A HISTORICAL NOTE

THE ROCKET RADAR

Walter E. Brown, Jr

February 9, 2002

The JPL radar program really began at 08:30 am MST on the 9th of May in 1966. An Aerobee rocket carried a JPL built radar up to 162Km. It was the first unclassified radar in space and it was there solely for scientific purposes. For those of us who had been struggling with development of the Rocket Radar for the previous 5 years, never have there been a more beautiful set of echoes.

Figure 1. Liftoff of the Aerobee 150 from the U.S. Navy Tower at White Sands Missile Range at 08:30 MST 09 May 1966, NASA Flight 4.106

THE DRIVING FUNCTIONS

First

The JPL Radioscience effort was initiated in the Space Science Division in 1960 with the invitation to the major players involved in radio astronomy to attend a symposium at Von Karman on June 16th and 17th . NASA was just forming at the time and the role of JPL was to be **planetary exploration**. The purpose of the symposium was to discuss radar and radiometer spacecraft instrumentation for the exploration of Venus.

The attendees included

Dr. W.H Pickering	*JPL*
Mr. W.E. Brown	
Mr. John Small	
Mr. Robert Stevens	
Prof J. Francis Reintjes	*MIT*
Mr. Allen r. Edison	*Univ of New Mexico*
Dr Thomas E. Tice	*Ohio State University*
Dr. Alan T. Waterman, Jr.	*Stanford University*
Dr. Von R Eshleman	
Dr. Gordon H. Pettingill	*Lincoln Labs*
Dr. Paul E. Green Jr	
Prof Keeve M. Siegel	*Univ of Michigan*
Prof John G Bolton	*Caltech*
Dr. Marshall Cohen	*Cornell*
Dr. Sam Silver	*Univ of California*
Dr. A. E. Lilley	*Harvard University*
Dr. A.W.Straiton	*Univ of Texas*
Colonel Haseman	*Army Map Service*
Mr. B.C. Ashenbreuner	*Autometric Corp*
Dr. A.H. Barrett	*UnivofMichigan*

One instrument design submitted by WEBrown for consideration for a Mariner Venus flight, was a radar radiometer. At that time we had little knowledge about the ionosphere, atmosphere and surface at Venus. The support and enthusiasm for exploration of Venus by this group added to the Lab's conviction to move ahead with radioscience studies and activities.

In the following two years, Frank Barath, Al Laderman, Rolando Jordan and Dave Martin were added to the Radioscience group. The radar/radiometer for the Mariner 3 mission to Venus became a radiometer and was launched in 1963 and measured the Venus disk temperature.

Second

The radar community felt that it had the need for a better understanding of radar backscatter. Here was a technique where one could generate a modulation function and reach out to a remote surface, electromagnetically speaking, and get back a response that could be a preview of what that surface was like. But the first echoes from the Moon obtained by Trexler did not behave in a manner one would have predicted, at least not at that time. Was this some strange effect of the Lunar surface, or some unknown response due to the large size of the Fresnel zone at the Moon or what? Thus an experiment was proposed to fly a radar at great height over a known surface, compare the response to that obtained from an aircraft radar at lower altitudes and the Earth based radar echoes from the Moon and Venus.

LET'S ROLL

The rocket radar implementation began in 1961 with Bendix building the first two systems. NASA Goddard handled the Aerobee rockets, they had been launching the Aerobees from Wollops Is. They were four fin rockets. We were the first program to request White Sands as the launch site. It required two launches of the three fin version of the Aerobee from WSMR to work out the differences in the Attitude Control System between the 4 fin and the 3 fin version. No radar data were obtained. The next two radars were designed and fabricated at JPL. Rolando and us helpers hand wound the filament toroids in the 7th floor long hallway in building 189 [after normal working hours of course], many times, until we found out how to do it so that they did not arc at high voltage.

