

# The Effect of NEXRAD Image Looping and National Convective Weather Forecast Product on Pilot Decision Making in the Use of a Cockpit Weather Information Display

NASA  
NAS1-99074  
Task 1032

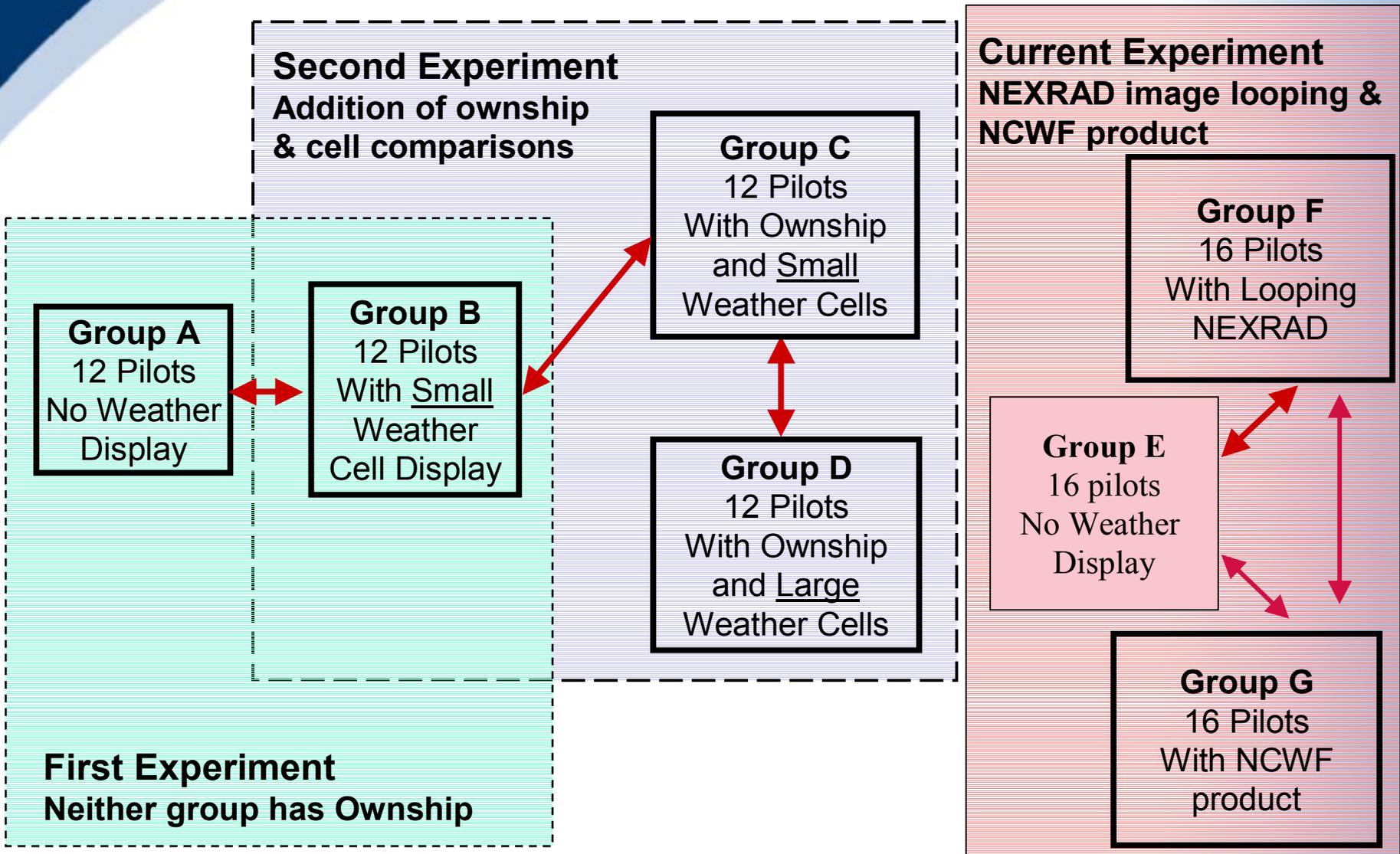
Malcolm Burgess



# Project Objectives

- **Develop a better understanding of the effect of NEXRAD image looping on pilot decision making and workload**
- **Develop a better understanding of the effect of using the National Convective Weather Forecast (NCWF) product on pilot decision making and workload**

# Subject Group Relationships



(red arrows show statistical comparisons)

# Hypotheses of Third Experiment

- 1) The provision of NEXRAD image looping will improve pilot decision making with respect to convective weather.**
- 2) The provision of NEXRAD image looping will increase pilot workload.**
- 3) The provision of NCWF products will improve pilot decision making with respect to convective weather.**
- 4) The provision of NCWF product will increase pilot workload.**

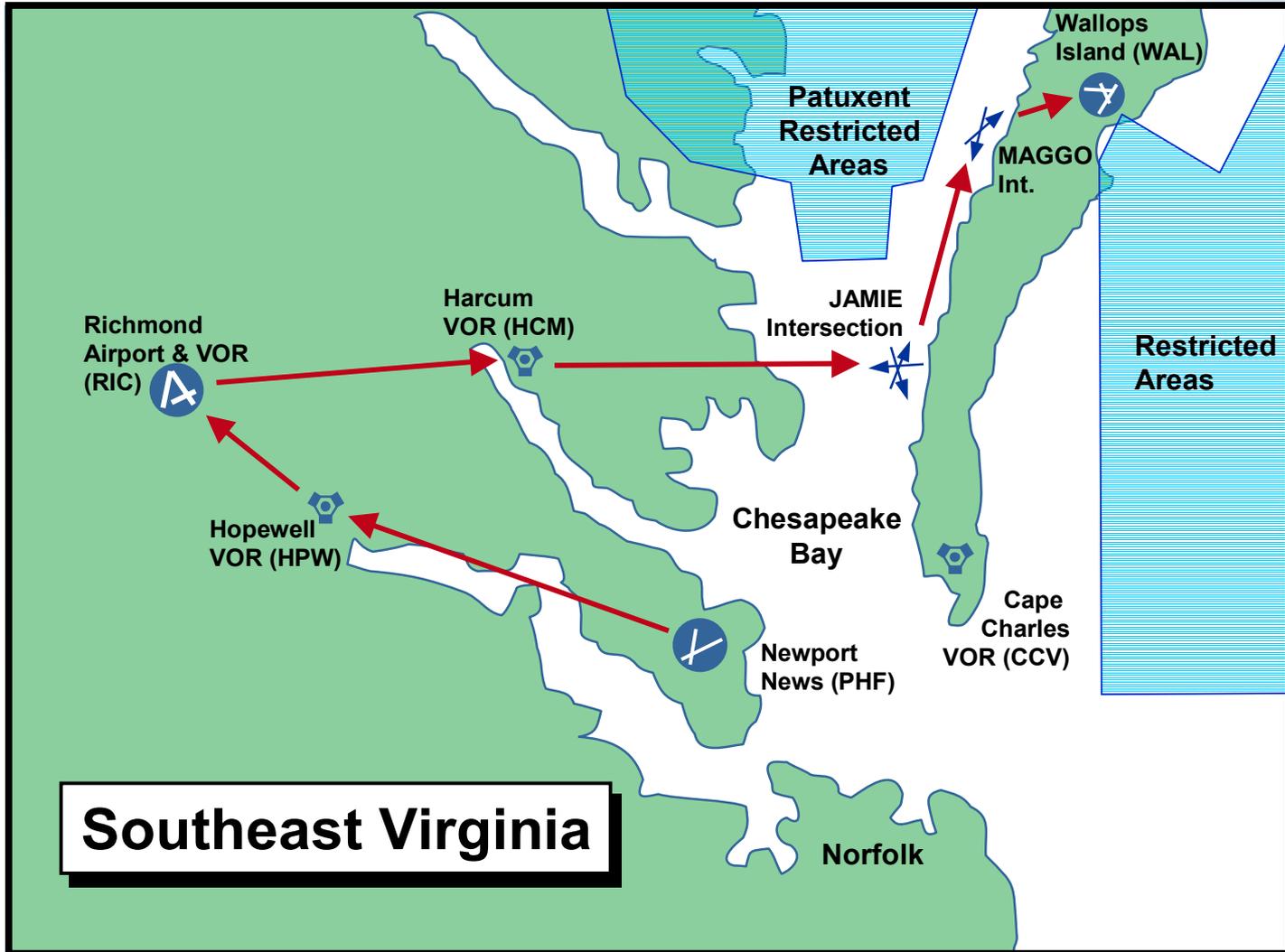
# Experiment Design

- **Three groups of pilots,**
  - 16 with no weather display,
  - 16 with NEXRAD image looping display
  - 16 with the NCWF product display
- **The simulator mission consisted of a two-leg flight with convective weather along the route**
- **All subjects were current Instrument Flight Rules (IFR) qualified general aviation pilots**
- **Primary data collection consists of weather related navigation decisions.**

# Subject Pilot Experience

<b>Experience &amp; Proficiency Measures</b>	<b>Mean</b>	<b>Standard Error</b>	<b>Max</b>	<b>Min</b>
<b>Mean Total Flight Hours</b>	<b>2469.42</b>	<b>428.77</b>	<b>15000.00</b>	<b>220.00</b>
<b>Mean Actual Instrument Hours</b>	<b>314.44</b>	<b>105.57</b>	<b>4000.00</b>	<b>1.40</b>
<b>Mean Hours “Under The Hood”</b>	<b>115.25</b>	<b>24.52</b>	<b>1000.00</b>	<b>.00</b>
<b>Mean Flight Simulation Hours</b>	<b>52.07</b>	<b>13.00</b>	<b>300.00</b>	<b>.00</b>
<b>Mean Hours Last 90 Days</b>	<b>12.91</b>	<b>4.06</b>	<b>150.00</b>	<b>.00</b>
<b>Weather Knowledge Scores</b>	<b>.66</b>	<b>2.57E-02</b>	<b>1.00</b>	<b>.23</b>

