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N93-19606

Session V. Doppler Related Research

Algorithms for Airborne Doppler Radar Wind Shear Detection

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ALGORITHMS FOR AIRBORNE DOPPLER RADAR WIND SHEAR DETECTION

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ABSTRACT

Honeywell has developed algorithms for the detection of wind shear/microburst using airborne Doppler radar. The Honeywell algorithms use three dimensional pattern recognition techniques and the selection of an associated scanning pattern forward of the aircraft. This "volumetric scan" approach acquires reflectivity, velocity and spectral width from a three dimensional volume as opposed to the conventional use of a two dimensional azimuthal slice of data at a fixed elevation. The algorithm approach is based on detection and classification of velocity patterns which are indicative of microburst phenomenon while minimizing the false alarms due to ground clutter return. Simulation studies of microburst phenomenon and X-band radar interaction with the microburst have been performed and results of that study are presented. Algorithm performance in detection of both "wet" and "dry" microbursts is presented.

SLIDE 1

Title Slide

SLIDE 2

The development of algorithms for detection of wind shear/microburst using airborne Doppler radar is a part of a larger Honeywell effort for the development of an Enhanced Situation Awareness System (ESAS). This multifunction system will increase pilot situation awareness through provision of landing guidance in adverse weather, detection of severe weather, detection of severe weather, detection of microburst/wind shear, detection of wake vortices and clear air turbulence. This integrated system seeks to provide the above functionality with minimal impact to the aircraft and minimal requirements for additional hardware.

SLIDE 3

The Honeywell remote windshear detection research has concentrated on development of algorithms which are not based on any particular sensor technology. The algorithms require measurements of air mass velocities that could be provided by laser doppler velocimeters, other types of laser radar as well as Doppler weather radar. The algorithm approach is based on detection and classification of velocity patterns which are indicative of microburst phenomenon while minimizing the false alarms due to ground clutter return. These algorithms have been developed and tested using the NASA-Langley Airborne Windshear Doppler Radar Simulation (AWDRS) and modeling of X-band Doppler radar characteristics.

SLIDE 4

The core of the Honeywell approach is the use of three dimensional pattern recognition techniques and the selection of an associated scanning pattern forward of the aircraft. This "volumetric scan" approach acquires reflectivity, velocity and spectral width from a three dimensional volume as opposed to the conventional use of a two dimensional azimuthal slice of data at a fixed elevation. For each volume element (voxel) in azimuth-elevation-range space the radar provides measurements of reflected power, mean velocity and spectral width. Receiver noise characteristics are measured and used to enhance the quality of the received data. Four separate types of features are then identified including regions of positive and negative divergence, regions of high reflectivity, regions of rotation and regions with similar spectral width. These regions are then collectively assessed by a three dimensional association algorithm which identifies three dimensional features which are associated clusters of the four basic feature types listed above. These three dimensional features are then compared with known attributes of microburst phenomenon and temporally tracked to identify those three dimensional features which are indications of microbursts.

SLIDE 5

These algorithms have been developed and tested using the NASA-Langley Airborne Windshear Doppler Radar Simulation (AWDRS) and modeling of X-band Doppler radar characteristics. We have modified the software for operation on our Sun workstations. It has also been modified to provide data from a simulated volumetric scan pattern and provides simulated output characteristic of that expected from nominal X-band Doppler radar using a Honeywell 12-inch flat plate antenna which produces an 8° beamwidth. We have been using the axisymmetric models developed in the past and are now upgrading the software to include the newer three dimensional models recently released.

SLIDE 6

The Honeywell approach was developed to minimize probability of false alarms at an acceptable detection capability. This is accomplished by the use of full three dimensional correlation approaches which reject those features which are characteristic of ground clutter and are not supported by measurements throughout the three dimensional scanning volume. Temporal tracking is used to assure the rejection of transient phenomenon. Additional information is also used to reduce false alarm rate including thresholding using the F-Factor hazard level, assessment of spectral width characteristics and comparison of the physical size of the hazard with known phenomenological understanding and aircraft upset requirements.