The first JPL version of the rocket radar flew in 1965 but acquired no data, It tested perfectly before and after flight but not a single pulse during flight. The mystery continued for several months after the flight until Rolando, dismantling the transmitter, happened to turn the magnetron over to set it on the bench and heard a faint rattling. The magnetron was opened up and we found that a small bead of metal that had been formed when the coupling loop was welded on the coax output by Raytheon, had broken off and migrated, in a zero G environment and a strong electric field to the area of the strongest field and shorted out the magnetron. On the ground, in a 1 G field, it fell to the bottom of the magnetron and had no effect. Raytheon built a second tube, at added cost, and it was installed in the rocket Radar. In addition, WEBrown was called to Washington to explain to Oran Nicks why the radar should be allowed to fly on the fourth Aerobee. That session was an all day explanation, which was finally accepted, but with some trepidation. So we went back to White Sands in April 1966 for one last chance to save the JPL radar program.

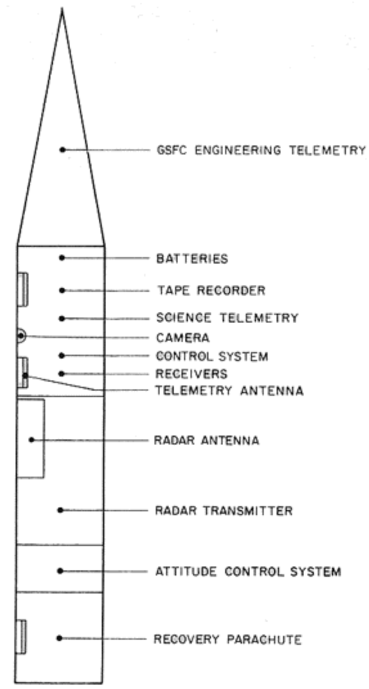

Figure x. *A description of the payload, length 128 inches, diameter 15 inches, the radar antenna is located on the side. After main engine cut-off the payload was programmed over to a horizontal orientation, the radar was turned on and the camera began taking photographs of the surface every 6.8 sec. It acquired some 32 photos over the entire flight.*

TABLE I

RADAR FLIGHT SYSTEM PARAMETERS

Parameter	Value
Radar	
Frequency	998 MHz
Wavelength	30 cm
Peak power	100 kW
Pulse width	10 μs
Pulse-repetition frequency	150 pps
Antenna gains	6 dB/7.5 dB
Total half-power beamwidth	60°
Polarization	linear
Isolation on axis	30 dB
Noise figures	7 dB/6 dB
IF bandwidth	2 MHz
Logarithmic dynamic range	60 dB
Linearity	± 1 dB
Tape recorder	Kinelogic
Tape width	$\frac{1}{4}$ in
Tracks	6
Speed	30 in/s
Bandwidth	200 kHz
Telemetry	FM
Frequencies	248.6 MHz 253.5 MHz
Power	4 watts
Deviation maxima	± 750 kHz
Information bandwidth	500 kHz
Radar system power	900 watts
Power-on interval	7 min
Radar weight	150 lb
Instrumentation ACS, recovery package weight	158 lb
Total payload weight	308 lb
Total payload length	128 inches
Diameter	15 inches

TABLE II

GROUND SUPPORT SYSTEM PARAMETERS

Parameter	Value
Calibrator	
Frequency	998 MHz
Peak power	200 W
Pulse width	100 μs
Step width	20 μs
Step levels	6 dB
Antenna	
polarization	circular
gain on axes	9 dB/7 dB
Transponding delay	850 μs
Underground receivers	
Frequency	998 MHz
Noise figure	7 dB
Depths	0, 1, 3 ft
Antenna	
polarization	circular
bandwidth	800–4000 MHz
gain (nominal) on axis	4 dB

Figure x. The Rocket Radar Crew in front of the Rocket Radar calibration antenna and the Navy Blockhouse; L-R, Dave Martin, Al Laderman, Rolando Jordan, Frank Barath, Flannagan, unknown tech, Howard Friedman, Bob Blakely; down front, Walt Brown, Walt Skotnicki, circa 1965

The people who made the rocket radar system work

JPL

Frank Barath - Camera, Timing & Control
Rolando Jordan – Transmitter
Al Laderman – Receivers
Walt Skotnicki – Flight tape machine
Howard Friedman – Flight tape machine
Dave Martin - Calibration
Flannagan – technician
Walt Brown – Ground support equipment, realtime data conversion

GSFC

G MacVeigh – Vehicle structure
W Russell - Attitude Control System
E Bissel - Telemetry
R Conrad – Telemetry
B Pincus – Instrumentation

