Session III. Flight Management

N91-24173

Wind Shear Training Applications for 91/135
Capt. Ed Arbon, Flight Safety Foundation

Operators

The requirement for windshear training of all pilots has been graphically demonstrated too often by the accident statistics of past years. While the tragic accidents such as New Orleans and Dallas receive most of the media attention, other aircraft operators have unfortunately experienced the same results when encountering windshear.

The need to expand the Windshear Training Aid that was developed by a team composed of The Boeing Company, McDonnell Douglas Corporation, Lockheed Corporation, United Airlines, Aviation Weather Associated, Hillwel, Inc working with FAA, NASA and other contributors to other segments of aviation was recognized immediately upon completion of the original project.

Slide #1

This group developed a classic document that has been used to train airline crews on the specific aircraft named in the Windshear Training Aid and to teach recognition of the metorological conditions that are conducive to windshear and microburst formation.

Slide #2

The remaining aircraft operated in 1988, according to the FAA's General Aviation Activity and Avionics Survey, were over 200,000 aircraft in use by non FAR 121.0 scheduled airlines. These aircraft flew approximately 33,600,000 hours. It would be follow that some of this flying was exposed to the risk of a windshear or microburst encounter.

In order to verify that the example Windshear Training Aid information and guidelines are transferrable to other categories of aircraft. FAA, under the guidance of Cliff Hay and Herb Slickenmaier, developed a project to test the concept. The Flight Safety Foundation, after concluding a teaming agreement with Flight Safety International, Simuflite and Flight Safety Services Corporation, responded to the RFP and was awarded a contract as the prime contractor.

Under the contract the group will test the transfer of the "Example Windshear Training Aid" on a sample test group of airplane pilots certified under 14 CRF Parts 91 and 135. This example is to include a representative cross section of both the domestic and international commuter, air taxi and corporate turbo-jet and turbo-prop aircraft flight simulators.

The program is to seek to demonstrate the effect of specific training on pilot performance. We are to demonstrate that during an inadvertent encounter with low altitude windshear that flight crew performance can be improved if pilots are trained in the techniques outlined in the "Windshear Training Aid". The principle lesson is avoidance. There are 120 crews in the test program who are divided into representative groups labeled A, B and C.

Training/testing is being done as follows:

A and B receive the entire WTA Group C only receive the ground school portion of WTA.

Group A are tested prior to and again after receiving the WTA.

Group B are tested after completing the WTA.

Group C is tested after the ground school portion of the WTA.

The crews in group "A" form a control group that receive no training prior to evaluation.

Group B receive specific training techniques in the simulator as detailed by the WTA for specific use in low-level windshear encounters prior to flying the test profile.

Group C receive only WTA ground school windshear avoidance and recovery training but no simulator training prior to flying the test profile.

Aircraft categories to be used are:

Turbo-prop

Twin-engine low thrust to weight turbo-jet

Twin-engine high thrust to weight turbo-jet

Three-engine turbo-jet

The aircraft chosen were

Saab 340

Cessna Citation III

Canadair 601

Falcon 50

These aircraft were felt to represent a reasonable cross section of the contract requirements and simulators are available in addition to adequate supply of crews.

The project officially began on February 21, 1990 and the contract team is well into the testing phase. The data is being evaluated as it is accumulated. The first of four industry reviews will be held on October 25, 1990 at FAA headquarters at 800 Independence Ave. If any of you wish to attend and haven't received an invitation please see me.

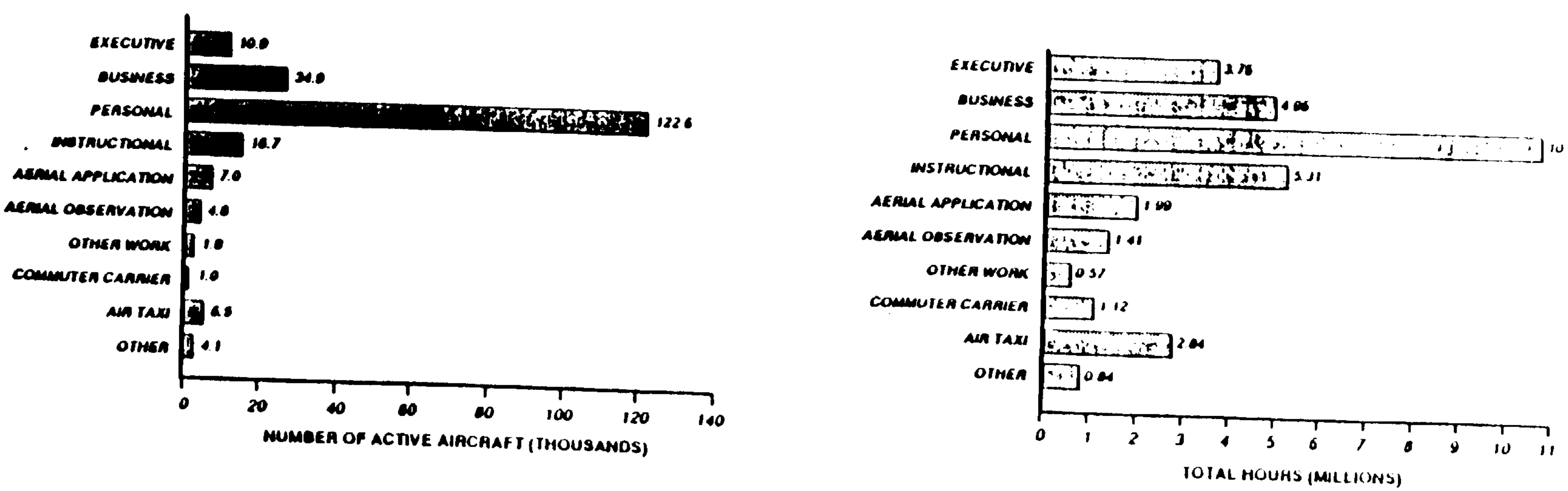
It is anticipated that the WTA will prove to be a valuable to the 91/135 operators as it has been to those who use it as guidelines for their training today. I believe everyone here would agree that the WTA has made the industry understand and respect the windshear/microburst phenomena and has aided flight crews immeasurably.

