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RADAR SIMULATION PROGRAM UPGRADE & ALGORITHM DEVELOPMENT

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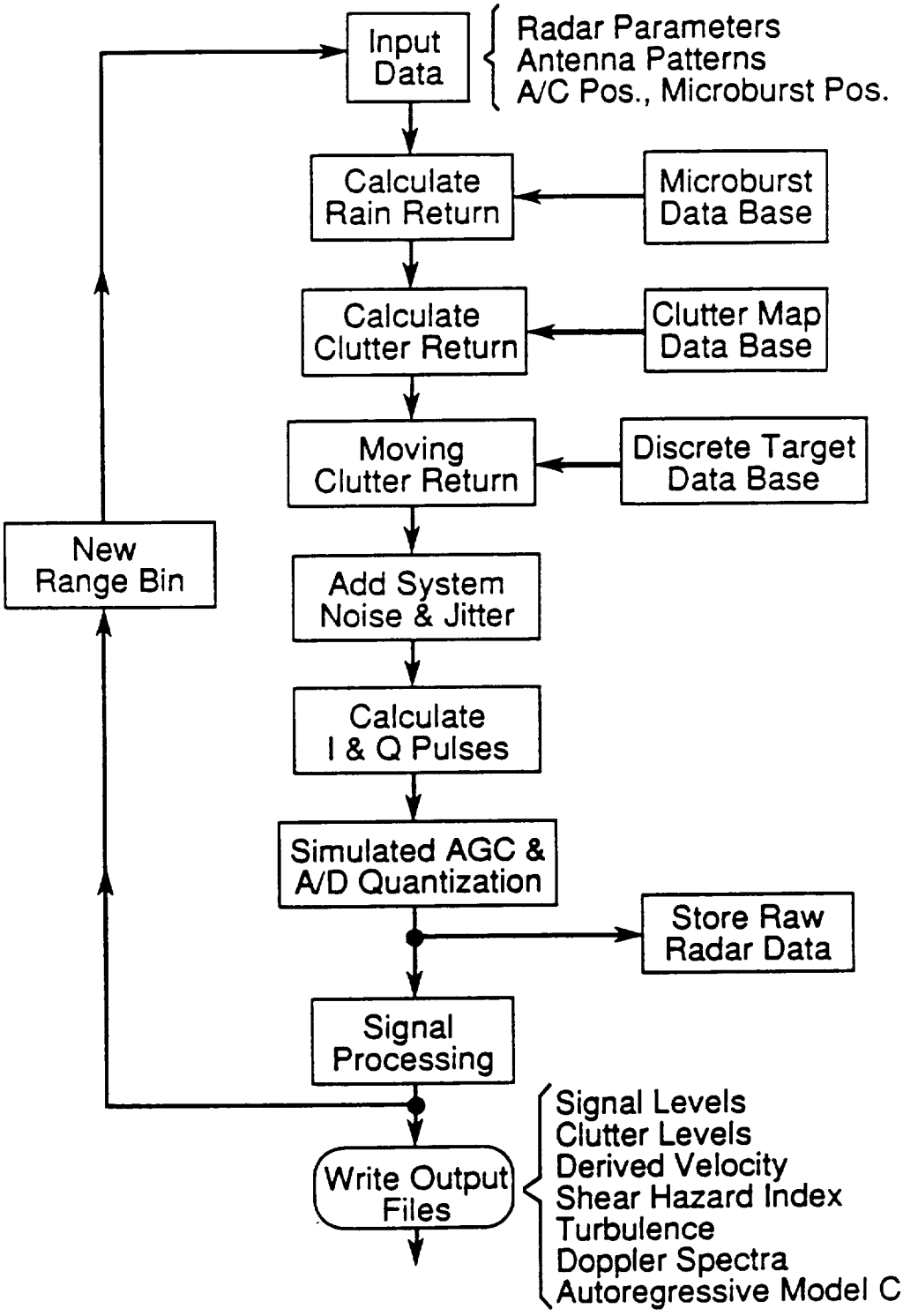
Radar Simulation

This is a block diagram of the NASA Radar Simulation program which was discussed extensively at the previous meeting. The radar simulation program is a comprehensive calculation of the expected output of an airborne coherent pulse Doppler Radar system viewing a low level microburst along or near the approach path. Inputs to the program include the radar system parameters and data files that contain the characteristics of the microbursts to be simulated, the ground clutter map, and a discrete target data base which provides a simulation of moving ground clutter. The data bases used in the simulation have been discussed previously.