SLIDE 7

The volumetric velocity and hazard region data for a "wet" microburst (core reflectivity of 60 dBz) event is shown for three elevation scans at 0°, 20° and 40° elevations. This data is simulated for a 1kW radar utilizing a Honeywell 12-inch antenna with a pulse repetition frequency of 6kHz and a pulse width of 1μsec. As is shown there is a large region at near ground level where significant hazard is identified. Note the extension of velocity and hazard features above in the 20° and 40° slices.

SLIDE 8

The reflectivity, Doppler velocity, intermediate data and final identified hazard region data for a "wet" microburst (core reflectivity of 60 dBz) event is shown. This data is simulated for a 1kW radar utilizing a Honeywell 12-inch antenna with a pulse repetition frequency of 6kHz and a pulse width of 1μsec. As is shown there is a large region at near ground level where significant hazard is identified. Note the rejection of spurious hazard regions surrounding the actual hazard region.

SLIDE 9

The volumetric velocity and hazard region data for a "dry" microburst (core reflectivity of 25 dBz) event is shown for three elevation scans at 0°, 20° and 40° elevations. This data is simulated for a 1kW radar utilizing a Honeywell 12-inch antenna with a pulse repetition frequency of 6kHz and a pulse width of 1μsec. As is shown there is a large amounts of clutter at near ground level. Note the extension of hazard features above in the 20° and 40° slices which eliminates most of the ground clutter as potential microbursts.

SLIDE 10

The reflectivity, Doppler velocity, intermediate data and final identified hazard region data for a "dry" microburst (core reflectivity of 25 dBz) event is shown. This data is simulated for a 1kW radar utilizing a Honeywell 12-inch antenna with a pulse repetition frequency of 6kHz and a pulse width of 1μsec. As is shown there is a large amounts of clutter at near ground level. Note the rejection of the significant level spurious hazard regions surrounding the actual hazard region

SLIDE 11

Honeywell is continuing the development of algorithms for detection of wind shear/microburst using airborne Doppler radar as well as developing data fusion approaches to utilize data provided from remote sensors as well as in-situ sensors for an overall integrated wind shear detection system. We anticipate testing of the algorithms using flight test data in 1992 and continued development of optimal guidance approaches exploiting data from remote sensors and in-situ sensors.

