

Experimental Evaluation of Candidate Graphical Microburst Alert Displays

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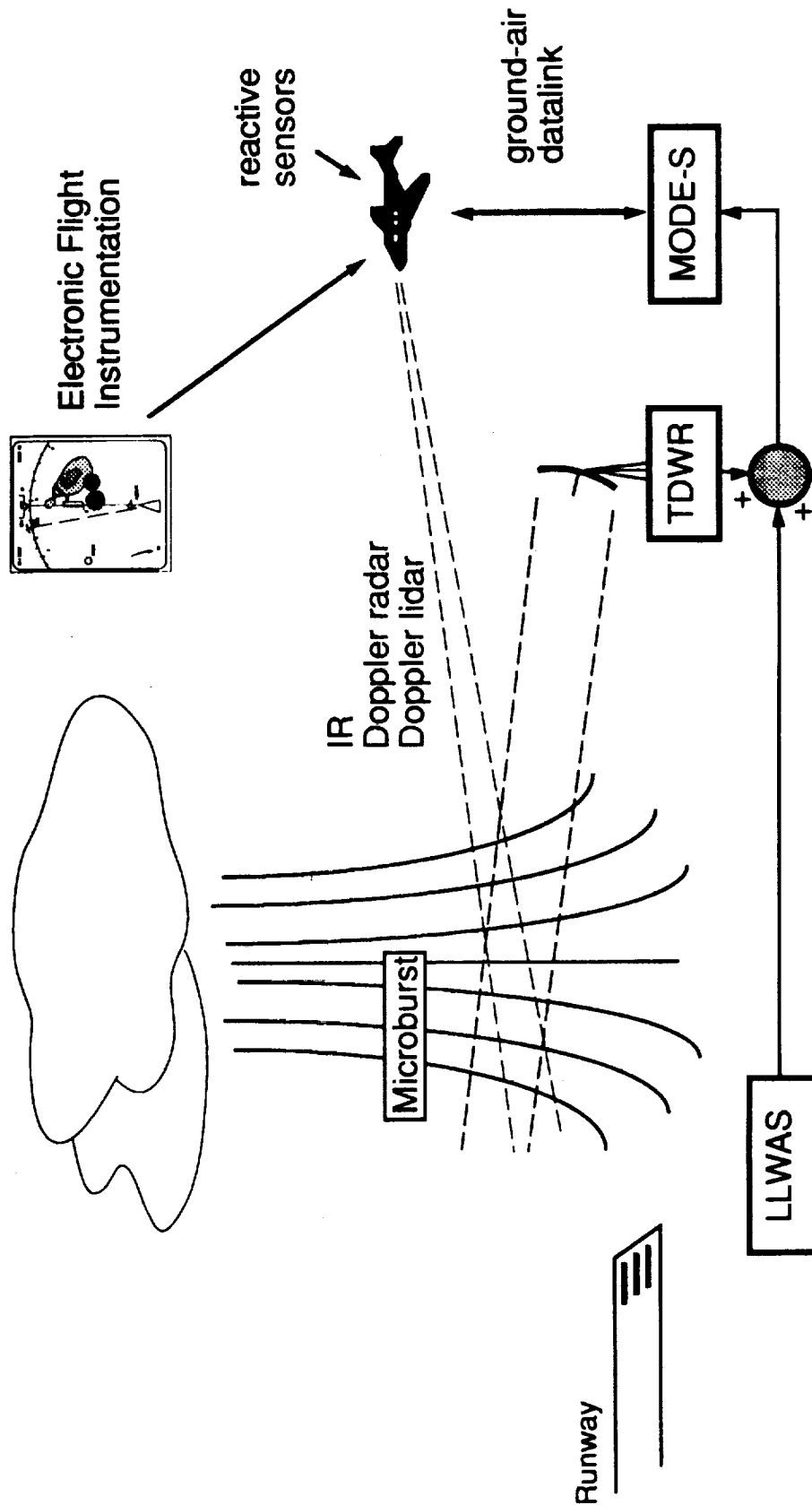
**Fourth Combined Manufacturers' and Technologists'
Airborne Wind Shear Review Meeting**

