Aircraft Wake RCS Measurement.

W. Gilson,

Massachusetts Institute of Technology

ABS: next page

Radar Measurements of Aircraft Wakes at Kwajalein, R.M.I.

William H. Gilson
Lincoln Laboratory, Massachusetts Institute of Technology
244 Wood Street
Lexington, Massachusetts 02173-9108

ABSTRACT

A series of multi-frequency radar measurements of aircraft wakes at altitudes of 5,000 to 25,000 ft. was performed at Kwajalein, R.M.I., in May and June of 1990. Two aircraft were tested, a Learjet 35 and a Lockheed C-5A. The cross-section of the wake of the Learjet was too small for detection at Kwajalein. The wake of the C-5A, although also very small, was detected and measured at VHF, UHF, L-, S-, and C-bands, at distances behind the aircraft ranging from about one hundred meters to tens of kilometers. The data suggest that the mechanism by which aircraft wakes have detectable radar signatures is, contrary to previous expectations, unrelated to engine exhaust but instead due to turbulent mixing by the wake vortices of pre-existing index of refraction gradients in the ambient atmosphere. These measurements were of necessity performed with extremely powerful and sensitive instrumentation radars, and the wake cross-section is too small for most practical applications.

This work was sponsored by the Office of Naval Technology. The views expressed are those of the author and do not reflect the official policy or position of the U.S. Government.

AIRCRAFT WAKE RCS MEASUREMENTS

WILLIAM H. GILSON

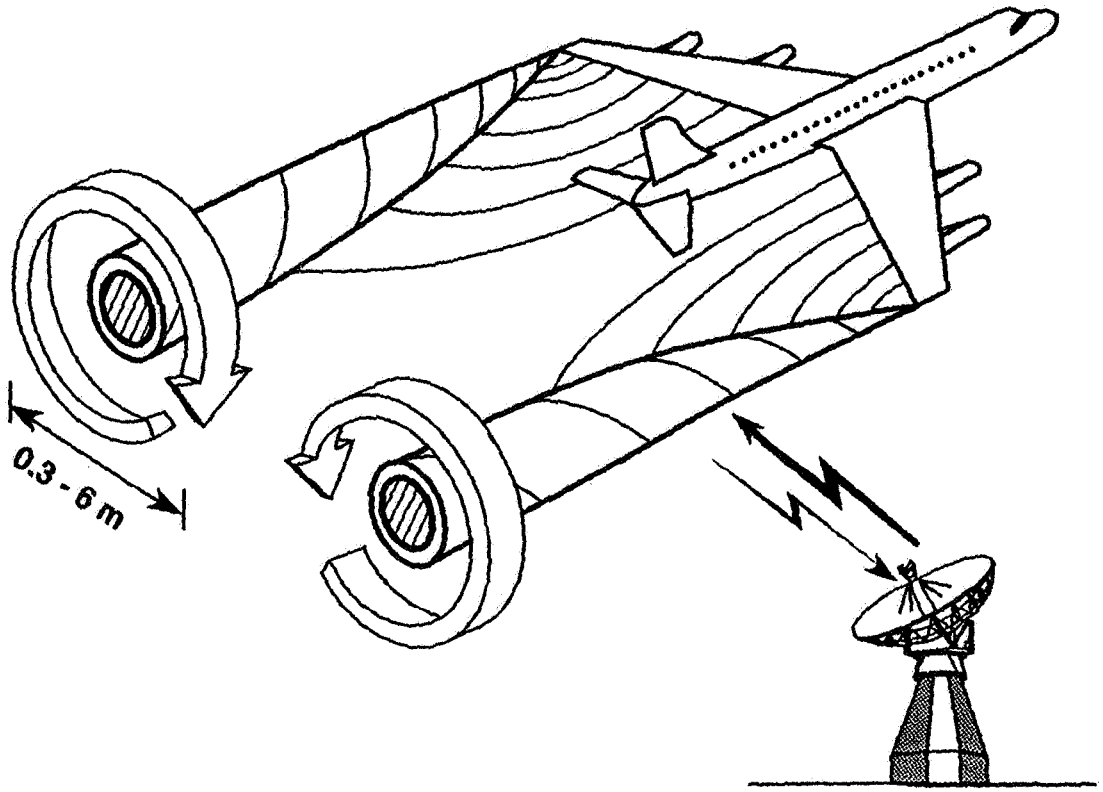
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

THIS WORK WAS SPONSORED BY THE OFFICE OF NAVAL TECHNOLOGY. THE VIEWS EXPRESSED ARE THOSE OF THE AUTHOR AND DO NOT REFLECT THE OFFICIAL POLICY OR POSITION OF THE U.S. GOVERNMENT

OUTLINE

- BACKGROUND
- RADARS AND AIRCRAFT
- RADAR DATA EXAMPLES
- WAKE SIGNATURES
  - STRENGTH
  - POSSIBLE MECHANISMS
  - ARE WAKES USEFUL "TELL-TALES?"
- SUMMARY

