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Session X. Airborne Doppler Radar / Industry

N91-24148

Status of General Motors Hughes Electronics Research
Dr. Brian Gallagher, Delco
Mark Selogie, Hughes

NASA/FAA
THIRD COMBINED MANUFACTURERS' AND
TECHNOLOGISTS' AIRBORNE WIND SHEAR
REVIEW MEETING

DELCO SYSTEMS OPERATIONS
DIVISION OF GENERAL MOTORS HUGHES ELECTRONICS

FORWARD LOOKING WINDSHEAR DETECTION PROGRAM 1989/1990 STATUS REPORT

Delco Systems
Operations

Brian J. Gallagher
October 18, 1990

DELCO SYSTEMS R&D PROGRAM ON FORWARD LOOKING WINDSHEAR DETECTION

COOPERATIVE EFFORT WITH HUGHES AIRCRAFT

- OBJECTIVES
- APPROACH
- PROGRESS
- CONCLUSIONS

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OBJECTIVES

Develop Predictive Windshear Detection System Based on Passive IR Remote Sensing Technology

- Advance Warnings of 10 to 30 seconds
- Acceptable False Alarm Rate <10^-4
- Small, Lightweight, Affordable

- Original Objective was Stand Alone Sensor
- Integrated Sensor Approach Studied in 1989

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APPROACH

- Inferential Approach Based on Temperature Differential of Downbursts Correlated with Vertical Velocity
- Sensor is Multi-Spectral Scanning Radiometer Operating in 10-14 micron Atmospheric Window
- Reliance on Measurement of Both Horizontal and Vertical Temperature Gradients of Atmosphere
- Primary Issue is Random Spatial Temperature Variations or Atmospheric Background 'Noise'

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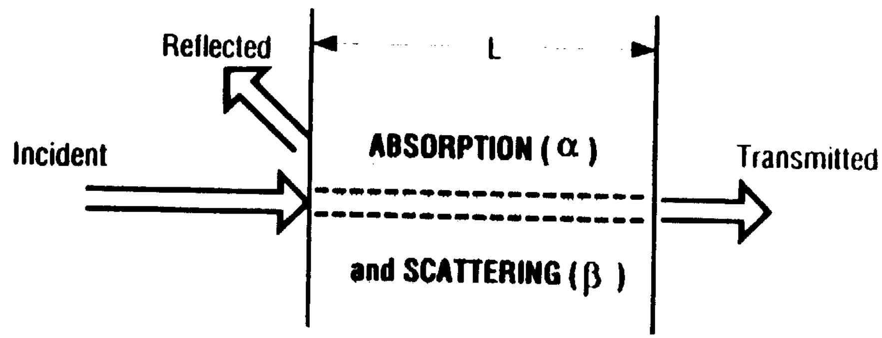
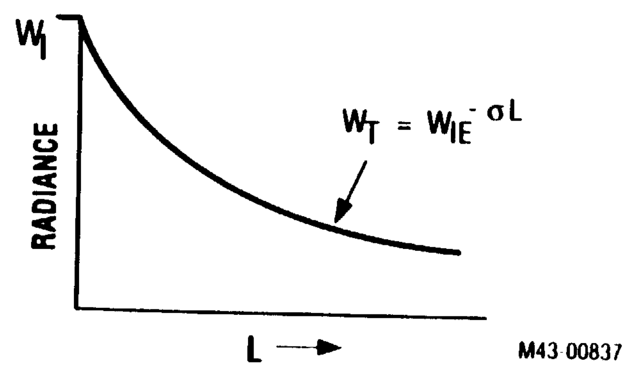
EXTINCTION OF RADIANCE BY ABSORBING AND SCATTERING MEDIA



σ = Absorption + Scattering = Extinction Coefficient (km^{-1})



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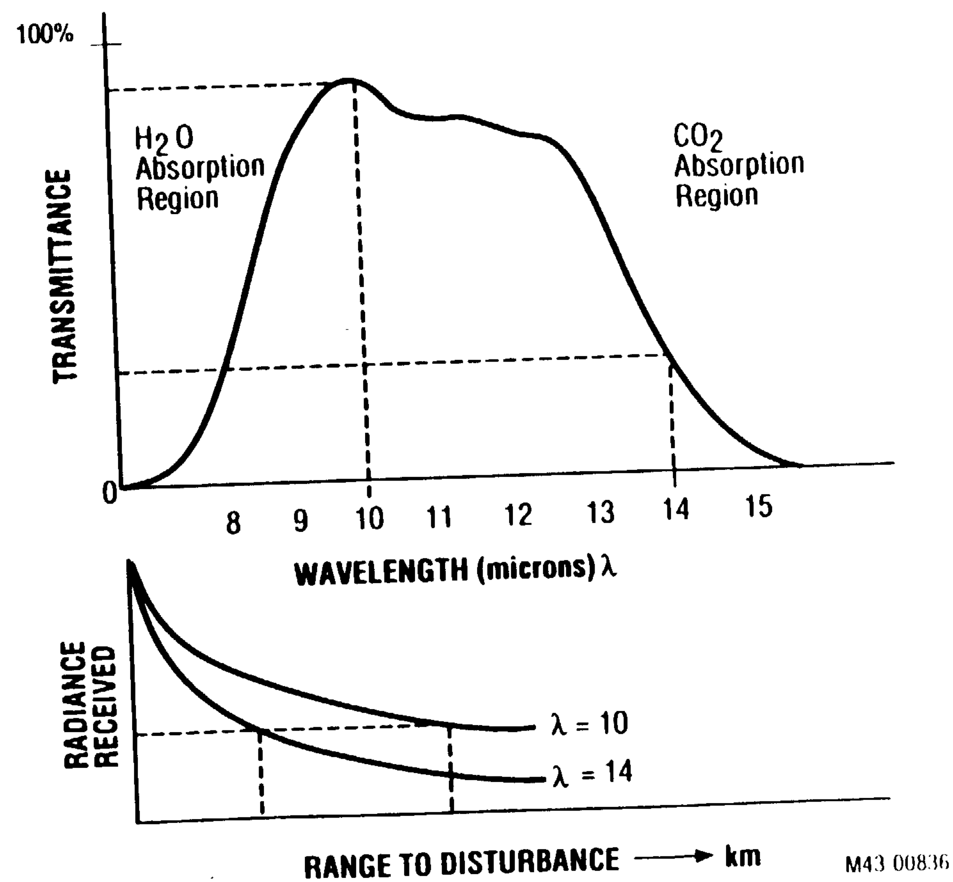
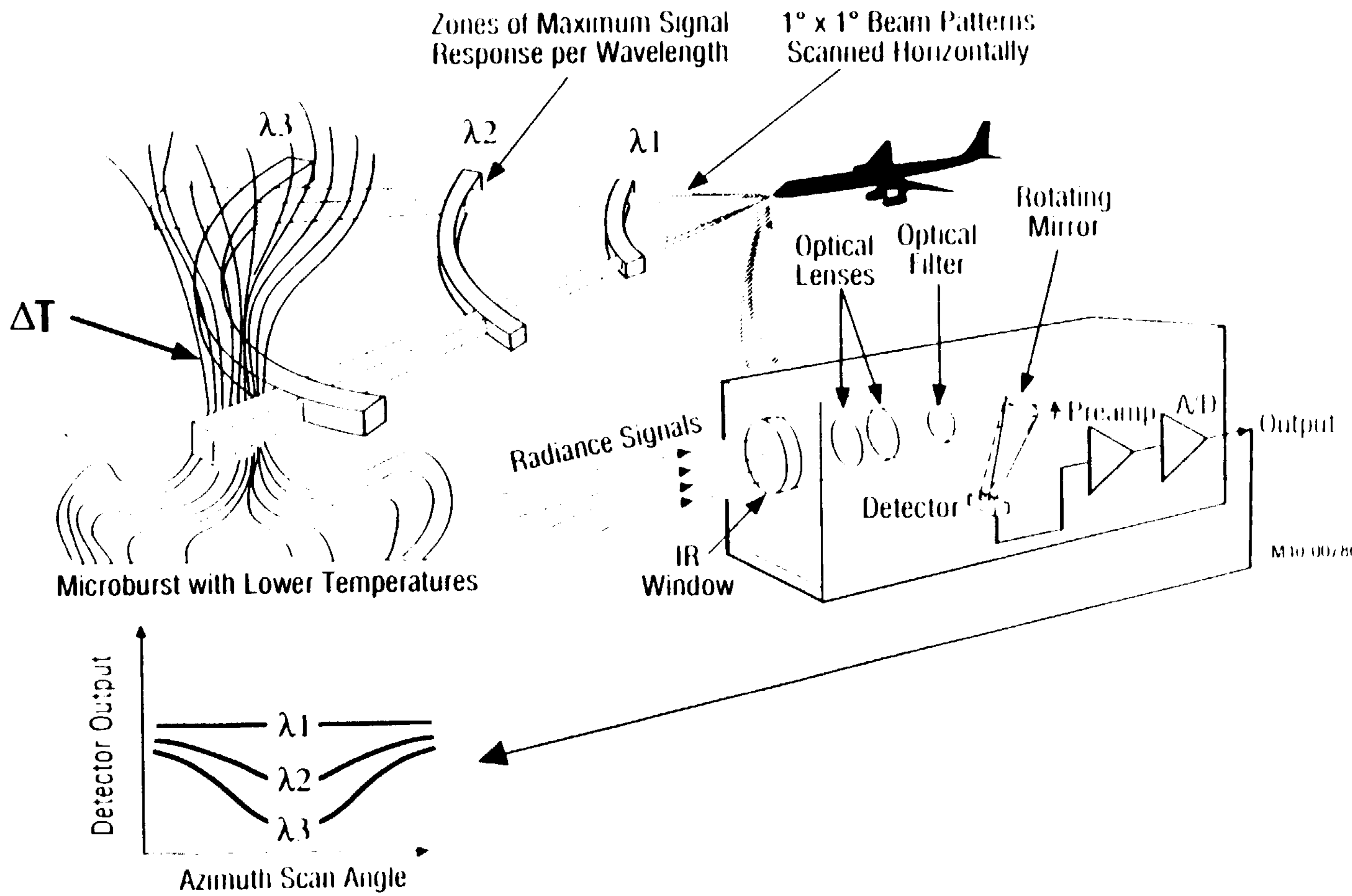
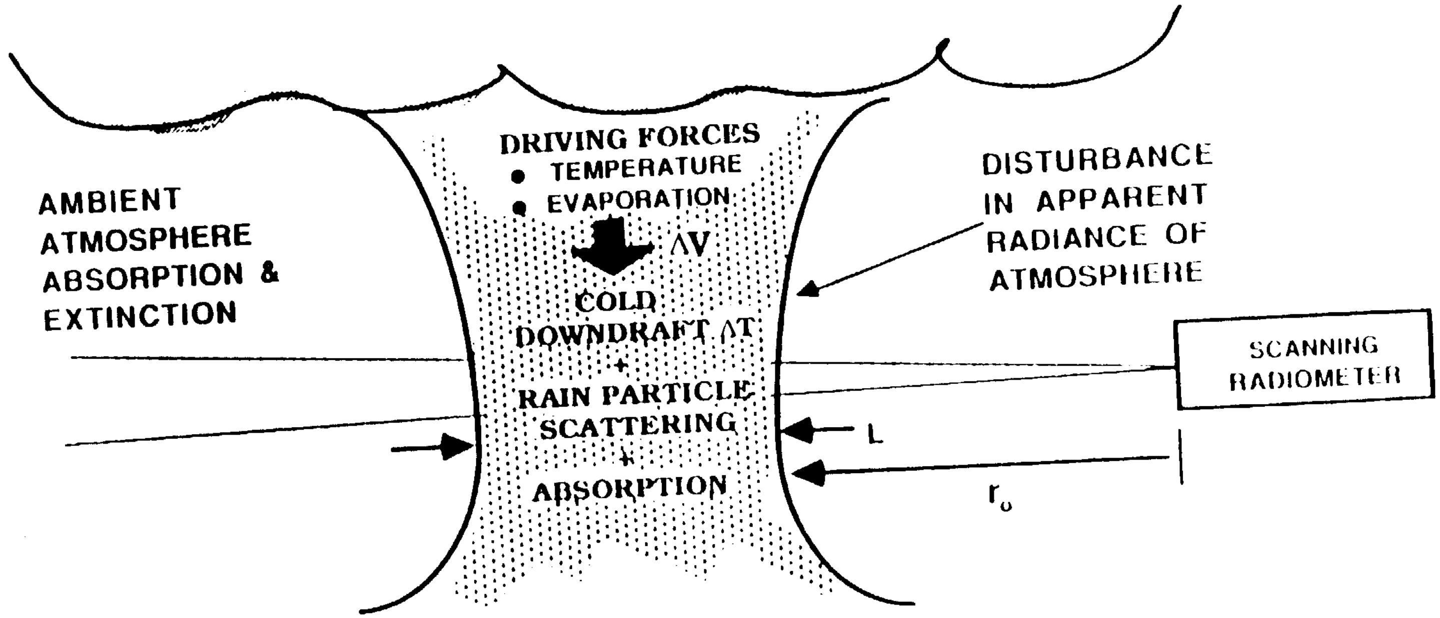
ATMOSPHERIC ABSORPTION IN FAR IR REGION