For each range bin, the simulation calculates the received signal amplitude level by integrating the product of the antenna gain pattern and the scattering source amplitude and phase of a spherical shell volume segment defined by the pulse width, radar range and ground plane intersection. A series of in-phase and quadrature pulses are generated and stored for further processing if desired. In addition, various signal processing techniques are used to derive the simulated velocity and hazard measurements and stored for use in plotting and display programs.

RADAR SIMULATION



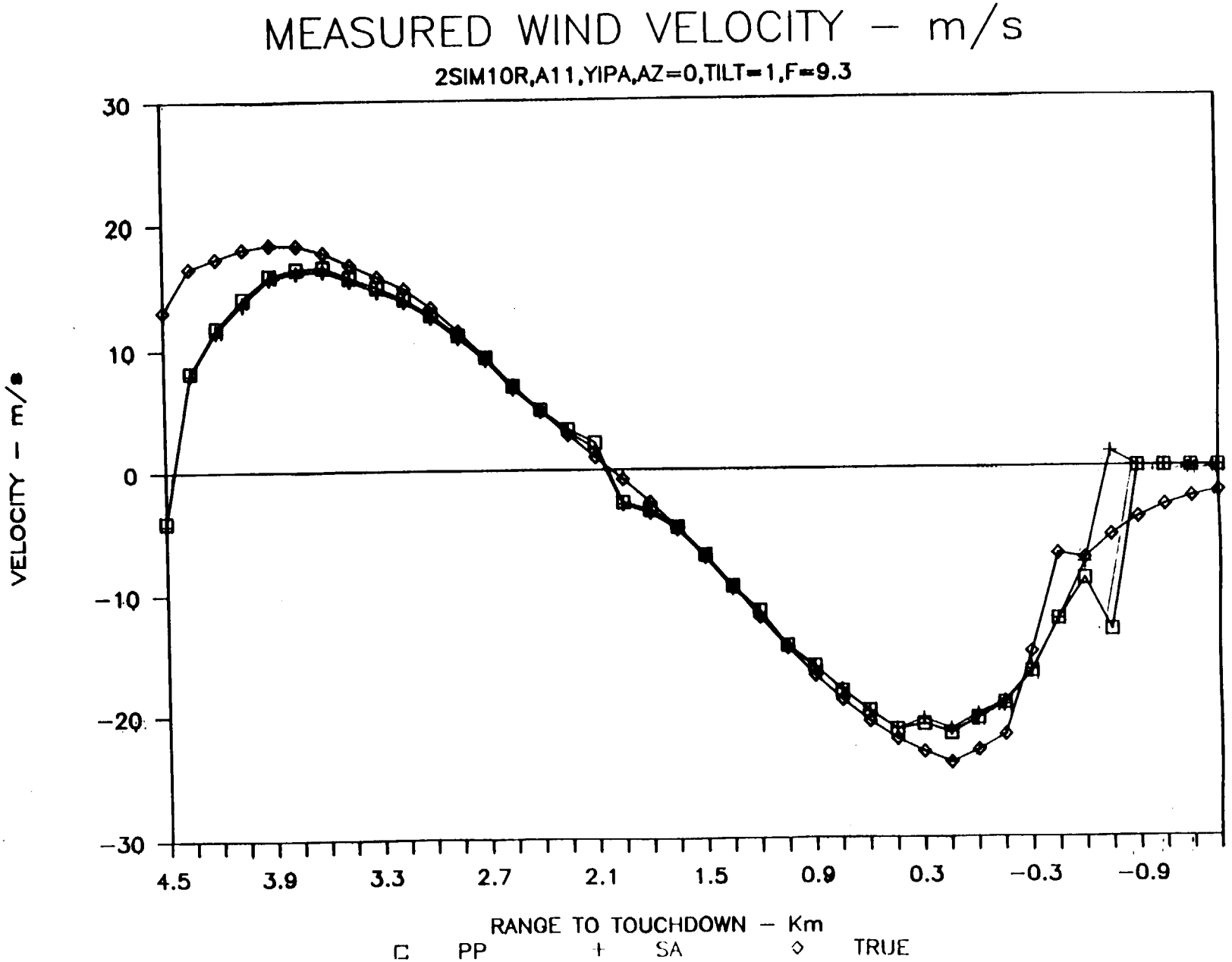
Airborne Doppler Radar Detection of Microburst Windshear

This view graph shows the situation that has been simulated using the radar simulation program. An aircraft on the glide slope encounters a microburst on the path between the aircraft and the touchdown point. This situation has been selected because it provides the most severe clutter environment for the radar.