AIRCRAFT WAKE STRUCTURE AND RADAR SCATTERING

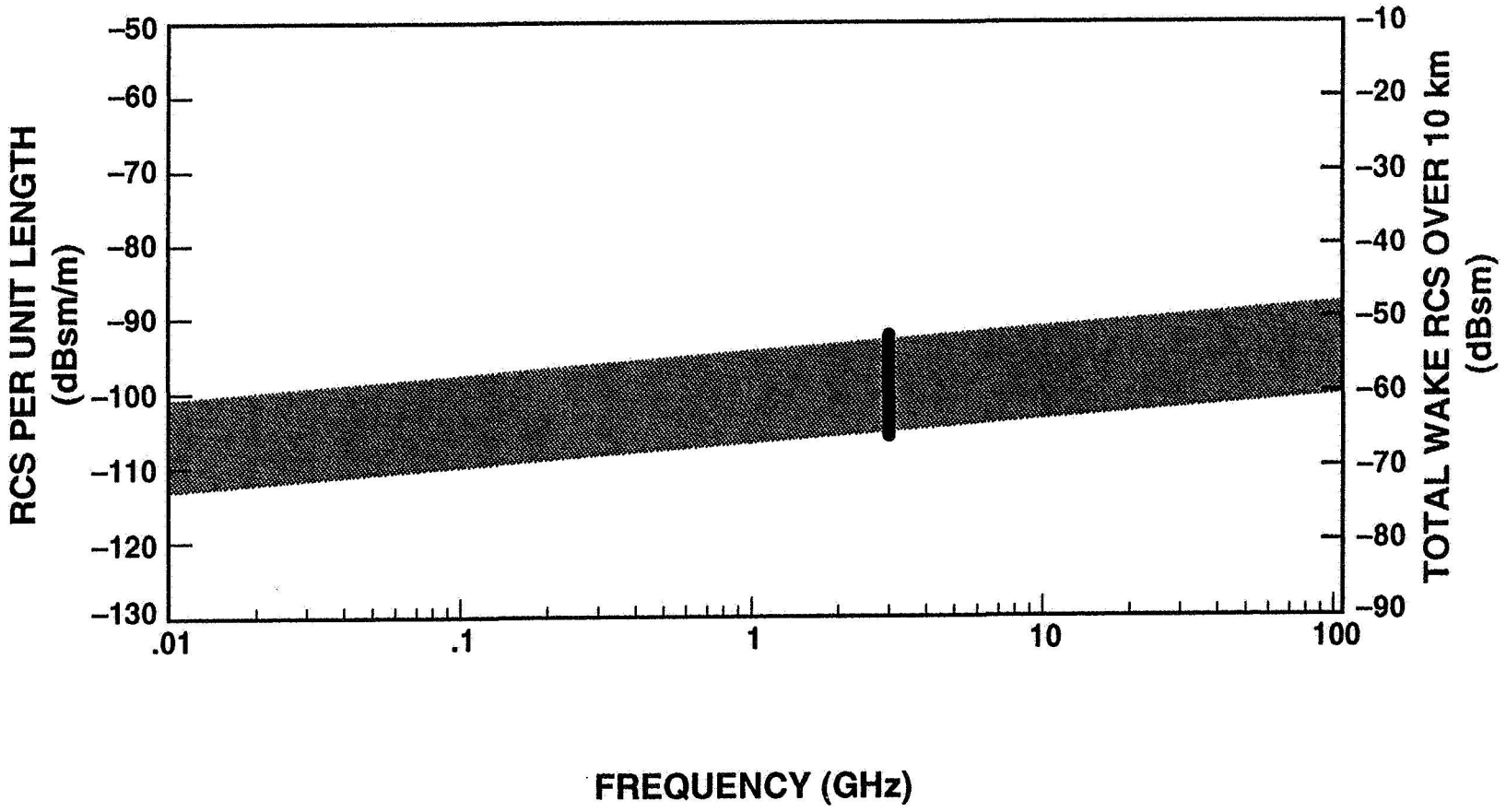


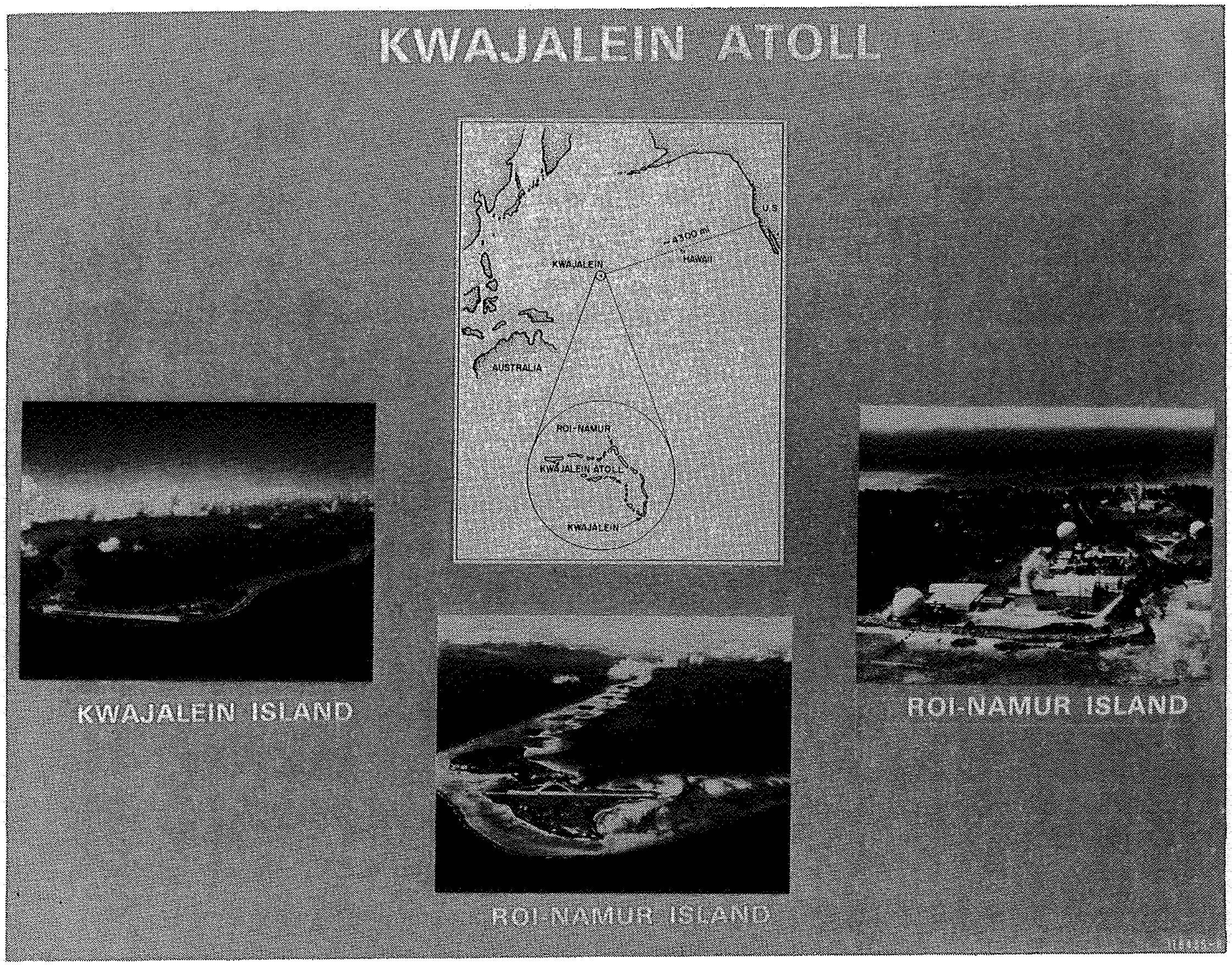
- WAKE STRUCTURES
  - — SENSITIVE TO AIRCRAFT CONFIGURATION
  - — INITIALLY LAMINAR FLOW DECAYS TO TURBULENCE
  - — UP TO 10 TO 20 km LONG

- POTENTIAL SCATTERING MECHANISMS
  - — REFRACTIVITY VARIATIONS
    - EXHAUST HEAT AND MOISTURE