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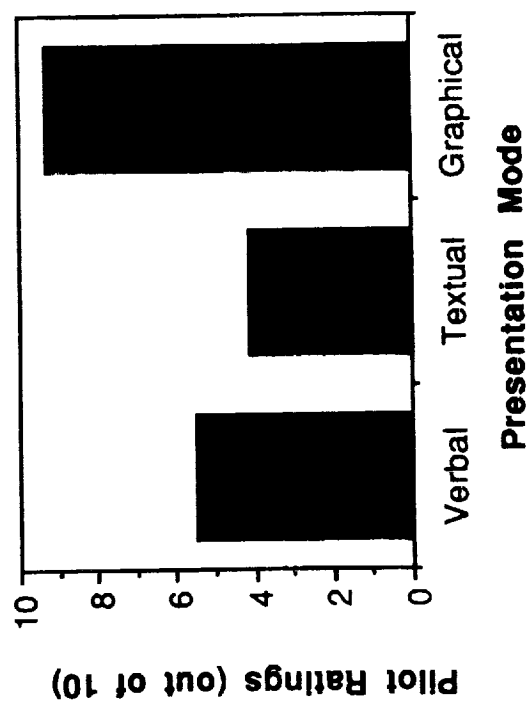
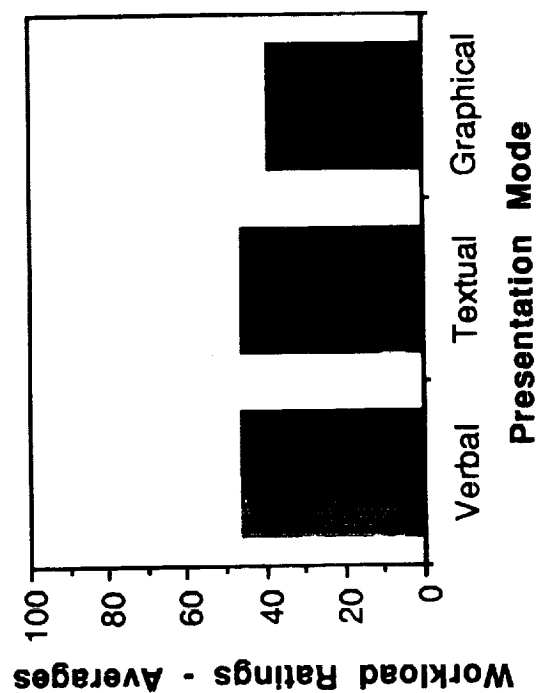
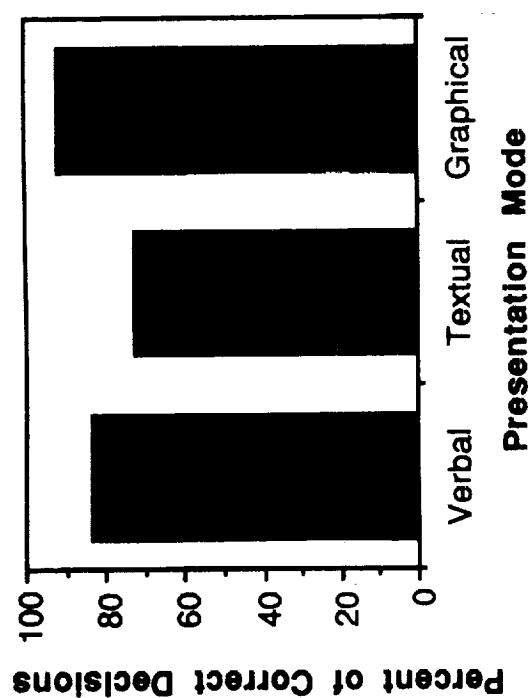
MICROBURST DETECTION AND ALERTING



PREVIOUS PART-TASK SIMULATOR EXPERIMENT: COMPARISON OF PRESENTATION MODES (6/89)

- Designed to compare verbal, textual, and graphical modes of cockpit presentation
- Evaluated microburst alert presentation and ATC clearance amendment delivery
- July-August 1989: 8 total subjects participated, active airline pilots qualified on 757-767 aircraft
- 9 scenarios flown by each subject:
 - Descent and Approach into DEN
 - 3 scenarios in each presentation mode
 - Descent: 3 ATC clearance amendments
 - Approach: Microburst alerts
- Sidetask, NASA subjective workload evaluation
- Post-session debriefing

PRESENTATION MODE COMPARISON: RESULTS



ADVANTAGES OF GRAPHICAL MODE OF PRESENTATION

- Very positive pilot response, preferred strongly over other modes
- Decreased workload with respect to other modes
- Decision-making accuracy and speed better than other modes
- Allowed pilots to plan and request non-standard missed approaches
- Graphical display is consistent with human cognitive mapping:
Speeds comprehension, improves situational awareness

GRAPHICAL MICROBURST ALERT EXPERIMENT: OBJECTIVES

Overall Goal:

To recommend an effective graphical alert format for use in a multi-sensor environment

Effective = clear, easily understood, aids crew situational awareness

Issues:

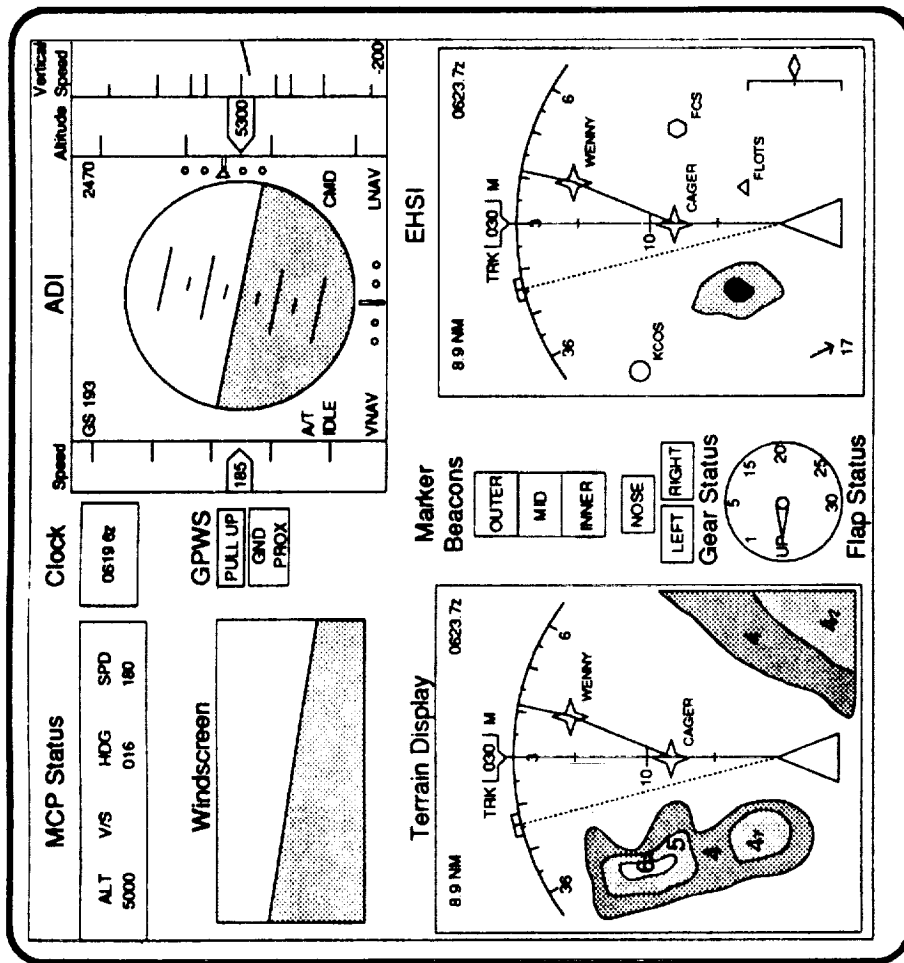
- Is presentation on the EHSI clear, effective?
- Should microbursts be displayed with multiple intensity levels, or only as a single-level “hazardous” alert?
- Should data from separate sensors be “fused” into a single alert, or displayed as “discrete” alerts?
- What are the procedural implications of using graphical microburst alerts?

--> Positional information is now present

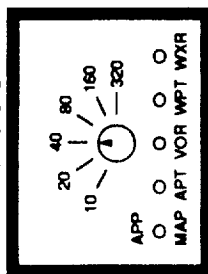
GRAPHICAL MICROBURST ALERT EXPERIMENT: OVERVIEW

- Used MIT Advanced Cockpit Simulator
- Three prototype display formats were tested
- 12 simulated approaches to fictional airports were flown by each subject
- Exit Questionnaire given
- June, 1991: Nine active line EFIS/FMC-qualified pilots participated
 - Subjects averaged 5890 hours of total flight experience, 1130 hours of flight experience on EFIS/FMC aircraft
- Combined with graphical terrain avoidance display experiment

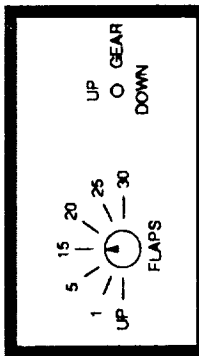
IRIS 4D Display



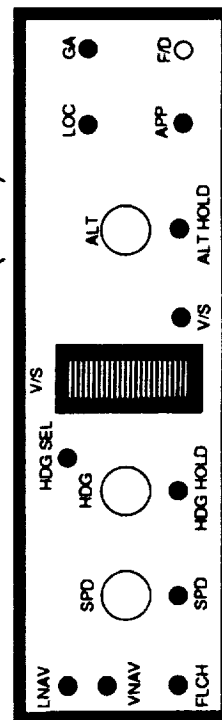
EHSI Display Controls



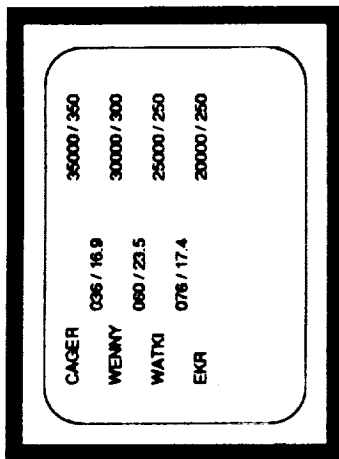
Landing Gear/Flap Controls



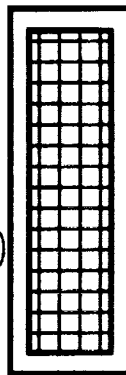
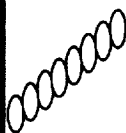
Mode Control Panel (MCP)



