THE ADVANCED LOW-LEVEL WINDSHEAR ALERT SYSTEM

OPERATIONAL DEMONSTRATION RESULTS

SUMMER, 1987

N88-17633

DENVER STAPLETON INTERNATIONAL AIRPORT

BY

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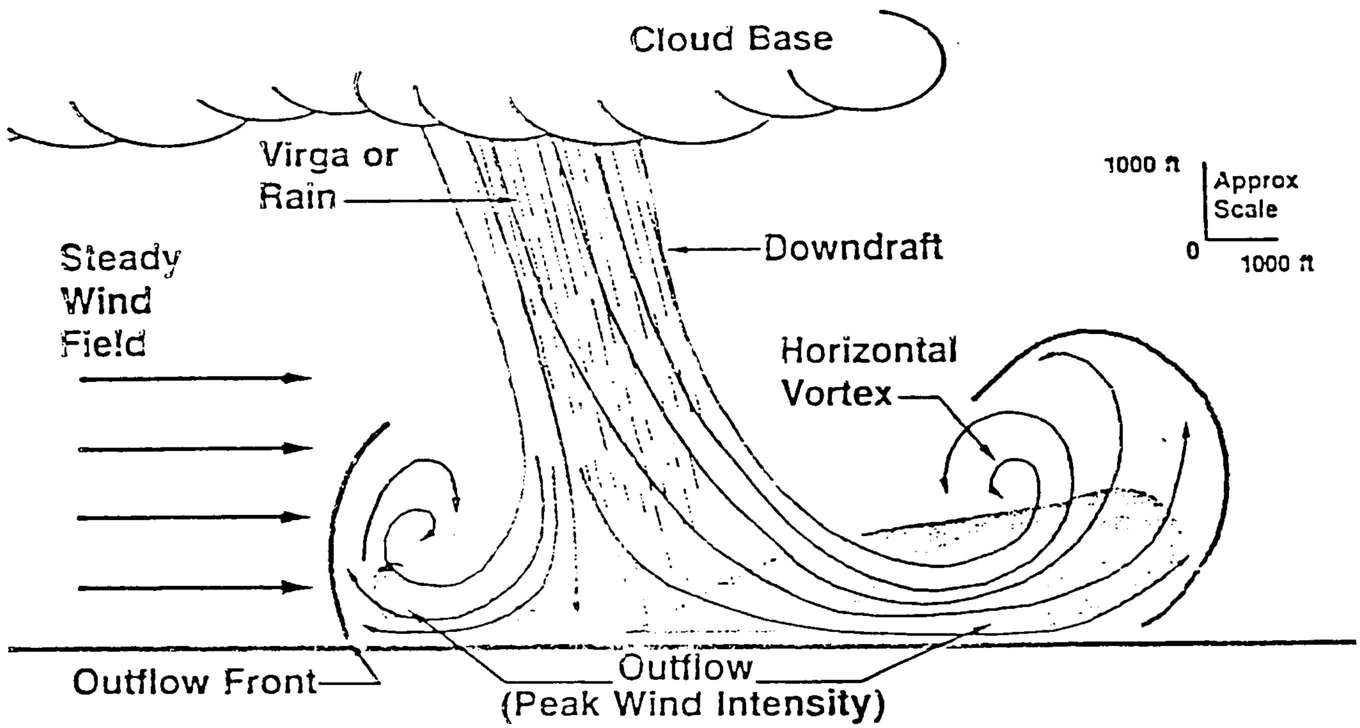
FOR THE

FIRST COMBINED MANUFACTURERS' AND TECHNOLOGY
AIRBORNE WIND SHEAR REVIEW MEETING

NASA LANGLEY RESEARCH CENTER

OCTOBER 22-23, 1987



	First Detection	Max Intensity
Max Velocity Differential	24 kn	47 kn
Distance	0.9 nmi	1.5 nmi

