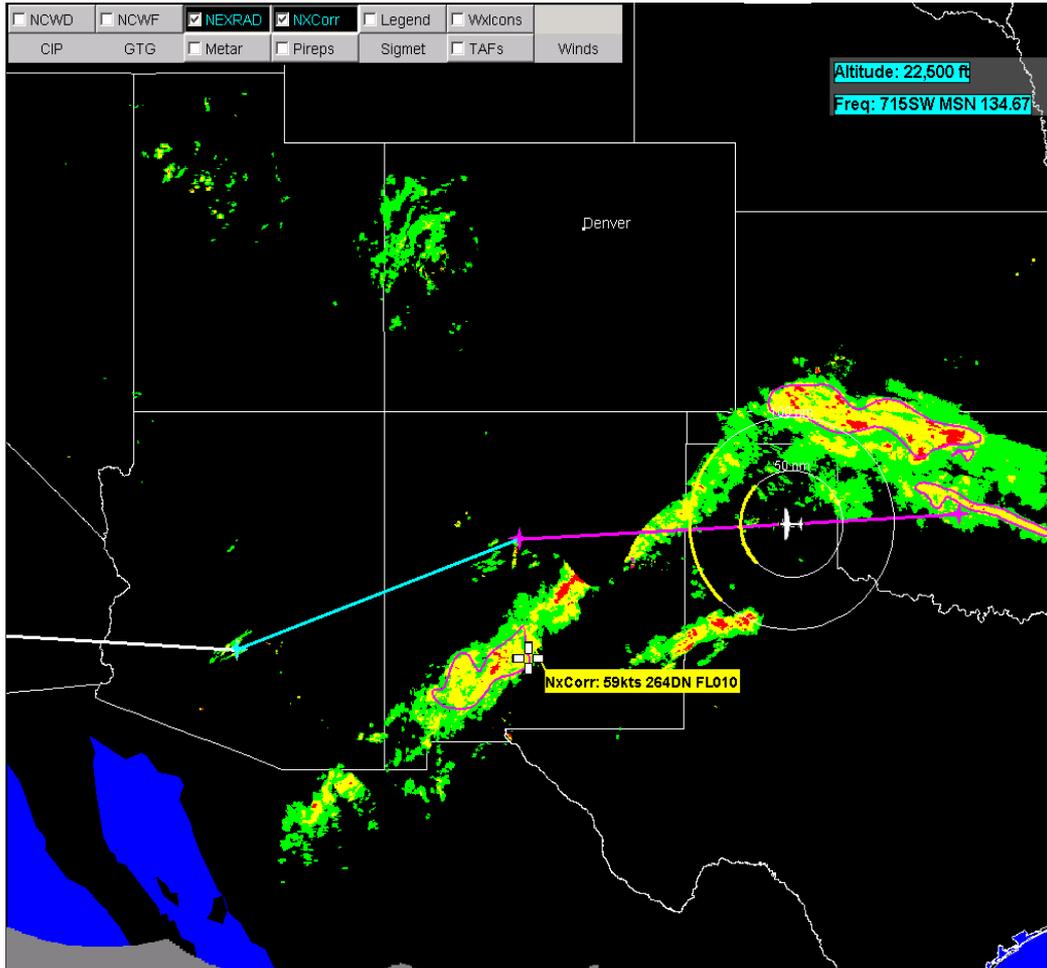
AHAS Strategic View (2)



- NCWD and NCWF selected.
- NCWD (active)
- NCWF (active)
 - Blue polygons--forecast
- Text box--decoded NCWF.