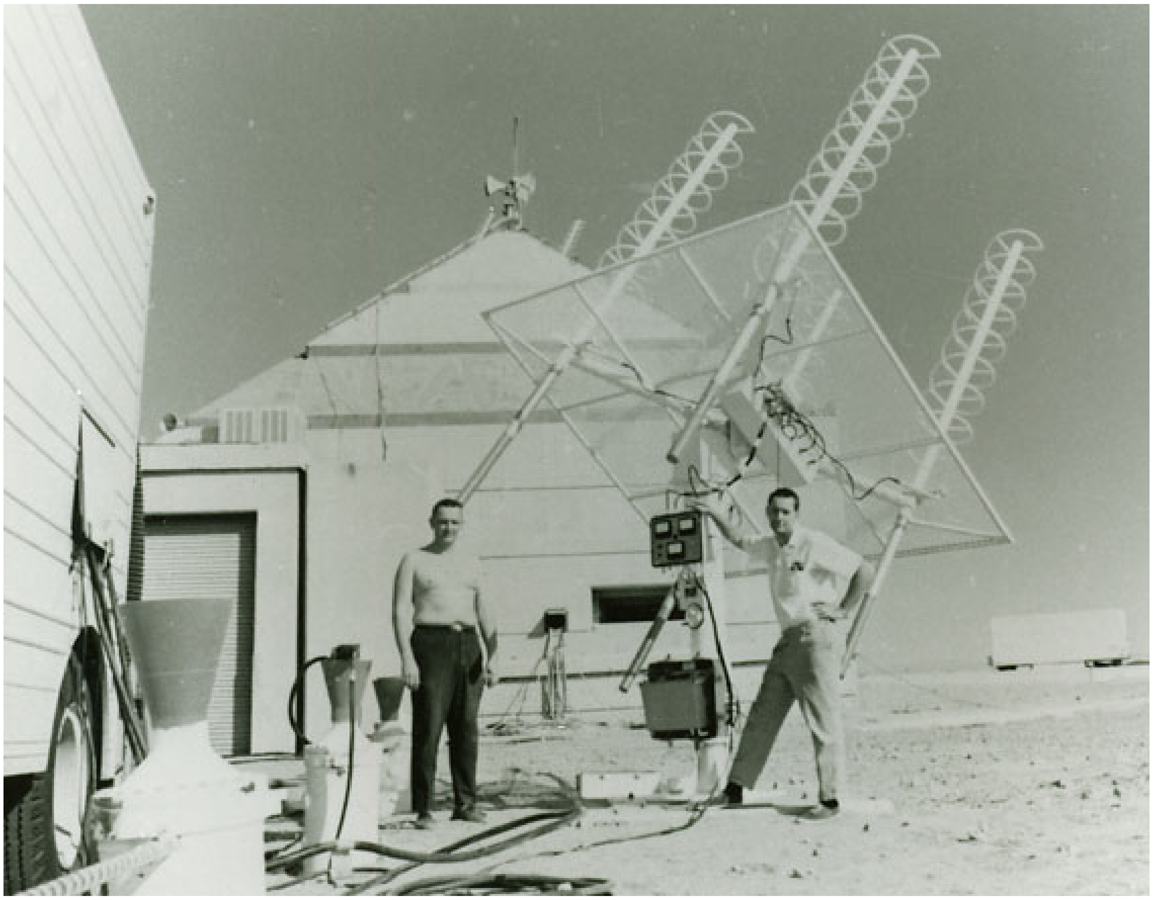

Figure x. *The Rocket Radar Calibration Antenna with Flanagan and Laderman; this antenna was circularly polarized, was used by Flanagan to manually track the Rocket Radar during flight . It received the radar transmitter pulse, displayed the difference signal from the left and right pairs of antennas and the difference signal between the top and bottom pairs of signals. The received signal was sent to a transponder which delayed the signal by 850μsec and transmitted a calibrated signal for the radar to receive. A real elegant way to obtain calibration. In this manner we were able to calibrate the entire system, both polarized and cross polarized channels and the Navy block house. Multipath from the blockhouse roof provided a 3dB modulation on the echoes – we thought for a moment we had discovered a new backscatter effect.*