Time to Max Intensity → 6.4 min

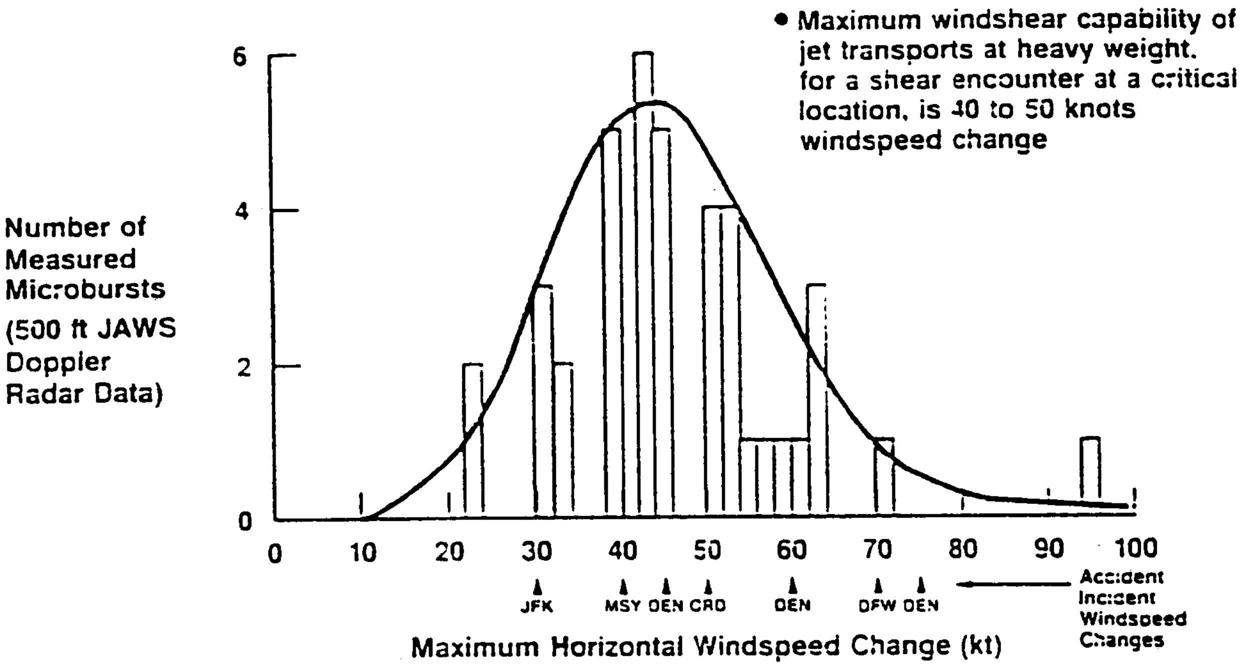


Figure 11. Microburst frequency versus intensity. Accidents have occurred in windshears within performance capability of airplane. Some windshears cannot be escaped successfully!

ENHANCED LOW-LEVEL WINDSHEAR ALERT SYSTEM (LLWAS)

ORIGINAL SIX-STATION:

- Spacing too crude to detect microbursts.
- Original six-station algorithm favored gust frontal wind shifts and generally did not detect microbursts.
- Format of old LLWAS message was confusing; confusion associated with this message listed as contributing cause of Pan Am Flight 759 in New Orleans.

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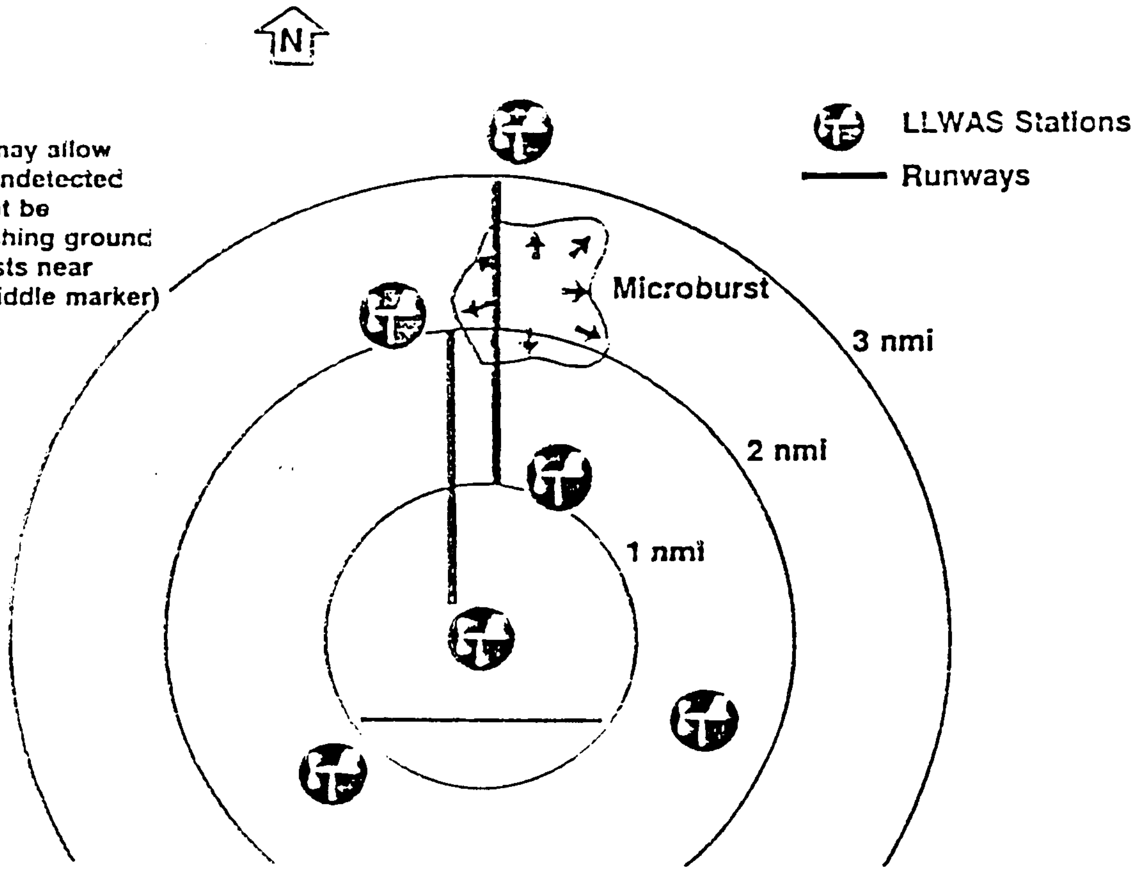
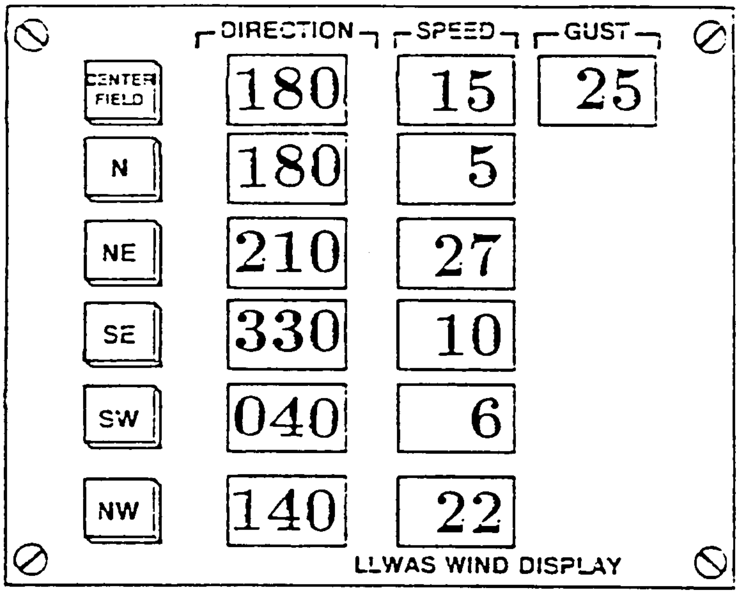
Limitations
- Sensor locations may allow microburst to go undetected
- Microburst may not be detected until reaching ground
- Coverage only exists near runways (inside middle marker)