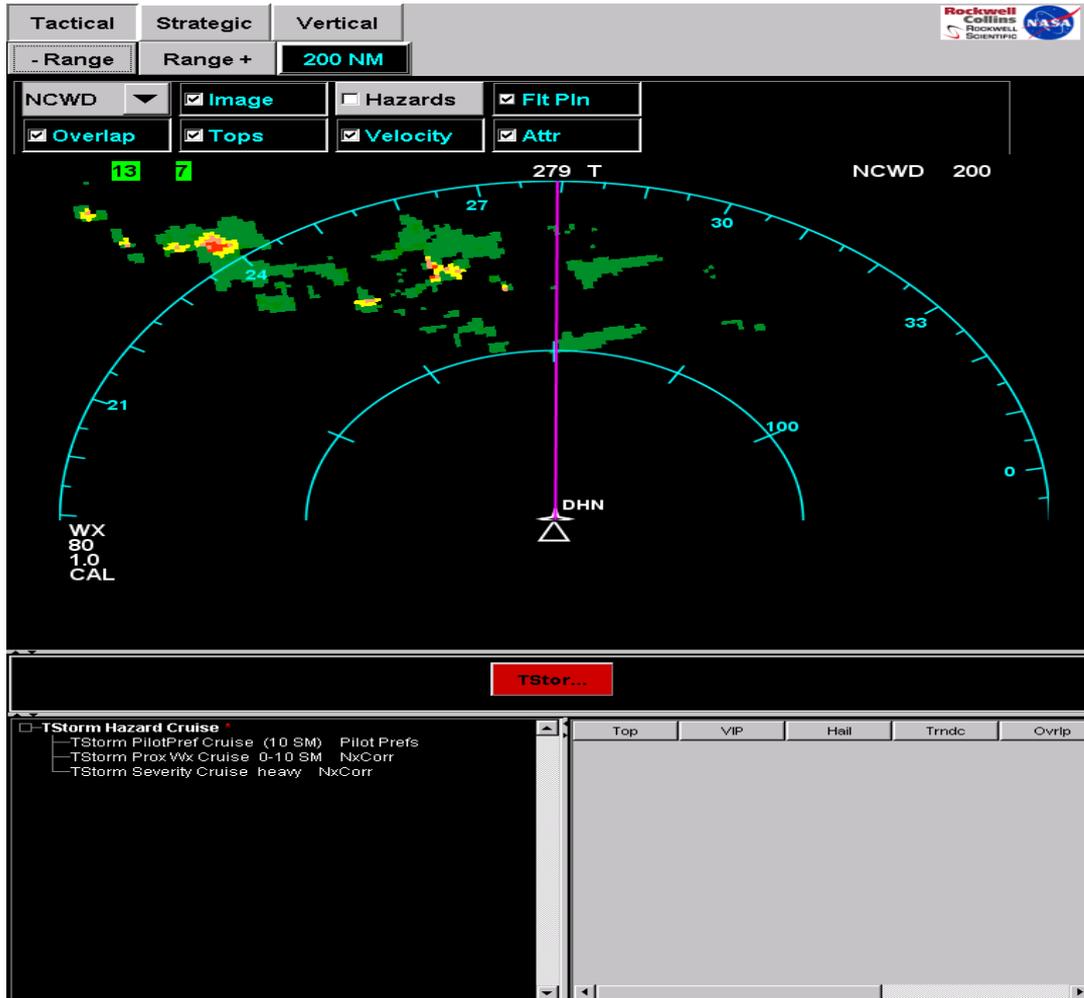
AHAS Strategic View (3)



- NEXRAD selected.
- NxCORR shown as polygon.
- Active mouseover
- Grey area indicates NEXRAD data not available.



AHAS Tactical View



Interface

- Control setup.
- Text boxes at bottom.
- NCWD data selected.