CONTROL DISPLAY UNIT



IBM PC & Keyboard

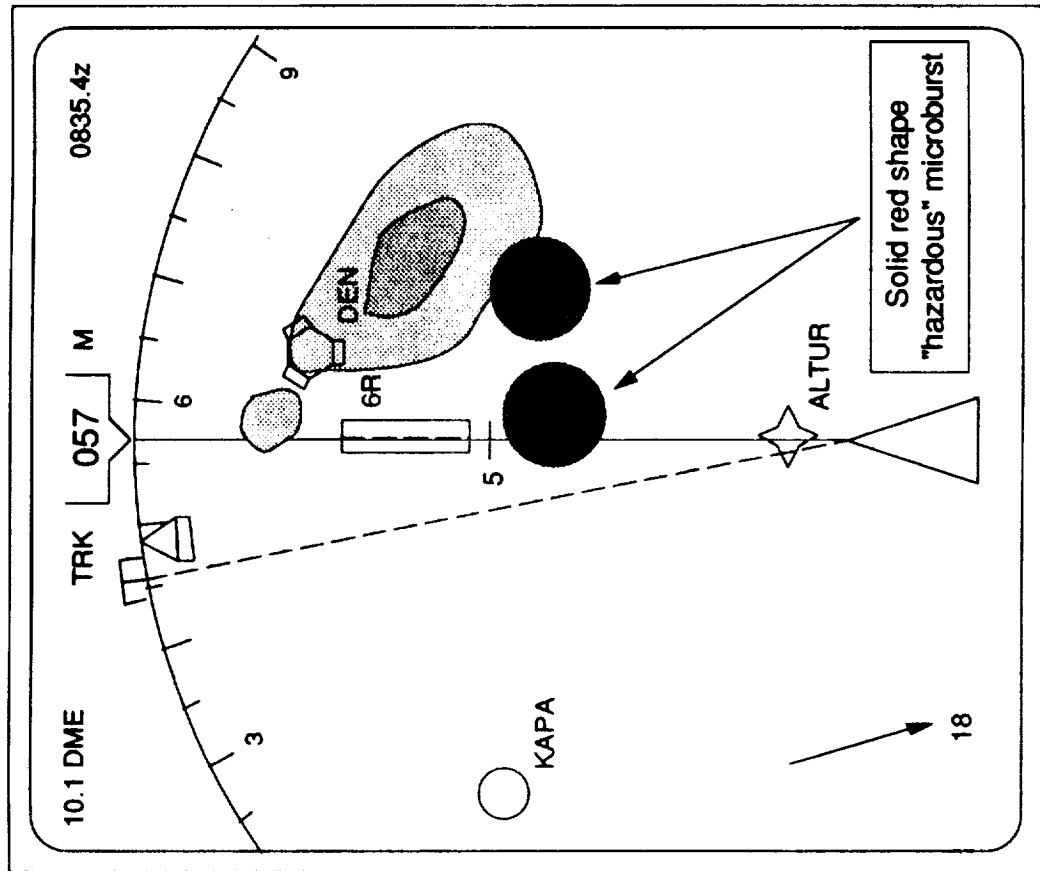


EHSI = Electronic Horizontal Situation Indicator
ADI = Attitude Direction Indicator

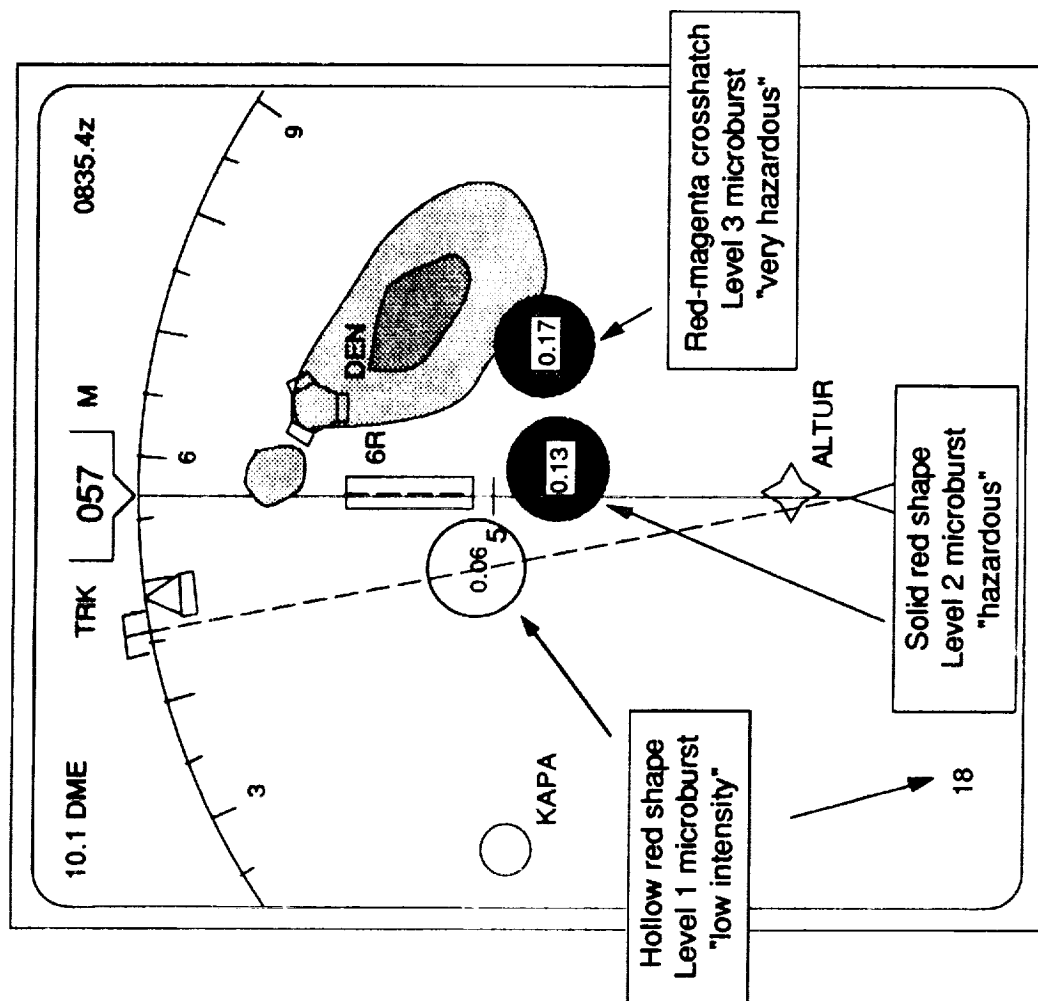
CANDIDATE DISPLAY DESIGN

- Three display formats designed to resolve two important issues in graphical alert design:
 - “Fused” vs. “Discrete” information display
 - Should intensity information be displayed?
- Nominal display “A” used “fused” information to display only those microbursts which exceed a hazard threshold
- Display “B” used three different hazard levels with different graphical symbols
- Display “C” used different icons for airborne look-ahead and ground-generated alerts
- Hazard Criterion: Average F-factor over one-half nm