Algorithms for Airborne Doppler Radar Wind Shear Detection

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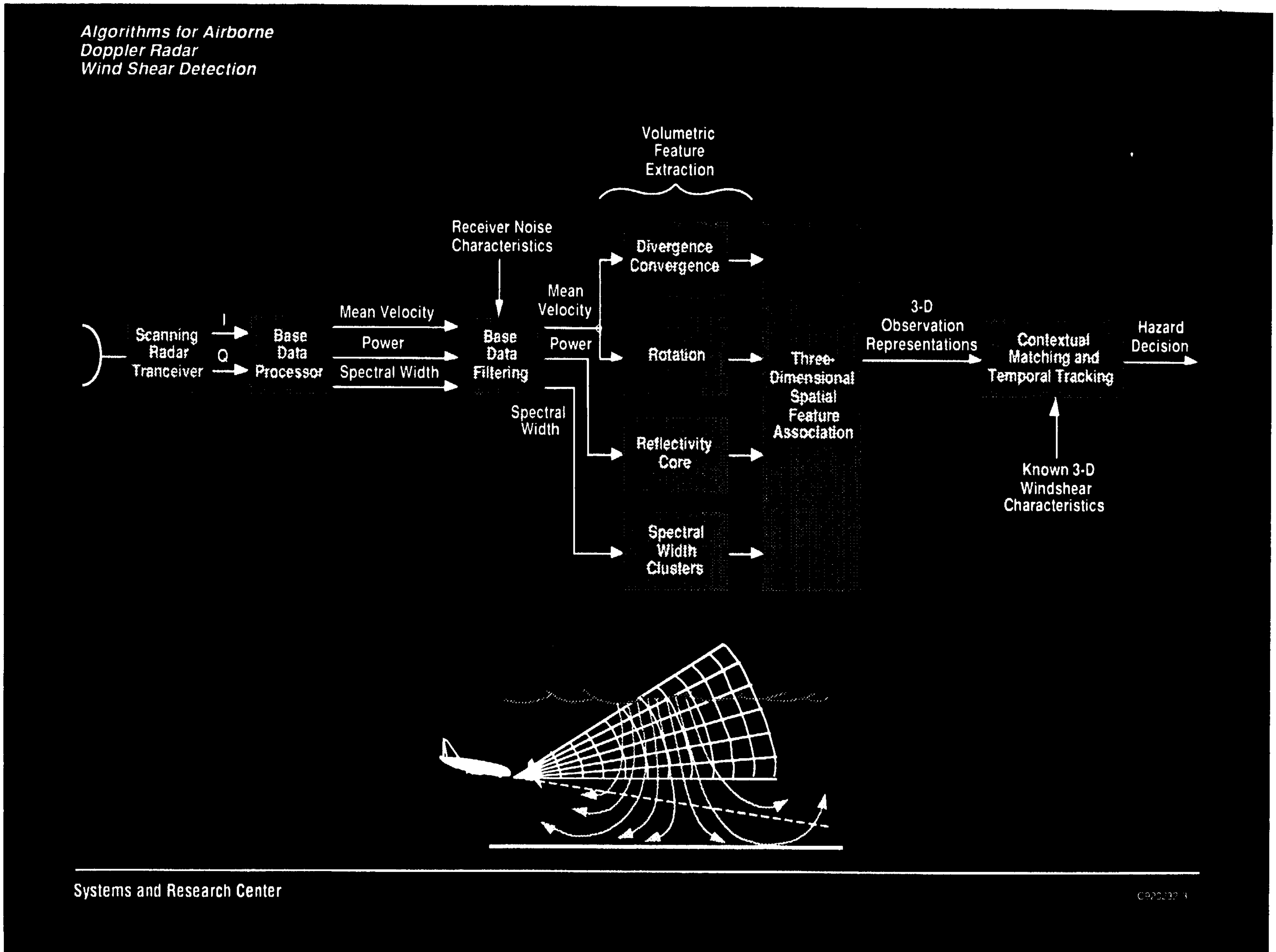
Enhanced Situation Awareness System (ESAS)

- Growing interest in ESASs for military and commercial aircraft
- ESAS required to provide situation awareness through
  - Adverse weather landing guidance
  - Detection of severe weather
  - Detection of microburst/wind shear
  - Detection of wake vortices
  - Detection of clear air turbulence

Honeywell Remote Wind Shear Detection Research

- Honeywell algorithm is not sensor-specific—velocity measurements required
  - LDV
  - Laser radar
  - Weather radar
- Based on locating velocity patterns indicative of hazardous wind shear while eliminating problems caused by ground clutter
- Microburst-specific algorithms developed and tested using NASA-Langley simulated data and X-band radar sensor model


Algorithms for Airborne
Doppler Radar
Wind Shear Detection
Scanning Radar Tranceiver
I
Q
Base Data Processor
Mean Velocity
Power
Spectral Width
Receiver Noise Characteristics
Base Data Filtering
Mean Velocity
Power
Spectral Width
Volumetric Feature Extraction
Divergence Convergence
Rotation
Reflectivity Core
Spectral Width Clusters
Three-Dimensional Spatial Feature Association
3-D Observation Representations
Contextual Matching and Temporal Tracking
Known 3-D Windshear Characteristics
Hazard Decision
Systems and Research Center

