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TRSB MICROWAVE LANDING SYSTEM DEMONSTRATION PROGRAM AT JOHN F. --ETC(U)
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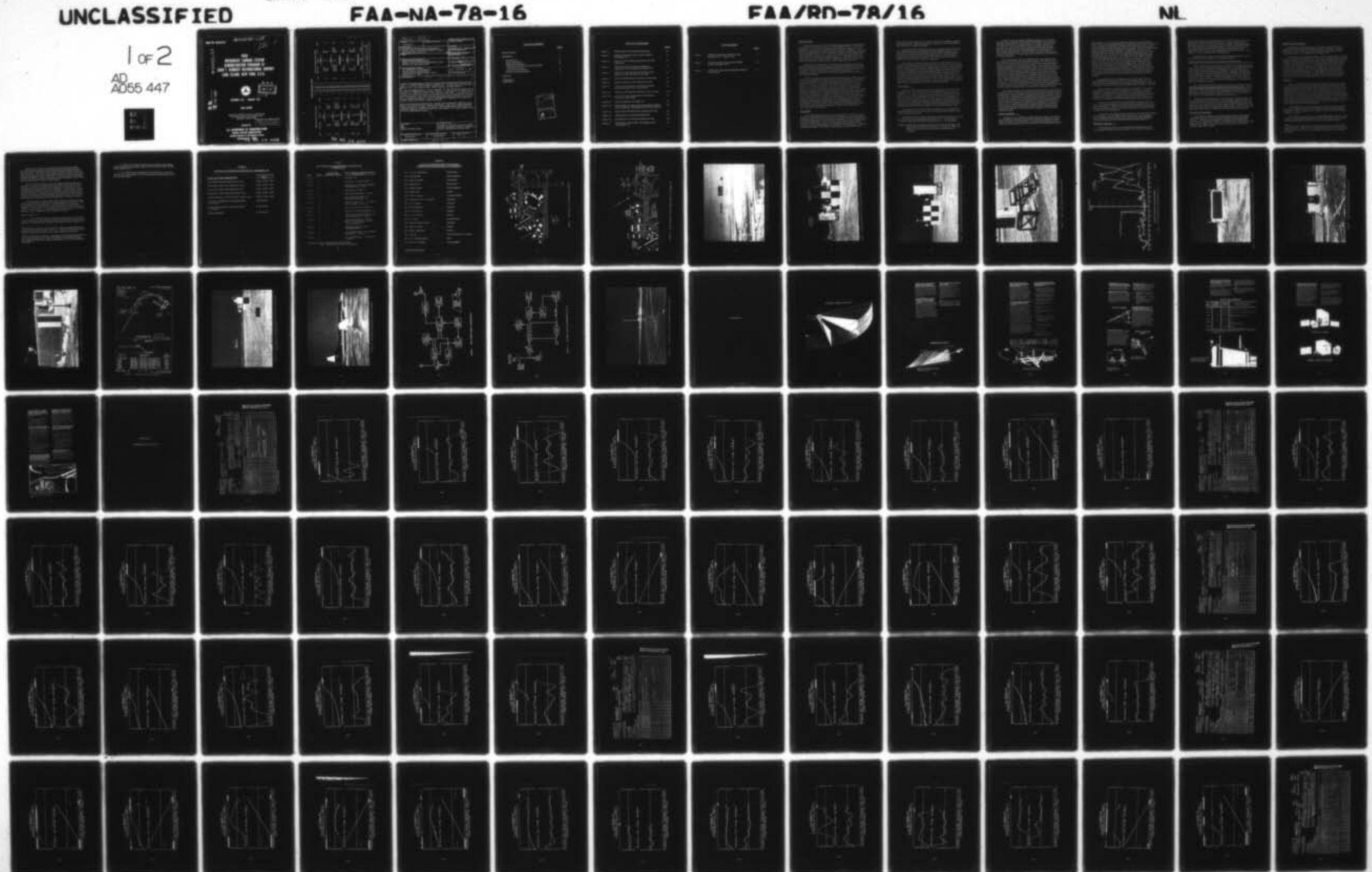

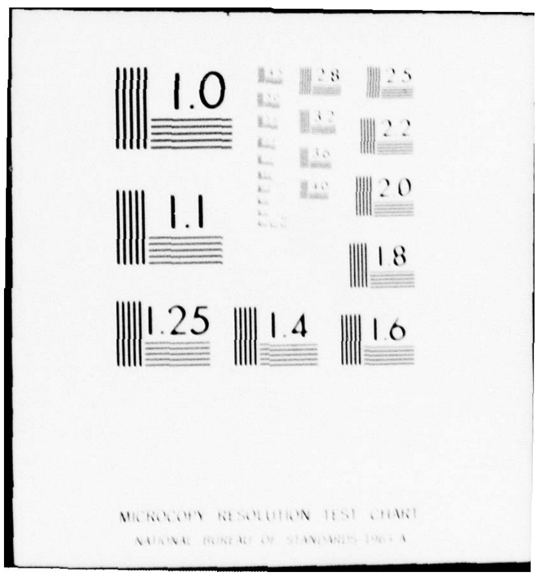
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NATIONAL BUREAU OF STANDARDS 1963-A

Report No. FAA-RD-78-16

TRSB MICROWAVE LANDING SYSTEM DEMONSTRATION PROGRAM AT JOHN F. KENNEDY INTERNATIONAL AIRPORT LONG ISLAND, NEW YORK, U.S.A.

DECEMBER 1977 - JANUARY 1978

FINAL REPORT

Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161.

Prepared for

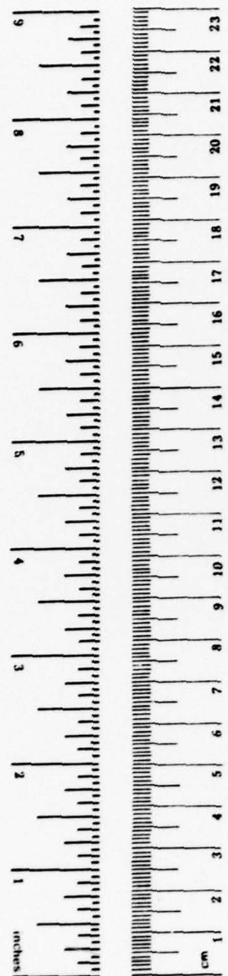
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
Systems Research & Development Service
Washington, D.C. 20590

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

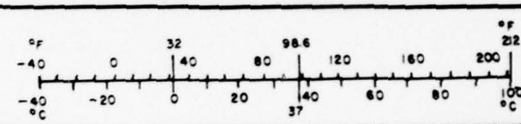
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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16. Abstract The demonstration at John F. Kennedy (JFK) International Airport was the fourth in a series of TRSB worldwide demonstrations. Previous demonstrations were held at other sites in the United States, Central America, and South America.

The TRSB system demonstration at JFK in December 1977 was installed on Runway 13L and consisted of a 1° phased array azimuth subsystem, a 1.5° elevation subsystem with an antenna of the Rotman lens design, and a precision L-Band DME. A new laser tracker, previously untried in the field, was provided for precise aircraft position data, but due to calibration survey errors and data processing software problems, the tracker data was considered unusable. However, TRSB airborne recordings are available for several flights and provide a useful data output.

During the operational demonstrations, national and international observers in the NASA B-737 aircraft flew the "Canarsie approaches," under fully coupled and manual flight conditions to touchdown and rollout. These demonstrations highlighted the important capability of MLS to provide precision guidance over complex approach paths to a busy international airport.

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JFK
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INTRODUCTION

Several years ago the Federal Aviation Administration (FAA) embarked on a program to develop a Microwave Landing System (MLS). Two design techniques, Time Reference Scanning Beam (TRSB) and Doppler scan were analyzed and developed for comprehensive comparative evaluation. Numerous tests were conducted at the FAA's National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey, before the FAA selected the TRSB system as the choice for final development. TRSB MLS is the United States/Australia (Interscan) candidate submission to the International Civil Aviation Organization (ICAO) as the eventual replacement for ILS.

In March 1977, following a 15-month period of intensive and comprehensive assessment of all competing microwave landing systems, the ICAO All Weather Operations Panel (AWOP) recommended TRSB as the preferred candidate microwave landing system for international adoption. This assessment involved more than 100 leading international experts in microwave landing systems.

The Air Navigation Commission (ANC) forwarded the AWOP recommendation to the ICAO Council, whereupon the Council scheduled a worldwide meeting for April 1978, to address the question of selecting the new international standard for an approach and landing guidance system. In the interim, in consonance with the ICAO Council suggestion that proposing States carry out demonstrations at operational airports, the FAA has developed a program to conduct operational demonstrations of several TRSB hardware configurations at selected airports in the United States and abroad. (Hereafter for simplicity, "TRSB MLS" will be referred to as "TRSB.") These demonstrations are intended to show that the TRSB signal format and system design are mature and satisfy the full range of requirements from general aviation use to scheduled air carrier operations, for Category I to Category III autoland. Additionally, these demonstrations provide opportunities for representatives and officials of the international aviation community to gain first-hand knowledge of TRSB and its application to their particular requirements.

DISCUSSION

The TRSB flights of December 5 through January 4, 1978, at John F. Kennedy International Airport represent the fourth in a series of operational demonstrations at domestic and foreign civil airports. These demonstrations had several objectives. First, the use of TRSB for automatic guidance on an actual complex path used for noise abatement and to resolve traffic conflicts with LaGuardia Airport, was planned for demonstration. Collection of engineering data on TRSB was a second objective which had the twin goals of providing a data base for further validation of multipath computer simulations and for collecting performance data to be used in the bilateral data comparison of DMLS and TRSB.

The operational demonstrations were accomplished without difficulty, and aviation officials and international technical experts observed and participated in coupled and manually controlled flights of TRSB equipped aircraft at this large and busy international airport. The operational flight profiles were patterned after the JFK noise abatement profiles to Runway 13L, known as the "Canarsie" approach.

The required engineering data to satisfy the second objective was unusable due to problems connected with the time correlation of the precision tracker data and the TRSB receiver angle output records, and the associated tracker calibrations and computer software required to process and reduce the data. Subsequently, the engineering data collection effort at JFK was rescheduled for early in March 1978, which would be immediately prior to the scheduled DMLS tests at JFK. This would allow sufficient time to resolve the tracker data processing problems and thus allow proper support of both the TRSB and DMLS test efforts. These latter efforts were successfully conducted during March 1978; the results are the subject of a separate report on the comparative tests of DMLS and TRSB at JFK.

Site Selection

Figure 1 shows the siting of the TRSB equipment at the JFK airport on Runway 13L. Note that two locations are indicated for the elevation subsystem. A "mixed" TRSB system was installed consisting of the Basic Wide "test bed" azimuth subsystem and the Basic Narrow elevation subsystem. Although the Basic Wide "test bed" was the designated system to be used in the comparative testing,* the elevation array had been returned earlier to the manufacturer (Bendix Corporation) for refurbishment and packaging in a case suitable for mobile field demonstrations, and had not become available at the time scheduled for the demonstrations at JFK.

The Basic Wide "test bed" azimuth subsystem is a conventional 1° beamwidth phased array, and provides $\pm 60^{\circ}$ proportional guidance, with vertical coverage up to 20°.

The Basic Narrow elevation subsystem has lateral coverage in excess of $\pm 40^{\circ}$, and vertical proportional coverage to 15°. The antenna is a microwave optics (Rotman lens) design which has a 1.5° beamwidth.

*NOTE: By bilateral agreement between the UK CAA and the FAA, JFK and two other airports were chosen for comparative DMLS and TRSB trials and specific ground system components were designated.

In order to provide complete TRSB coverage of the "Canarsie" approach from centerline to the Canarsie (CRI) VOR, lateral azimuth coverage to about 45° and lateral elevation coverage in excess of 55° are required. Thus, the ± 60° azimuth unit is well suited for this approach, but the elevation signal is attenuated more than desirable near the CRI VOR due to the increased pattern roll-off beyond the 40° coverage specification. The Basic Wide "test bed" elevation subsystem with its wider coverage capability would be the preferred choice for this installation.

The available Basic Narrow elevation array was installed on the north elevation pad for the demonstration flights. This left the south pad open for the Basic Wide "test bed" array when it became available, without disrupting the demonstration schedule. Also, computer simulations suggested that measurable effects due to reflection of the elevation signal by the hangar line to the north of Runway 13L would be observed. Siting on the north pad would provide the best chance to acquire data applicable in further validation of the computer simulations, although the elevation signal quality would be somewhat degraded in the -25° to -30° azimuth region (about halfway between the centerline and the CRI VOR). Siting the elevation on the south pad would be the normal installation at JFK. This would also reduce the signal shadowing by the hangars to the north, and move any hangar reflection on the Canarsie approach to wider azimuth angles (beyond 35°). This more typical operational siting was the preferred location for the DMLS/TRSB comparative testing.

In the final analysis, the test bed elevation subsystem did not become available in time for installation during the demonstration period, and the demonstrations were completed using the Basic Narrow elevation sited on the north pad. Difficulties with deploying the newly acquired laser tracker and achieving integration into the data collection and processing systems, plus the late availability of the designated test bed elevation subsystem required that the comparative profiles be accomplished at a later time. Thus, no error data with precision tracking was obtained during this demonstration period, although the available airborne receiver angle records (see Appendix B) can provide some support to the simulation validation efforts.

System Installation

Runway 13L is 10,000 feet (3,048 meters) in length, but has thresholds displaced 1,000 feet (305 meters) at both ends, yielding a usable length of 8,000 feet (2,438 meters). The azimuth subsystem was sited along the extended centerline 2,170 feet (661 meters) beyond the stop end of the runway. The elevation subsystem as sited on the north pad was 250 feet (76 meters) perpendicular to the centerline and 769 feet (234 meters) from threshold. In less than 3 workdays from equipment arrival at JFK Airport, installation and alignment were completed. This was accomplished under extremes of weather conditions. Additionally, in the course of initial equipment set-up the electronic scan was inadvertently set to scan less than the $\pm$ 60°, and this was corrected before demonstrations and data gathering was undertaken. The TRSB sites with respect to Runway 13L and surroundings are depicted in Figure 2. Figure 3 is a general view of the TRSB elevation site in the vicinity of the hangar line to the north. Figure 4 is a closer view of the Basic Narrow elevation site, and Figure 5 shows this site from the opposite side. The JFK airport control tower and some of the airline terminal buildings at the airport can be seen in the background of this figure. Figure 6 details the mounting of the elevation antenna on the concrete pad. Although not shown in these views, the field monitor horn antenna for the elevation subsystem was located 1000 feet (30.5 meters) directly in front of the elevation antenna.

It is apparent from the perspective in Figures 2 and 3 that the three-hangar complex adjacent to the site has the potential to provide both reflection and shadowing effects at lower elevation angles. "Horizon" profiles for both the north and south elevation sites are shown in Figure 7.

Figure 8 shows the azimuth subsystem installation. The antenna and electronics for the azimuth subsystem are located in the antenna enclosure. In the background of this figure is the commissioned ILS localizer for Runway 13L. Although the azimuth subsystem was located in front of the localizer, it had no adverse effect on the localizer performance as verified by FAA Eastern Region flight-check inspections.

Figure 9 is a view of the azimuth subsystem enclosure from the rear. The mounting details of the enclosure on the concrete pads can be seen in this figure. Although not shown, the field monitor horn antenna for the azimuth sub-system was located 100 feet (30.5 meters) directly in front of the azimuth antenna.

Located near the TRSB azimuth subsystem, 309.4 feet (94.3 meters) to the northeast, was the DME electronics package. It was located in the van shelter which housed the laser tracker rather than within the azimuth enclosure where it would normally be housed (Figure 10).

Flight Path Geometry

The flight path used for the operational demonstrations was the curved Canarsie approach route to Runway 13L as shown in Figure 11.

Flights were made with an initial altitude of 2,300 feet (701 meters) over the Canarsie VOR and continued from there in a fully coupled curved approach on a steady 3.15° descent to final autoland. This approach path over Jamaica Bay and the Shore Parkway is a preferred route for avoiding traffic conflicts with LaGuardia Airport to the northeast and for reducing aircraft noise over heavily populated residential districts. Currently, it is only available under VFR conditions.

Standard profiles (radials, partial orbits and approaches) were used for the data acquisition flights and are listed in Table 1.

TRSB Operational Demonstration and Data Acquisition Flights

Close coordination between project personnel on the TRSB demonstration team and JFK air traffic controllers at the N. Y. Common IFR Facility and the ATC Tower permitted use of Runway 13L during daylight hours for the TRSB operational demonstration flights. However, the data acquisition flights had to be made between the hours of 0300 EST and 0700 EST, because the data flight patterns required the test aircraft to fly into the LaGuardia Airport airspace. Flights demonstrating the curved Canarsie approach encountered occasional delays when departing aircraft penetrated the Canarsie approach region.

The 14 operational demonstration flight periods are listed in Table 2, TRSB Operational Demonstration Flights at JFK, December 1977. Table 3 lists the international representatives who participated in these flights as observers. The aircraft used on the operational demonstration flights was the NASA Terminal Configured Vehicle (TCV) B-737. Figure 12 shows this aircraft on a typical TRSB approach to Runway 13L.

The data acquisition flights were flown with the NAFEC Convair 580 (N-49) test bed aircraft (Figure 13). The final data acquisition flight was on January 4, 1978, with the Basic Narrow elevation antenna moved to the south side of the runway when it became apparent that the Basic Wide "test bed" array would not be available in this time period. A series of Canarsie approaches were flown for comparison with data collected previously.

Airborne Instrumentation

The airborne equipment used in the demonstrations consisted of a TRSB angle receiver, course deviation indicator, and precision DME receiver. Associated instrumentation consisted of data multiplexer, synchronizer, digital data recorder, and analog video recorder (Figure 14). Digital AZ-EL-DME and serially coded time data were recorded on magnetic tape in the aircraft.

Mobile Van Instrumentation

In order to provide information on multipath sources for use in connection with the Lincoln Laboratory computer simulations, a NAFEC mobile test van was used to determine reflection coefficients of major reflecting surfaces at the approach end of Runway 13L.

The mobile test van was positioned at various locations near reflection sources to measure multipath levels. The van was equipped with the complement of equipment shown in Figure 15 plus a vertical telescoping mast with a TRSB receiving antenna. Figure 16 shows the test van beside Runway 13L near the touchdown region. The TRSB elevation site can be seen to the left. The mast antenna height was variable from 5 feet (1.5 meters) to 51 feet (15.5 meters). The receiving antenna could also be rotated through a horizontal sweep of $\pm 90^{\circ}$. Two different receiving antennas were used for different purposes. A wide angle $\pm 90^{\circ}$ aperture was used to receive combined direct and multipath radiation, and a $\pm 20^{\circ}$ aperture directional horn was used to separate the direct and reflected signals.

RESULTS

The system installation and operational demonstrations were highly successful and gave the many participants considerable insight into operational benefits available by application of TRSB at JFK. In the case of the NASA 737 autolands, 45 of 60 were conducted without incident despite wind conditions and a trajectory which stressed the nonoptimized area navigation computer used for this very close-in capture of the final approach path. There were 15 cases where it was not possible to complete the full approach automatically due to the inability of on-board equipment to cope with those winds, and in a few cases due to failure of aircraft instrumentation electronics. There were no cases where problems with TRSB MLS guidance accuracy were responsible for incomplete autoland.

The airborne data records indicate good quality guidance throughout most of the TRSB coverage region. However, these records (although qualitative in nature) indicate certain regions of reduced guidance quality worthy of comment.

The receiver records for azimuth show high quality guidance on most profiles. Some shadowing effects are noted at low angles; the occasional isolated perturbation is assumed to be due to local airport traffic*.

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*This traffic was on Runway 22L-4R which was in active use when these tests were made. However, in an operational situation, this cross runway would normally not be in use when landings were being made on Runway 13L-31R.

The receiver records for elevation show the expected guidance deterioration at wide angles due to the Basic Narrow elevation antenna coverage limits. Also noted are the longer reflection effects at azimuth angles outside of -25^{o} and the hangar blockage effects at the wider azimuth angles on the opposite side of centerline.* From accumulated knowledge of TRSB and DMLS as well as from theoretical understanding, these effects would be experienced by either C-Band system.

On the Canarsie approach route, the hangar reflection effects, as expected, are found in a region centered on -27^{o} azimuth with the elevation antenna on the north pad and are noticeable in the vicinity of -38^{o} azimuth with the antenna moved to the south pad. At wide angles, beyond the design limits of the Basic Narrow elevation antenna, noise increases rapidly indicating, as expected, that the Basic Narrow elevation antenna coverage is marginal for this application and that the basic wide elevation antenna which was planned for this demonstration, is the proper choice.

It is important to recognize that these results are only the receiver output and are not error plots which can be quantitatively assessed. Without the benefit of comparison with a tracking system (a measurement standard), the effects of aircraft motion are still included in the data presented. For this reason, it is appropriate to exercise caution in interpreting these results, especially in any comparative sense.**

Specific results are:

1. The operational flights demonstrated conclusively the capability of the system to provide guidance for performing the Canarsie curved-path approach and landings under automatic and manual control to Runway 13L.

---

*The hangars of concern at JFK runway 13L violate the ICAO obstruction clearance limit (OCL) by some 31 feet (i.e., they are 80 feet high whereas the OCL limit for that distance from runway centerline is 49 feet).

**Before publishing this report, a subsequent set of comparative TRSB and DMLS data was gathered for CAA/FAA bilateral comparison purposes. That independent activity is reported separately so as to avoid misleading the reader.

2. There were no adverse effects from the observed multipath signal disturbances during the flights in the FAA Convair 580, CV-880, and the NASA B-737.

3. The TRSB system installation was completed in a short time interval in a routine manner in the very complex environment of a busy international airport.

TABLE 1

TRSB DATA ACQUISITION FLIGHTS AT JFK, DECEMBER 1977

FLIGHT PATTERN DESCRIPTION	FLIGHT ALTITUDE FEET
Level flight centerline radial from 15 nmi	2,000, 4,000, 6,000
Level flight radial at 38° right from 15 nmi	2,000, 4,000, 6,000
Level flight radial at 38° left from 15 nmi	2,000, 4,000, 6,000
Clockwise arc 90° right to 90° left at 5 nmi	2,000, 4,000, 5,000
Counterclockwise arc 90° left to 90° right at 5 nmi	2,000, 4,000, 5,000
3° centerline approach to runway/overflight from 10 nmi	2,000 (initial)
5° centerline approach to runway/overflight from 10 nmi	2,600 (initial)
Canarsie Approach	2,300 (initial)

TABLE 2

TRSB OPERATIONAL DEMONSTRATION FLIGHTS AT JFK
DECEMBER 1977

DATE	FLIGHT	APPROACHES AUTOLAND	APPROACHES MANUAL	PARTICIPANTS BY ORGANIZATIONAL AFFILIATION
12/5/77	1	4	-	USA Press - 11
12/5/77	2			USA Press - 5; Television News - 3
12/6/77	1	3	3	USA Aviation - 7; National Transportation Safety Board - 2; FAA - 1
12/6/77	2			USA Aviation - 8; FAA - 2
12/7/77	1	4	2	USA Congressional Staff - 11; FAA - 2
12/7/77	2			USA Congressional Staff - 10; Electronics Manufacturer - 1
12/8/77	1	5	1	ICAO-1; Foreign Gov't. - 5; TV News 3 France Industry - 1; FAA - 2
12/8/77	2			ICAO - 12; Norway Civil Aviation - 1
12/9/77	1	4	2	New York Area Aviation Interests - 12
12/9/77	2			New York Area Aviation Interests - 10; Lincoln Laboratories - 1; FAA-1
12/12/77	1	5	1	FAA Eastern Region - 8; FAA D. C. Office - 3; Aircraft Mfg. - 1, New York Port Authority - 1
12/12/77	2			FAA Eastern Region - 9; FAA Washington Office - 4
12/13/77	1	5	-	Air Transport Assoc. - 10, Electronics Manufacturer - 1; FAA-2
12/13/77	2			Air Transport Assoc. - 9; USA Press - 1; FAA -4

Abbreviations: FAA - Federal Aviation Administration
ICAO - International Civil Aviation Organization

TABLE 3

TRSB MLS DEMONSTRATION PARTICIPANTS REPRESENTING INTERNATIONAL GOVERNMENTS

Mr. T. H. M. Hagenberg	Netherlands
Mr. Keith Watling	United Kingdom
Mr. Sandor Grashoff*	Netherlands
Mr. Daniel Dayer	Switzerland
Mr. William Codner	United Kingdom
Mr. Ronald Chafe	Canada
Mr. James M. Ahwai*	Trinidad/Tobago
Vice Commodore Elio J. Acosta*	Argentina
Mr. R. W. Gross*	Australia
Mr. Fachri Mahmud*	Indonesia
Mr. M. Abouchacra*	Lebanon
Mr. Y. M. Lambert*	France
Dr. F. Crznar*	Czechoslovakia
Mr. Eduardo Guillen Acuna*	Honduras
Mr. Stuart T. Grant*	Canada
Mr. Jarl H. Edvardsen	Norway
Dr. J. Krieg	Federal Republic of Germany
Mr. P. K. Ramachandran*	India
A. V. M. J. B. Russel*	United Kingdom