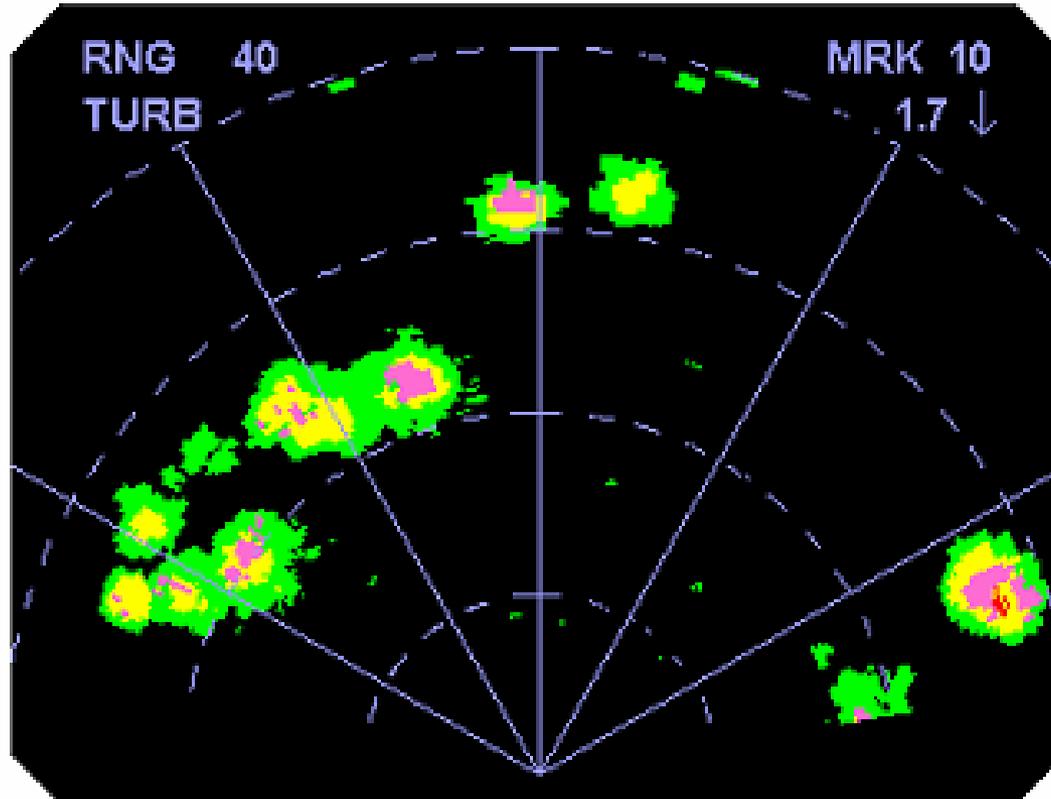
TPAWS Displays



- TPAWS airborne system display consists of two components.
- Awareness component.
 - Shows location and severity (moderate or severe) of predicted turbulence event.
 - Implemented on ships weather radar display.
 - Accuracy of prediction increases as selected range decreases.
- Alerting component.
 - Visually and aurally alerts crew to probable turbulence encounter.
 - Two levels of alerts: Caution and Warning.
 - Implemented in crew fovea as light mounted on glare shield or text annunciation on PFD similar to wind shear alerts.
 - Much higher cost to implement than awareness component.