As new technology is introduced this study will still be the backbone for recognition and avoidance of encounters.

The product of our project, if we are able to prove the data is transferrable, will be our example WTA including the ground school course - Video and 35mm slides, 16mm film and a/c for Part 1/135 operations. This will be basically a re-issue of the original WTA.

# Flight Safety Foundation

Figure 3.1
1988 GENERAL AVIATION NUMBER OF AIRCRAFT AND TOTAL HOURS BY PRIMARY USE



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This document, Windshear Overview For Management, and its companion documents, Pilot Windshear Guide, Example Windshear Training Program, Windshear Substantiating Data, and video presentations "A Windshear Avoided" and "Windshear What the Crew Can Do" were prepared pursuant to Federal Aviation Administration Prime Contract DFTA01-86-C-00005 with The Boeing Company as a training aid for flight in windshear conditions. The information contained herein and in the companion materials was derived from information originally developed for the Boeing 727, and provides a base-line training program with additional recommendations, developed and approved by Boeing, Douglas or Lockheed for their respective aircraft, regarding how that program might be adapted for use in specific commercial transport aircraft manufactured by Boeing [727, 737, 747, 757, and 767], Douglas [DC-9, MD-80, and DC-10] and Lockheed [L-1011]. ANY USE OF THIS WINDSHEAR OVERVIEW FOR MANAGEMENT FOR ANY PURPOSE RELATED TO AIRCRAFT OR CONDITIONS OTHER THAN THOSE SPECIFIED ABOVE IS NOT AUTHORIZED AND MAY RESULT IN IMPROPER AIRCRAFT OPERATION, LOSS OF AIRCRAFT CONTROL, INJURY AND LOSS OF AIRCRAFT AND LIFE. ANY USE, ADAPTATION AND/OR USE AFTER ADAPTATION OF THE MATERIAL IN THIS WINDSHEAR OVERVIEW FOR MANAGEMENT BY ANY ENTITY FOR ANY PURPOSE RELATED TO AIRCRAFT, CONDITIONS OR TO TRAINING PROGRAMS OTHER THAN THOSE SPECIFIED ABOVE SHALL BE COMPLETELY AT THE RISK OF THE ENTITY RESPONSIBLE FOR USING, ADAPTING AND/OR USING THE ADAPTATION OF THIS WINDSHEAR OVERVIEW FOR MANAGEMENT, AND SUCH ENTITY BY SUCH USE, ADAPTATION AND/OR USE AFTER ADAPTATION ASSUMES SUCH RISK AND WAIVES AND RELEASES ALL CLAIMS IT MAY HAVE AGAINST THE BOEING COMPANY, McDONNELL DOUGLAS CORPORATION, LOCKHEED CORPORATION, UNITED AIRLINES, AVIATION WEATHER ASSOCIATES, HELLIWELL, INC., THEIR DIVISIONS, SUBSIDIARIES, AFFILIATES AND THEIR OFFICERS, DIRECTORS, SUBCONTRACTORS AND EMPLOYEES FROM ANY LIABILITY WHATSOEVER, WHETHER BASED ON CONTRACT (INCLUDING BUT NOT LIMITED TO EXPRESS AND IMPLIED WARRANTY CLAIMS), TORT (INCLUDING BUT NOT LIMITED TO NEGLIGENCE AND STRICT LIABILITY CLAIMS) OR OTHERWISE, ARISING FROM SUCH USE, ADAPTATION AND/OR USE OF SUCH ADAPTATION. ANY SUCH ENTITY (INCLUDING WITHOUT LIMITATION ANY MANUFACTURER OF OTHER AIRCRAFT OR OPERATOR WITH ANOTHER TRAINING PROGRAM BUT NOT THE UNITED STATES GOVERNMENT) WHICH USES THIS WINDSHEAR OVERVIEW FOR MANAGEMENT OR ADAPTS AND/OR USES AN ADAPTATION THEREOF WITH RESPECT TO SUCH OTHER AIRCRAFT, CONDITIONS OR TRAINING PROGRAM THEREBY AGREES TO INDEMNIFY AND HOLD HARMLESS THE BOEING COMPANY, McDONNELL DOUGLAS CORPORATION, LOCKHEED CORPORATION, UNITED AIRLINES, AVIATION WEATHER ASSOCIATES, HELLIWELL, INC., THEIR DIVISIONS, SUBSIDIARIES AND AFFILIATES AND THEIR OFFICERS, DIRECTORS, AGENTS, SUBCONTRACTORS AND EMPLOYEES FROM ANY LIABILITY WHATSOEVER, WHETHER BASED ON CONTRACT, (INCLUDING BUT NOT LIMITED TO EXPRESS AND IMPLIED WARRANTY CLAIMS), TORT (INCLUDING BUT NOT LIMITED TO NEGLIGENCE AND STRICT LIABILITY CLAIMS) OR OTHERWISE, ARISING FROM SUCH USE, ADAPTATION AND/OR USE OF SUCH ADAPTATION.

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## Wind Shear Training Applications for 91/135 - Questions and Answers

Q: WAYNE SAND (NCAR) - Even though we have not had a microburst accident involving air carriers for over 5 years, we continue to have numerous fatal accidents involving general aviation aircraft. General aviation includes aircraft less capable than the four being tested. Why isn't the training aid being adapted for these smaller general aviation airplanes?