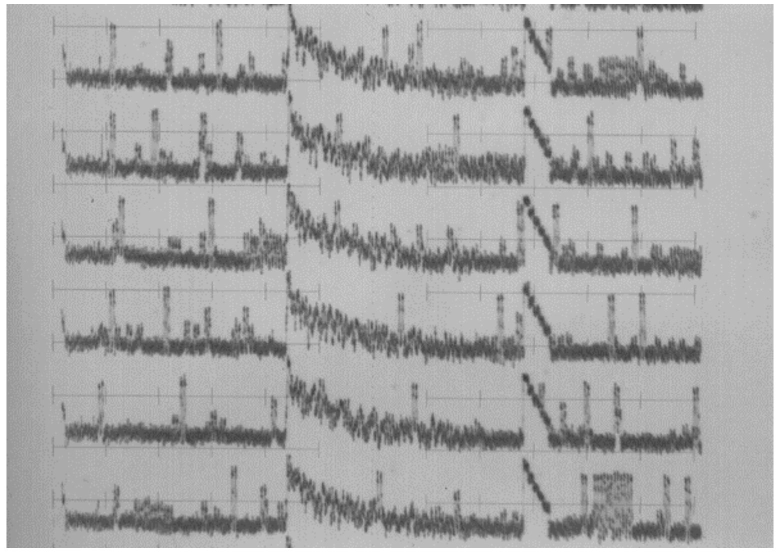

Figure x. *A sample of the Rocket Radar echoes taken from the polarized channel in real time. The interference is from various TACAN transponders [Tactical Aircraft Communications and Navigation]. When your receiver gets up to high altitudes, it can see dozens of stations. A time domain filter was designed that eliminated the interference. We hope they had a filter to eliminate our signal.*

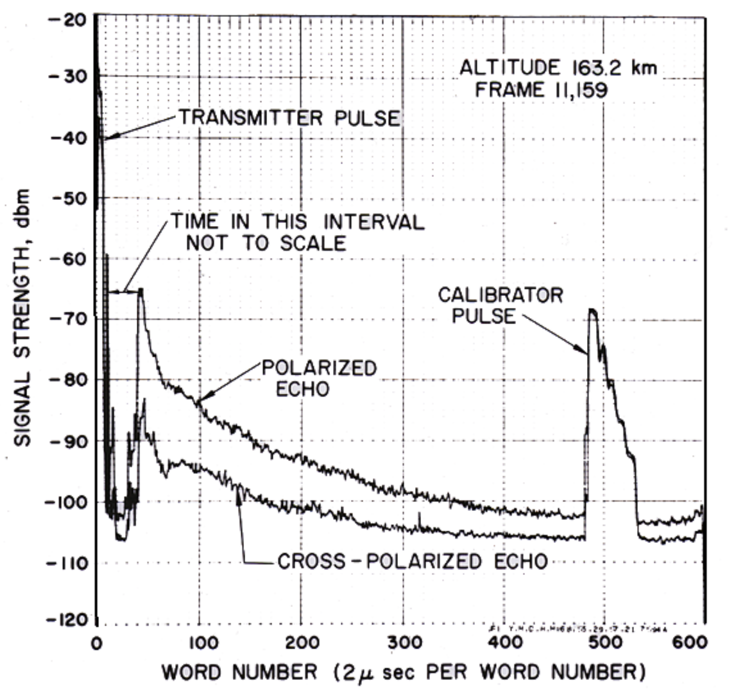

Figure x. ***The polarized and cross polarized echoes after filtering. Each point is an average of 100 echoes.***