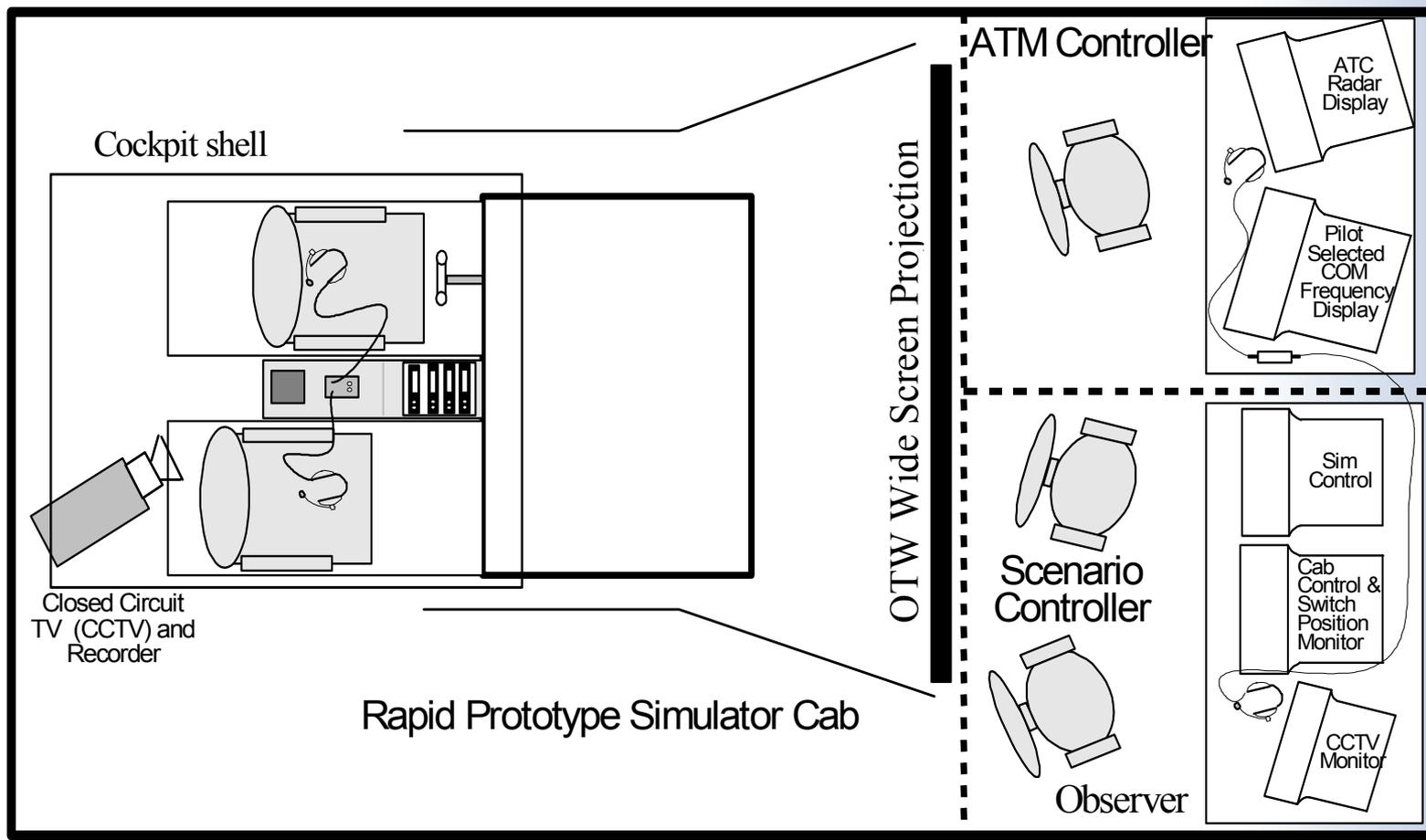
# Mission Route



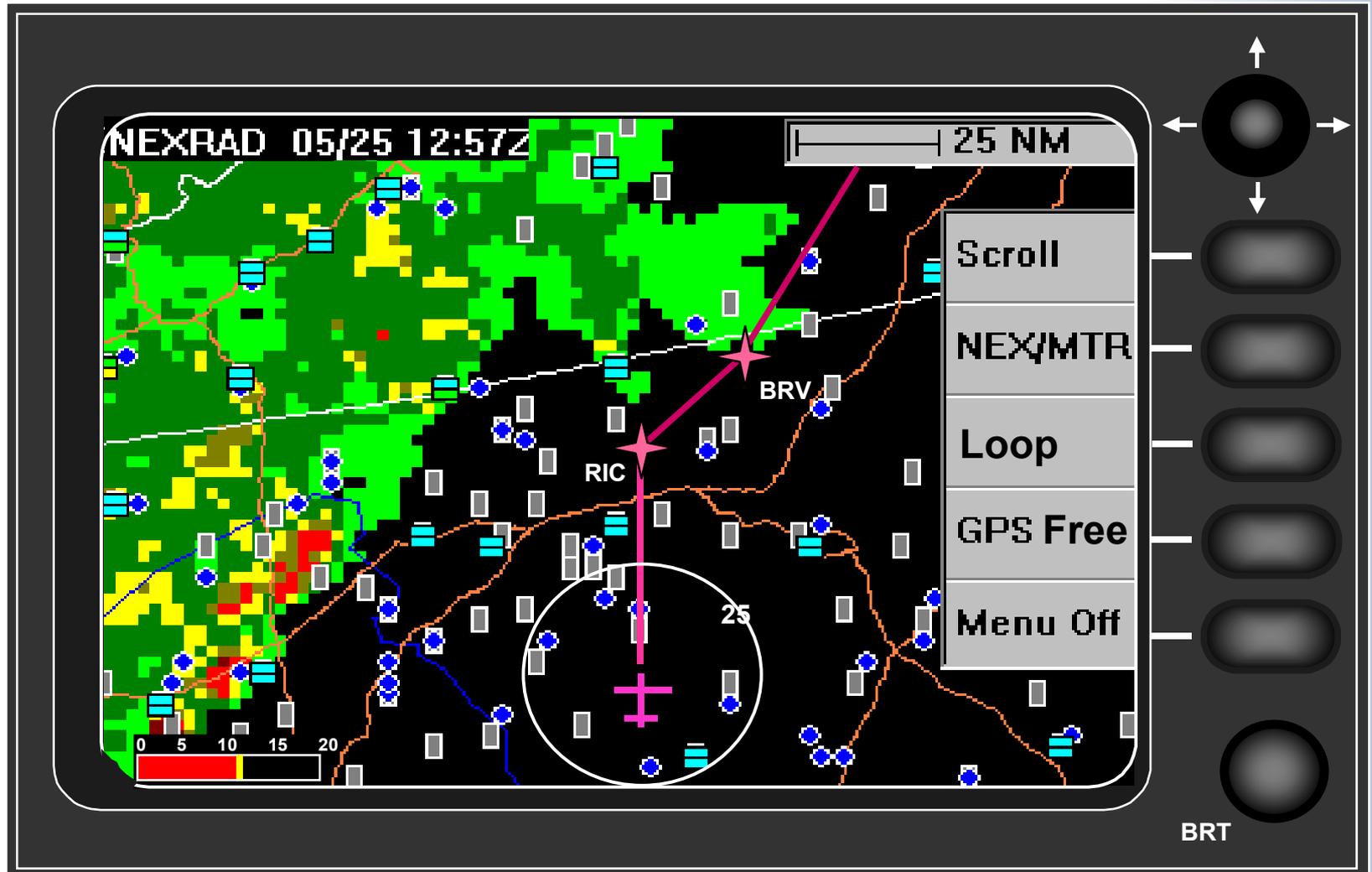
# RTI Cockpit Research Facility Configuration Used for Study



# RTI Cockpit Research Facility Used for Study



# Looping NEXRAD Image Display



# Graphical METAR Codes

## CEILING

**Red** – Less than 500 ft.  
**Yellow** – 500 to 1000 ft.  
**Green** – 1000 to 3000 ft.  
**Blue** – More than 3000 ft.

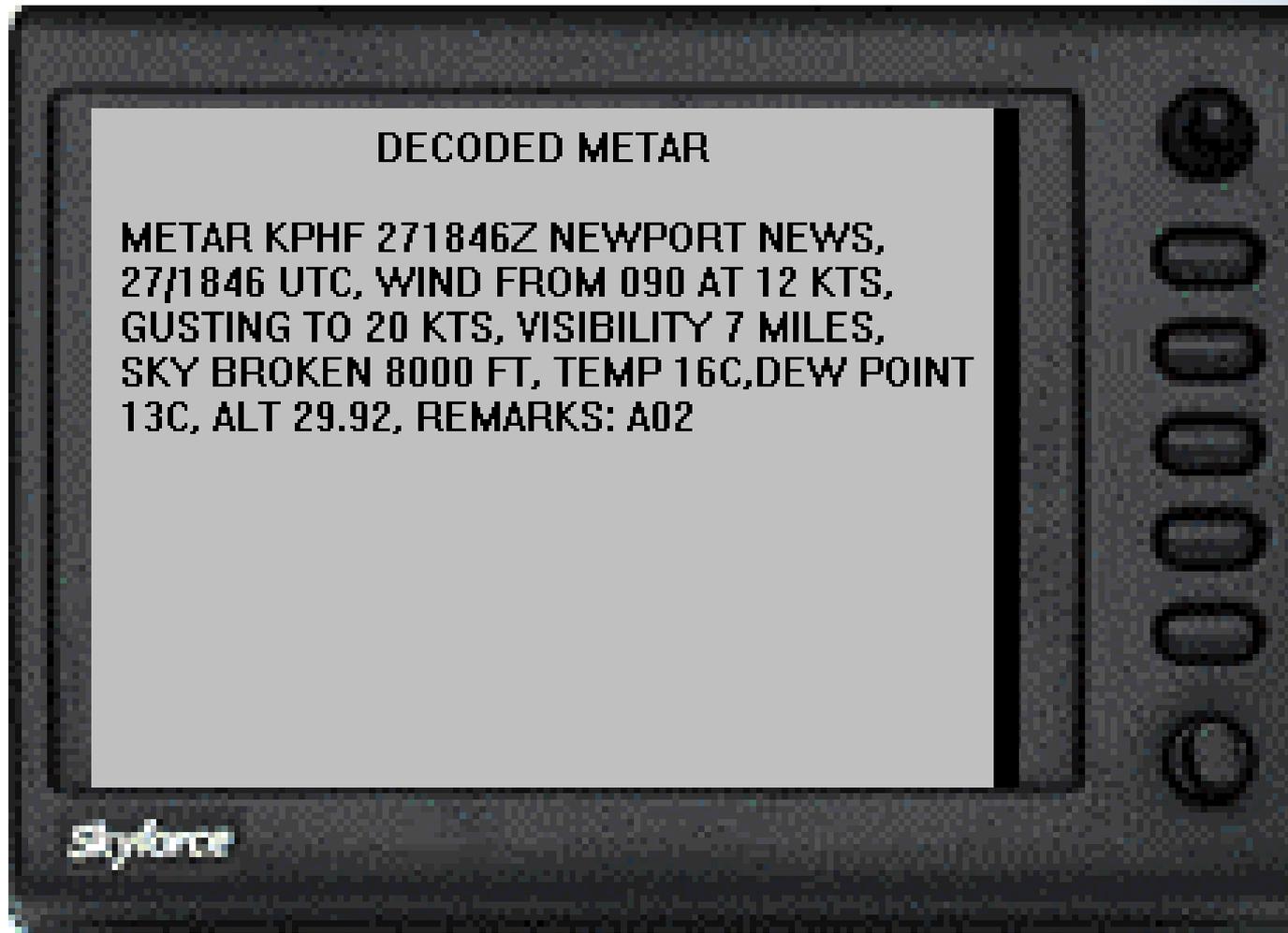
**Red** – Low IFR  
**Yellow** – IFR  
**Green** – Marginal VFR  
**Blue** – Unlimited