    - MIXING OF ATMOSPHERIC STRATA
    - VORTEX DYNAMICS
  - — EXHAUST PARTICULATES AND AEROSOLS

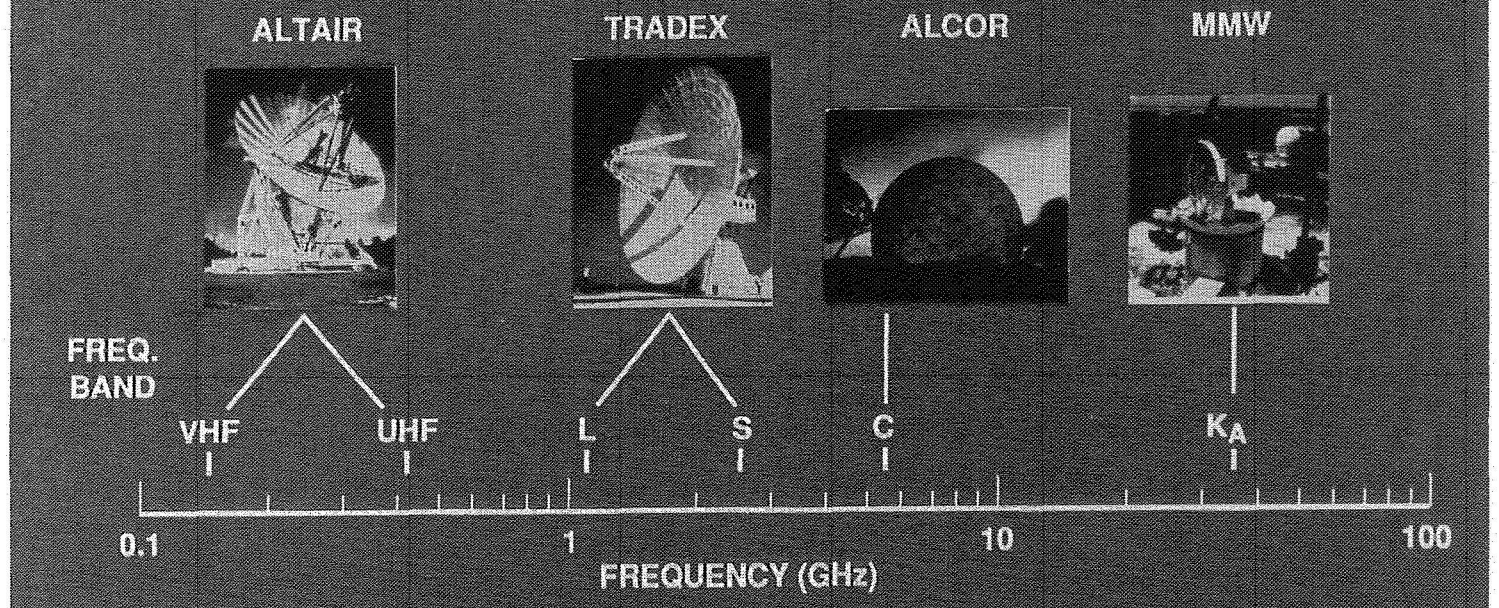
AIRCRAFT WAKE SIGNATURE
PRIOR MEASUREMENTS AND CALCULATIONS

EXTRAPOLATION




KWAJALEIN ATOLL
U.S.
~4300 mi
HAWAII
KWAJALEIN
AUSTRALIA
ROI-NAMUR
KWAJALEIN ATOLL
KWAJALEIN
KWAJALEIN ISLAND
ROI-NAMUR ISLAND
ROI-NAMUR ISLAND