INFRAMETRICS IMAGING RADIOMETER



BASIC RADIANCE SIGNAL EQUATION



PEAK SIGNAL RADIANCE AT λ_i IN CO_2 ABSORPTION BAND

$$S_i \cong G_i \, W_{\lambda b} \, \frac{4 \Delta T}{T} \underbrace{\left[1 - e^{-(\sigma_\lambda + \Delta\sigma) L} \right]}_{\text{emissivity}} \underbrace{e^{-\sigma_\lambda r_0}}_{\text{atmospheric transmission}}$$

ΔT proportional to ΔV

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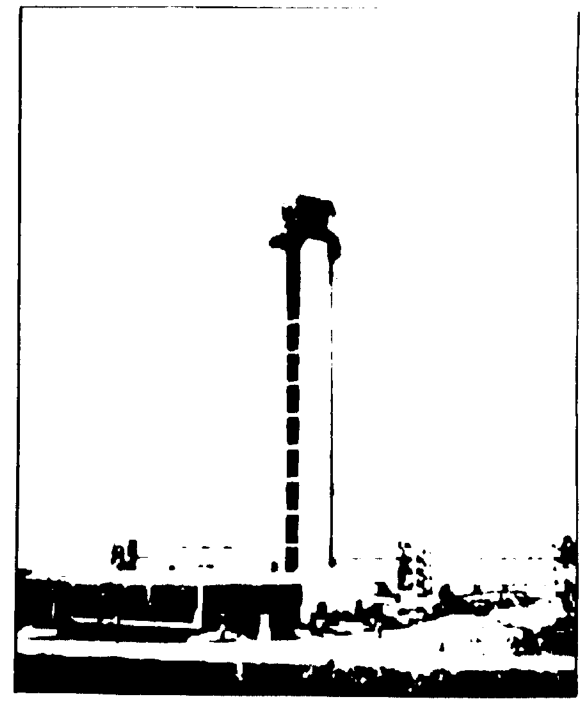
TOWER TEST PLAN

- Install test radiometer on 150-foot high control tower at Milwaukee airport to simulate airplane environment
- Collect atmospheric radiance data for different weather conditions during June and July 1989
- Reduce and analyze data using thermogram card and VAX computer programs
- Checkout computer algorithms, verify lapse rate measurements, and investigate atmospheric noise



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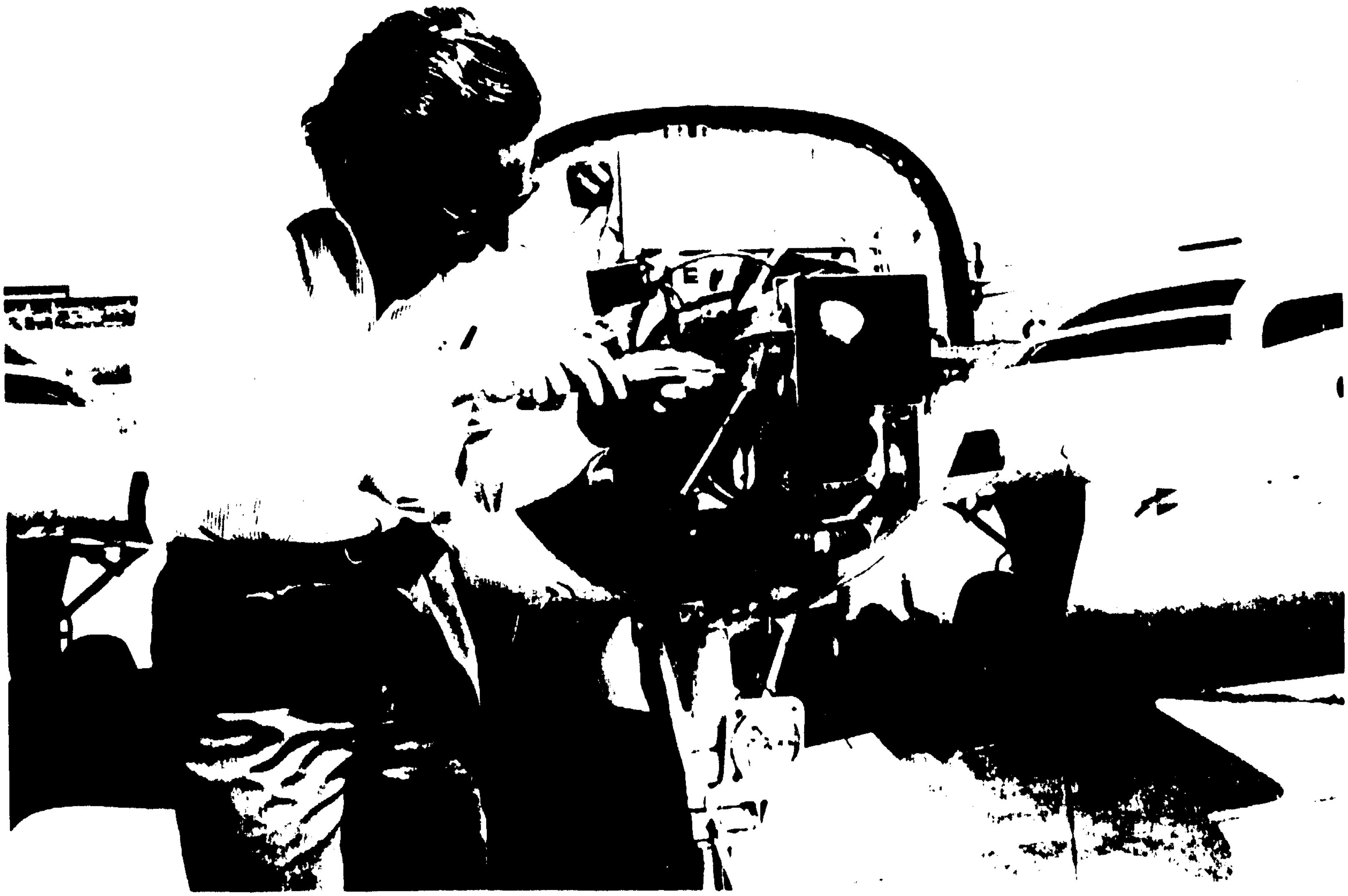
FLIGHT TEST PLAN