DISPLAY A: "FUUSED" ALERTS

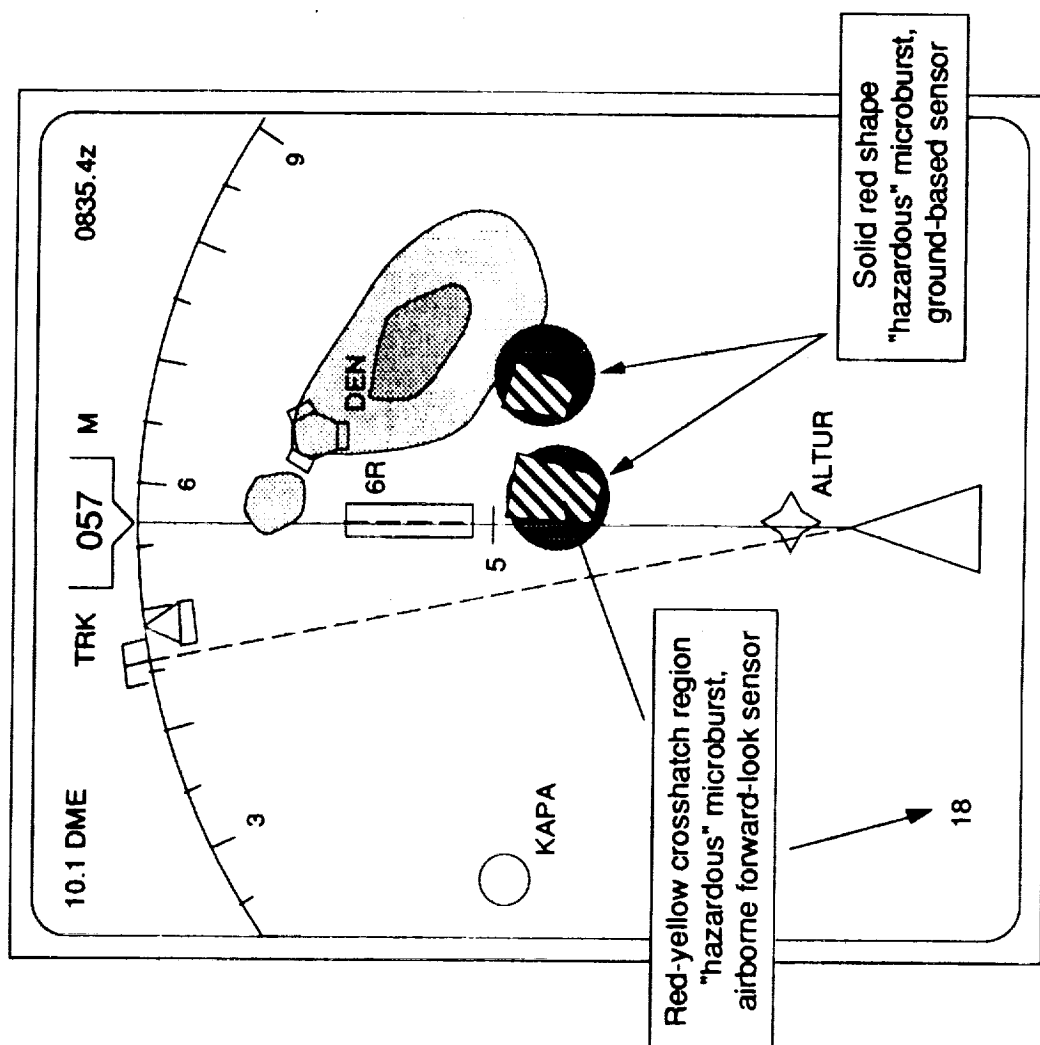


DISPLAY B: "FUSED" ALERTS + INTENSITY



EXPLANATION OF F-FACTOR CRITERION TO PILOTS

- Needed to explain F-factor to pilots clearly, relevant to their experience:
 - Loss in available climb capability, due to both head wind loss and downdraft in microburst core
- Three intensity levels displayed, based on highest F-factor averaged over one-half nautical mile (3000 feet):
 - $0.05 < F < 0.1$: “Low Intensity” alert
Aircraft will lose one-third to two-thirds of available climb capability
 - $0.1 < F < 0.15$: “Hazardous” alert
Aircraft will lose two-thirds to all of available climb capability
 - $F > 0.15$ “Very Hazardous” alert
Aircraft will be forced to descend
- These conditions will occur if the aircraft is flown through the center of the microburst (icon).
- Pilots were receptive to this explanation

