Session VII. 2nd Generation Reactive Systems

Status of Sundstrand Research
Don Bateman, Sundstrand
STATUS
of
Windshear R and D

at
Sundstrand Data Control, Inc.
17 October, 1990
Windshear Detection Status

- 2nd Generation Detection System is Here

- 3rd Generation Detection System is in Work

- Look-Ahead is in Research and Development
SECOND GENERATION DETECTION

IMPROVE RATIO OF:
USEFUL ALERTS
UNWANTED ALERTS

- Q-BIAS
- GAMMA BIAS
- TEMP BIASES
- MANEUVERING FLIGHT MODULATION
- ALTITUDE MODULATION

- CERTIFIED 1988 -
Q - BIAS

- Reduces unwanted alerts for approach into high surface wind when aircraft has high energy
- Sensitizes system when energy is low
TEMPERATURE BIASES

LAPSE RATE .... IMPROVES USEFUL ALERT TIME

TEMPERATURE VALUE .... REDUCES UNWANTED ALERTS
CURRENT SYSTEM PERFORMANCE

- Valid warnings are occurring worldwide
- Crews are responding per appropriate procedure
- Rate of unwanted warnings is less than 1 in 3500 segments
- Windshear "CAUTION" (positive shear) $> f = -0.1$ are proceeding negative shears by 10 to 15 seconds
- Predictive sensors will augment positive shear detection
- Temp. lapse rate bias is providing 3 - 5 seconds improvement in warning time
Windshear
WORLDWIDE COMMERCIAL JET FLEET

ACCIDENTS

YEAR

68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90

FATAL ACCIDENTS

TRAINING PROGRAMS

Updated Chart Taken From Flight Safety Foundation,

SOURCE: BOEING/FSF
Hi folks, this is your pilot... You know, we could have elected to equip this plane with that new-fangled stuff that measures wind shear, but we thought you'd rather we put the money into upgrading the food.

Bon Appétit!
Third Generation Windshear Detection
Windshear
Accidents with no Warning
For Current Detection Systems

ACCIDENTS

YEAR

68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90

FATAL ACCIDENTS
Effectivity of Second Generation Windshear Systems

27 WINDSHEAR RELATED ACCIDENTS/INCIDENTS
(NATIONAL ACADEMY OF SCIENCES DATA BASE)
1 MARCH 1964 - 28 JULY 1982
Windshear Threshold

TYPICAL WINDSHEAR DETECTOR THRESHOLD

WINDSHEAR WARNINGS FOR 17 ACCIDENTS/INCIDENTS

PROBABILITY OF EXCEEDANCE

10 ACCIDENTS/INCIDENTS NO WARNING

TAILWIND

KNOTS/SECOND

HEADWIND
Accident Examples Where Windshear Was A Contributory Cause and The Estimated Windshear Values Are Less Than TSO-C117 Warning Requirements, or the Aircraft Performance Capability.

- Okinawa DC-8  -1.2 Kts/Sec for 12 Seconds
- Pago Pago B707  -1.3 Kts/Sec for 10 Seconds
- Boston DC-10  +0.8 Kts/Sec for 15 Seconds
- Ankara B727  +0.8 Kts/Sec for 36 Seconds
- Dade-Collier DC-8  -1.5 Kts/Sec for 10 Seconds

+ Increasing Energy Windshear
FIGURE 1
SHEAR INTENSITY CURVE

\[ f_{sv,x} = \text{average shear intensity to cause a warning at time } t_x (\text{resulting in a 20 knot windspeed change, bounded as shown; applies to horizontal, vertical, and combination shear intensities}) \]

\[ \int_{t_x}^{t_y} f(t) \, dt \quad \text{whereby } f(t) = \text{instantaneous shear intensity at time } t \]

1 A nuisance warning test utilizing the Dryden turbulence model and a discrete gust model are conducted independently from alert threshold tests to verify the acceptability of potential nuisance warnings due to turbulence or gusts.
Flight Path Profile
DC-10-30
BOSTON, MASS.
17 DECEMBER, 1973

NOTE:
NO WINDSHEAR CAUTION OR WARNING FOR CONVENTIONAL WINDSHEAR DETECTION SYSTEMS
(> 2.5 KTS/SECOND)

118 KTS TAILWIND

3°00' GLIDESLOPE

1 DOT LOW

GPWS BELOW GLIDESLOPE
MK I, MK II, MK III
WARNING ENVELOPE

MK V & MK VII ALERT WARNING AREA

0.8 KTS/SECOND WINDSHEAR

AUTO-PILOT DISCONNECTED

MODERATE RAIN

6 KTS HEADWIND

NO GPWS INSTALLED
MK I, MK II, MK III
WARNING

NO GPWS INSTALLED
MK I, MK II, MK III
WARNING

CURRENT WARNING
NOTE:
Circumstances: ILS Approach Encountered micro burst–macro burst in rain at night and hit 3600 feet short of runway at 23:40 local time.
Weather: 18 @ 40 @ 110 @ 10 miles Wind 030/20 kts 25 gust. Light rain. Heavy rain shower near.
Loss: Aircraft destroyed $5.5 million 97 fatalities of 101 on board. $20 million liability.