DIRECTION
SPEED
GUST
CENTER FIELD
180
15
25
N
180
5
NE
210
27
SE
330
10
SW
040
6
NW
140
22
LLWAS WIND DISPLAY

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ENHANCED LOW-LEVEL WINDSHEAR ALERT SYSTEM (LLWAS)

ENHANCED TWELVE-STATION:

- Spacing between stations cut in half, does considerably better job on detecting microbursts.
- Algorithms specifically identify *MICROBURST WIND SHEAR ALERT* as a first priority, then identifies all other wind shear events detected as *WIND SHEAR ALERT*.
- Format of enhanced system provides pilots with runway-oriented wind shear message:

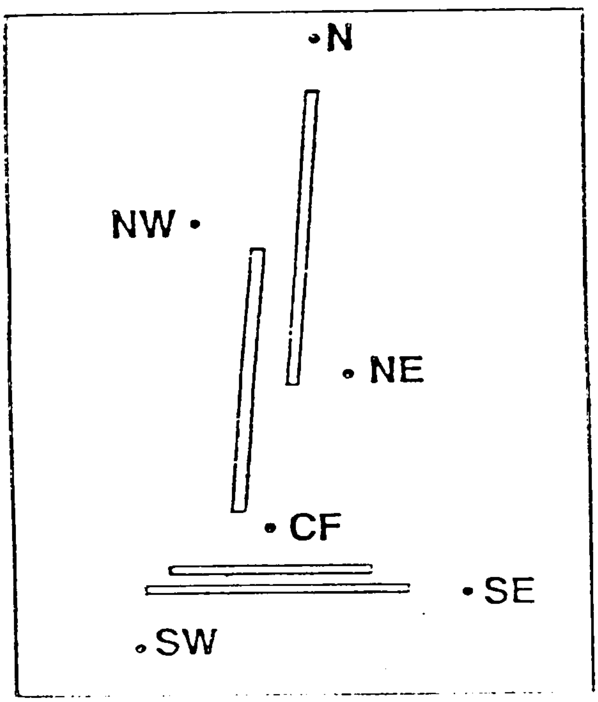
  UNITED FLIGHT 226, RUNWAY 26 LEFT, MICROBURST ALERT, 50 KNOT LOSS, ON THE RUNWAY

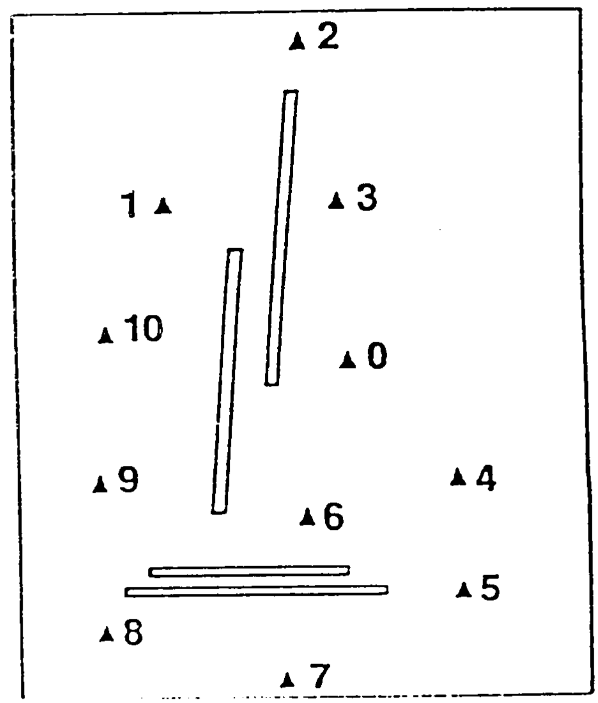
  DELTA FLIGHT 341, RUNWAY 17 RIGHT, WIND SHEAR ALERT, 15 KNOT GAIN, 1 MILE FINAL, THRESHOLD WIND 230 AT 22