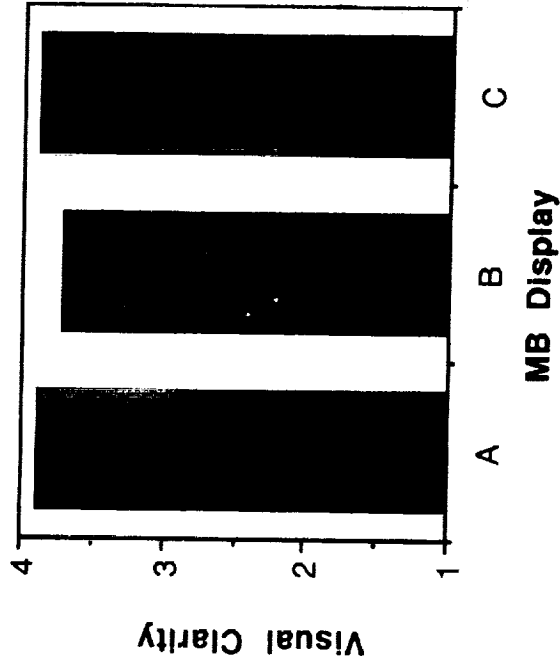


SCENARIO DESIGN

- 12 approach scenarios to fictional airports
- Test matrix variables
 - Three display types
 - “Wet” and “dry” weather conditions
 - “Threat”, “non-threat”, “no microburst” scenarios
- Designed to evaluate performance differences between displays, “wet” and “dry” situations
- How far from a hazardous microburst is the go/no-go decision made?
- Provide enough situations to get useful commentary from pilots, useful observations of pilot reactions

RESULTS: VISUAL CLARITY OF ALERTS ON EHSI

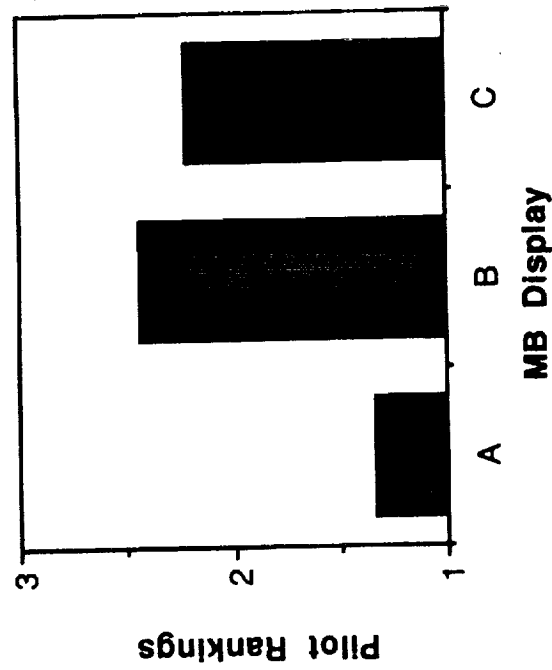
- Pilots were asked to rate visual clarity on a scale of 1 to 4:
 1 = "very difficult to read" 4 = "very easy to read"



Display A: "Fused" data, single intensity level
 Display B: "Fused" data, three levels of intensity
 Display C: "Discrete" data, single intensity level

RESULTS: OVERALL RANKINGS

- Pilots were asked to rank the displays in order of preference



Display A: "Fused" data, single intensity level

Display B: "Fused" data, three levels of intensity

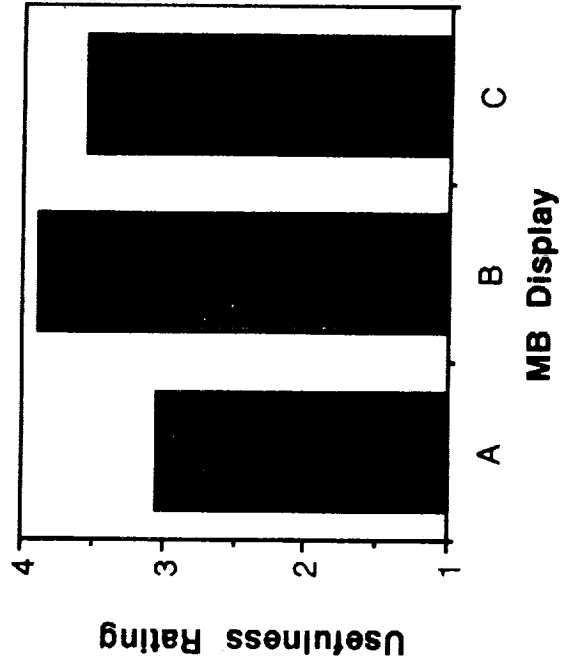
Display C: "Discrete" data, single intensity level

RESULTS: USEFULNESS

- Pilots were asked to individually rate the three displays in terms of how useful they were to understanding the weather situation

1 = "not at all useful"

4 = "very useful"