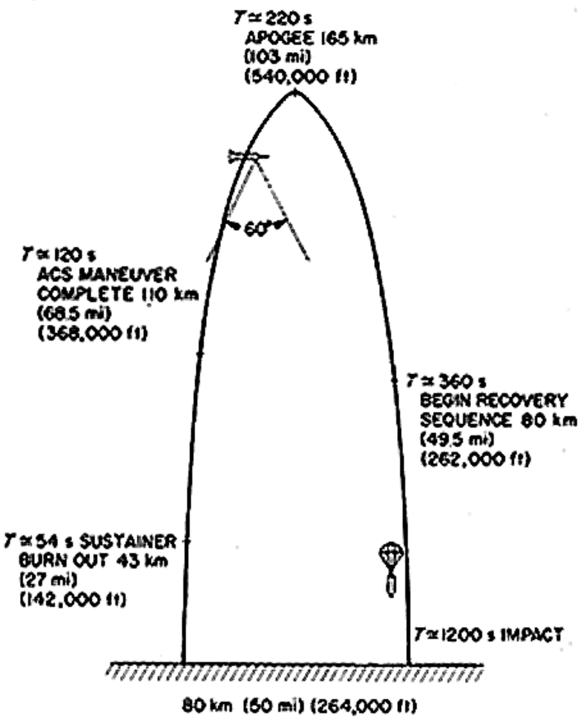

Figure X. Events versus trajectory

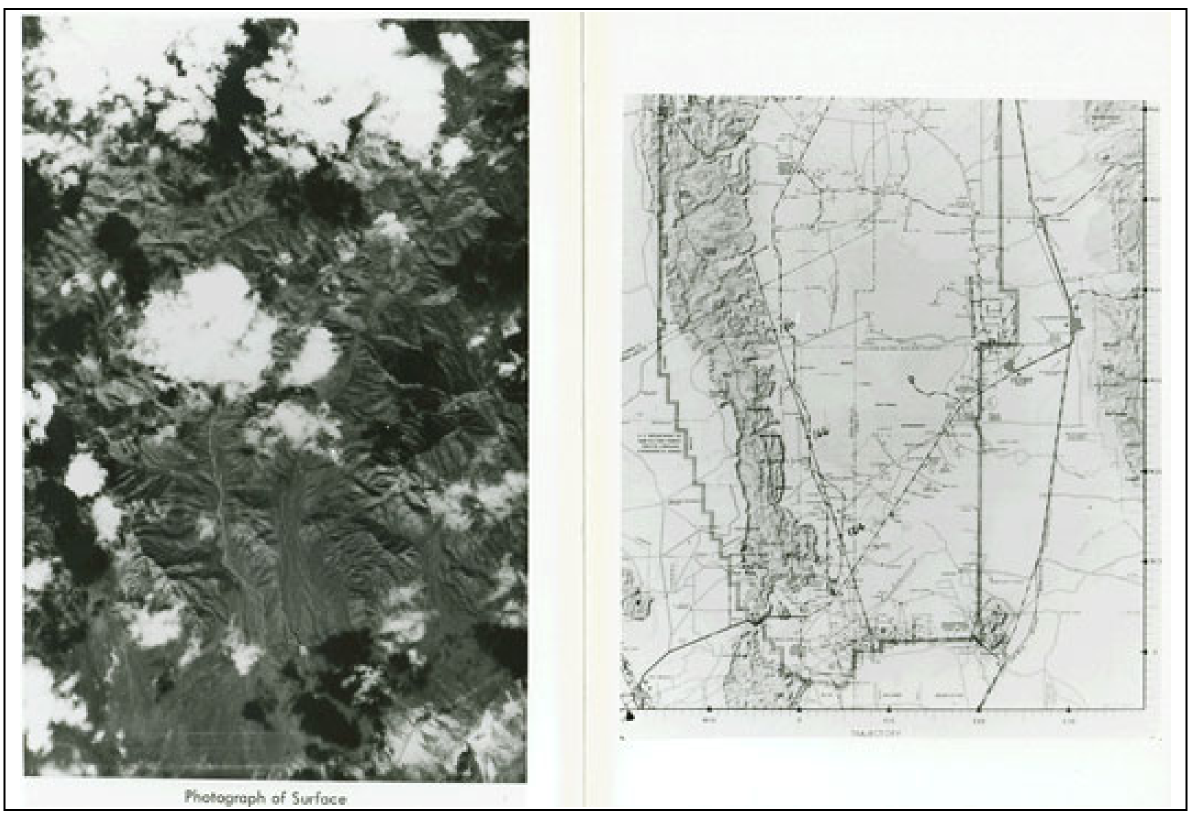

Figure x . A plot of the trajectory and a photo taken during flight

Figure x. The Rocket Radar after the flight. It was recovered by the recovery crew which included Al Laderman and returned to the Navy Lab where post flight calibration was conducted. The radar antenna and camera aperture can be seen facing upwards.