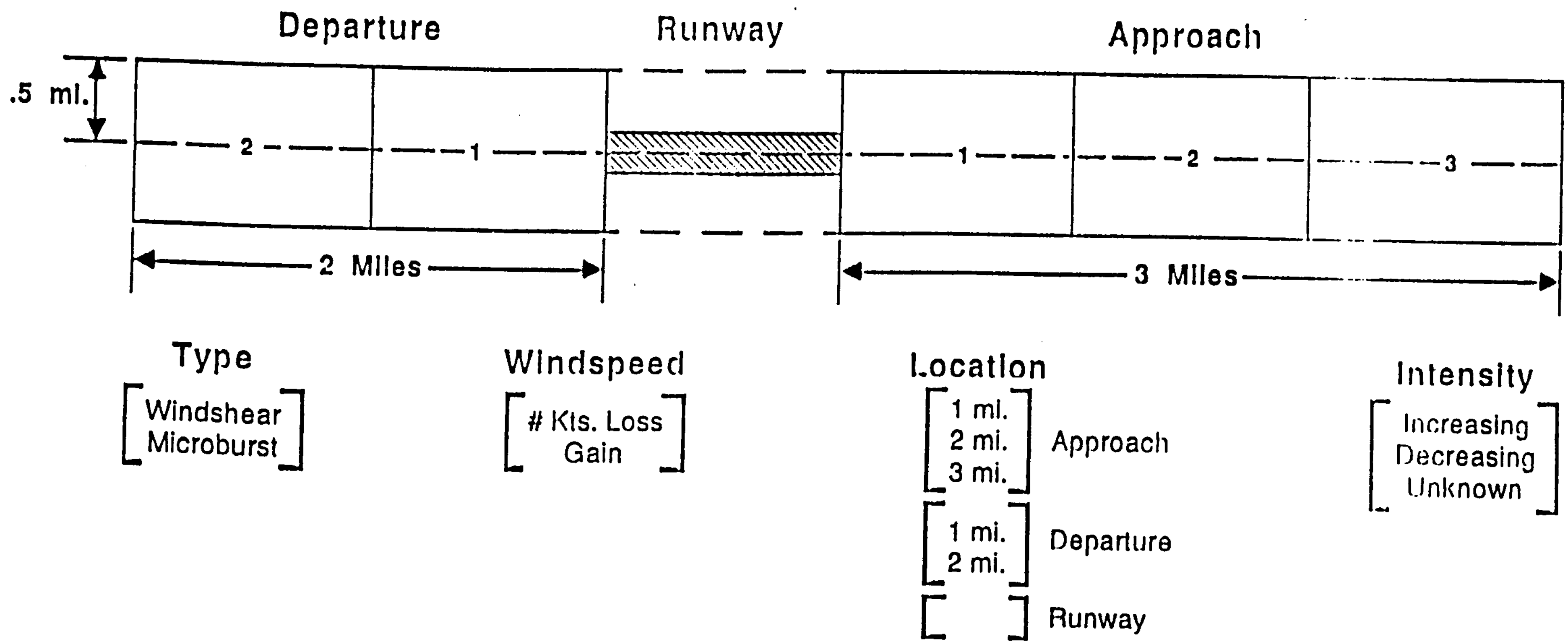
  CESSNA 9477 MIKE, RUNWAY 08 RIGHT, WIND SHEAR ALERT, 15 KNOT SHEAR, 1 MILE FINAL, THRESHOLD WIND 090 AT 15, WIND SHEAR OUTSIDE THE NETWORK

- We are testing a geographical situation map-type display in the tower, to appraise controller interest in such a display.

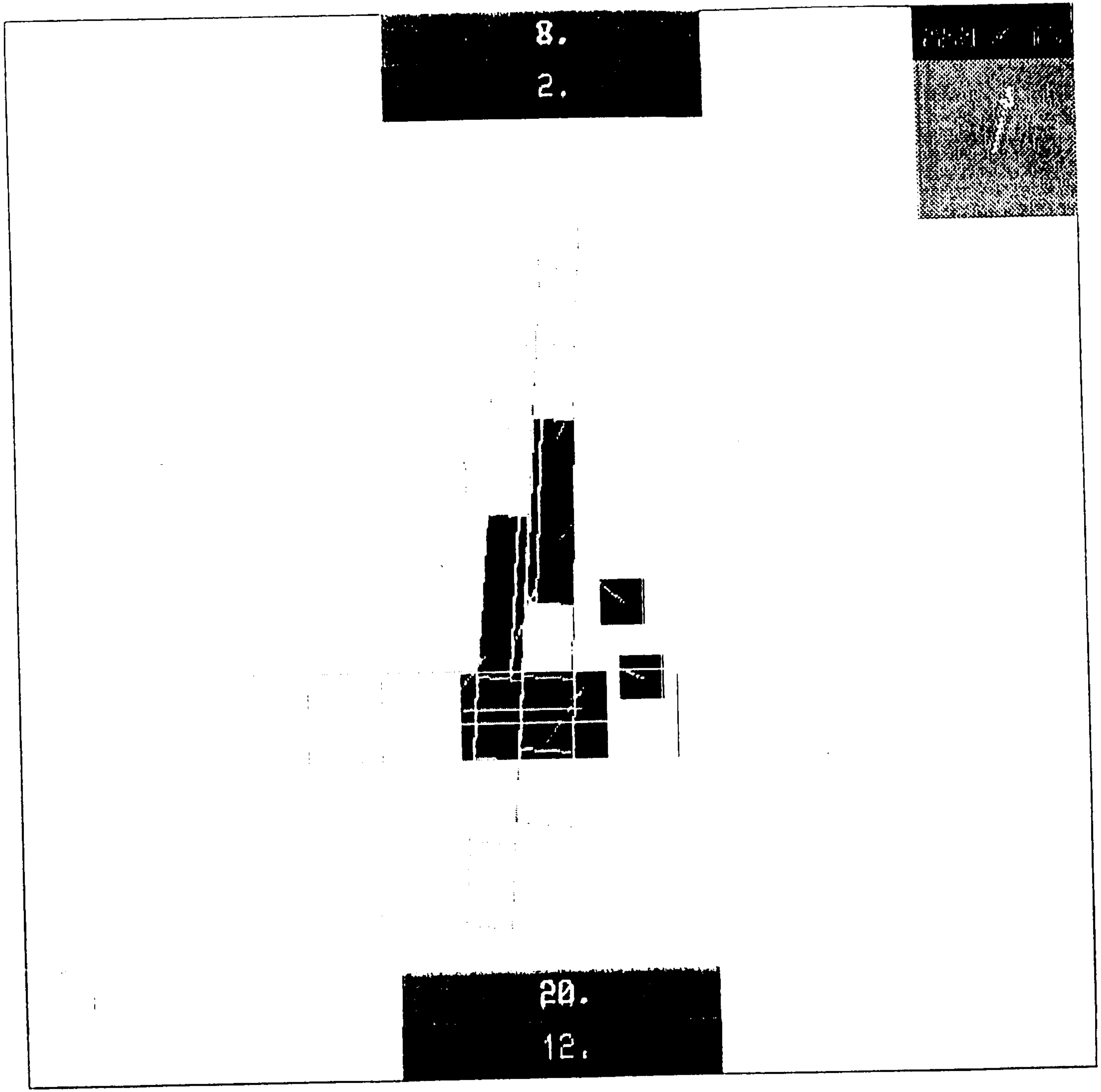
DRAFT






Departure
Runway
Approach
.5 mi.
2
1
1
2
3
2 Miles
3 Miles
Type
Windshear
Microburst
Windspeed
Kts. Loss
Gain
Location
1 mi.
2 mi.
3 mi.
Approach
1 mi.
2 mi.
Departure
Runway
Intensity
Increasing
Decreasing
Unknown