Display A: "Fused" data, single intensity level

Display B: "Fused" data, three levels of intensity

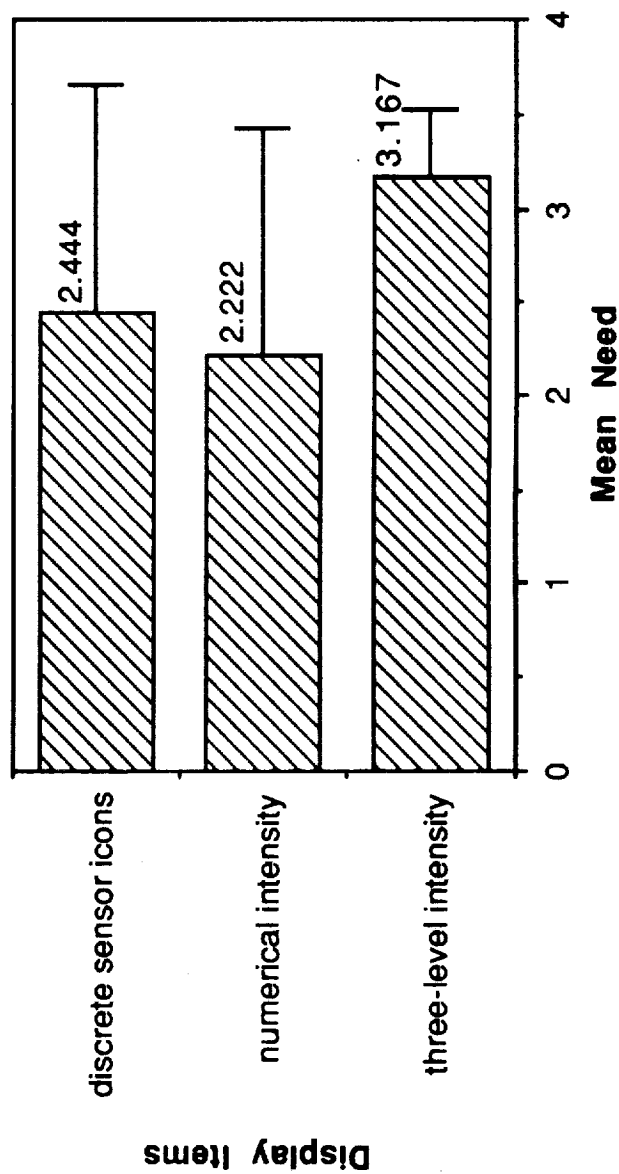
Display C: "Discrete" data, single intensity level

RESULTS: NEED RANKINGS OF DISPLAY FEATURES

- Pilots were asked to rate the need for individual display features

1 = "unnecessary"

4 = "essential"

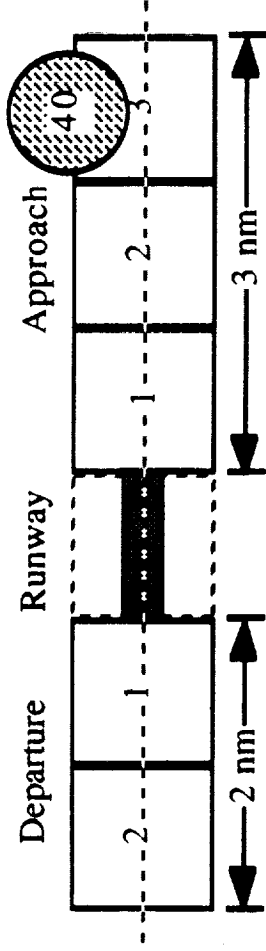


PROCEDURAL IMPLICATIONS OF GRAPHICAL ALERTS

- “Decision distance” to make go/no-go decision
Mean response: 4.26 nm Std Dev = 1.15 nm
At limit range of airborne lookahead systems under development
- Missed approach planning
Can negotiate a turn with ATC prior to declaring missed approach
Potential difficulty with emergency deviations
- “Secondary” alerts carry significant weight due to visual impact of graphical display -- lowest alert threshold is critical
It is likely that pilots will not fly through any icon on the approach
Compare with current TDWR “wind shear with loss” alerts

PROCEDURAL IMPLICATIONS OF GRAPHICAL ALERTS

- Lateral safety margin: “How close can a hazardous microburst icon be to the approach track where you will still continue the approach?”
- Responses from 2 to 15 nm
- Compare with TDWR alert methodology:



Microburst shapes which fall more than one-half mile from approach track do not generate an alert

...But an overwarning problem is perceived by pilots anyway

- Presenting the information graphically would explain to the pilot the “nuisance alerts” generated when microburst is off the flight path!

CONCLUSIONS AND RECOMMENDATIONS

- Multiple intensity levels should be used
 - More visually compelling, intensity trend information, can maintain greater distance from very intense events
 - F-factor hazard criterion was understood, accepted by pilots
- Issue of “fused” vs. “discrete” alerts was not resolved
 - Possible solution: display “fused” icons to gain accuracy advantages of data fusion, and use separate indicators to show when airborne sensors detect a microburst
- Additional training is necessary
 - Straight-ahead missed approach is an option
 - Microbursts are localized, low-altitude events
- Can take the form of recommended crew procedures for use with automated graphical microburst alerts

CURRENT WORK: MULTI-SENSOR DATA FUSION

- Desirable parameters for crew alerting have been determined
 - Location & Extent
 - Intensity Level
- Multiple sensors may be available:
 - Platforms: Airborne, Ground-Based
 - Type: Remote, *in-situ*
 - Large differences in measurement type and update rate
 - No single sensor has “ideal” geometry
- Multi-sensor data fusion could have significant benefits.
 - Improved accuracy
 - Resolve conflicting measurements
- Can occur on “product level” or “data level”
- Current work: development of a data-level algorithm for multi-sensor microburst hazard assessment