- Install test radiometer in modified nose cone of flight test aircraft with TV camera, video recorders, and controls
- Install test computer and monitors with in-flight data collection, display, analysis, and recording software
- Instrument aircraft with Kollman Research Systems Data Acquisition and Recording System
- Perform in-flight data collection and real-time analysis test flights during August and September 1989, under different weather conditions, and correlate with meteorological sounding data
- Reduce and analyze data and determine atmospheric noise distribution and lapse rates

APPROACH

EXPERIMENTAL RADIOMETER INSTALLED IN FLIGHT TEST AIRCRAFT



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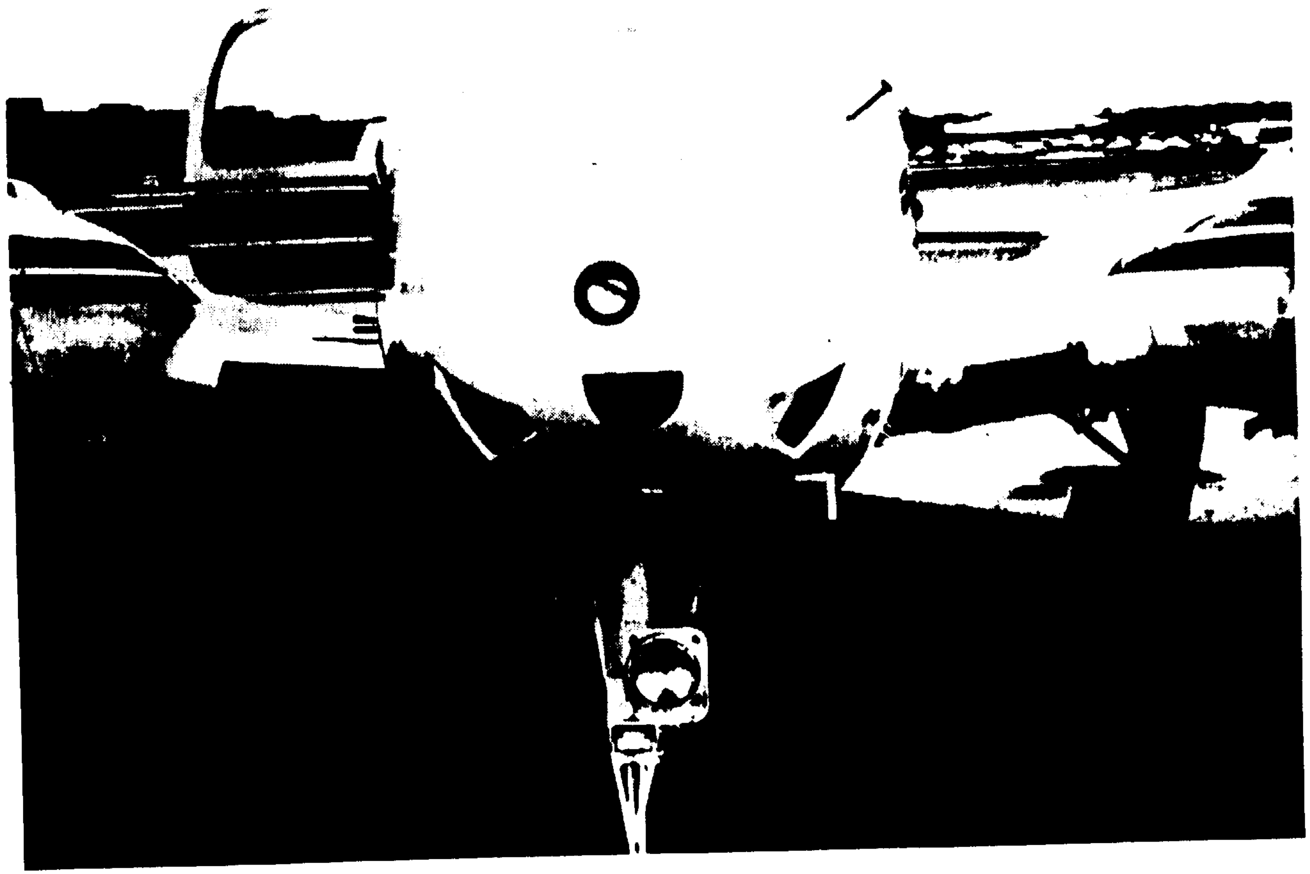
APPROACH

MODIFIED NOSECONE SHOWING INFRARED AND VISIBLE WINDOWS FOR RADIOMETER AND TV CAMERA



APPROACH

FLIGHT TEST INSTRUMENTATION, DISPLAYS, AND OPERATING CONTROLS CONSOLE

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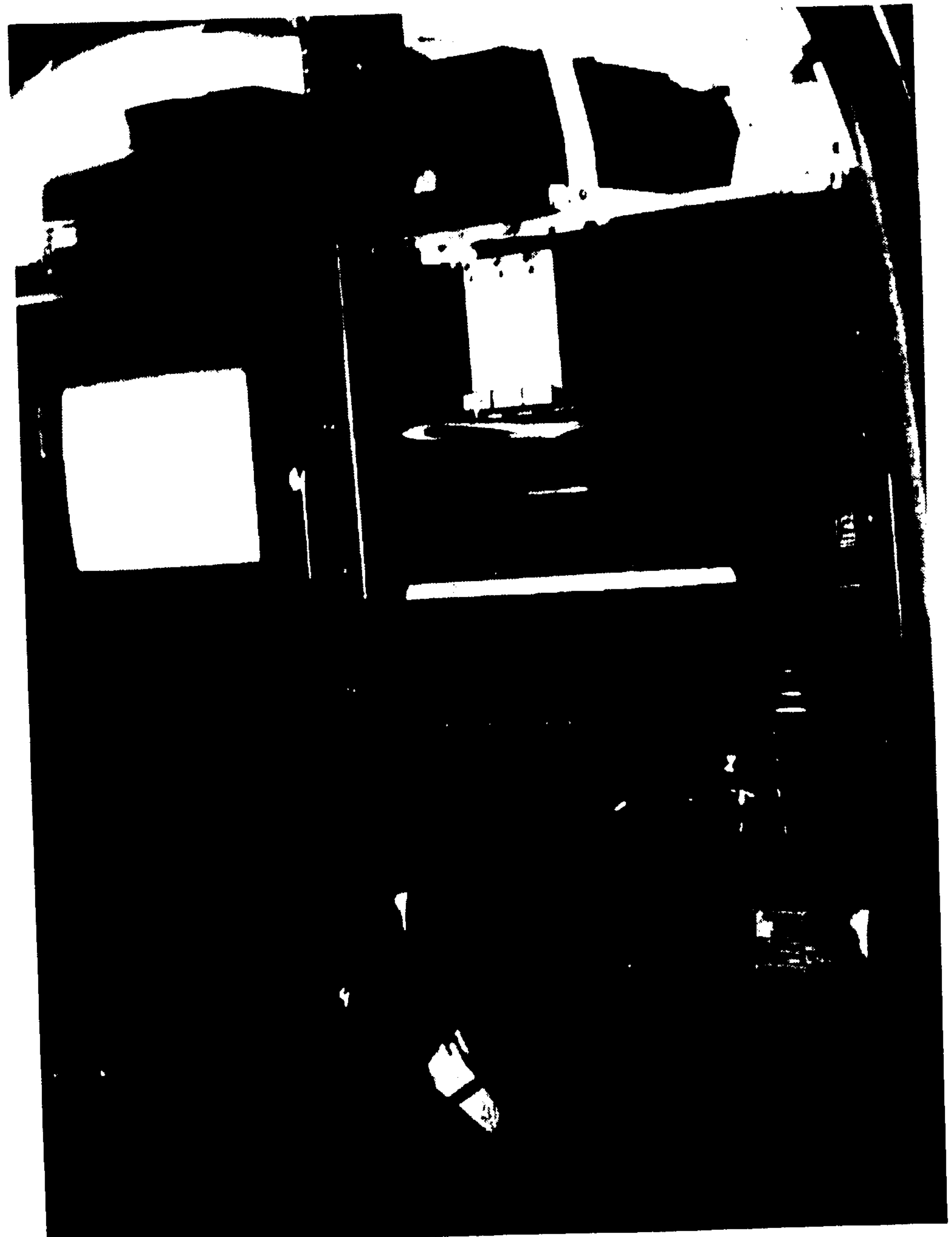
APPROACH