KIERNAN REENTRY MEASUREMENT SYSTEM (KREMS) RADARS



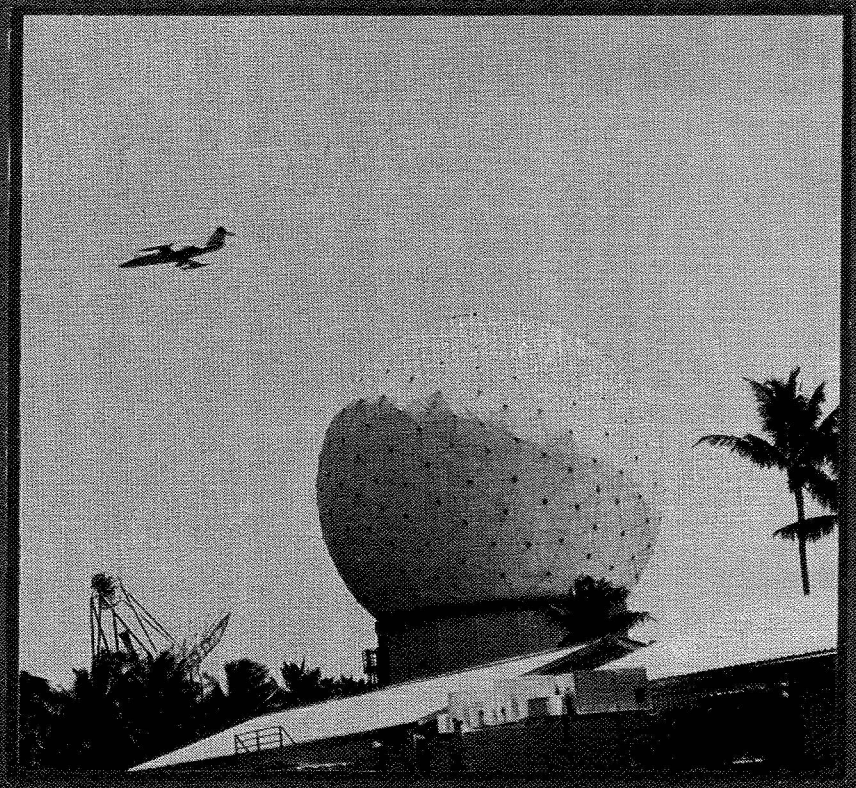
	ALTAIR		TRADEX		ALCOR	MMW
APERTURE DIAMETER (ft)	150		84		40	45
	VHF	UHF	L	S	C	K_A
PEAK POWER (MW)	7	5	2	2	3	0.025
SINGLE PULSE SENSITIVITY AT 200 km (dBsm)	–64	–73	–68	–56	–51	–45

178707-1

AEROMET LEARJET 36 FLY-BY
25 MAY 1990

GATES LEARJET 36

WING SPAN	12 m
MASS, EMPTY	4300 kg
MASS, MAX T.O.	8300 kg
FUEL FLOW AT 45,000 ft	1100 lbs/hr