*ICAO Representatives

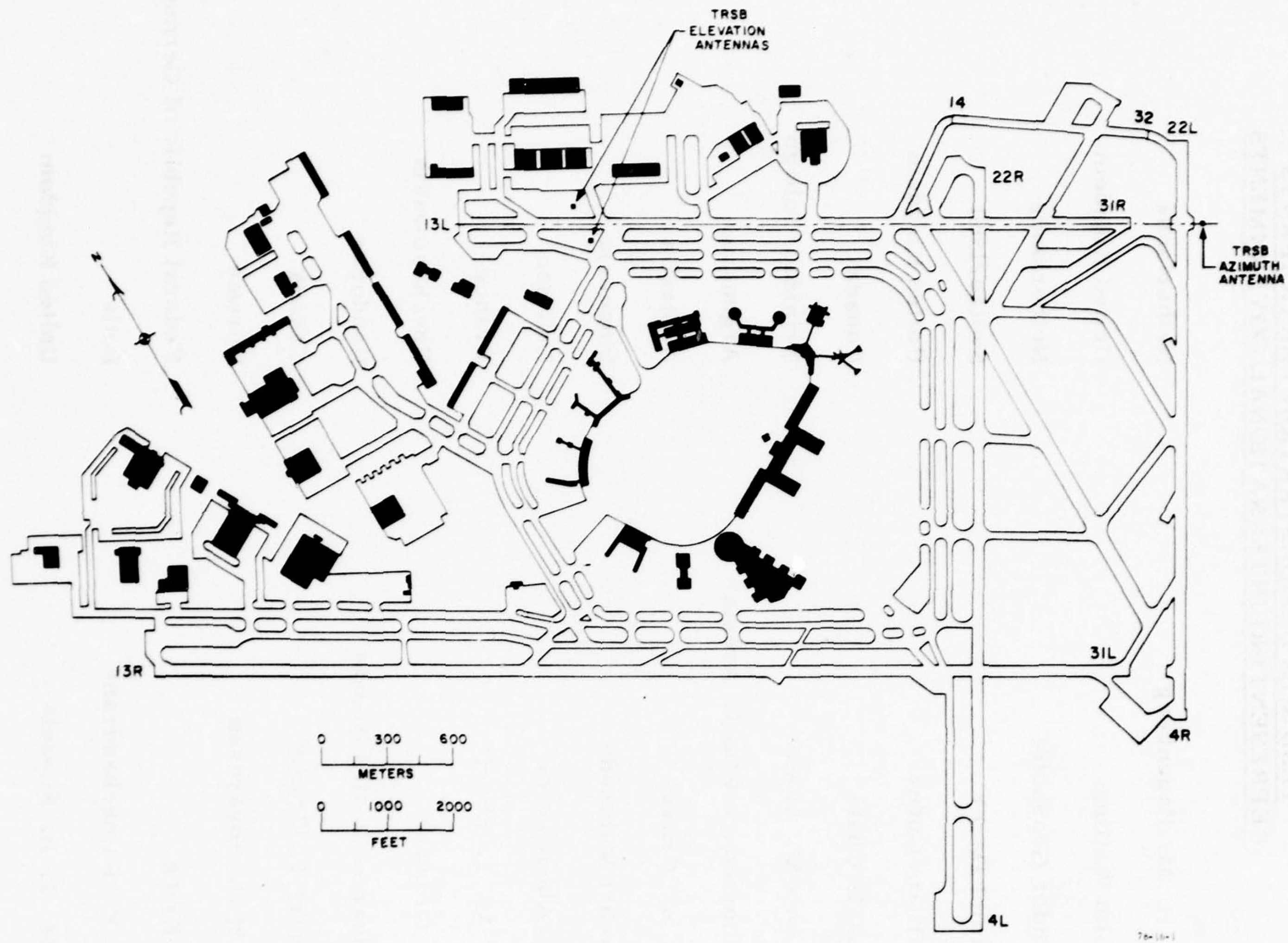


FIGURE 1. TRSB LAYOUT AT JFK INTERNATIONAL AIRPORT

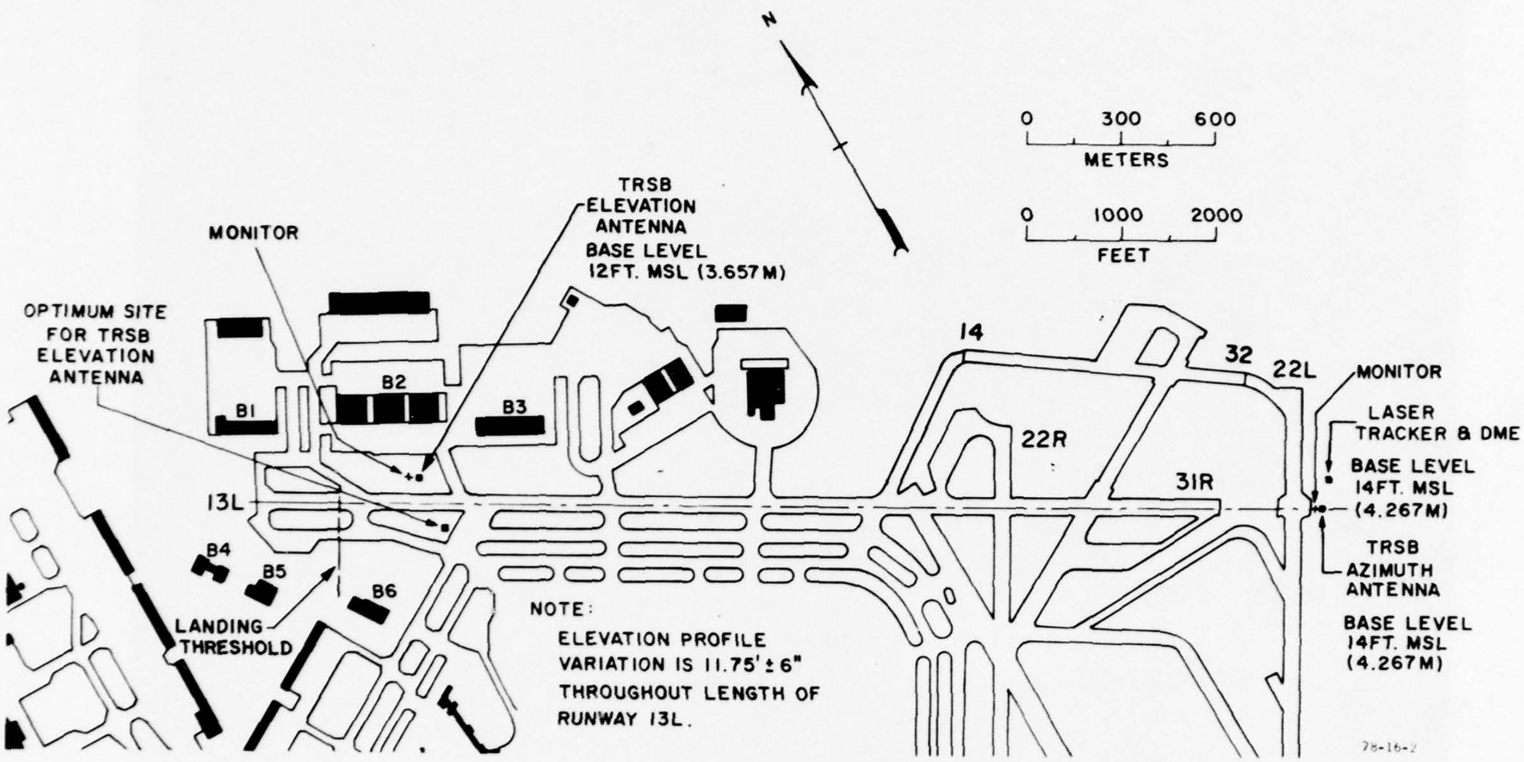


FIGURE 2. TRSB AND PRECISION LASER TRACKER SITING AT JFK RUNWAY 13L

FIGURE 3. GENERAL VIEW OF TRSB ELEVATION SITE NEAR JFK RUNWAY 13L

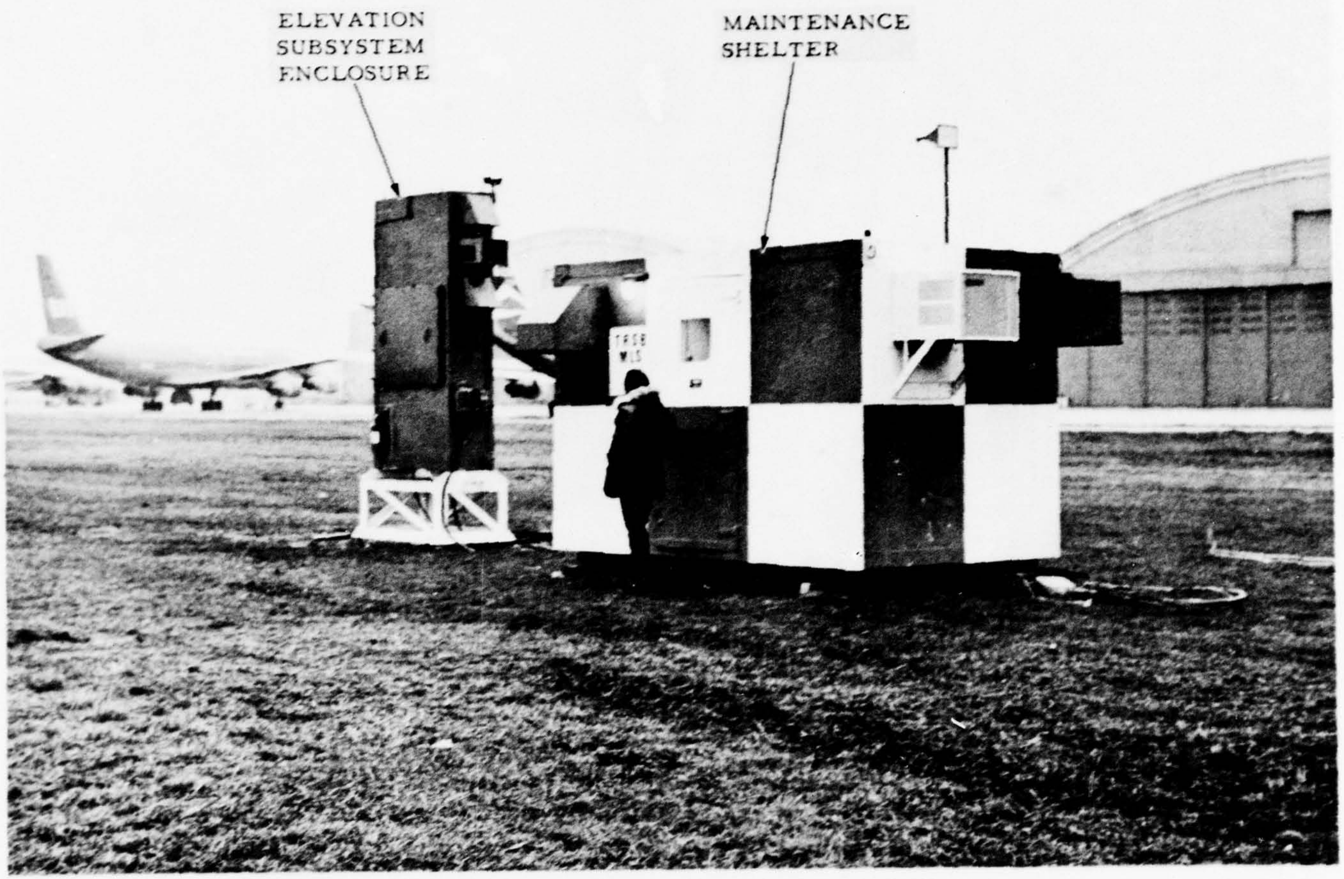


FIGURE 4. TRSB BASIC NARROW ELEVATION SUBSYSTEM INSTALLATION AT JFK VIEWED FROM RUNWAY 13L

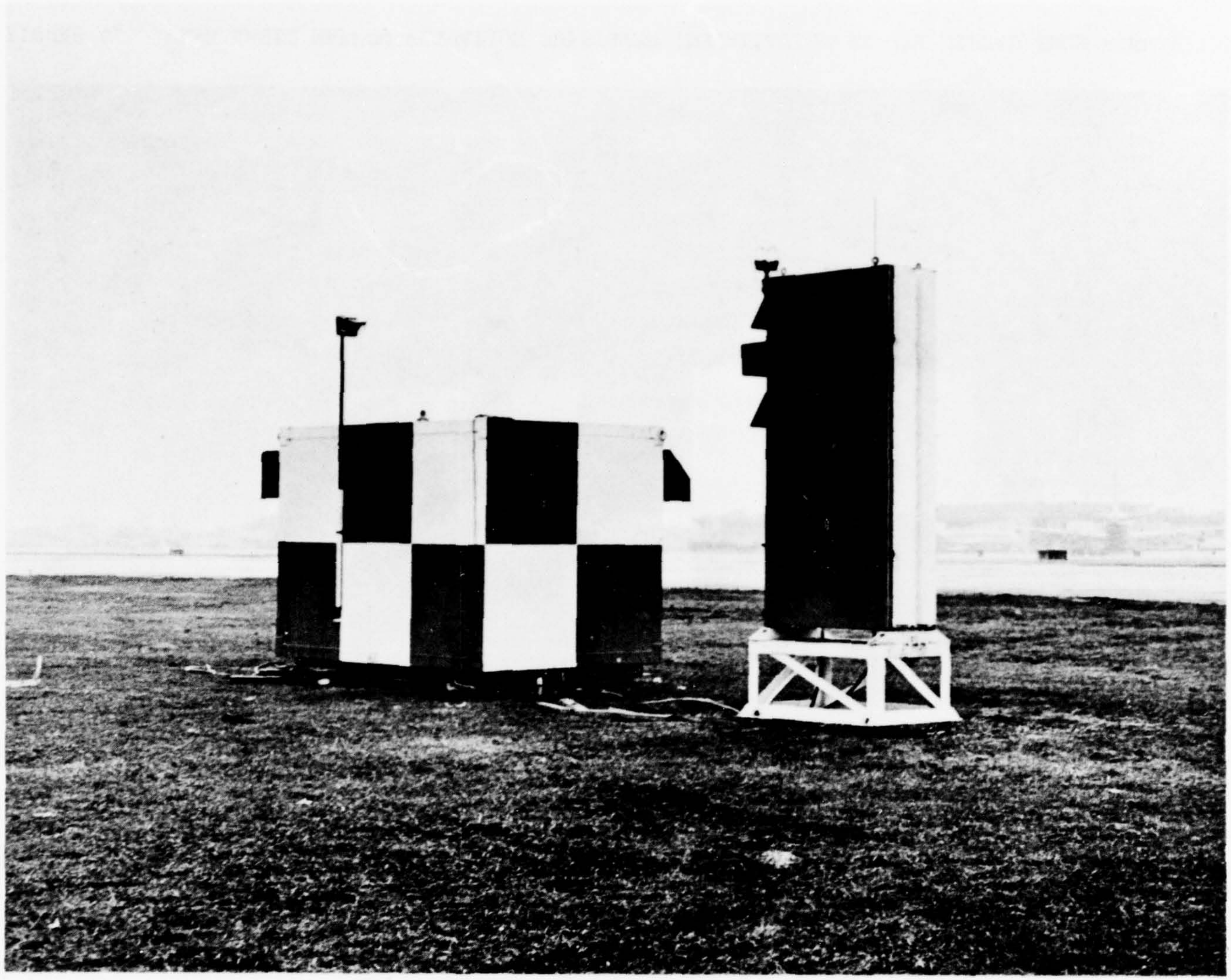


FIGURE 5. TRSB BASIC NARROW ELEVATION SUBSYSTEM WITH RUNWAY 13L AND JFK TOWER TO THE REAR

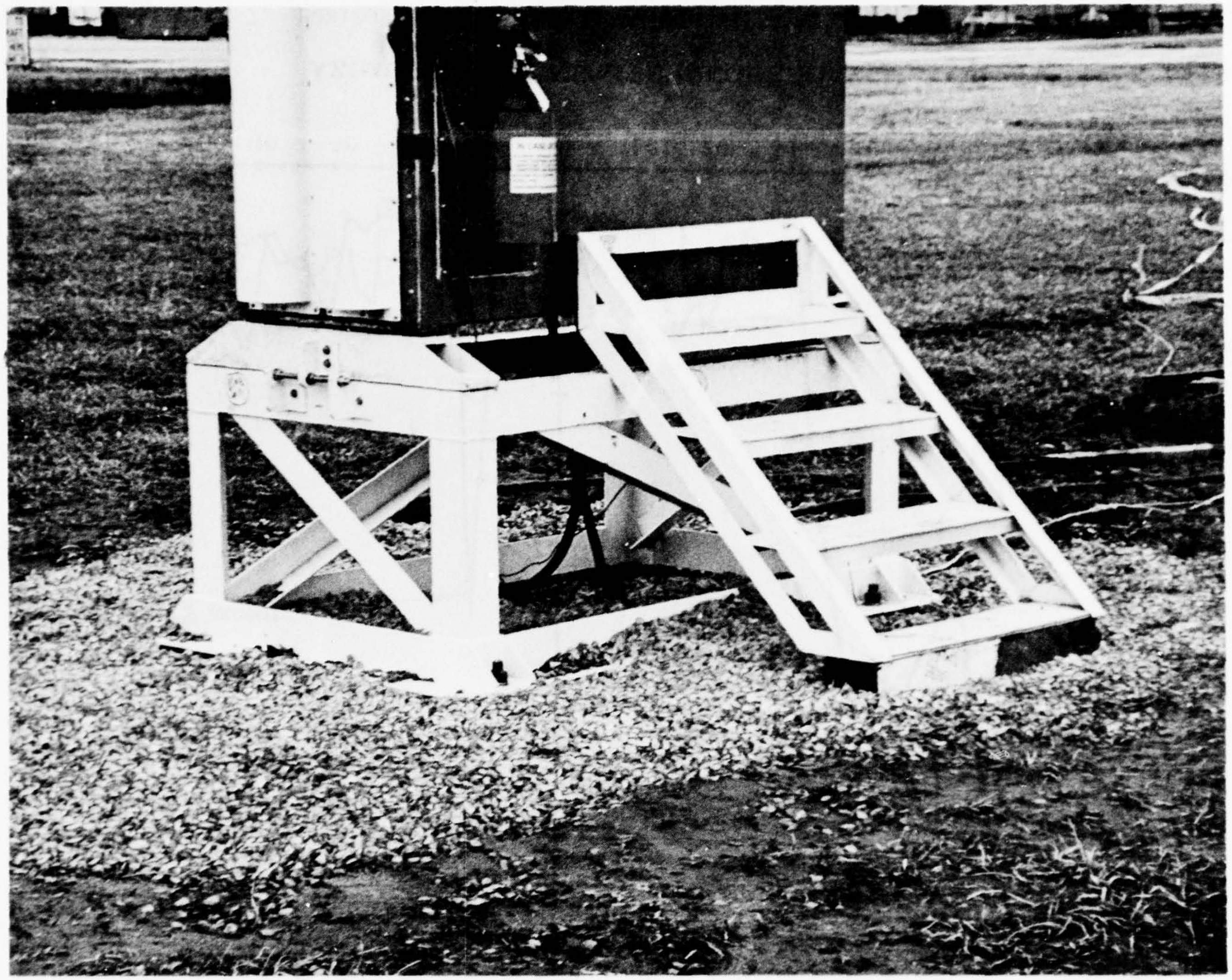


FIGURE 6. DETAIL OF TRSB ELEVATION ANTENNA BASE MOUNTING

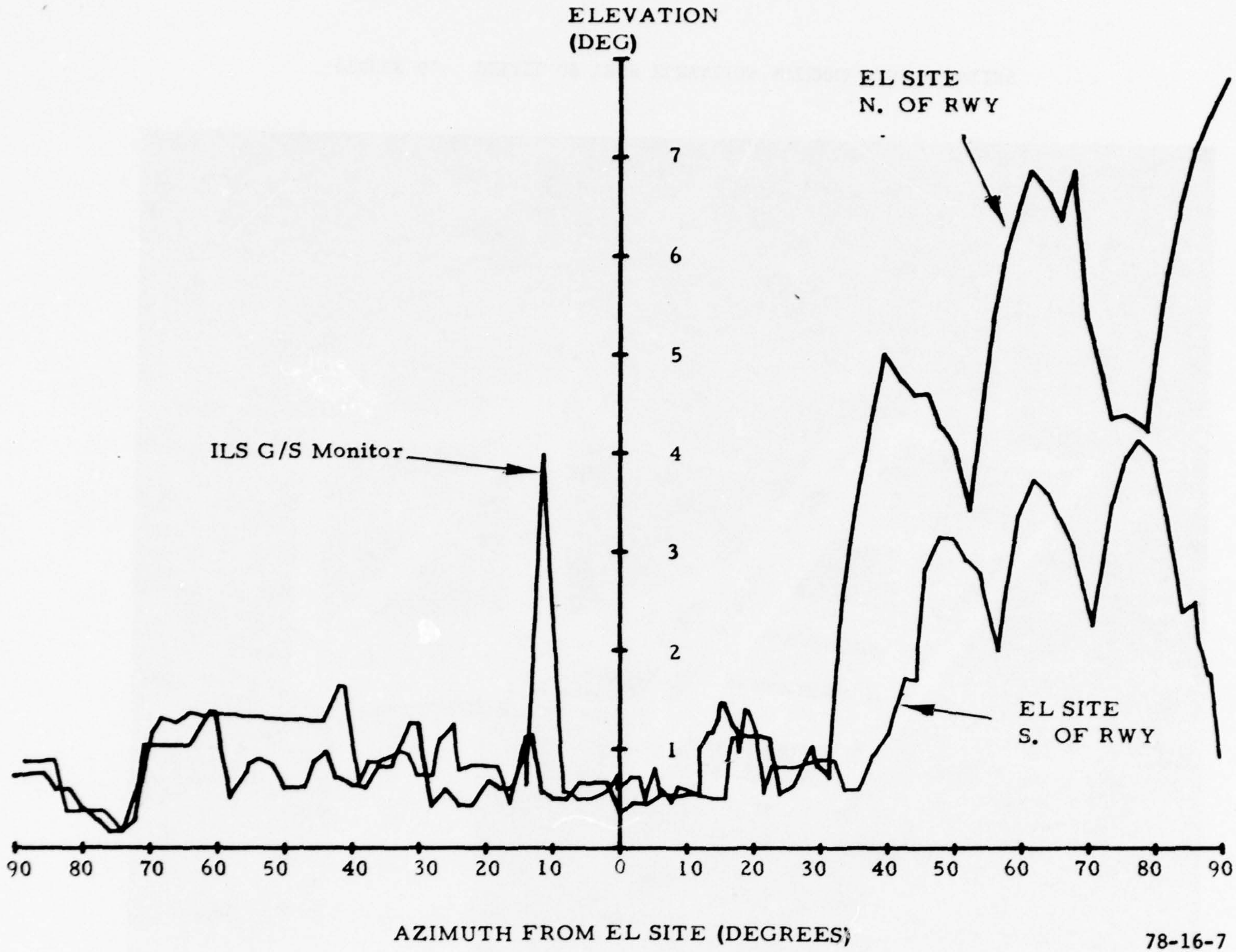


FIGURE 7. HORIZON PROFILES FOR ELEVATION SITES AT JFK

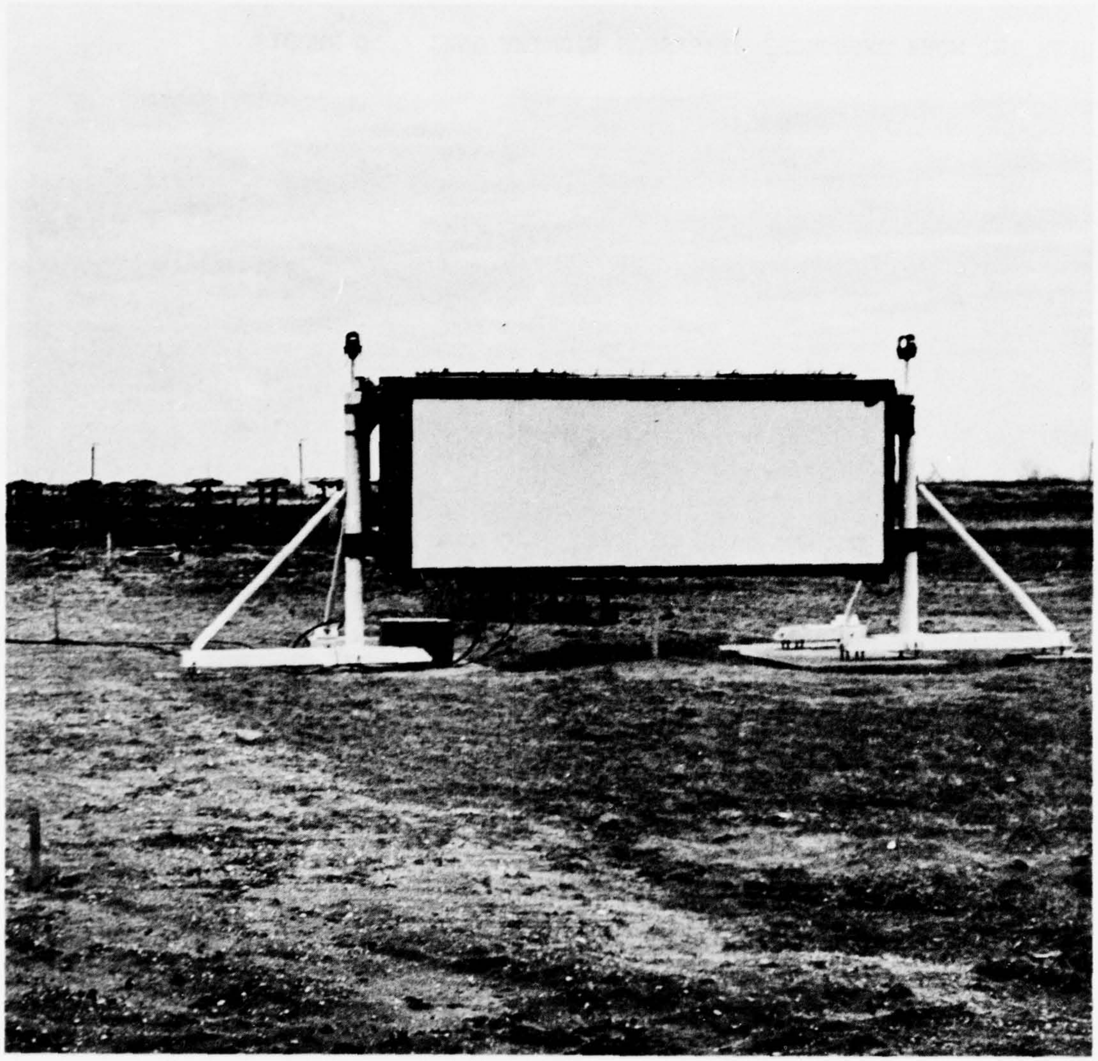


FIGURE 8. TRSB AZIMUTH SUBSYSTEM INSTALLATION BEYOND THE END OF RUNWAY 13L AT JFK AIRPORT

FIGURE 9. TRSB AZIMUTH SUBSYSTEM ENCLOSURE FROM THE REAR

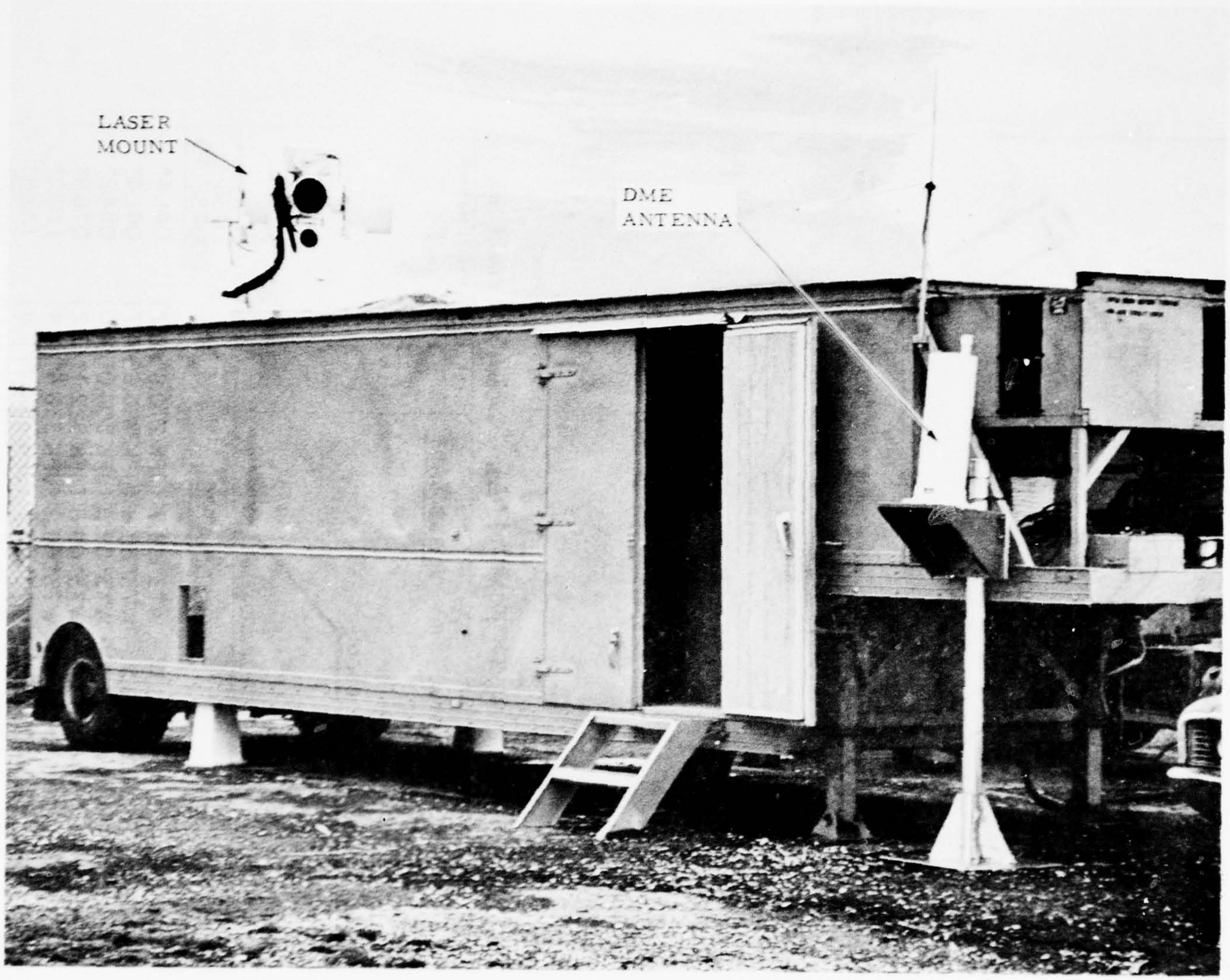
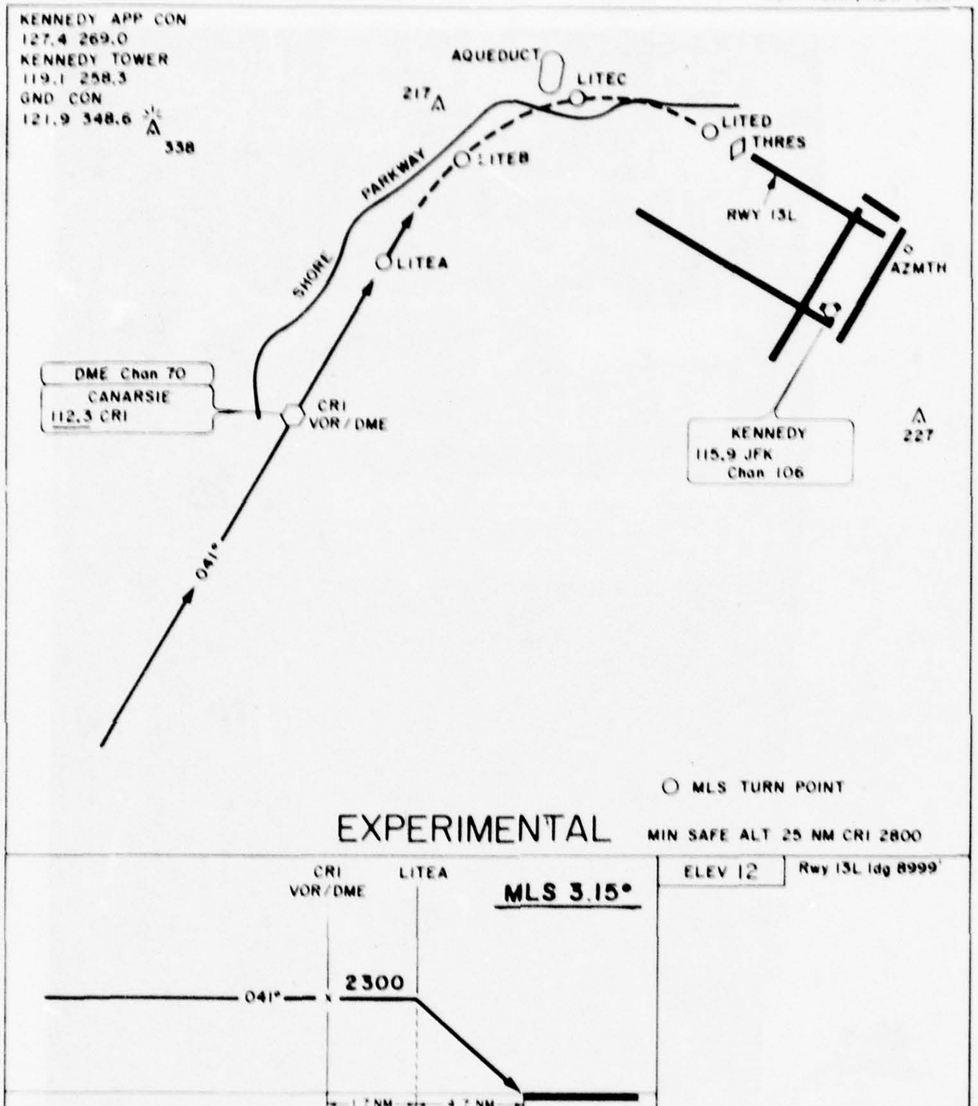


FIGURE 10. LASER TRACKING VAN INSTALLATION INCLUDING THE PRECISION L-BAND DME

CRI MLS RWY 13L

JOHN F. KENNEDY INTERNATIONAL
NEW YORK, NEW YORK



MLS FIX	COORDINATES	OBS COURSE TO
CRI VOR/DME	N40° 36.7' – W73° 53.7' (JFK 270.8°/5.7)	041.4°
LITEA	N40° 38.2' – W73° 52.6' (JFK 286.6°/4.7)	041.4°
LITEB	N40° 39.3' – W73° 51.3' (JFK 304.0°/4.0)	054.2°
LITEC	N40° 39.9' – W73° 49.6' (JFK 322.1°/3.2)	076.8°
LITED	N40° 39.8' – W73° 48.2' (JFK 336.4°/2.4)	110.2°
THRES	N40° 39.3' – W73° 47.1' (JFK 351.1°/1.6)	132.8°
AZMTH	N40° 38.5 – W73° 45.4' (JFK 073.4°/1.0)	132.8°

MLS RWY 13L

40° 38'N – 73° 46'W

NEW YORK, NEW YORK
JOHN F. KENNEDY INTERNATIONAL

FIGURE 11. CANARSIE APPROACH TO RUNWAY 13L

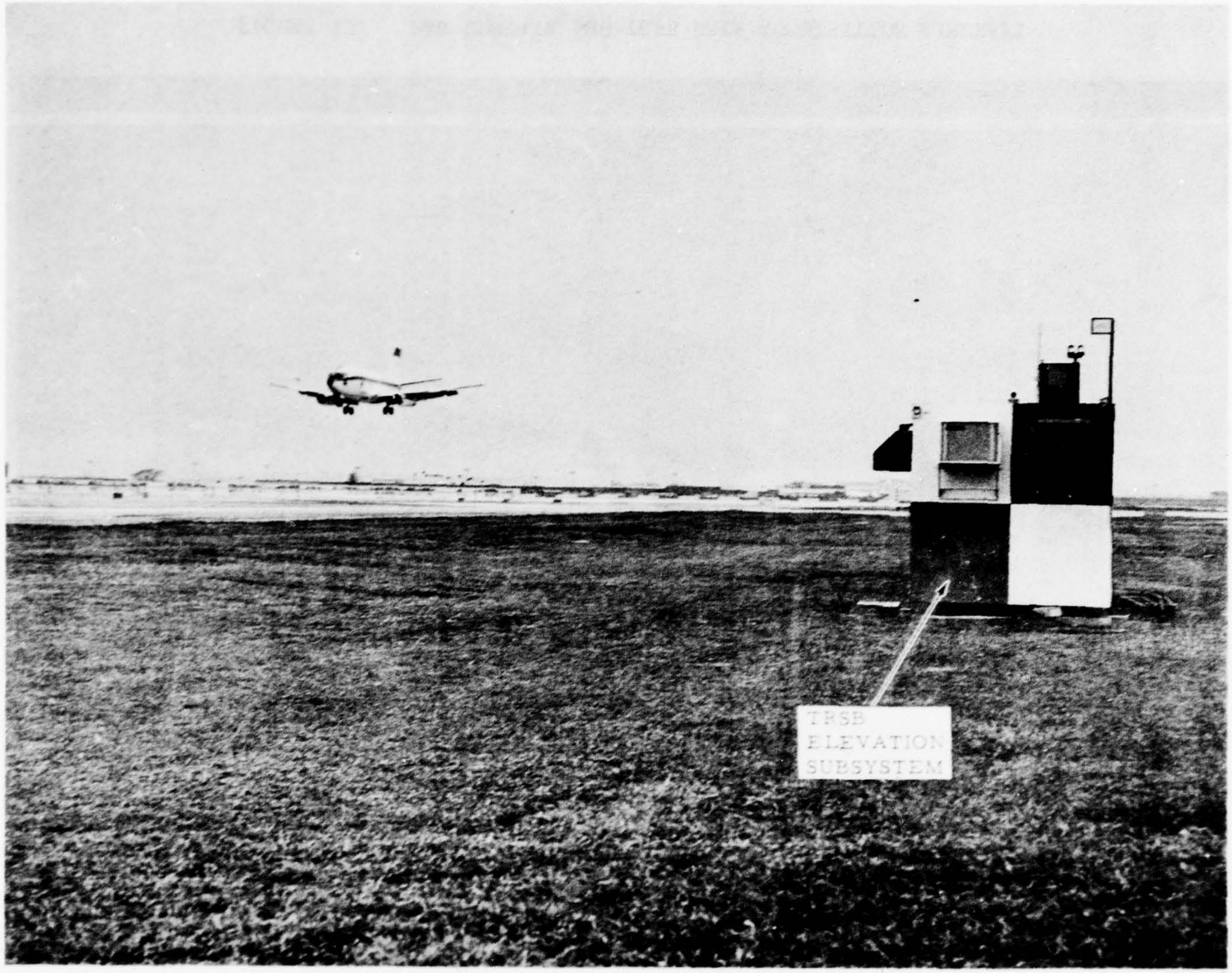


FIGURE 12. NASA BOEING 737 OPERATIONAL DEMONSTRATION FLIGHTS; AIRCRAFT MAKING A TRSB APPROACH TO JFK RUNWAY 13L

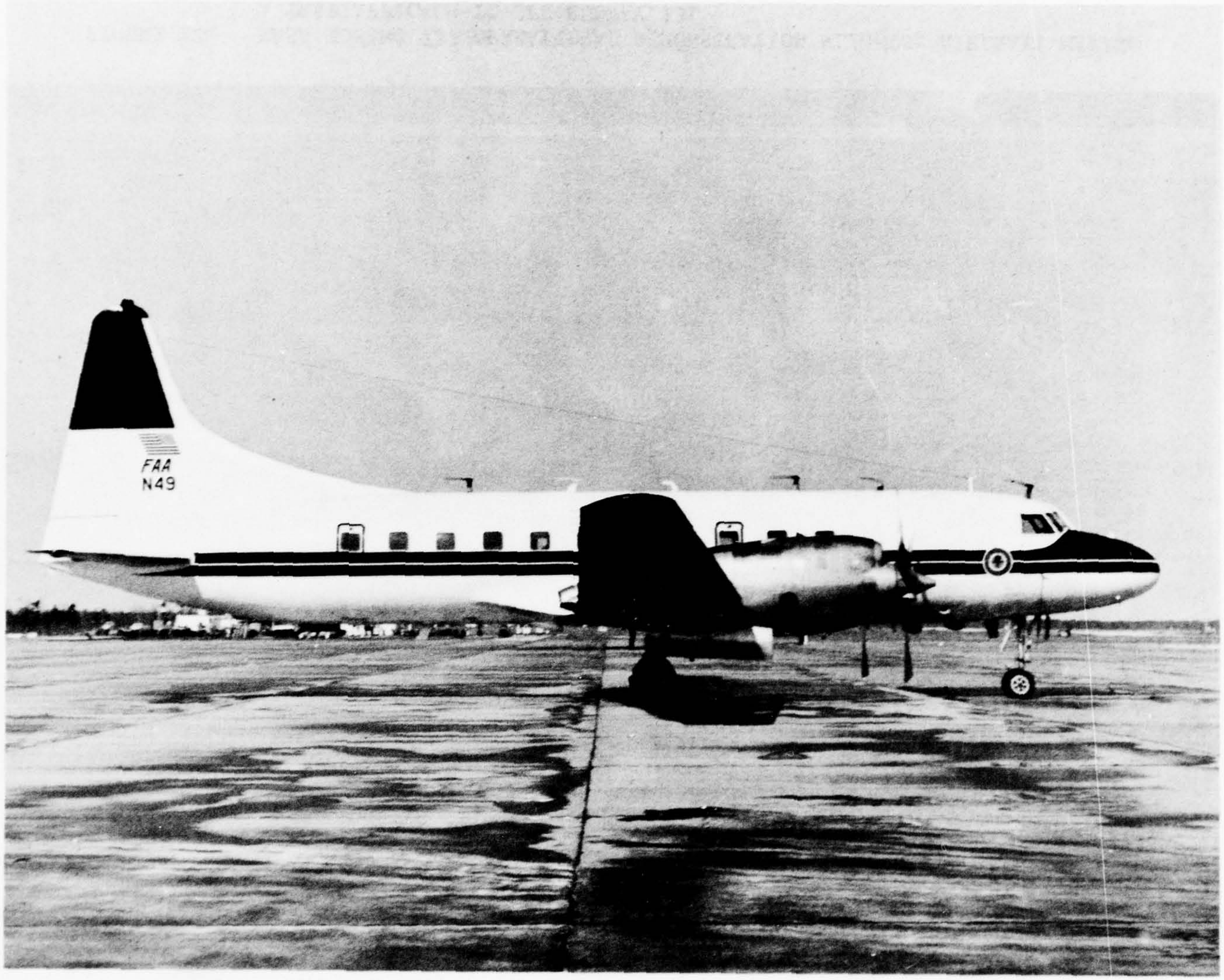


FIGURE 13. FAA CONVAIR 580 TRSB DATA ACQUISITION AIRCRAFT

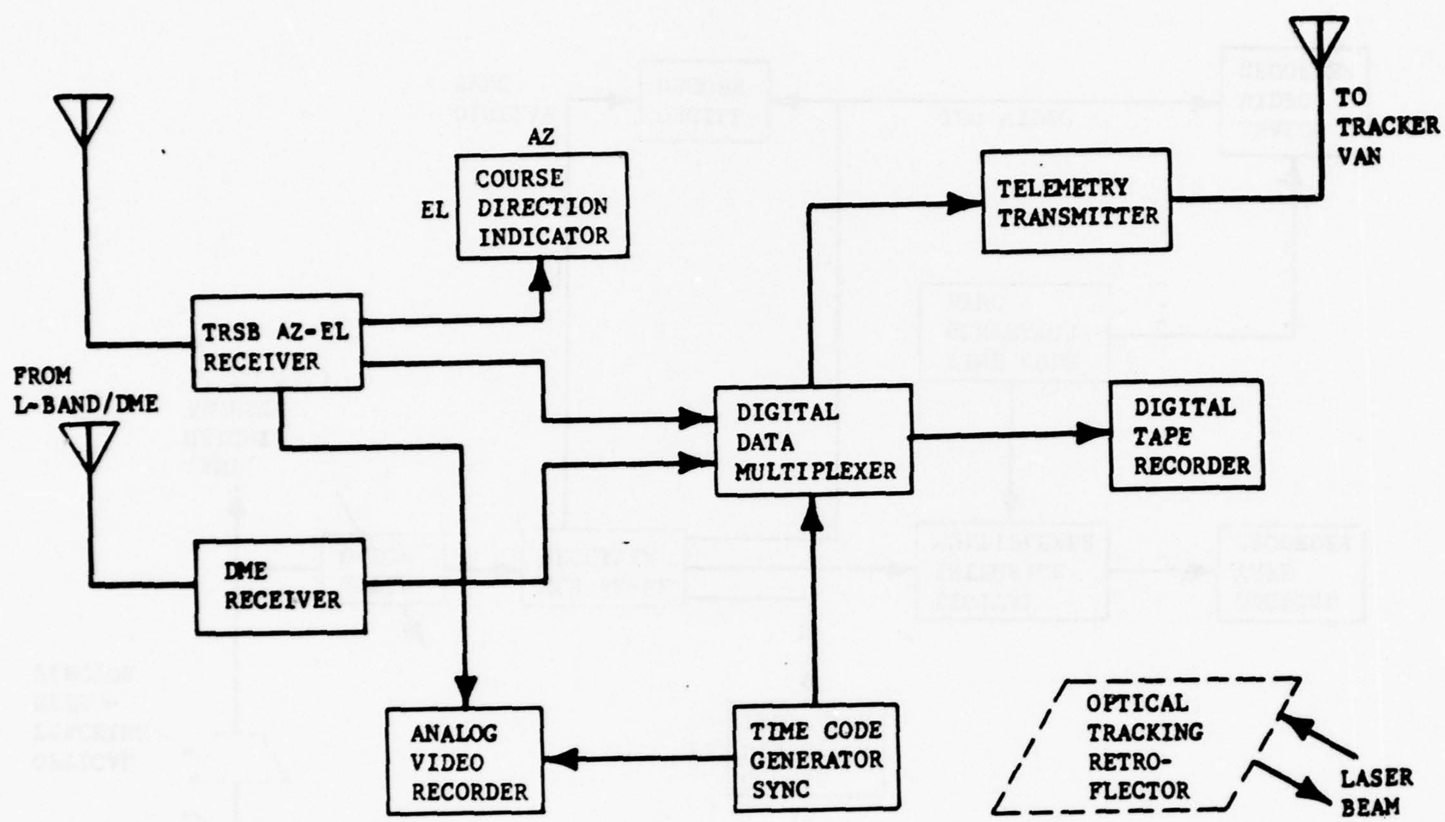


FIGURE 14. TRSB AIRBORNE TESTBED INSTRUMENTATION

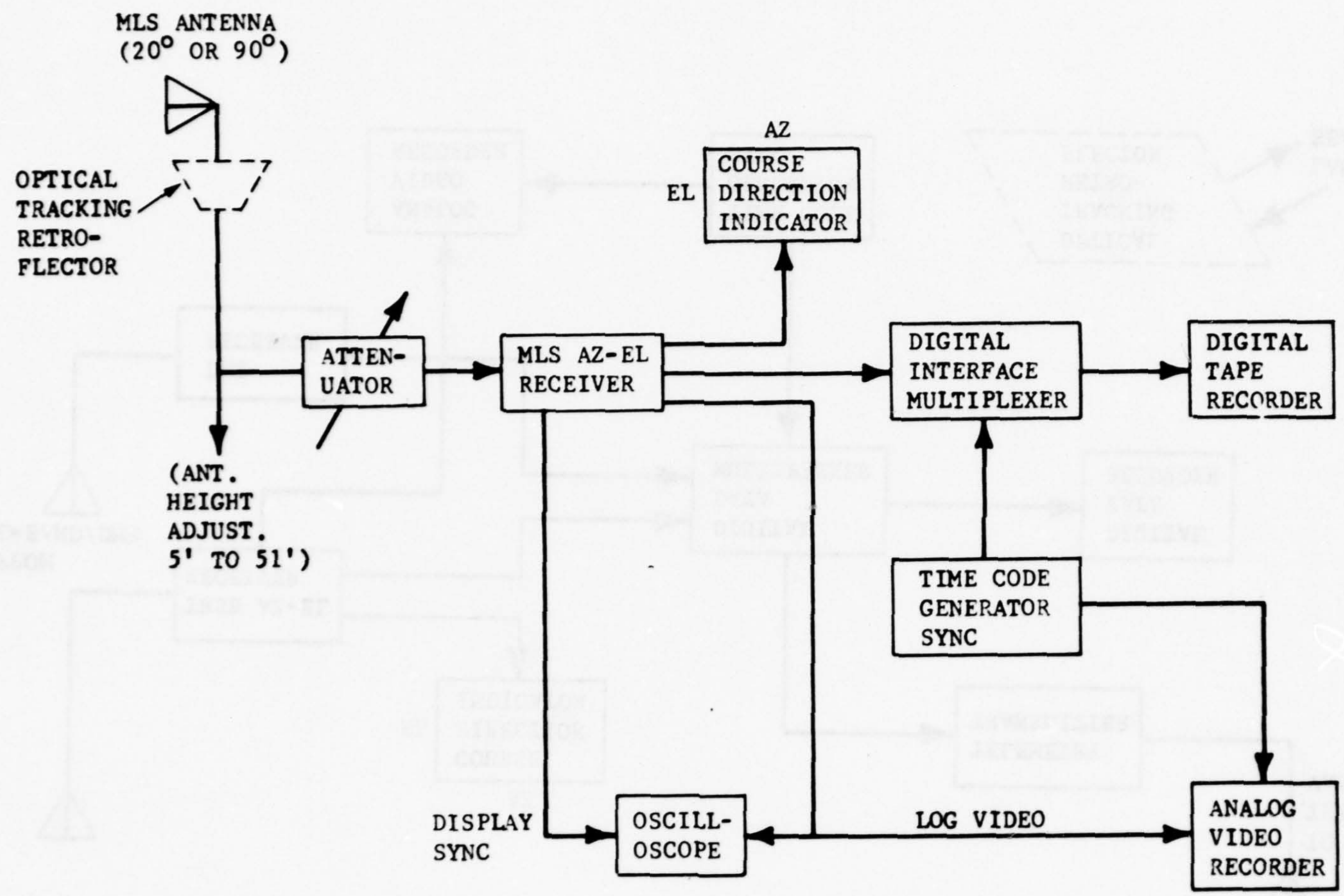
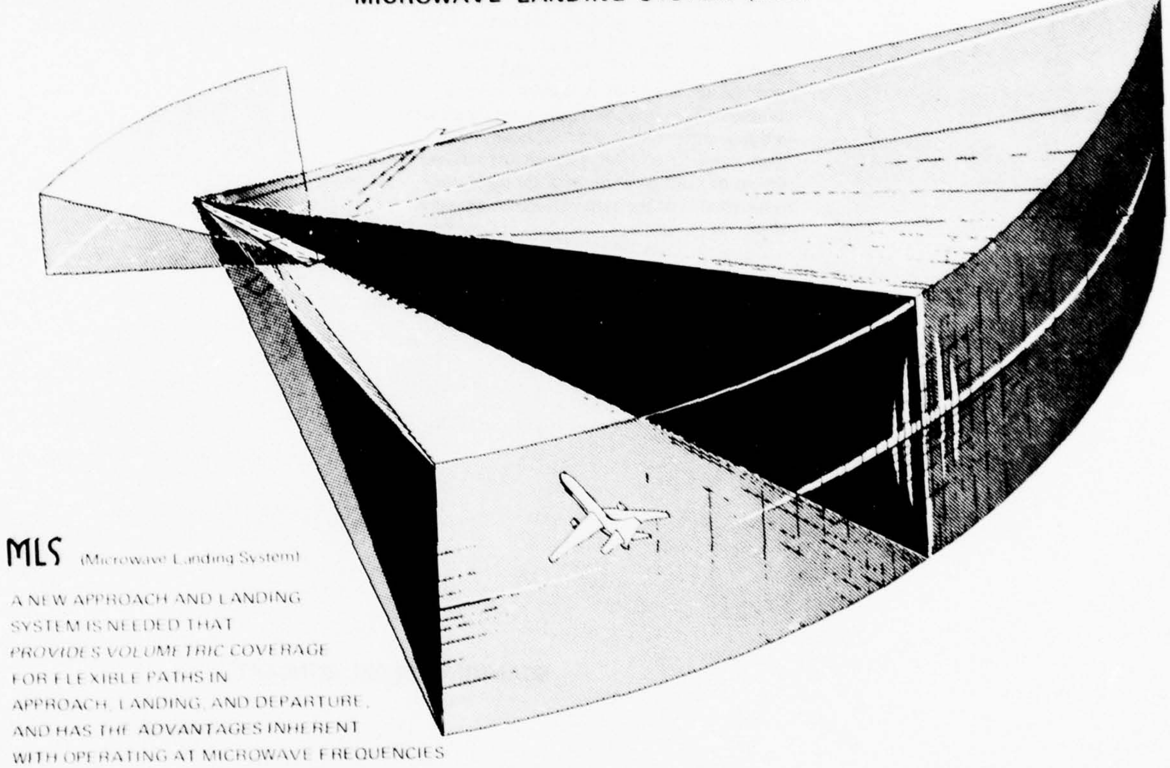


FIGURE 15. MLS MOBILE TEST VAN INSTRUMENTATION AT JFK

FIGURE 16. MLS MOBILE TEST VAN NEAR TOUCHDOWN AREA OF JFK RUNWAY 13L

APPENDIX A

MICROWAVE LANDING SYSTEM (MLS)



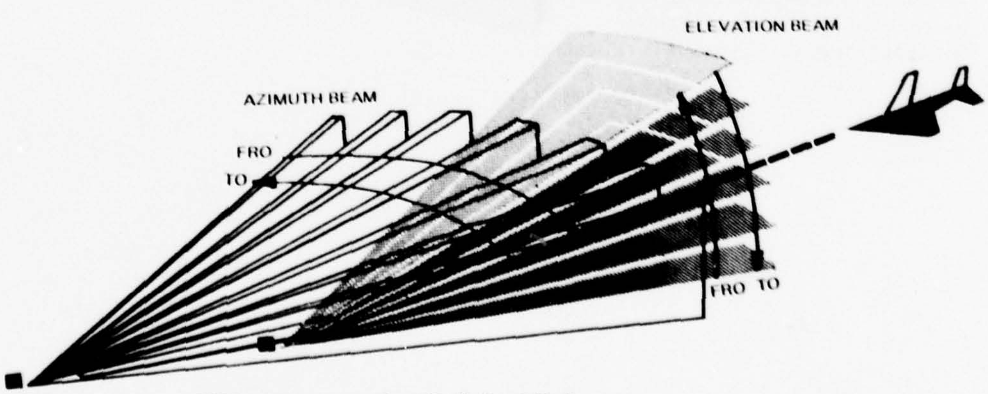
TIME REFERENCE SCANNING BEAM (TRSB) MLS IS AN AIR-DERIVED APPROACH AND LANDING SYSTEM. An aircraft can determine its position *in space* by making two angle measurements and a range measurement. A simple ground-to-air data capability provides airport and runway identification and other operational data (such as wind speed and direction, site data, and system status).

FAN BEAMS PROVIDE ALL ANGLE GUIDANCE (APPROACH AZIMUTH, ELEVATION, FLARE, AND MISSED APPROACH). The TRSB ground transmitter supplies angle information through precisely timed scanning of its beams and requires no *form of modulation.* Beams are scanned rapidly "to" and "fro" throughout the coverage volume as shown below. *In each* complete scan cycle, two pulses are received in the aircraft—one in the "to" scan, the other in the "fro" scan. The aircraft receiver derives its position angle directly from the measurement of the time difference between these two pulses.

RANGE IS COMPUTED IN THE CONVENTIONAL MANNER. TRSB proposes to use L-Band Distance Measuring Equipment (DME) that is compatible with existing navigation equipment. It provides improved accuracy and *channelization* capabilities. The required 200 channels can be made available by assignment or sharing of existing channels, using additional pulse multiplexing. The ground transponder is typically collocated with the approach azimuth subsystem.

NOTE: The DME (ranging) function is not discussed in detail because it is independent of angle guidance subsystems and therefore is not critical to the description of TRSB.

SCANNING BEAM CONCEPT



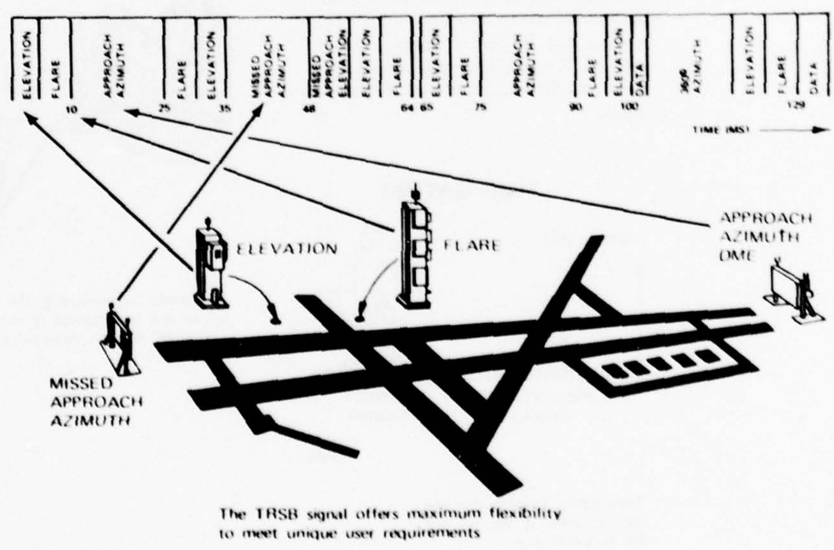
TRSB beams are scanned rapidly "to" and "fro" (back and forth for azimuth, down and up for elevation) at a precise rate

TRSB USES A TIME-SEQUENCED SIGNAL FORMAT FOR ANGLE AND DATA FUNCTIONS. Angle and data functions (that is, approach azimuth, elevation, flare, missed-approach guidance, and auxiliary data) are sequentially transmitted by the ground station on the same channel. Primary operation is C-band, with 300 KHz spacing between channels. However the format is compatible with Ku-Band requirements. (Note: DME is an independent function on a separate frequency and is not a part of this format.)

THE SIGNAL FORMAT IS DESIGNED TO ALLOW A MAXIMUM DEGREE OF FLEXIBILITY. Functions can be transmitted in any order or combination to meet the unique operational needs of each site. This flexibility is made possible by a function preamble identification message. This message sets the airborne receiver to measure the angle or decode the data function that will follow. The ordering or timing of transmissions, therefore, is not important. This flexibility permits individual functions to be added or deleted to meet specific airport requirements. It also permits any TRSB airborne receiver to operate with any ground system. The only requirements are that a minimum data rate (minimum number of to-fro time-difference measurements per second) be maintained for each angle function, and that these measurements be relatively evenly distributed in time. An example of two 64-millisecond sequences of a configuration that utilizes all available functions is illustrated below.

THE TRSB FORMAT PROVIDES FOR CURRENT AND ANTICIPATED FUTURE REQUIREMENTS. Included are

- Proportional azimuth angle guidance to ±60° relative to runway centerline at a 13.5-Hz update rate (that is, data are renewed 13.5 times each second.)
- Proportional missed-approach azimuth guidance to ±40° relative to runway centerline at a 6.75-Hz update rate
- Proportional elevation guidance up to 30° with a 40.5-Hz update rate
- Flare guidance up to 15° with a 40.5-Hz update rate
- 360° azimuth guidance with a 6.75-Hz update rate
- Missed-approach or departure elevation function with a 6.75-Hz update rate
- Basic data prior to each angle function (includes function identification, airport identification, azimuth scale factors, and nominal and/or minimum selectable glide slope)
- Auxiliary data (for example, environmental and airport conditions)
- Facility status data
- Ground test signals
- Available time for other data and/or additional future functions.