AIRBORNE DOPPLER RADAR DETECTION OF MICROBURST WINDSHEAR

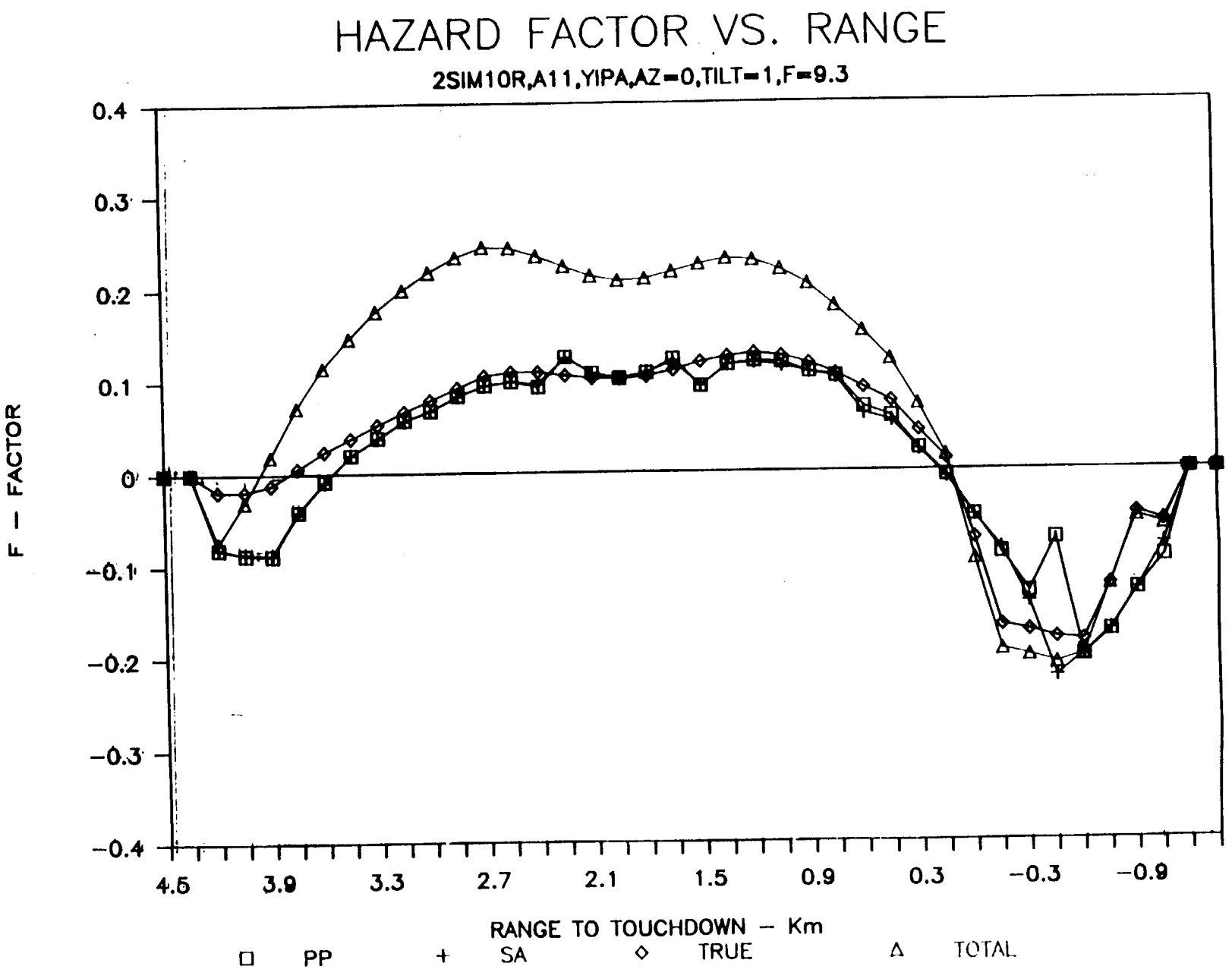
Measured Wind Velocity

The following view graphs indicate examples of the outputs of the radar simulation program. View graph 3 shows the measured wind velocity plotted versus range-to-touchdown for pulse-pair and spectral average processing. In addition, the "true" wind velocity is plotted for comparison.