FLIGHT TEST DATA ACQUISITION AND DISPLAY CONSOLE



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OF POOR QUALITY

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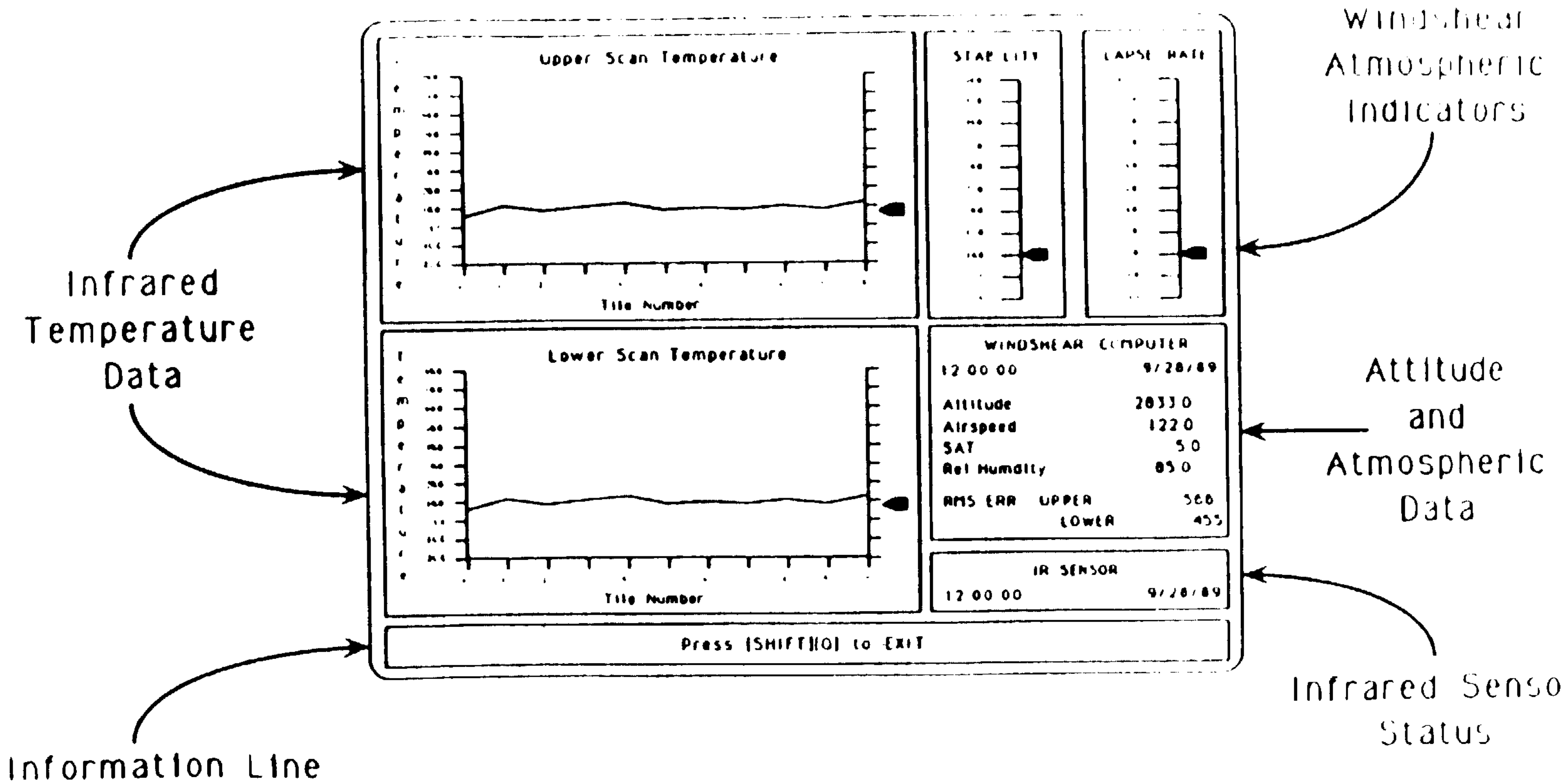
DATA ACQUISITION SYSTEM DISPLAY



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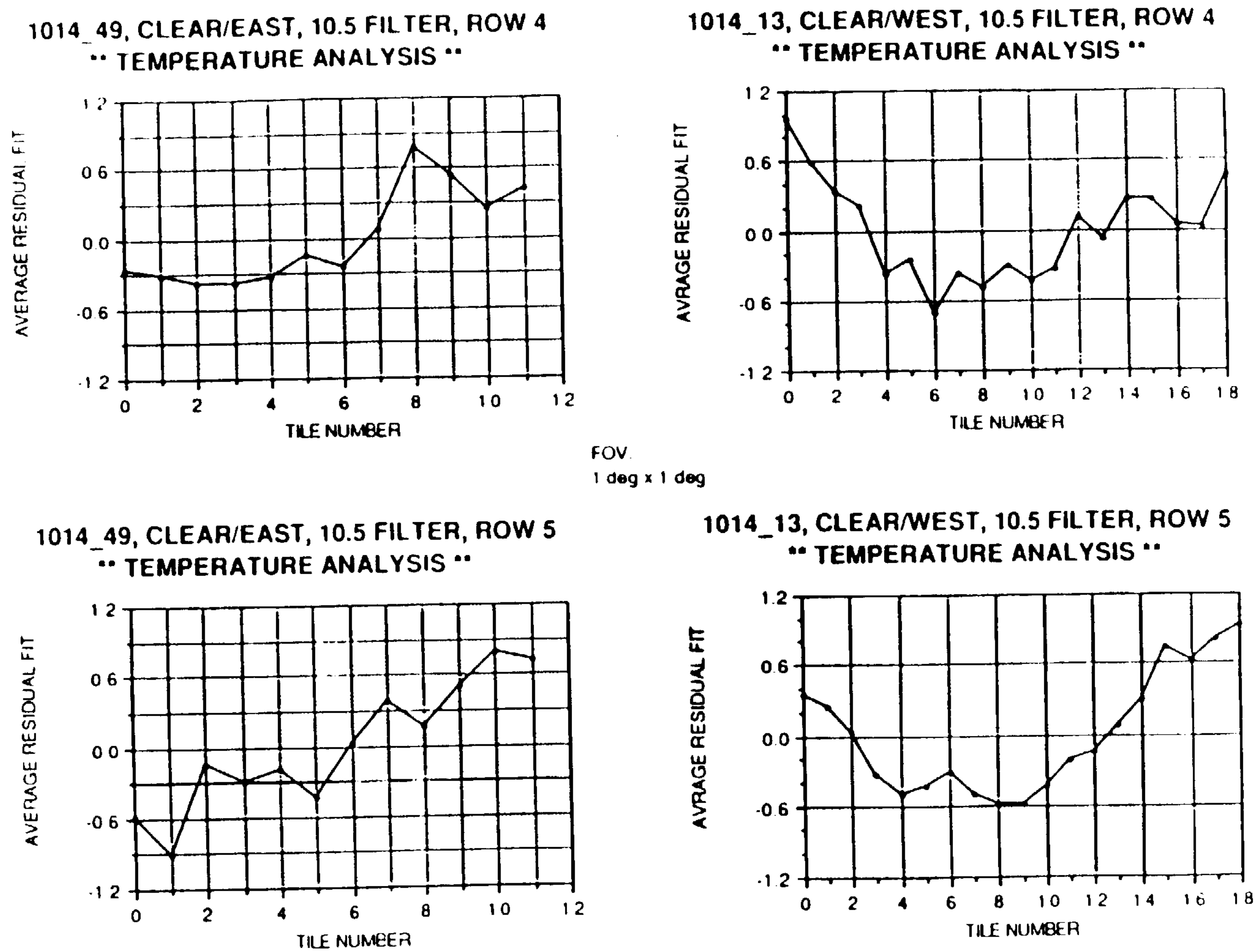
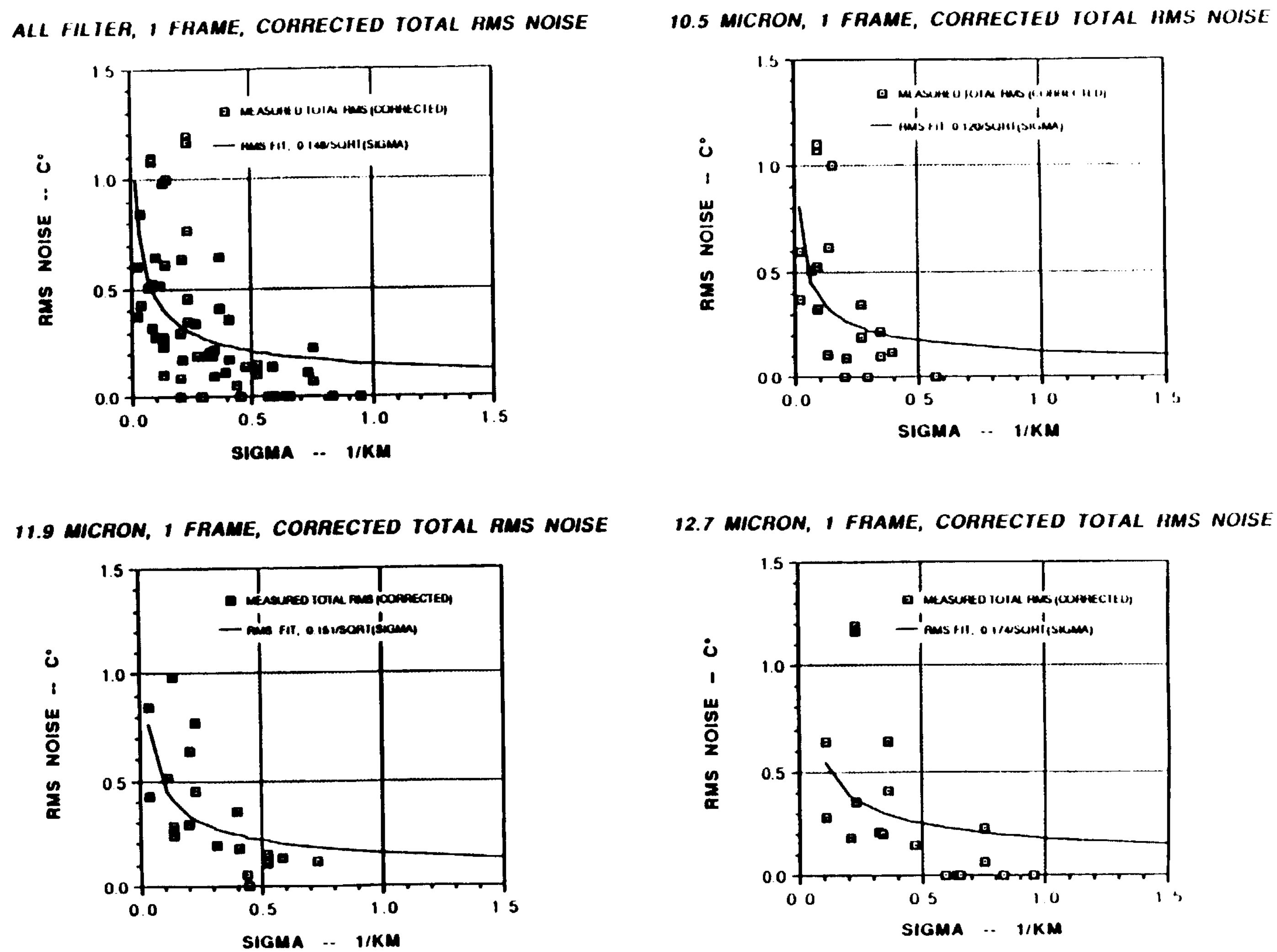