TPAWS Awareness Display





TPAWS Awareness Display



Off Path Severe Turbulence





TPAWS Awareness Display With Alerting



Caution





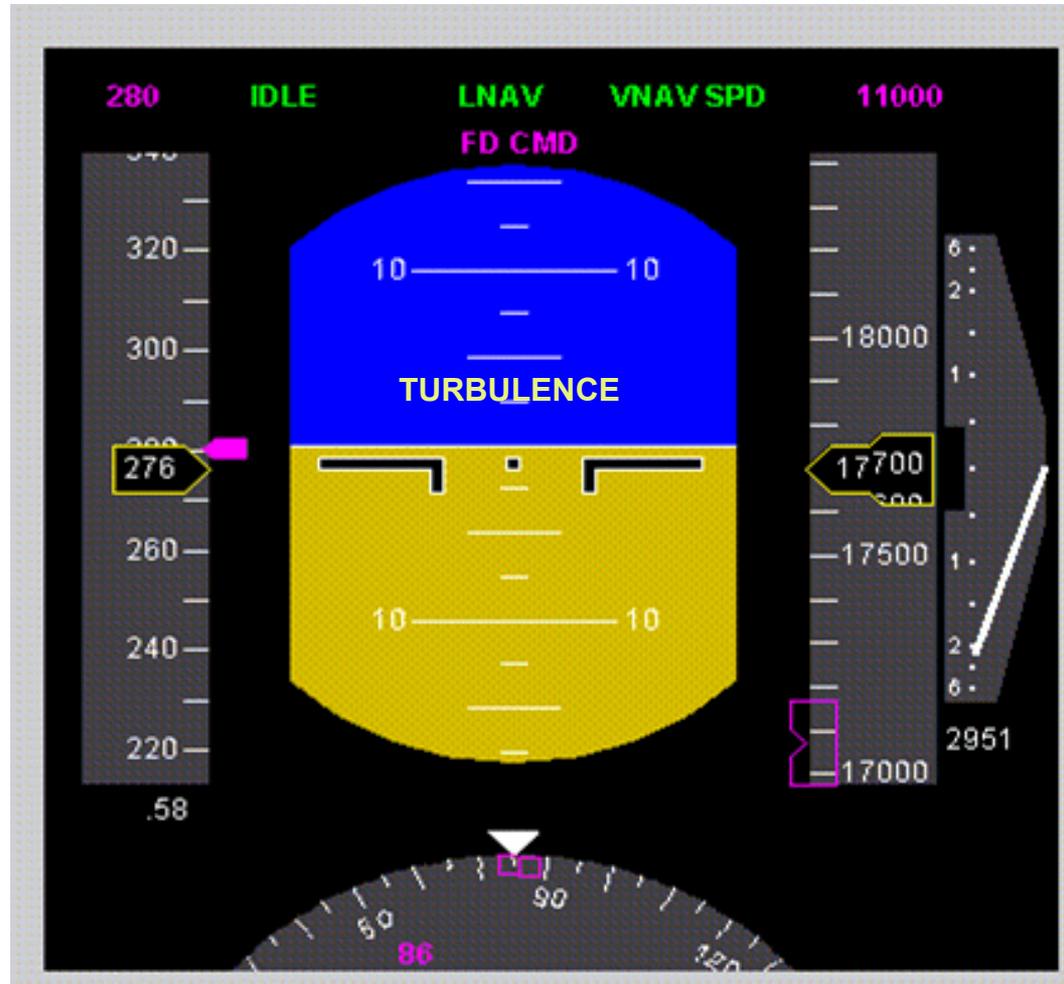
TPAWS Alerting Display



Caution



Caution Sound
plus
“Turbulence
Turbulence”