MEASURED WIND VELOCITY – m/s
2SIM10R,A11,YIPA,AZ=0,TILT=1,F=9.3
VELOCITY – m/s
30
20
10
0
-10
-20
-30
4.5
3.9
3.3
2.7
2.1
1.5
0.9
0.3
-0.3
-0.9
RANGE TO TOUCHDOWN – Km
PP
SA
TRUE

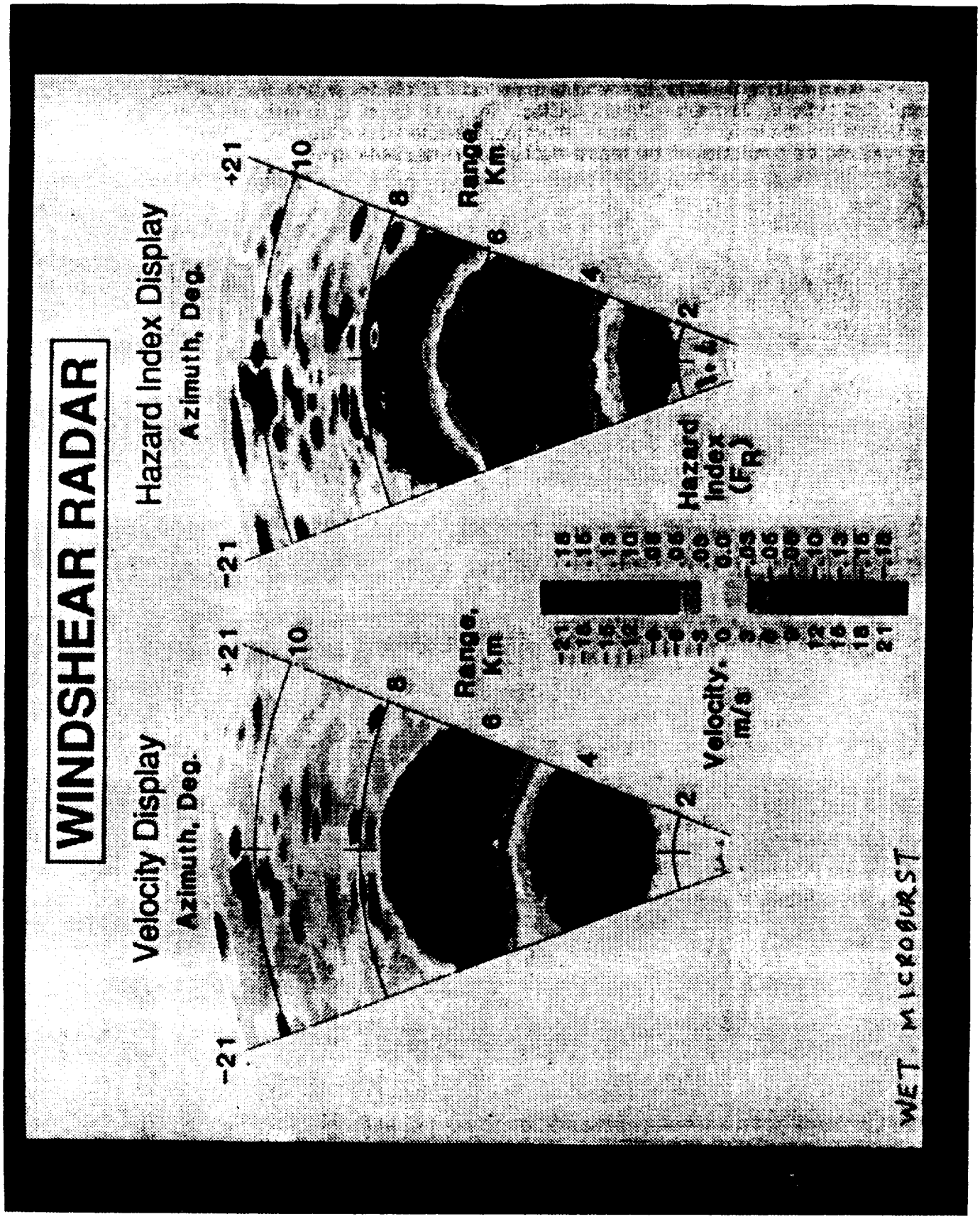
Hazard Factor Vs. Range

View Graph 4 provides another example of the simulation output. In this case the hazard factor is plotted versus range for both pulse-pair and spectral average processing. In addition, true hazard factor and the total hazard factor is plotted. The total hazard factor includes the vertical component of the hazard factor calculation (the vertical component is not measured by the radar).