10/ 3/11 0: 1:42



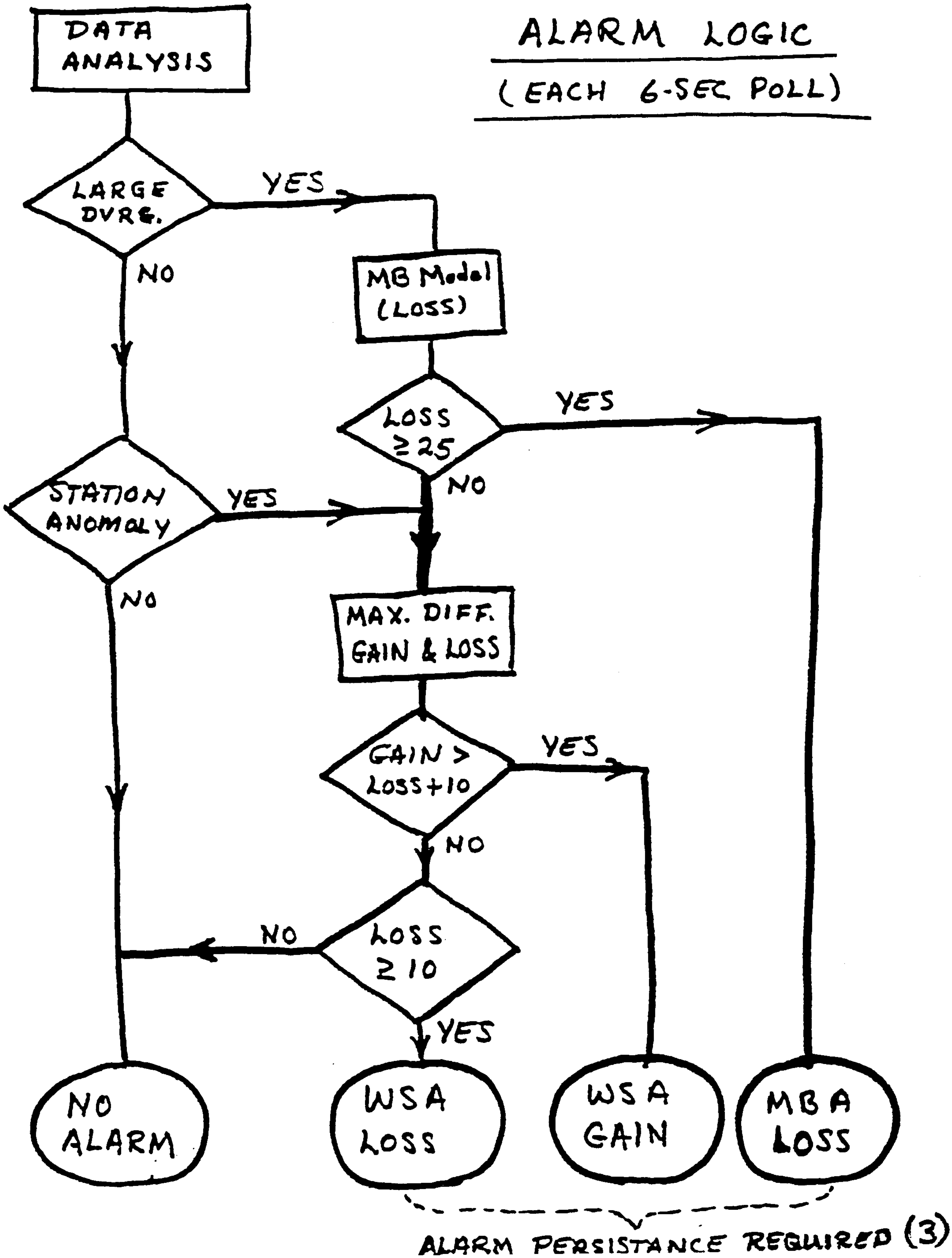
KNOTS
10
20

		CF	190	15 G 25		
MBA	26 A	330	15	G 25	RWY	35-
MBA	8 A	045	15		RWY	20-
MBA	26 D	045	15		RWY	35-
MBA	8 D	330	15	G 25	RWY	20-

CF 190 16 G 25

MBA	35 LD	160	22	G 30	RWY	50-
MBA	35 RD	180	5		RWY	25-
MBA	35 LA	030	23	G 30	1 MF	55-
	35 RA	180	10		3 MF	60-
MBA	17 LA	180	5		RWY	25-
MBA	17 RA	160	22	G 30	RWY	55-
	17 LD	180	10		RWY	60-
MBA	17 RD	030	23	G 30	RWY	55-

CF	280	6
35 LD	270	5
35 RD	290	4
35 LA	CALM	
35 RA	280	6
17 LA	290	4
17 RA	270	5
17 LD	280	6
17 RD	CALM	


ALARM LOGIC
(EACH 6-SEC POLL)
DATA ANALYSIS
LARGE DVRG.
YES
NO
MB Model (LOSS)
LOSS ≥25
YES
NO
STATION ANOMALY
YES
NO
MAX. DIFF. GAIN & LOSS
GAIN > LOSS+10
YES
NO
LOSS ≥10
NO
YES
NO ALARM
WSA LOSS
WSA GAIN
MBA LOSS
ALARM PERSISTANCE REQUIRED (3)