FLIGHT PATH PROFILE
B-707-300B
Pago Pago, American Samoa
31 January 1974

NOTE:
NO WINDSHEAR WARNING FOR CONVENTIONAL WINDSHEAR SYSTEMS (App. 25 Kts/Second)

CAUTION ONLY

HEADWIND
-15 GLIDESLOPE
-1 DOT LOW
-2 DOT LOW
NEW MK VII ALERT WARNING AREA

MICRO BURST
18 Kts
12 Kts
9 Kts

MACRO BURST
13 Kts/Second
1 Kt/Second for last 13 seconds
35 Kts
9 Kts

WINDSHEAR:

GPWS GLIDESLOPE WARNING ENVELOPE

TERRAIN

ALTITUDE
FEET

DISTANCE ~ NM

TIME ~ SECONDS

WIND DATA = FUJITA

MK V & MK VI WARNING
"SINKRATE"
"GLIDESLOPE"
"SINKRATE"

MK I
"GLIDESLOPE"

CURRENT WARNING SYSTEMS
Flight Path Profile
DC-8-62
DADE-COLLIERT, FLORIDA
10 MAY, 1977

NOTE:
NO WINDSHEAR CAUTION OR WARNING FOR CONVENTIONAL WINDSHEAR DETECTION SYSTEMS (~2.5 KTS/SECOND)

-1.5 KTS/SECOND WINDSHEAR
For Last 10 Seconds

NOTES
Circumstances
Print leaving incident
Auto-coupled R/S approach to
150 feet Windshear
Manual approach initiated
in heavy to moderate rain
Airplane touched down short at
11:20 EET

Weather
1115 EDT E 15 3 1 78 36/02 29.84
1121 EDT E 15 11 RW 74 29/08 29.84

Loss
50.15 Million

NO GPWS WARNING (MKI)
FOR INSTALLED SYSTEM

CURRENT WARNING SYSTEM
WINDSHEAR MODULATION OF MODES 1 AND 5

ENHANCED MODE 1 ENVELOPE

ENHANCED MODE 5 ENVELOPE
Flight Path Profile
DC-10-30
BOSTON, MASS.
17 DECEMBER, 1973

NOTES:
Circumstances: Flight 933 scheduled flight
Auto-coupled ILS approach to
175 feet with set to headwind shear
Autothrottle left engaged
Visual transition at 175 feet
in moderate rain
Weather: 3/4 mile visibility, fog, moderate rain
Time: 17:47 EST
Loss: Aircraft Destroyed 521 5 million
3 seriously hurt, 13 injured out of 168

118 KTS TAILWIND

3/800 GLIDESLOPE
1 DOT LOW

GPWS BELOW GLIDESLOPE
MK I, MK II, MK III WARNING ENVELOPE

MK V & MK VII ALERT WARNING AREA

NOTE:
NO WINDSHEAR CAUTION
OR WARNING FOR
CONVENTIONAL WINDSHEAR
DETECTION SYSTEMS
(~ -2.5 KTS/SECOND)

+0.8 KTS/SECOND WINDSHEAR

AUTO-PILOT DISCONNECTED

MODERATE RAIN

6 KTS HEADWIND

TIME - SECONDS

CAUTION "GHEAP" "GlIDESLOPE" "SINlRATE"
"SINKRATE"
MK VI WARNING

MK V WARNING

NO GPWS INSTALLED
NO WARNING FOR
MK I, MK II, MK III
IF INSTALLED

ADVANCED WARNING SYSTEMS
FLIGHT PATH PROFILE  
B-707-300B  
Pago Pago, American Samoa  
31 January 1974

NOTE:  
NO WINDSHEAR WARNING  
FOR CONVENTIONAL WINDSHEAR SYSTEMS (App. 2.5 Kts/Second)
Flight Path Profile
DC-8-62
DADE-COLLIER, FLORIDA
10 MAY, 1977

NOTE:
NO WINDSHEAR CAUTION OR WARNING FOR CONVENTIONAL WINDSHEAR DETECTION SYSTEMS
(-2.5 KTS/SECOND)