HAZARD FACTOR VS. RANGE
2SIM10R,A11,YIPA,AZ=0,TILT=1,F=9.3
F – FACTOR
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
4.5
3.9
3.3
2.7
2.1
1.5
0.9
0.3
-0.3
-0.9
RANGE TO TOUCHDOWN – Km
□ PP
+ SA
◇ TRUE
Δ TOTAL

Windshear Radar Display

View Graph 5 shows the examples of simulated sector scans produced by the radar simulation program. A false color display of radar measured velocity and hazard index are shown. The hazard index display clearly shows areas in which the hazard index exceeds a given value.



Simulation Improvements

View Graph 6 lists the major improvements to the radar simulation program that have been accomplished since the last manufacturers meeting. The major topics to be discussed in the talk include the development of the hazard detection, characterization and threat alarm algorithms and the completion of the hazard display and alarm simulation.

SIMULATION IMPROVEMENTS

- Incorporation of moving ground clutter.
- Simulation of asymmetrical (3-D) microbursts.
- Addition of simulated automatic antenna tilt control.
- Addition of autoregressive model calculations.
- Development of hazard detection, characterization and threat alarm algorithms.
- Completion of hazard display and alarm simulation.

Windshear Radar Alarm Algorithms

View graph 7 indicates the requirements that the windshear radar alarm algorithms must meet in order to provide an alarm to the aircrew. These requirements include detection, characterization of the hazard and evaluation of the threat to the aircraft.

WINDSHEAR RADAR ALARM ALGORITHMS

- Detect hazardous windshear.
- Compute location, extent and motion of hazardous area.
- Evaluate threat to aircraft and provide timely alarm.

Detection of Hazard

View graph 8 indicates the techniques and algorithms used in the simulation (and to be used in the NASA experimental weather radar) to detect a hazardous windshear situation.