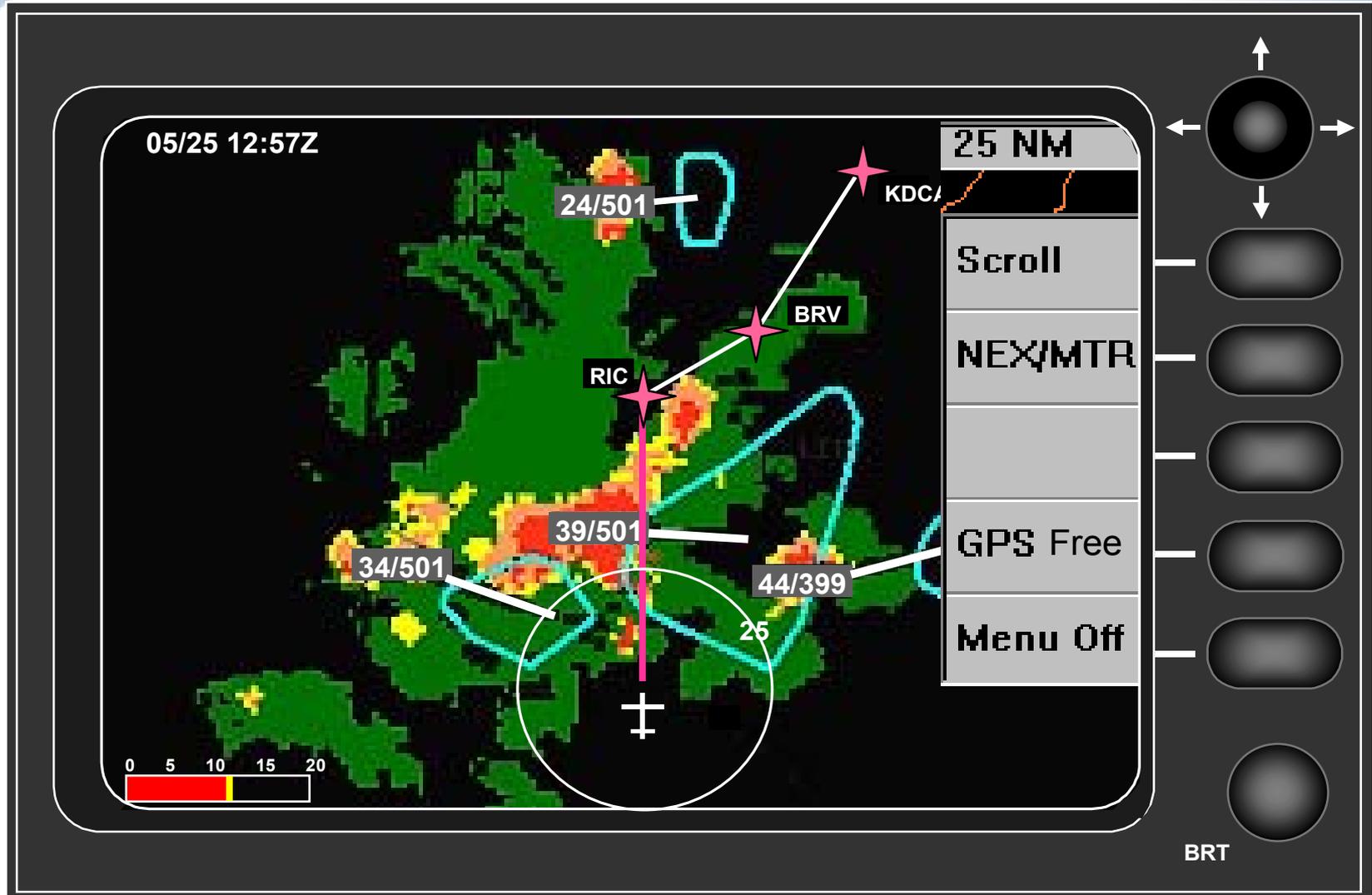
## VISIBILITY

**Red** – Less than 1 mi.  
**Yellow** – 1 to 3 mi.  
**Green** – 3 to 5 mi.  
**Blue** – More than 5 mi.

# METAR Text Display



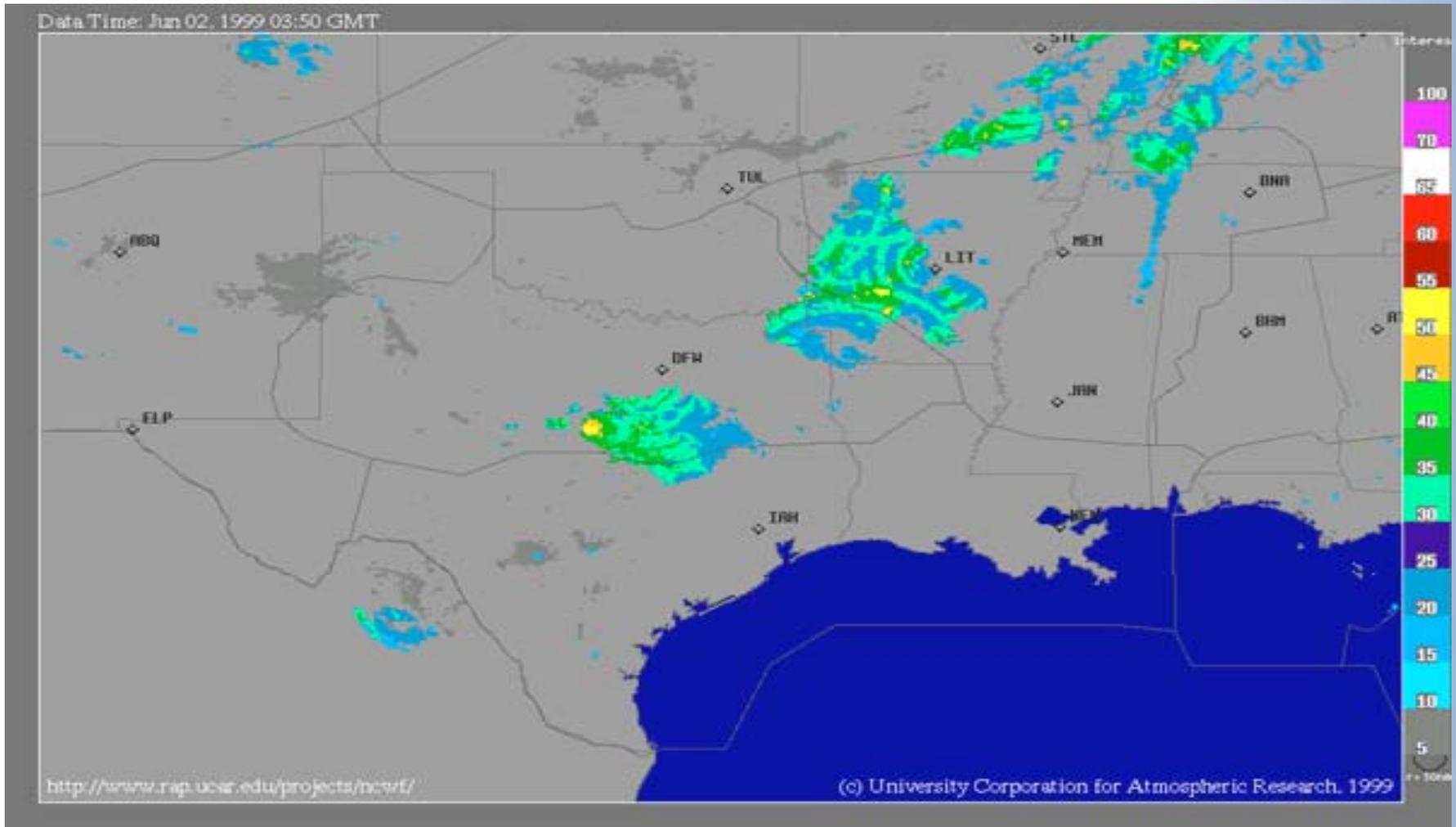
# National Convective Weather Forecast Display