Radar/Microburst/ Clutter Modeling

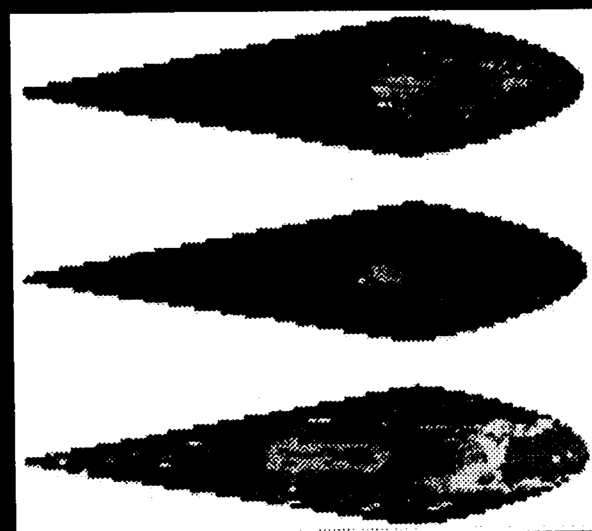
- Utilized NASA-Langley airborne windshear doppler radar simulation (AWDRS)
- Modified software/parameters
  - Hosted on Sun workstation
  - Volumetric scan pattern
  - Generic X-band doppler radar parameters
  - Pattern for 12" Honeywell antenna (8° beamwidth)
- Currently upgrading to use the newer 3-D microburst models

Clutter Rejection

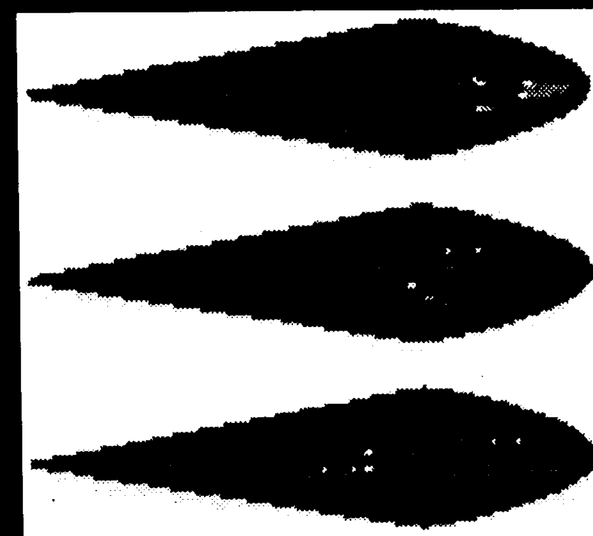
- Clutter rejection accomplished through registration of features throughout full 3-D scanned data
- Only those features that are correlated throughout the 3-D scan and which that a priori definitions of wind shear phenomenon are considered hazards
- Temporal tracking/filtering used to reduce false alarm rate
- Additional thresholds regarding hazard characteristics
  - F-factor hazard level
  - Spectral width characteristics
  - Physical size