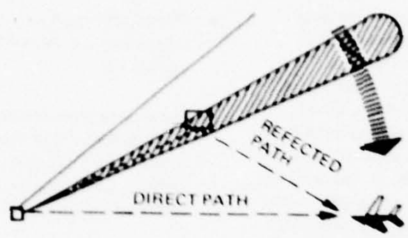


The TRSB signal offers maximum flexibility to meet unique user requirements

TRSB OPERATES EFFECTIVELY IN SEVERE MULTIPATH ENVIRONMENTS. TRSB offers several unique solutions to the multipath problem that has limited the implementation of other landing systems.

THERE ARE TWO TYPES OF MULTI-PATH. Multipath occurs when a microwave signal is reflected from a surface, such as an airport structure, a vehicle, and certain types of terrain. The resulting reflected beam is classified as either out-of-beam multipath or in-beam multipath, depending on its time of arrival in the aircraft receiver relative to the direct signal.

REFLECTED SIGNALS



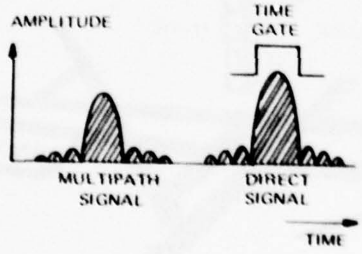
IN-BEAM MULTIPATH. When the reflected and direct signals reach the aircraft almost simultaneously (the angle of arrival is very small), multipath is said to be in-beam. TRSB combats in-beam multipath by

- Shaping the horizontal pattern of the elevation antenna to reject lateral reflections
- Motion averaging, by utilizing the high data rates of TRSB
- Processing only the leading edge of the flare/elevation beam, which is not contaminated by the ground reflections.

COVERAGE CONTROL IS AVAILABLE TO ELIMINATE MULTIPATH AT EXTREMELY SEVERE PROBLEM SITES. Any MLS system will experience acquisition or tracking problems in those cases where the reflected signal is known to be persistent and greater in amplitude than the direct signal. A TRSB feature called coverage control can be implemented, at no cost, in such cases by simply programming the Beam Steering Unit (BSU). This feature permits a simple adjustment of the ground facility to limit the scan sector in the direction of the obstacle and thereby prevents acquisition of erroneous signals.

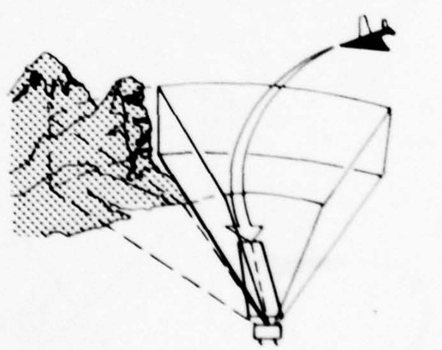
OUT-OF-BEAM MULTIPATH. If the angle and therefore the time between the reflected and direct beam are relatively large, the aircraft receiver is subjected to out-of-beam multipath. In this case, the TRSB processor automatically rejects the reflected signal by placing a time gate, as illustrated below, around the desired guidance signal. This ensures that the correct signal is tracked even if the multipath signal amplitude momentarily exceeds that of the desired signal.

TIME GATING



Time gating ensures that the correct signal is tracked, not the reflected one

SELECTIVE COVERAGE CONTROL



By simple programming, the scan sector can be adjusted to prevent undesired obstacle reflections

TRSB IS A MODULAR SYSTEM WHICH CAN BE CONFIGURED TO MATCH THE NEEDS OF THE USER. A set of phased-array subsystems has been designed that may be installed in any combination to meet the broad range of user requirements.

The minimum system configuration consists of approach azimuth and elevation subsystems. Flare, missed-approach, and range subsystems may be included or added later. Several antenna beamwidths are available, as indicated in the table below, from which a ground configuration can be designed to provide guidance signals in space of uniform quality in all airport environments.

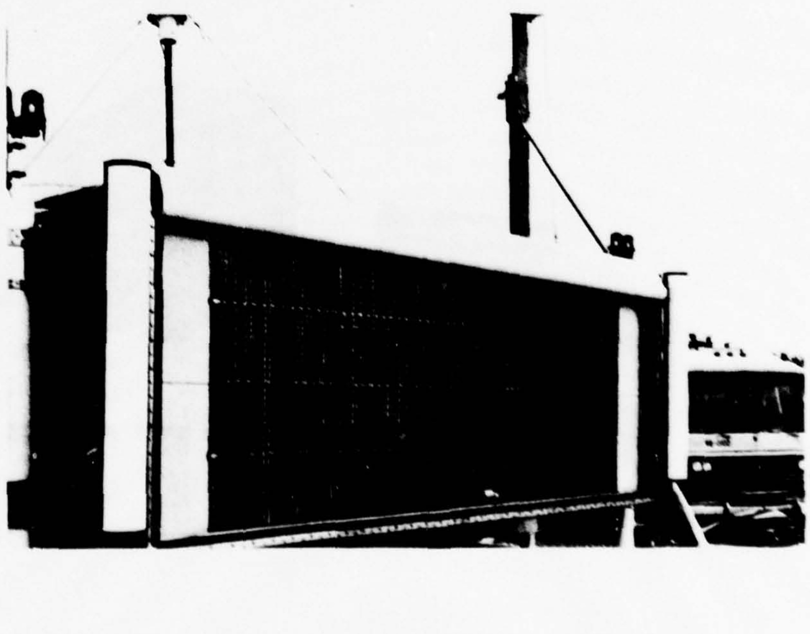
NOTE: DME is an independent subsystem which is combined with appropriate azimuth and elevation subsystems to make up the total guidance system.

GROUND ANGLE SUBSYSTEMS

SUB-SYSTEM	NOMINAL BEAMWIDTH (DEGREES)	COVERAGE (DEGREES) *	PRINCIPAL APPLICATIONS
Azimuth	1	Up to ±60	Approach Azimuth; Long Runways
Azimuth	2	Up to ±60	Approach Azimuth; Intermediate Length Runways
Azimuth	3	Up to ±60	Approach Azimuth; Short Runways Missed Approach Azimuth
Elevation	0.5	Up to 15	Flare
Elevation	1	Up to 30	Elevation (Severe multipath sites)**
Elevation	2	Up to 30	Elevation (Less severe multipath sites)**

* Coverage determined by Beam Steering Unit (BSU) for all arrays.

** **See multipath discussion.**



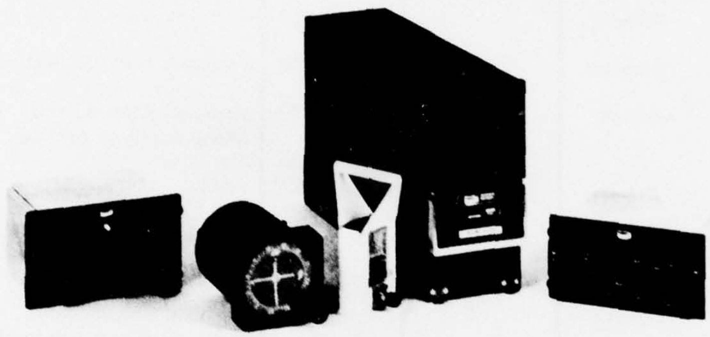
Phased Array Azimuth Antenna installed at the National Aviation Facilities Experimental Center. Radome is rolled back to expose radiating elements.

AIRBORNE RECEIVER DESIGNS ALSO STRESS THE MODULARITY CONCEPT. Users need only procure what is necessary for the services desired from any ground facility. To obtain approach and landing guidance at the lowest cost, an aircraft needs only an antenna and a basic receiver-processor unit operating with existing ILS displays. An air-transport category aircraft equipped for operation to low-weather minimums will carry redundant equipment and, in the future, advanced displays to fully utilize all of the inherent operational capabilities provided by TRSB.

The 200-channel TRSB angle receiver-processor provides angle information from the scanning beam azimuth and elevation subsystems and decodes the auxiliary data for display. Special monitoring ensures the integrity of the receiver output.

A second airborne unit is the DME. It is channeled to operate with the angle receiver-processor and provides a continual readout of distance.

Both the angle receiver-processor and the DME provide standard outputs to existing flight instruments and autopilot systems. An optional airborne computer would be used to generate curved or segmented approaches based on TRSB position information.



AIRLINE TYPE AVIONICS

GENERAL AVIATION TYPE AVIONICS

TRSB CAN PROVIDE ALL-WEATHER LANDING CAPABILITY AT MANY RUNWAYS THAT PRESENTLY DO NOT OFFER THIS SERVICE. This is made possible by

- The proposed channel plan, which contains enough channels for any foreseeable implementation
- High system integrity and precision
- Minimum siting requirements.

THE LARGE COVERAGE VOLUME PROVIDES FLIGHT PATH FLEXIBILITY. Transition from en route navigation is enhanced through the wide proportional coverage of MLS. Such flexibility in approach paths, coupled with high-quality guidance, can be used to achieve

- Improvements in runway and airport arrival capacity
- Better control of noise exposure near airports
- Optimized approach paths for future V/STOL aircraft
- Intercept of glide path and of runway centerline extended without overshoot
- Lower minimums at certain existing airports by providing precise missed-approach guidance
- Wake vortex avoidance flight paths.

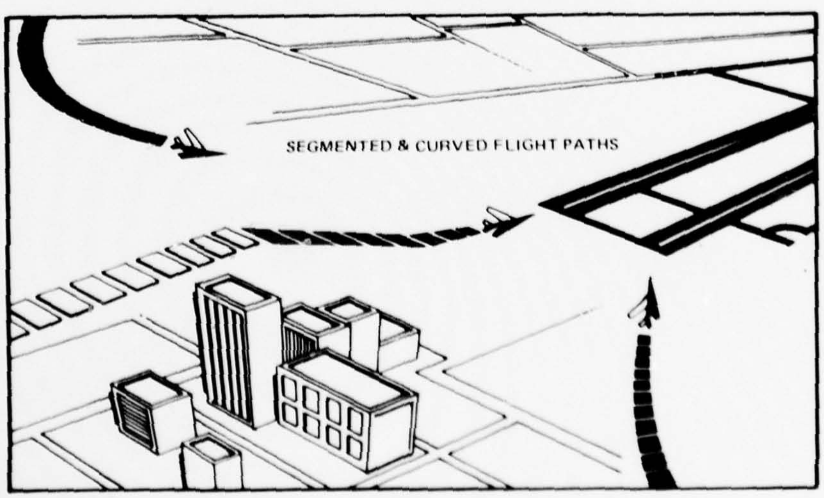
THE TRSB SIGNAL FORMAT ENSURES THAT EVERY AIRBORNE USER MAY RECEIVE LANDING GUIDANCE FROM EVERY GROUND INSTALLATION. Compatibility is ensured between facilities serving international civil aviation and those serving unique national requirements.

TRSB SPANS THE ENTIRE RANGE OF APPROACH AND LANDING OPERATIONS FOR ALL AIRCRAFT TYPES. This includes CTOL, STOL, and VTOL aircraft operating over a wide range of flight profiles. The particular needs of users, ranging from general aviation to major air carriers, are accommodated. TRSB is adaptable to special military applications, such as transportable or shipboard configurations on a compatible basis with civil systems.

HIGH RELIABILITY, INTEGRITY, AND SAFETY OF TRSB ARE ENHANCED BY SEVERAL IMPORTANT FEATURES. These include

- Simple TRSB receiver processing
- Multipath immunity features on the ground and in the airborne receiver processor
- A comprehensive monitoring system that verifies the status of all subsystems and the radiated signal. Status data are transmitted to all aircraft six times each second.
- Coding features, such as parity and symmetry checks, that prevent the mixing of functions.

TRSB PROVIDES CATEGORY-III QUALITY GUIDANCE. TRSB signal guidance quality has already been proved via demonstration of fully automatic landings, including rollout, in a current commercial transport aircraft (Boeing 737) and an executive jet (North American Sabreliner).



TRSB provides precision guidance for curved and segmented approaches for noise abatement and traffic separation, as well as for autoland and rollout

APPENDIX B

AIRBORNE RECEIVER DATA

AIRBORNE DATA LOG
MLS PHASE III

SYSTEM UNDER TEST : Bendix Basic wide AZ / " " [illegible]
TEST PLAN TABLE # :
PATTERN # :

RUNWAY # : JFK 13L

DATE : 12-2-77
FLIGHT # : [illegible]
AIRCRAFT # : N49 [illegible]

GROUND EQUIPMENT:
AIRBORNE EQUIPMENT:

(AZ) (EL) SYSTEM #	EL 2 RECEIVER #	(DME) CONT HEAD #	BK AZ DME #	INTERFACE #
1	P109	10 [illegible]	III	[illegible]
2	—	—		

WIND: 290° [illegible] KNOTS
TEMP.: [illegible]
CEILING: [illegible]
VISIB: [illegible] NM
PILOT: John Ryan
COPILOT: [illegible]
OBSERVERS: [illegible], J. [illegible]

KENNEDY #
HONEYWELL # X
STRIP REC # X

TRACK #	1	2	3	4	5	6	7
SIGNAL	—	—	-	-	-	-	—
SIGNAL	—	-	-	-	-	-	—

RUN #	TAPE #	FILE #	TIMES START	TIMES STOP	# EDI	FAIR	THE	LASE	DESCRIPTION AND COMMENTS
1	1	1	052325	[illegible]	1	—	—	✓	CL LEVEL RADIAL @ 6000' FROM 15 NM (NO TRKG)
2	1	2	053517	053130	1	—	—	✓	" " " " " " "
3	1	3	054730	055210	1	—	—	✓	" " " " " " " No tracking
4	1	4	[illegible]	[illegible]	1			✓	+38° " " " " " " "
5	1	5	[illegible]	061240	1				" " " " " " "
6	1	6	[illegible]	[illegible]	1				-38° " " " " " "
7	1	7	[illegible]	[illegible]	1				" " " " " " "
7	1	7	065017	[illegible]	1				CW PARTIAL ORBIT " " @ 5NM RADIUS [illegible]
9	1	9	[illegible]	[illegible]	5	—	—	✓	CCW " " " " " " [illegible]
									Submitted to R. Weiss 12/13/77
									No tracking on runs 1,3,9

[illegible] inbound on @ 2.3 NM and continuous till over site
" outbound on @ site and continuous till [illegible] NM, then intermittent thru [illegible] NM, then flagged out.
Run 3 no EL info (flagged)

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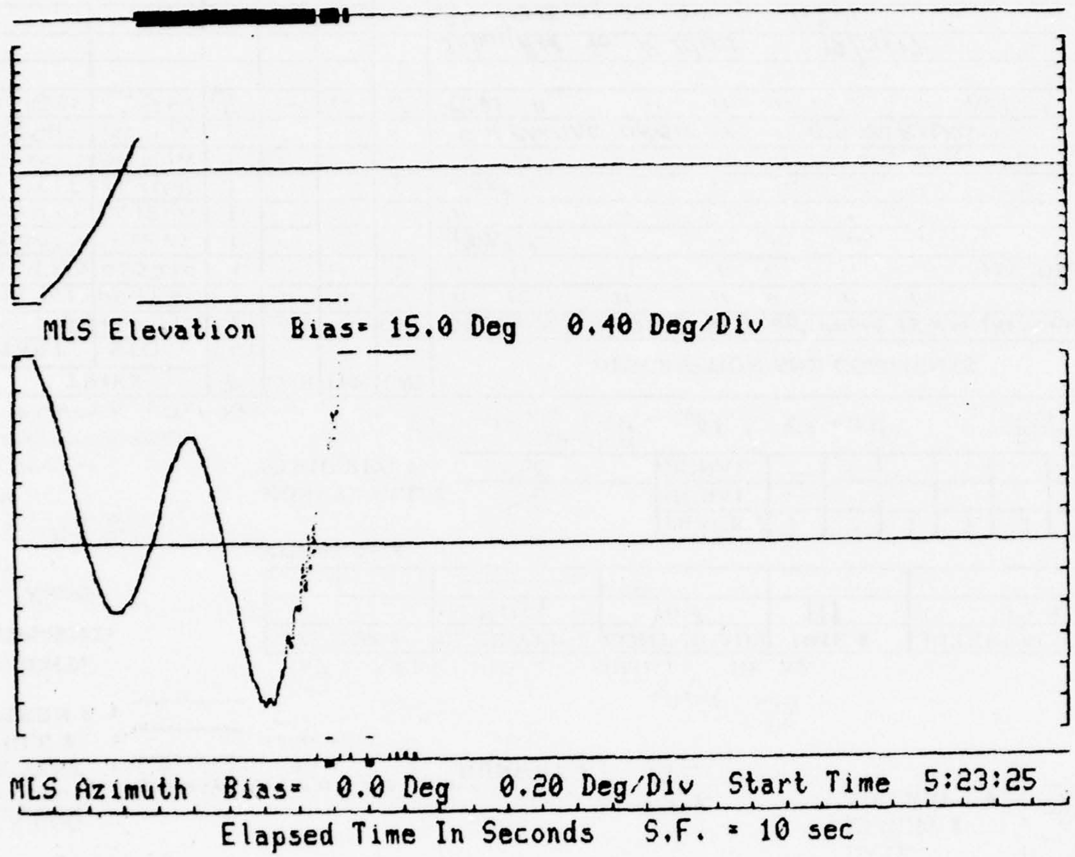
FROM COPY FURNISHED TO DDC

N 49 AIRBORNE DATA
Flight Date 12/ 2/77 System 1
JFK International Airport, New York



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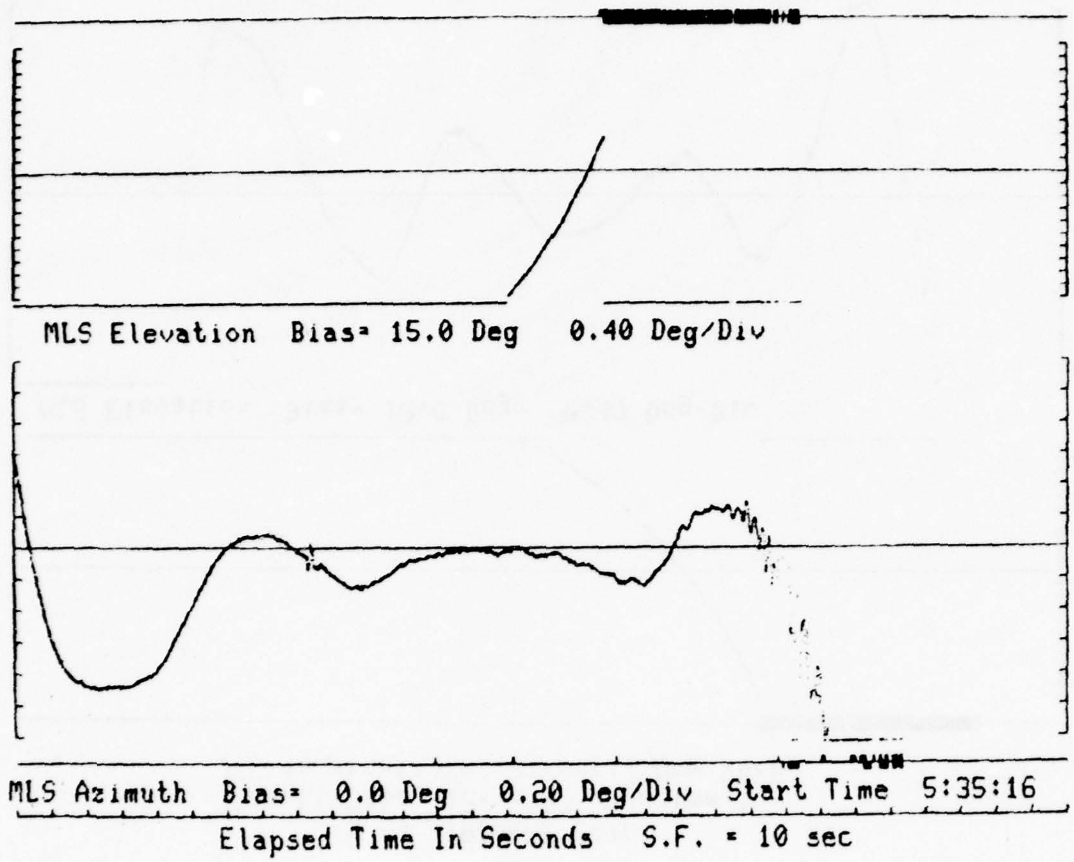
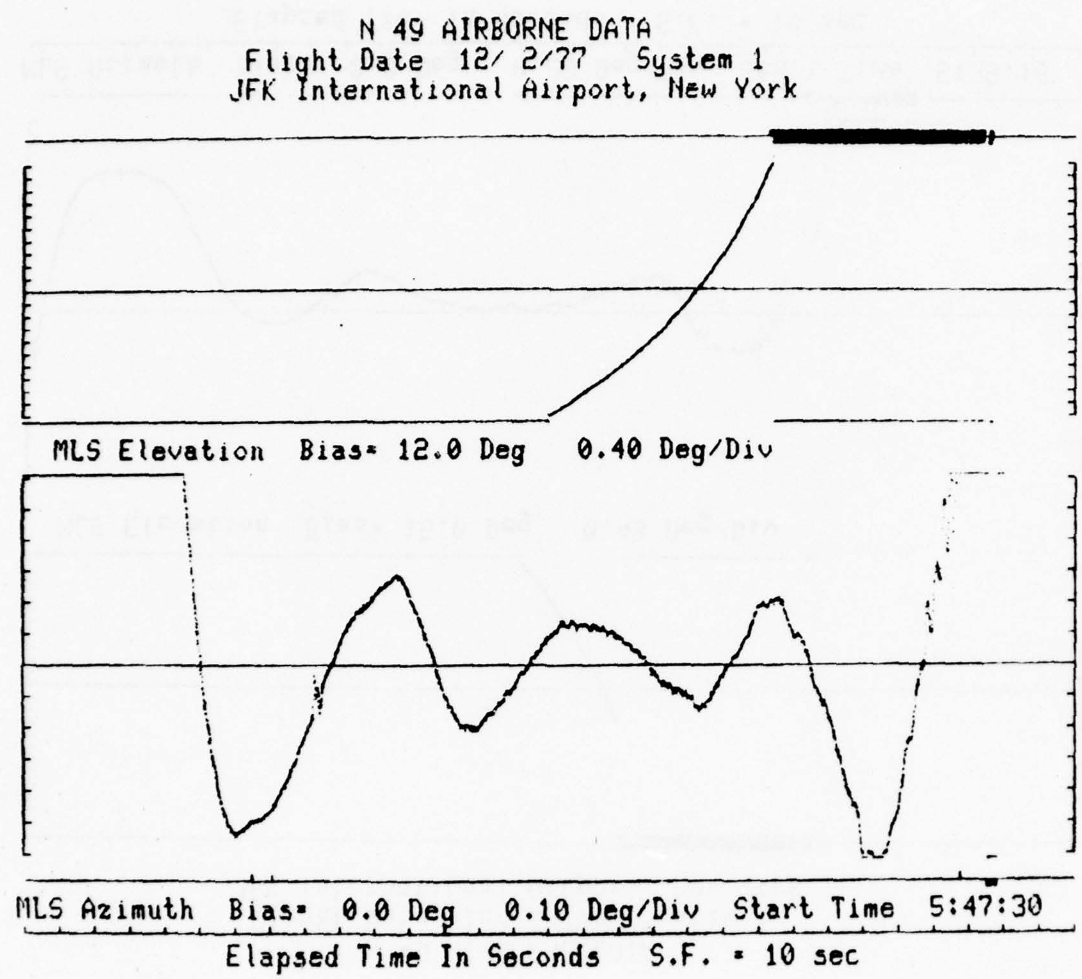
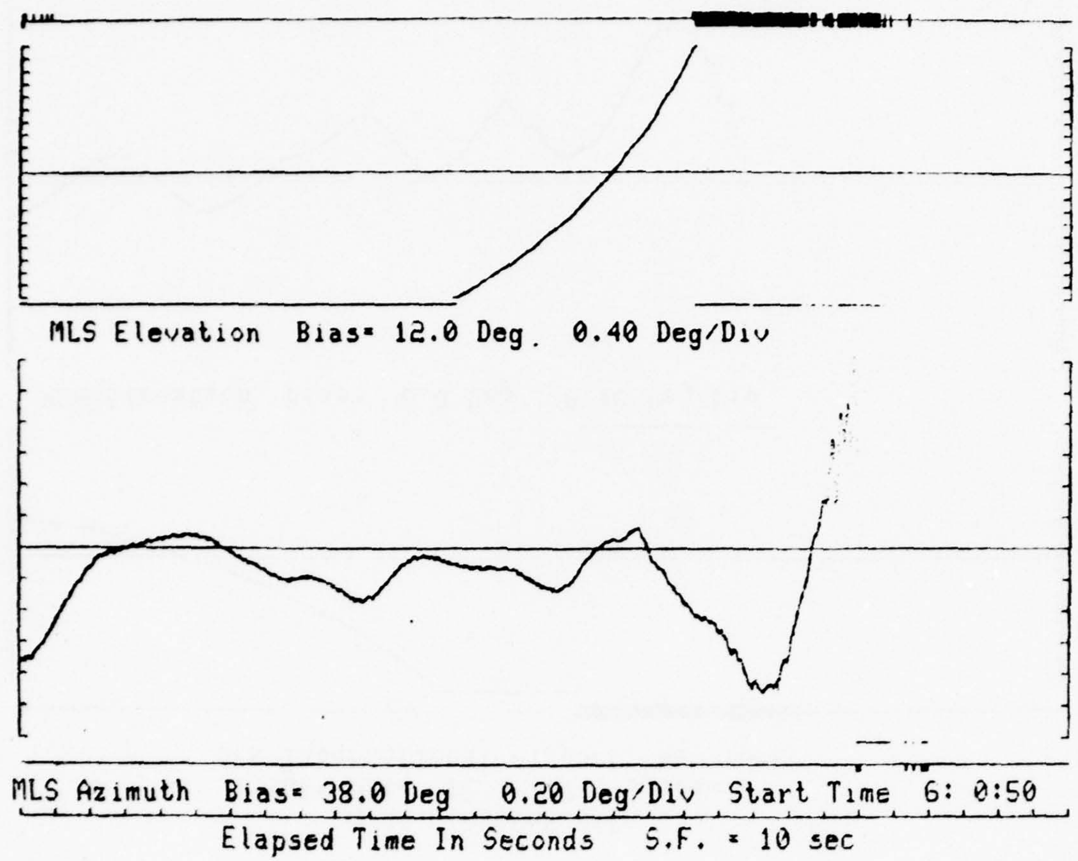
Flight Date 12/ 2/77 System 1
JFK International Airport, New York





N 49 AIRBORNE DATA
Flight Date 12/ 2/77 System 1
JFK International Airport, New York
MLS Elevation Bias= 12.0 Deg 0.40 Deg/Div
MLS Azimuth Bias= 0.0 Deg 0.10 Deg/Div Start Time 5:47:30
Elapsed Time In Seconds S.F. = 10 sec

N 49 AIRBORNE DATA
Flight Date 12/ 2/77 System 1
JFK International Airport, New York



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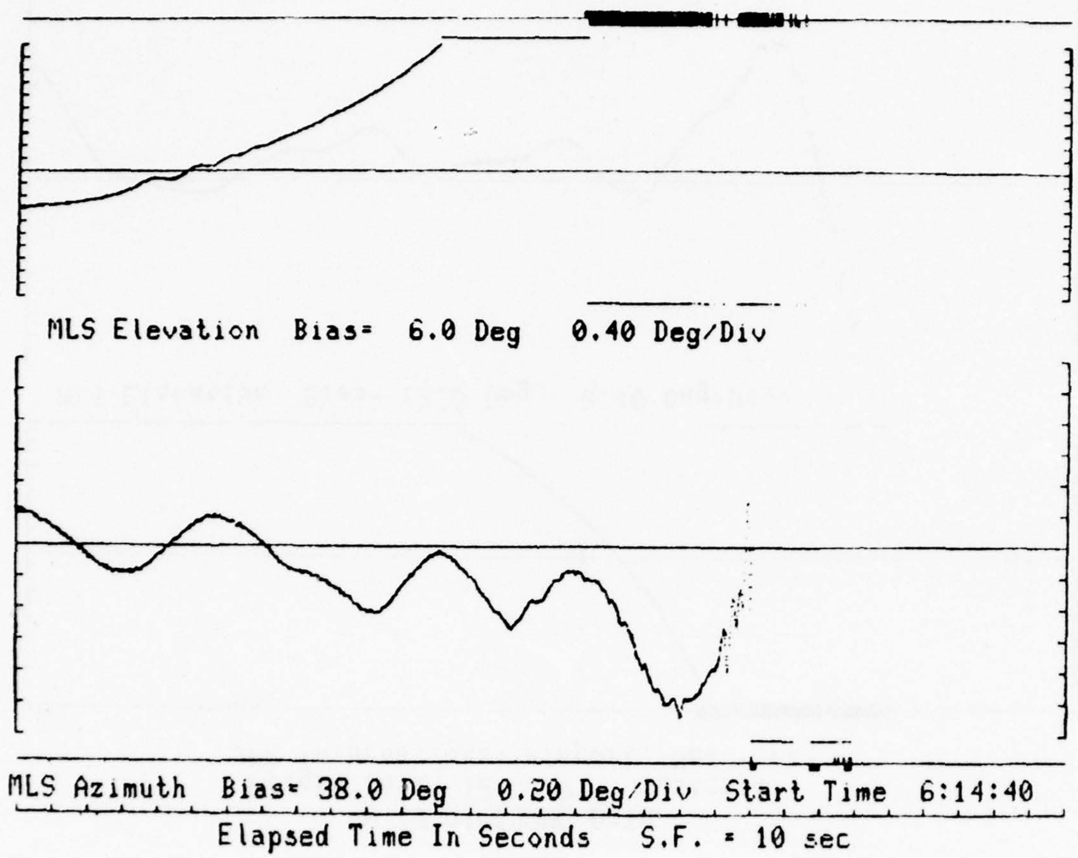
Flight Date 12/ 2/77 System 1
JFK International Airport, New York



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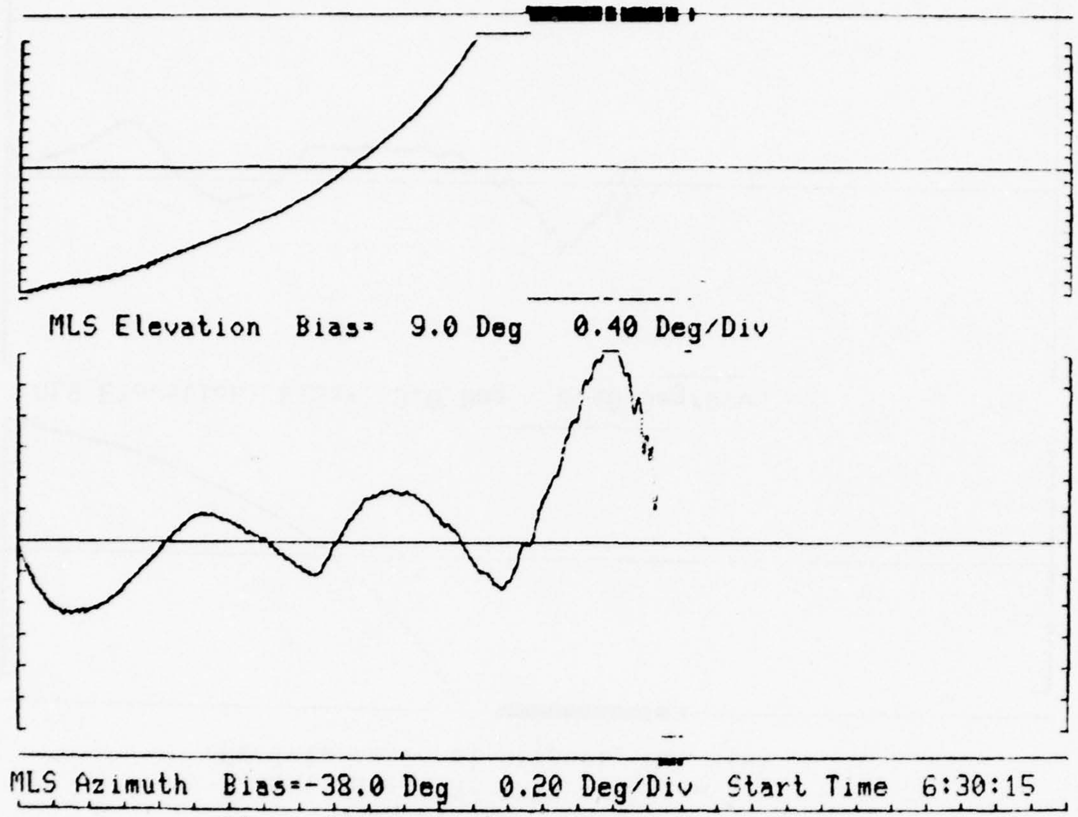
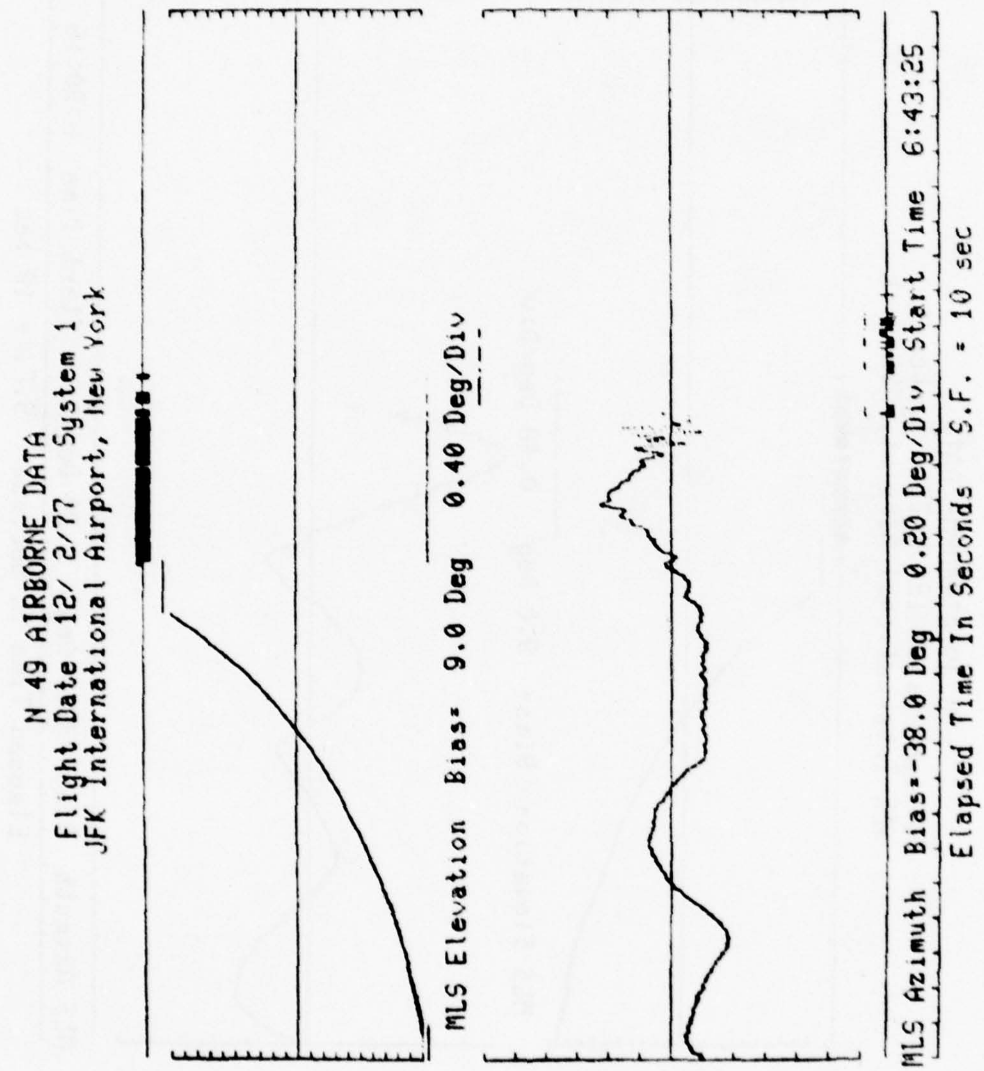
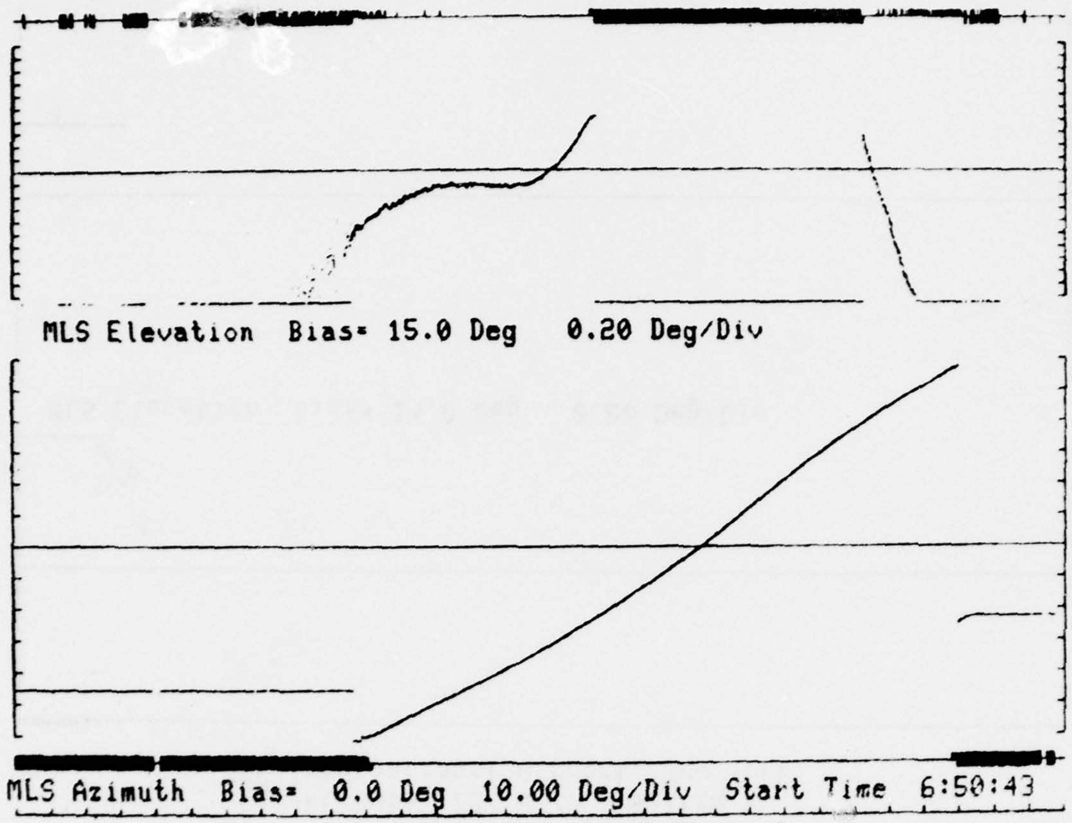
JFK International Airport, New York



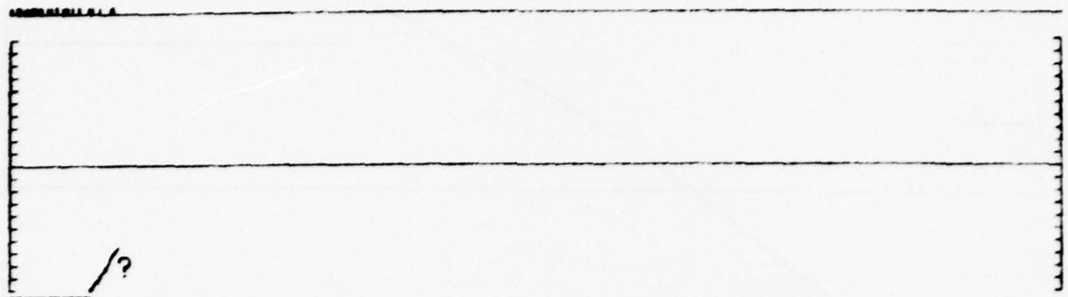
Elapsed Time In Seconds S.F. = 10 sec


N 49 AIRBORNE DATA
Flight Date 12/ 2/77 System 1
JFK International Airport, New York
MLS Elevation Bias= 9.0 Deg 0.40 Deg/Div
MLS Azimuth Bias=-38.0 Deg 0.20 Deg/Div Start Time 6:43:25
Elapsed Time In Seconds S.F. = 10 sec

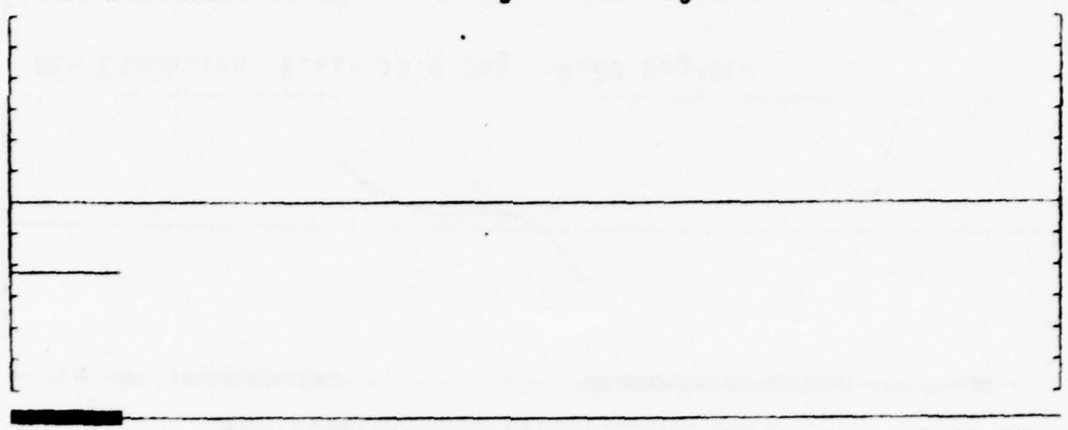
N 49 AIRBORNE DATA
Flight Date 12/ 2/77 System 1
JFK International Airport, New York



N 49 AIRBORNE DATA
Flight Date 12/ 2/77 System 1
JFK International Airport, New York



MLS Elevation Bias= 14.0 Deg 0.20 Deg/Div



MLS Azimuth Bias= 0.0 Deg 10.00 Deg/Div Start Time 6:58:33

Elapsed Time In Seconds S.F. = 10 sec

DATE : 12-5-77
FLIGHT # : 0300-0700
AIRCRAFT # : N49 (CV580

AIRBORNE DATA LOG
MLS PHASE III
SYSTEM UNDER TEST : BENDIX BASIC WIDE AZ CHANNEL 130
BENDIX BASIC NARROW EL
L BAND DME FREQ 112.50
RUNWAY # : JFK 13L
TEST PLAN TABLE # : LEVEL RADIALS
PATTERN # : PARTIAL ORBITS