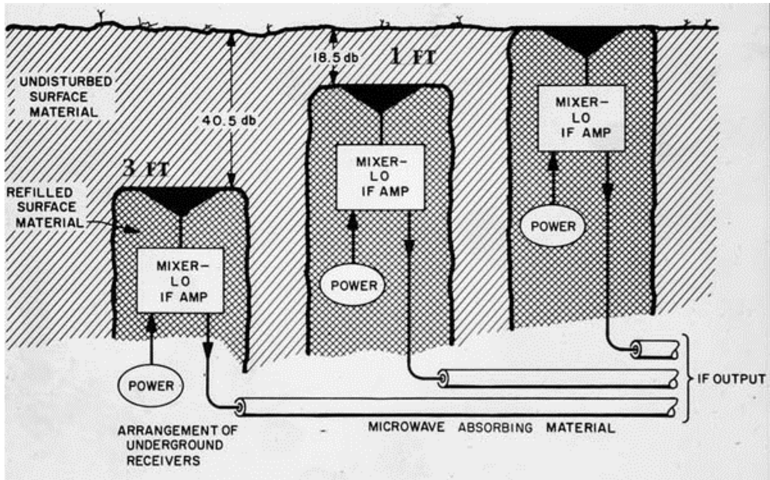

Figure x. Part of the Rocket Radar experiment included making measurements of the penetration of he 30 cm EM wave into the ground. The antennas were circularly polarized and placed in the ground in a manner to minimized and disturbance of the surface material. In the years 1962 to 1965, the surface was very dry with annual rainfall of a fraction of an inch of rain. In fact we had hopes of penetration of several feet. We had been running some system tests out on the pad radiating from the flight antennas. Right after Laderman and Flanagan dug the hole for the receivers, in fact, that night, there was a major down pour that filled the hole with water, so we concluded that 30 cm radiation causes rain and redesigned the experiment to test nearer the surface. The flight went about 3 weeks after this event, but the soil there does not drain well.