Volumetric Feature Grouping Identifies Microburst Windshear

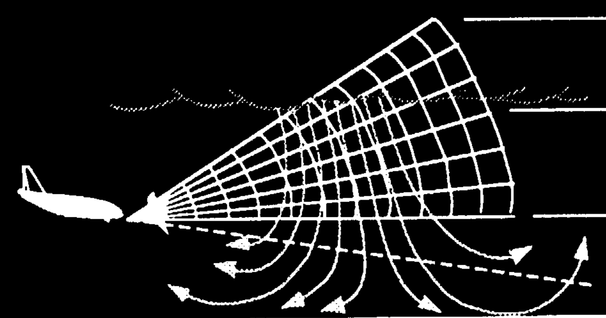
"Wet" Microburst

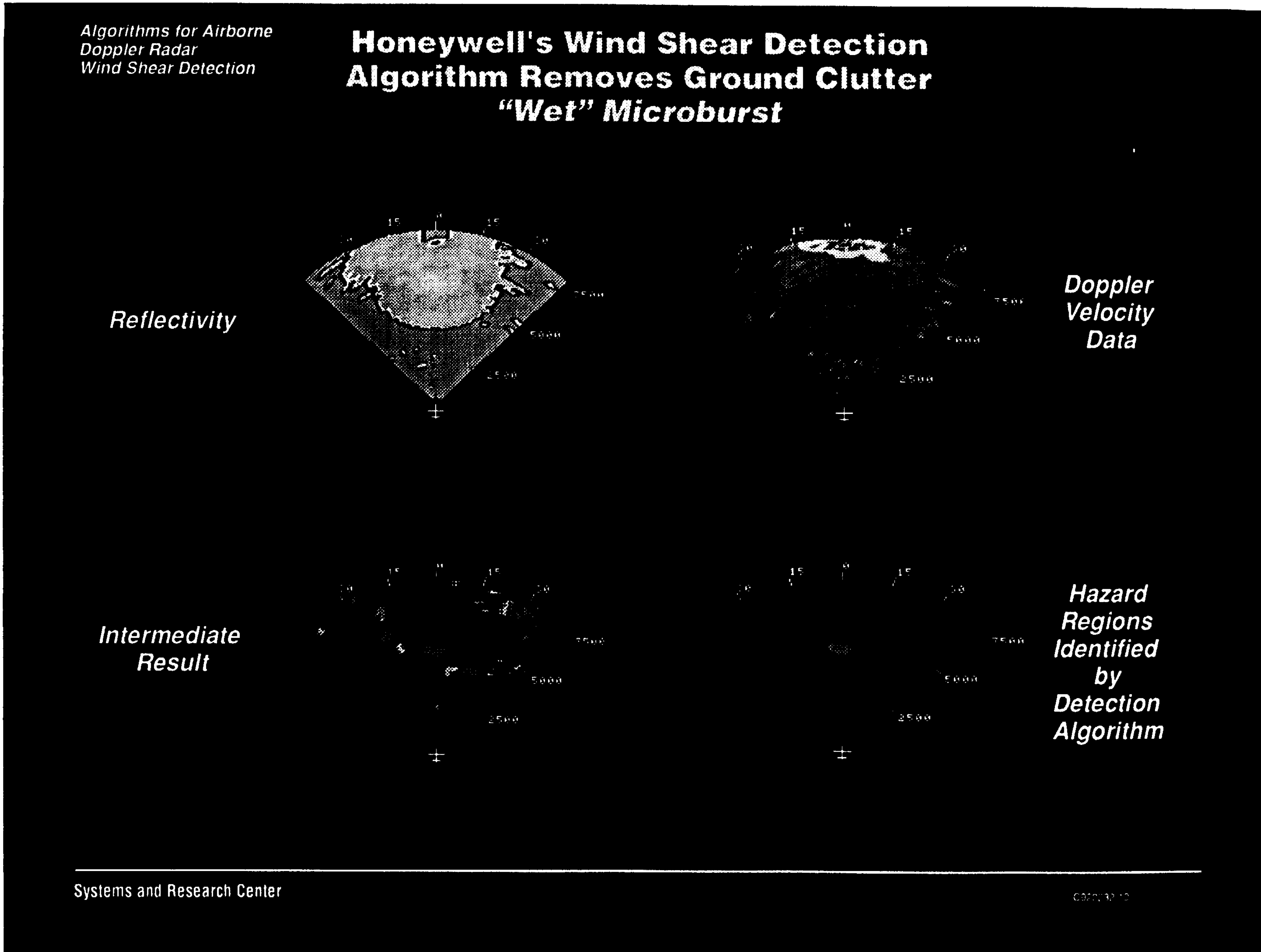


Doppler Velocity "Slices"



Identified Hazard Region "Slices"