OVERVIEW OF ALGORITHM

- Basic Concept: Use our knowledge of microburst fluid mechanics and measured microburst statistics to estimate microburst hazard.
- Assumes that microburst can be represented by a simple analytical model
 - Modified Vicroy-Oseguera-Bowles microburst model
- Estimate the “best” parameters of that model given all of the available wind measurements
 - TDWR, LLWAS, inertial data, airborne radar, airborne lidar
- Intensity, Location, and Extent can then be determined from the current list of parameters
- Based on an Extended Kalman Filter: Allows use of measured historical microburst characteristics to aid estimation process
- Can be used with multiple microbursts
- Currently testing with simulated microburst winds: will be tested on real data in the future

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Questions and Answers

Q: Unknown - Did you look at the cases where perhaps where there was a disagreement between ground based information or airborne sensor data?

A: Craig Wanke (MIT) - We did not. That is actually one of the major points. For the data fusion cases we showed two icons that were essentially overlaid. Clearly there is a significant problem if those do not line up. If you have a computer algorithm that attempts to interpret that in a realizable way, that is probably more effective than showing the pilot the two non agreeing icons on a three mile final and asking him to figure out what is really going on. That is really one of the biggest arguments for data fusion. But, that is something that we could not really test in our experiment.

Bob Hall (Airline Pilots Association) - I don't have a question, but I wanted to find the appropriate time to make a comment to the group here. This looked like it might be a good time to do that. I wanted to offer a few words of encouragement and motivation to the industry from the ultimate end user, which are the pilots. As you are probably aware, ALPA has been very active in this whole wind shear endeavor for probably over ten years, even before some of the major accidents occurred. We would like to think that we were instrumental in getting some of the FAR changes which mandated the reactive devices that are going into our cockpits now. We are very thankful to be getting these reactive devices into our cockpits. As nice as the reactive device is, we kind of view it as a nice back up. What we would really like to have is a predictive systems, which is what we are talking about in this conference today. A few years ago we were very concerned that even though we had gotten the reactive devices mandated, we were concerned that the industry would drop all the research and development on the predictive devices. We were concerned that in endorsing those changes we might lose out in what we really wanted. I am just here to emphasize and motivate you to keep up the good work. We are very glad to see the progress that is being made, especially in the Doppler radar. I was a little discouraged several years ago about the clutter problems. It looks like those have been really overcome and now we are pressing on to talking about how do we get the information to the cockpit. So please keep up the good work, and be assured that pilots do want accurate, reliable, predictive systems that will help us to avoid the wind shear hazards.

Q: Howard Williams (Gulfstream Aerospace) - I believe we can echo what has just been stated. Relative to your pilot evaluation, did you have any FAA pilots as part of the team?

A: Craig Wanke (MIT) - No, we did not. These were all airline pilots.

Q: Howard Williams (Gulfstream Aerospace) - Do you feel that these types of displays are certifiable or have you reached that stage yet?

A: Craig Wanke (MIT) - We haven't really reached that stage yet. We haven't thought seriously about the certifiability issues.

John Hansman (MIT) - We see what we are doing more as baseline work. We are not trying to certify a specific display, but provide baseline data on the utility of these type of display concepts. As you go into a particular display configuration there will be certifiability issues. These were not designed to be certified displays.

Q: Sam Shirck (Continental Airlines) - Did you make any studies that involved TCAS on your displays?

A: Craig Wanke (MIT) - No we did not.

Sam Shirck (Continental Airlines) - I would encourage you, if your marching orders permit, to look at an independent display for hazards such as TCAS and wind shear. As much as I like to see wind shear on a moving map, I don't think we can put much more on an EHSI than we have right now. If you have ever ridden in the cockpit going into the Denver area, and watch what happens on the TCAS system on an EFIS, it is very exciting. Although the engineering is capable of putting all this stuff on there, I am not sure that we as pilots can get it off and use it. TCAS is a very important part of this whole display issue. I would encourage you to investigate a dedicated display for hazards and to involve the TCAS scenarios in that.

A: Craig Wanke (MIT) - That is certainly a consideration and that is something that probably should be worked on, but I don't know that we have any plans to do TCAS studies. We are doing some similar stuff with terrain alerting displays.

John Hansman (MIT) - That is a very valid point. The whole issue of display clutter and display priority is a critical issue for this, for data link, for a whole bunch of areas. What do you do when you have two high priority messages that over write? Craig alluded to the fact that we are doing a second experiment which was a terrain alerting experiment with a separate dedicated terrain alerting display. As you are aware there is a display space availability problem in the cockpit. There is also a second problem, which is if you have a short term critical alert you do not want the crew to go heads down to evaluate the threat and resolve it. So you go into this trade off of where do you want the crew looking. We understand the issue. We didn't include TCAS because of experimental difficulties, not because we do not think it is a problem.

Pat Adamson (Turbulence Prediction Systems) - I encourage everybody to look at the S7 ARP wind shear document. There is a lot of work going on with that committee on displays with regard to short look and longer look predictive systems. In fact, there is a draft out of a display concept. I think that the entire community should be looking at that as well as studies of such displays. Clearly there are several types of wind shear systems being considered from short look to longer look. I guess I would encourage you to take a look at that document as part of your studies.