GROUND EQUIPMENT: (AZ) (EL) EL 2 (DME) BK AZ

AIRBORNE EQUIPMENT:

SYSTEM #	RECEIVER #	CONT HEAD #	DME #	INTERFACE #
1	P102	106	101	[illegible]
2	—	—	—	—

WIND: 060° @ 7 KNOTS
TEMP.: 33°F
CEILING: 8000' OVERCAST
VISIB: 10 NM
PILOT: J. RYAN
COPILOT: F. DUER

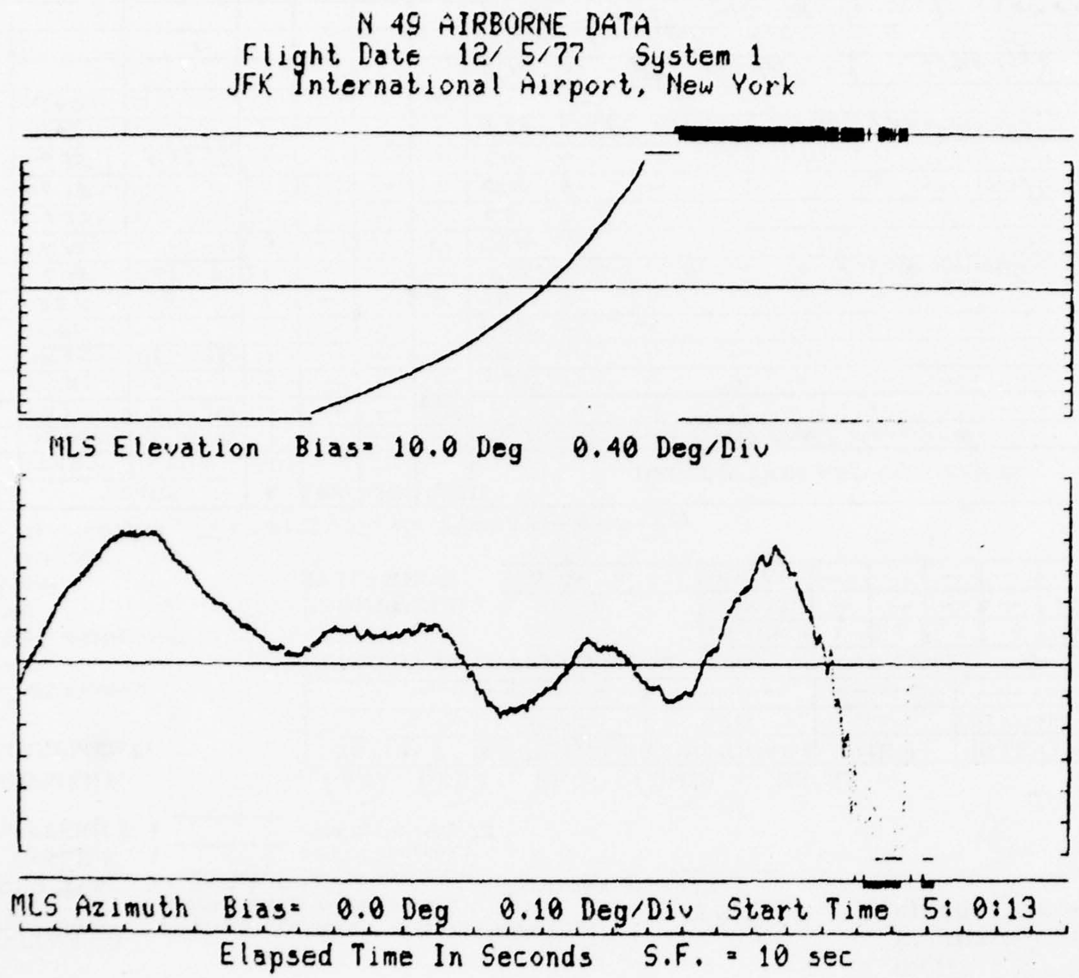
KENNEDY # FSN 7450-NAL-2917 MODEL 9800 9 TRACK

TRACK #	1	2	3	4	5	6	7
HONEYWELL # N/A SIGNAL	—	—	—	—	—	—	—
STRIP REC # N/A SIGNAL	—	—	—	—	—	—	—

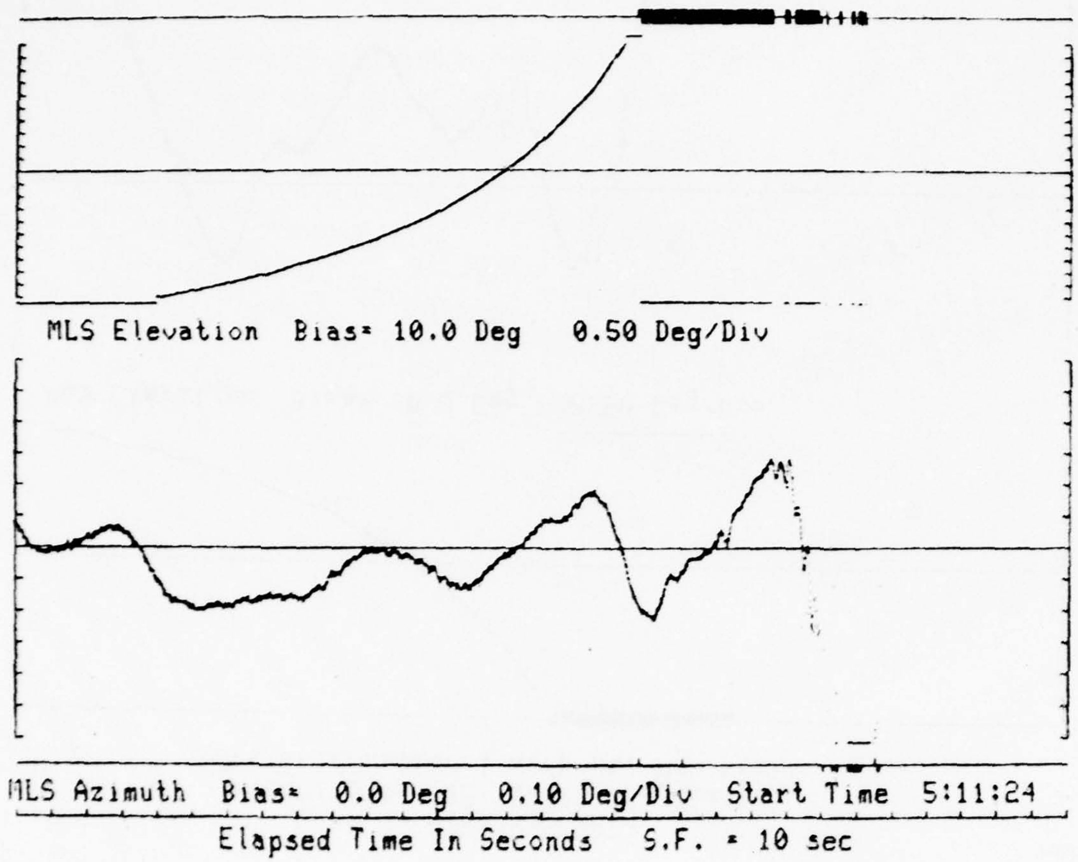
OBSERVERS: M. PLOTKA, T. LOGUE, C. JEZIERSKI - ANA-310

	RUN #	TAPE #	FILE #	TIMES START	TIMES STOP	# EDI	FAIR	TIB	LASER	DESCRIPTION AND COMMENTS	
	1	1	1	050013	050436	1	—	—	✓	CL LEVEL RADIAL @ 6000' FROM 15NM	HORN ANT.
	2	1	2	051124	051530	1	—	—	✓	" " " " " " "	"
	(3)	1	3	05252[illegible]	[illegible]	1	—	—	✓	+38° " " " " " "	"
	4	1	4	053513	053936	1	—	—	✓	" " " " " " "	"
*	5	1	5	054621	[illegible]	1	—	—	✓	-38° " " " " " "	"
*	6	1	6	05571[illegible]	[illegible]	1	—	—	✓	" " " " " " "	"
	7	1	7	060515	0609[illegible]	1	—	—	—	CW PARTIAL ORBIT " " @ 5NM RADIUS (-70° to +70°)	OMNI ANT.
	8	1	8	06121[illegible]	[illegible]	5	—	—	✓	CCW " " " " " " (+70° to -70°)	"
	9	2	1	062210	[illegible]	1	—	—	✓	CW " " " " " " (-70° to +70°)	"
	10	2	2	06282[illegible]	[illegible]	1	—	—	✓	CCW " " " " " " (+70° to -70°)	"
	11	2	3	06355[illegible]	063947	1	—	—	✓	CW " " " " " " (-70° to +70°)	"
**	12	2	4	064616	06513[illegible]	1	—	—	✓	+38° LEVEL RADIAL @ 4000' FROM 15NM	HORN ANT.
**	13	2	5	065916	070[illegible]	5	—	—	✓	" " " " " " "	"
										Run 3: A/C not tracked (Laser log)	
										Airborne tapes received at Green to R.W. 12/6/77 [illegible]	
										Runs 7→11 A/C not tracked (not on trk tape)	

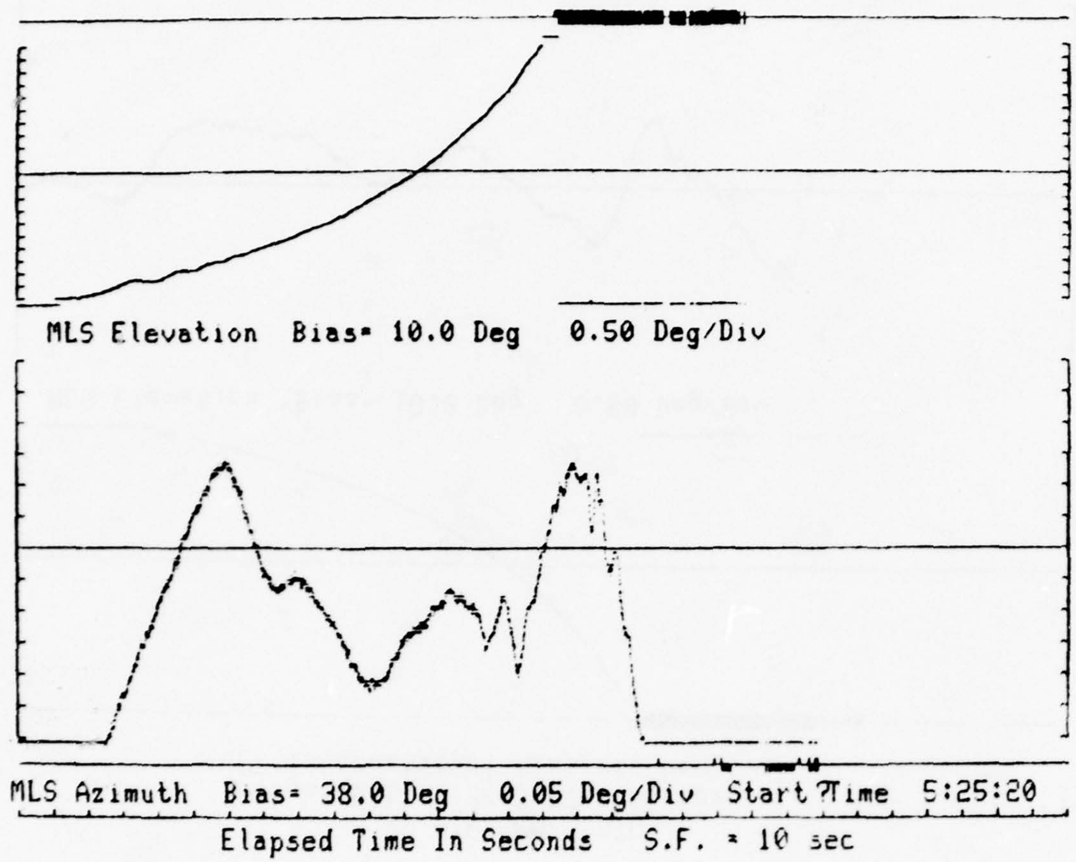
* EL FLAGGED INTERMITTENTLY BETWEEN 15 & 13 NM
** NO EL SIGNAL FROM 15NM TO 8.2 NM.
PILOT [illegible] TUNED TO 113.50 INDICATED [illegible]


N 49 AIRBORNE DATA
Flight Date 12/ 5/77 System 1
JFK International Airport, New York
MLS Elevation Bias= 10.0 Deg 0.40 Deg/Div
MLS Azimuth Bias= 0.0 Deg 0.10 Deg/Div Start Time 5: 0:13
Elapsed Time In Seconds S.F. = 10 sec

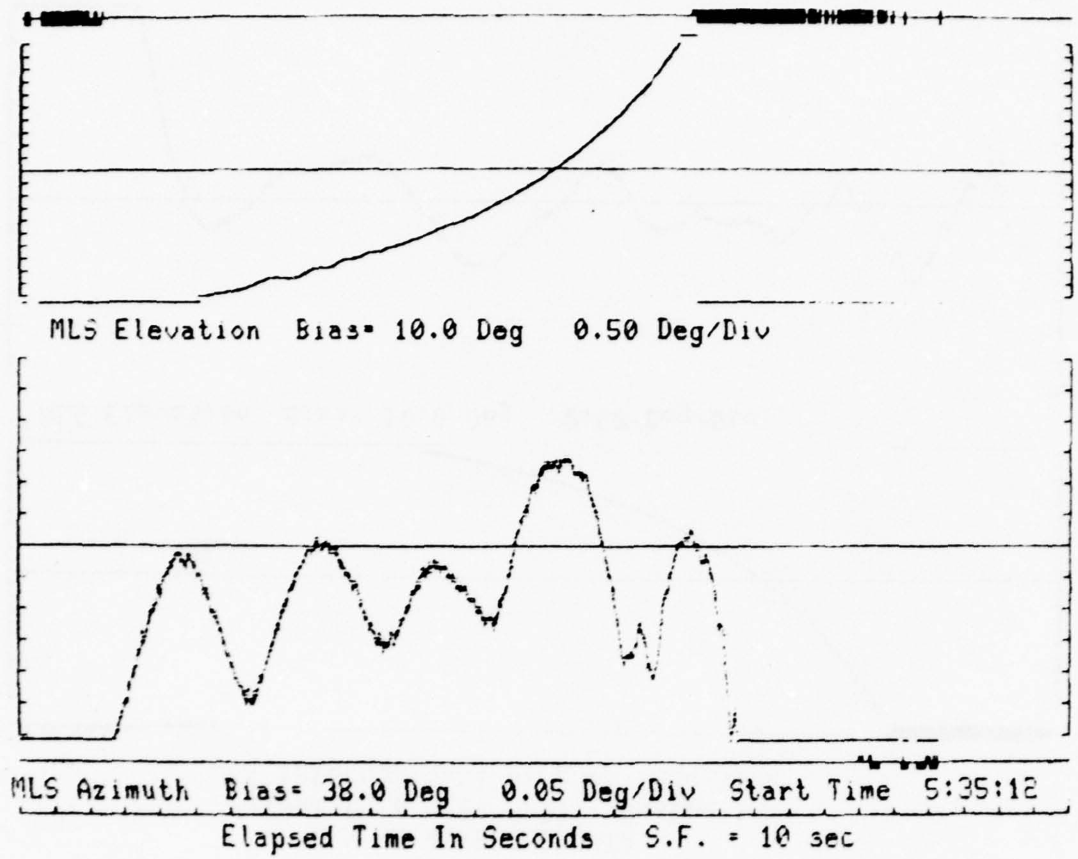
N 49 AIRBORNE DATA
Flight Date 12/ 5/77 System 1
JFK International Airport, New York



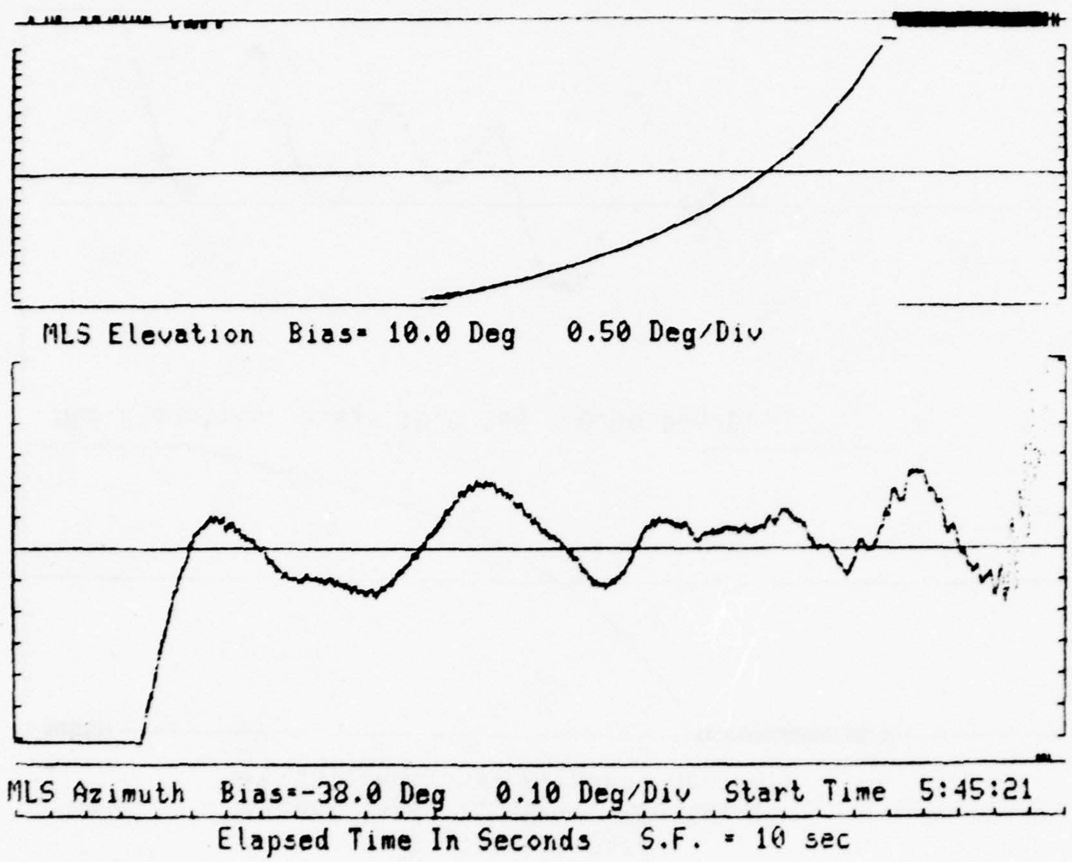
N 49 AIRBORNE DATA
Flight Date 12/ 5/77 System 1
JFK International Airport, New York



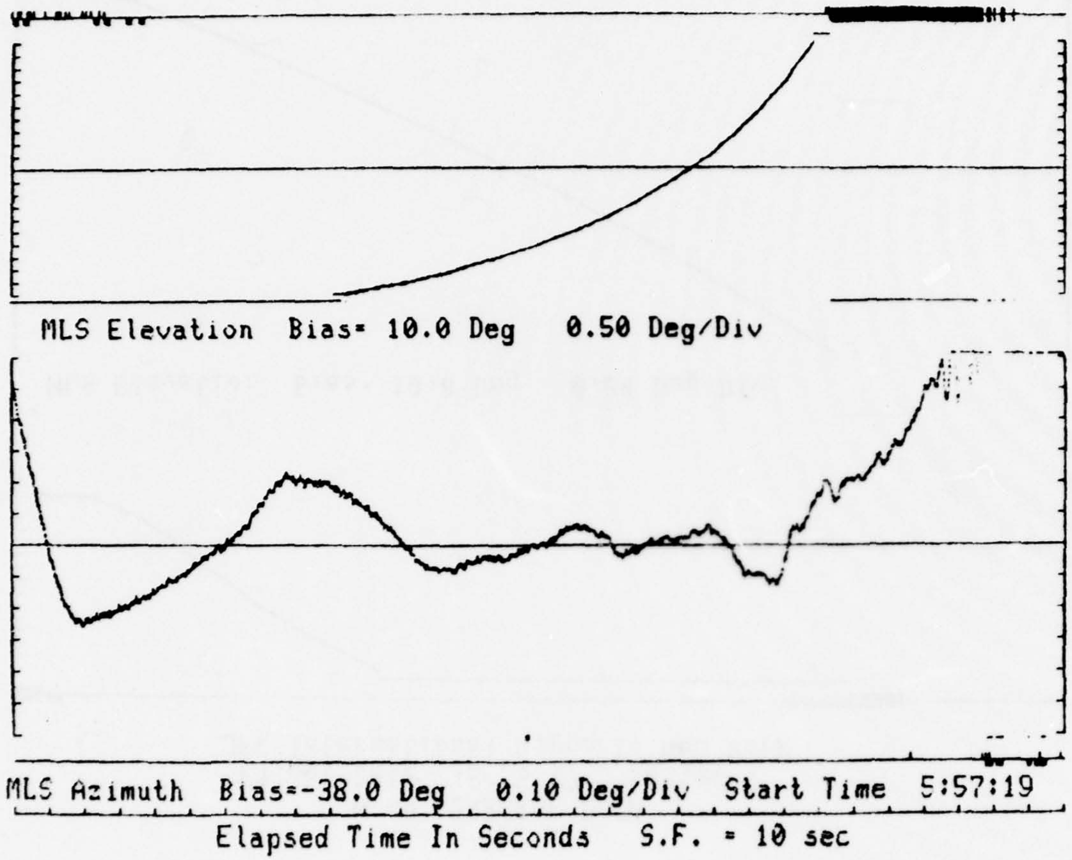
N 49 AIRBORNE DATA
Flight Date 12/ 5/77 System 1
JFK International Airport, New York



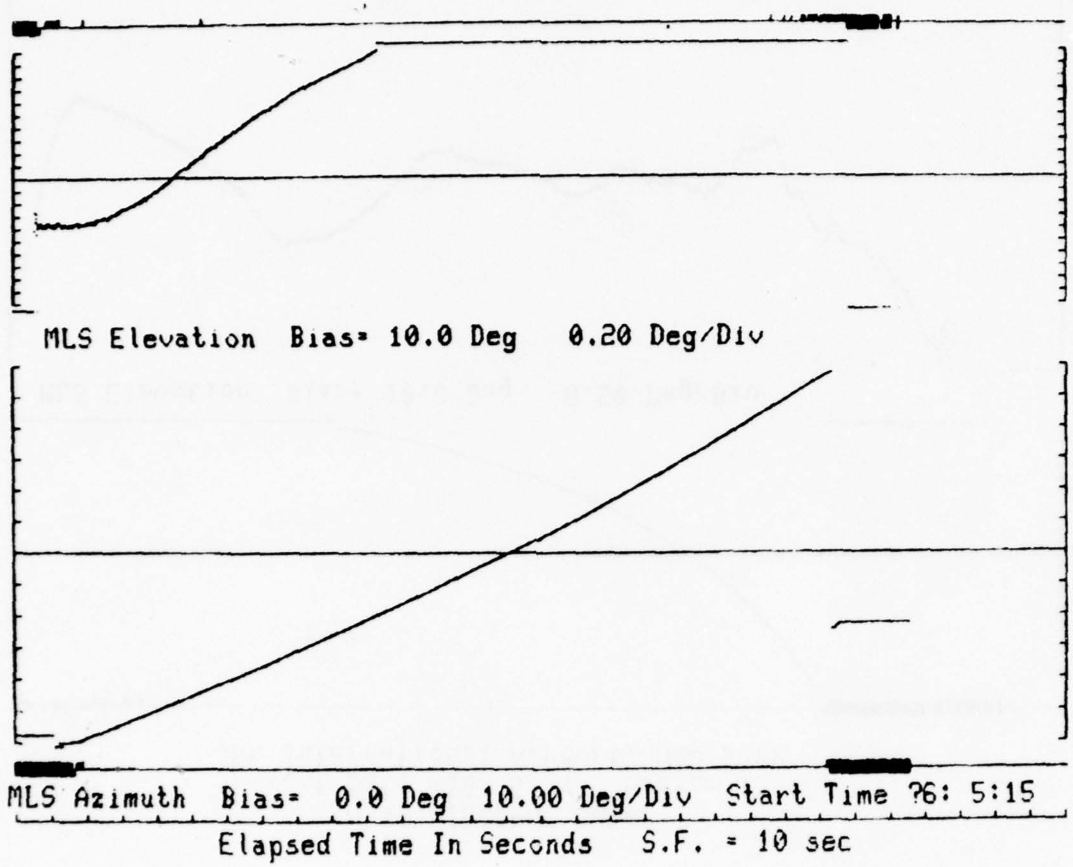
N 49 AIRBORNE DATA
Flight Date 12/ 5/77 System 1
JFK International Airport, New York

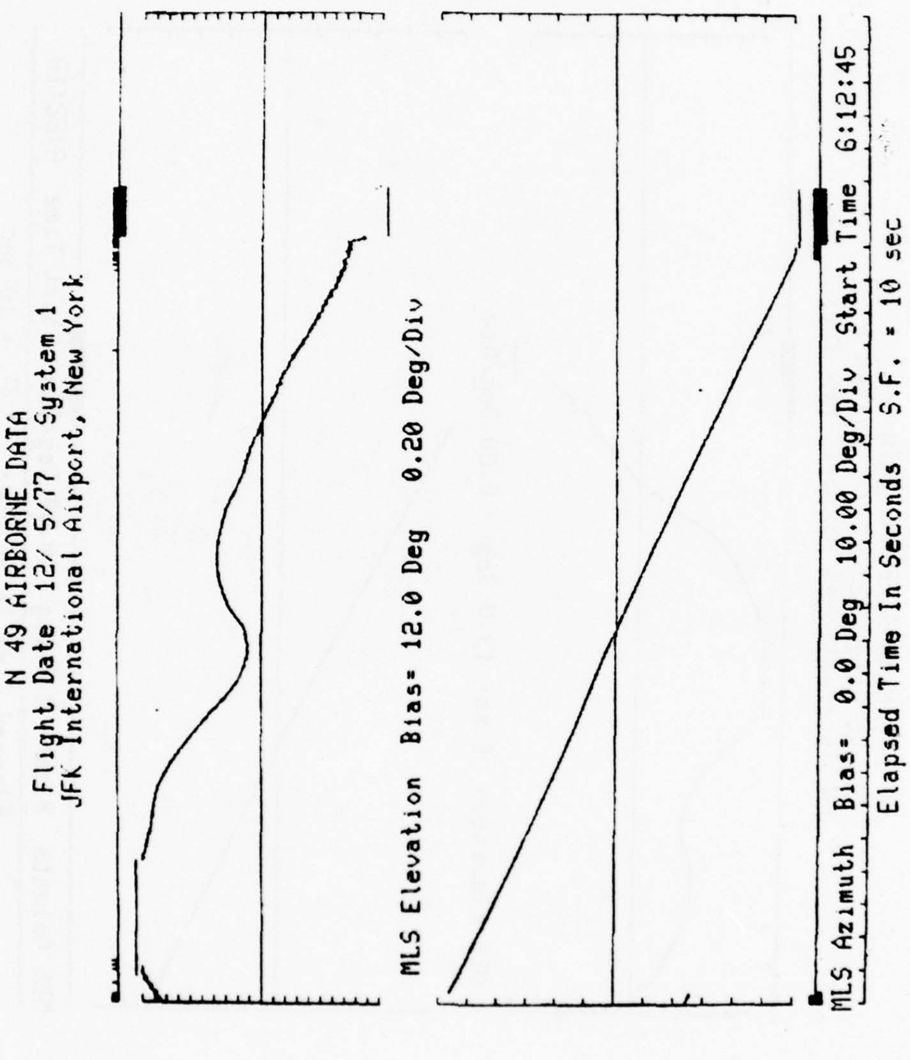


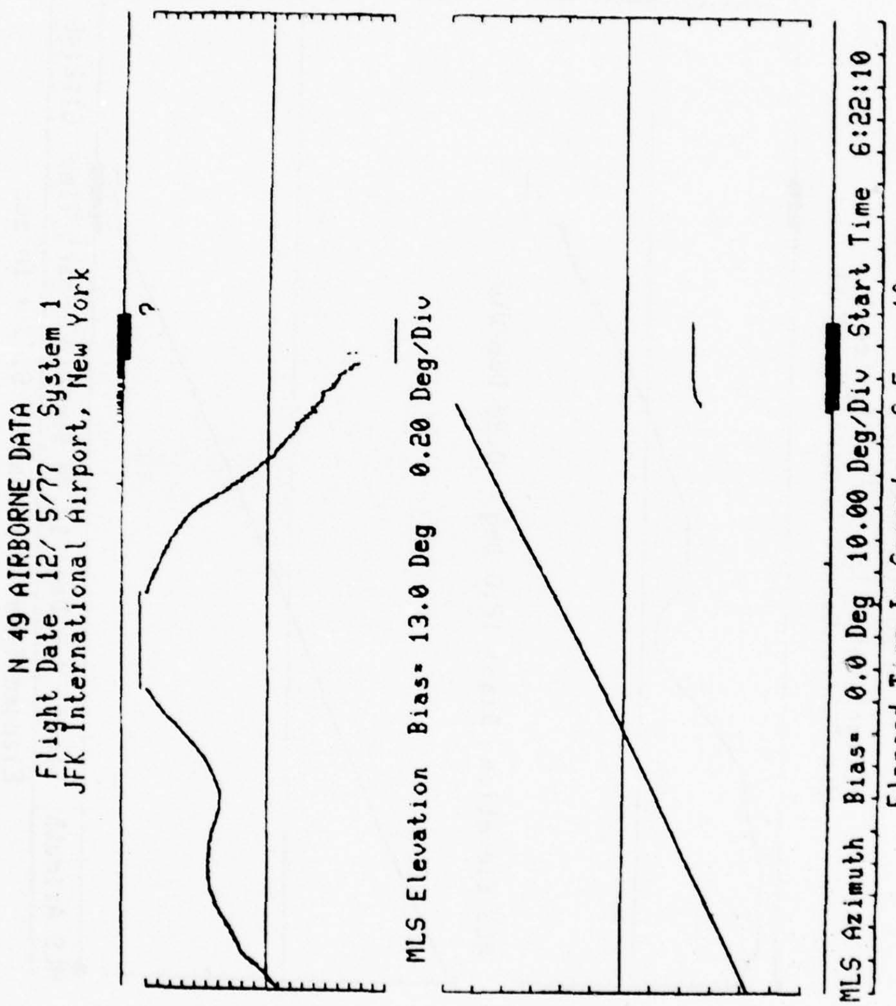
N 49 AIRBORNE DATA
Flight Date 12/ 5/77 System 1
JFK International Airport, New York



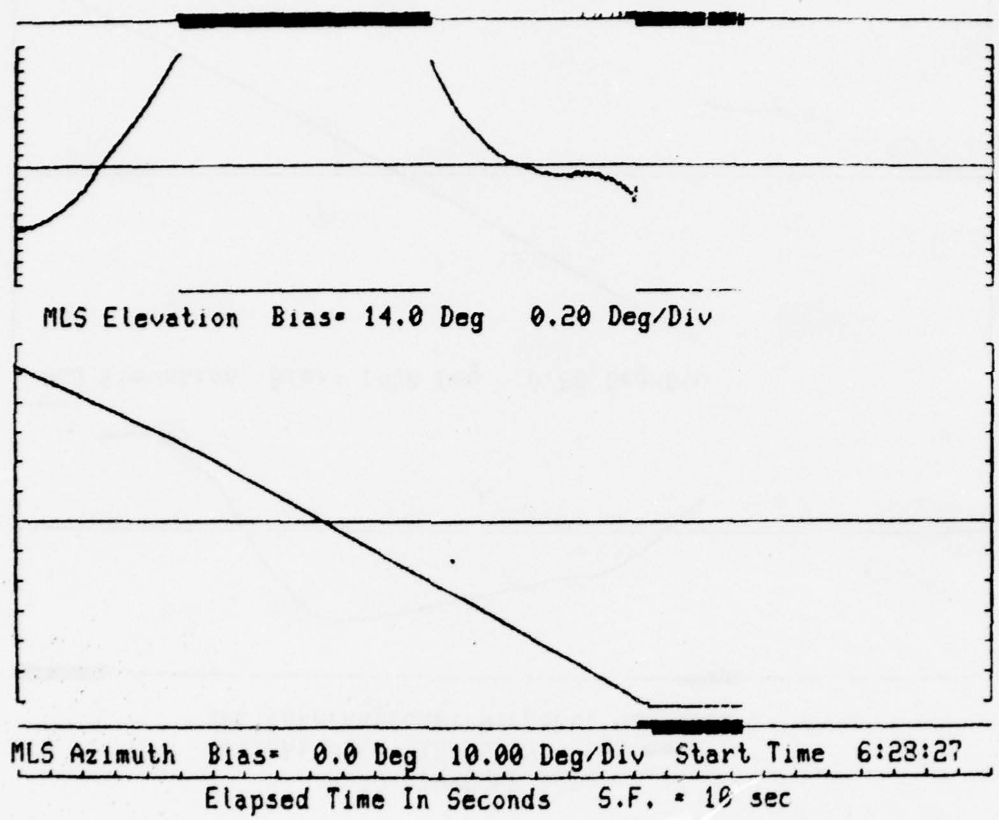
N 49 AIRBORNE DATA
Flight Date 12/ 5/77 System 1
JFK International Airport, New York



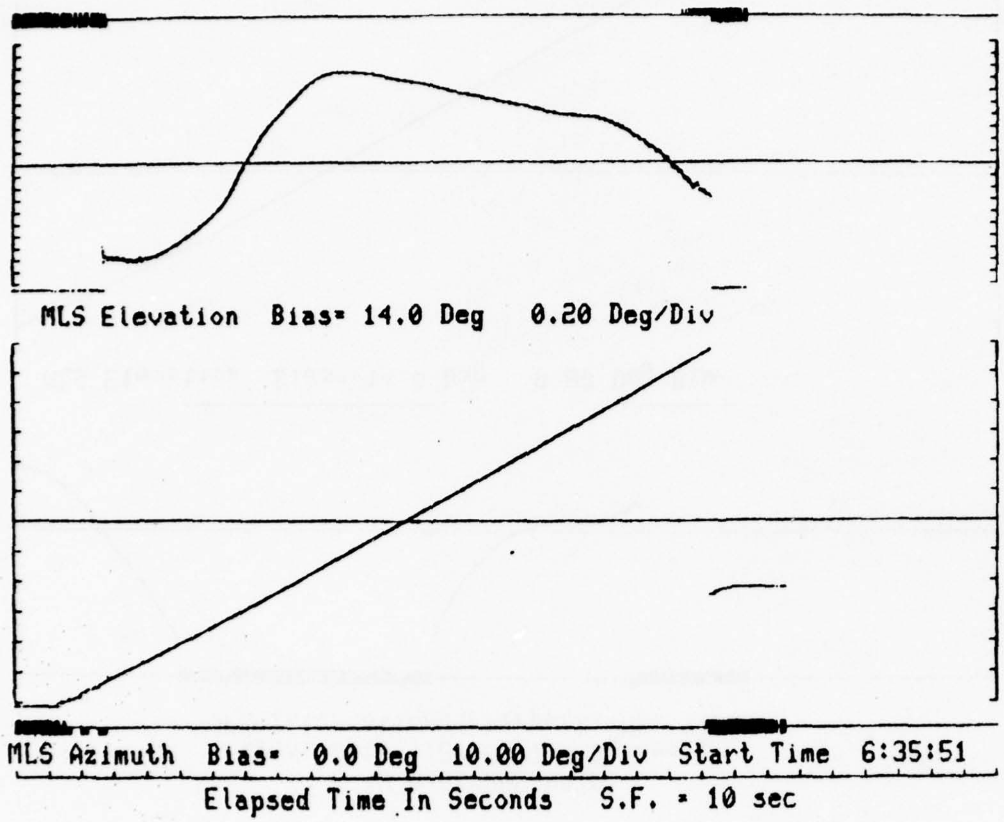

N 49 AIRBORNE DATA
Flight Date 12/ 5/77 System 1
JFK International Airport, New York
MLS Elevation Bias= 12.0 Deg 0.20 Deg/Div
MLS Azimuth Bias= 0.0 Deg 10.00 Deg/Div Start Time 6:12:45
Elapsed Time In Seconds S.F. = 10 sec

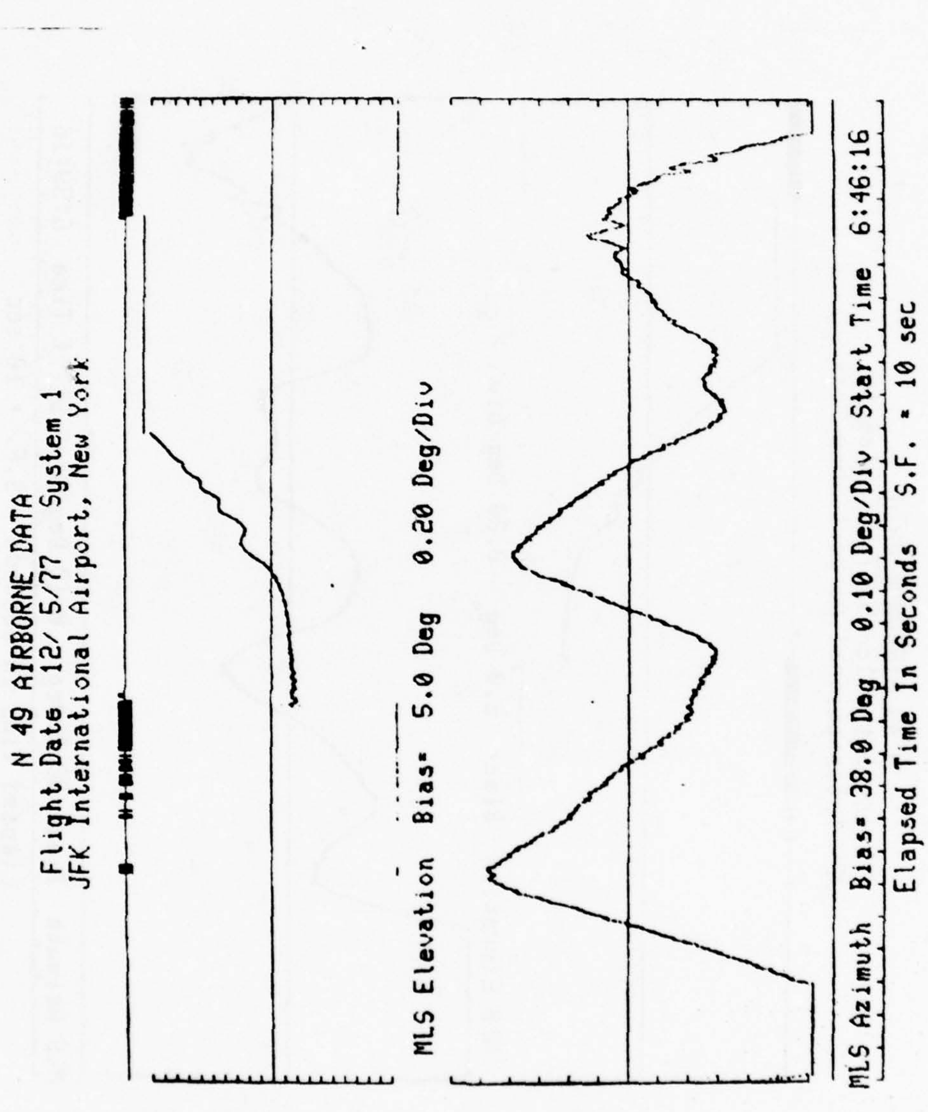

N 49 AIRBORNE DATA
Flight Date 12/ 5/77 System 1
JFK International Airport, New York
MLS Elevation Bias= 13.0 Deg 0.20 Deg/Div
MLS Azimuth Bias= 0.0 Deg 10.00 Deg/Div Start Time 6:22:10
Elapsed Time In Seconds S.F. = 10 sec

N 49 AIRBORNE DATA
Flight Date 12/ 5/77 System 1
JFK International Airport, New York

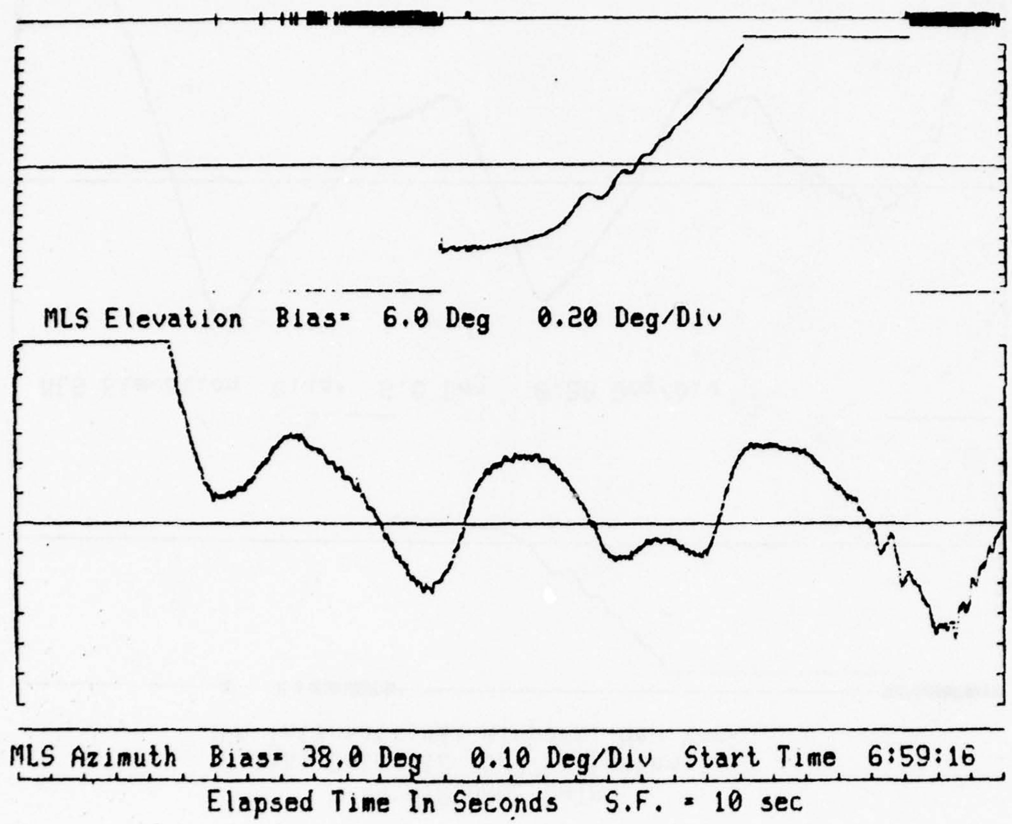


N 49 AIRBORNE DATA
Flight Date 12/ 5/77 System 1
JFK International Airport, New York