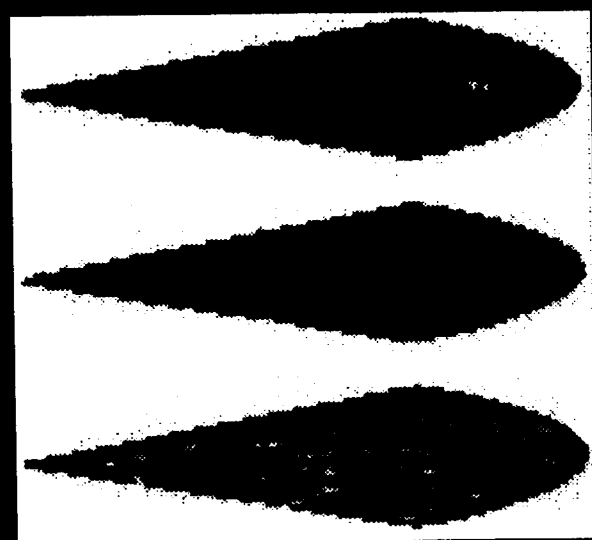



Algorithms for Airborne
Doppler Radar
Wind Shear Detection
Honeywell's Wind Shear Detection
Algorithm Removes Ground Clutter
"Wet" Microburst
Reflectivity
Doppler
Velocity
Data
Intermediate
Result
Hazard
Regions
Identified
by
Detection
Algorithm
Systems and Research Center

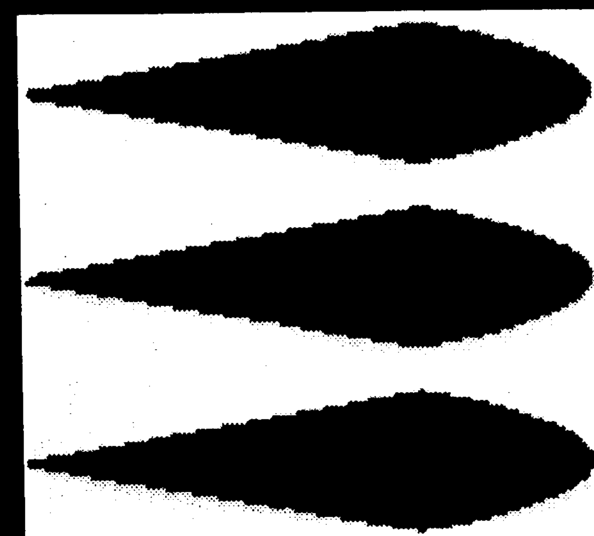
Algorithms for Airborne
Doppler Radar
Wind Shear Detection

Volumetric Feature Grouping Identifies Microburst Windshear

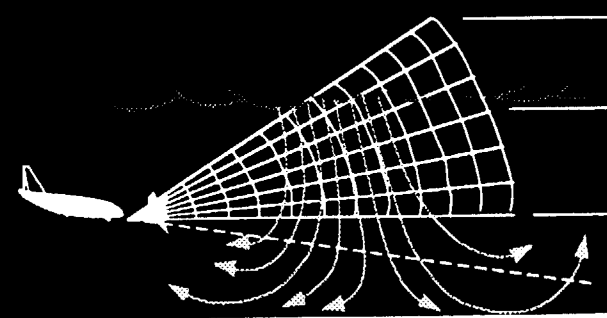
"Dry" Microburst



Dopper Velocity "Slices"



Identified Hazard Region "Slices"



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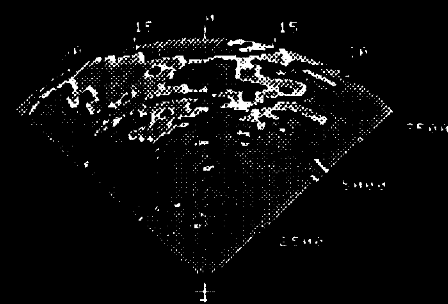
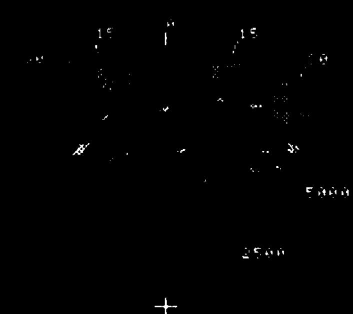
Honeywell's Wind Shear Detection Algorithm Removes Ground Clutter
"Dry" Microburst