A: HERB SCHLICKENMAIER (FAA) - What we're trying to put together is an application of the wind shear training aid for 91 and 135. 91 kind of covers everything. If there is some particular engineering issues that are unique to, and I'm not picking on one manufacturer over another, but are unique to a Cessna 150 that bear no resemblance whatsoever to operators of the Falcon 50 aircraft then, yes, I think there is an issue for some point of departure. Some of the hypothesis that the program office is putting together is that there's a body of knowledge that will transfer, in the model of flight crew action that starts all the way from wind shear weather evaluations through precaution and eventually to escape and recovery, if those conditions are met. And, that 91, whether its a 150 or a Falcon 50 may be able to make use of the wind shear weather evaluation portion regardless of the airplane type.

UNKNOWN - I think that the Cessna 150 has a lot less in common with the Falcon 50 than the Falcon 50 does with the 727. I mean we're talking about an airplane that has a very different wing loading, very different thrust to weight ratio, and a very different airspeed. Consequently, I think there is going to be less surprises with the executive jets in that study than there are for example for the Saab 340 and I think that what you learned from the Saab 340 may have more application for the Cessna 150 for example. It's not at all clear that the same procedures are going to apply for the single GA type aircraft. Whereas it's very possible that what you do for the Falcon 50 will look rather familiar.

ED ARBON (Flight Saftey International) - The one thing I would like to point out is that we don't have the opportunity to use the advanced simulators for the other aircraft that we need to prove any of this hypothesis that we're talking about. So we have to use these categories. I hope you remember that we're using categories of airplanes that were chosen for certain specific things, low thrust weight, high thrust weight, three engine and the turbo prop, which are representative of the commuter industry. The other side of the coin is the fact that in the Cessna 150 and such ,the most important part of the wind shear training aid is the avoidance section and the recognition of wind shear conditions. That part we certainly hope is transferrable as is. But really the point is simply avoid the wind shear.

Q: WAYNE SAND (NCAR) - The GA guys that are out there are still getting killed on a one to two at a time bases, and on a very regular bases. My question is, if your not going to say anything to the GA guys, why not? If you are, I'd like you to tell me you are.

A: HERB SCHLICKENMAIER (FAA) - What are the four products we're looking at? We're looking at an update to advisory circular 0050 "Wind Shear", which is the basic informational document to everybody. We're looking at a ground school training curricula for 135 operators. We're looking at developing a 135 simulator training for those 135 operators who wish to use it. And we're talking about putting together a part 91 home study course with computer aided instruction, with videos, pamphlets, and informational documents to get the message out on the hazards, the need to avoid, what to do to look for it , how to coalesce the information and how to make a decision about it. In that regard, yes, we've got a product, the homestudy course and it is designed directly for 91 operators, not just corporates but for everybody.

Q: WAYNE SAND (NCAR) - Based on experience working with the GA community of flyers of 182's and such, the question has come up, when is something coming out for me? When is the Wind Shear Training Aid going to be adapted so that it really applies to the class of airplane I fly?

A: HERB SCHLICKENMAIER (FAA) - December 21, 1991.

PETE SINCLAIR (Colorado State University) - I agree with Wayne, as a GA pilot and researcher, we use small aircraft and there's really no connection between your simulator approach which involves stick shaker and all those kinds of things to the GA airplane. We've flown many microbursts and the GA airplane on penetration has to do something quite different. You're not going to make the same penetration or have the same penetration procedure as you have in a Falcon or turbo prop for a GA airplane that has 500 to 700 feet per minute rate of climb capability. It just isn't the same. So you're going to have to write your manual quite differently and that's why we're still having these accidents. Wayne's perfectly right, we have these accidents over the mountains where there's no recovery altitude at all. The GA airplane is at maximum altitude and now it gets into a microburst from the clouds that are sitting right over the peaks and there is no capability at all to recover. We can't apply any of the techniques you're talking about here. I think that's an important question. A lot of GA accidents are classed as something else but they're really microburst operations.

HERB SCHLICKENMAIER (FAA) - I won't argue, Peter, with you or with Wayne. This is an issue we're taking a look at. Whether we will be able through the testing of Group C, the ground school instruction group, to determine whether there will be that last loop in the model of flight crew actions that sits down and says "hey guys, when you've made a decision, this is what the recommendation is." Can we transfer that? That's part of the testing that Ed and his people on the contract team are trying to come up with. Will we be able to transfer that part? I don't know. But I've got to kind of think that in the information on how you evaluate the weather and how you figure what's going on out there before you get into it, there's got to be something valuable. We think that if it can transfer we're going to move it into the general aviation community as fast and as hard as we can.

PETE SINCLAIR (Colorado State University) - I agree with the weather part, but the procedural part for the pilots has to be quite different, I would think.

AL MATTOX (Airline Pilots Association) - So far we keep talking about wind shear detection or wind shear this or that or the other and as an operator I get really confused. It seems to me like we seem to think we've invented wind shear. Wind shear has been here for a long time in various forms. I submit that the training aide has done a lot for the community. But, there are different operators that look at that document with varying levels of enthusiasm. To take that document alone and say that this is the solution to what I think most of us are talking about, which is a recovery from a microburst, is totally different than the other piece of the pie. Which is, there has to be an operation philosophy in the cockpit, there has to be crew coordination, there has to be understanding of basic cross wind limitations. When I make the approach and I've got 50 knots of wind with gusts to whatever, I don't make the distinction between that as a wind shear and a microburst. It all has to be put in the same context. I don't think it's fair to give, as good as it is, the training aid more credit than it deserves. You've got to have some other stuff to support it.

HERB SCHLICKENMAIER (FAA) - I can't disagree with that a bit. What we're trying to do is follow a philosophy we've had with this program from the beginning, which is to provide incremental steps. We think there is some tremendous benefit to be gained by getting some information out to the general aviation community and the air taxi commuter community as early as possible. There is more to be done and you're absolutely right. We've been with wind shear for a long time. What we've got to do is, step by step, as we learn, put it together. I think getting the information out to a tremendous side of the community is the first step.