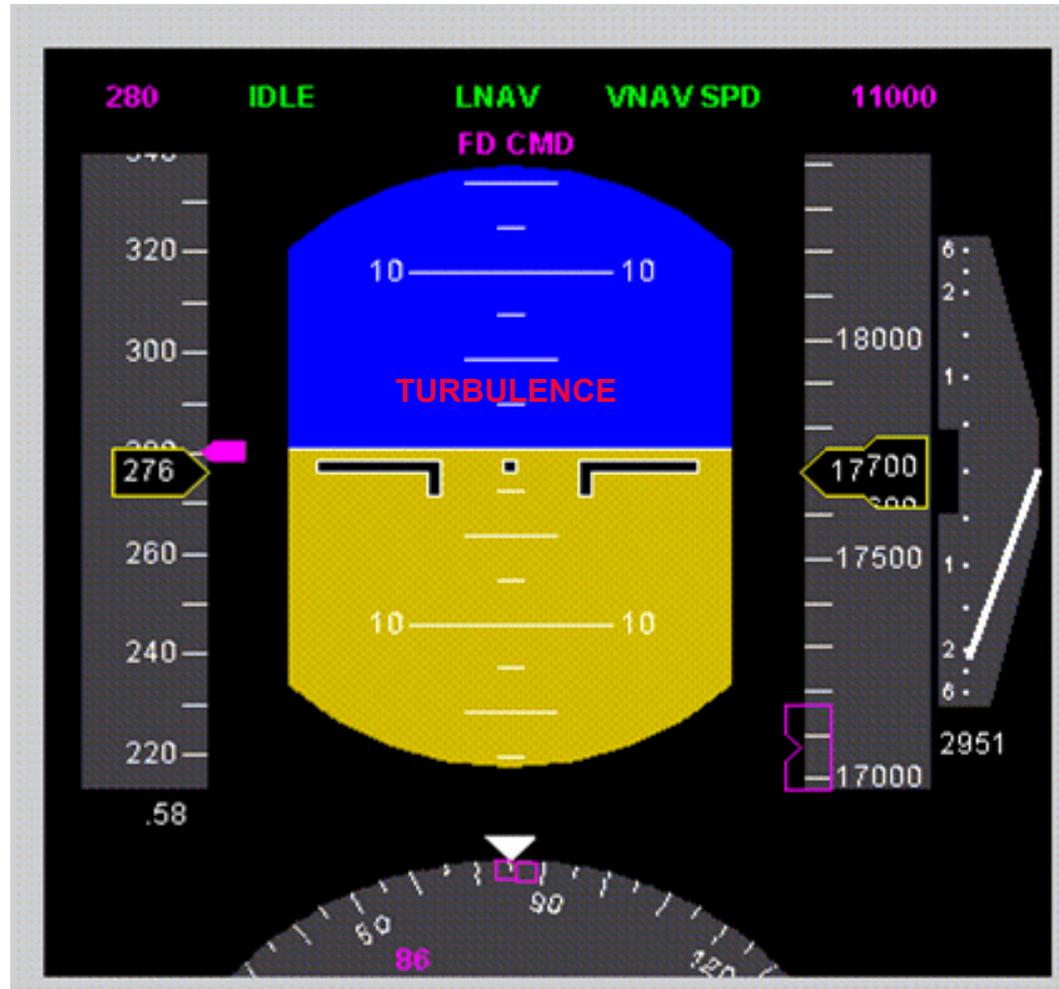
TPAWS Alerting Display



Warning



Warning Sound
plus
“Warning Turbulence
Warning Turbulence”





Hypotheses



- Hypothesis 1:** The addition of strategic weather information through the use of AHAS will increase crew response efficiency to turbulence events.

- Hypothesis 2:** The addition of the turbulence alerting system will increase use of the AHAS tactical mode.

- Hypothesis 3:** Addition of decision aids to the AHAS baseline will decrease workload.

- Hypothesis 4:** Addition of decision aids to the AHAS baseline will increase situational awareness.

- Hypothesis 5:** For the AHAS strategic display, pilots will prefer NCWD/NCWF over NEXRAD.

- Hypothesis 6:** For the AHAS tactical display, pilots will prefer the “split-view” display over the display of individual weather.



Hypotheses Continued



- Hypothesis 7:** Turbulence awareness display will increase crew preparedness for turbulence encounters.
- Hypothesis 8:** The addition of the turbulence alerting system will result in fewer unprepared for turbulence encounters.



Approach



- Piloted Evaluations
 - Flight Scenarios
 - Daytime flights.
 - Enroute commercial type line flight.
 - Each flight to run 30 minutes.
 - Initialized at cruise altitude (all flights > FL180).
 - Flights will be approaching convective activity.
 - Total of 7 research flights.
 - Subjects
 - 747 rated airline pilots.
 - Will be run in crews (Captain and First Officer).
 - Ten crews.



Approach



- Piloted Evaluations

- Concept
 - Scenarios developed to address AWIN/TPAWS hypotheses.
 - Experimental comparison across:
 - TPAWS factors: Turbulence awareness vs turbulence alerting.
 - AWIN factors: No AHAS, AHAS (no decision aids), AHAS (with decision aids).
 - Control condition with no TPAWS or AHAS systems.
- Objective and subjective data
 - Simulator data.
 - Subjective pilot data (**Workload, Situational Awareness, Questionnaires**).
- Facility
 - NASA Ames 747-400 Crew Vehicle Systems Research Facility