The Enhanced LLWAS issues three kinds of alarms:

MBA: Microburst Alarm (Loss $\geq$ 25)

WSA-: Wind Shear Alarm with LOSS

WSA+: Wind Shear Alarm with GAIN

We have compiled alarm statistics for the months of JUL AUG 1987 and have distinguished between the active afternoon and evening period and the more passive night and morning period. On average, we have found the following:

MONTHLY AVERAGES

	ACTIVE Min/10 Hrs		PASSIVE Min/14 Hrs		COMBINED Min/Day	
	JUL	AUG	JUL	AUG	JUL	AUG
MBA	1.6	.7	.8	.2	2.6	.9
WSA+	4.8	1.9	1.5	.1	6.5	2.0
WSA-	12.3	5.9	1.5	.2	14.3	6.1
Total Alarms	15.5	7.1	3.1	.3	18.2	7.4
CFA		11.2		1.3		12.5

SOME ACTIVE DAYS (min/10 HR)

	MBA	WSA+	WSA-	TOTAL	CFA
AUG 20 (2MB)	7.6	2.9	11.2	18.5	13.1
AUG 4 (THERM)	.5	3.9	5.5	9.0	37.1
AUG 5 (THERM)	3.3	.4	10.9	13.8	18.5

WHAT WE LEARNED FROM THE ADVANCED LLWAS OPERATIONAL DEMONSTRATION

MCCARTHY (OCTOBER 1987)

1. Alpha-numeric message quite successful from controller usage; several minor changes recommended that are being implemented.

2. Advanced LLWAS geographical situation display developed and fielded for NCAR tower meteorologist were successful; provided:

   Advanced LLWAS wind field over runway map in a manner that provided supervisory controller with means of "seeing" two-dimensional wind field at airport, on an approximately 5 n mi radius map overlay. In a non-alert status, this map provided limited ability for supervisor to reconfigure runways, based on prevailing wind situation (of course, wind shift prediction of TDWR would substantially improve this capability, after CLAWS results).

   Map-type display of wind shear alert information, that allowed supervisory controller to reconfigure approach/departures, depending on where alerts were occurring (i.e., if alerts were occurring only on N-S runways, controller would frequently use GSD to determine that E-W runways remained viable.

3. Preliminary Advanced LLWAS algorithm results (general impressions):

   Microburst detection alerted on approximately 25 knot differential (although alert threshold was divergence-dependent). Worked apparently well, except that very rare thermal that appeared divergent alerted system.

   Microburst detection always reported loss, based on a fit to a symmetric microburst model; likely misrepresented wind field on some occasions, presumably due to microburst asymmetries, or to semi-divergent winds imbedded in gust frontal structures.

   Wind shear alerts (station anomaly algorithm) worked very well, except that thermals occasionally fired the alarm; two types of WSAs occurred: wind speed loss, wind speed gain.

   No alarms were sounded if computed runway loss or gain did not exceed ten knots; this was a demonstration glitch - threshold should have been 15 knots. This would have eliminated some inappropriate alarms (alarms that presumably did not represent hazards).

   Some sheltering clearly caused some false alarms; this includes microburst and wind shear alarms.

4. Controller and Pilot feedback; still under review. Initial reactions suggest controllers wildly enthusiastic. All written pilot reaction favorable, but I have observed caution regarding accuracy of advanced LLWAS.

MCCARTHY'S GENERAL IMPRESSION OF ADVANCED LLWAS

1. Operational User Group display product concept very successful; estimate of runway effects, tailored to each runway direction, made quantum advance in terminal information content.

2. Non-alert status of advanced LLWAS provided excellent routine and very useful information to ATC; area supervisor will get advanced LLWAS alpha-numeric display in TRACON; is requesting GSD for supervisors in tower and TRACON.

3. Visual inspection of comparison between wind field seen on advanced LLWAS and alert message indicated at least qualitative and some quantitative agreement; somewhat but not always substantiated by pilots.

4. Advanced LLWAS concept should be cornerstone of TDWR operational display. In non-alert status, advanced LLWAS winds need to be displayed on TDWR 5 and 12? n mi GSD display, and on TDWR alpha-numeric display.

TERMINAL DOPPLER WEATHER RADAR (TDWR)

1987 TESTING:

- Running automatic microburst detection algorithms, off-line, to verify accuracy.
- Maintaining independent assessment of microburst presence; verification of all microbursts present.
- Over 200 microbursts identified within 30 km of Lincoln Lab radar since 18 May 1987!
- Goal is a 90% probability of microburst detection, and a 10% false alarm. Scoring is not yet complete, but results to date are very encouraging.
- Assuming 1987 scoring is satisfactory, plan to have full TDWR operational demonstration in 1988.

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SUMMARY OF TERMINAL DOPPLER WEATHER RADAR ACTIVITIES

SUMMER, 1987

MCCARTHY (10-19-87)

1. Over 300 microbursts identified within 30 km of MIT/Lincoln Lab radar!

2. Microburst surface divergence detection ground truthing provided POD greater than 90% and FAR less than 5 % (target was 90/10).