# Session III. Flight Management

Determining Target Pitch Angle
Herb Schlickenmaier, FAA

# Generalized Method
# of
# Determining Target Pitch Angle
# for the
# Windshear Escape and Recovery
# Maneuver

H. W. Schlickenmaier
*Determining Target Pitch Angle*

Systems Technology Division, ARD-200
Federal Aviation Administration

October 1988
Chart 1

# Objective

Organize a set of technical documents that describe a method for determining target pitch angle for a windshear escape and recovery maneuver.

# Technique

<u>Operators --</u>
<u>What is the recommended target pitch angle?</u>

"... The recommended target pitch angle for your aircraft is 15°, unless the manufacturer of your aircraft recommends otherwise ...."

# Approach

<u>Manufacturers --</u>
<u>How can it be determined?</u>

- Kupcis, et al, described an approach, used in the development of the FAA Windshear Training Aid (February 1987).

- Bray described an approach based on an observation of the target pitch angles that were reported by Boeing, Douglas and Lockheed, during their development of the FAA Windshear Training Aid, to wit, the initial target pitch angle can be estimated using the stall angle of attack (AOA) for the aircraft.

# Strategy

Supporting Analysis --
Do fixed wing airplanes stand up to Bray's hypothesis?

- Dassault has provided their target pitch angles -- as have all of the manufacturers of aircraft that are used in the current 91/135 study -- and their target pitch angles have been independently "validated" in flight and in advanced simulators.

- Since AOA is not called out in the FAR's, a reproduction of the stall tests is simulated, the new variable added to the list is pitch. The estimated pitch at the appropriate $V_{stall}$ becomes the target pitch angle.

- Flight dynamic research is also being conducted that will describe:
  - o an analytical methodology to determine target pitch angle, and
  - o an analysis of Bray's hypothesis using OTA.

- A description of the larger issues revolving around TPA, such as:
  - o turbojet versus propeller,
  - o straight wing versus swept, and
  - o clean-wing versus high-lift leading edge devices.

# Conclusion

The FAA Windshear Training Aid delivered to the FAA in February 1987 by the contract team headed by Boeing, is a robust document that describes a method for reducing the pilot's exposure to the risk of encountering hazardous windshear by ensuring that the flight crew is well-trained.

The training is centered around the model of flight crew actions:

- Avoid known windshear -- windshear weather evaluation
- Be prepared if you're not quite sure -- precautionary techniques
- If you encounter a windshear, execute a windshear escape and recovery technique -- *power and pitch*.

The analysis into a generalized method for determining target pitch angle is a small piece of an integrated approach for the flight crew to make use of to mitigate the windshear risk.

## Determining Target Pitch Angle - Questions and Answers

Q: FRANK DREW (Lockheed Austin Division) - Why are we looking for a max performance pitch angle rather than an angle of attack? It would seem I can get into real bad trouble by flying to a canned pitch angle if I don't integrate my vertical vector and my micro air mass velocity vector. Am I missing something?

A: HERB SCHLICKENMAIER (FAA) - No. I don't think you are. The question comes up, how do we get the information out in a general set of techniques that can be applied to the community? If you take a look at what Don Bateman and his guys at Sundstrand are doing or Joe Youssefi and the people at Honeywell and the rest of the people around the world that are building boxes that are taking a look at some sophisticated processing, and certainly when you get into the guts of what NASA's second generation reactive device are going to be doing; there's some processing going on there that's going to be incredible. When you're talking about a pilot who's just realized that they're sitting in the middle of a microburst, now what's the recommended "Oh gosh, what do I do here?" We're not asking you to go to a max pitch angle, we're never advocating stick shaker to go to directly. We're trying to come up with something that's moderating in between that gives you just a little bit of reserve when you get back down to the bottom. I always recommend you take a look at the issues appendix in the documented, the substantiated data document. It kind of references where those decisions were made and that was one of the points that came up during the training.

CARL YOUNG (Eastern Airlines) - In your presentation you spoke of pitch and power, not perhaps in those words, but that was the essence of it and no one has touched upon power so far and I do not see it on the agenda. My comment is there was one national resource specialist from the FAA that was quizzing whether using max available power was a good idea. In interviewing crews that have been through three serious wind shear incidences, to a man, they all said, we don't think we would have made it without all available power. Based on full authority digital engine controls and electronic engine controls and other assets that limit power, do we really think as an industry that that's a good idea? And I would also like to comment that General Electric, to their great credit, is the only large engine manufacturer that I know of that published their statistics to max performance with engine deterioration and that was 1017 degrees based on a 945 degree max EGT, and this was done for 5- 1/4 minutes. That's a tremendous spread.

HERB SCHLICKENMAIER (FAA) - At one point I had heard there was some discussions going on, I wasn't quite sure whether it was the NRS propulsion people or whether it was one of the folks out at one of the aircraft certification offices in propulsion, but the question came up about multiple near simultaneous failures, i.e., you find yourself in a wind shear, you go to take all available power and run the engine all the way up. The question as I recall is: "what happens if we over temp an engine and now we flame one out?" There have been some discussions going on with the manufacturers of the engines, the airplanes, and with the certification people. Quite honestly I don't know what the resolution of that is. From what we've seen from the case studies in past, as Roland has been aptly quoted, there is no replacement for excess thrust to weight available to extricate yourself out of a wind shear. Again, I recommend you take a look at the issues section in the back of the training aide for the 121 applications on those 9 aircraft. There was some discussion that went on in the appendix regarding moving the engine throttles all the way up, and I'd be hard pressed to quote it right now.