N 49 AIRBORNE DATA
Flight Date 12/ 5/77 System 1
JFK International Airport, New York
MLS Elevation Bias= 5.0 Deg 0.20 Deg/Div
MLS Azimuth Bias= 38.0 Deg 0.10 Deg/Div Start Time 6:46:16
Elapsed Time In Seconds S.F. = 10 sec

N 49 AIRBORNE DATA
Flight Date 12/ 5/77 System 1
JFK International Airport, New York



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PAGE

AIRBORNE DATA LOG
MLS PHASE III
SYSTEM UNDER TEST : B.D. [illegible]/B.D. El
TEST PLAN TABLE # : [illegible] Coordinating [illegible]
PATTERN # :

RUNWAY # : 13L (JFK)

DATE : 12/13/77
FLIGHT # :
AIRCRAFT # : [illegible]

[illegible] 135.85
[illegible]

GROUND EQUIPMENT: (AZ) (EL) EL 2 (DME) BK AZ
AIRBORNE EQUIPMENT:

SYSTEM #	RECEIVER #	CONT HEAD #	DME #	INTERFACE #
1	109/102K	106SC	101	[illegible]
2				

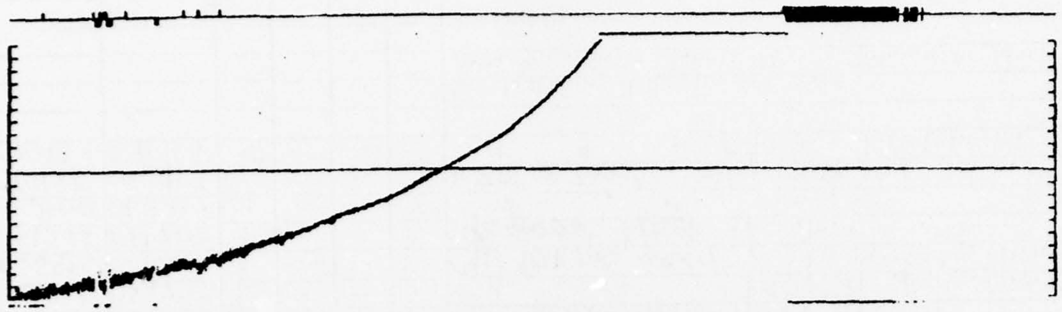
WIND: 340 @ 5
TEMP.: 34°F
CEILING: [illegible]
VISIB: [illegible] -H
PILOT: B. Hughes
COPILOT: [illegible]
OBSERVERS: R. Russell, J. Mcgowan, C. Mackin

KENNEDY # [illegible]
HONEYWELL # [illegible]
STRIP REC # N/A

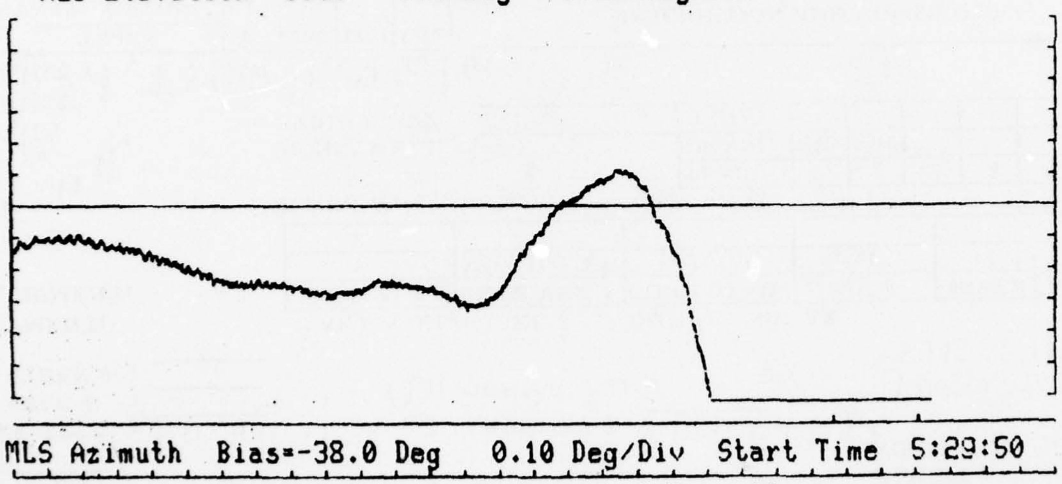
TRACK #	1	2	3	4	5	6	7
SIGNAL	VID	TIME					
SIGNAL							

RUN #	TAPE #	FILE #	TIMES START	TIMES STOP	# EDF	FAIR	THD	LASER	DESCRIPTION AND COMMENTS
1	1	1	052950	053415	1	—	—	Y	R38° level @ 4000' laser at [illegible]
2	1	2	054345	054755	1	—	—	Y	" " laser at [illegible]
3	1	3	055525	055900	1	—	—	Y	CW PARTIAL ORBIT [illegible]
4	1	4	061225	061700	1	—	—	Y	@ 2000' laser at [illegible]
5	1	5	062800	063210	1	—	—	Y	" " [illegible]
6	1	6	064815	065117	1	—	K	Y	L38° @ 2000', Change [illegible] to 102 [illegible]
7	1	7	070135	070514	5	—	—	—	" " [illegible] NO LASER
									No tracking data for runs 2 & 3
									[illegible] tape [illegible] 12-13-77 Submitted 12-13-77

N 49 AIRBORNE DATA
Flight Date 12/13/77 System 1
JFK International Airport, New York

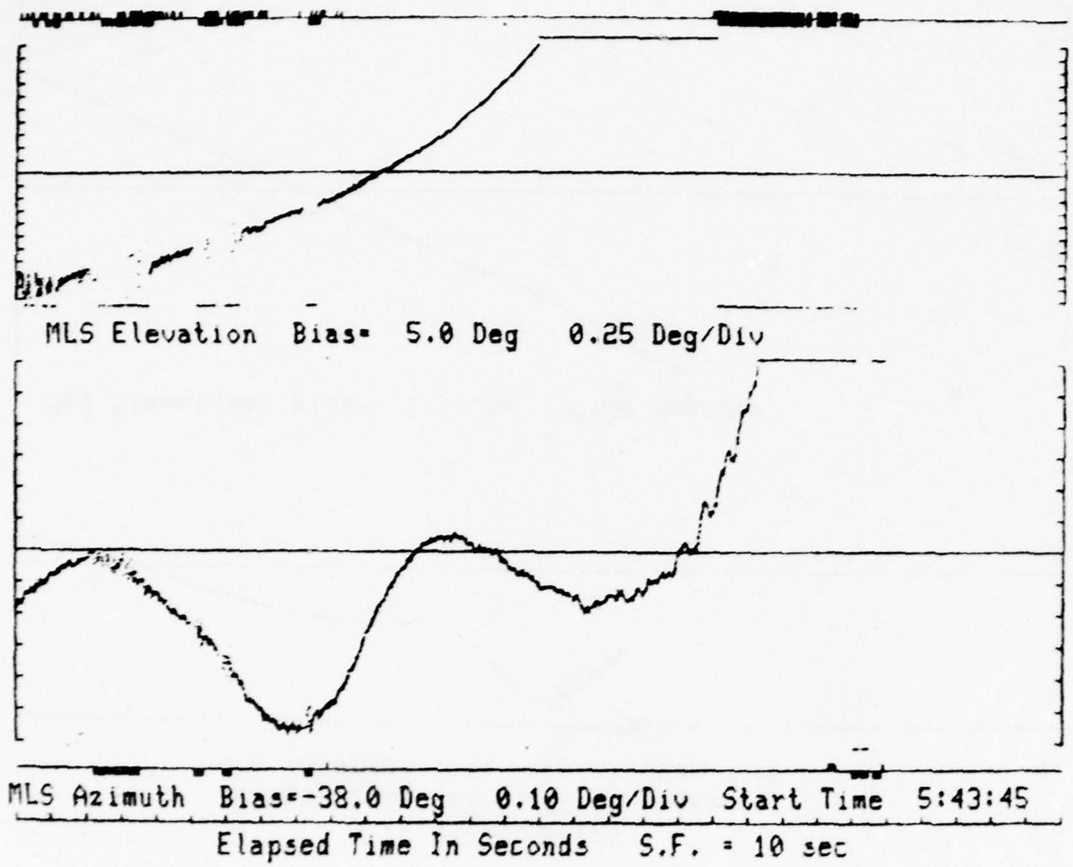


MLS Elevation Bias= 5.0 Deg 0.25 Deg/Div

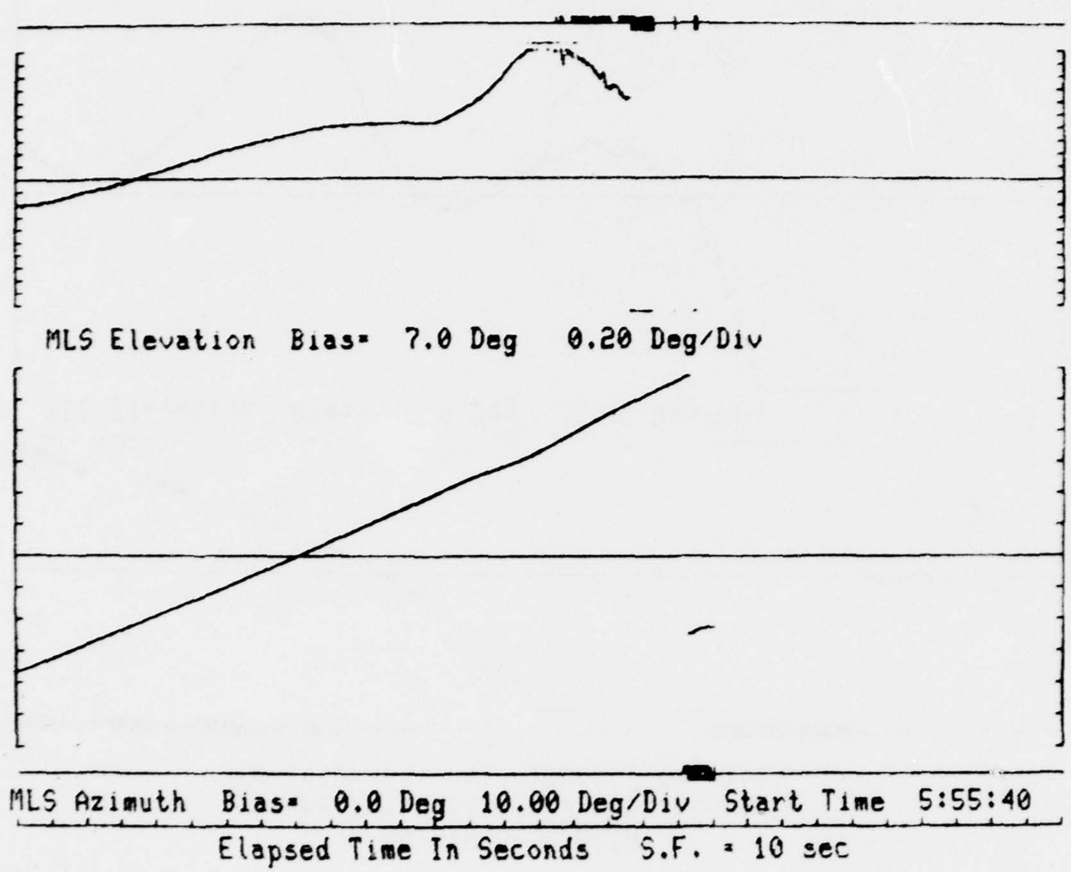


MLS Azimuth Bias=-38.0 Deg 0.10 Deg/Div Start Time 5:29:50
Elapsed Time In Seconds S.F. = 10 sec

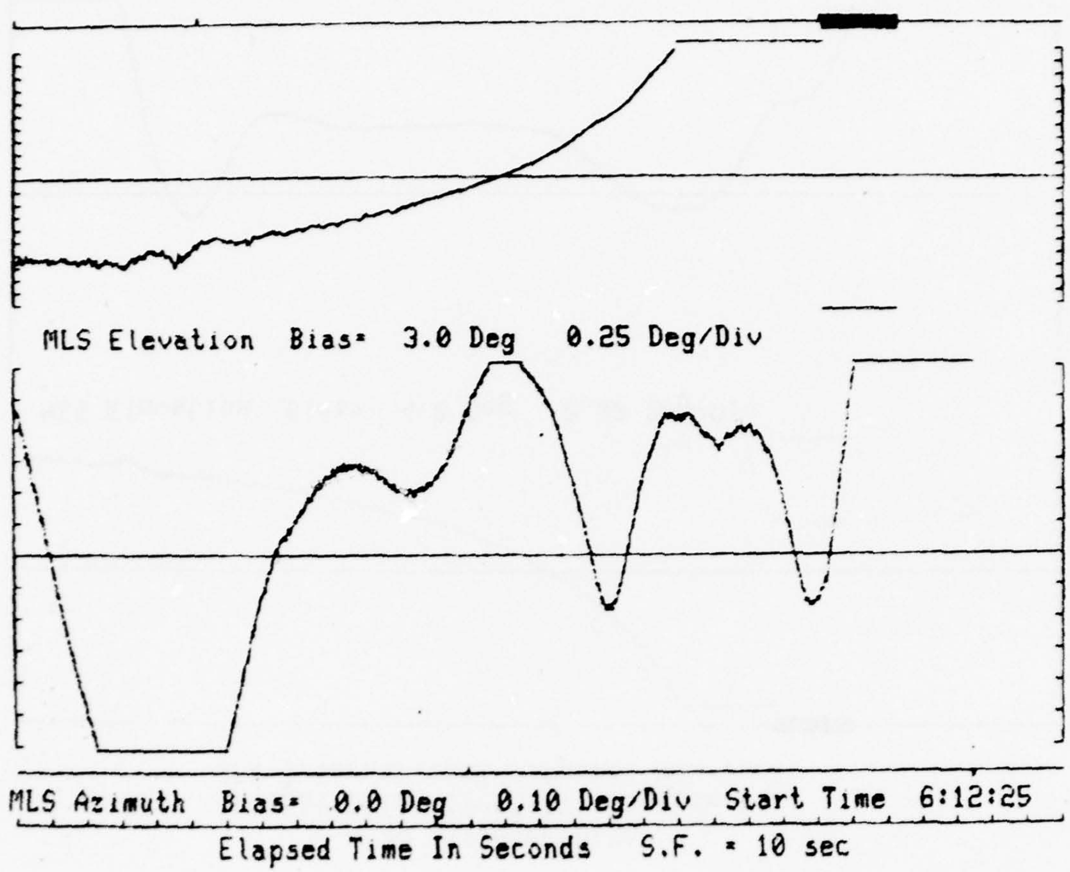
N 49 AIRBORNE DATA
Flight Date 12/13/77 System 1
JFK International Airport, New York

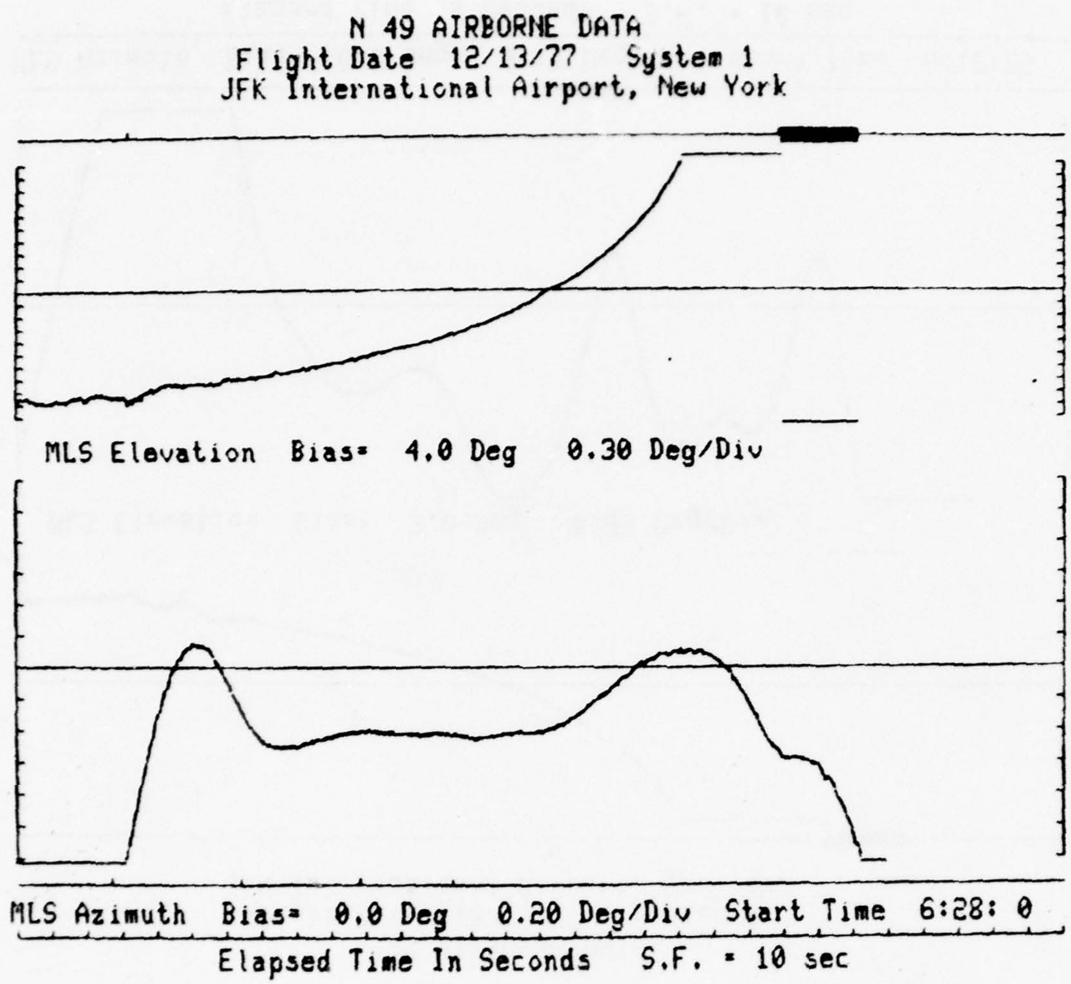


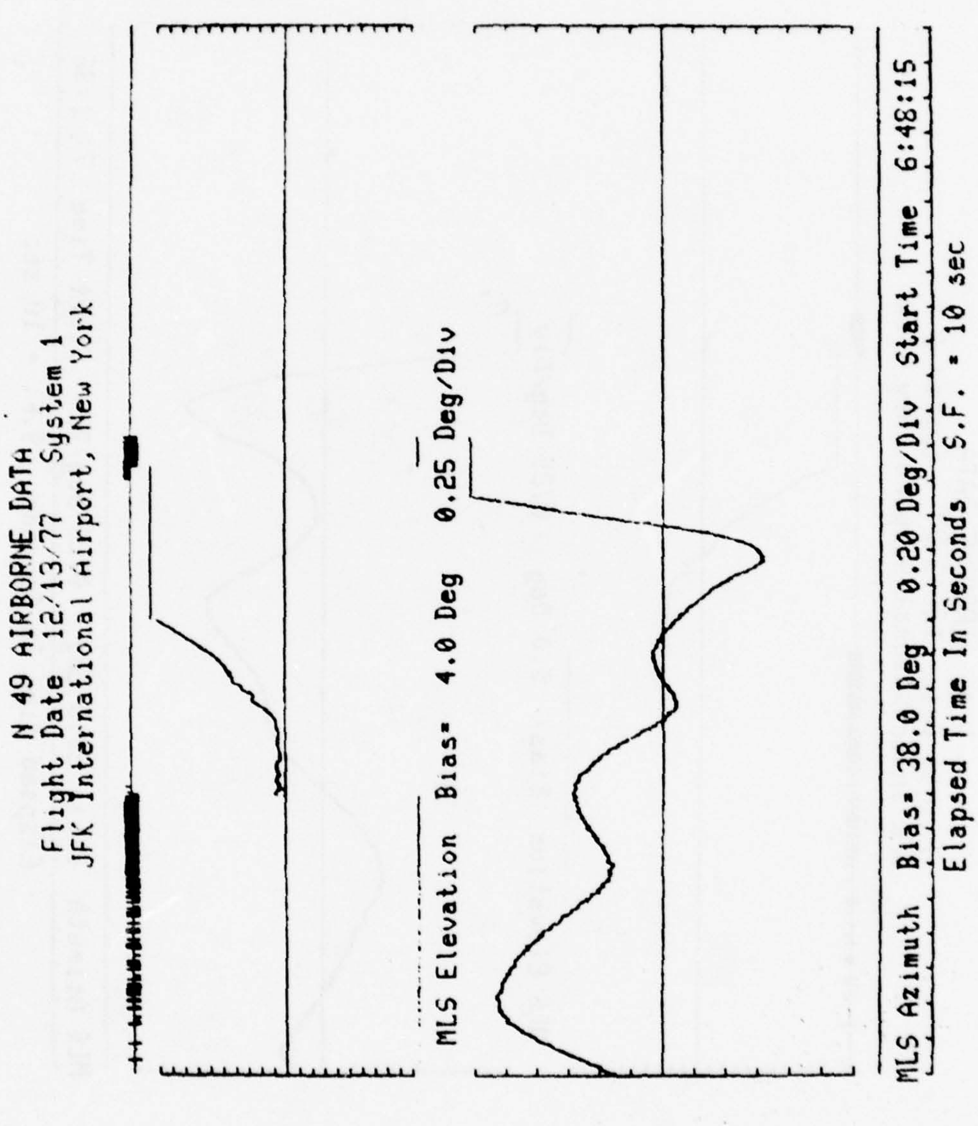
N 49 AIRBORNE DATA
Flight Date 12/13/77 System 1
JFK International Airport, New York



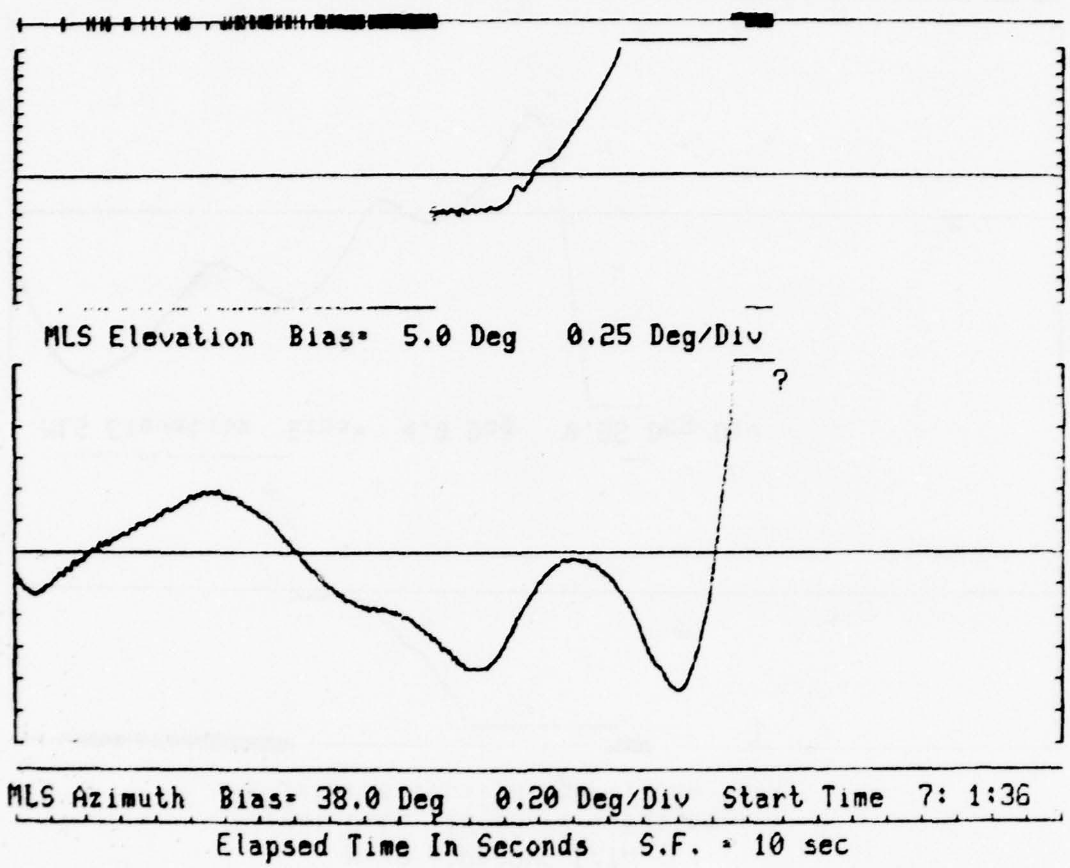
N 49 AIRBORNE DATA
Flight Date 12/13/77 System 1
JFK International Airport, New York




N 49 AIRBORNE DATA
Flight Date 12/13/77 System 1
JFK International Airport, New York
MLS Elevation Bias= 4.0 Deg 0.30 Deg/Div
MLS Azimuth Bias= 0.0 Deg 0.20 Deg/Div Start Time 6:28: 0
Elapsed Time In Seconds S.F. = 10 sec


N 49 AIRBORNE DATA
Flight Date 12/13/77 System 1
JFK International Airport, New York
MLS Elevation Bias= 4.0 Deg 0.25 Deg/Div
MLS Azimuth Bias= 38.0 Deg 0.20 Deg/Div Start Time 6:48:15
Elapsed Time In Seconds S.F. = 10 sec

N 49 AIRBORNE DATA
Flight Date 12/13/77 System 1
JFK International Airport, New York



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PAGE

AIRBORNE DATA LOG
MLS PHASE III

DATE : 12/16/77
FLIGHT # :
AIRCRAFT # : [illegible]49

SYSTEM UNDER TEST : BW Az/BN El
TEST PLAN TABLE # : } JFK Comparative data
PATTERN # :
RUNWAY # : JFK 13L

GROUND EQUIPMENT: AZ EL EL 2 DME BK AZ
AIRBORNE EQUIPMENT:

SYSTEM #	RECEIVER #	CONT HEAD #	DME #	INTERFACE #
1	BD102	106SC	101	TM Modified
2	—	—	—	—

WIND: 060@5
TEMP.: 34°F
CEILING: UDL
VISIB: UDL
PILOT: G. Decker
COPILOT: E. Lamprecht
OBSERVERS: Mackin, Logue

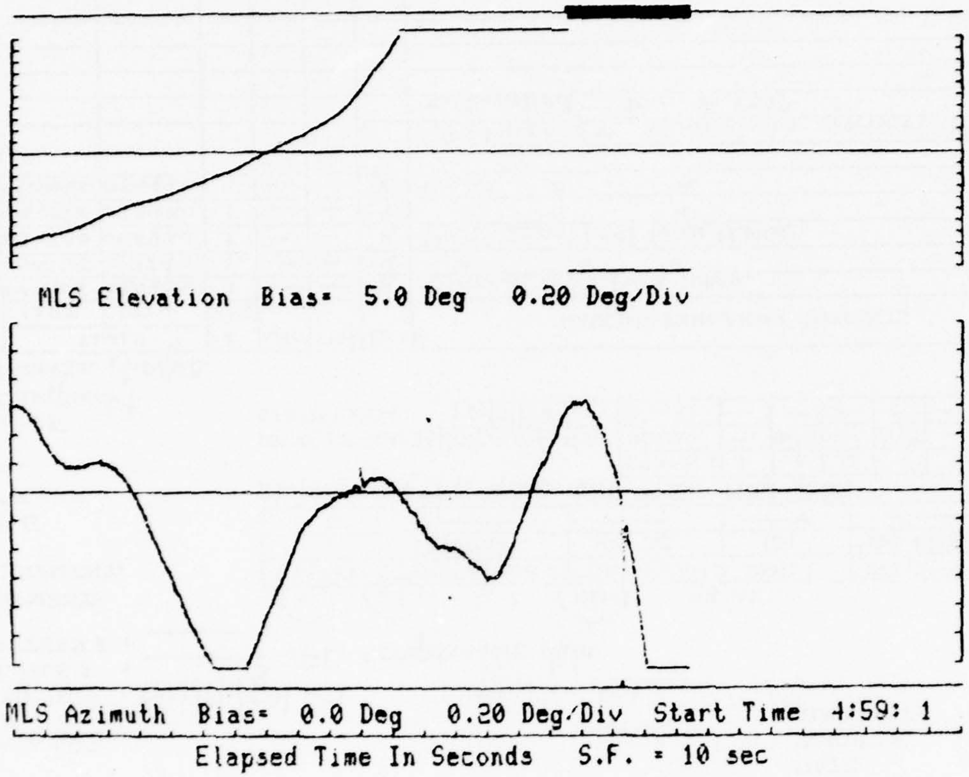
KENNEDY #9 TRK 9800 WIP 7450 NA2 2917

HONEYWELL # NAFEC [illegible]
STRIP REC # Not Used

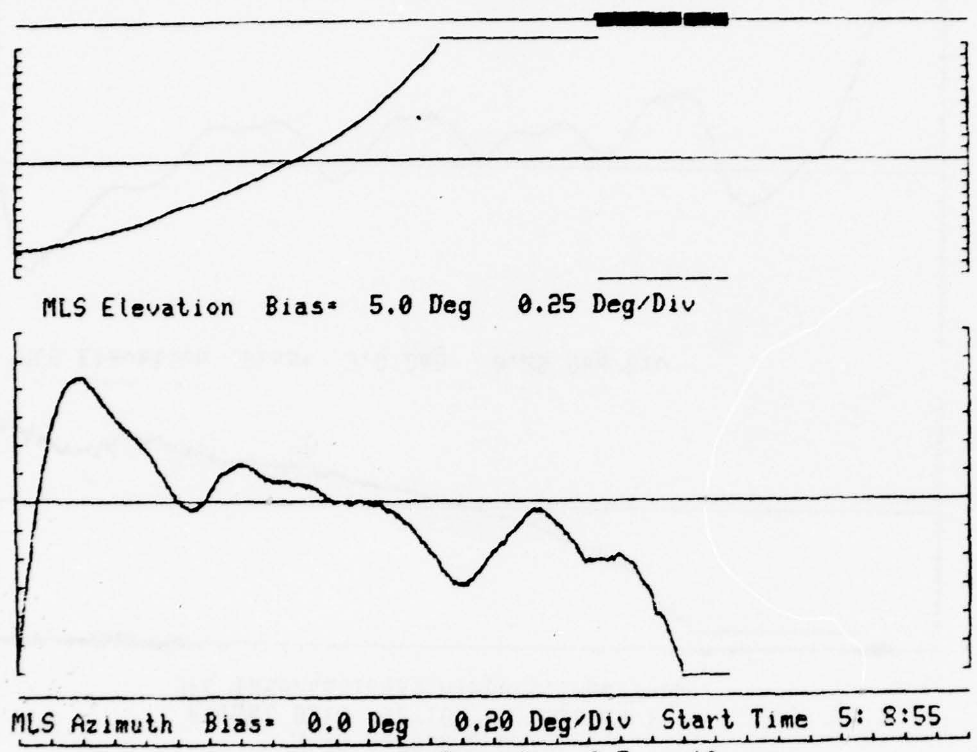
TRACK #	1	2	3	4	5	6	7	8
SIGNAL	—	[illegible]	—	AGC	—	[illegible]	—	—
SIGNAL	—	—	—	—	—	—	—	—

RUN #	TAPE #	FILE #	TIMES START	TIMES STOP	# EDP	FAIR	FHD	LASER	DESCRIPTION AND COMMENTS
1	1	1	045905	050335	1	—	—	X	℄ 4000' level from 12 nmi
2	1	2	050655	051240	1	—	—	X	" " "
3	1	3	051030	052320	1	—	—	X	R30° 2000' level from 12 nmi
4	1	4	053020	053450	1	—	—	X	" " "
5	1	5	054040	054430	5	—	—	X	L30° " "
									[illegible] data processed & submitted Dec 16, 1977

N 49 AIRBORNE DATA
Flight Date 12/16/77 System 1
JFK International Airport, New York

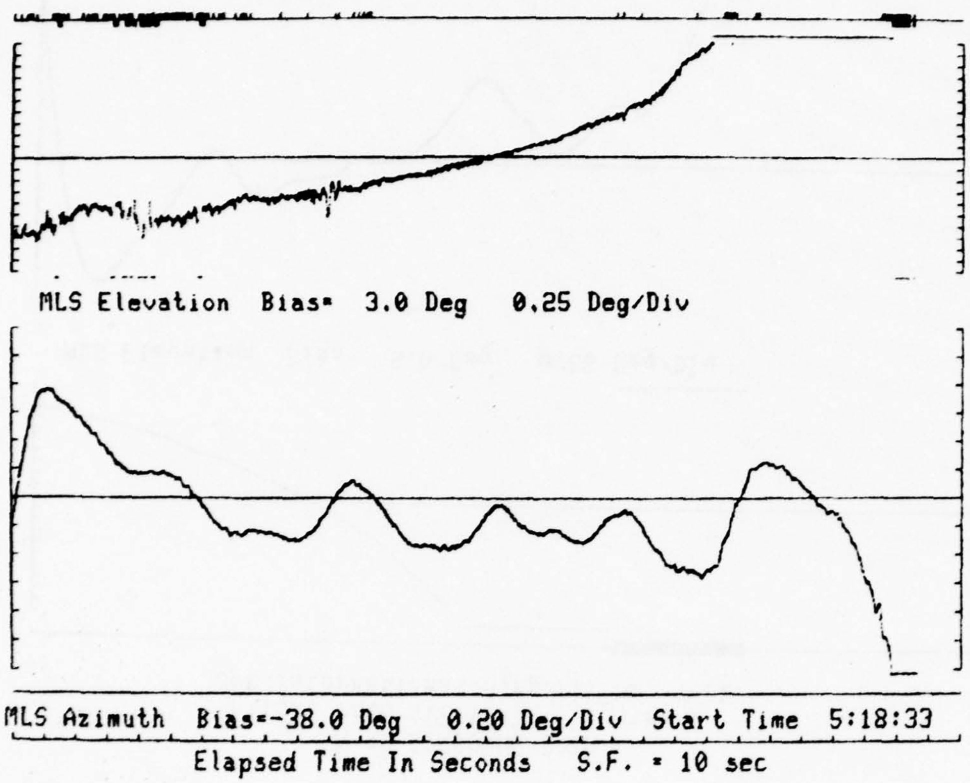


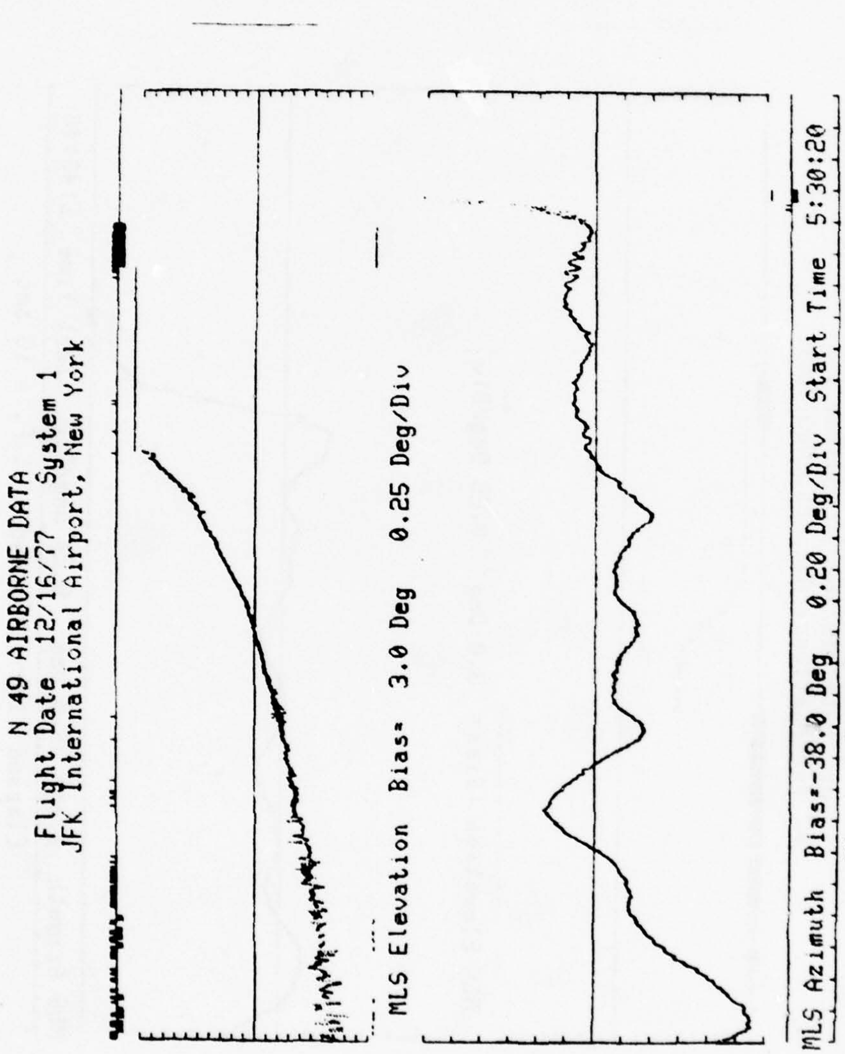
N 49 AIRBORNE DATA
Flight Date 12/16/77 System 1
JFK International Airport, New York



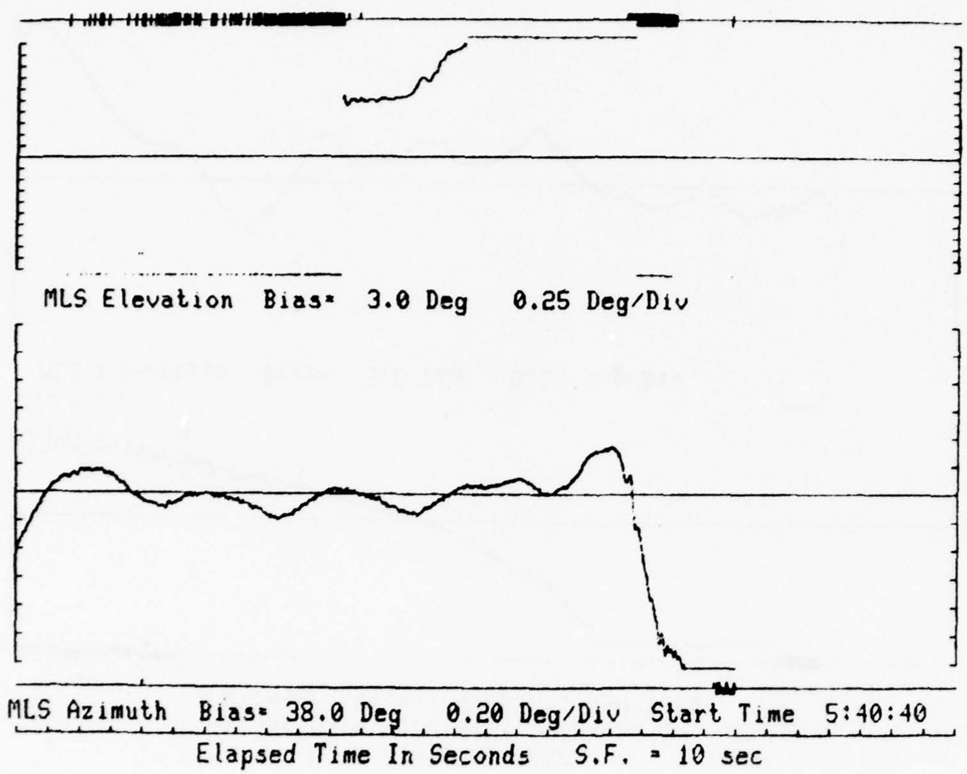
Elapsed Time In Seconds S.F. = 10 sec

N 49 AIRBORNE DATA
Flight Date 12/16/77 System 1
JFK International Airport, New York




N 49 AIRBORNE DATA
Flight Date 12/16/77 System 1
JFK International Airport, New York
MLS Elevation Bias= 3.0 Deg 0.25 Deg/Div
MLS Azimuth Bias=-38.0 Deg 0.20 Deg/Div Start Time 5:30:20
Elapsed Time In Seconds S.F. = 10 sec

N 49 AIRBORNE DATA
Flight Date 12/16/77 System 1
JFK International Airport, New York



AIRBORNE DATA LOG
MLS PHASE III
SYSTEM UNDER TEST : BW Az/BNEl
TEST PLAN TABLE # : ______ } JFK Comparative Data
PATTERN # : ______

RUNWAY # : JFK 13L

DATE : 12/17/77
FLIGHT # :
AIRCRAFT # : N49

All runs horn antenna

GROUND EQUIPMENT: (AZ) (EL) EL 2 (DME) BK AZ
AIRBORNE EQUIPMENT:

SYSTEM #	RECEIVER #	CONT HEAD #	DME #	INTERFACE #
1	BN108	665C	101	TM Modded
2				

WIND: 040@6
TEMP.: 31°F
CEILING: UNL
VISIB: UNL
PILOT: A. Bazer
COPILOT: J. Terry
OBSERVERS: C. Mackin, W. Lynn

KENNEDY # 9TRK 9800 WID 7450 NA2 2917

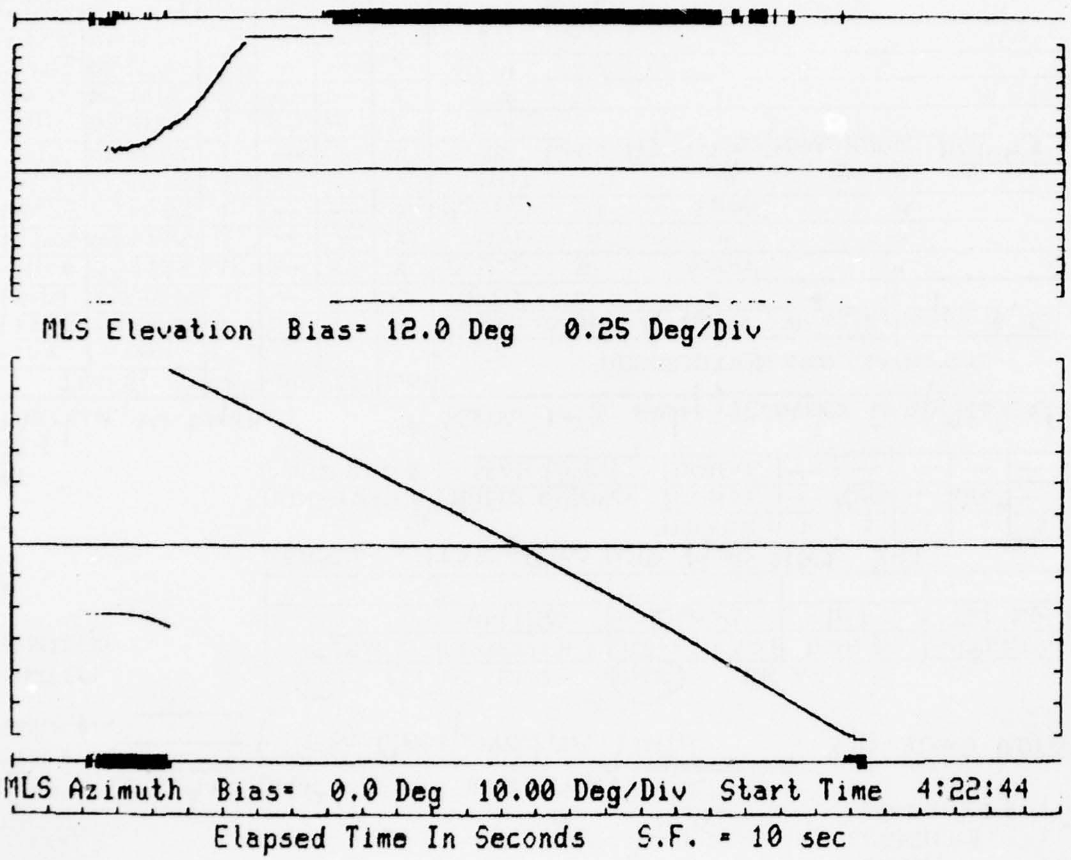
HONEYWELL #* MAFEC 84040
STRIP REC # Not Used