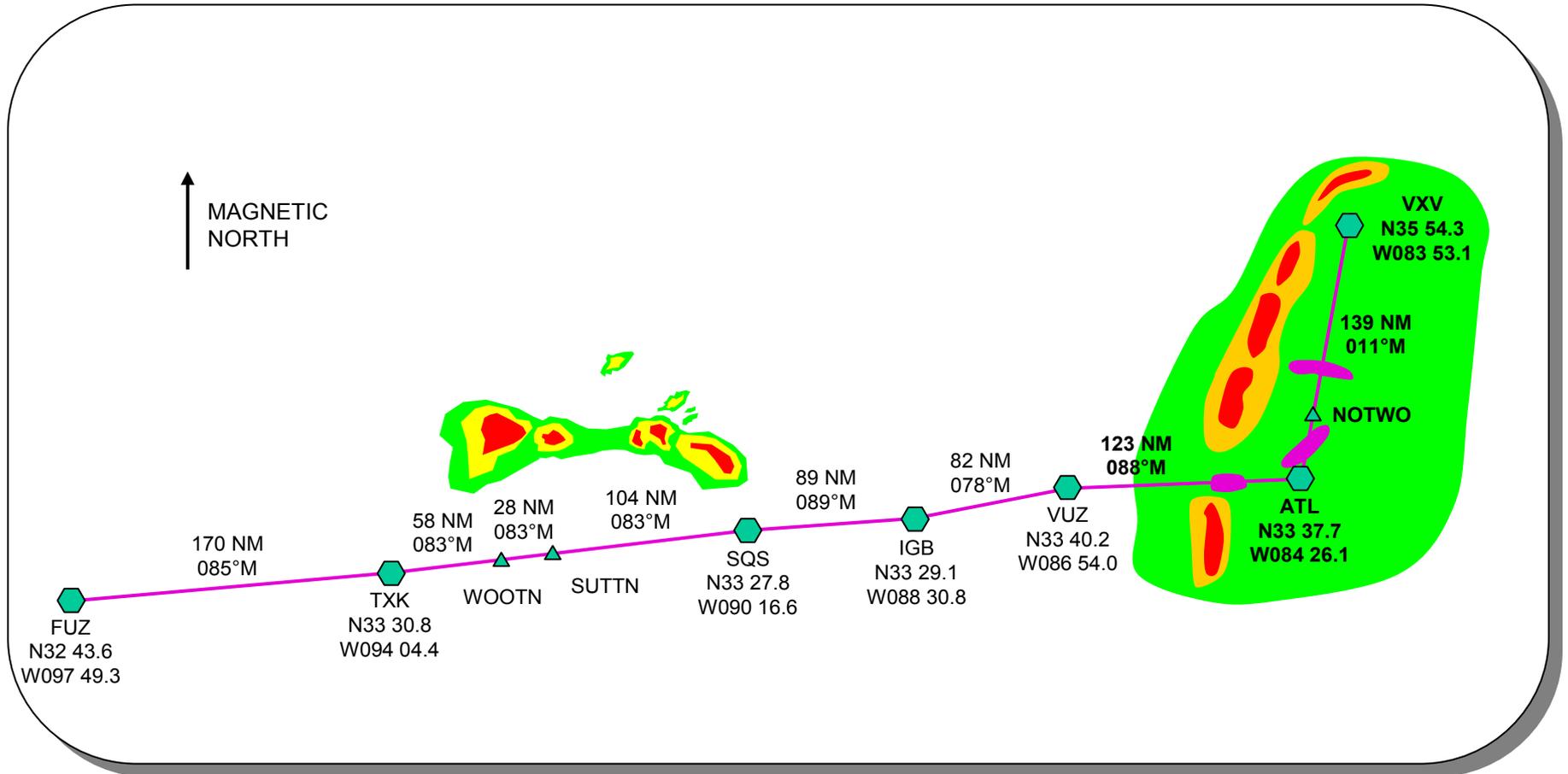
Approach—Scenario Development



- Flight scenarios will be developed using historical weather data.
 - Available from Rockwell ground station archive.
 - Will select one weather day from database with high degree of convective activity and build flight scenarios around that day.
 - Method has been used successfully in prior simulation studies.
 - Data will allow AHAS to be fully functional.
 - Will work with NASA and/or industry pilots to establish scenarios.
 - Scenarios will employ pre-determined simulator levels of light, moderate, and severe turbulence which will be saved and “locked” for the experiment.
- Moderate and severe turbulence settings for experiment.