# Session III. Flight Management

Probabilistic Reasoning for Wind Shear Avoidance
Dr. Robert Stengel, Princeton University
Alex Stratton, Princeton University

# Artificial Intelligence Advisory System for Wind Shear Avoidance

3rd Combined Manufacturers' and Technologists' Airborne Wind Shear Review Meeting

October 16, 1990, Hampton Virginia

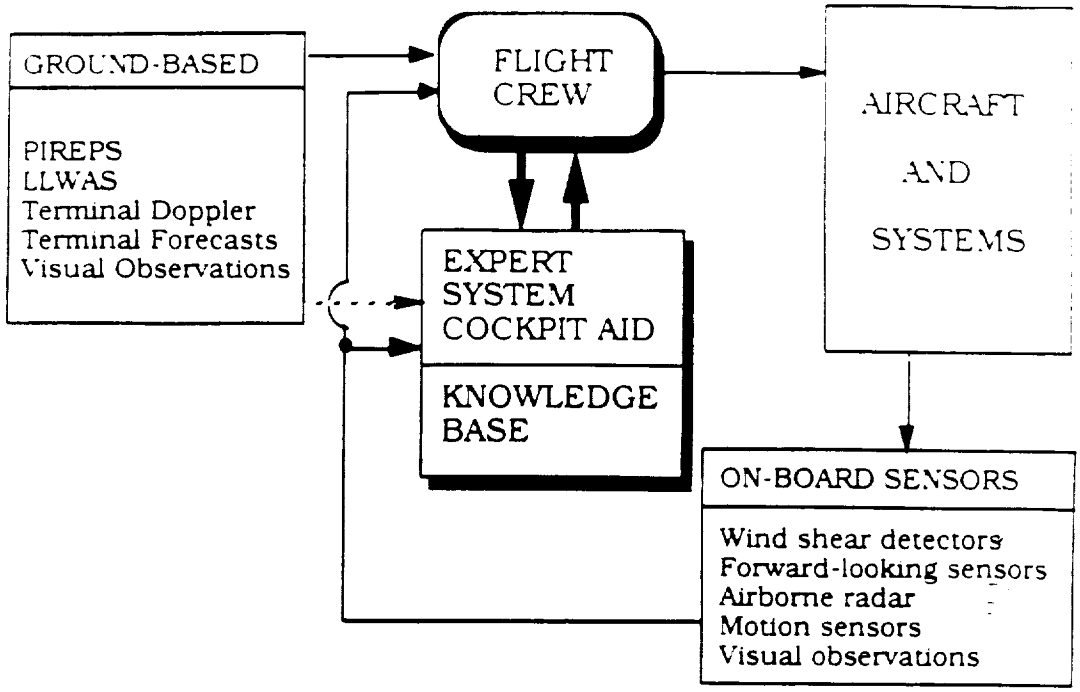
## Presentation Outline

- An Expert System for Wind Shear Avoidance
- Risk Assessment and Probability Theory
- Probabilistic Model for Wind Shear Avoidance

# Avoidance of Severe Wind Shear

- Remote wind shear detection
  - Airborne doppler radar, lidar, flir
  - Ground-based, TDWR, LLWAS
- Meteorological environment
  - NIMROD, JAWS, FLOWS
  - statistical results
- Flight crew training, guidance and control
  - F.A.A. Windshear Training Aid (1986)
    - Example training program
    - Precautionary, escape procedures
    - Avoidance guidelines

# Expert System for Wind Shear Avoidance




- Increase crew decision reliability
  - Monitor sources
  - Prediction
  - Apply knowledge, assess risk
  - Recommend alternatives

- Rule-based implementation
  - ~200 "IF-THEN" rules
  - Goal-directed, cyclical search
  - Real-time, translation

# Probability Theory for Risk Assessment

- Windshear Training Aid avoidance guidelines
  - "Low," "Medium," and "High" risk
  - Avoidance appropriate: "High" risk
  - "Low + Medium = High"
  - "Convective weather near flight path"
  - "Rainshowers" vs. "heavy precipitation"
  - "Use of [the avoidance guidelines] should not replace sound judgment."

- Probability theory
  - Widespread understanding
  - Meteorological statistics
  - Detection reliability statistics
  - Efficient implementation - Bayesian network

# Elements of Probability Theory

- Condition probabilities: **Bayes's rule**

H: Hypotheses of wind shear
E1: Alert of wind shear

$$\Pr\{H \mid E1\} = \frac{\Pr\{E1 \mid H\}}{\Pr\{E1\}} \Pr\{H\}$$

Prior probability, Pr{H}
Probability of detection, Pr{E1 | H}
Probability of false alarm, Pr{E1 | ¬ H}

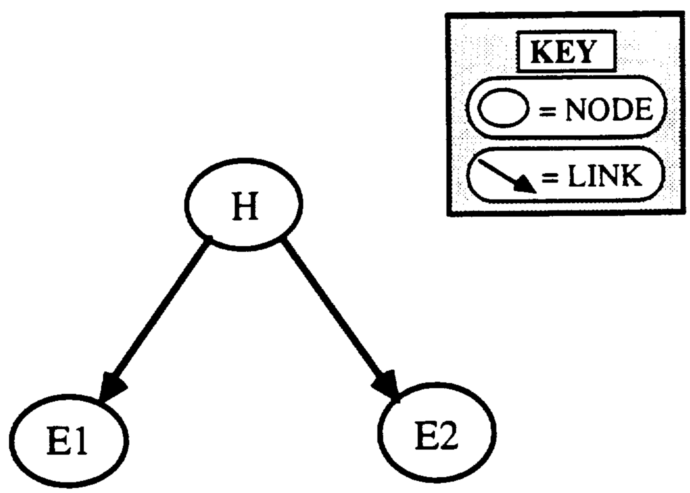
- Multiple evidence, structure

$$\Pr\{H \mid E1,E2\} = \frac{\Pr\{E1,E2 \mid H\}}{\Pr\{E1,E2\}} \Pr\{H\}$$

Conditional independence assumption:
**alerts independent consequents of wind shear**

$$\Pr\{H \mid E1,E2\} = \frac{\Pr\{E2 \mid H\}}{\Pr\{E2 \mid E1\}} \Pr\{H \mid E1\}$$