177348-4

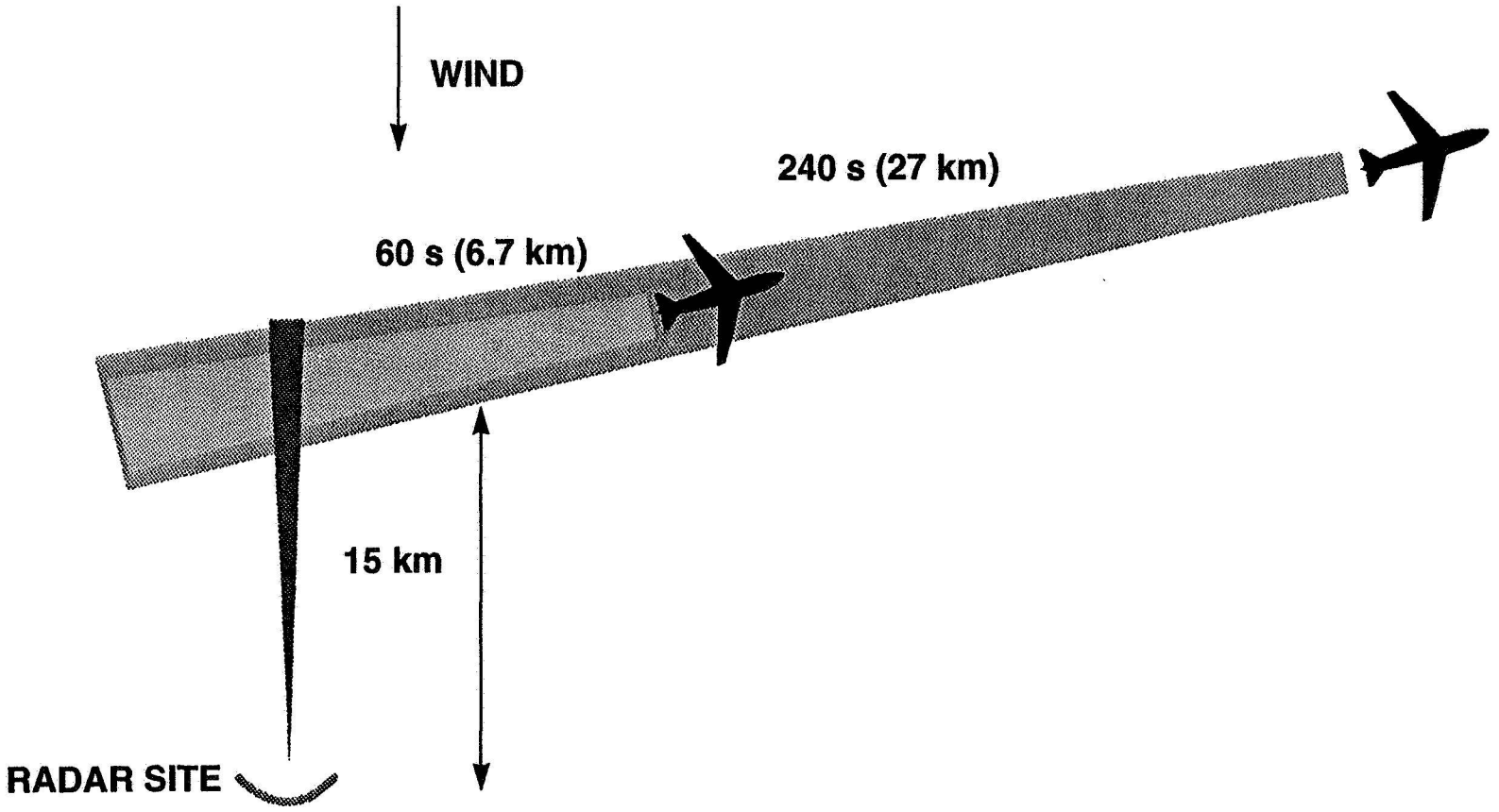
439 MAW C-5A FLY-BY
15 JUNE 1990

LOCKHEED C-5A GALAXY