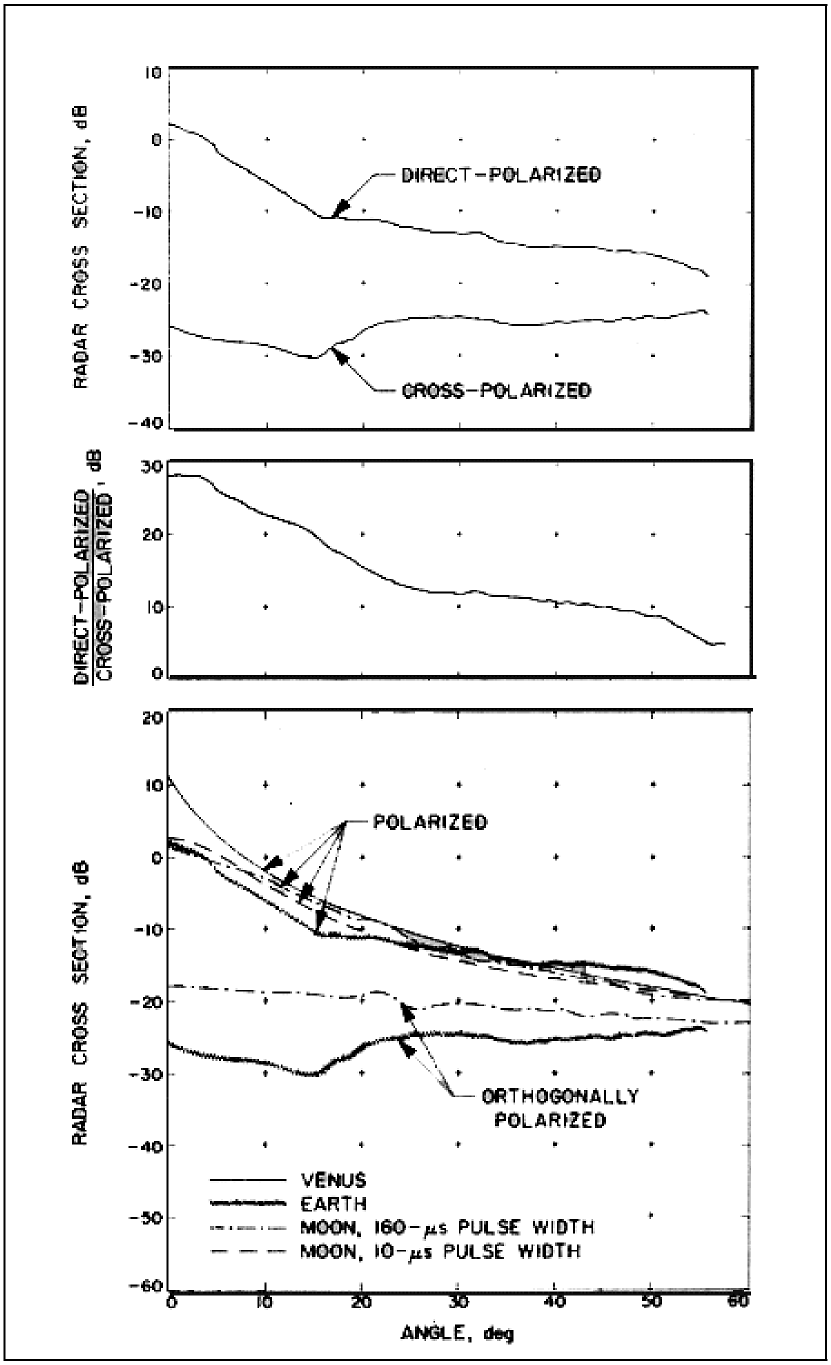

Figure x. *The results of the Rocket Radar Experiment compared with radar measures from the Moon and Venus. The conclusion is that the radar does not see much difference between the echoes from the surface of the Earth , the surface of the Moon and the surface of Venus. All is well in the local universe from the radar backscatter point of view.*

References

[1] R. K. Moore and C. S. Williams, Jr., "Radar terrain return at near-vertical incidence," *Proc. IRE*, vol. 45, pp. 228–238, February 1957.

[2] W. H. Peake, R. L. Cosgriff, and R. C. Taylor, "Terrain scattering properties for sensor system design (Terrain Handbook II), Ohio State University, Columbus, Engrg. Experiment Station Bull. 181, May 1960.

[3] B. L. Basore, "Analysis of cross-polarized components of radar reflection data," this issue, pp. 687–688.

[4] "Radar studies of the moon," M.I.T. Lincoln Lab., Lexington, Mass., Final Rept., vol. 1, August 31, 1967.

[5] W. E. Brown, Jr., "A lunar and planetary echo theory," *J. Geophys. Res.*, vol. 65, pp. 3087–3095, October 1960.

[6] J. V. Evans and T. Hagfors, "Study of radio echoes from the moon at 23 centimeters wavelength," *J. Geophys. Res.*, vol. 71, pp. 4871–4889, October 1966.

[7] W.E.Brown, Jr, "Radar Studies of the Earth," Proc. IRE, vol 57, NO 4, pp. 612-620, April, 1969

The spare radar unit [in the 15 inch diameter package] was mounted on the NASA Ames CV990 for measurement of echo characteristics at altitudes of 5Km and 10Km.

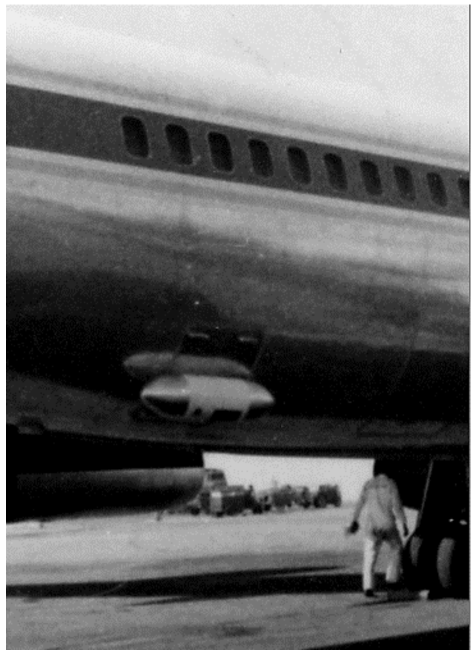

Figure 2. The Rocket Radar antenna adapted to the mounting on the baggage door of the CV990 NASA 711