TRACK #	1	2	3	4	5	6	7
SIGNAL	—	Video	—	AGC	—	time	—
SIGNAL	—	—	—	—	—	—	—

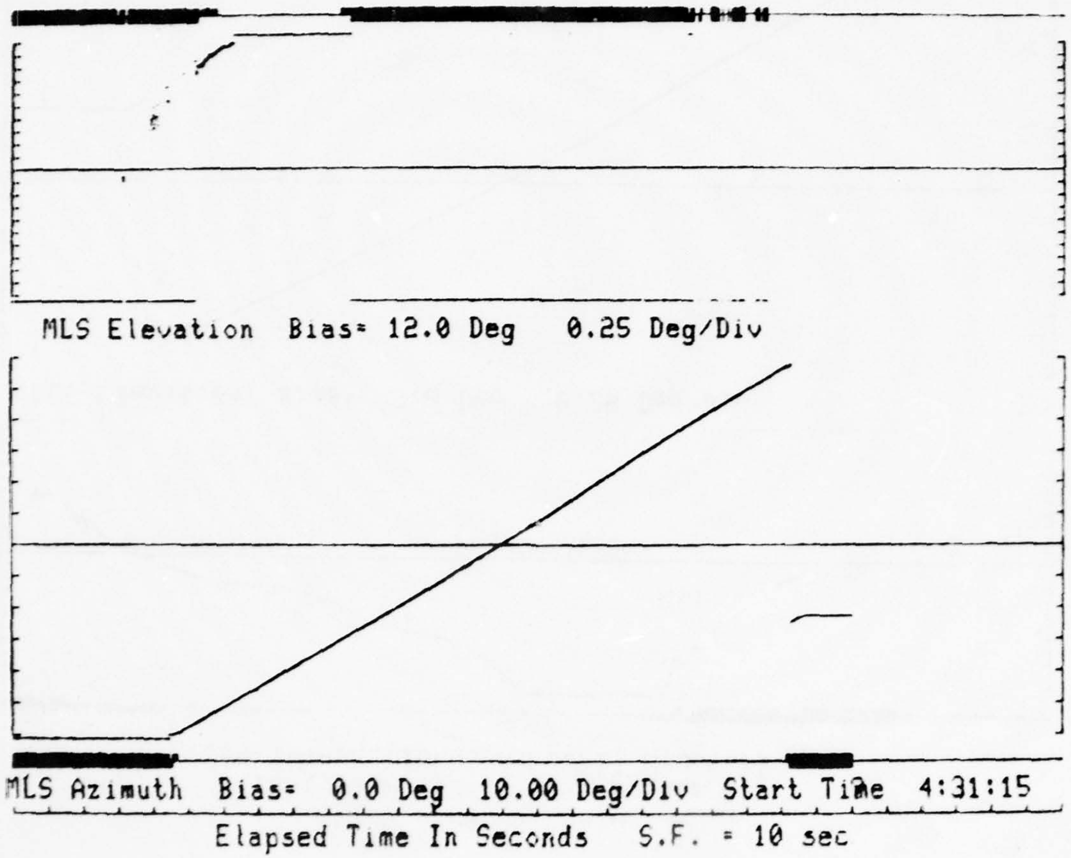
* Runs 1-3 only; recorder inop thereafter

RUN #	TAPE #	FILE #	TIMES START	TIMES STOP	# EDI	FAIR	THEO	LASER	DESCRIPTION AND COMMENTS
1	1	1	042240	042650	1	—	—	X	5nmi. (CCW) orbit at 6000'. Az monitor pole ↑, El monitor pole ↓
2	1	2	043115	043510	1	—	—	X	(CW) " " " "
3	1	3	044100	044525	1	—	—	X	(CCW) " 4000' " "
4	1	4	044755	045218	1	—	—	X	(CW) " " " "
5	1	5	045625	050035	1	—	—	X	(CCW) " 2000' " "
6	1	6	050320	050835	1	—	—	X	(CW) " " " "
7	1	7	051515	051945	1	—	—	X	3° G/S Low Approach from 10nmi. Az pole ↓, "
8	1	8	052915	053127	1	—	—	X	" " " "
9	1	9	054025	054415	5	—	—	X	" " " , El pole ↑
10	2	1	055215	055540	1	—	—	X	5° " " " "
11	2	2	060750	061105	1	—	—	X	" " " "
12	2	3	061755	062217	1	—	—	X	" " " "
13	2	4	062622	063026	1	—	—	X	CCW orbit at 6000' & 5nmi. Az pole ↓, El pole ↑
14	2	5	063240	063750	5	—	—	X	CW " " " " "
									Run 14 terminated @063535 by Lynn
									ABN & LASER PROC & Submitted 12/17/77

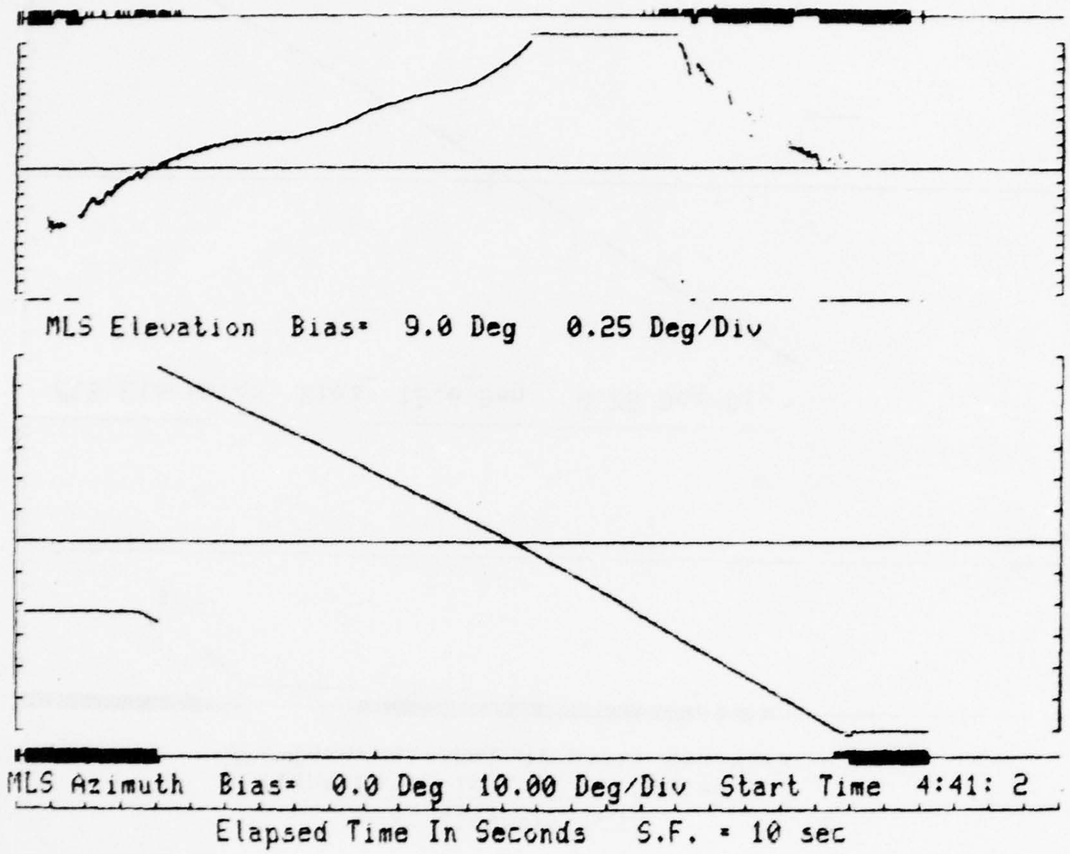
N 49 AIRBORNE DATA
Flight Date 12/17/77 System 1
JFK International Airport, New York

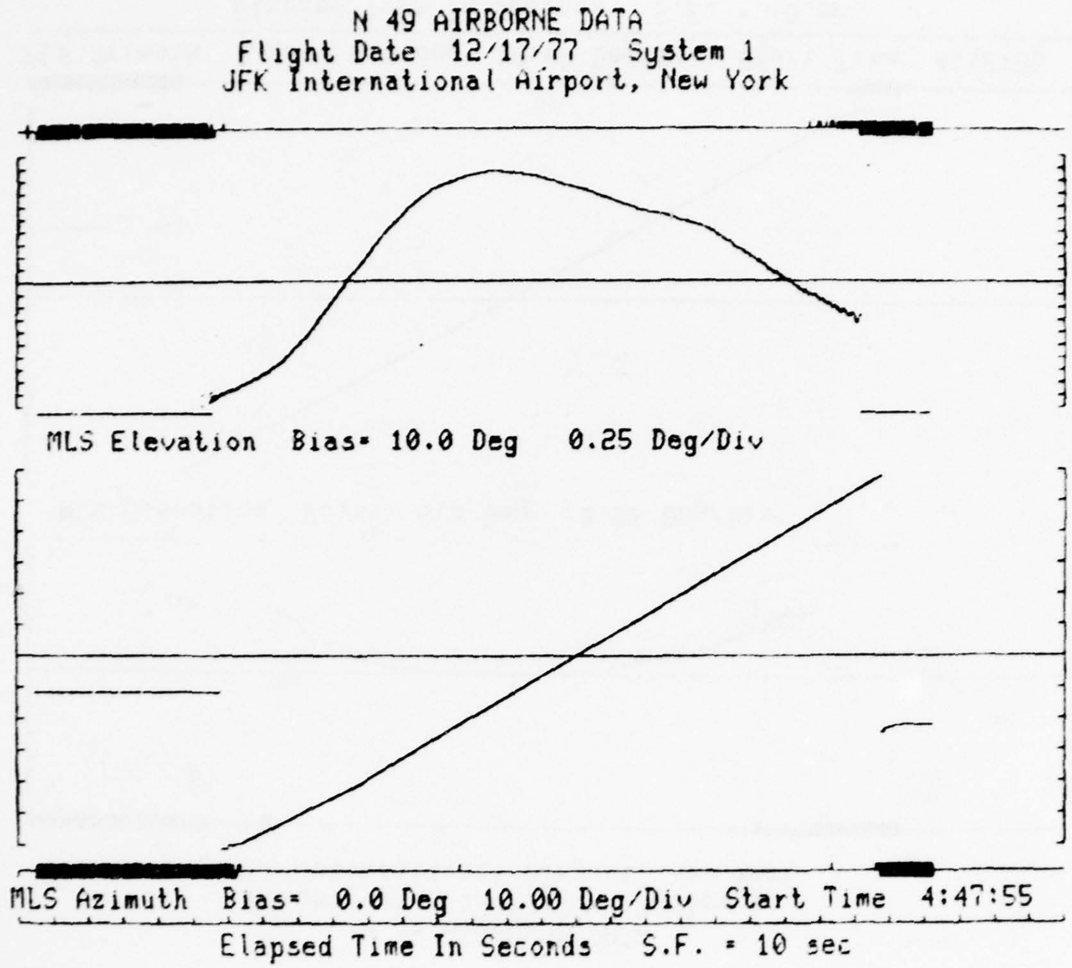


N 49 AIRBORNE DATA
Flight Date 12/17/77 System 1
JFK International Airport, New York

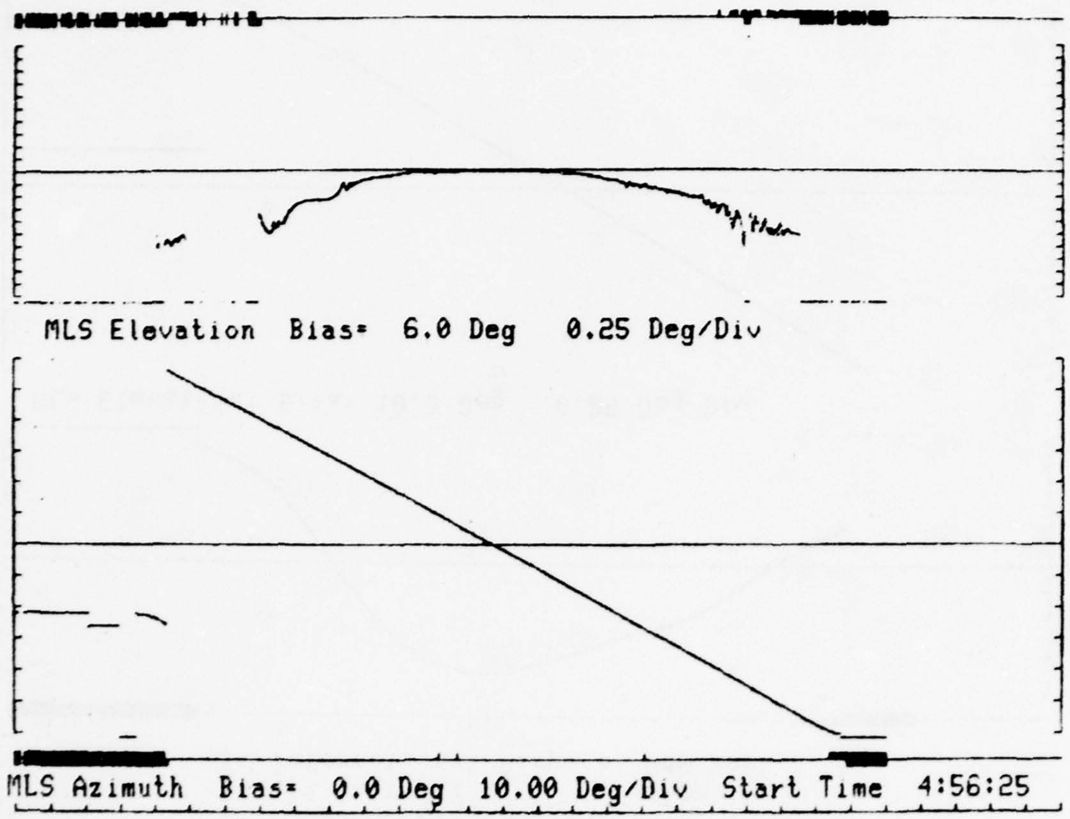


N 49 AIRBORNE DATA
Flight Date 12/17/77 System 1
JFK International Airport, New York

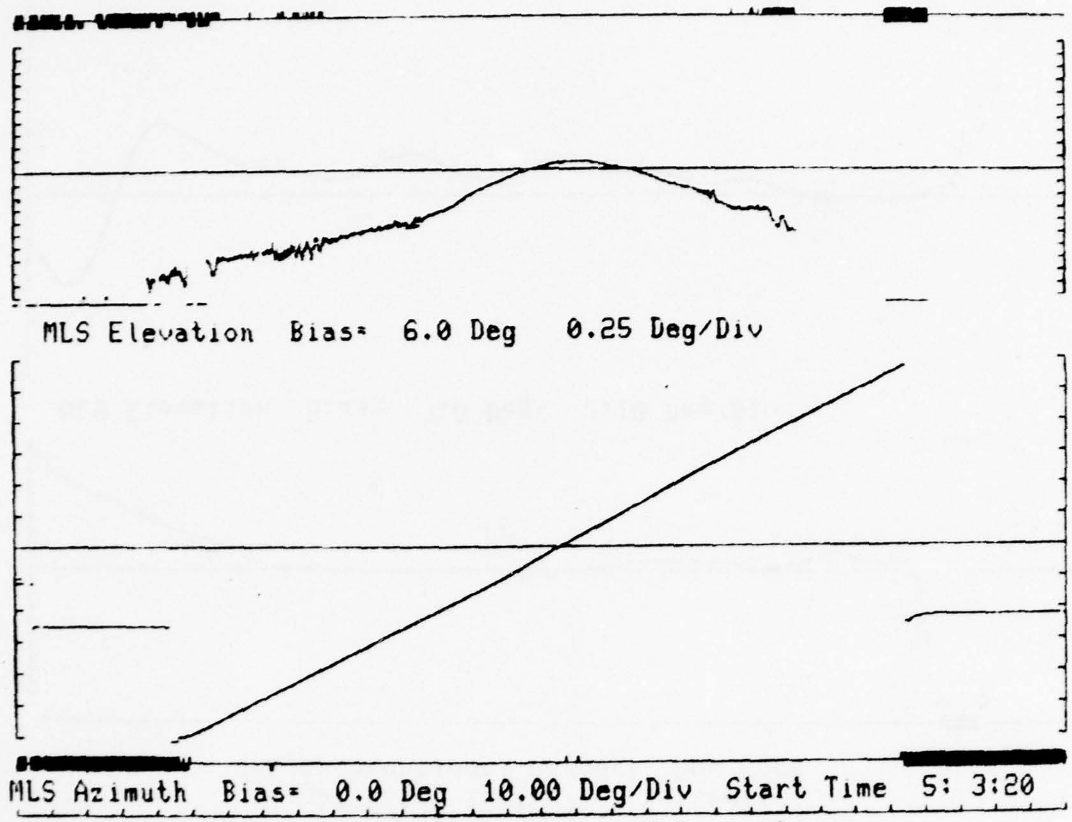



N 49 AIRBORNE DATA
Flight Date 12/17/77 System 1
JFK International Airport, New York
MLS Elevation Bias= 10.0 Deg 0.25 Deg/Div
MLS Azimuth Bias= 0.0 Deg 10.00 Deg/Div Start Time 4:47:55
Elapsed Time In Seconds S.F. = 10 sec

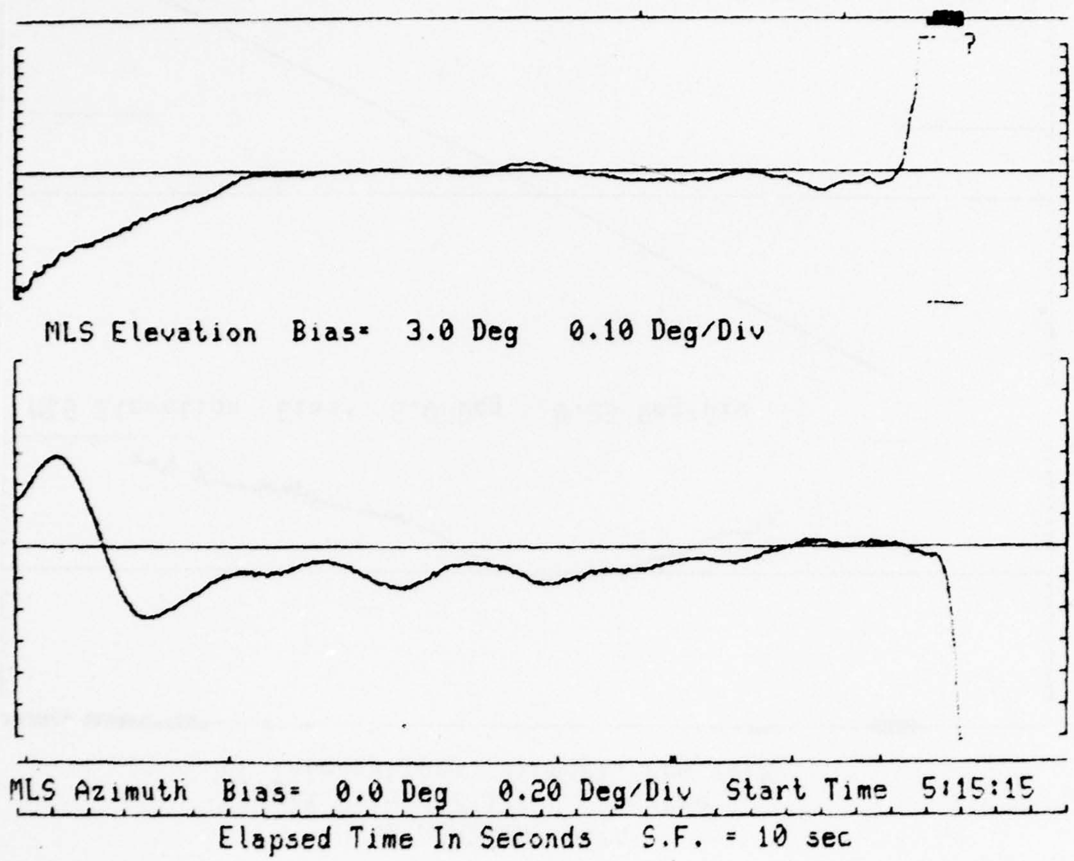
N 49 AIRBORNE DATA
Flight Date 12/17/77 System 1
JFK International Airport, New York



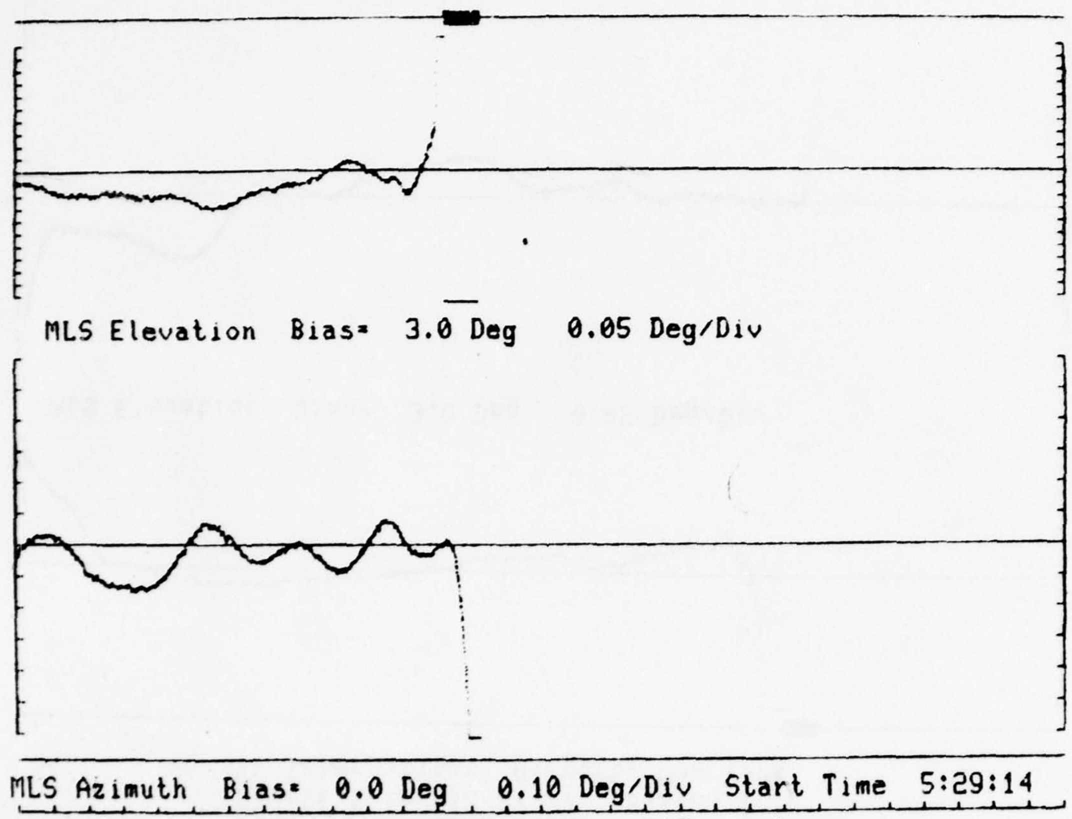
N 49 AIRBORNE DATA
Flight Date 12/17/77 System 1
JFK International Airport, New York



N 49 AIRBORNE DATA
Flight Date 12/17/77 System 1
JFK International Airport, New York

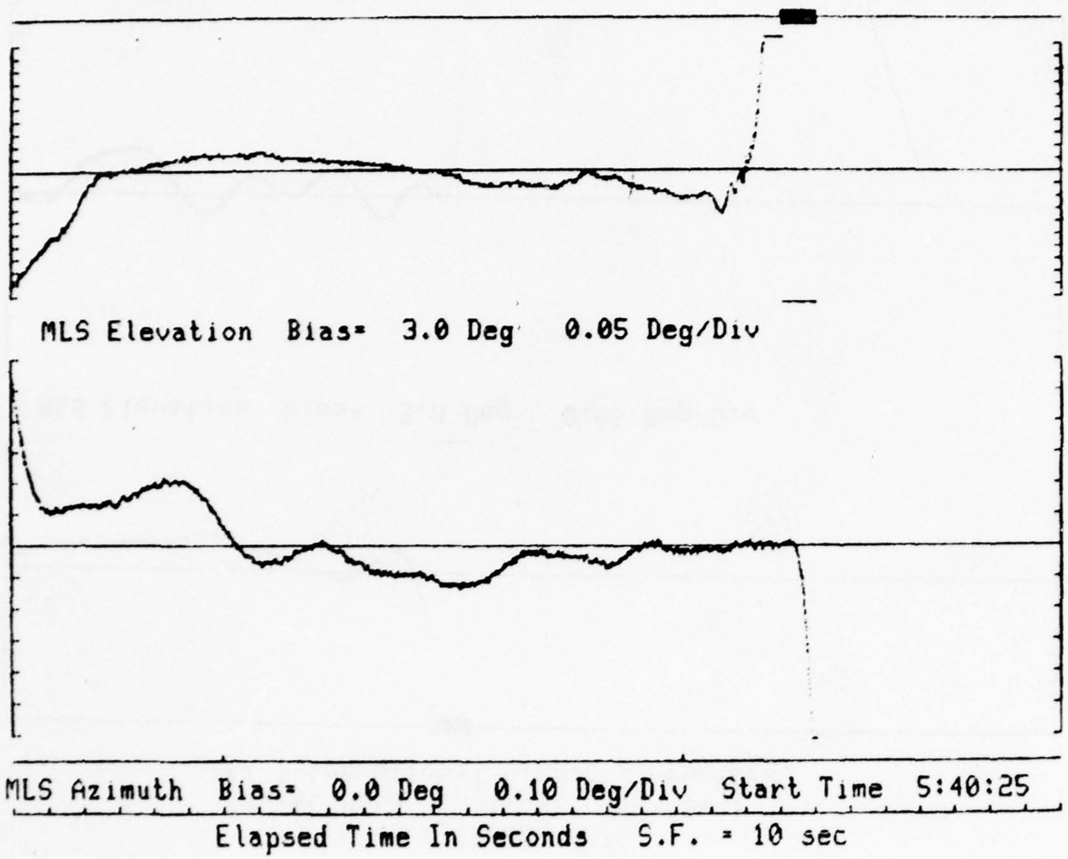


N 49 AIRBORNE DATA
Flight Date 12/17/77 System 1
JFK International Airport, New York

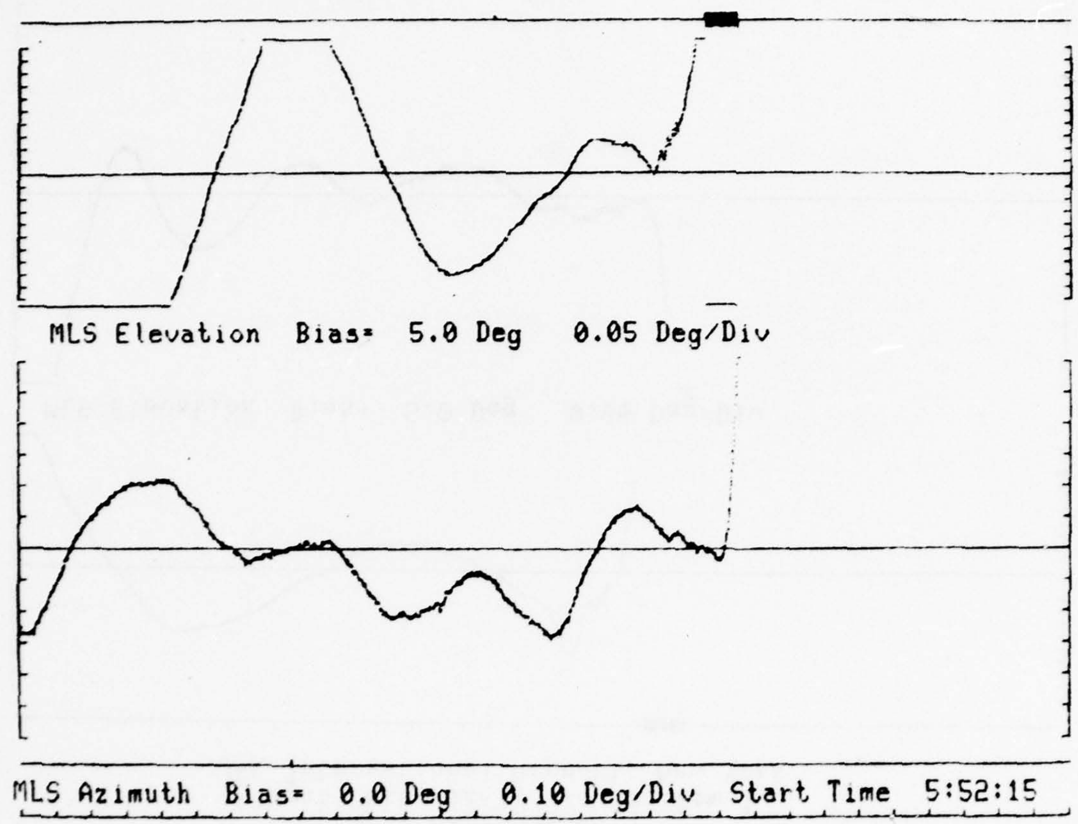


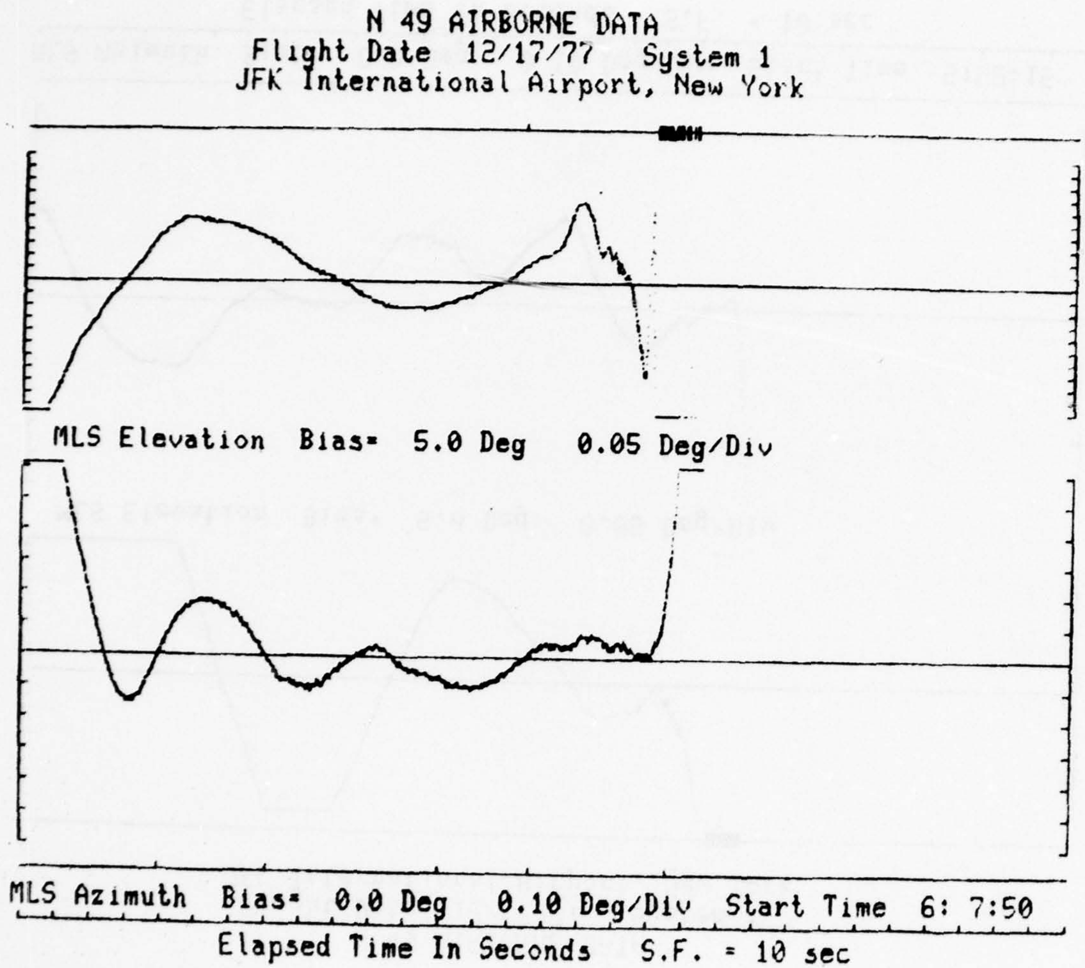
Elapsed Time In Seconds S.F. = 10 sec

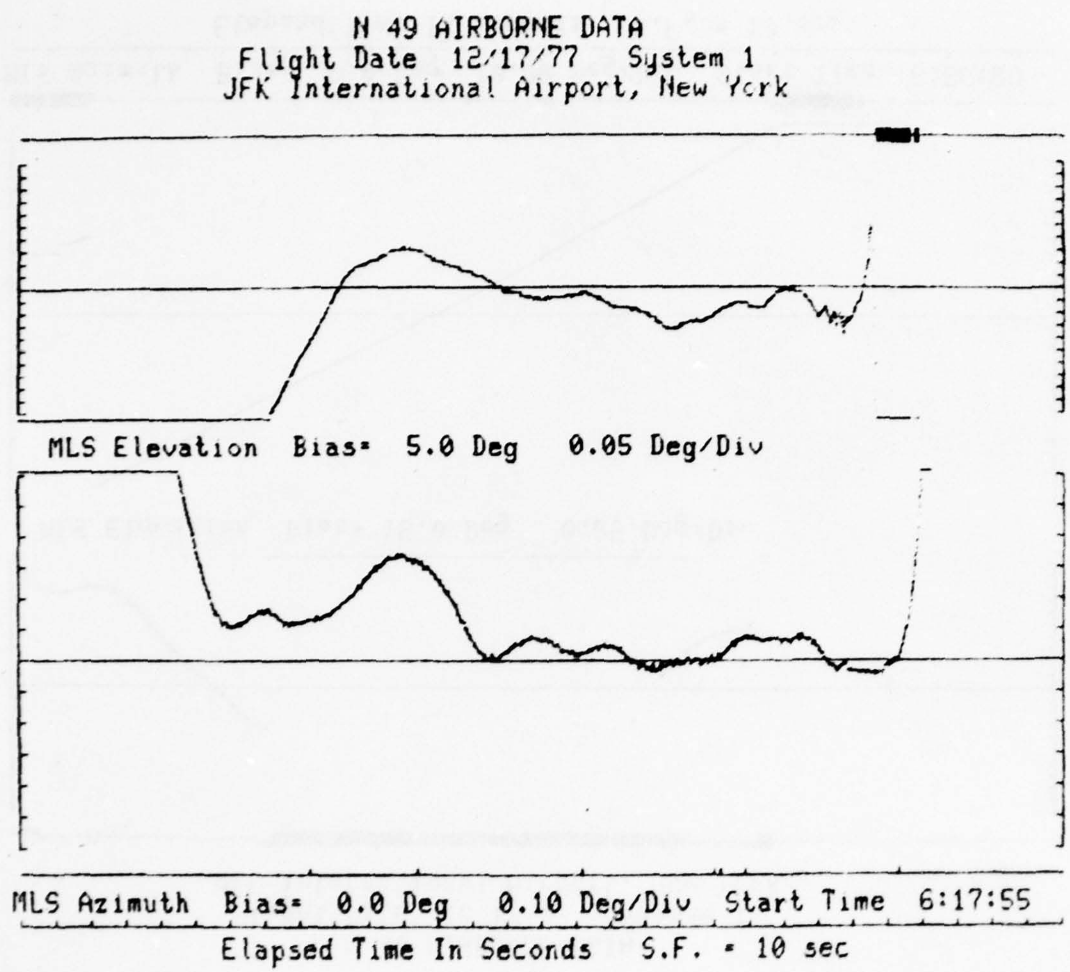
N 49 AIRBORNE DATA
Flight Date 12/17/77 System 1
JFK International Airport, New York



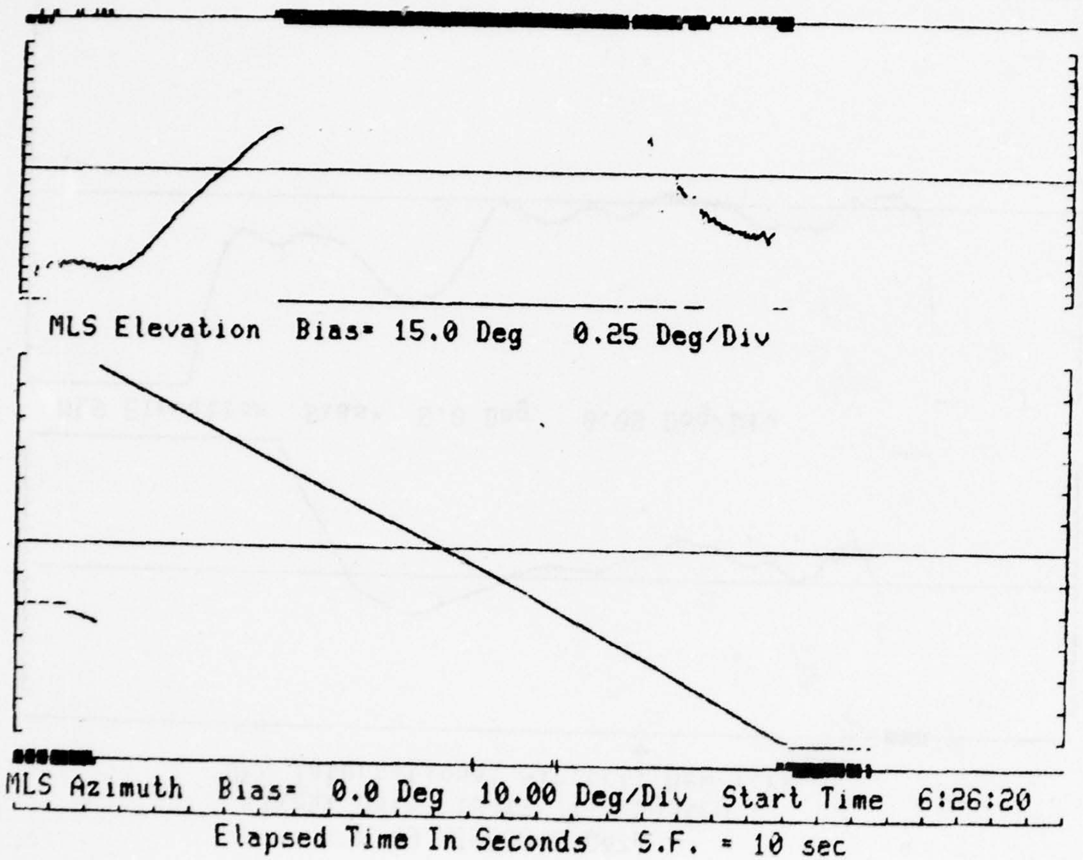
N 49 AIRBORNE DATA
Flight Date 12/17/77 System 1
JFK International Airport, New York

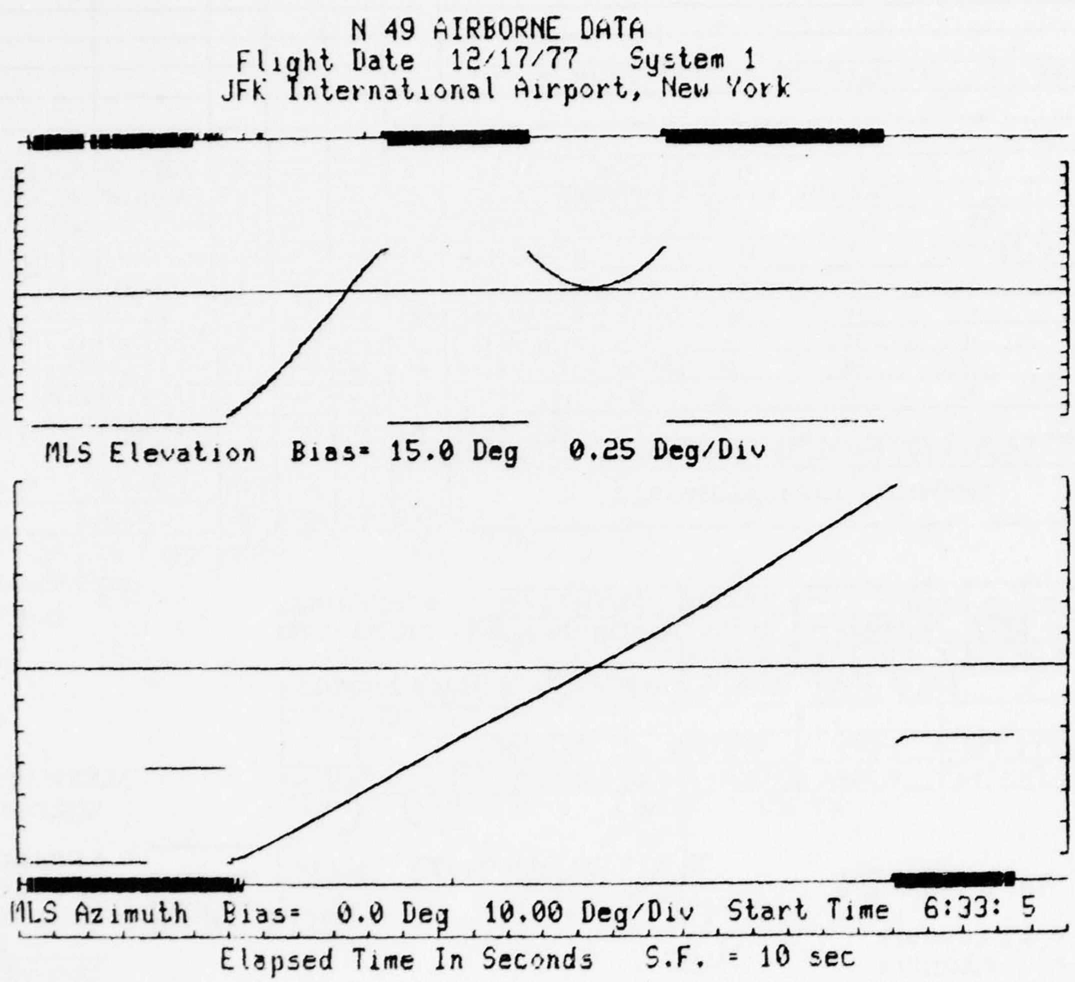



N 49 AIRBORNE DATA
Flight Date 12/17/77 System 1
JFK International Airport, New York
MLS Elevation Bias= 5.0 Deg 0.05 Deg/Div
MLS Azimuth Bias= 0.0 Deg 0.10 Deg/Div Start Time 6: 7:50
Elapsed Time In Seconds S.F. = 10 sec