Approach—Hypothetical Scenario





Approach—Experimental Design



| | TPAWS AWARENESS | TPAWS ALERTING |
|-------------------------------------|--------------------|-------------------|
| NO AHAS | | |
| AHAS WITHOUT DECISION AIDS | | |
| AHAS WITH DECISION AIDS | | |

- Incomplete Factorial with Control
- Completely Within-Subjects
- Crews not run in same order

Control: No
TPAWS or
AHAS
systems



Data



Subjective

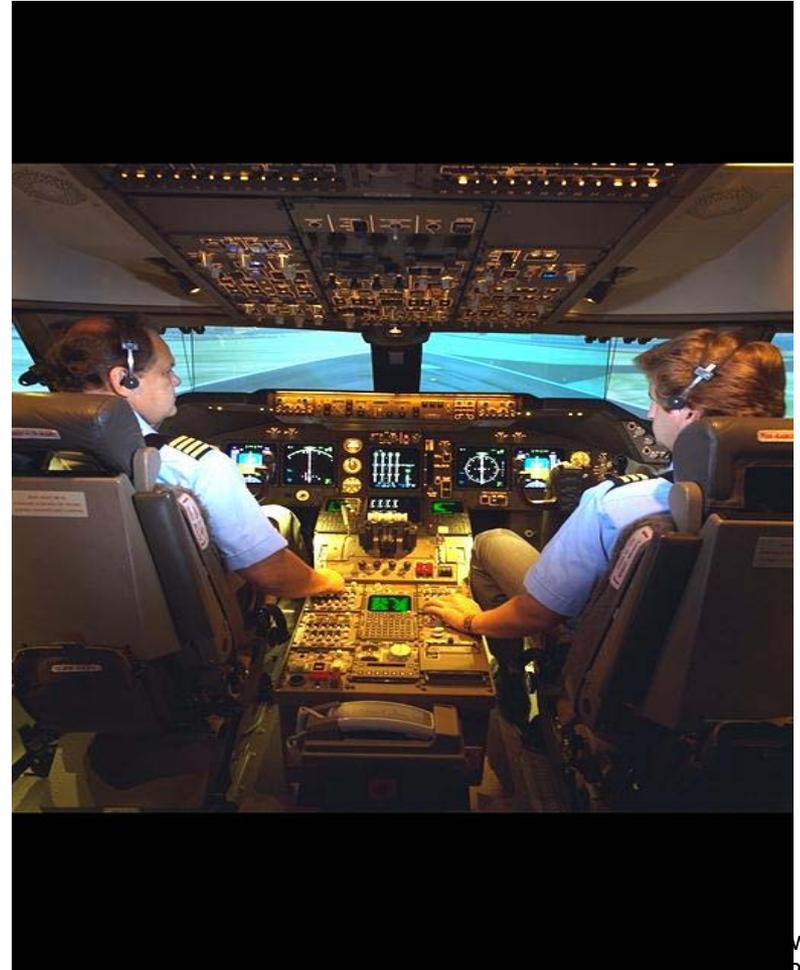
- Pilot Workload
 - Modified Cooper Harper
- Situational Awareness
 - Initial development
- Pilot Questionnaires
- Video Recording of Crew



Facilities



NASA Ames Crew Vehicle Systems Research Facility 747-400





NASA Ames Crew Vehicle Systems Research Facility

747-400 Critical Experimental Features



- Programmable flight displays.
 - *Enables capability to program TPAWS display concepts.*
- Fully digital control loading system.
- Six degree-of-freedom motion system.
 - *Enables realistic weather-induced motion cues.*
 - *Enables use of predetermined turbulence levels in scenarios.*
- Sound and aural cues.
- Fully integrated autoflight system.
- Weather radar system simulation.
 - *Enables presentation of simulated weather on NAV display.*
- Flight safety international VITAL VIIIi visual system.
 - *Visual weather radar and motion systems tightly coupled thereby simulating weather effects with a high degree of realism.*
- ARINC 429 and 453.
 - *AHAS system can receive FMS flight plan.*
 - *Experimental data provided on CD-ROM to PIs post-run.*