-1.5 KTS/SECOND WINDSHEAR
For Last 10 Seconds

CAUTION SHEAR "GLIDESLOPE" "ABERRATION" "UNUSUAL"
THIRD GENERATION SYSTEM

- USE WINDSHEAR COMPUTATION TO AUGMENT FLIGHT PATH AND TERRAIN ALERTS

- MODULATION OF ALERT THRESHOLDS BASED ON WIND/TERRAIN DATA BASE

- INCORPORATE WINDSHEAR/TERRAIN ALERT ENHANCEMENTS FROM PREDICTIVE SENSOR DATA
Q: JOHN McCARTHY (NCAR) - Are you aware of a Cuban Allusion 62 fatal accident? Havana, Cuba, September, 1989. There was 125 killed. Departure profile similar to Pan Am 759. The Cuban Civil Aviation Authority blamed (1) microburst, (2) crew training, (3) pilot actions. So the record is not clean since 1985.

A: DON BATEMAN (Sundstrand) - The chart I presented did not include any Soviet Union, Eastern bloc countries or Cuba. To me, this illustrates that the value of having an open society of nations where people trade back and forth accident information. As everyone knows in this room it was very difficult to get any information at that time, back in the 60s, the cold war, which really meant anything. Obviously if we put the Cuban and Russian and the other countries on the chart, we would probably have a continuing accident profile all the way across. Again I say the training programs, the education, avoidance, has really paid off. It’s paying off everywhere in the world and I’m very proud that a lot of it came from the United States. I should say that since 1988 things are really changing. Mr. Gorbachev, who got the Nobel Prize yesterday, has really helped change that. Cuba still is very, very difficult, so close to us, yet so far in communicating with each other. Even Mr. Gorbachev hasn’t been able to convince that openness that we need.

Q: PAUL KELLY (21st Century Technology) - What is the logic behind a wind shear alerting system that simply tells the crew somewhere in the vicinity is a wind shear? Without qualitative and quantitative data on the shear characteristics? Is not the only logical approach to crew alert some format that indicates the nature of the shear, its relevant position in respect to that aircraft as well as information on advisable maneuvering options? What’s the good of spending money on any alerting system that does not address these three factors?

A: DON BATEMAN (Sundstrand) - Well, I wish we could give the pilot pictures. I think the speakers yesterday talking about the TDWR data transmittal to the airplane and displaying that, that adds another breadth to this, for the pilot to be able to really see what’s going on out there. But this is nothing new. You have to start somewhere. I believe when a wind shear warning is given, the pilot is not asked what the picture is, or what the characteristics of the shear are, he is asked to leave. Perhaps with time maybe we’ll get the pictures that the pilot really needs to see to help. I myself believe in not treating the pilot like a monkey, but to give him some information.

PAUL KELLY (21st Century Technology) - A very relevant adjunct to that question was as we saw this morning, sometimes a shear or the focal point of a microburst is not lined up with the longitudinal axis of the aircraft and it can be such that if the aircraft resorts to standard evasive maneuver by going on to standard missed approach path for that airport, it could very well end up putting himself into a tail wind, which of course will have the maximum danger. So, what is so important I believe, is that pilot needs to have some idea with regard to the physical characteristics of the microburst because standard evasive action could lead to him getting into a more dangerous situation which he would otherwise avoid if he had some information that made him realize that factor.

TERRY ZWEIFIL (Honeywell Sperry) - Yes, ideally that's what we would have. There would be some kind of situational display. Unfortunately there is 3000 commercial airplanes out there who have no capability to do that. The second point is, the reactive type systems are not predictive. That is, they only detect shears when you are in them. So it's going to be almost moot in terms of what part of the shear that you're in. It will either say you are in a shear or it will not. It's all one red light that comes on and says, "wind shear,
wind shear, wind shear." The standard guidance procedure, no matter who's system you're looking at, in terms of roll, is to keep the wings level. Therefore, we are never instructing the pilot to turn one way or the other where he might in fact turn into the shear. Actually the real reason we do that is to keep the drag on the airplane down. So unless you just happen to have a very bad day and you just happened upon the shear just as it moves across as you're coming into it, you could in fact get into a worse condition. But the reactive systems, as they're designed today, have no way of anticipating what that is. Like I say, in the future we hope to change all of that and that's why we have all of these forward looking guys with the TDWRs and LLWAS and those sort of things. But for right now, we need to protect the airplane population that's out there without any of these display capabilities, which even if we could generate the display, we have no where to put it. So they're kind of at the mercy right now of a simpler system.