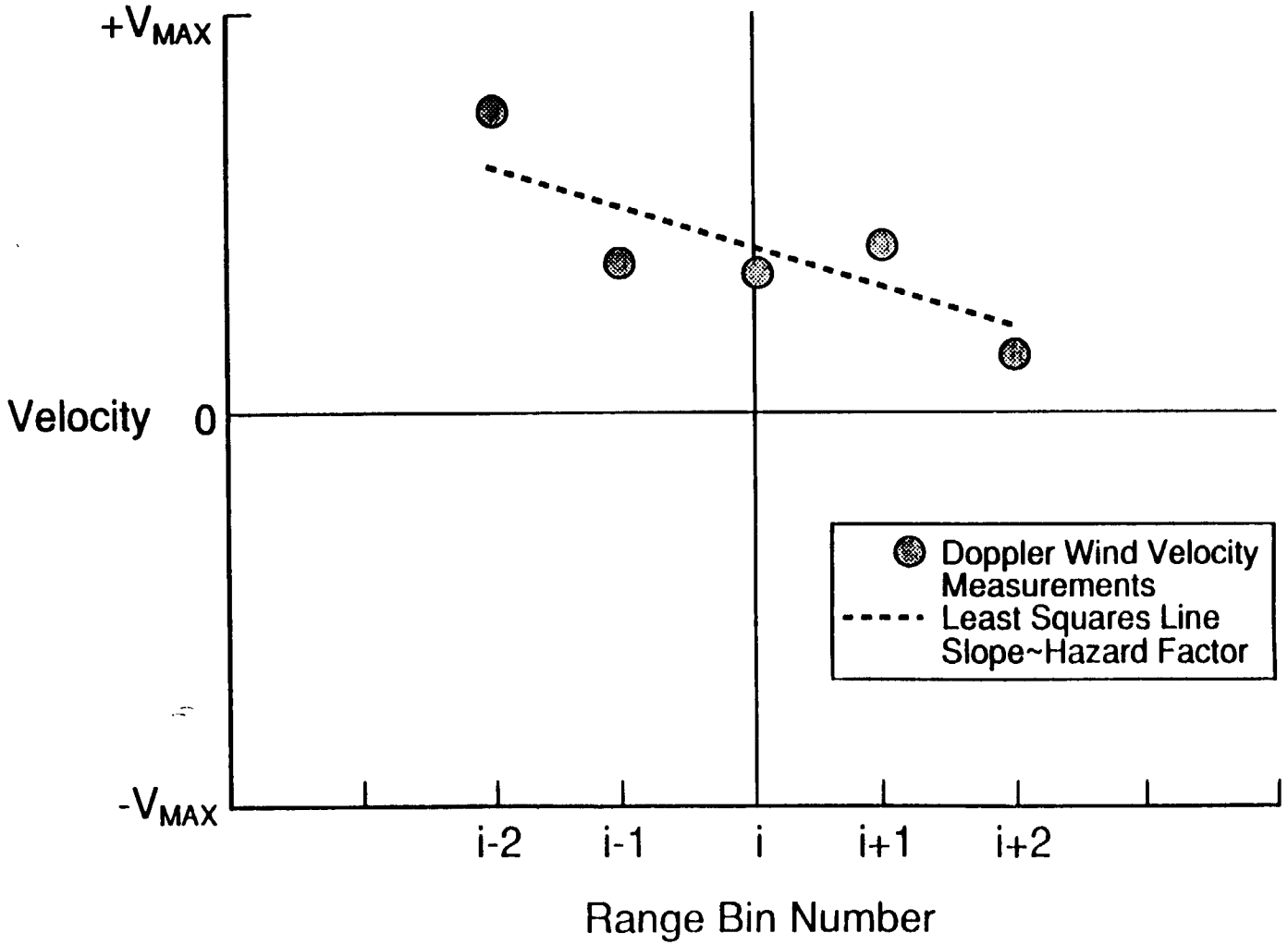
DETECTION OF HAZARD

- Independent AGC for each range cell with large dynamic range.
- Range limiting.
- Antenna tilt control.
- Stationary ground clutter filter.
- Weighted least squares hazard estimation.

Weighted Least Squares Hazard Estimator

View graph 9 is a sketch indicating how the weighted least-squares hazard estimation algorithm estimates the slope of a series of velocity measurements in adjacent range bins. The slope of the velocity/range line is proportional to the horizontal component of the hazard factor. The measurements that are used to estimate the least squares line are weighted by the spectral width. It has been observed through simulation that large spectral widths are associated with measurements that contain extensive moving ground clutter and therefore may not be accurate measurements. Weighting the individual velocity measurements in this way tends to improve the estimate of the true hazard.

WEIGHTED LEAST SQUARES HAZARD ESTIMATOR



Characterization of Hazard

View Graph 10 indicates the techniques used to characterize the hazard detected by the radar. The size and the centroid of a hazardous area detected by the radar are computed and the centroid is tracked by the radar. An extensive set of track-while-scan algorithms eliminate many false hazard areas due to moving ground clutter by elimination of hazardous areas less than a threshold area and by assuring that a hazardous area exist over several radar scans. This set of algorithms tends to eliminate many false hazard areas (false alarms) due to moving and stationary ground clutter.

CHARACTERIZATION OF HAZARD

- Computation of extent and centroid of hazardous areas.
- Elimination of hazardous areas less than a threshold area.
- Centroids of hazardous areas are tracked by radar.
- Track-while-scan algorithms eliminate many false hazard areas due to moving ground clutter.

Threat Evaluation

After a hazardous area has been detected and tracked, a time-to-closest approach to the aircraft (TAU) is calculated and an alarm to the aircrew is given if the time-to-closest approach is less than a threshold value.

THREAT EVALUATION

- For each confirmed hazard area tracked, a time-to-closest approach (TAU) is calculated.
- Alarm to aircrew is given if the time-to-closest approach is less than threshold value.