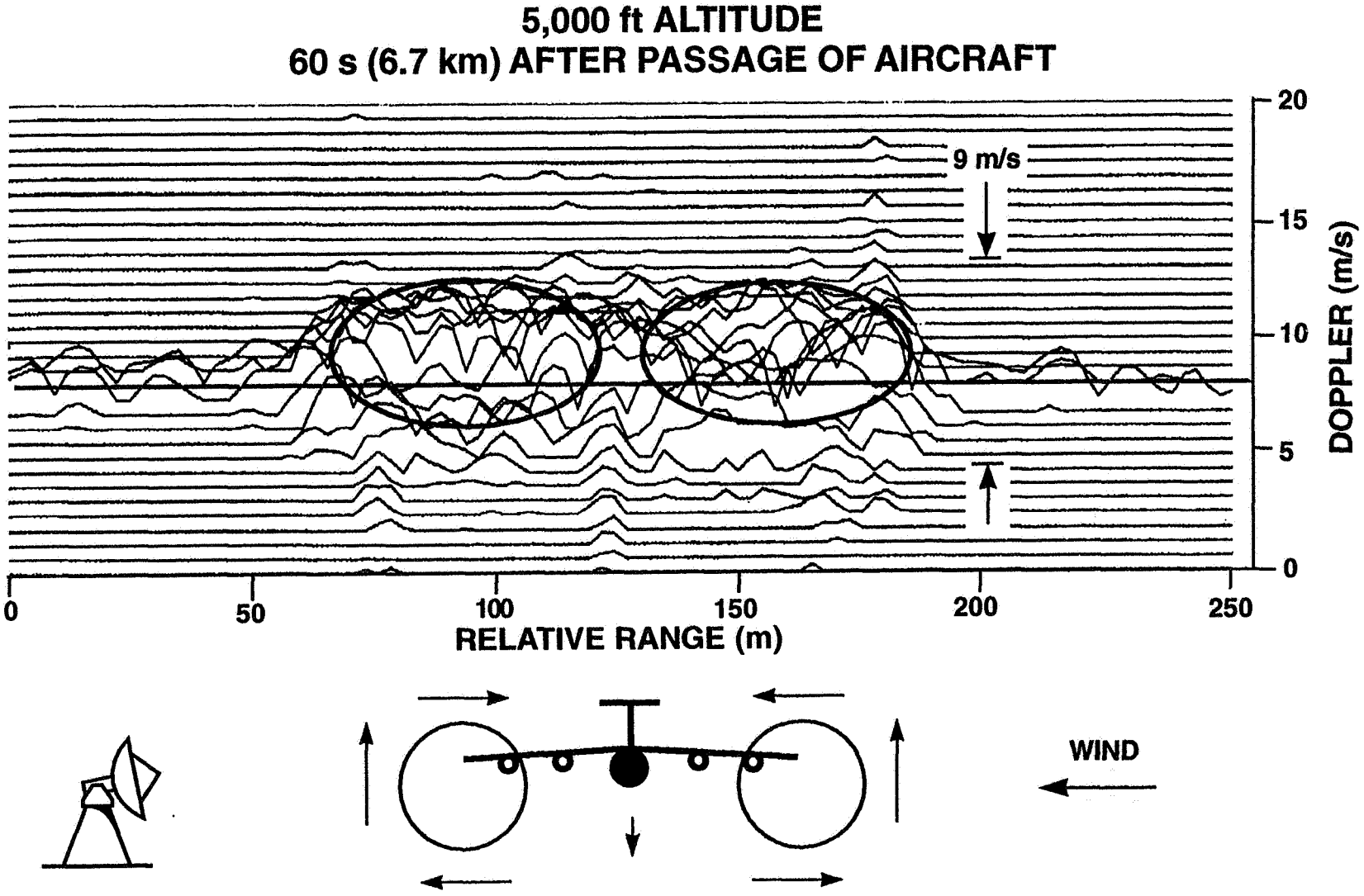
WING SPAN	68 m
MASS, EMPTY	150,000 kg
MASS, MAX T.O.	350,000 kg
FUEL FLOW AT 40,000 ft	18,000 lbs/hr