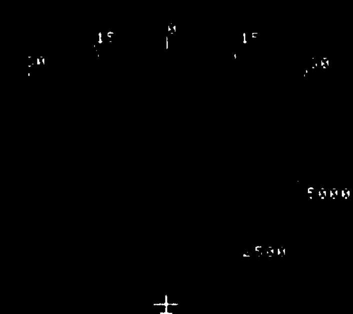
Reflectivity



Doppler Velocity Data

Intermediate Result





Hazard Regions Identified by Detection Algorithm

Future Plans

- Continued development and fusion with in situ/reactive sensors and algorithms
- Potential flight testing in 1992
- Development of optimal guidance algorithms using remote detection data

Algorithms for Airborne Doppler Radar Wind Shear Detection
Questions and Answers

Q: Kim Elmore (NCAR) - What did you use as a basis for using spectrum width estimates as an indicator of a hazard? Also, simply as a caveat, we found that in the Denver environment the use of rotation and convergence aloft does not seem to work very well as an estimation of whether the storm is actively producing a microburst or will produce one. It does work in the wet kind of environments in the South East, but it doesn't seem to work very well for us. Jim Wilson and Rita Roberts spent quite some time on that and finally threw up their hands in despair. How do you plan to address that, if this is going to be a primary constituent of the hazard determination. Secondly, what did you use as the basis to utilize spectrum width as a hazard estimation?

A: Earl Benser (Honeywell) - Right now there is a minimum and maximum spectral width threshold set that are used. We also look for areas that are of common spectral width for the volumetric feature recognition. So those are the two approaches that we have been using in terms of spectral width thresholding for detection. In terms of the correlation of all the volumetric features simultaneously, we do not necessarily demand that they are all simultaneously present, but we use the lack of all features as a part of the clutter rejection approach.

Q: Kim Elmore (NCAR) - I am curious as to where you got your information to form a hypothesis about spectral width associations.

A: Earl Benser (Honeywell) - I guess I am not necessarily familiar with those details of the activity.

Kim Elmore (NCAR) - Again, I wound up spending a lot of time chasing spectral width on Denver storms, and we found that it was next to useless. It was extremely viewing angle dependent. It may well be that you have done some sort of correlation with your beam width and what kind of spectral width you can expect from a meteorological aspect. That may have some utility. But, the work we did with our radars showed that it was not necessarily a good indicator.

Earl Benser (Honeywell) - As I understand it, and again I am not necessarily familiar with the details of that particular part of the algorithm, there are spectrum widths that are consistent with the type of phenomenon we are looking at. Things that have very little spectral width tend to be point targets as opposed to distributed targets that have relatively moderate spectral widths. The large spectral widths, as I understand it, are somewhat noisy. Anyway, the basic point is that there is activity going on in that area. I am not really familiar with the details.

Q: Paul Robinson (Lockheed) - From your slides it looks like you could estimate the hazard at zero degrees relative to the horizon, but you had the airplane flight path that looked like it was three degrees down. Does that not mean that you are looking at a hazard that the airplane may not encounter and perhaps underestimating that hazard?

A: Earl Benser (Honeywell) - The analysis that was presented today showed results where we looked at zero up to 40 degrees in 10 degree slices. Our activity right now is looking at specific scan pattern issues with respect to overall scan rate, scan range, and scan resolution.

Q: Paul Robinson (Lockheed) - Is there some reason why the program may not work looking three degrees down?

A: Earl Benser (Honeywell) - We do not have any reason to believe that it should not work. We have not completed the testing. Zero degrees was the initial completed activity.

Q: Dan Vicroy (NASA Langley) - Are you estimating a vertical winds? The fact that you are doing multiple vertical scans allows you to do some pretty interesting things in the vertical domain.

A: Earl Benser (Honeywell) - We have not gotten that far in our efforts. To date we have been looking at merely the in-plane velocity information, for detection of areas with consistent shear numbers for feature identification. We have not gotten to the point to either map out the vertical velocity structure within the events or to develop an F-factor estimate based on that initial data.

Session VI. Airborne Doppler Radar / NASA

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