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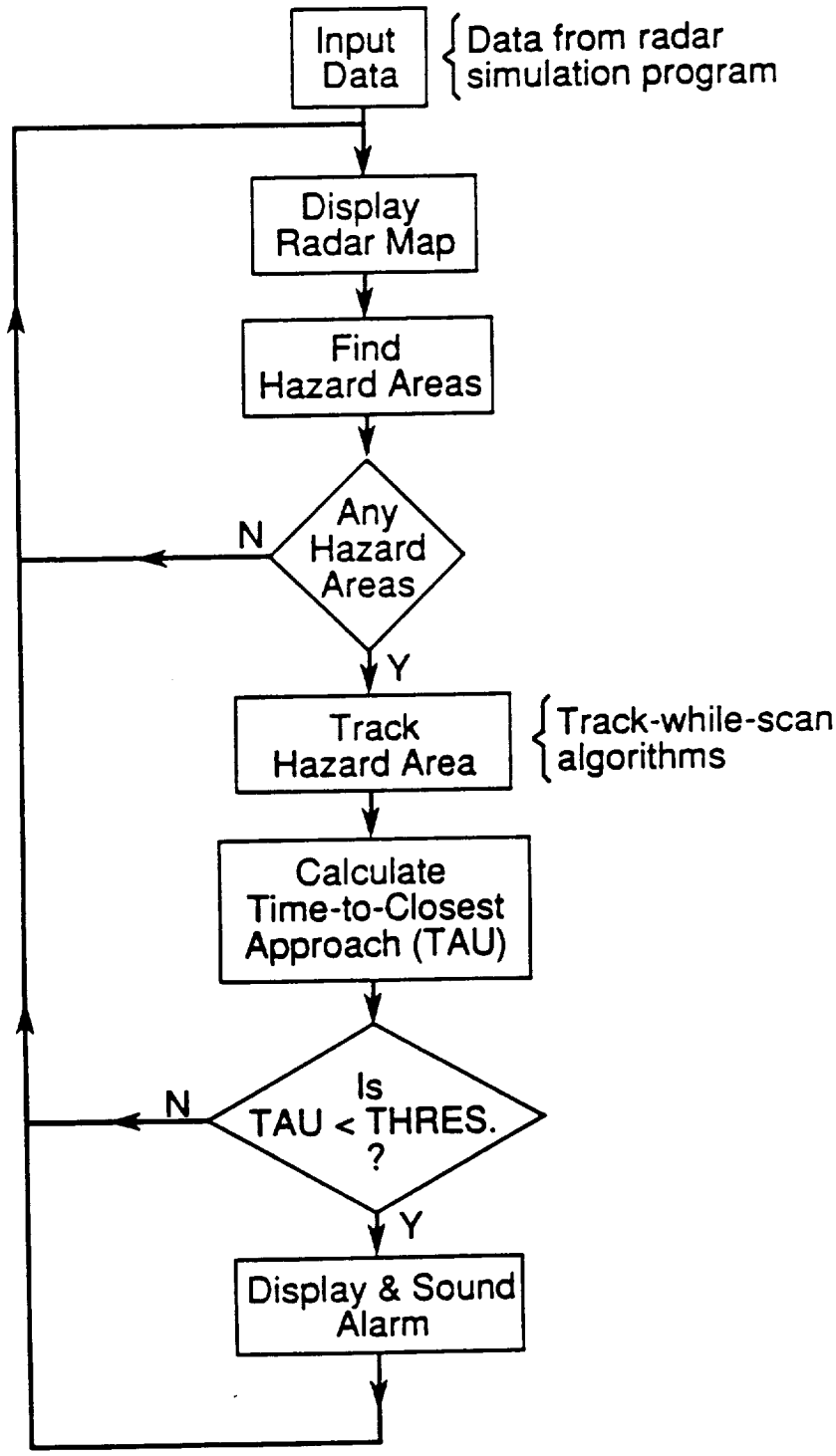
Display, Tracking and Alarm Program