Linear Slope

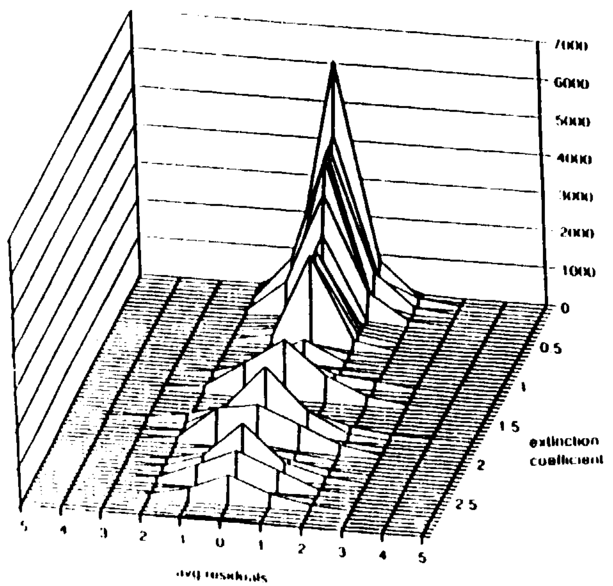
Parabolic Slope

Examples of Data Showing Linear and Parabolic Slope

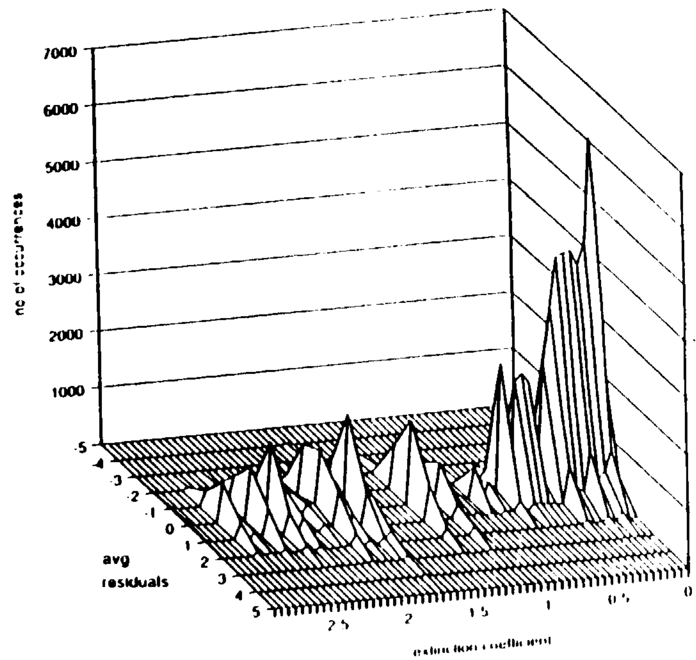


Corrected Total RMS Noise versus Extinction Factor

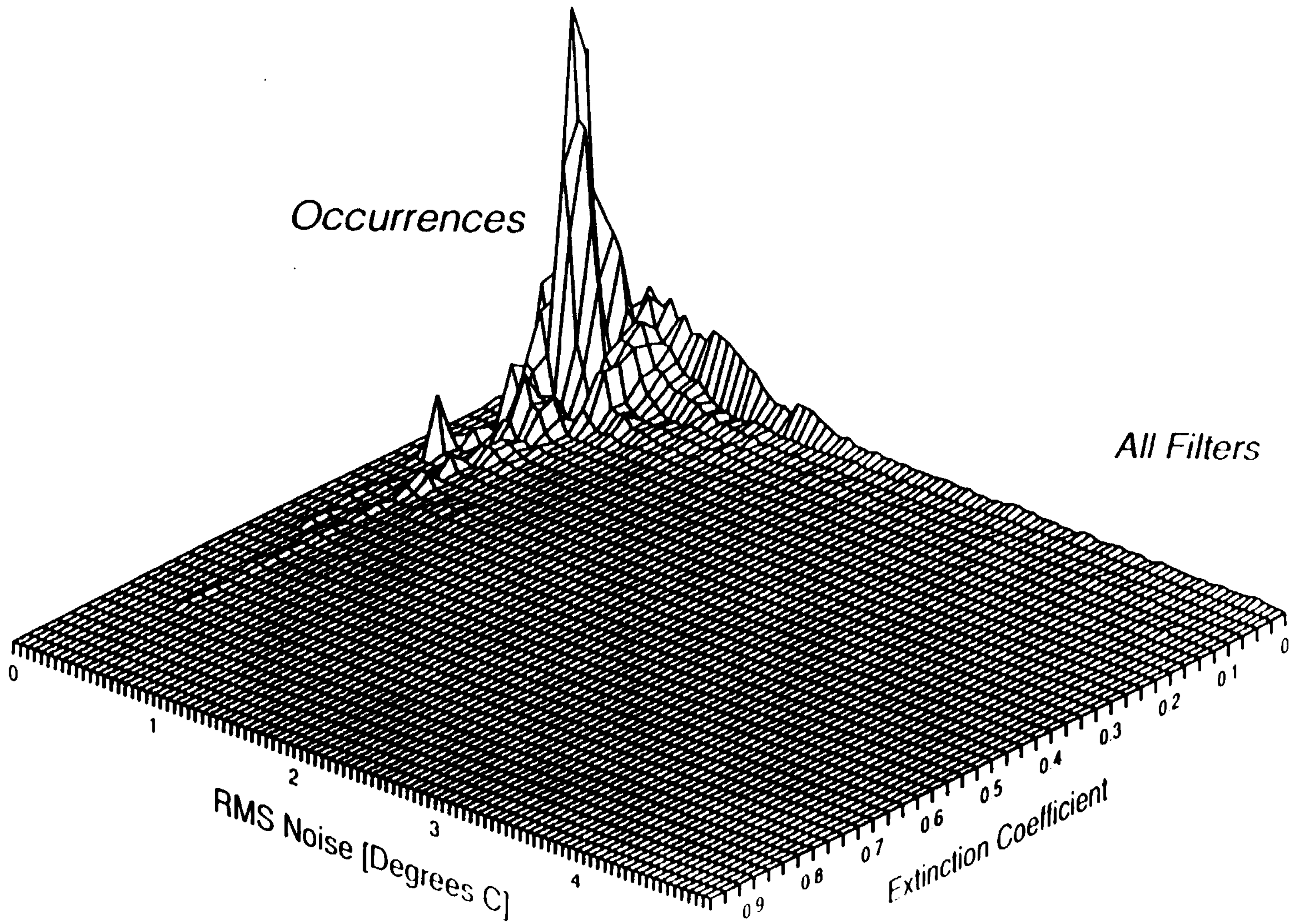
Avg residual values vs ext coef for all filters
(all frozen images)