# Graphical Representations of Dependency




- Graphical representations
  - Hypotheses, Nodes
  - Dependencies, Links
  - Cause-effect, Arrows

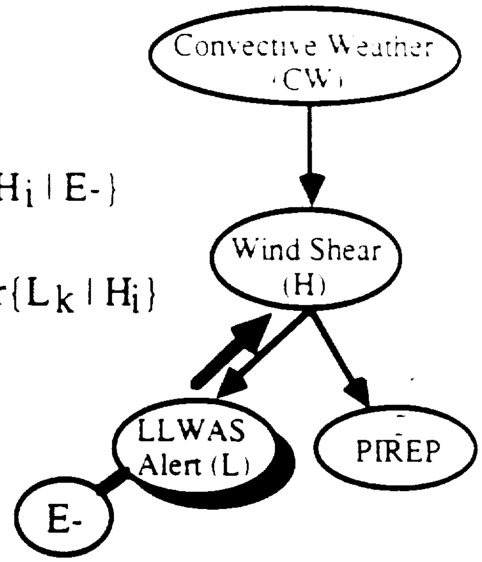
- Causal hierarchies
  - Lightning, precipitation dependent
  - Independent given convective weather

# Probabilistic Reasoning in Bayesian Networks

- Evidential Reasoning (Effect to Cause)

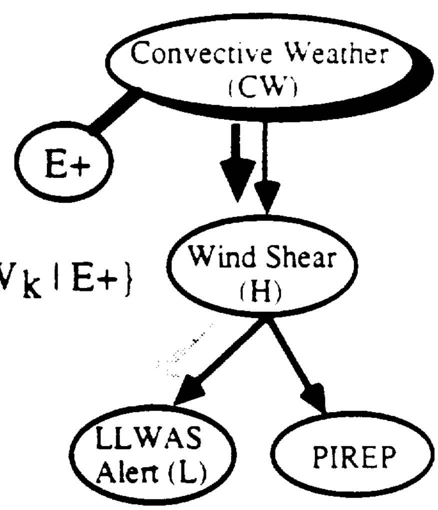
$$Pr\{H_i \mid E-\} = \frac{Pr\{E- \mid H_i\}}{Pr\{E-\}} Pr\{H_i \mid E-\}$$

$$Pr\{E- \mid H_i\} = \sum_k Pr\{E- \mid L_k\} Pr\{L_k \mid H_i\}$$

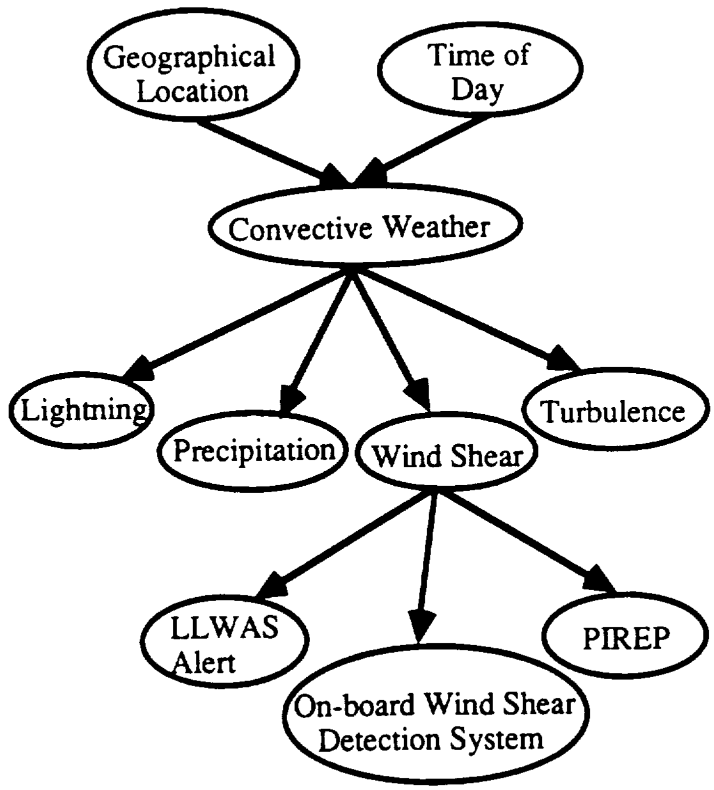



- Causal Reasoning (Cause to Effect)

$$Pr\{H_i \mid E+\} = \sum_k Pr\{H_i \mid CW_k\} Pr\{CW_k \mid E+\}$$

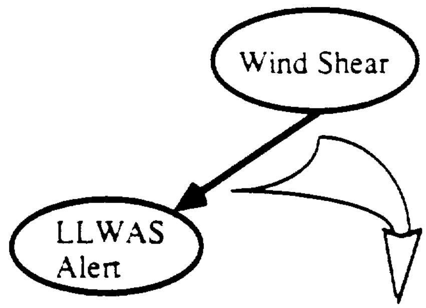


# Probabilistic Model of Windshear Training Aid Guidelines




- JAWS, NIMROD, FLOWS, LLWAS
- Relevance to terminal operation
- Combined judgments involving uncertainty
  - Convective weather near flight path
  - Alerts versus weather features
  - "rainshowers" vs. "heavy precipitation"