3. Microburst lines not well identified.

4. Gust front/wind shift detection/prediction not adequate.

ALGORITHM VERIFICATION

AND REFINEMENT PROCESS

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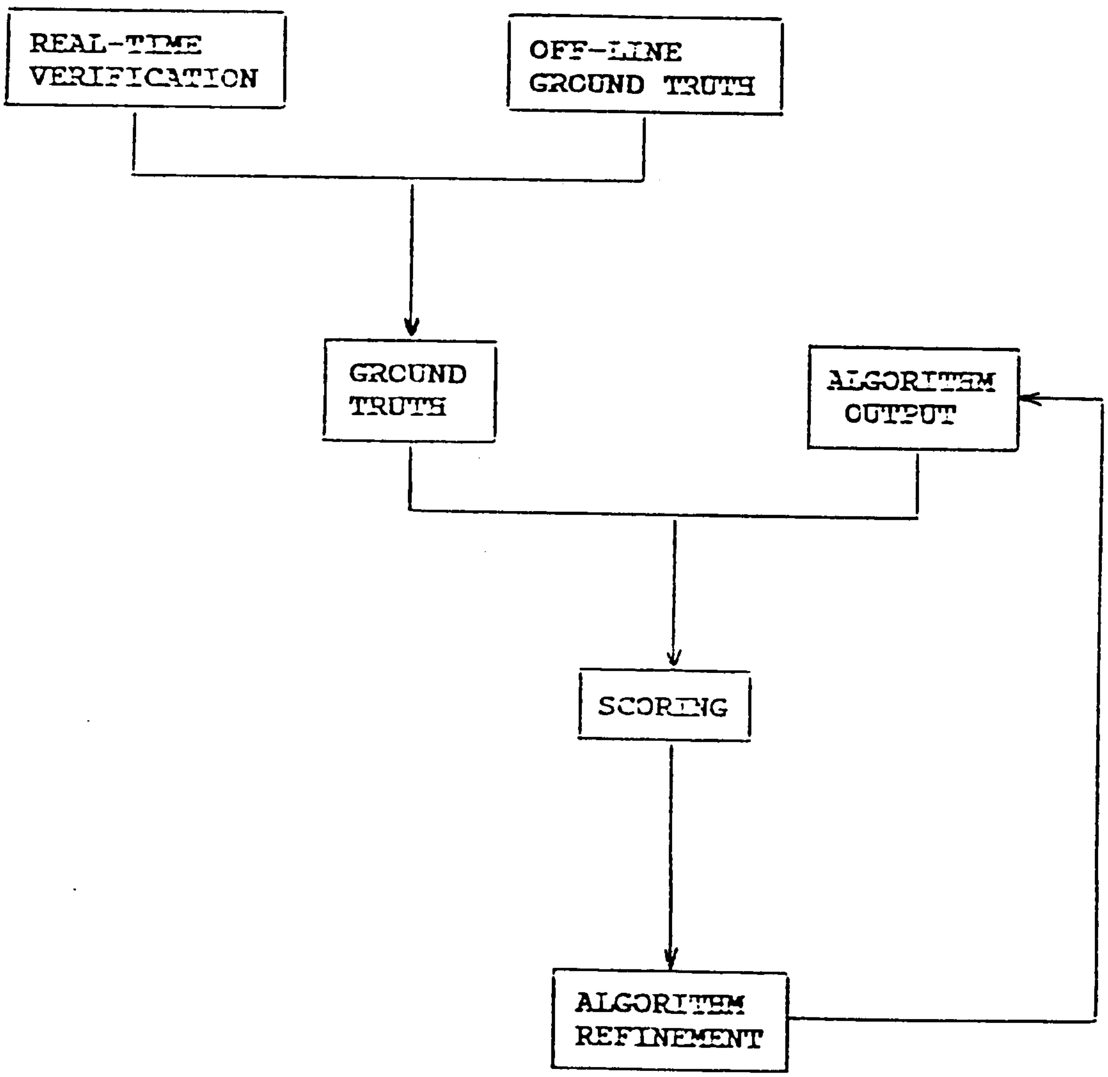

SINGLE-DOPPLER DATA: ASSESS THE FIDELITY OF THE ALGORITHM

DUAL-DOPPLER DATA: ASSESS THE FIDELITY OF THE SYSTEM

PLANS FOR SUMMER, 1988 OPERATIONAL DEMONSTRATION

1. Major RAP concentration on making microburst algorithm output user friendly and displayable to ATC, using model of Operational User Group as demonstrated with Advanced LLWAS; Cleon Biter and Wayne Sand have action here.

2. MIT/LL will concentrate on making 3-D microburst algorithm run faster in real time.

3. NSSL will concentrate on getting gust front/wind shift algorithm to work effectively.

4. RAP will concentrate on developing sophisticated NOWCASTING display system, utilizing Alliant/Symbolics/Pixar combination with Lutz/Barron/J. Wilson talents.

5. Summer, 1989 advanced operational demonstration is anticipated.

LOW-ALTITUDE WIND SHEAR RESEARCH AND DEVELOPMENT

THE MAJOR PLAYERS

<u>THE LLWAS SYSTEM:</u>

FEDERAL AVIATION ADMINISTRATION

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

FAA TECHNICAL CENTER

FAIRCHILD-WESTON, INC.

CLIMATRONICS, INC.

MARTIN-MARIETTA CORP.

<u>THE TDWR PROGRAM:</u>

FEDERAL AVIATION ADMINISTRATION

MIT LINCOLN LABORATORY

NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

NATIONAL SEVERE STORMS LABORATORY

UNIVERSITY OF NORTH DAKOTA

MARTIN-MARIETTA CORP.

TRANSPORTATION SYSTEMS CENTER, DOT

QUESTIONS AND ANSWERS

RICK PAGE (FAA Tech Center) - Jim, just a point of clarification. The graphic display that was in the tower during the period of test in Denver -- I might want to point out to the audience -- was not part of the LLWAS system itself. That display is not part of the LLWAS.