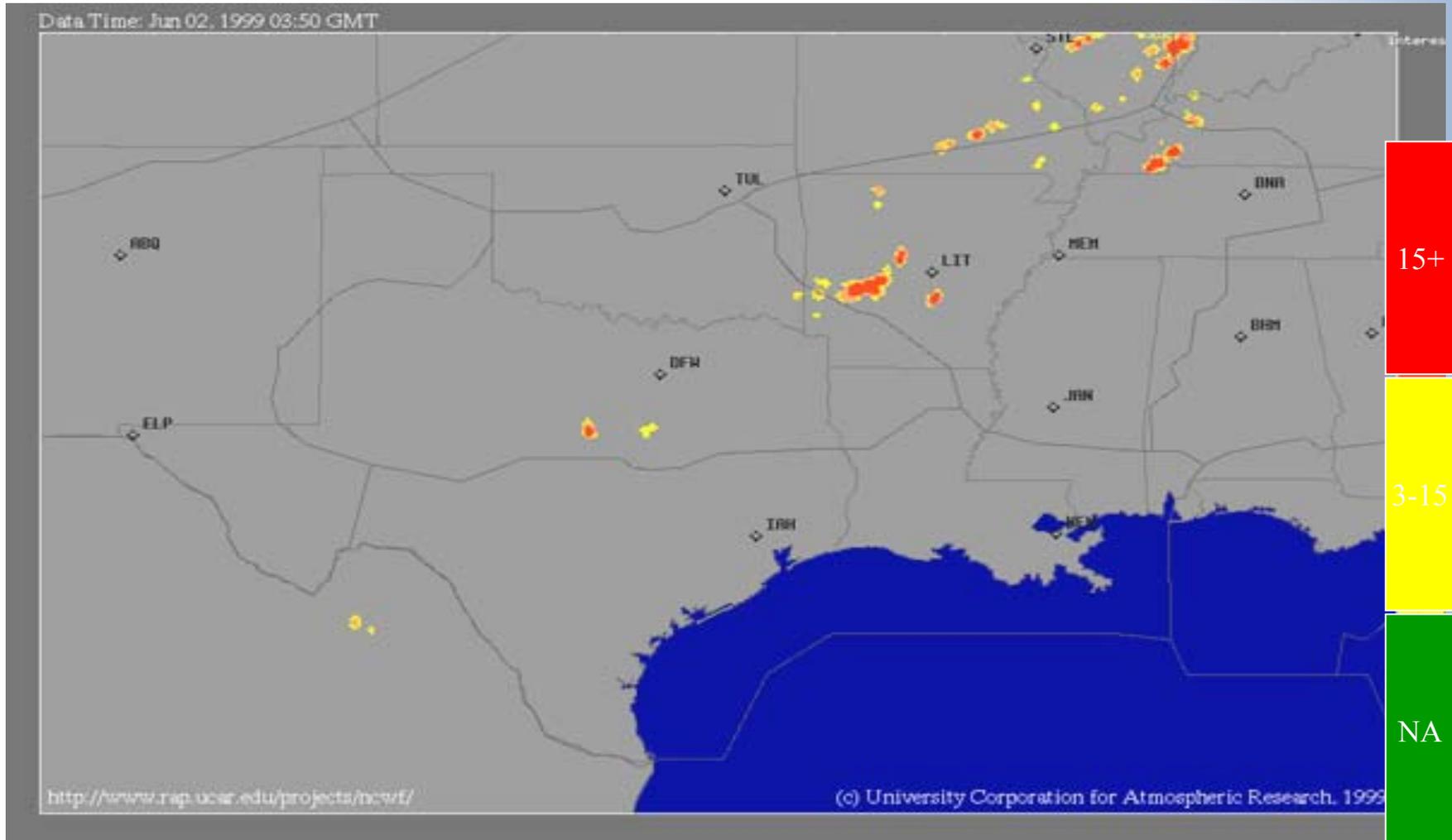
# NCWF Hazard Field



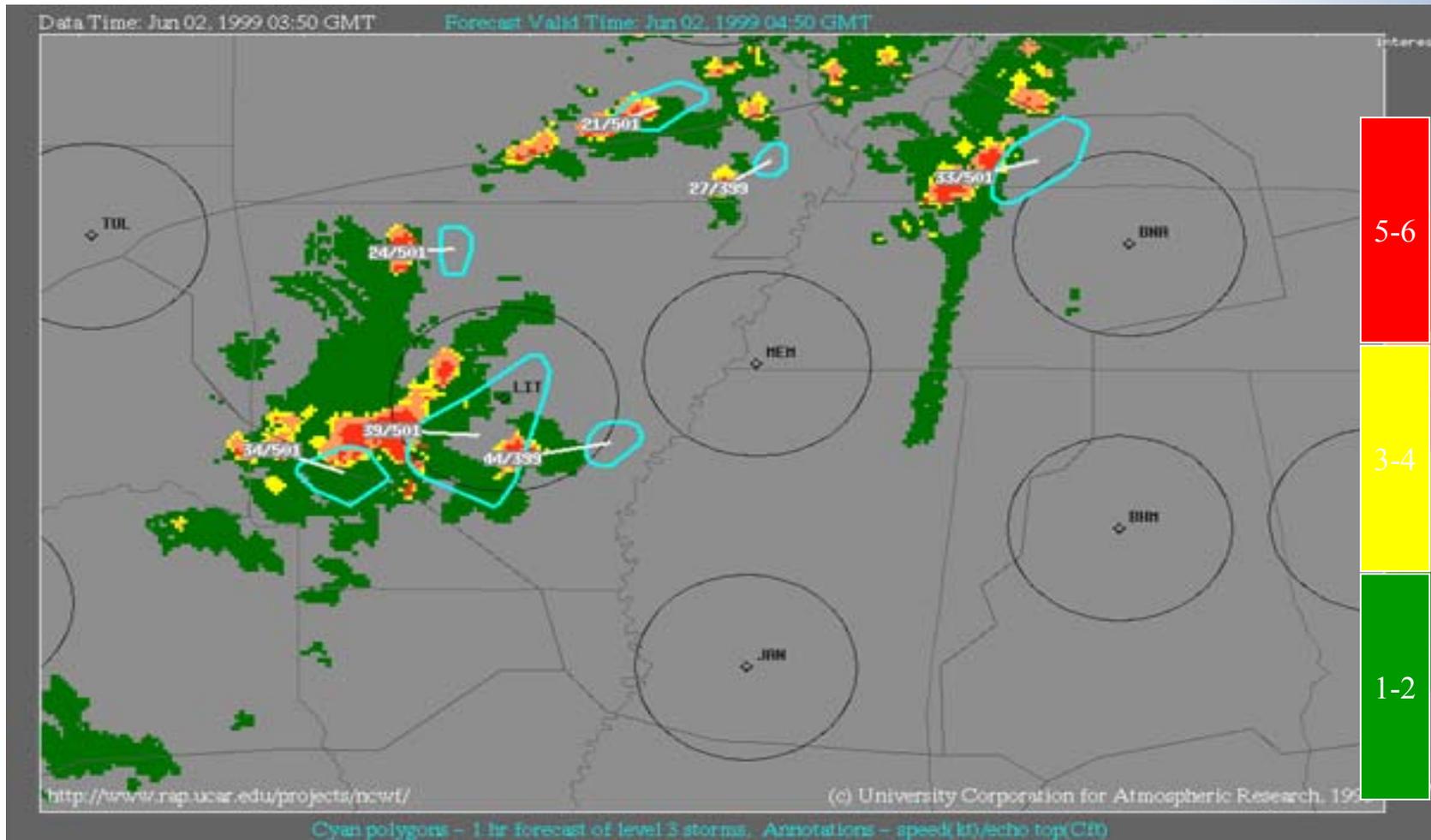
# NCWF Tops Filter



# NCWF Lightning Grid



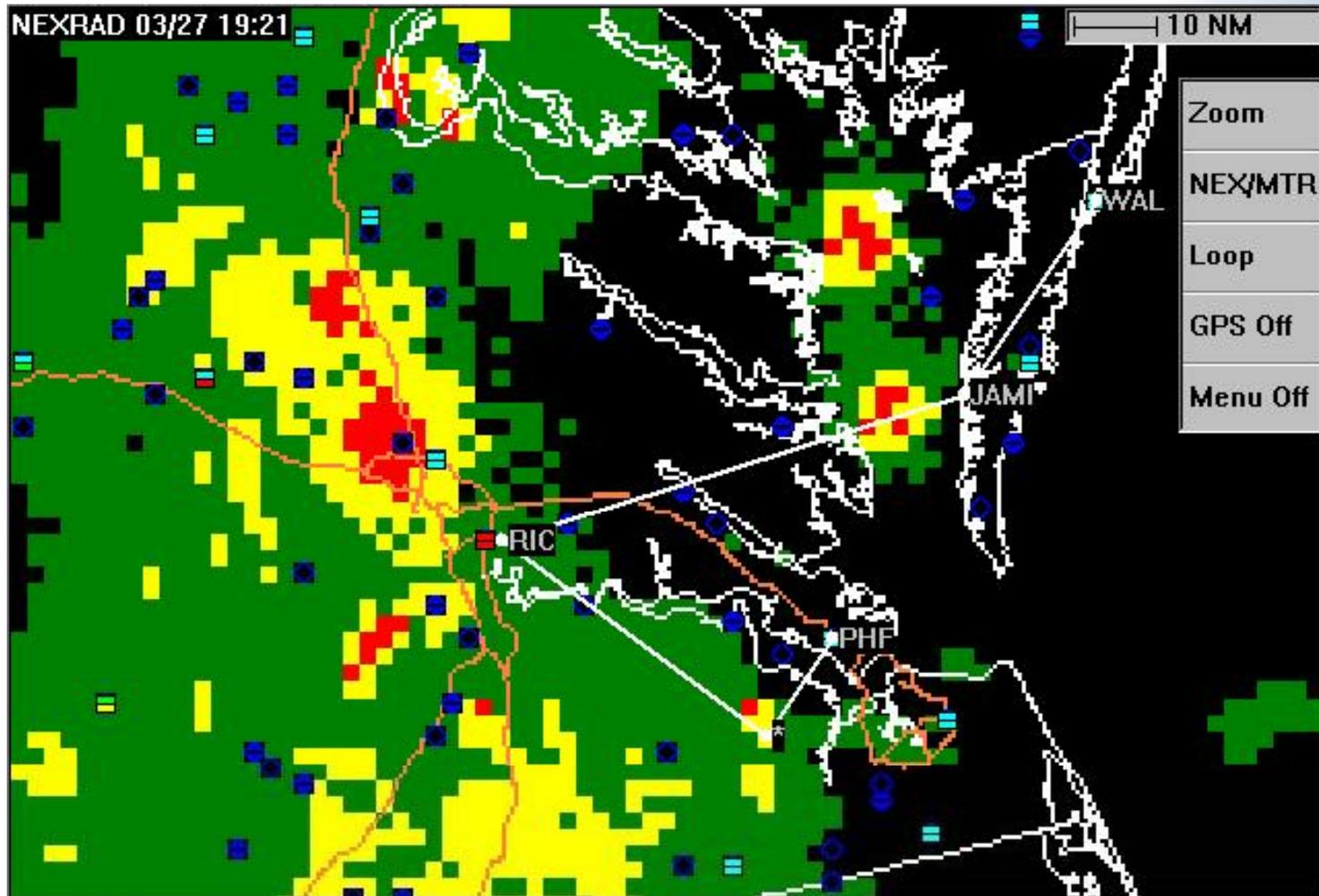
# NCWF Final Product



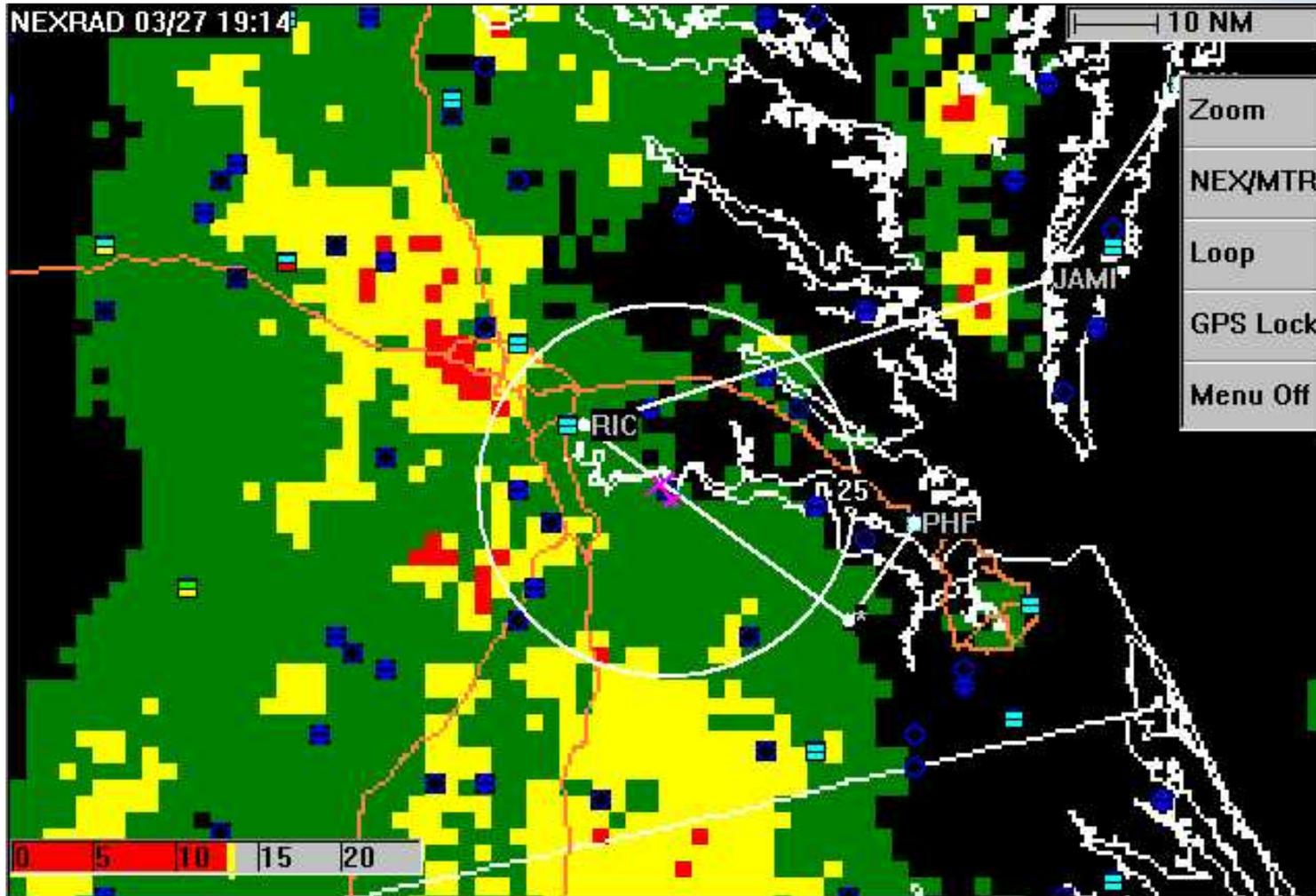
# Weather Information Sources

- **ATIS**
- **Flight Service Station**
- **Flight Watch**
- **ASOS reports via radio**
- **Air Traffic Control**
  - Tower**
  - Departure**
  - Enroute**
  - Approach**
- **Data-Link Weather Display**

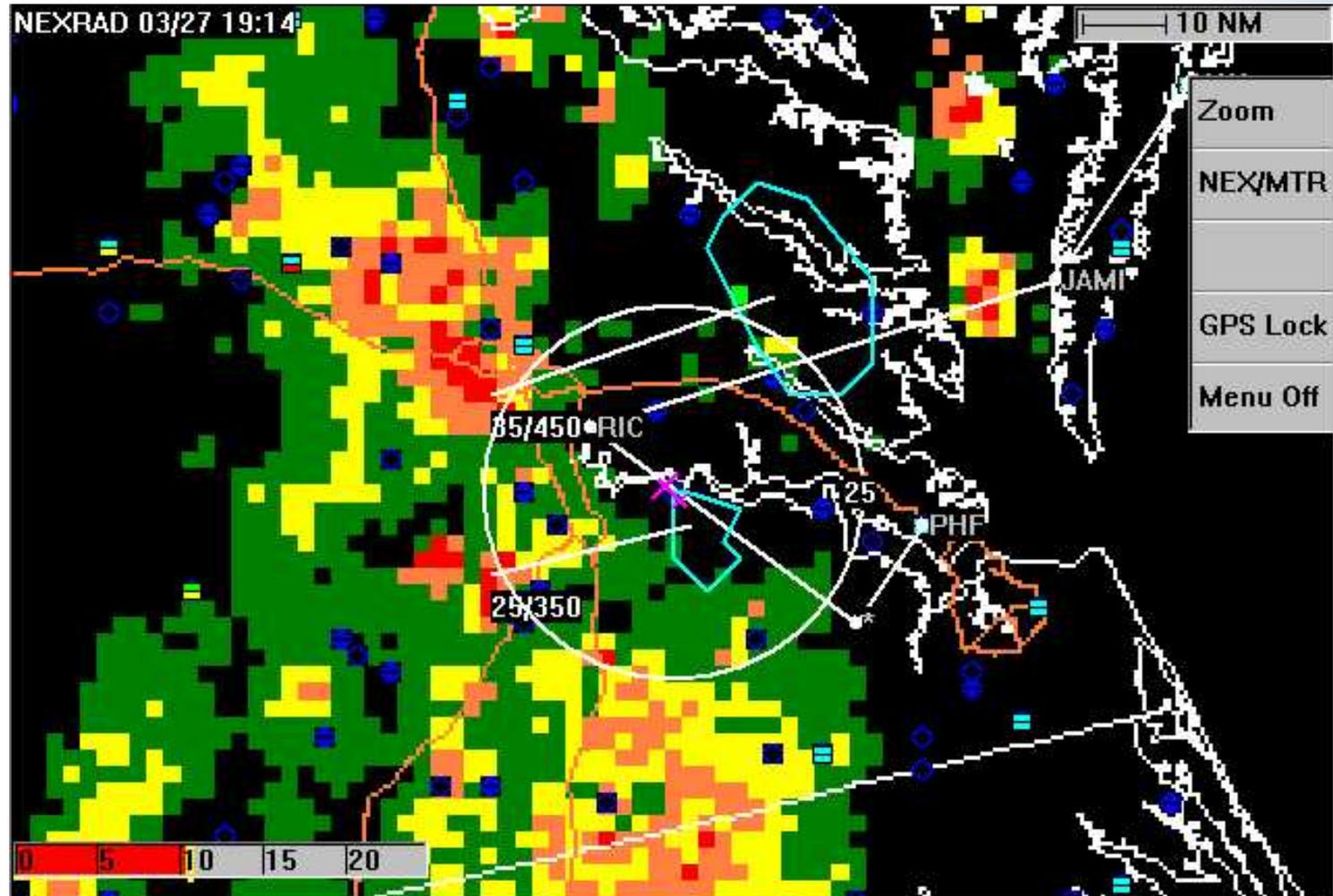
# Actual Conditions at Richmond Airport (As Seen In NEXRAD Mosaic Image with 1921Z Time Stamp)



# NEXRAD Display (with looping) Seen by Subject Pilots



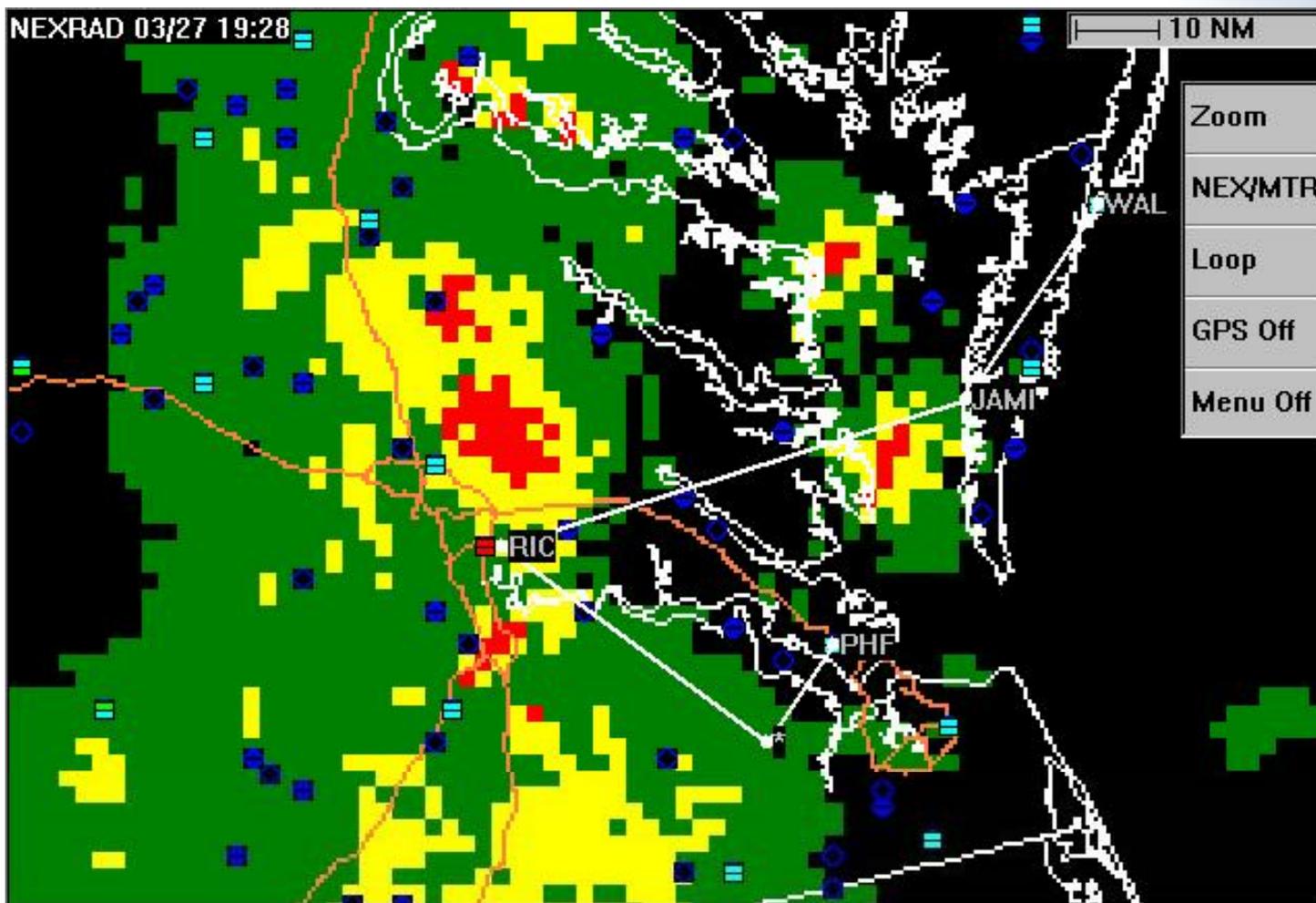
# NCWF Display Seen By Subject Pilots Inbound to Richmond Airport IAF (10nm Scale)