177345-5

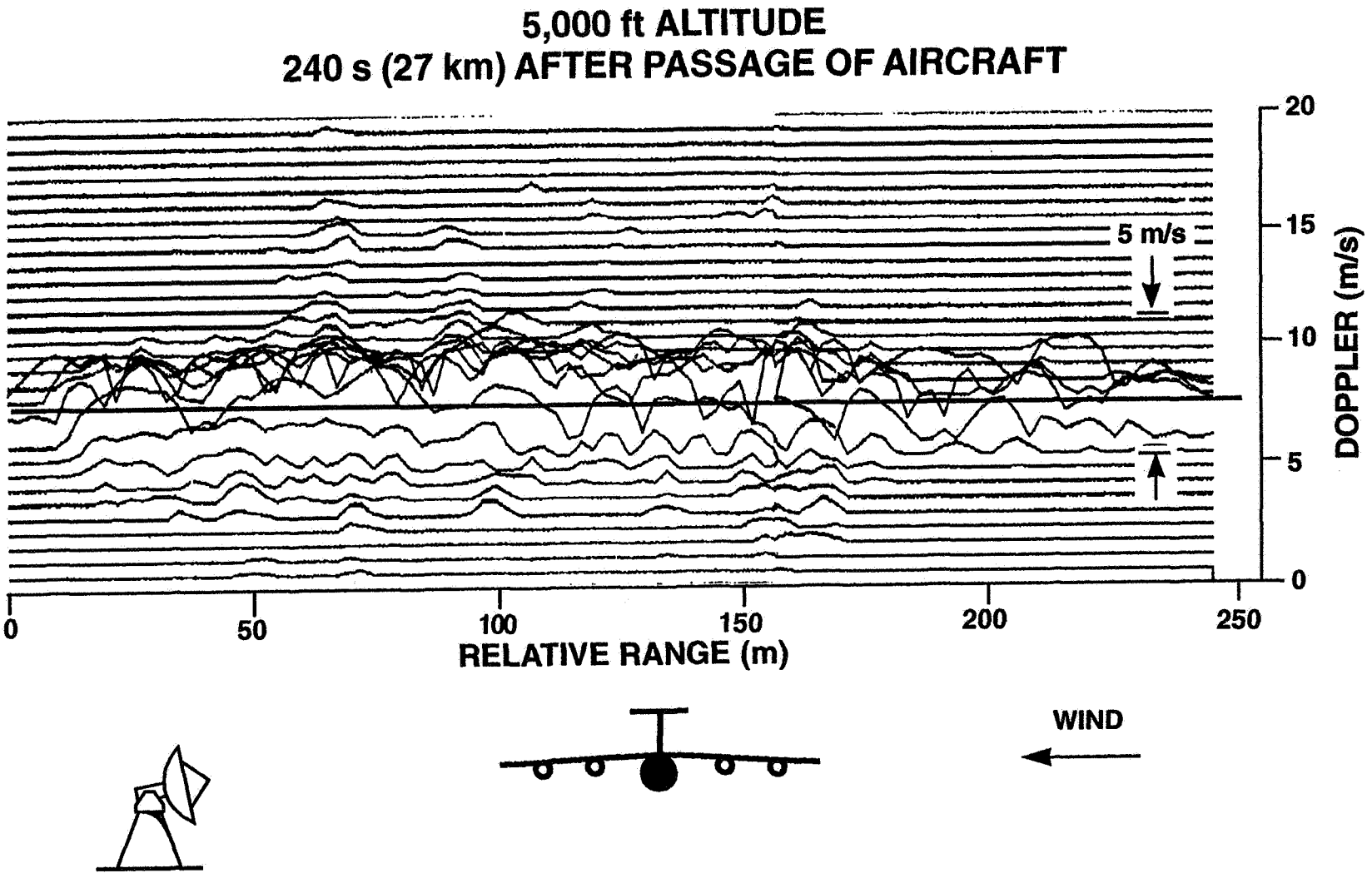
FLIGHT PATH AND DATA RECORDING
TEST RUN AT 5,000 ft ALTITUDE



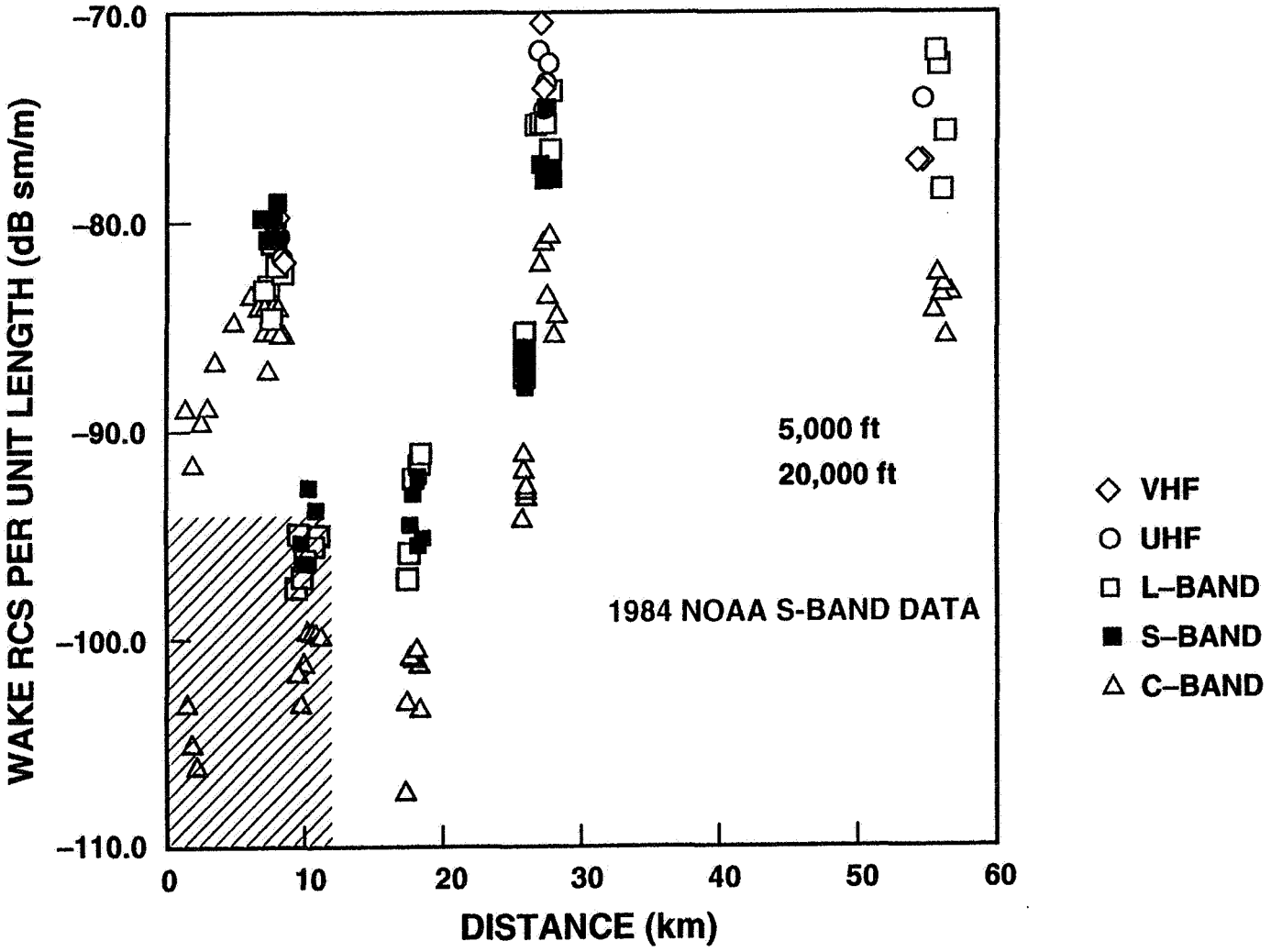
S-BAND RANGE-DOPPLER SLICE THROUGH C-5A WAKE