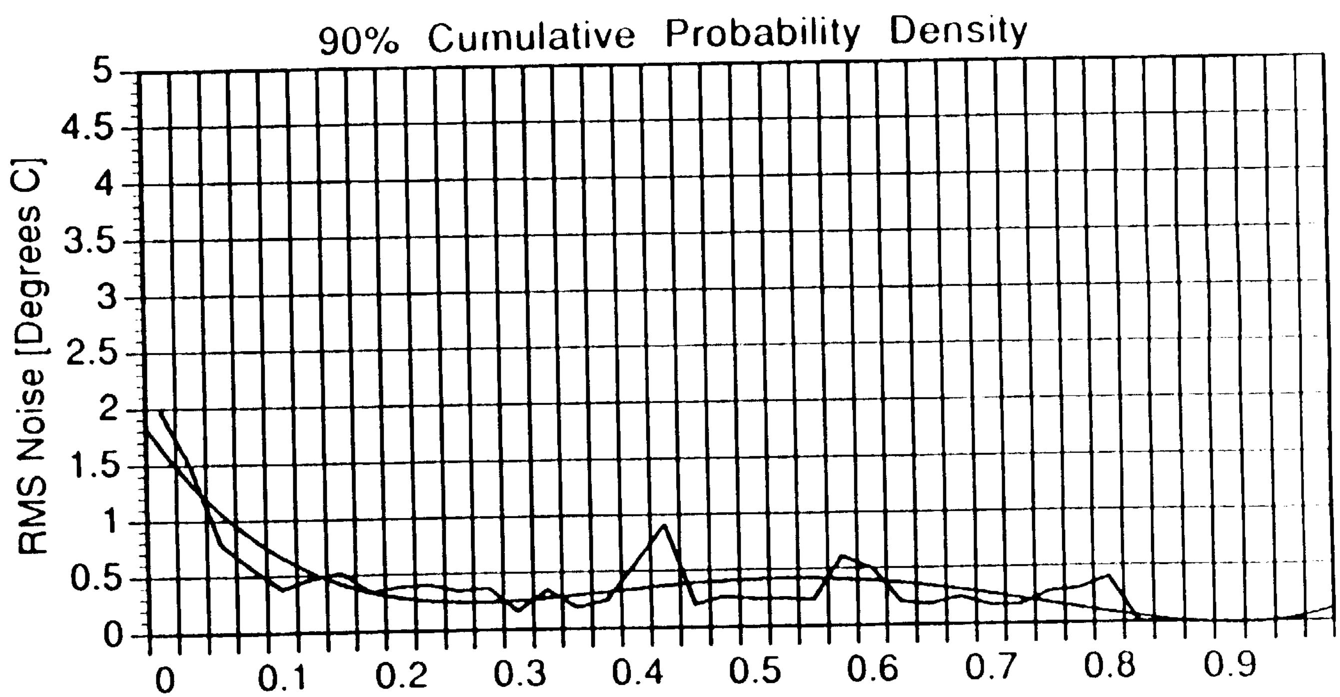
Avg residual values vs ext coef for all filters
(all frozen images)



Frozen Image Total Residual Error Distributions

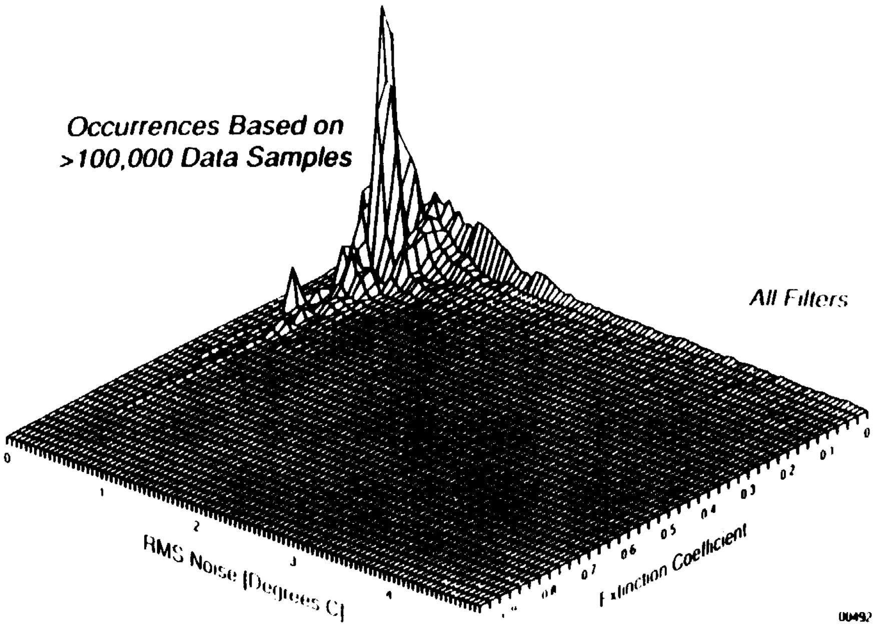


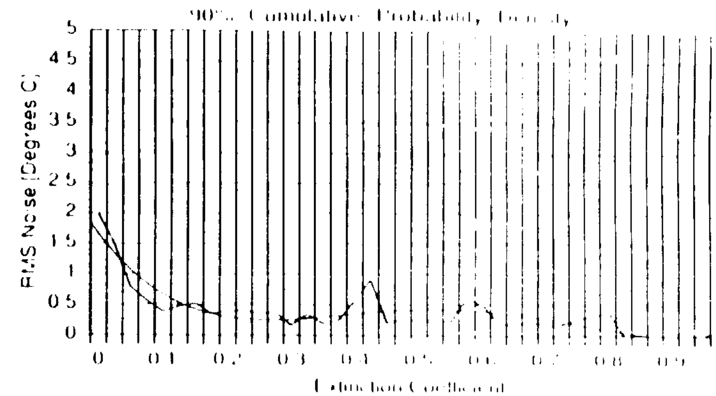
Atmospheric Noise - Corrected for Instrument Noise



Horizontal Gradient Noise - Corrected for Instrument Noise

FROZEN IMAGE RMS NOISE SUMMARY





IR FILTER (micron)	APPROX σ (km^{-1})	APPROX RANGE (km)	LOW FREQUENCY SPATIAL NOISE (°C)
10.5	0.1	10	0.446
11.9	0.33	3	0.405
12.7	0.5	2	0.458
13.8	1.0	1	0.389

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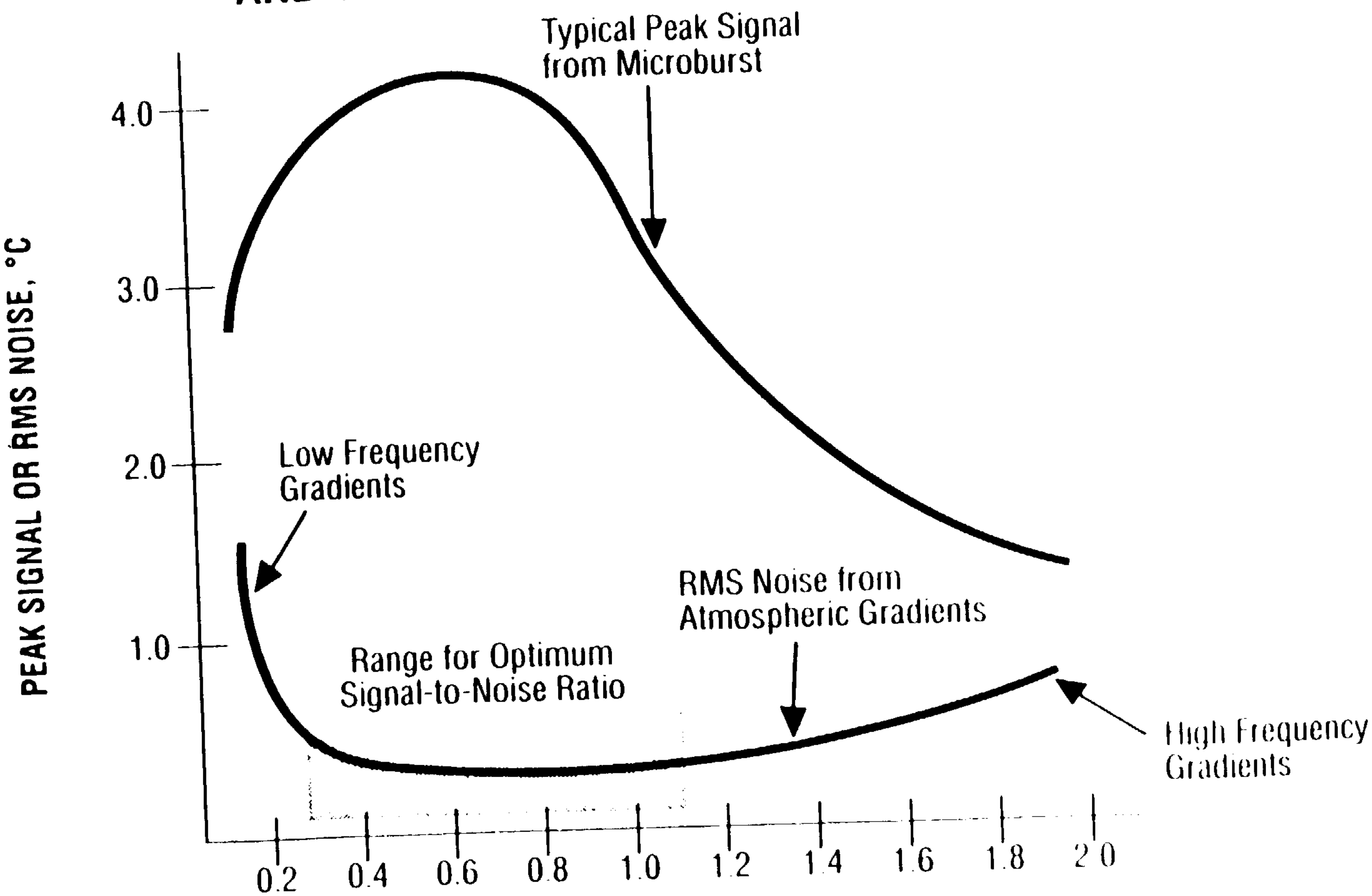
RESULTS OF ATMOSPHERIC SIGNAL, NOISE, AND RADIOMETER RESPONSE ANALYSIS