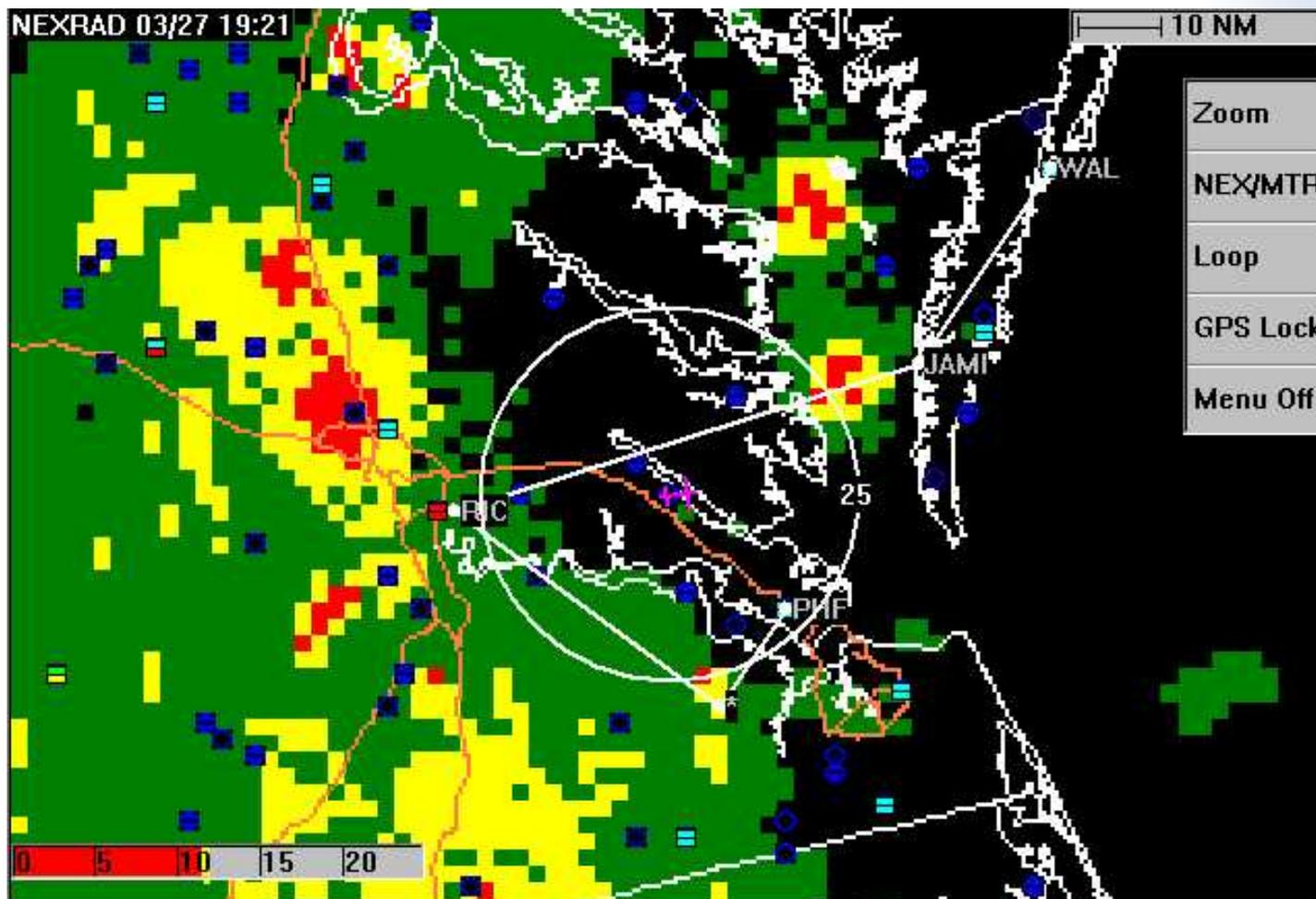
# Richmond Decision Criteria

- 1 - Pilot continued approach into poor weather and was waved off the approach by the tower controller at the Final Approach Fix.**
- 2 - Pilot abandoned approach less than five (5) miles outside of the outer marker, but flew within five (5) miles of a red NEXRAD image cell, while in the Richmond area.**
- 3 - Pilot abandoned approach less than five (5) miles outside of the outer marker, and flew more than five (5) miles from a red NEXRAD image cell, while in the Richmond area.**
- 4 - Pilot abandoned approach more than five (5) miles outside of the outer marker, and flew more than five (5) miles from a red NEXRAD image cell.**

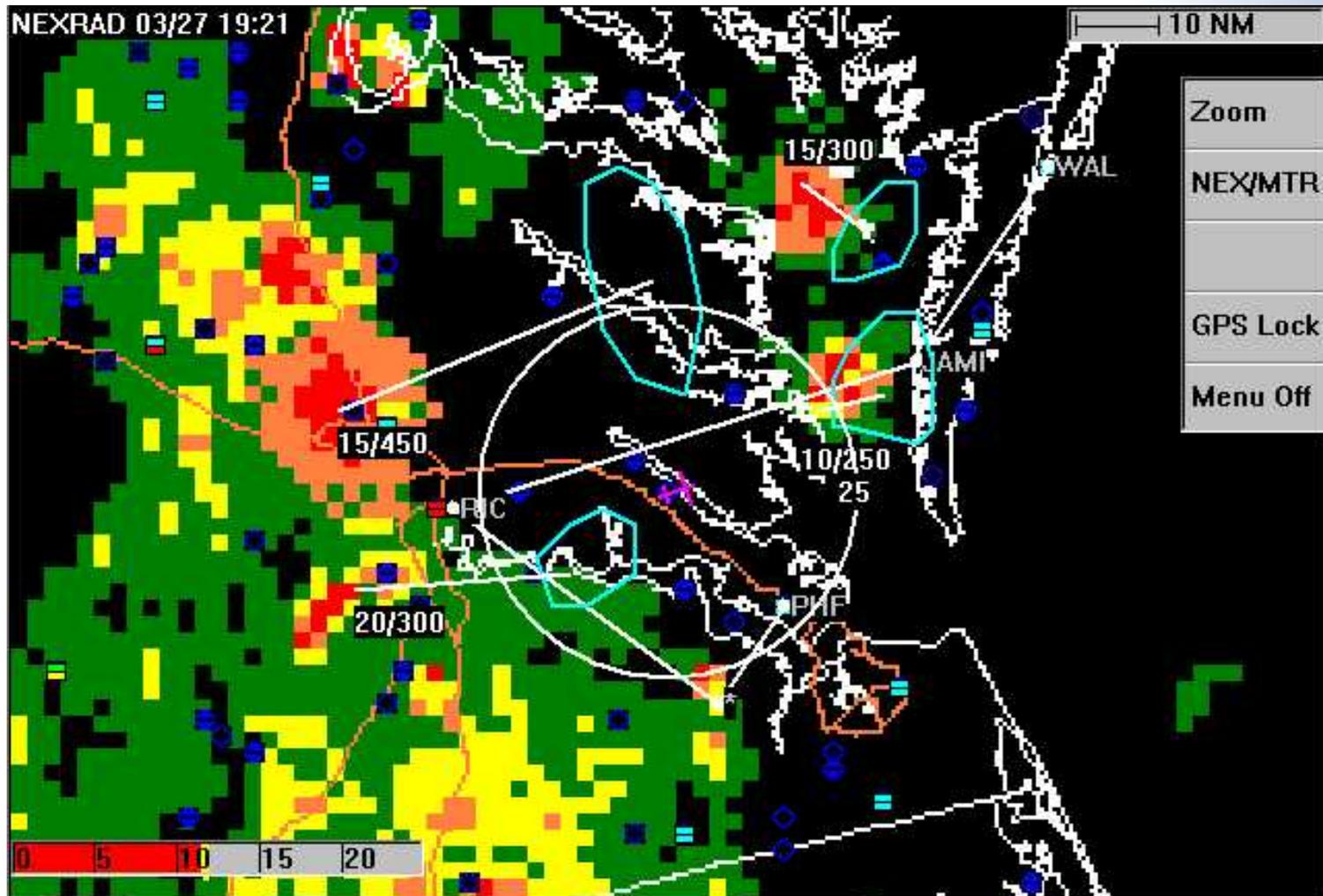
# Actual Conditions Enroute to Wallops Island (As Seen in NEXRAD Mosaic Image with 1928Z Time Stamp)



# NEXRAD Display (with looping) Seen by Subject Pilots Along Route to Wallops At Decision Time (10nm Scale)



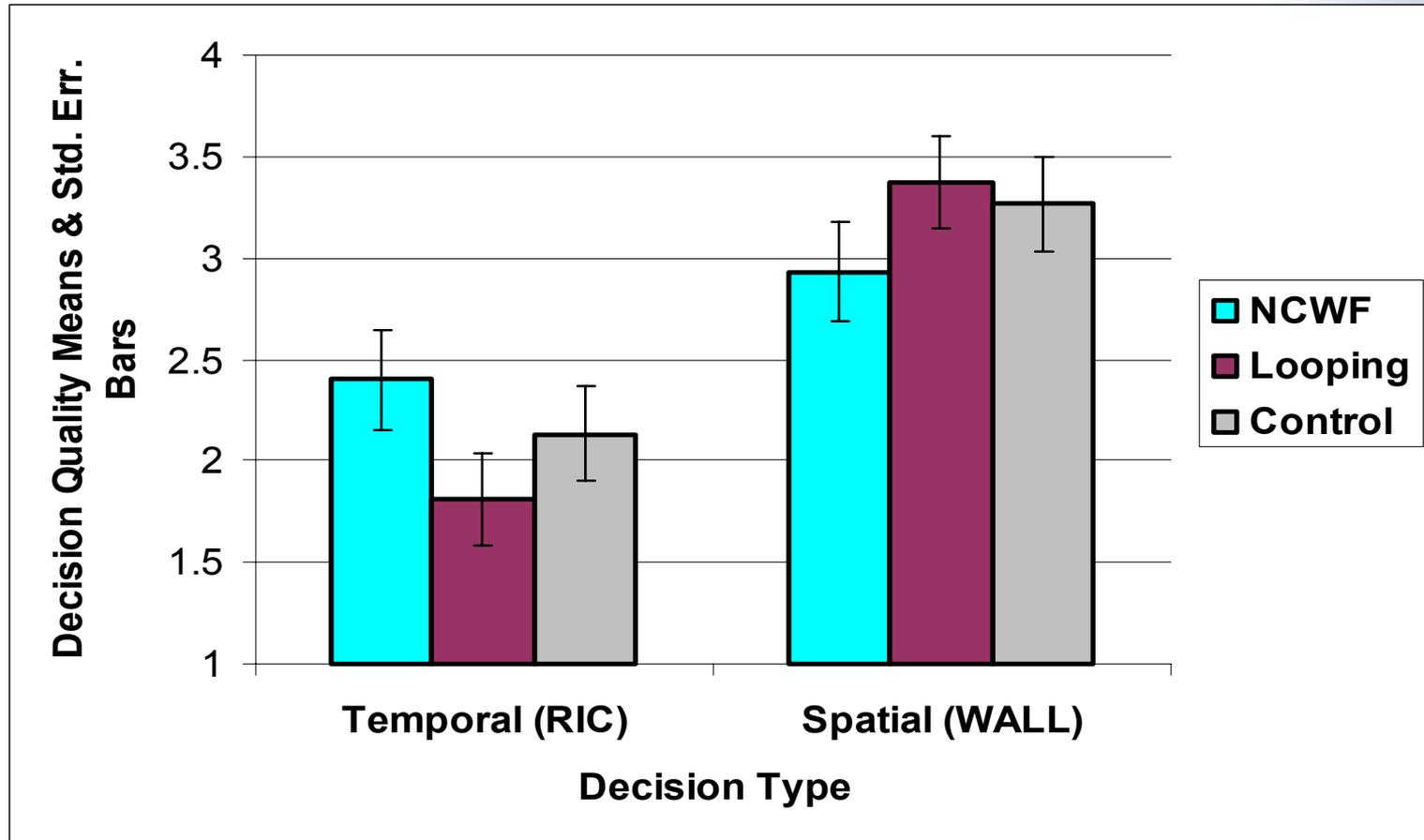
# NCWF Display Seen by Subject Pilots Along Route to Wallops At Decision Time (10nm Scale)



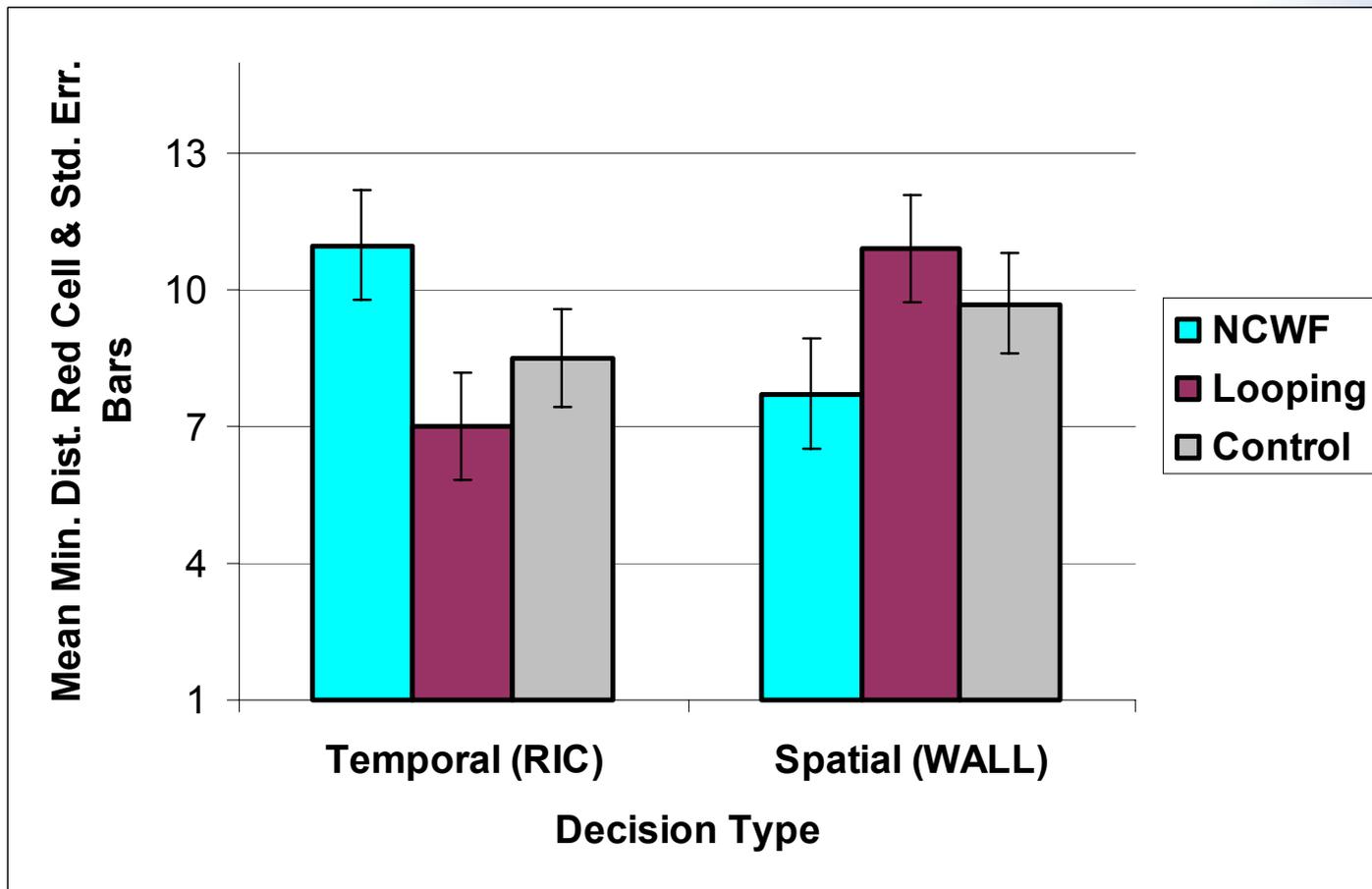
# Wallops Island Decision Criteria

- 1 - Pilot flew within 10 miles of a red cell while circumventing the storms over the bay using the pilot's own route planning.**
- 2 - Pilot flew within ten miles of a red cell, but only because of a delayed turn or distraction. Intent was to circumvent by at least 10 miles.**
- 3 - Pilot flew within 10 miles of a red cell, but was following vectors from ATC and for whatever reason, ATC vectored the pilot to within 10 miles.**
- 4 - Pilot avoided a red cell by 10 miles or more.**