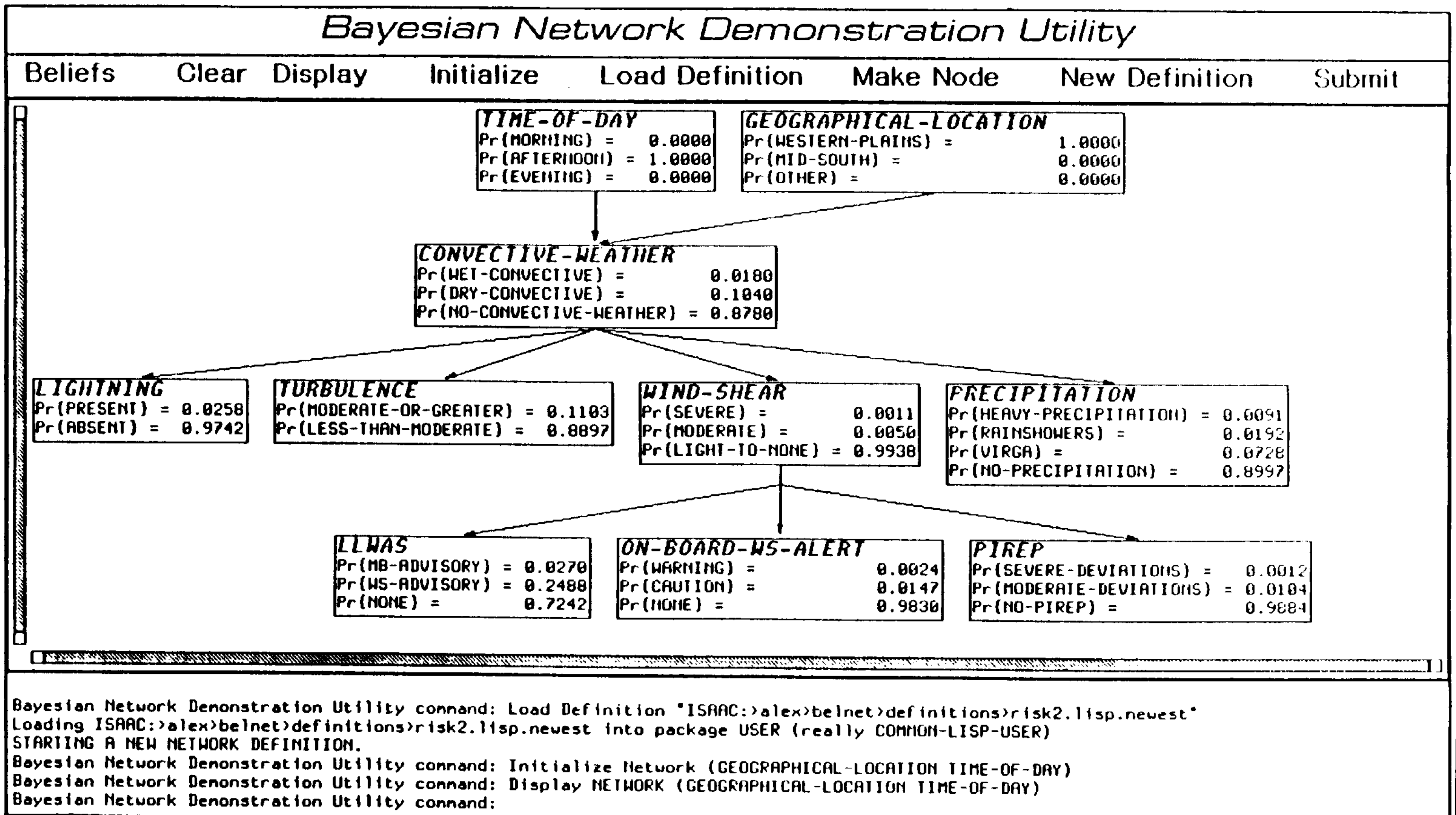
# Requirements for Probabilistic Representation




| Given the level of wind shear on flight path is: | Severe | Moderate | Light |
|---|---|---|---|
| Probability of LLWAS Microburst Advisory is: | 0.649 | 0.082 | 0.026 |
| Probability of LLWAS Wind Shear Advisory is: | 0.223 | 0.810 | 0.246 |
| Probability of no LLWAS Advisory is: | 0.128 | 0.108 | 0.728 |

- Link probabilities
  Enhanced LLWAS, wind shear detectors
- Conditional weather and prior probabilities
  JAWS, NIMROD, FLOWS
- Uncertain probabilities
  Turbulence