N 49 AIRBORNE DATA
Flight Date 12/17/77 System 1
JFK International Airport, New York
MLS Elevation Bias= 5.0 Deg 0.05 Deg/Div
MLS Azimuth Bias= 0.0 Deg 0.10 Deg/Div Start Time 6:17:55
Elapsed Time In Seconds S.F. = 10 sec

N 49 AIRBORNE DATA
Flight Date 12/17/77 System 1
JFK International Airport, New York




N 49 AIRBORNE DATA
Flight Date 12/17/77 System 1
JFK International Airport, New York
MLS Elevation Bias= 15.0 Deg 0.25 Deg/Div
MLS Azimuth Bias= 0.0 Deg 10.00 Deg/Div Start Time 6:33: 5
Elapsed Time In Seconds S.F. = 10 sec

AIRBORNE DATA LOG
MLS PHASE III

SYSTEM UNDER TEST : BWAz BWEl
TEST PLAN TABLE # : ______ } JFK Comparative Data
PATTERN # : ______

RUNWAY # : 13L JFK

DATE : 12/22/77
FLIGHT # :
AIRCRAFT # : 1149

All runs horn antenna

GROUND EQUIPMENT: (AZ) (EL) EL 2 (DME) BK AZ
AIRBORNE EQUIPMENT:

SYSTEM #	RECEIVER #	CONT HEAD #	DME #	INTERFACE #
1	JRD102	106SC	101	TM Mod [illegible]
2				

WIND: 040/9/10
TEMP.: 36°F
CEILING: 7000'
VISIB: [illegible]
PILOT: G. Doctor
COPILOT: R. Lamprecht
OBSERVERS: C. Mackin, W. Lynn

KENNEDY # 9TRK 9800 WIP #7450 NAZ 2917
HONEYWELL # WIP #5700 NAD 630
STRIP REC # Not Used

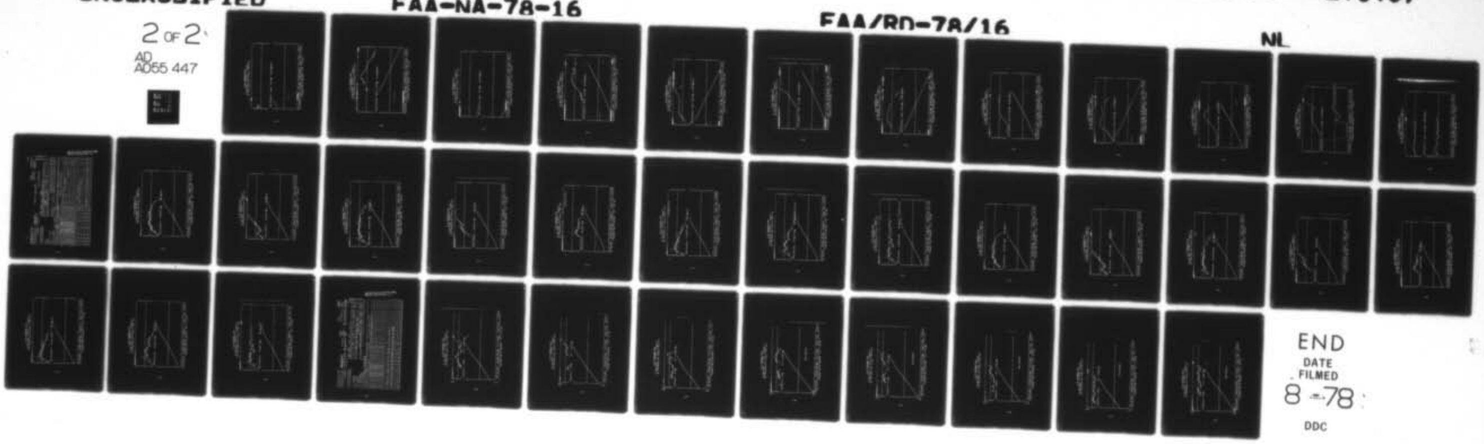
TRACK #	1	2	3	4	5	6	7	
SIGNAL	—	Vid	—	AGC	—	[illegible]	—	—
SIGNAL	—	—	—	—	—	—	—	—

RUN #	TAPE #	FILE #	TIMES START	TIMES STOP	# EDF	FAIR	THE	LASER	DESCRIPTION AND COMMENTS
1	1	1	043630	043740	1	—	—	X	(4) 5 mi 2000' orbit. Az pole [illegible], El pole [illegible].
2	1	2	044000	044620	1	—	—	X	(4) " " " " "
3	1	3	045041	045520	1	—	—	X	(4) " " " " "
4	1	4	050045	050500	1	—	—	X	(4) " 4000' " " "
5	1	5	050841	051551	1	—	—	X	(4) " " " " "
6	1	6	052005	052450	1	—	—	X	(4) " 5000 " " "
7	1	7	053020	053215	1	—	—	X	(4) " " " " "
8	1	8	054145	[illegible]	1	—	—	X	(4) " " " " . El pole [illegible]
9	1	9	055110	[illegible]	5	—	—	X	(4) " " " "
10	2	1	061450	061900	1	—	—	X	[illegible] [illegible] from 10 nmi "
11	2	[illegible]	062100	062900	5	—	—	X	[illegible] " " " " "
									Laser + ADR processed by ANA-310 22 Dec 77

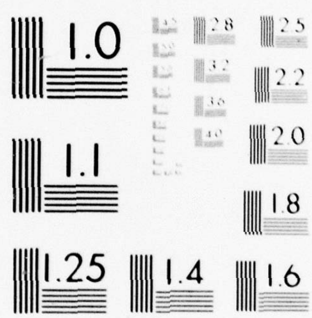
AD-A055 447 NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER ATL--ETC F/G 17/2.1
TRSB MICROWAVE LANDING SYSTEM DEMONSTRATION PROGRAM AT JOHN F. --ETC(U)
JAN 78

UNCLASSIFIED FAA-NA-78-16 FAA/RD-78/16 NL

2 OF 2
AD
A055 447

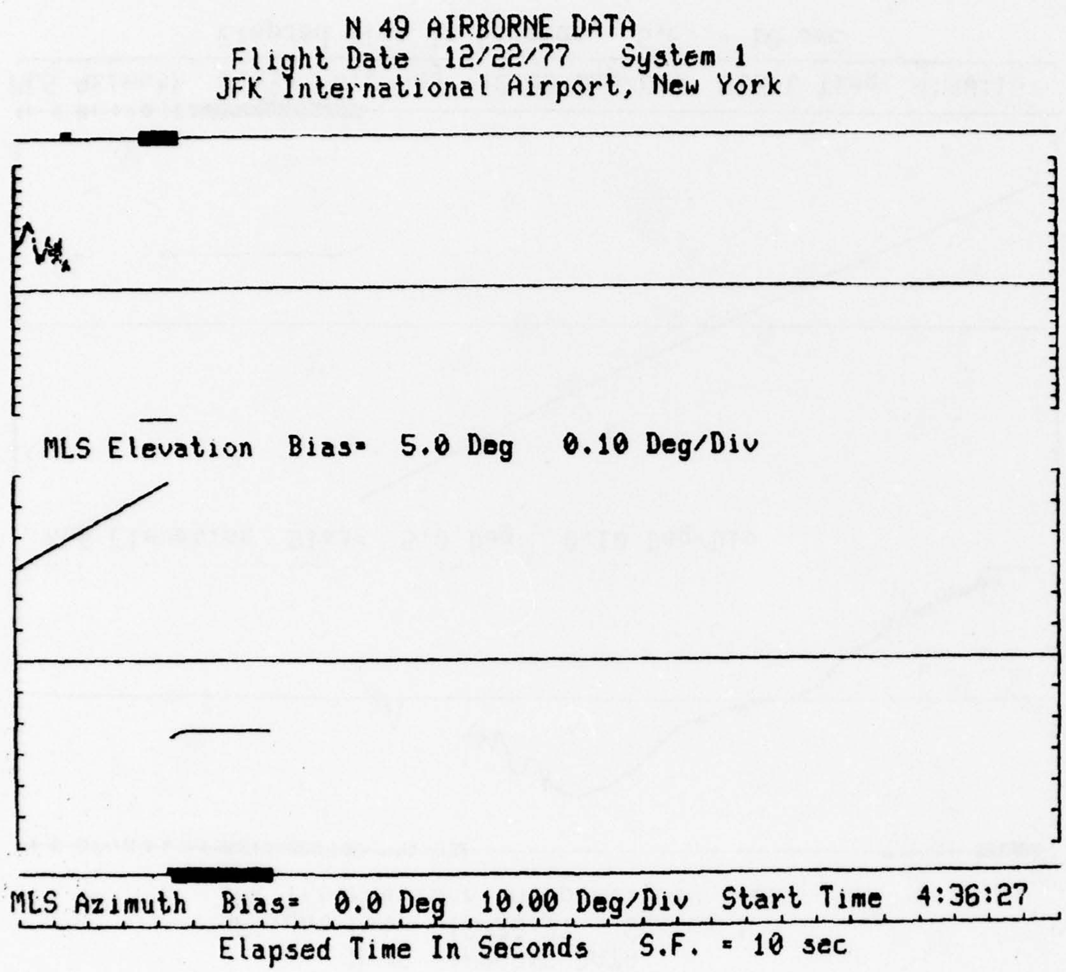


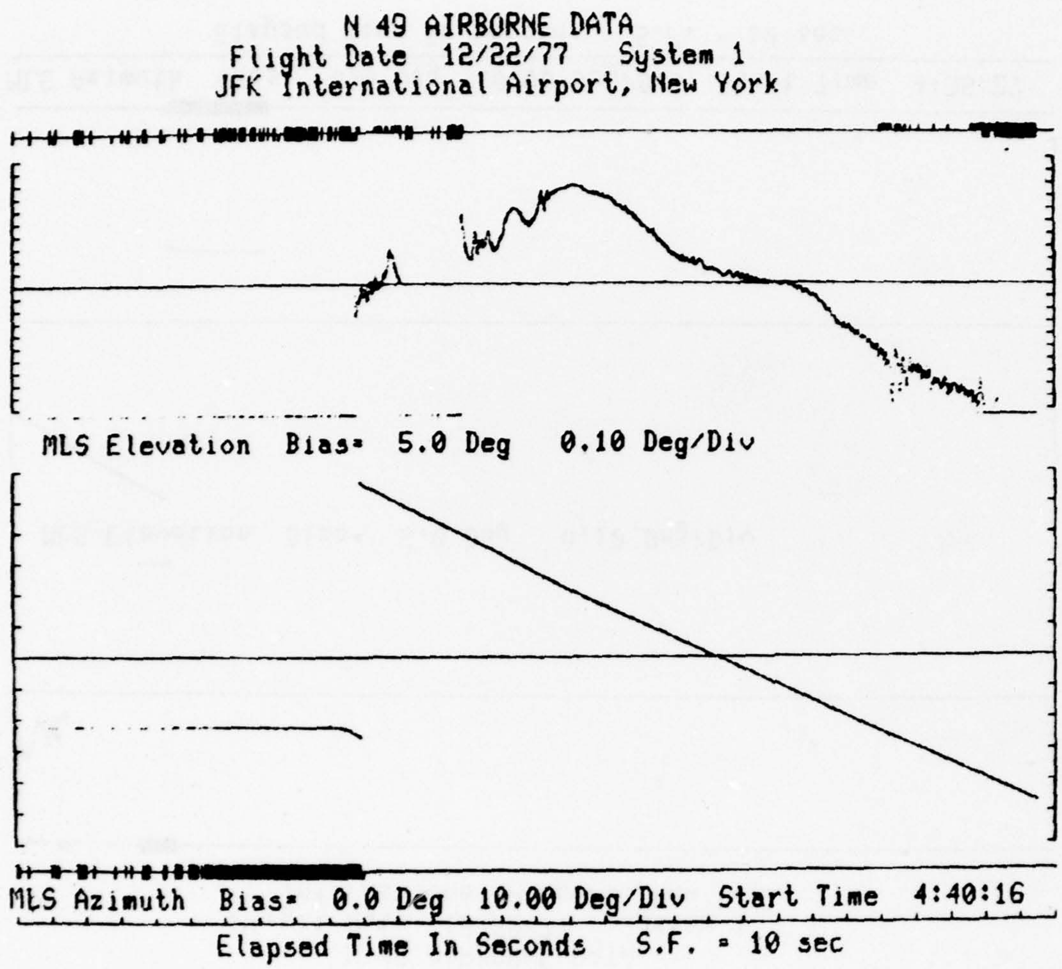
END
DATE
FILMED
8-78
DDC



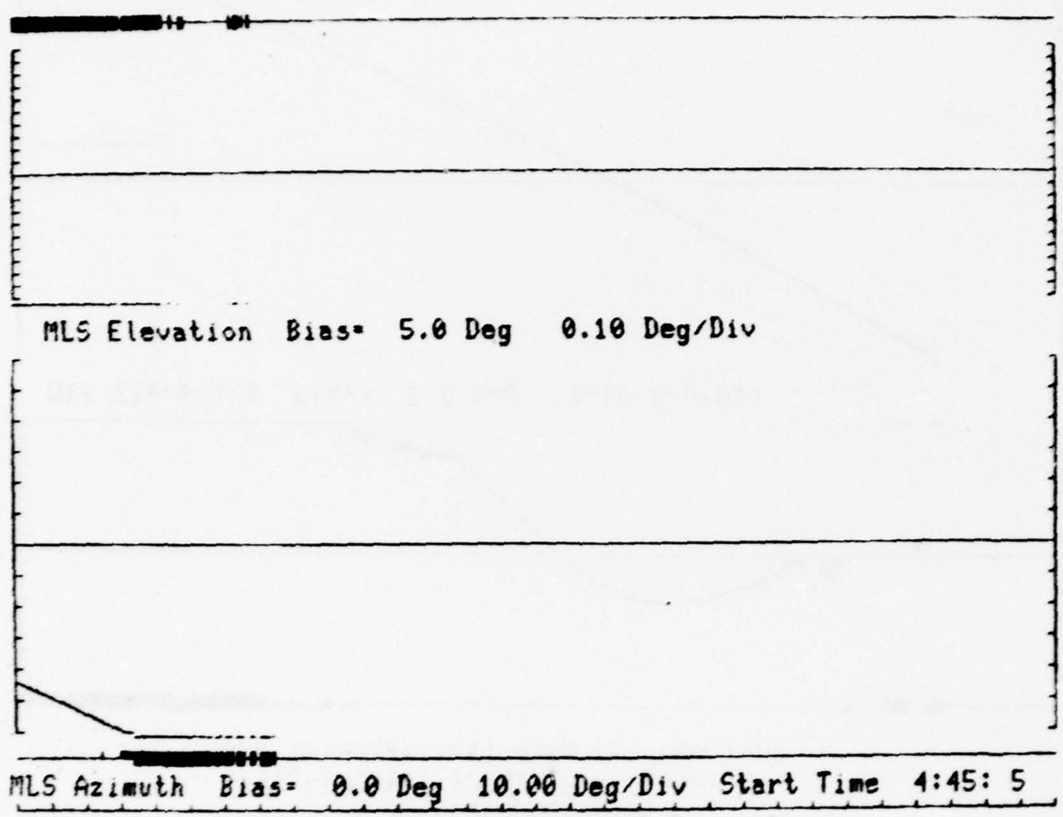
MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS 1963 A


N 49 AIRBORNE DATA
Flight Date 12/22/77 System 1
JFK International Airport, New York
MLS Elevation Bias= 5.0 Deg 0.10 Deg/Div
MLS Azimuth Bias= 0.0 Deg 10.00 Deg/Div Start Time 4:36:27
Elapsed Time In Seconds S.F. = 10 sec

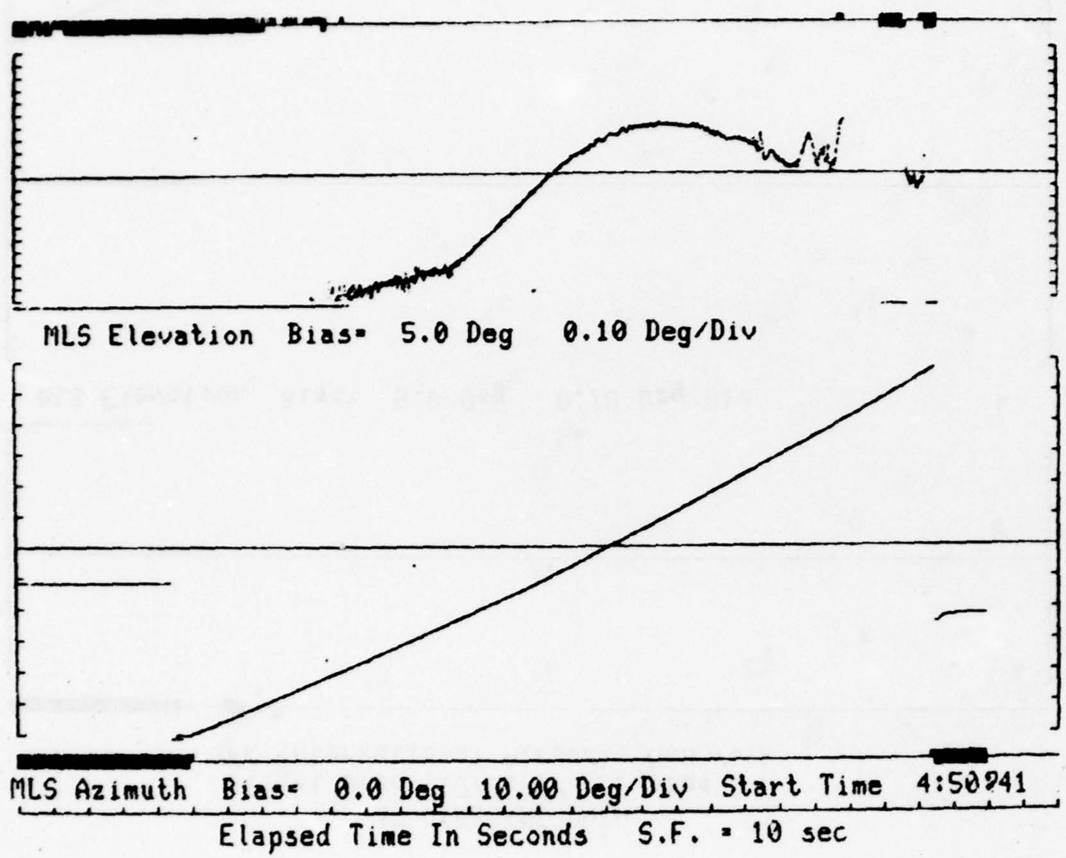

N 49 AIRBORNE DATA
Flight Date 12/22/77 System 1
JFK International Airport, New York
MLS Elevation Bias= 5.0 Deg 0.10 Deg/Div
MLS Azimuth Bias= 0.0 Deg 10.00 Deg/Div Start Time 4:40:16
Elapsed Time In Seconds S.F. = 10 sec

N 49 AIRBORNE DATA
Flight Date 12/22/77 System 1
JFK International Airport, New York

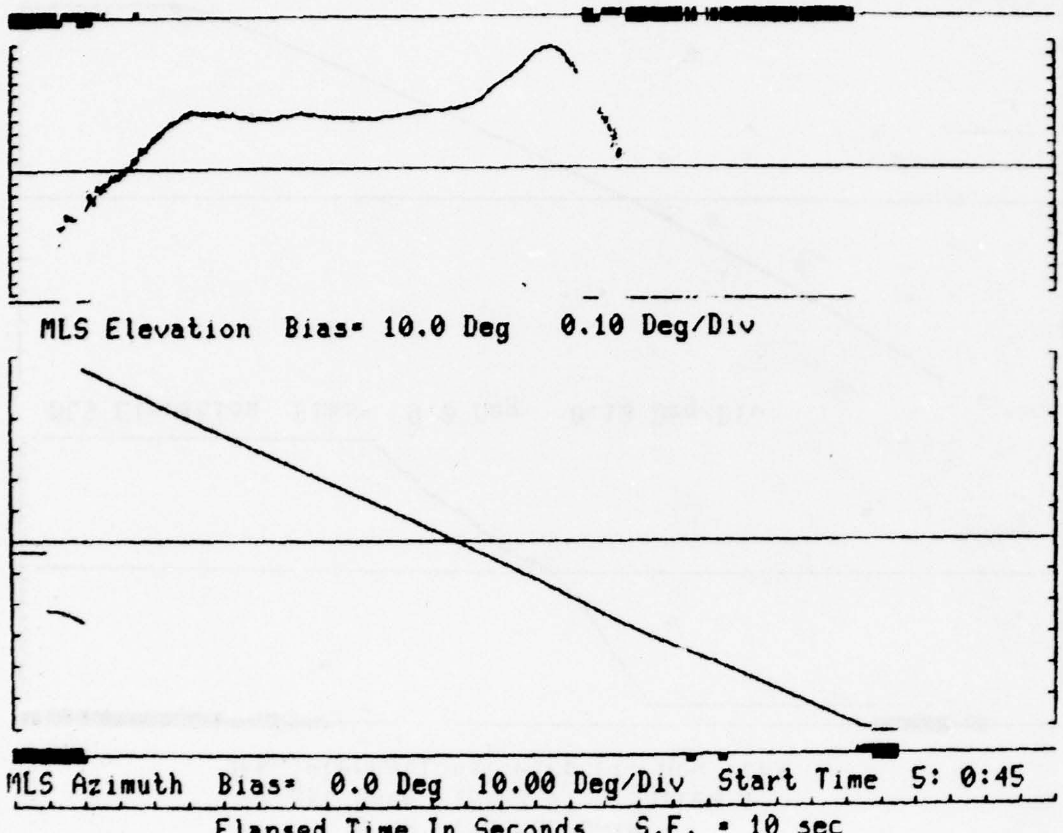


Elapsed Time In Seconds S.F. = 10 sec

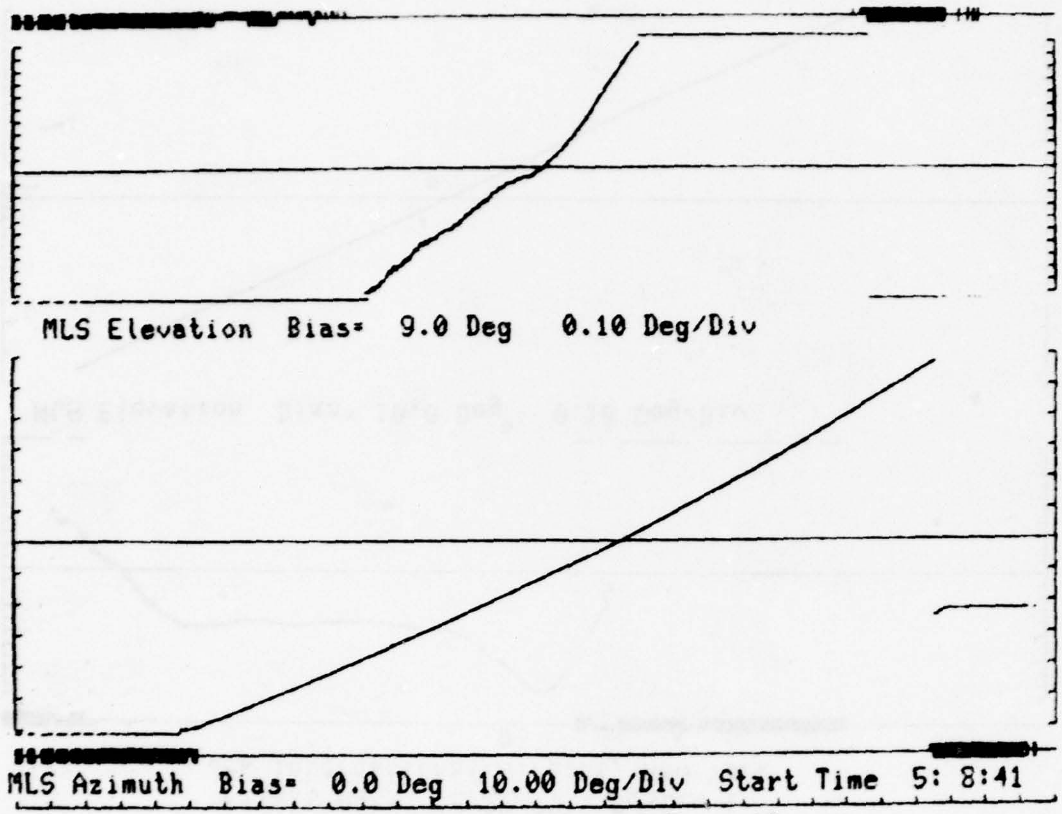
N 49 AIRBORNE DATA
Flight Date 12/22/77 System 1
JFK International Airport, New York



N 49 AIRBORNE DATA
Flight Date 12/22/77 System 1
JFK International Airport, New York

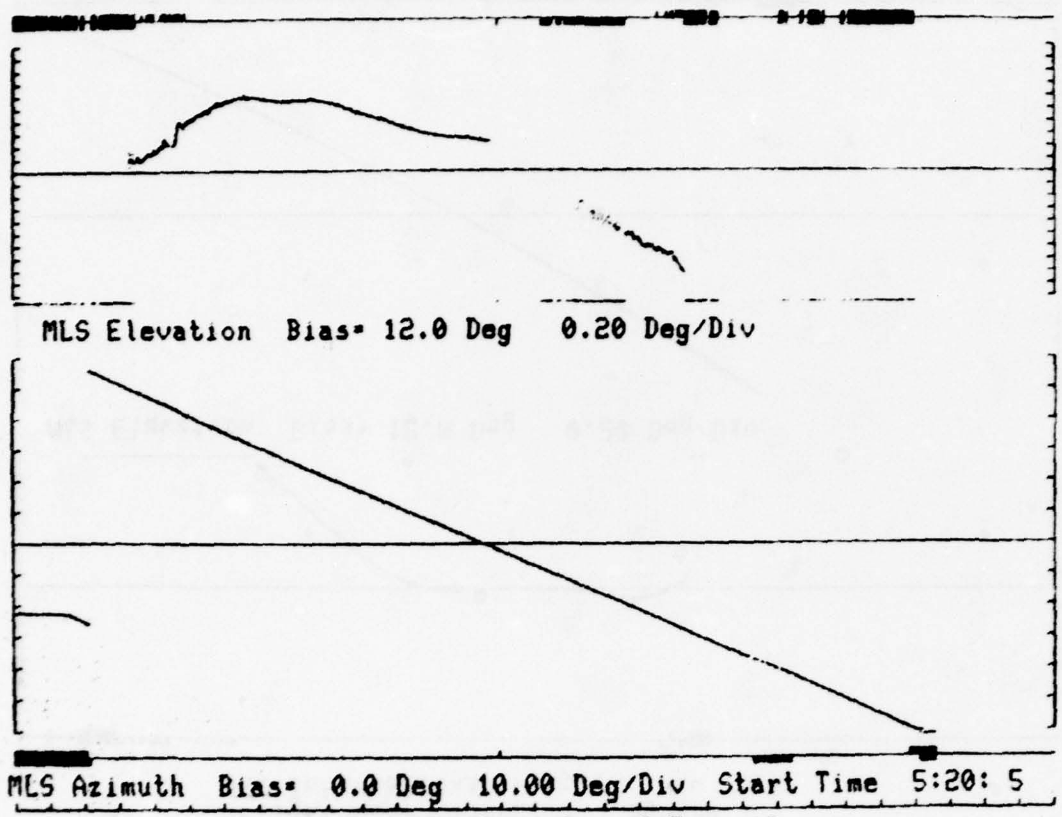


N 49 AIRBORNE DATA
Flight Date 12/22/77 System 1
JFK International Airport, New York

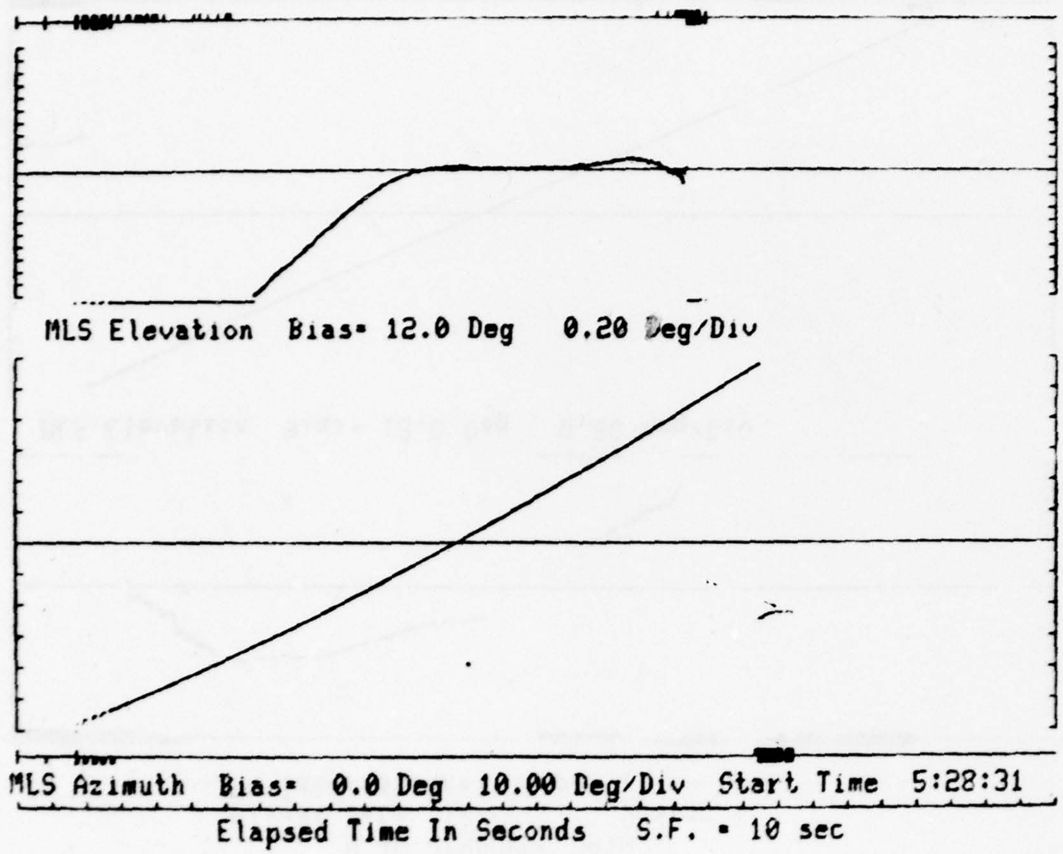


Elapsed Time In Seconds S.F. = 10 sec

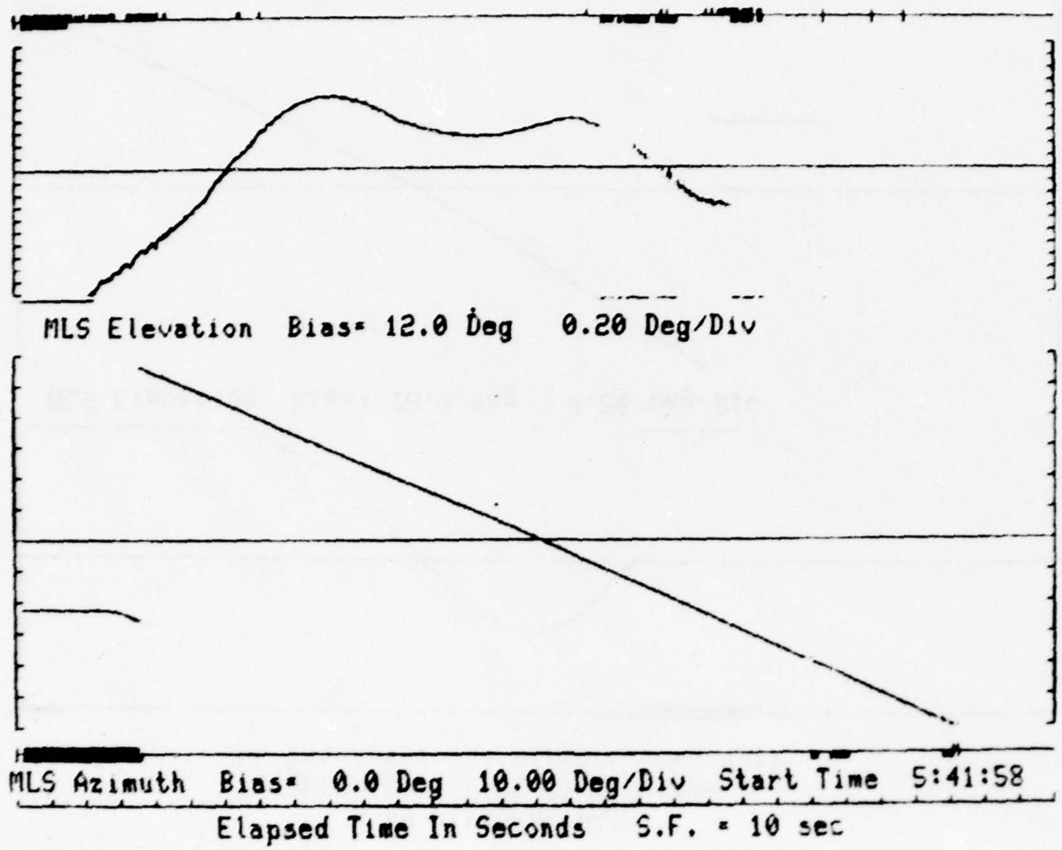
N 49 AIRBORNE DATA
Flight Date 12/22/77 System 1
JFK International Airport, New York



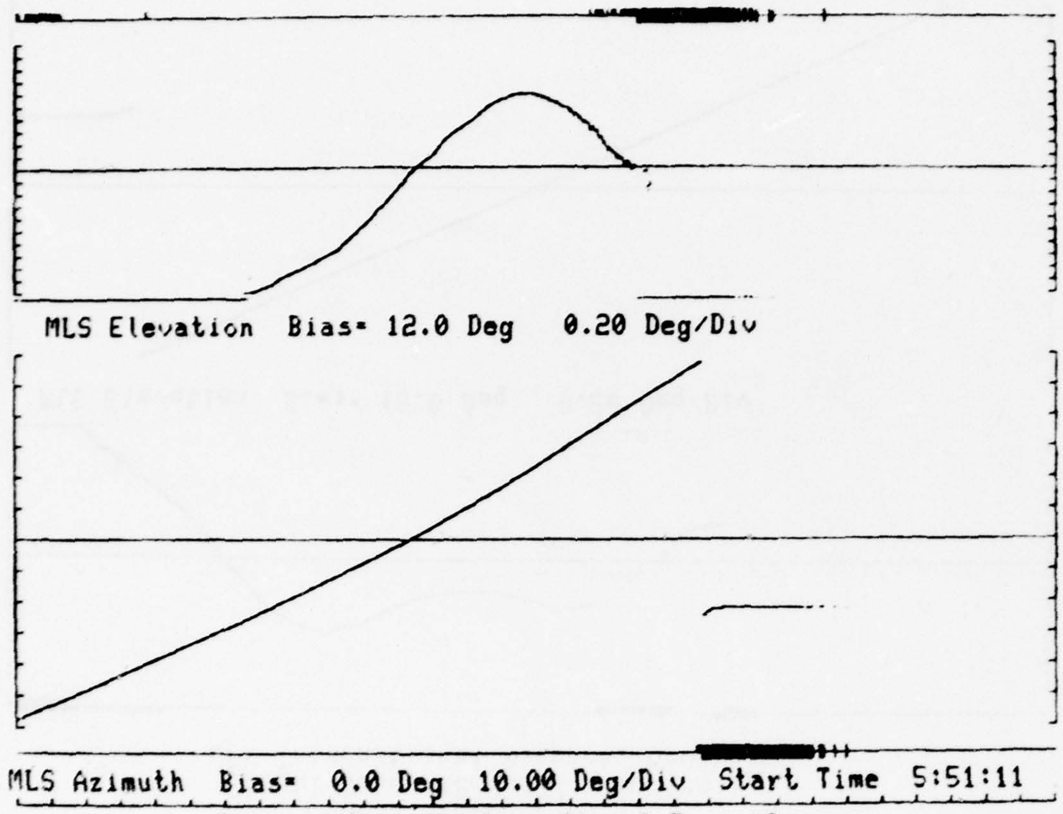
N 49 AIRBORNE DATA
Flight Date 12/22/77 System 1
JFK International Airport, New York



N 49 AIRBORNE DATA
Flight Date 12/22/77 System 1
JFK International Airport, New York

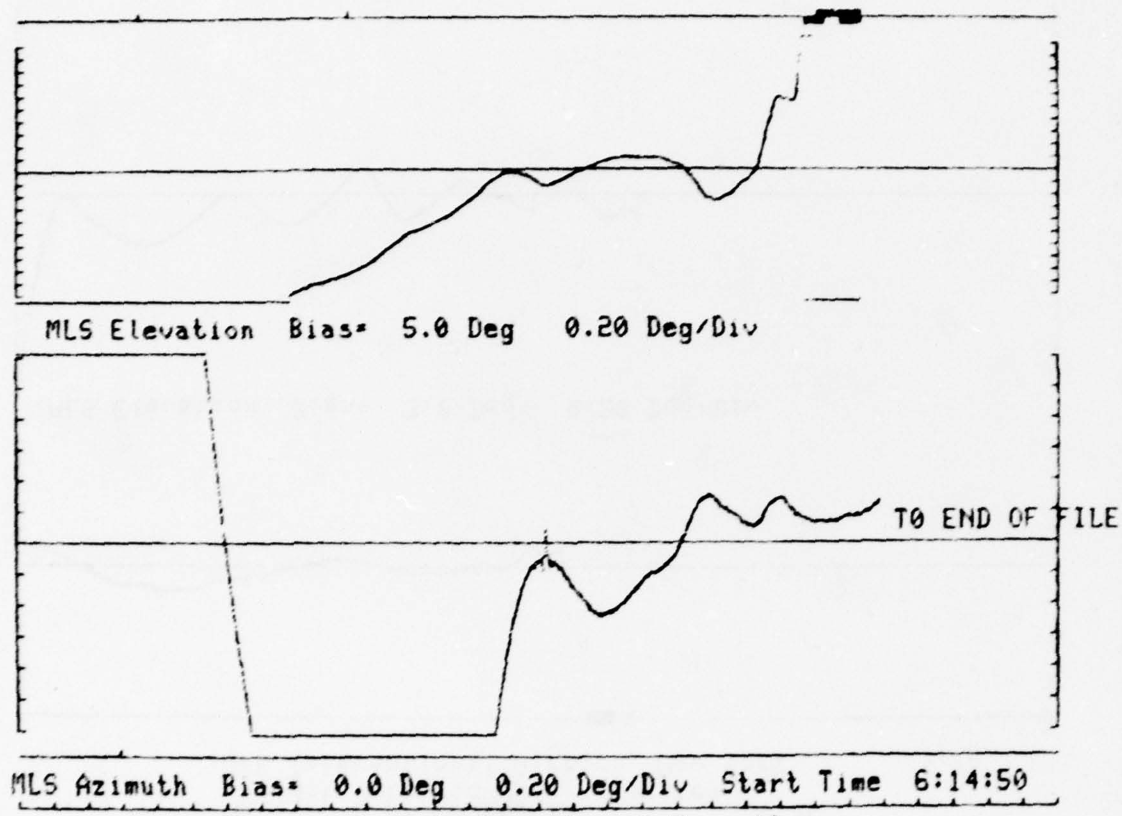


N 49 AIRBORNE DATA
Flight Date 12/22/77 System 1
JFK International Airport, New York

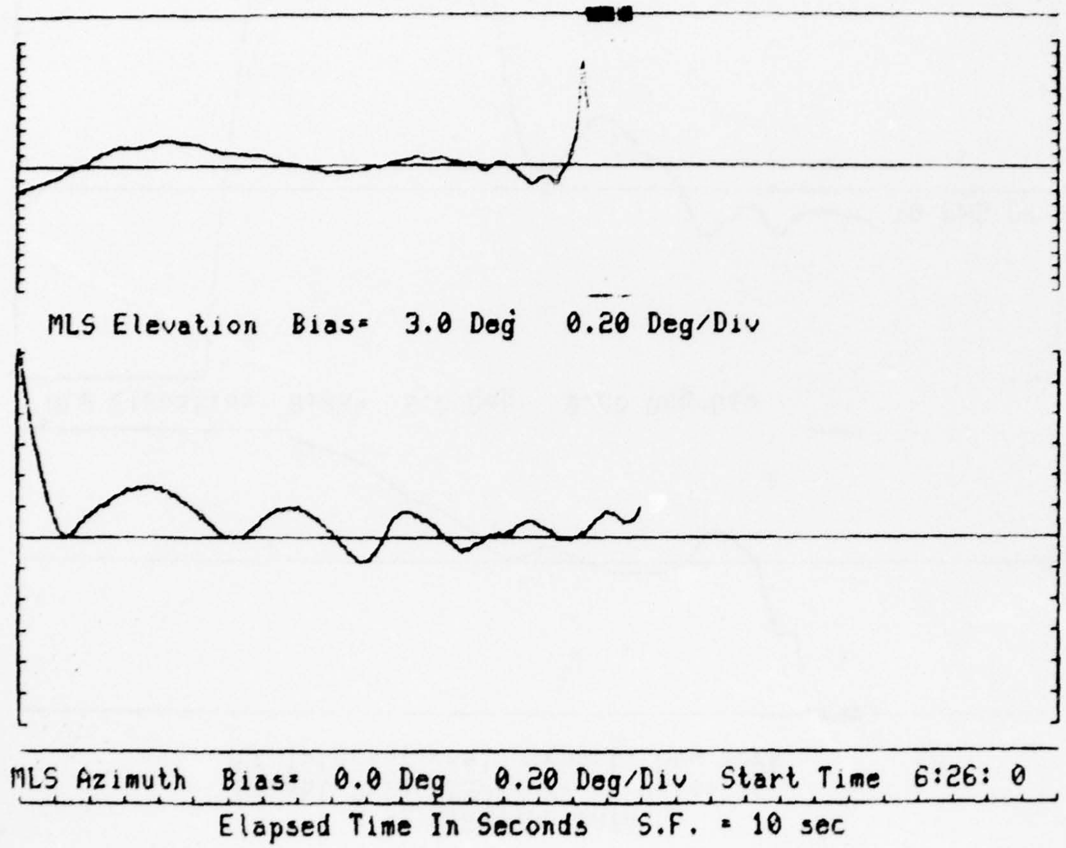


Elapsed Time In Seconds S.F. = 10 sec

N 49 AIRBORNE DATA
Flight Date 12/22/77 System 1
JFK International Airport, New York