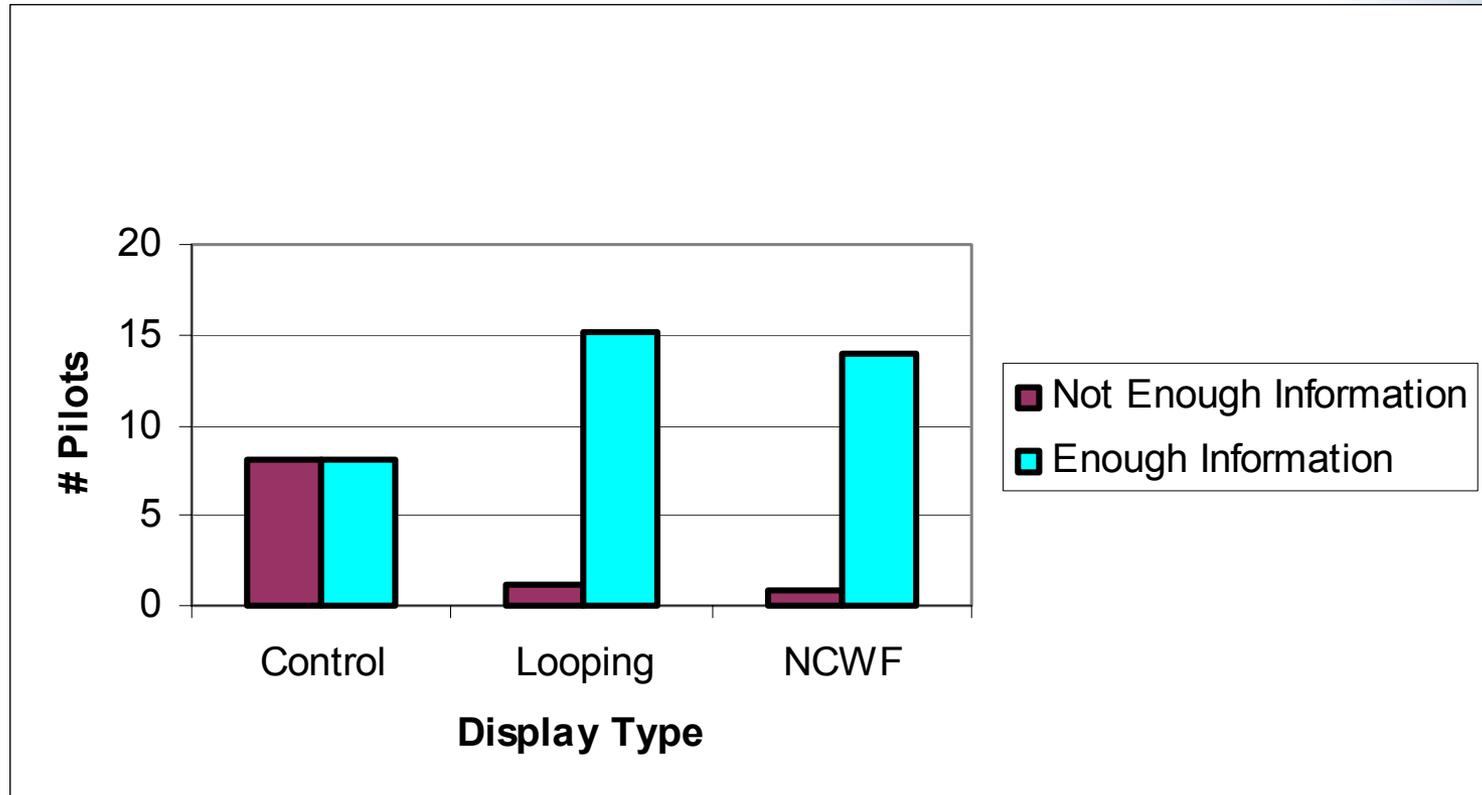
# Mean Observer Ratings of Decision Quality by Decision Type and Display Type



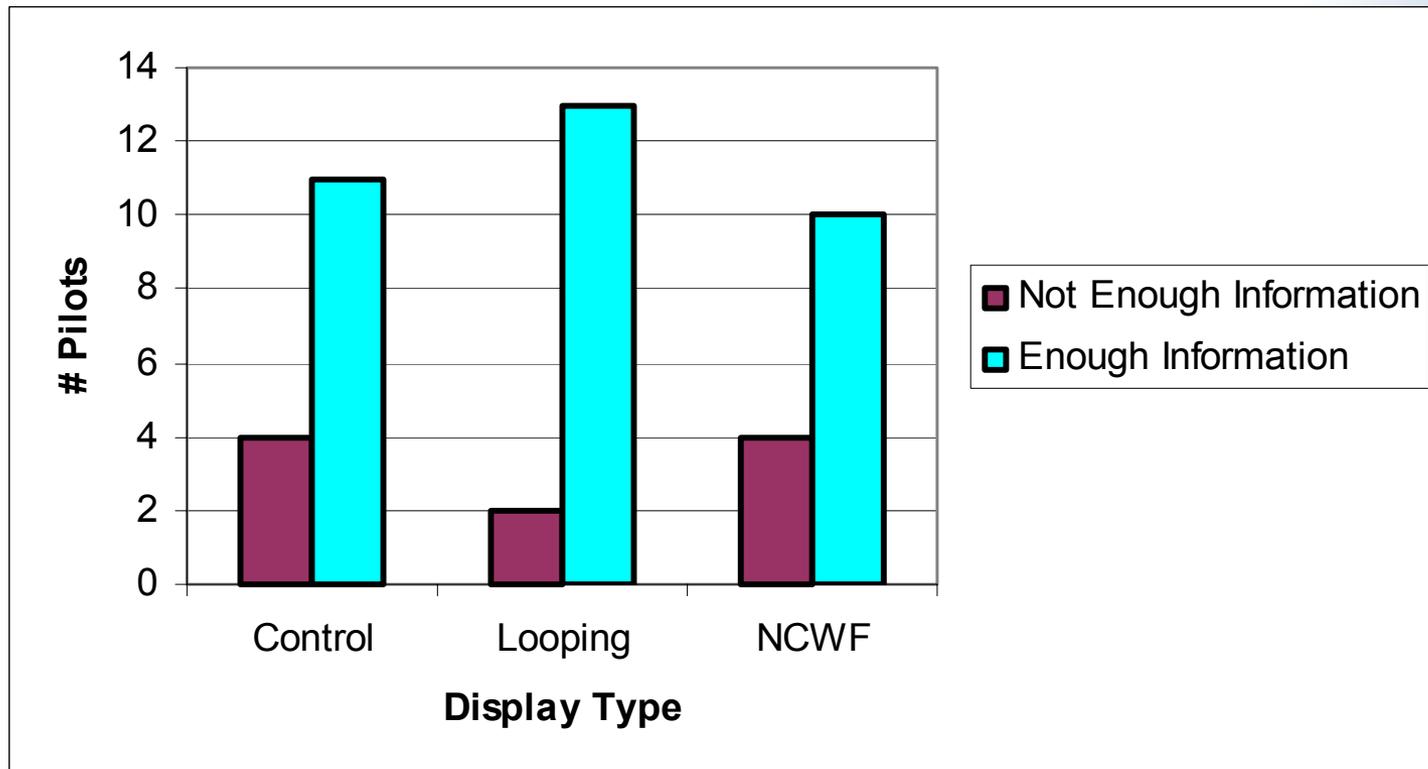
# Mean Minimum Distance from Red Cell by Decision Type and Display Type



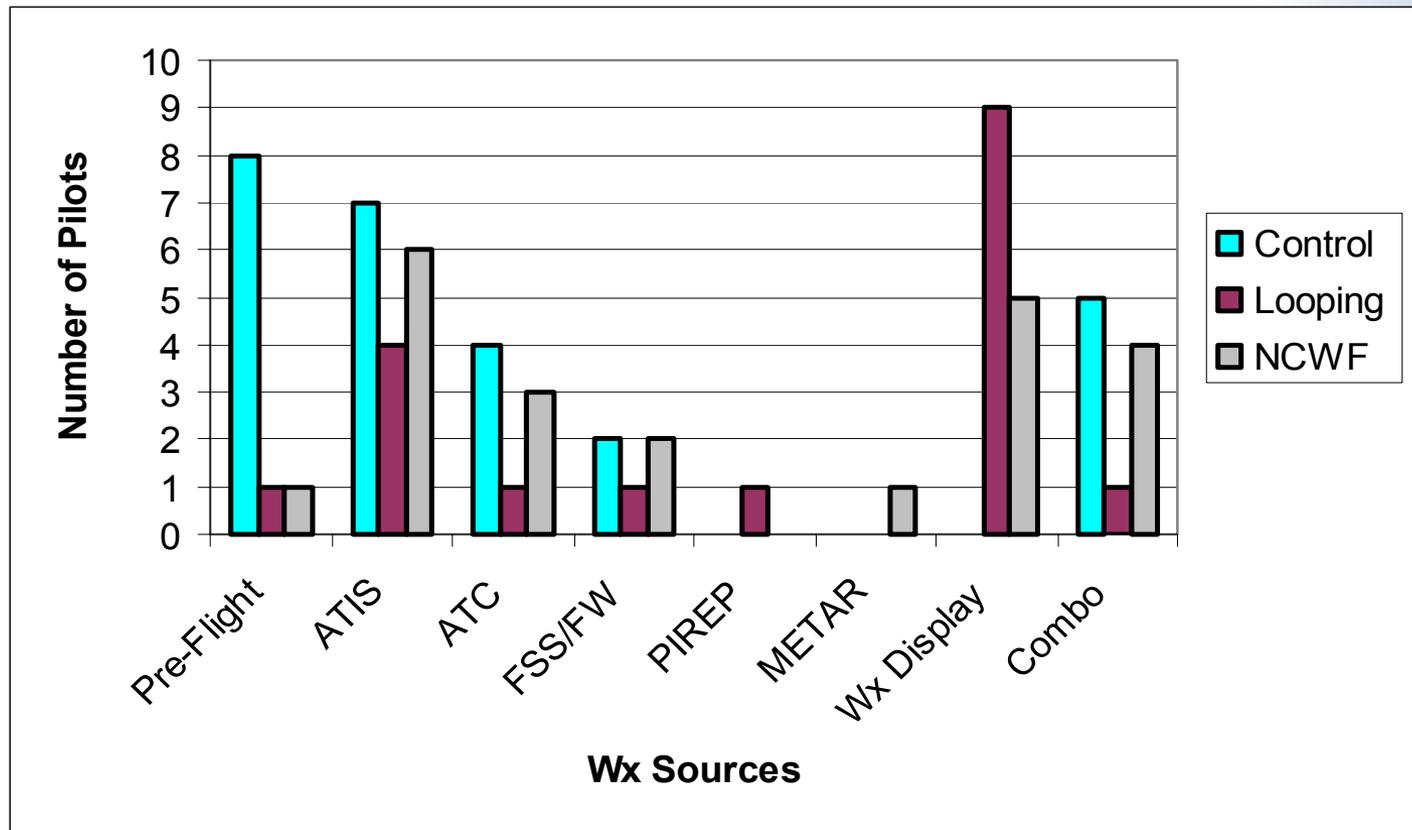
# Pilots' Perception that They Had Sufficient Information to Make Confident Decisions on Richmond Leg