# Demonstration of Probabilistic Reasoning



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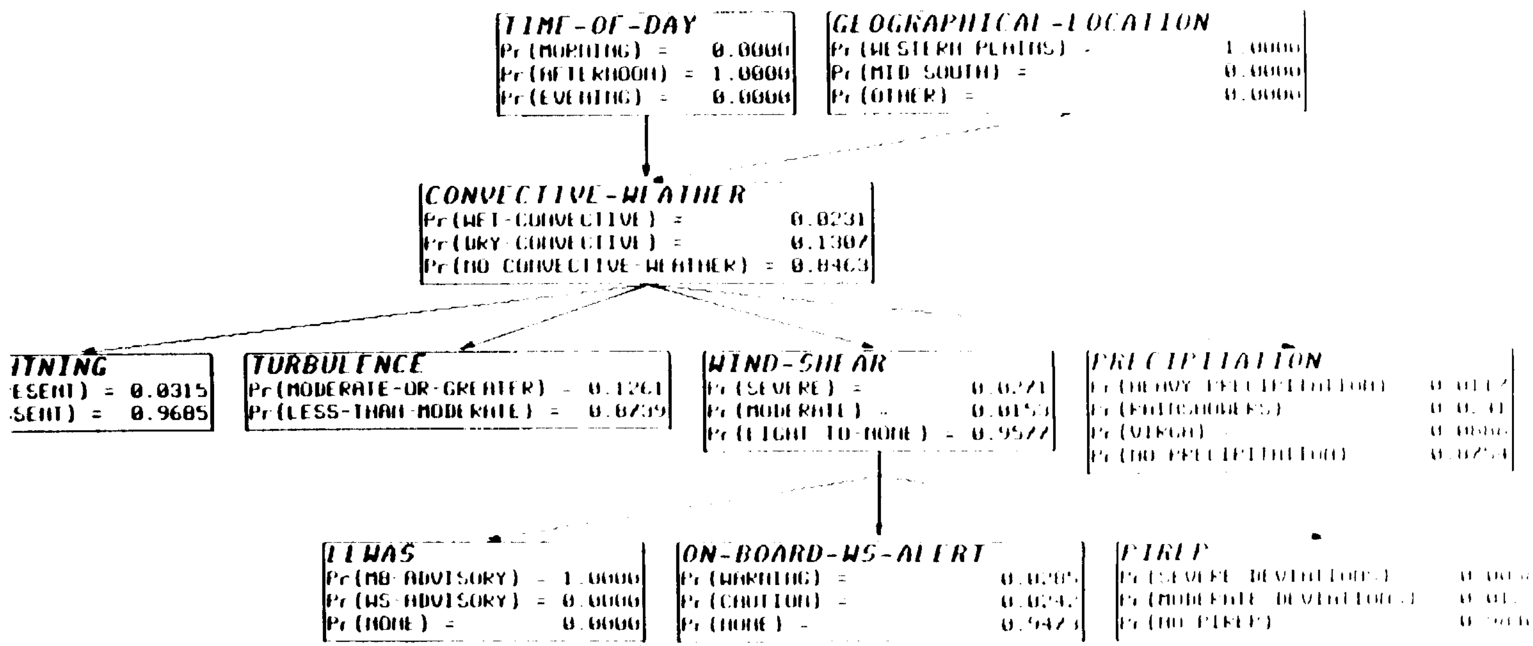
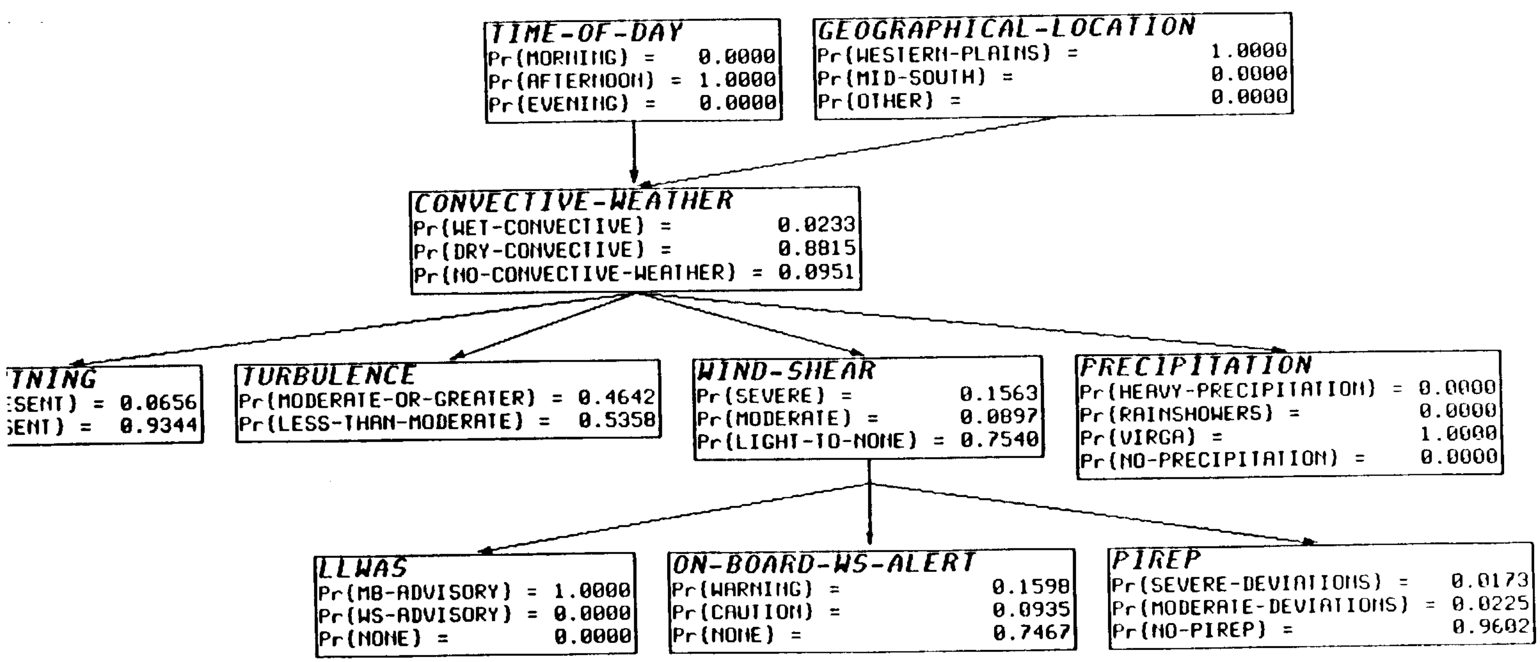
# Effect of LLWAS Microburst Advisory




• **PROBABILITY OF SEVERE WIND SHEAR INCREASES 2500 %**

# Effect of Convective Weather Observation




- **PROBABILITY OF WIND SHEAR INCREASES 600 %**

# Conclusions

- Bayesian networks assimilate meteorological knowledge
  - manages uncertainty
  - fusion of evidence
  - stochastic prediction

- Probability provides scientific basis for avoidance guidelines
  - meaningful summaries
  - documented experience

- Uncertain probabilities
  - refinement by component
  - basis for meteorological studies

# Session IV. Sensor Fusion & Flight Evaluation