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CONCLUSIONS

- In worst case, atmospheric low frequency noise appears twice as high as desirable for reliable detection of minimum velocity microbursts without false alarms (0.4°C instead of 0.2°C rms)
- Neural network study of University of Wisconsin-Milwaukee shows promise of significant noise reduction technique through adaptive filtering
- Forward Looking Windshear Detection using IR technology has definite potential as a complementary integrated sensor

RECOMMENDATIONS

- Need to correlate noise data with winds to determine how much "noise" is actually turbulence induced versus random background
- Low noise multispectral radiometer and real microburst data collection program essential for final concept verification
- Fusion of IR sensor data with Doppler radar, Ladar, and inertial sensor systems to reliably detect windshears and clear air turbulence should be pursued in future programs

DESIGN CONSIDERATIONS FOR AN AIRBORNE WINDSHEAR DETECTION RADAR

OCTOBER 18, 1990

HUGHES

DESIGN CONSIDERATIONS FOR AN AIRBORNE WINDSHEAR DETECTION RADAR

Hughes Aircraft Company

An airborne radar can be used to provide reliable forward looking windshear detection. The radar uses a direct measure of wind velocity to determine the hazard F-factor and issue a warning to the pilot. The radar measures wind velocity as a function of range and determines the presence of windshear if there is an abrupt change in wind direction over a short range interval. This change in wind direction is recognized by the radar as a distinct S-shaped curve in the range-velocity domain. The NASA windshear simulation has been used to verify the radar's ability to detect this S-shaped windshear curve.

In order to provide a useful alert to the pilot, the radar must provide at least 15-20 seconds of warning and provide this warning with a very low false alarm rate. In addition, the radar must have adequate range to penetrate the windshear to enough depth to discriminate dangerous shears from benign shears. Scan-to-scan correlation logic may be employed to lower the false alarm rate. The overall design issues involved in specifying a radar to detect windshear include its frequency, transmitter power, antenna beamwidth, coherent doppler processing, range resolution and interference rejection.

RADAR MEASURES WIND VELOCITY TO DETECT WINDSHEAR

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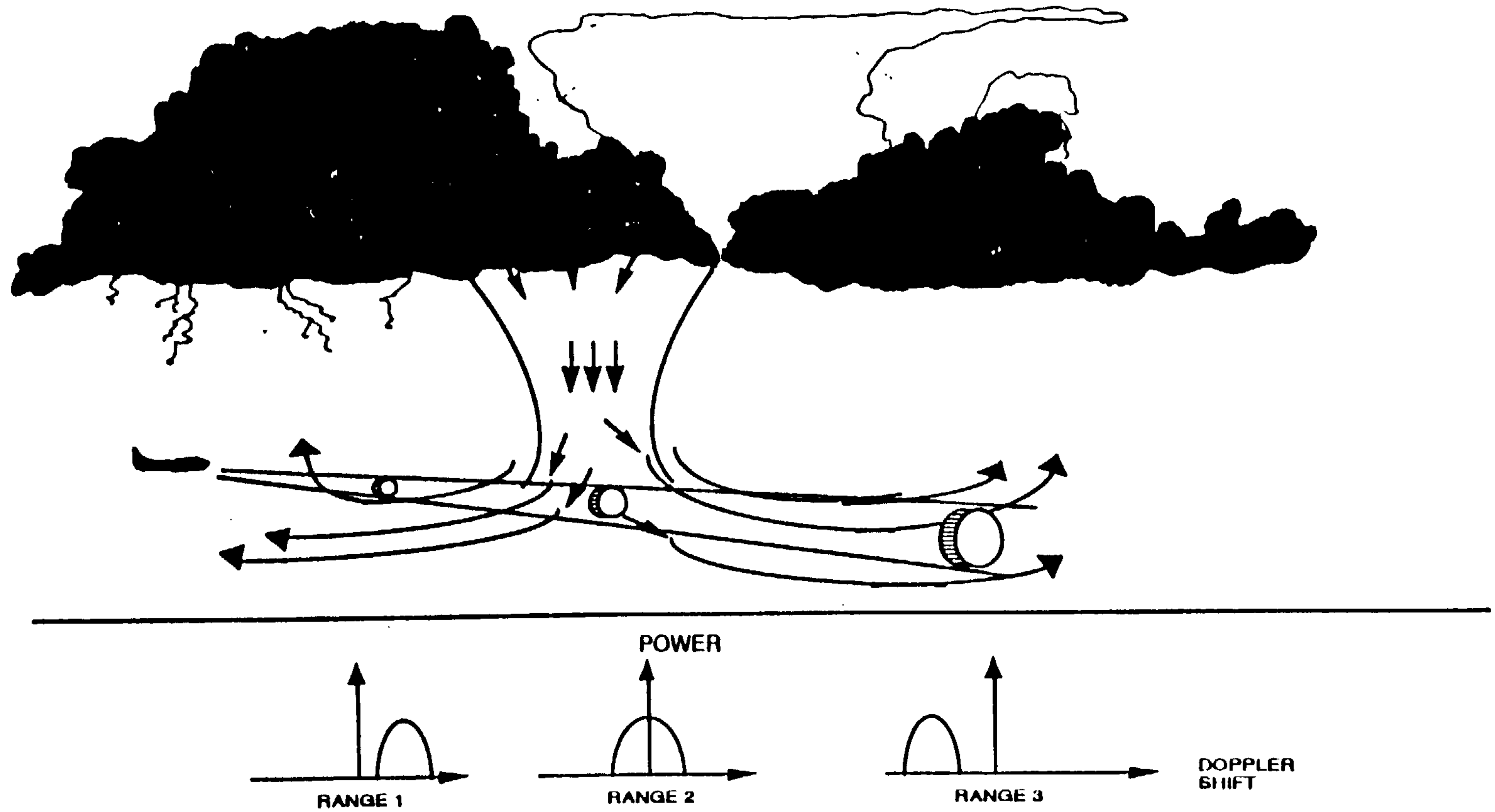

- RADAR MEASURES RADIAL VELOCITY VS. RANGE

10/15/90

RADAR WINDSHEAR SIGNATURE

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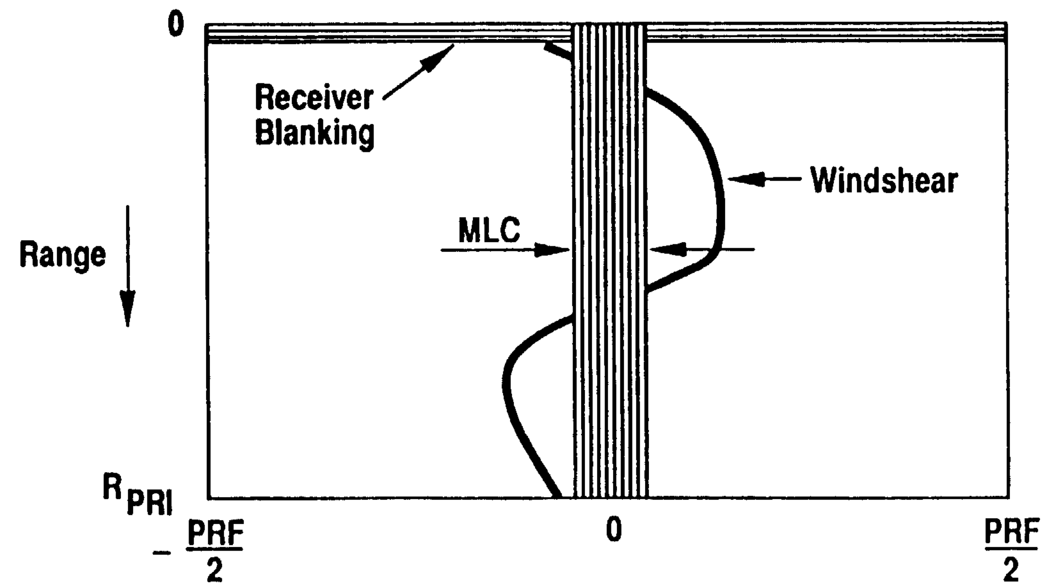
- RADAR GENERATES RANGE - VELOCITY MATRIX AT EACH BEAM POSITION