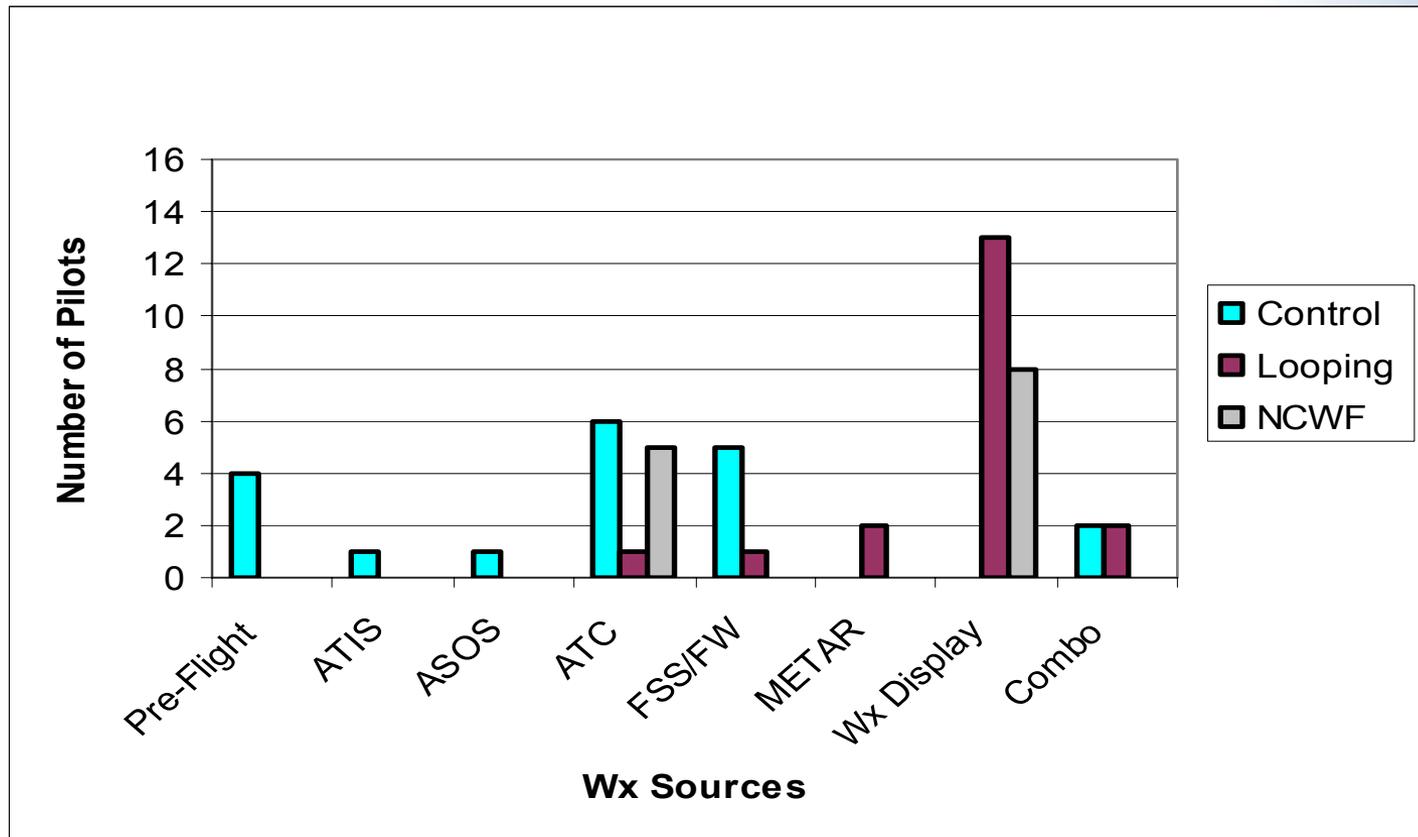
# Pilots' Perception that They Had Sufficient Information to Make Confident Judgment of Situation on Wallops Leg



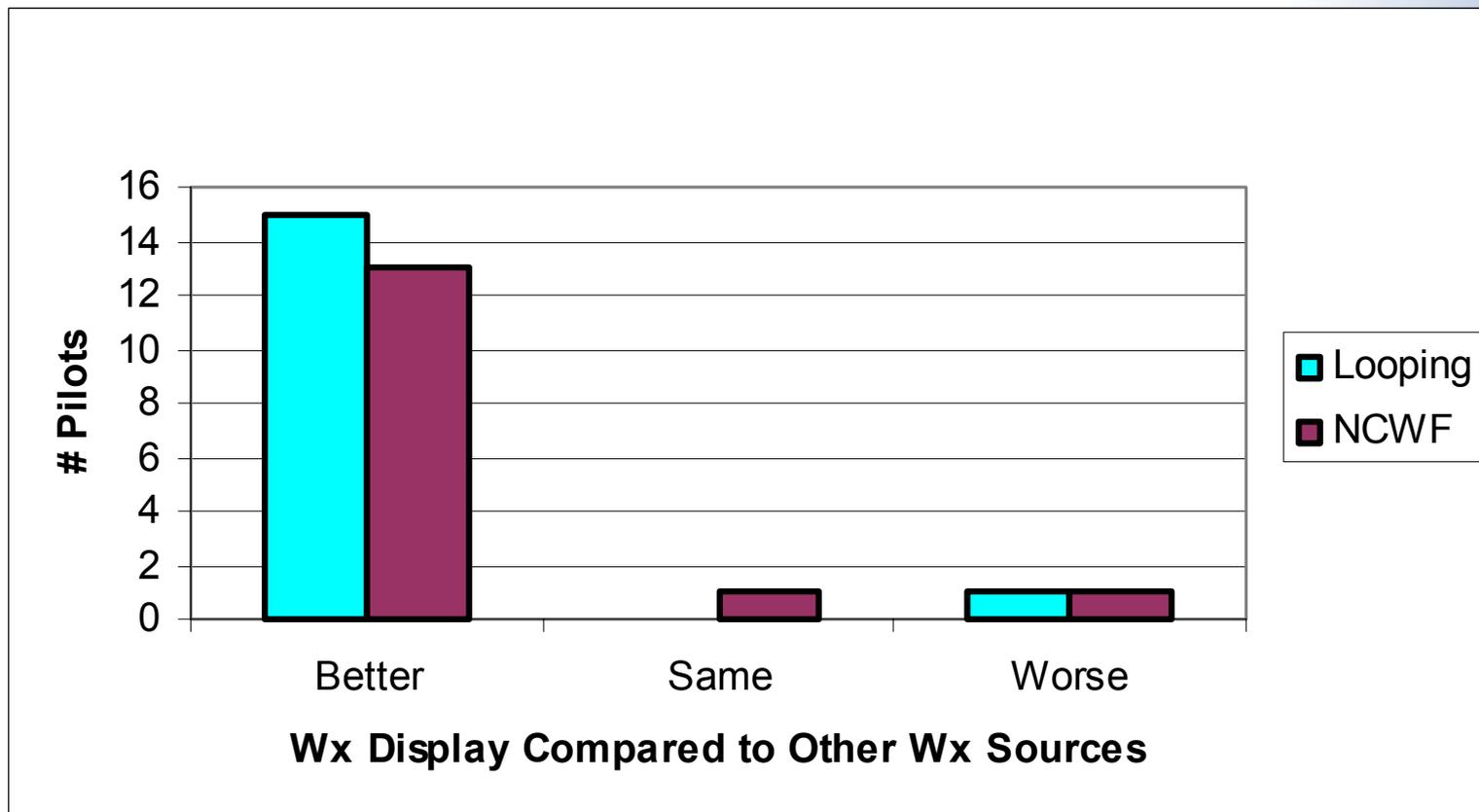
# Primary Weather Information Sources Used Enroute to Richmond



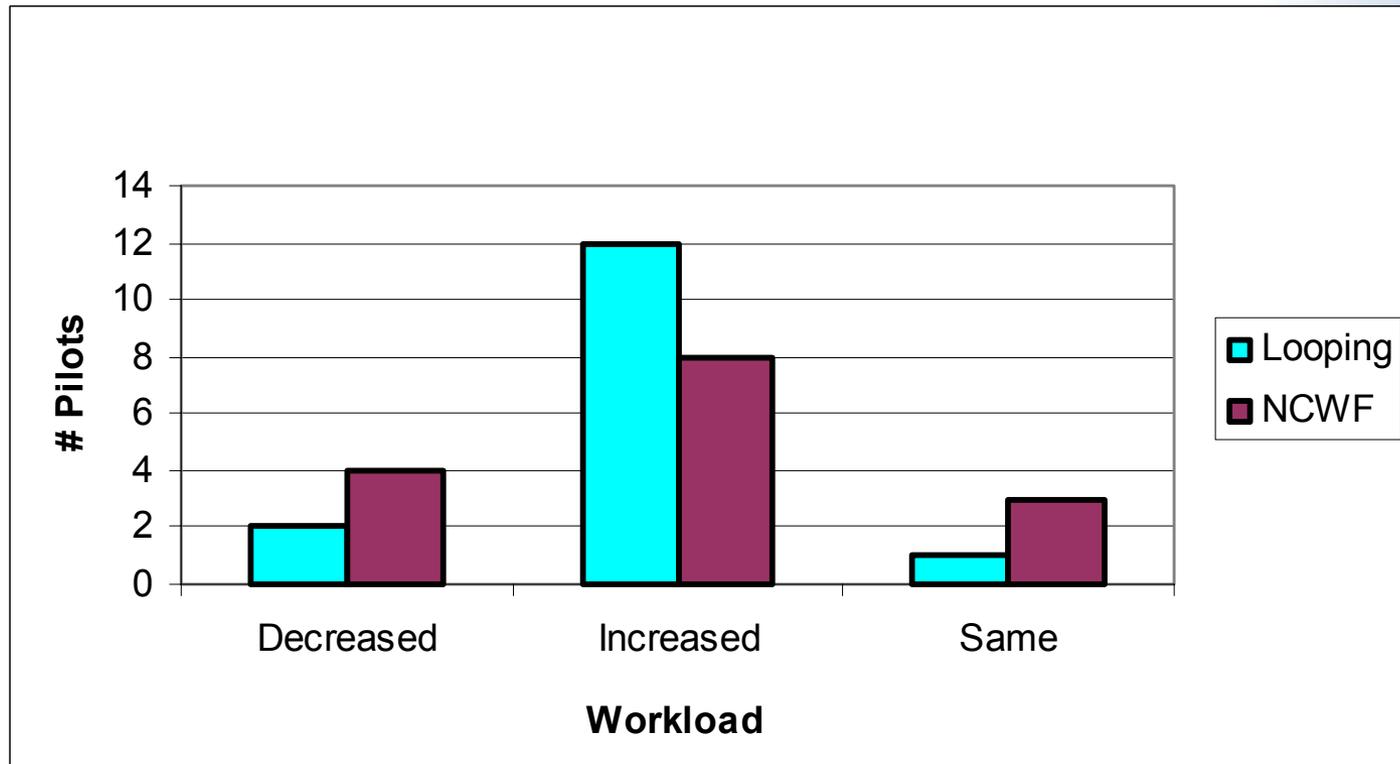
# Primary Weather Information Sources Used Enroute to Wallops Island



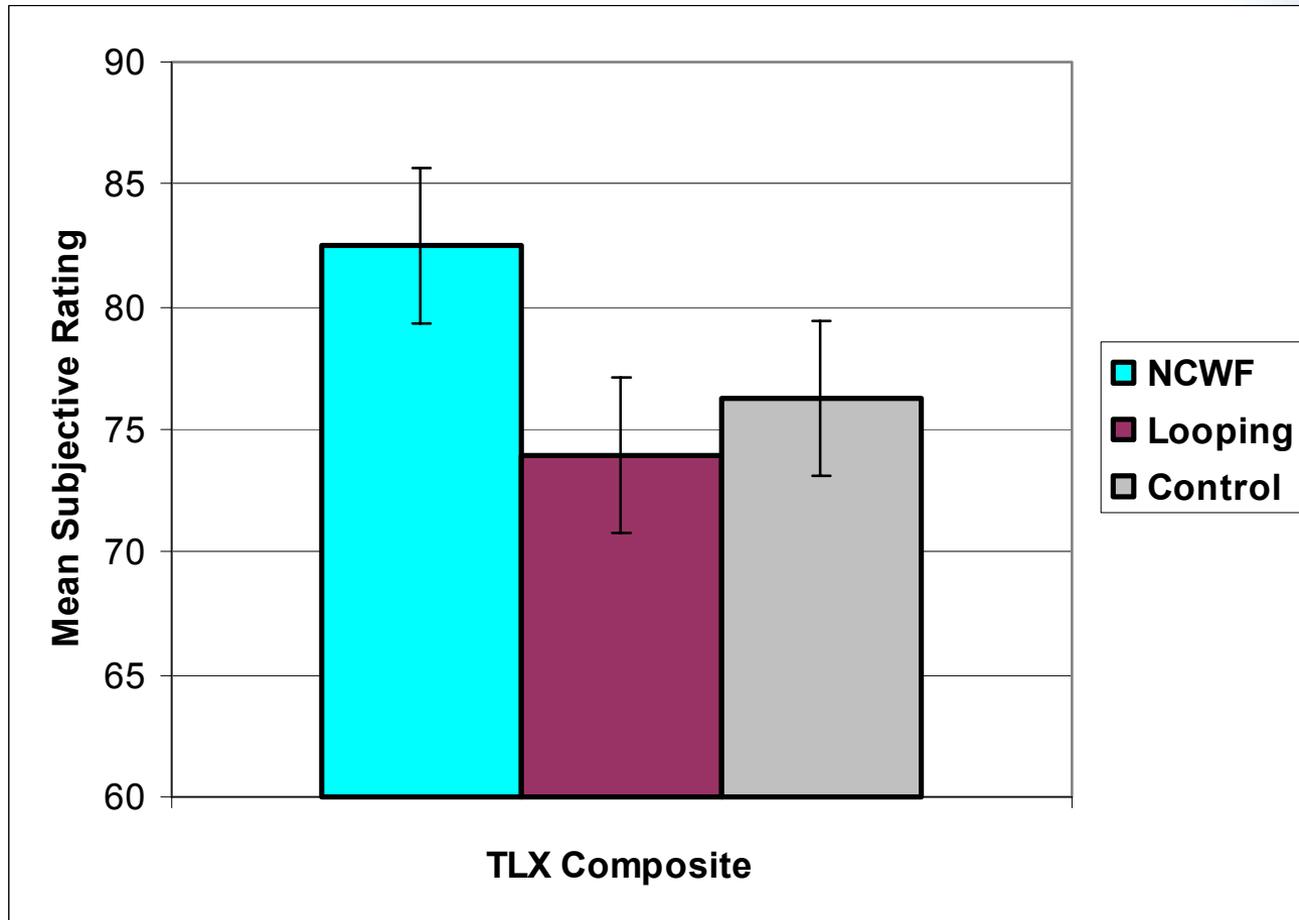
# Pilots' Perception As To Usefulness of Weather Display Information To Other Sources of Weather Information (ATIS, Flight Watch, etc.)



