Session VII. 2nd Generation Reactive Systems

N91-24183

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

SOURCE: BOEING/FSF

Updated Chart Taken From Flight Safety Foundation, 42nd IASS, Athens, 1989, Page 33.
-- That because of the effectiveness of our pilot training programs

SYLVIA / Nicole Hollander

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

-4 -3 -2 -1 0 +1 +2 +3 +4

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

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

\[ = \int_0^{t_x} f(t) dt \text{ whereby } f(t) = \text{instantaneous shear intensity at time } t \]

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

NOTES
Circumstances
Flight 933 scheduled flight
Auto-coupled ILS approach to
175 feet with tail to headwind shear
AUTHORITIES LEFT ENGAGED
Visual transition at 175 feet
in moderate rain
Weather
3/4 mile visibility. Low, moderate rain
Time
15:43 EST
Loss
An 18 is destroyed $71.5 million
3 seriously hurt, 13 injured out of 168

118 KTS TAILWIND

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

1.000 GLIDESLOPE

1 DOT LOW

AUTO-PILOT DISCONNECTED

MODERATE RAIN

6 KTS HEADWIND

NO GPWS INSTALLED
NO WARNING FOR
MK V & MK VI
INSTALLED

CURRENT WARNING
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)

NOTE:
Circumstances: ILS Approach Encountered
micro burst-macro burst in
rain at night and hit
3600 feet short of runway at
2340 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.

CAUTION ONLY

HEADWIND
18 Kts
-1 DOT LOW
-2 DOT LOW
NEW MK VII ALERT WARNING AREA
3°15' GLIDESLOPE
9 Kts
12 Kts
18 Kts
1000
900
500
1500
ALTITUDE FEET

TERRAIN

DISTANCE ~ NM

0 1 2 3

TIME ~ SECONDS

60 50 40 30 20 10 0

WIND DATA + FUJITA

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

MK I
"GLIDESLOPE"

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

NOTES
Circumstances
- Printed training incident
- Auto-coupled AF Approach
- 150 feet wind shear
- Manual approach initiated in heavy to moderate rain
- Airplane touched down short at 11:26 EST

Weather
- NTS T 15: 2140 27.984
- NTS T 15: 2140 27.984
- Low 50-151 Miles

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

-1.5 KTS/SECOND WINDSHEAR
For Last 10 Seconds

GPWS GLIDESLOPE WARNING ENVELOPE
MK V & MK VII ALERT WARNING AREA
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 103 scheduled flight
Auto-coupled ILS approach to
175 feet; set to headwind shear
Visual transition at 175 feet
Weather: 3/4 mile visibility; fog, moderate rain
Time: 15:43 EST
Aircraft Destroyed 81.5 million
3 seriously hurt, 13 injured out of 168

118 KTS TAILWIND

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

+0.8 KTS/SECOND WINDSHEAR

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

MK V & MK VI ALERT WARNING AREA

CAUTION "SINKRATE" "SINKRATE"
"SINKRATE" "SINKRATE"

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

ADDITIONAL 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 KIAS)

NOTE:
Circumstances: ILS Approach. Encountered
microburst–macro burst in
rain at night and hit
3800 feet short of runway at
2340 local time.
Weather:
Weather:
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.

HEADWIND
-18 Kts

CAUTION ONLY
MACRO BURST
-0 Kts

WINDSHEAR:
-13 Kts
1 Kt/Sec
13 seconds

35 Kts

GWGS GLIDESLOPE
WARNING ENVELOPE

MK V & MK VII ALERT
WARNING AREA

TERRAIN

DISTANCE - NM

ALTIMETER
FEET

60 50 40 30 20 10 0

TIME - SECONDS

ADVANCED WARNING
MK V WARNING

"CAUTION: SHEAR"
"SINK RATE"
"GLIDESLOPE"
"GWGS GLIDESLOPE"

MK I & MK II
"GWGS GLIDESLOPE"

WIND DATA: FUJITA

ADVANCED WARNING SYSTEMS

473
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

CAUTION SHEAR
GLIDESLOPE
SLOPE
SINKRATE
ADVANCED WARNING
SYSTEMS

ADVANCED WARNING SYSTEMS

NOTE:
(NO GPWS WARNING [MKV] FOR INSTALLED SYSTEM)

NOTES
Circumstances
Auto coupled ILS approach to
150 foot windshear
Manual approach indicated
as being the minimum case
Aircraft touched down short at
1130 EST

Weather
1115 EST E 15 31/6 30°01.2 29.84
1120 EST E 15 41°30.6 29.84
1121 EST E 15 41°30.6 29.84

MK V & MK VII ALERT WARNING AREA

ALTITUDE - FEET

TIME - SECONDS

DISTANCE - NM

2°50' GLIDESLOPE
-1 DOT LOW
HEADWIND
TAILWIND
HEAVY RAIN

600
500
400
300
200
100
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.