- RADAR DETECTS S-SHAPED WINDSHEAR SIGNATURE AND CALCULATES HAZARD F-FACTOR

TYPICAL WINDSHEAR PROFILE PREDICTED BY THE NASA SIMULATION

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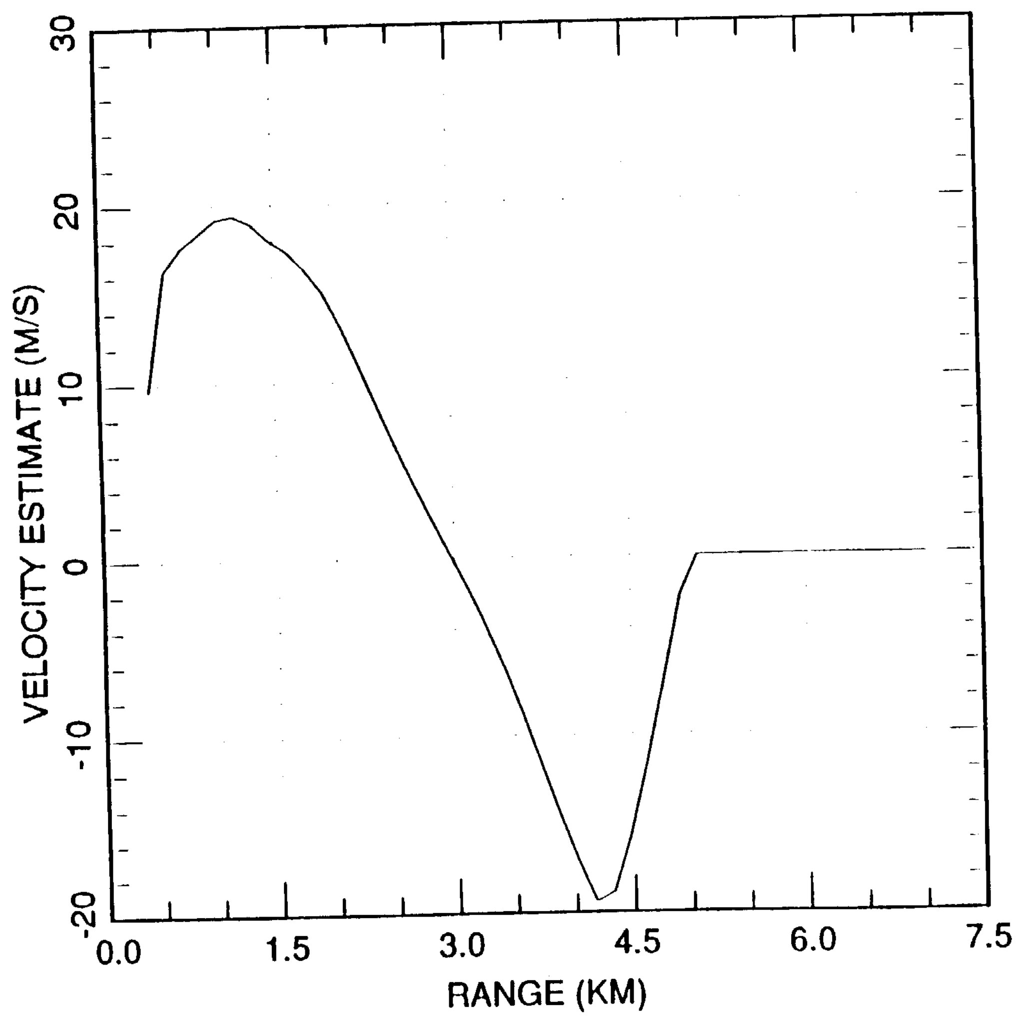

NO CLUTTER AND NO GMTS

WET MICROBURST (T11)

LOOKING STRAIGHT AHEAD ALONG GSL

WINDSHEAR DETECTION RANGE

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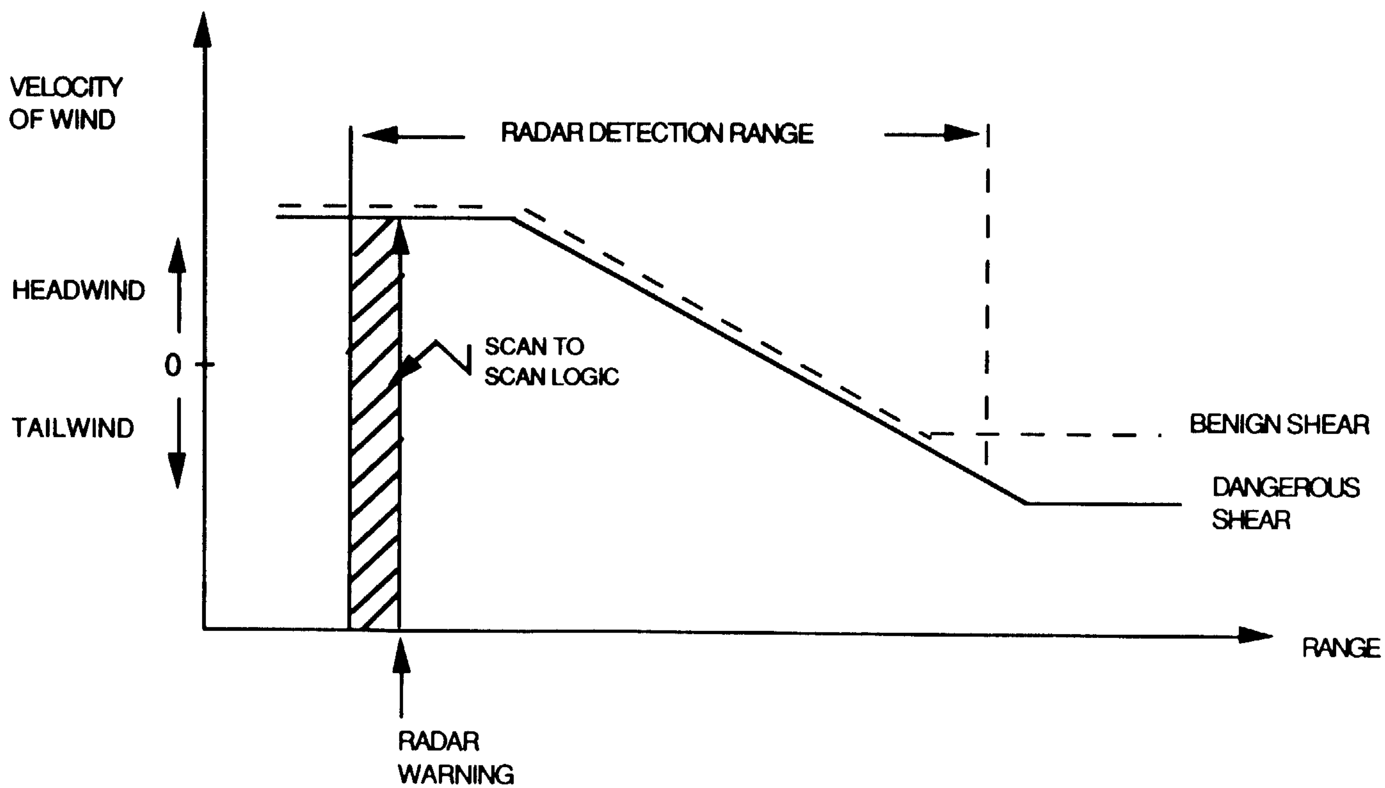
DESIGN GOAL: PROVIDE THE PILOT WITH AT LEAST 15-20 SECONDS WARNING TIME WITH LOW FALSE ALARM RATE



10/18/90

RADAR DESIGN ISSUES

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MLS1012.1

- FREQUENCY
- TRANSMITTER POWER
- ANTENNA BEAMWIDTH
- COHERENT DOPPLER PROCESSING
- RANGE RESOLUTION
- INTERFERENCE REJECTION

Status of General Motors Hughes Electronics Research
Questions and Answers

Q: SUSAN KIM (Boeing) - You mentioned your goal is a targeted false alarm/nuisance rate of 1 per 10,000 flight. How do you plan to test/verify/achieve this rate?

A: BRIAN GALLAGHER (Delco) - We plan to achieve the rate through the discrimination techniques that we are developing which primarily rely on the horizontal temperature gradient. For example, angular size would be an important means of discriminating cold fronts, gust fronts, things that are non threatening. As far as verifying that, or testing that, that's a good question. I'll give you a pat answer. This is per discussions that we had with the FAA Los Angeles Certification Office. The answer is primarily through systems' simulations with "sufficient data to support the integrity of the simulation model." The question is what is sufficient data. And that data will be collected through flight tests and in-service evaluations that are being planned.

Q: SUSAN KIM (Boeing) - How do you define a false alarm?

A: BRIAN GALLAGHER (Delco) - Another word for a false alarm is a false alert. It's an alert which occurs when the design wind shear threshold conditions do not exist. An example that I could give is an atmospheric temperature gradient that emulates or masks or emulates a microburst without any turbulence whatsoever. Those things do exist out there and as a result we're going to have nonperfect systems.

Session X. Airborne Doppler Radar / Industry

Saberliner Flight Test
Bruce Mathews, Westinghouse