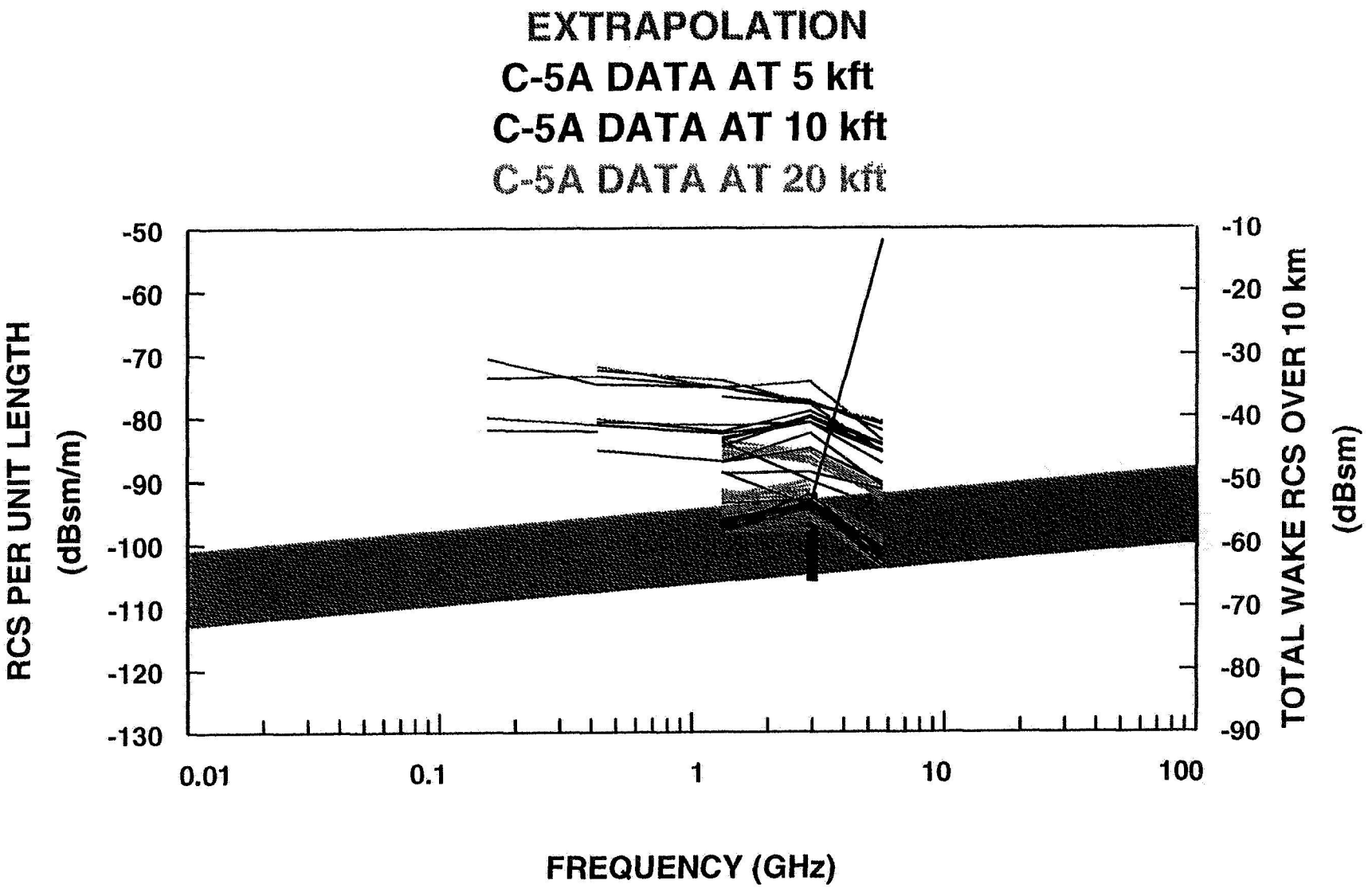
S-BAND RANGE-DOPPLER SLICE THROUGH C-5A WAKE



C-5A WAKE DATA



AIRCRAFT WAKE SIGNATURE
PRIOR MEASUREMENTS AND CALCULATIONS



SUMMARY OF C-5A WAKE SIGNATURE DEPENDENCE

PARAMETER	DEPENDENCE	CONCLUSION
DISTANCE	INCREASES FOR CA. 10 km, THEN TRAILS OFF	RELATED TO TURBULENCE
FREQUENCY	LARGELY FLAT, FALLING OFF AT C-BAND	NOT PARTICULATES
ALTITUDE	DECREASES WITH HEIGHT; NOT SEEN ABOVE 27 kft	RELATED TO LOW-ALTITUDE CLIMATE
ENGINE THRUST	NONE: IDLE TO MILITARY RATED THRUST	WEAK EXHAUST CONTRIBUTION
FLAP SETTING	NONE: ZERO TO HALF FLAPS	INDEP. OF DETAILED VORTEX STRUCTURE
AIR SPEED	NONE: 100 kn VARIATION	INDEP. OF DETAILED VORTEX STRUCTURE

POSTULATED MECHANISM

- TURBULENT MIXING OF ATMOSPHERIC INDEX OF REFRACTION GRADIENTS
  - CONSISTENT WITH RCS DEPENDENCE ON
    - ALTITUDE
    - THRUST
    - TIME
    - FREQUENCY
- STRENGTH DEPENDS ON CLIMATE
  - STRONGEST IN TROPICS NEAR SEA LEVEL
- EXHAUST HEAT AND MOISTURE MAY GIVE LOWER LIMIT

SUMMARY

- PRIOR WORK SUGGESTED A VERY SMALL WAKE RCS
- AT KWAJALEIN
  - ENGINE EXHAUST COMPONENT NOT DISCERNIBLE
  - DOMINANT ATMOSPHERIC MIXING CONTRIBUTION
- NO USEFUL "TELL-TALE"
  - STRONG CLIMATE DEPENDENCE
  - LARGE AND COMPLEX SYSTEM
  - CLEAR AIR TURBULENCE CLUTTER

WSMR V. (KWA) WAKE RCS MEASUREMENTS

RADAR	MOTR	ALCOR	ALCOR/MOTR
Peak power	1 MW	3 MW	5 dB
Beam width	1°	5°	-14 dB
Duty factor	0.1%	5%	17 dB
Range	3km	15km	-14 dB
Beam-filling loss (100 m wake)	←		-10 dB
Relative sensitivity to wake C_n^2 i.e. MOTR more sensitive			-16 dB

AIRCRAFT	A-7	LEARJET 36	C-5A	
	22 klbs	10 klbs	330 klbs	dry

QUESTION #3

Can a radar detect and quantify the VORTEX STRENGTH?

OBVIOUS ANSWER - In principle - YES, WITH ENOUGH RANGE OR ANGULAR RESOLUTION?

MY QUESTION FOR THE AERODYNAMICISTS?

WHAT IS ENOUGH RESOLUTION?

(e.g. 1m range by 50 m (cross range))

ATMOSPHERIC DATA FOR WAKE RCS MEASUREMENTS

	WSMR	KREMS
Rawinsondes	AM, PM	1130, from Kwaj.
Weather reports	Met. Station, Before & after fly-bys	Met. station on Kwaj. Mornings, before missions.