JIM MOORE (NCAR) - If I didn't make that clear, the LLWAS display itself was a this and/or this [pointing to slide]. If there was an alert status, this type of a display would be there and if there was not an alert status there would be this type of a display. The situation display was a separate color graphic--it being used by people like myself and others to help evaluate the system. The issue, the thing though is that the supervisors especially were very interested in that display and did come over and look at that quite often during these events to see what was going on. Not only during the alert situations but during more normal scenarios where they were interested in just what the wind pattern was across the airport.

RICK PAGE (FAA Tech Center) - And another point of clarification, although that graphic display will be looked at in the future, it is not intended to be installed as part of the LLWAS system in the immediate future. I want to make that point clear.

JOHN CHISHOLM (Sierra Nevada Corp.) - Mark Merritt when he was discussing his doppler radar said he had sort of a scorecard or 95% probability 10% false alarms. If you did that for the old LLWAS what would the number be? And what would it be for the new LLWAS? My guess maybe is a ... (paused)

RICK PAGE (FAA Tech Center) - As a result of the summer test we are in the process right now of evaluating in a quick-look report those exact figures. What we did is take an event and we broke the event down into time slices and we evaluated, or are in the process of evaluating, the relationship between the old LLWAS and the new LLWAS. And we will have those figures within the next week or two. The report is in draft status now and that will be available to the community. So you might look for that.

JIM MOORE (NCAR) - In addition, I indicated that we had a doppler radar on the airport that was looking up the runway components as well. At NCAR we are trying to do some analysis with the new LLWAS and comparing that to doppler radar data to see how well we did.

JOHN CHISHOLM (Sierra Nevada Corp.) - One last question. Has anybody said in order to make LLWAS as good as a doppler radar I would have to put out so many anemometers and they would cost so much versus the cost of a TDWR. Is it 100 or 1000 or would it be 2,000,000 dollars versus 5,000,000. Does anybody have a crude number to that? I'm just sort of curious.

JIM MOORE (NCAR) - I don't know that a specific number has been addressed, I do know that there have been studies done with respect to what the spacing needs to be in order to cover a phenomenon like microburst. The number 12 seems to be some reasonable compromise. With respect to the resolution you would get with a doppler radar (which might be 150-200 meters versus what you are able to do here which is on the order of a kilometer), you have a ways to go. I'm not familiar with the exact number that would be required to make the match a true one.

TODD CERNI (OPHIR Corp.) - Just a comment on his question, you have to keep in mind that the surface base sensors don't measure quite the same thing as the remote sensors. That is, the LLWAS does not give you velocity along the glidescope. Okay? So the LLWAS may sound an alarm after the events pass through the glidescope and it's too late. This is part of the problem in the Dallas crash. Another problem with the Dallas crash is that the event was outside the airport property and the LLWAS sounded the alert after the event took place.

EMEDIO BRACALENTE (NASA LaRC) - Are these measurements made at 10 meters altitude? How high are they above the ground.

JIM MOORE (NCAR) - That's the standard height but there is some variation. In the Denver area, especially to the west of the airport there is the problem with a tree canopy very close to the end of the runway. So they actually had to run the tower up through the trees.

EMEDIO BRACALENTE (NASA LaRC) - Has there been any thought given to doing profiling to try to get winds at higher altitude by acoustic techniques or whatever that looks up, would that be useful information if that could be gathered?

JIM MOORE (NCAR) - Well there is a profiler in Denver for which data is provided to go back to several of the groups in Boulder. At that point it still is a point observation and if you have a microburst that is not right on the beam, you are never going to ... (paused)

EMEDIO BRACALENTE (NASA LaRC) - Well I was thinking at every LLWAS location to have a profile in addition to it.

JIM MOORE (NCAR) - That could get pretty pricey.

HERB SCHLICKENMAIER (FAA) - Well, if I can add--and Rick you can probably update this even more--there was some work looking into using acoustics, lasers, not as a profiler but as a replacement for 1000 ft. tall towers. As Jim was saying, with the practical day-to-day things that the LLWAS program has been dealing with for years, one of those practical problems is very very tall towers to get out of obstruction-type shear. Some consideration has been given to it at this point--some very preliminary tests have been going on. It is, in essence, to reproduce what an anemometer does, and also be able to program the height without all the mechanical constraints of a tower. I noticed there was about one more question to go.

BUD LAYNOR (NTSB) - Just in addressing the gentlemen's question on the TDWR comparison with the LLWAS, I thought maybe Mark might want to address some aspect of that. But it was our impression that the TDWR can also be used to look at the upper level convergence or the twisting of the core which would provide some lead-time predictive capability that the LLWAS is never going to provide. Even if you did go out beyond the field with the anemometers on the surface.

JIM MOORE (NCAR)- Well I think John's [Chisholm] question was only with reference to making a surface-similar type, the lowest level scan and what the comparison might be.

BUD LAYNOR (NTSB) - Well I agree, but I think that if the algorithm can be developed to give lead time it certainly is very important.

JIM MOORE (NCAR) - Yes, the predictive capabilities of the radar clearly outweigh whatever LLWAS ... (paused)

BUD LAYNOR (NTSB) - And the other question I'll ask Rick Page is: I don't understand why the FAA would be reluctant to put the CRT display in the towers as part of the LLWAS, or certainly as part of the TDWR when it comes along. If it is indeed as effective for the supervisor as it seemed to me as it was when I was out in the Denver tower.

RICK PAGE (FAA Tech Center) - I did not say we were reluctant to put it in. I just said that there were no immediate plans to put it in the tower. We will be looking at that particular display and other types of graphic representation of the data. It is just that that particular display (although it was in the Denver tower--and it was being looked at by the supervisors) for reconfiguration of runways was not part of the test, and the data that we acquired and the decisions we were making in relationship to the display itself did not include this particular display. That is why I made the distinction. The reports that we will be issuing will be based upon the CRT display.