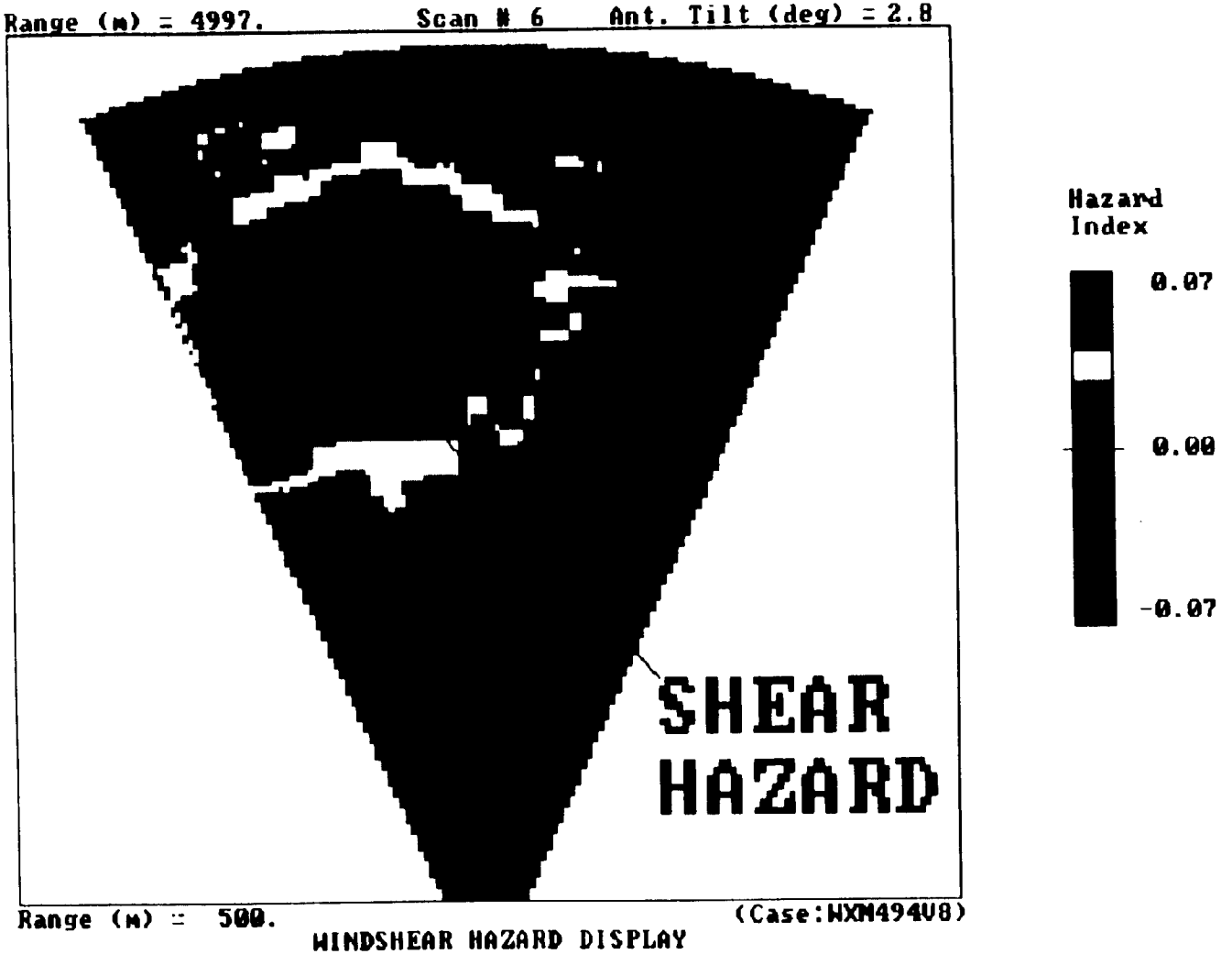
This is a simplified block diagram of the display, tracking and alarm program that is used to provide the map displays and simulated windshear alarms. The program uses the data generated by the radar simulation program discussed previously. The program implements the algorithms discussed.

DISPLAY, TRACKING & ALARM PROGRAM



Windshear Hazard Display

This is a windshear hazard display generated by the display tracking and alarm program. When all criteria have been met for a hazard alarm, "SHEAR HAZARD" is printed on the screen along with a red ball to indicate the hazard area on the map. A dynamic simulation of this hazard display will be shown on the computer monitor.



WINDSHEAR HAZARD DISPLAY

Future Efforts

This view graph indicates some of the efforts that will conducted in the near future. With the development of the NASA experimental radar system it is expected that real ground clutter data will be obtained and will be used in the simulation program in place of the existing ground clutter models. Many alternate algorithms will be developed, such as auto-regressive modeling techniques, and will be investigated using the simulation program.

Additional work is being done to determine a technique for estimation of the vertical component of the hazard index and the incorporation of this component in the alarm algorithms.

FUTURE EFFORTS

- Incorporate real clutter data in simulation.
- Extensive evaluation of alternate algorithms.
- Estimate missed and false alarm performance.
- Improved models of moving and stationary ground clutter.
- Estimation of vertical component of hazard index.