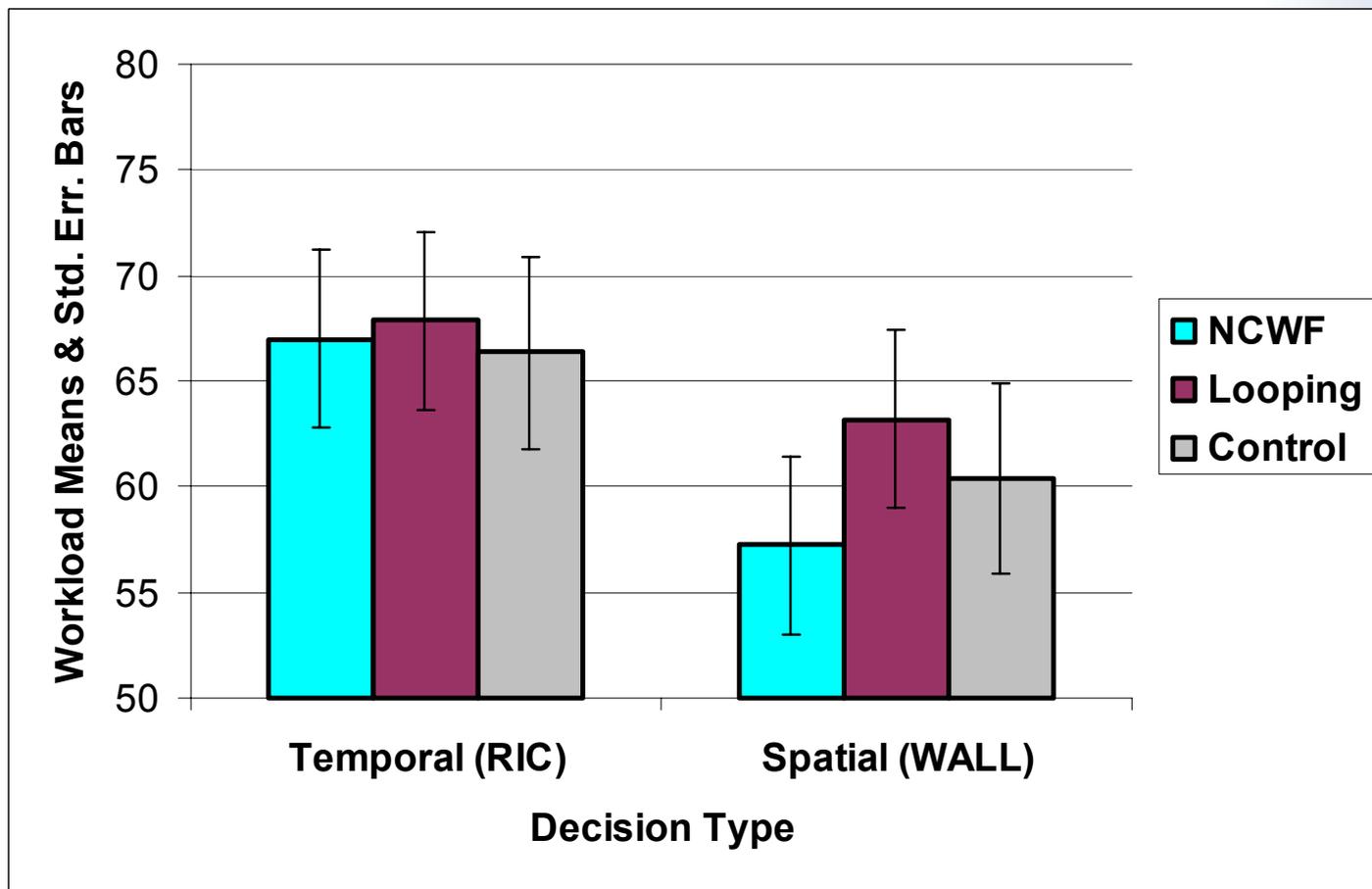
# Pilot's Perception of the Effect of Use of Weather Display On Workload



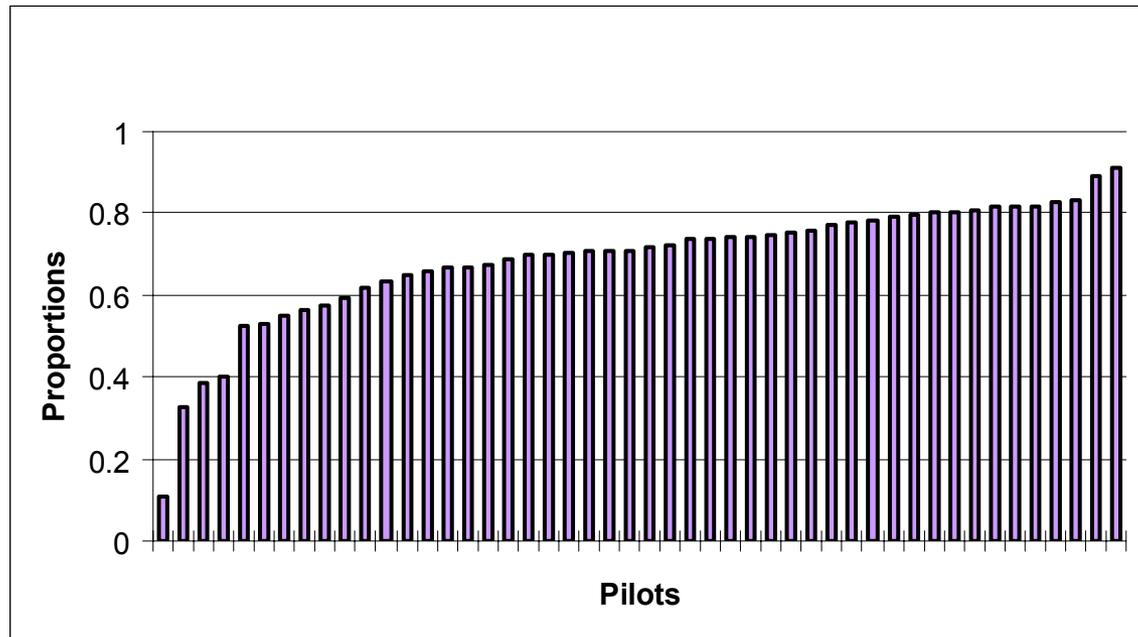
# TLX Composite Index of Subjective Workload by Display Type



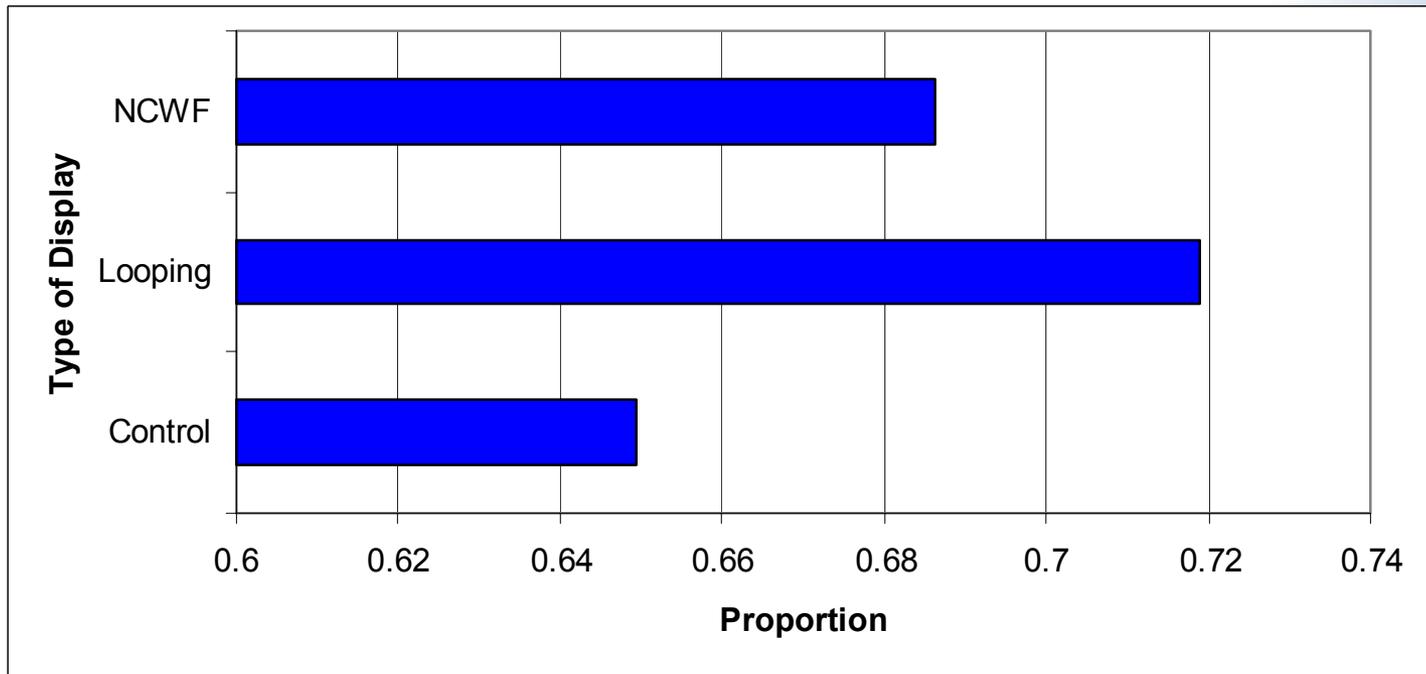
# Mean Observer Ratings of Workload by Decision Type and Display Type



# Proportion of Flight Autopilot Engaged



## Proportion of Flight Autopilot Engaged by Type of Display



# Results

**Experimental Hypothesis #1 – The experimental hypothesis that the NEXRAD mosaic image looping feature would improve pilot decision making was not supported by the results of the experiment.**

The NEXRAD mosaic image looping feature did not improve pilot decision making over pilots with no weather display in either the temporal decision at the Richmond Airport or the spatial decision enroute to the Wallops Island Facility.

**Experiment Hypothesis #2 - The experimental hypothesis that NEXRAD image looping would lead to increases in pilot workload was not supported by the results of the experiment.**

The majority of the pilots flying with the NEXRAD mosaic image looping feature did not rate themselves as experiencing significantly higher workload than the control pilots. Nor did the observers rate the workload of pilots having the NEXRAD image looping display to be significantly higher than pilots without a weather display.

# Results (Continued)

**Experimental Hypothesis #3 - The experimental hypothesis that pilots with the NCWF display would make better decisions concerning hazardous weather was not supported by the results of the experiment.**

Pilots with the NCWF display did not make better decisions than control pilots in the spatial decision at the Richmond Airport. Nor did pilots with the NCWF display make significantly better decisions than control pilots in the temporal decision enroute to Wallops Island

**Experimental Hypothesis #4 - The experimental hypothesis that the NCWF display would lead to increases in pilot workload was not supported by the statistical data.**

Pilots with the NCWF display were not observed to experience significantly higher workload than pilots without a weather display. Analysis of the TLX questionnaire results also showed no significant difference in workload between the pilots using the NCWF display and pilots in the control group, although the overall pattern of TLX results suggests that pilots with the NCWF display generally rated themselves as experiencing higher workload than did pilots in the control group.

# Key Conclusions of Study

- **Both cockpit weather displays provided significant increase in awareness to the pilot of location, proximity, and direction of movement of hazardous convective weather conditions**
- **Both cockpit weather displays provided an incomplete understanding of the information required to successfully deal with hazardous convective weather conditions, and will require substantial pilot training to permit their safe and effective use.**
- **Overuse of both displays by the pilots, at the expense of accessing other sources of information such as ATC, offset the improved situation awareness and other benefits provided to the pilots by the weather displays - the performance of the pilots having the weather displays was no different statistically than that of the pilots in the control group having no weather display.**

# Key Conclusions of Study (Cont)

- **There was no significant difference in the effect of the two different types of weather displays on the likelihood that the pilots would overly depend on their weather display in their navigation and decision making in dealing with hazardous weather conditions.**
- **A minimum level of training, and a curriculum providing this minimum level of training, must be identified and implemented as a means to prevent misuse of any variant of the data link NEXRAD cockpit weather display.**
- **The safe and effective use of a cockpit weather display in actual instrument conditions requires the support of an autopilot for all pilots.**