N 49 AIRBORNE DATA
Flight Date 12/22/77 System 1
JFK International Airport, New York



AIRBORNE DATA LOG
MLS PHASE III

DATE : Dec. 29, 1977
FLIGHT # :
AIRCRAFT # : N-42 CV 880

SYSTEM UNDER TEST : BBW & BN
TEST PLAN TABLE # : Curved Path
PATTERN # :

RUNWAY # : 13L JFK

Laser tracking only

GROUND EQUIPMENT: (AZ) (EL) EL 2 (DME) BK AZ
AIRBORNE EQUIPMENT:

SYSTEM #	RECEIVER #	CONT HEAD #	DME #	INTERFACE #
1	P103	P102	101	
2	P104	P109	106	

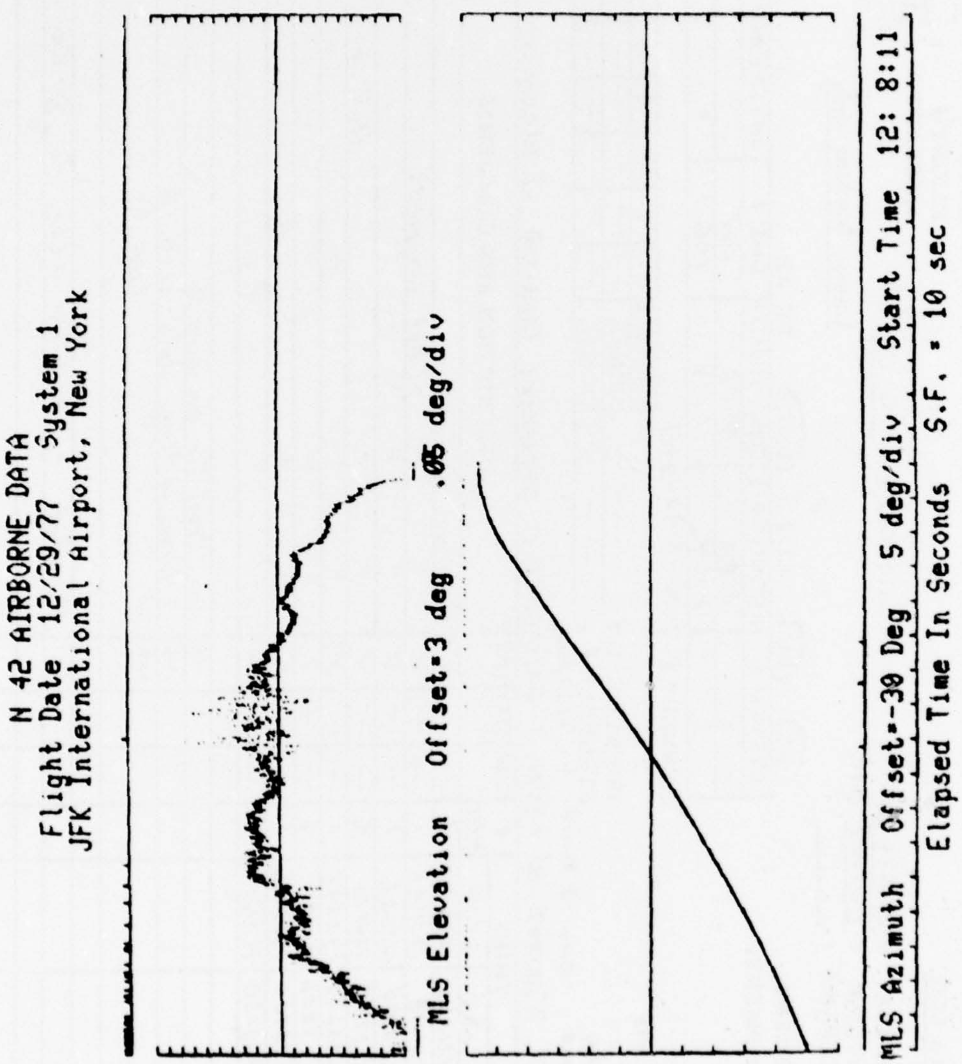
WIND:
TEMP.:
CEILING: Unlmtd
VISIB:
PILOT: J. Bailey
COPILOT: R. Grace
Crew: R. Powell, L. De Stefano

KENNEDY # 7450-NA2-2917
HONEYWELL # ——
STRIP REC # ——

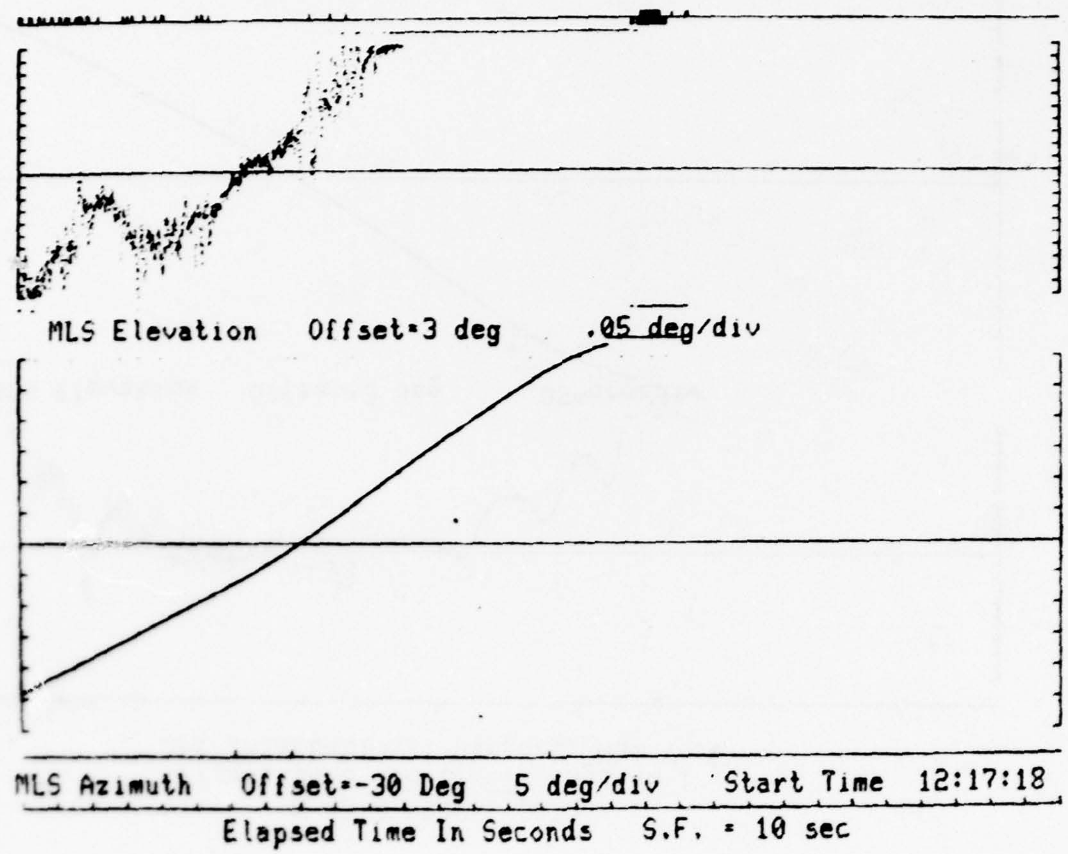
TRACK #	1	2	3	4	5	6	7	
SIGNAL	—	—	—	—	—	—	—	—
SIGNAL	—	—	—	—	—	—	—	—

OBSERVERS: J. D'OTTAVI, W. LYNN, J. GALLAGHER, C. JEZIERSKI (ANA-310) J. WILLIAMS (ANA-33)

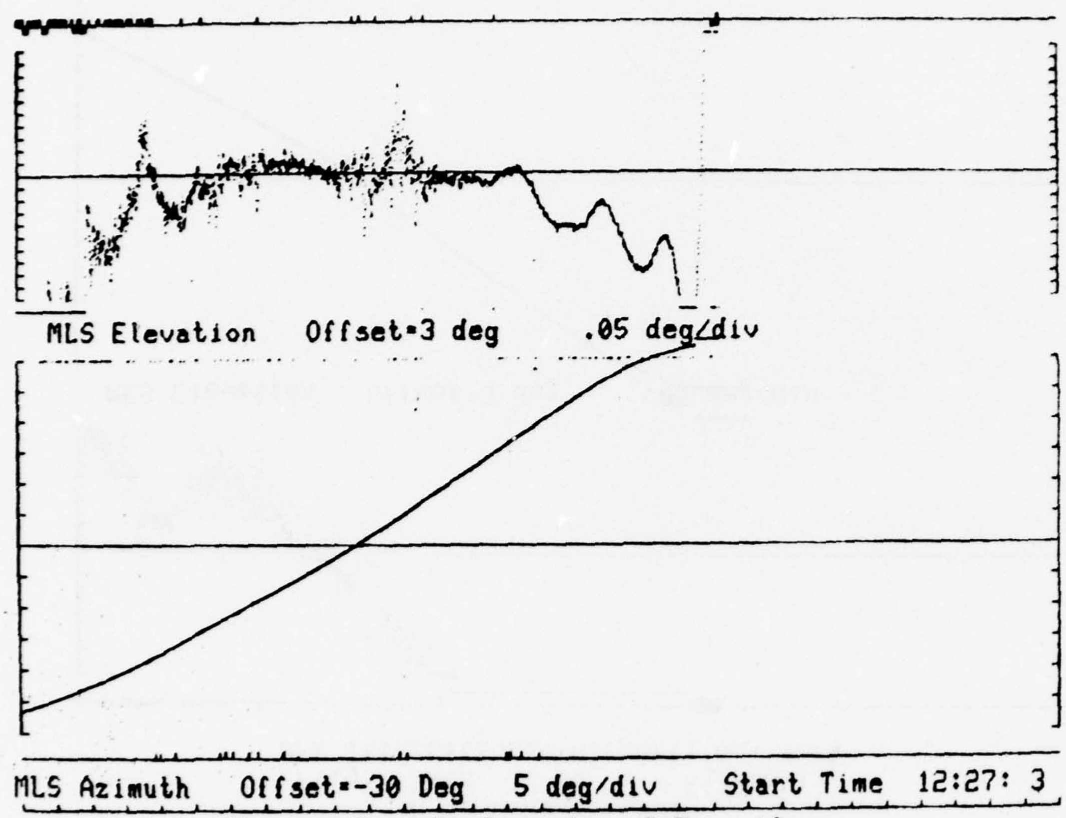
	RUN #	TAPE #	FILE #	TIMES START	TIMES STOP	# EDF	EAIR	THEO	LASER	DESCRIPTION AND COMMENTS
*	1	1	1	120806	121006	1	—	—	✓	Canarsie approach
	2	1	2	121718	122031	1	—	—	✓	" " (3rd waypoint)
	3	1	3	122704	123026	1	—	—	✓	" "
	4	1	4	123735	124110	5	—	—	✓	" " (full stop)
	5	2	1	132227	132545	1	—	—	✓	" "
**	6	2	2	133856	134153	1	—	—	✓	" " Right
***	7	2	3	135450	135802	1	—	—	✓	" "
**	8	2	4	140730	141112	5	—	—	✓	" "
									*	no tracking on run 1
									**	1 break in laser data (run 6,8)
									***	2 " " " " (run 7)
										Submitted to R. Weiss & Lasers to E. Gibson 12-30-77


N 42 AIRBORNE DATA
Flight Date 12/29/77 System 1
JFK International Airport, New York
MLS Elevation Offset=3 deg .05 deg/div
MLS Azimuth Offset=-30 Deg 5 deg/div Start Time 12: 8:11
Elapsed Time In Seconds S.F. = 10 sec

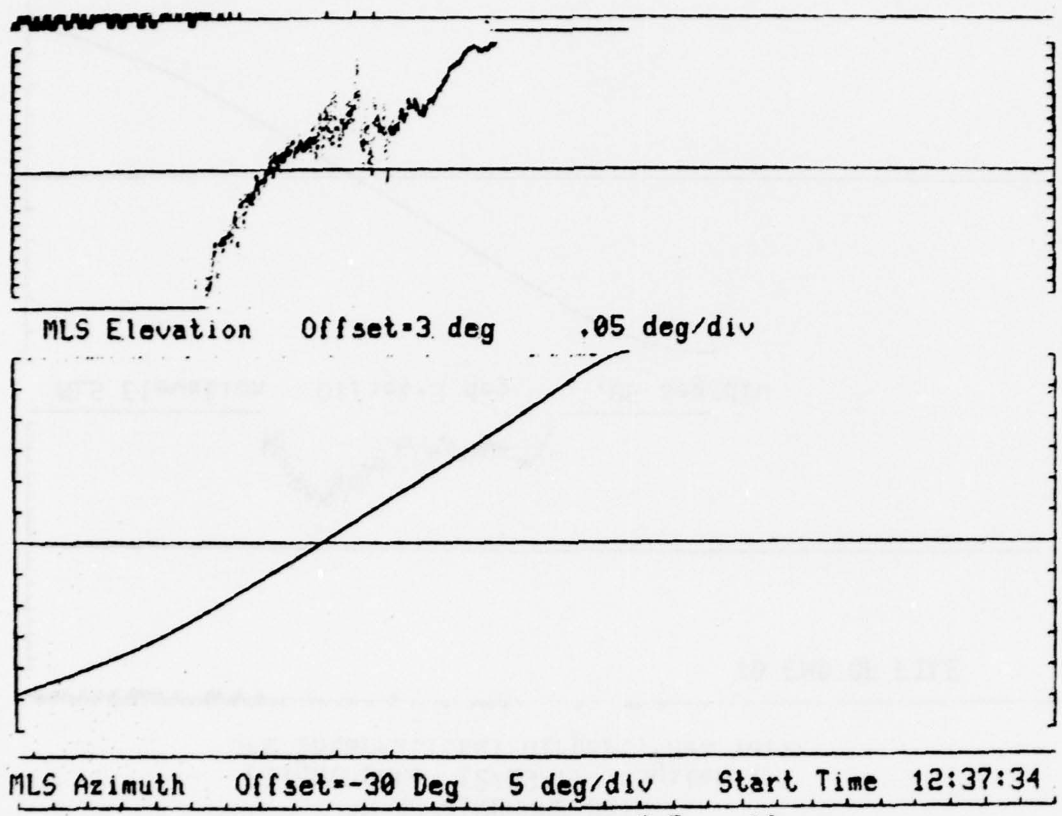
N 42 AIRBORNE DATA
Flight Date 12/29/77 System 1
JFK International Airport, New York



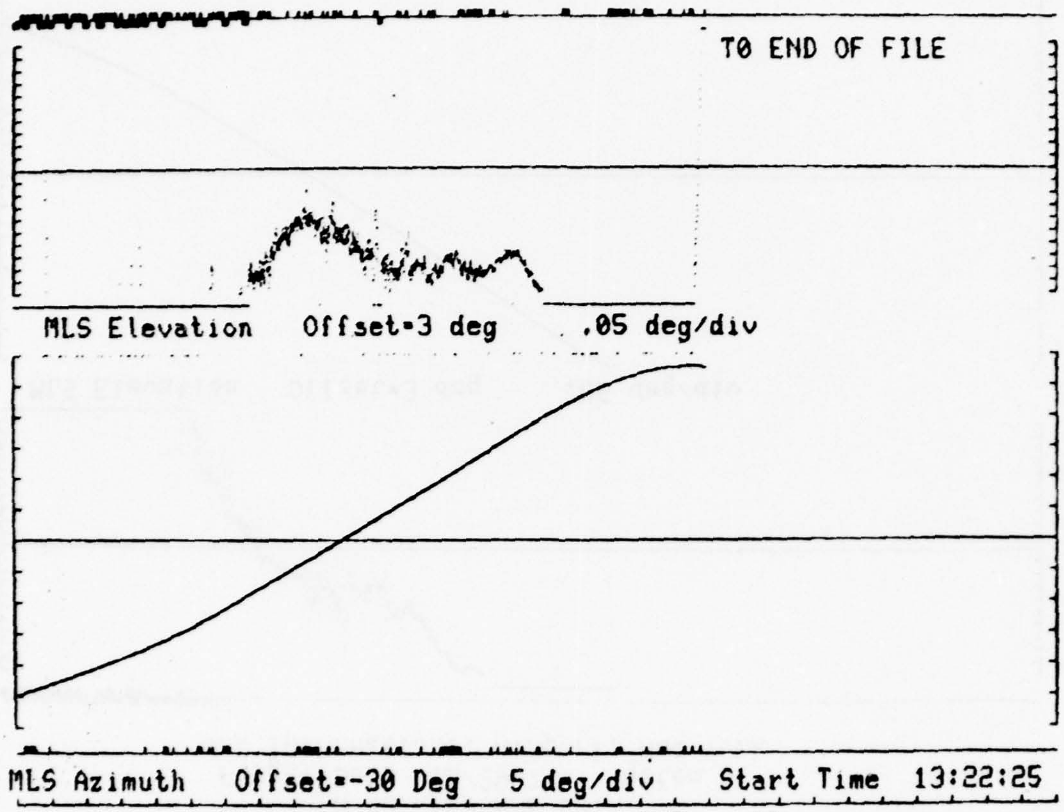
N 42 AIRBORNE DATA
Flight Date 12/29/77 System 1
JFK International Airport, New York



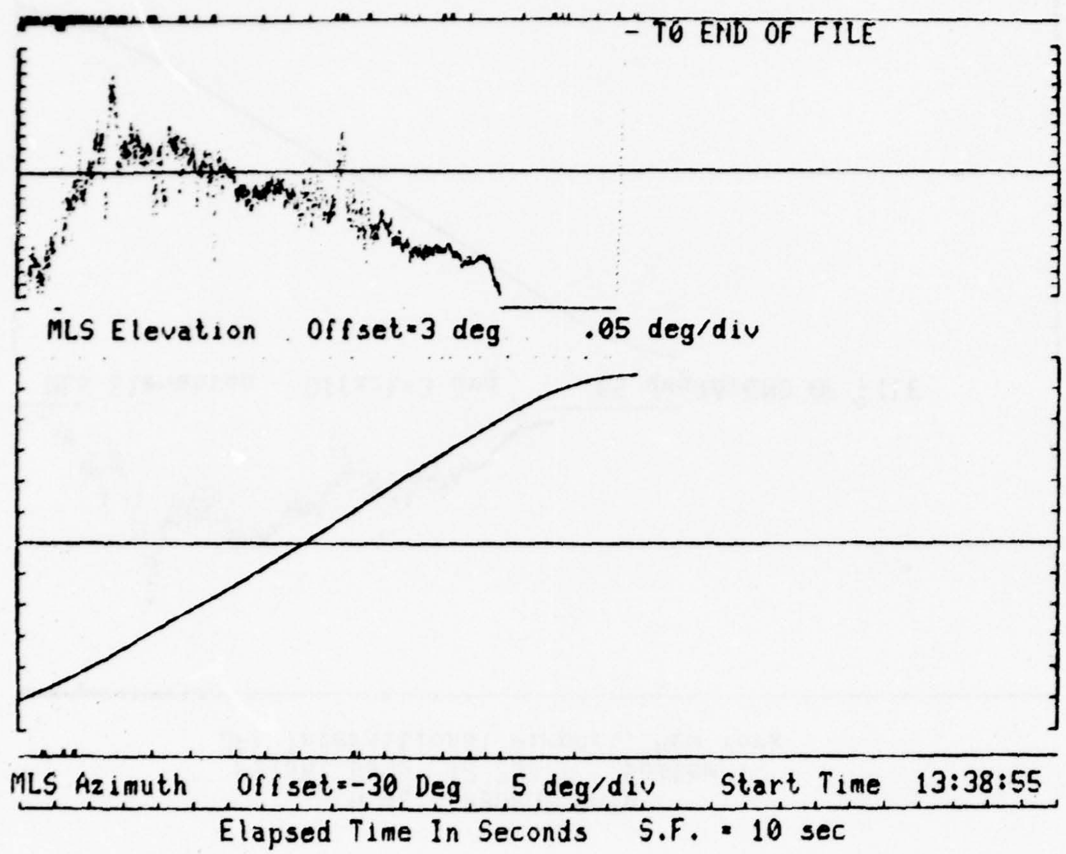
N 42 AIRBORNE DATA
Flight Date 12/29/77 System 1
JFK International Airport, New York



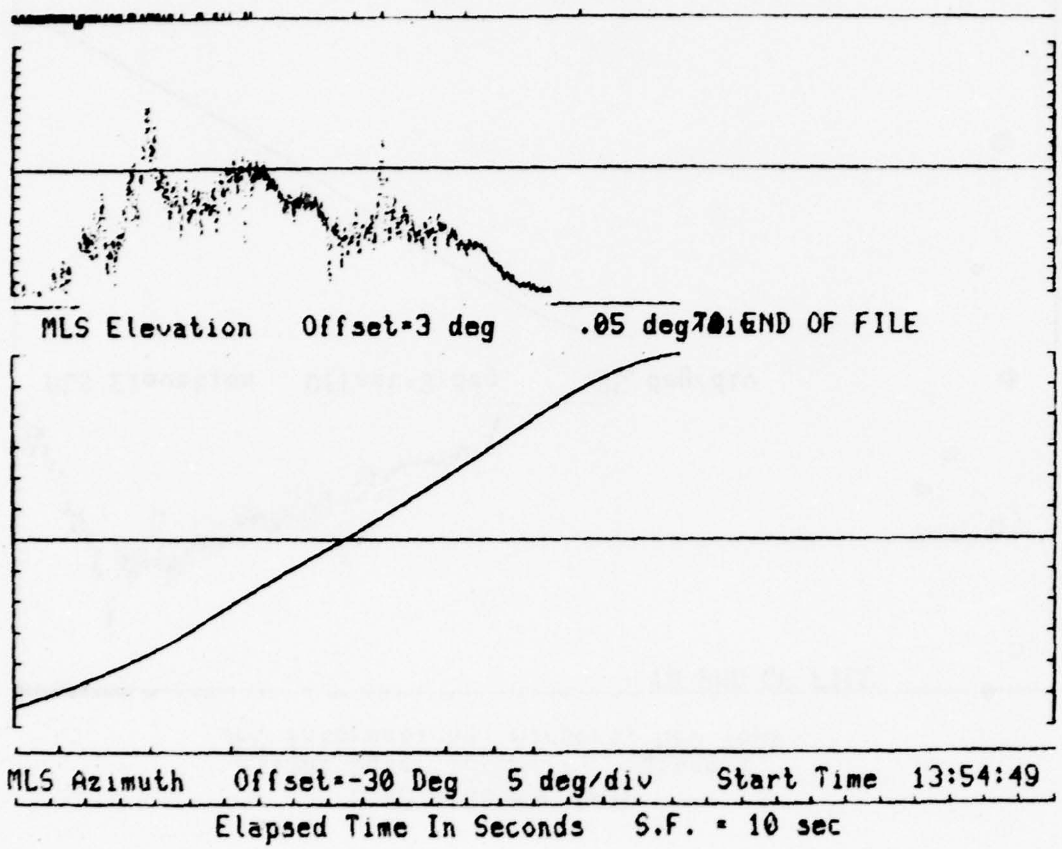
N 42 AIRBORNE DATA
Flight Date 12/29/77 System 1
JFK International Airport, New York



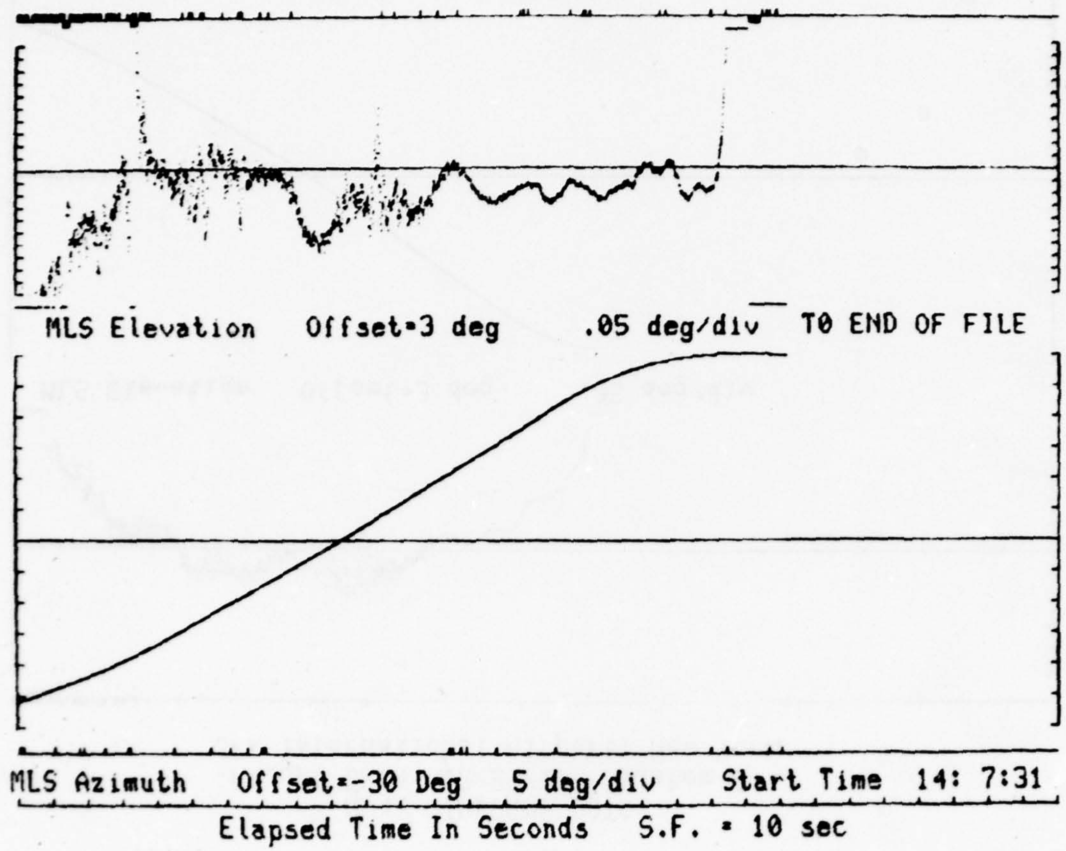
N 42 AIRBORNE DATA
Flight Date 12/29/77 System 1
JFK International Airport, New York

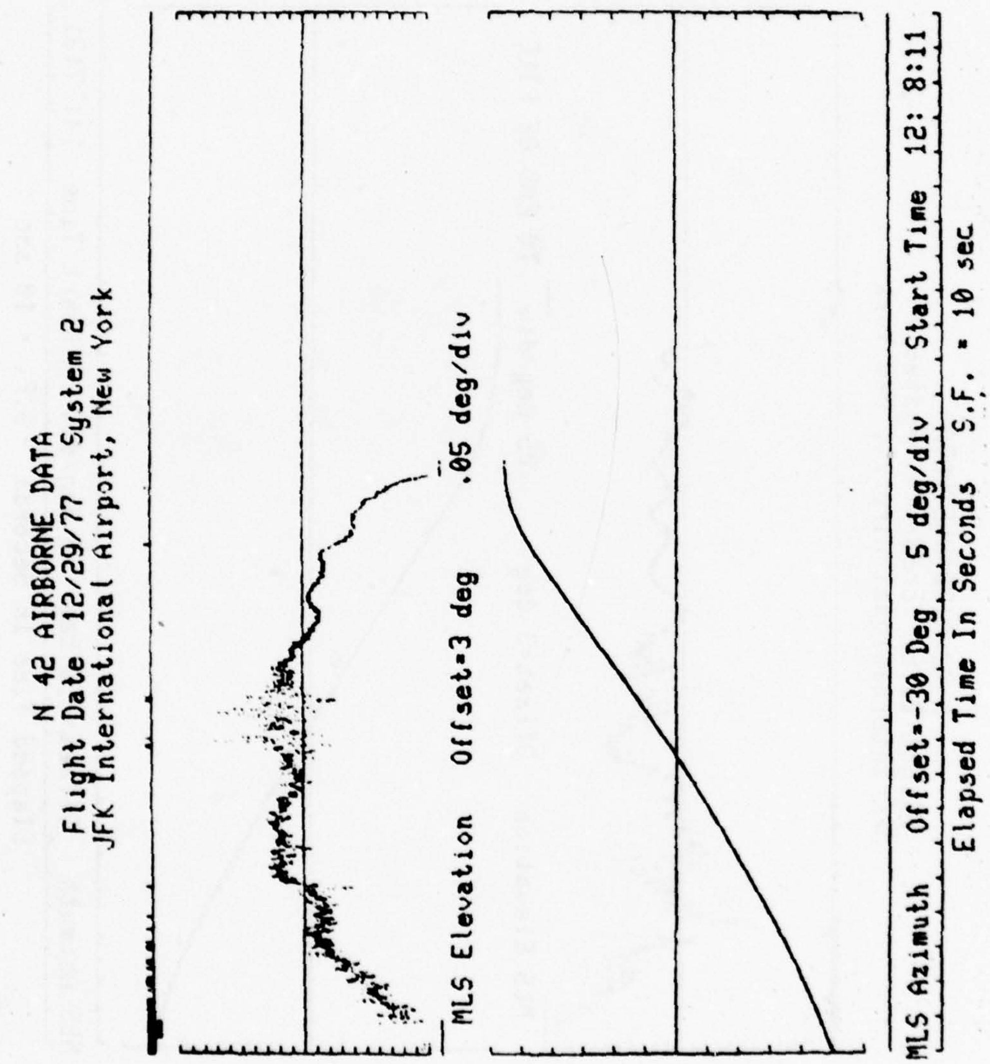


N 42 AIRBORNE DATA
Flight Date 12/29/77 System 1
JFK International Airport, New York

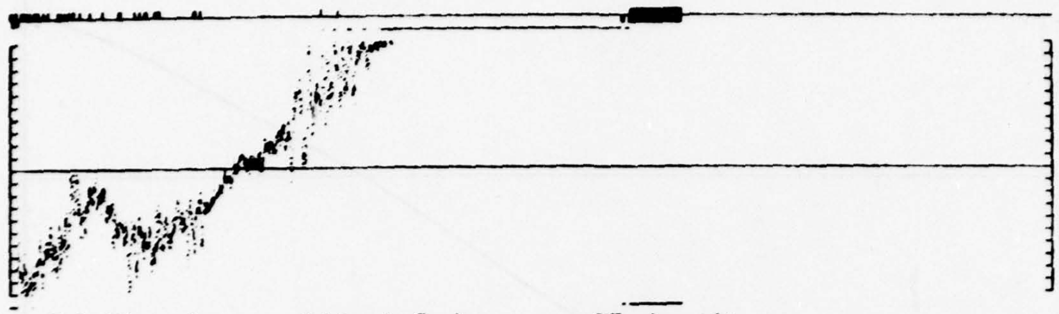


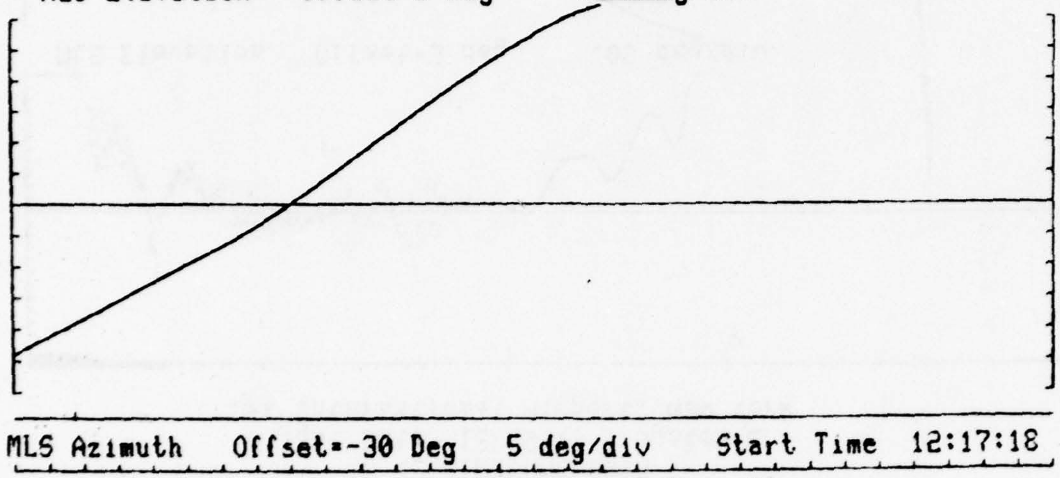
N 42 AIRBORNE DATA
Flight Date 12/29/77 System 1
JFK International Airport, New York

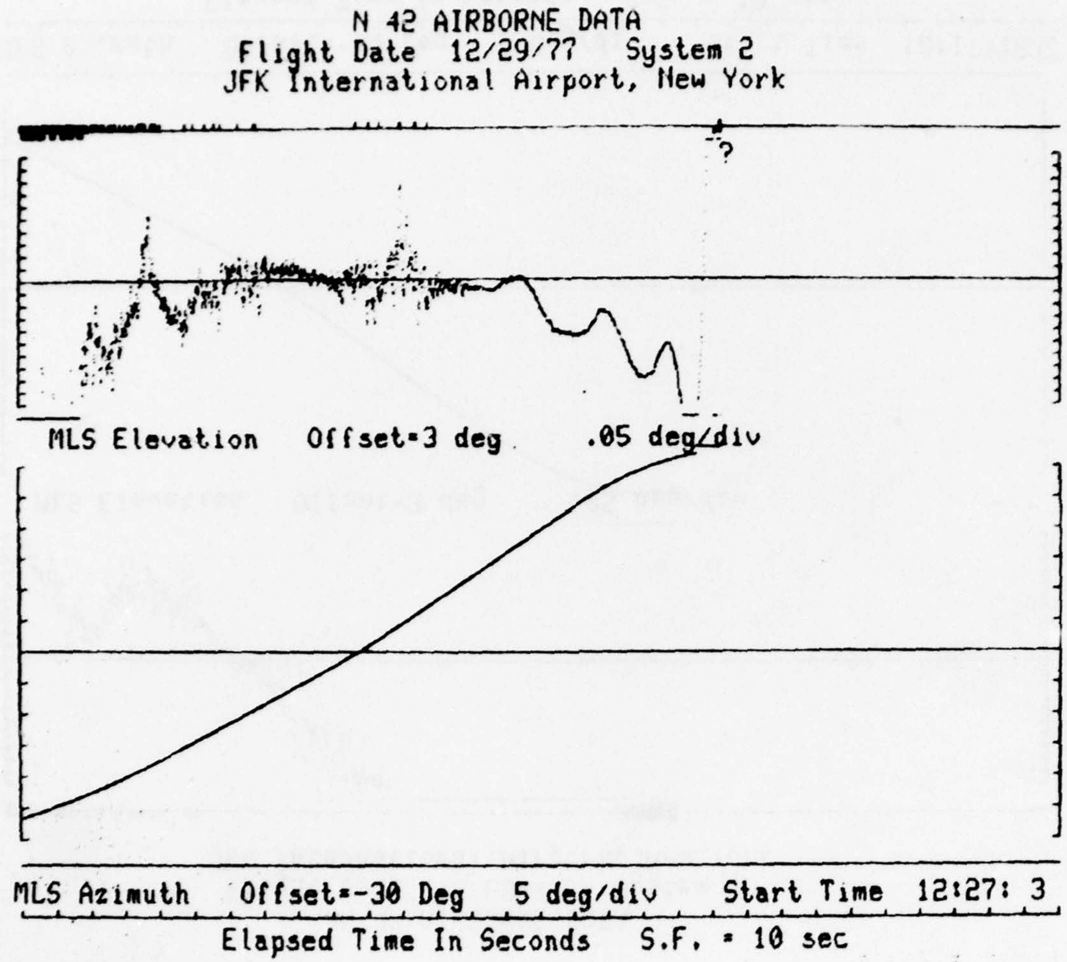



N 42 AIRBORNE DATA
Flight Date 12/29/77 System 2
JFK International Airport, New York
MLS Elevation Offset=3 deg .05 deg/div
MLS Azimuth Offset=-30 Deg 5 deg/div Start Time 12: 8:11
Elapsed Time In Seconds S.F. = 10 sec

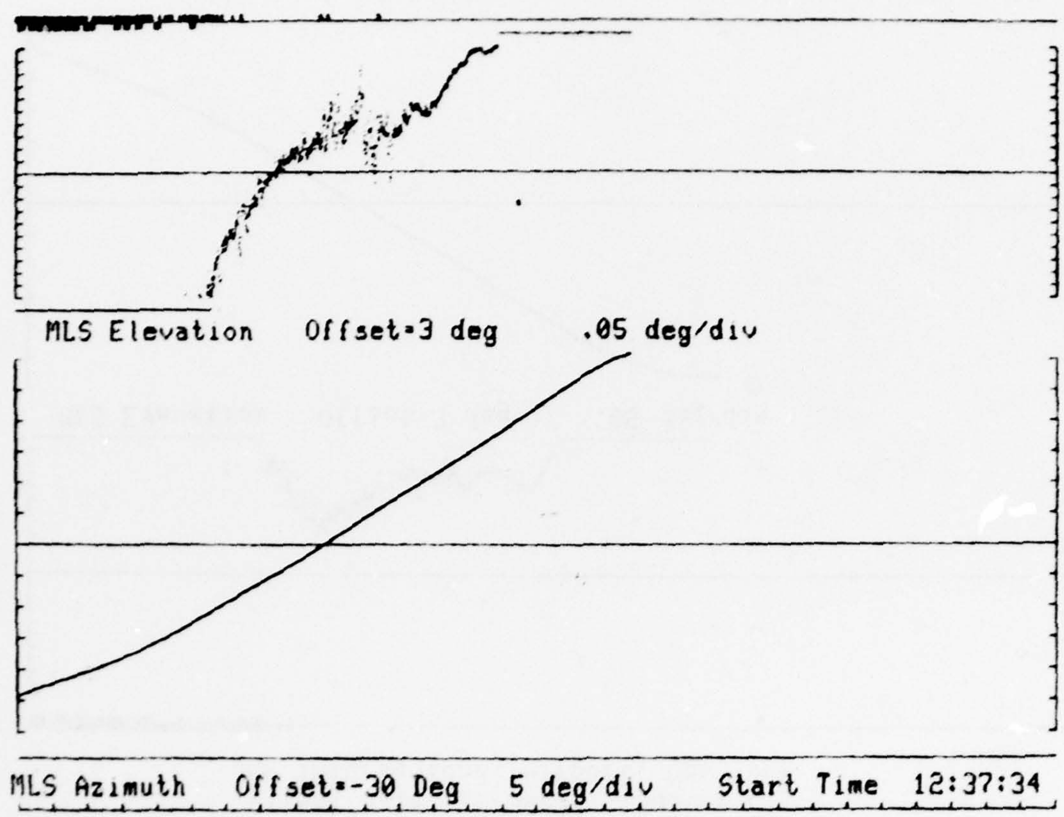
N 42 AIRBORNE DATA
Flight Date 12/29/77 System 2
JFK International Airport, New York



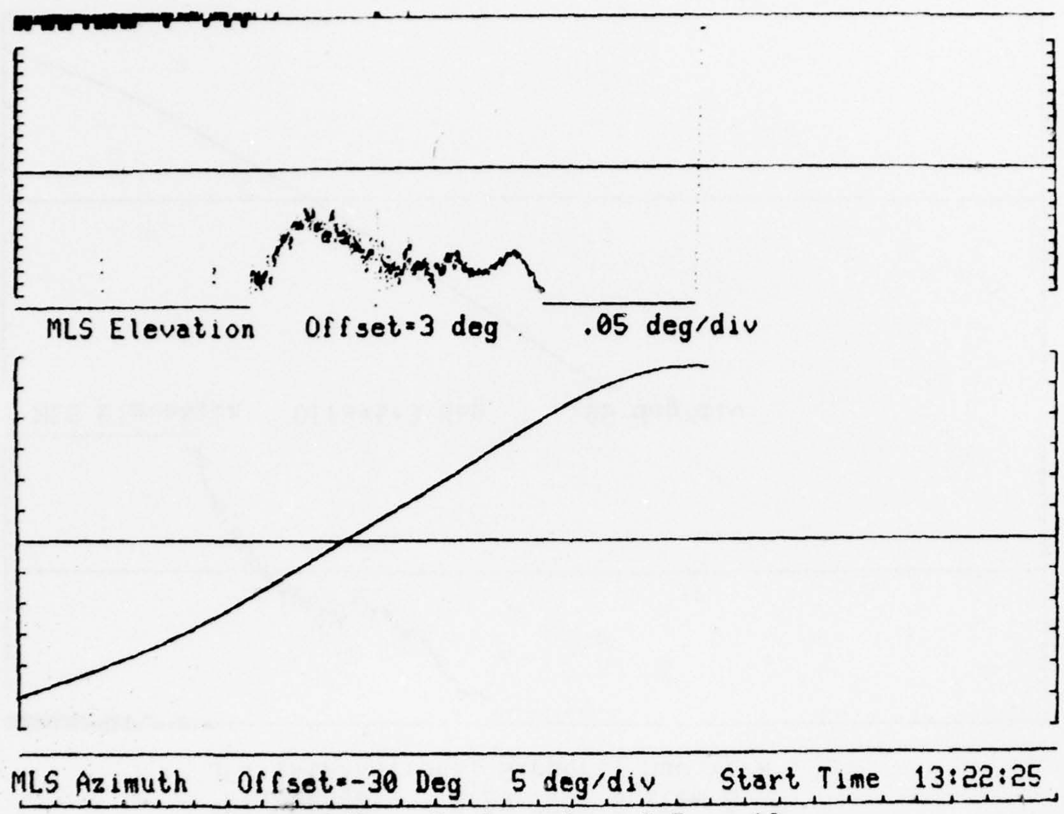


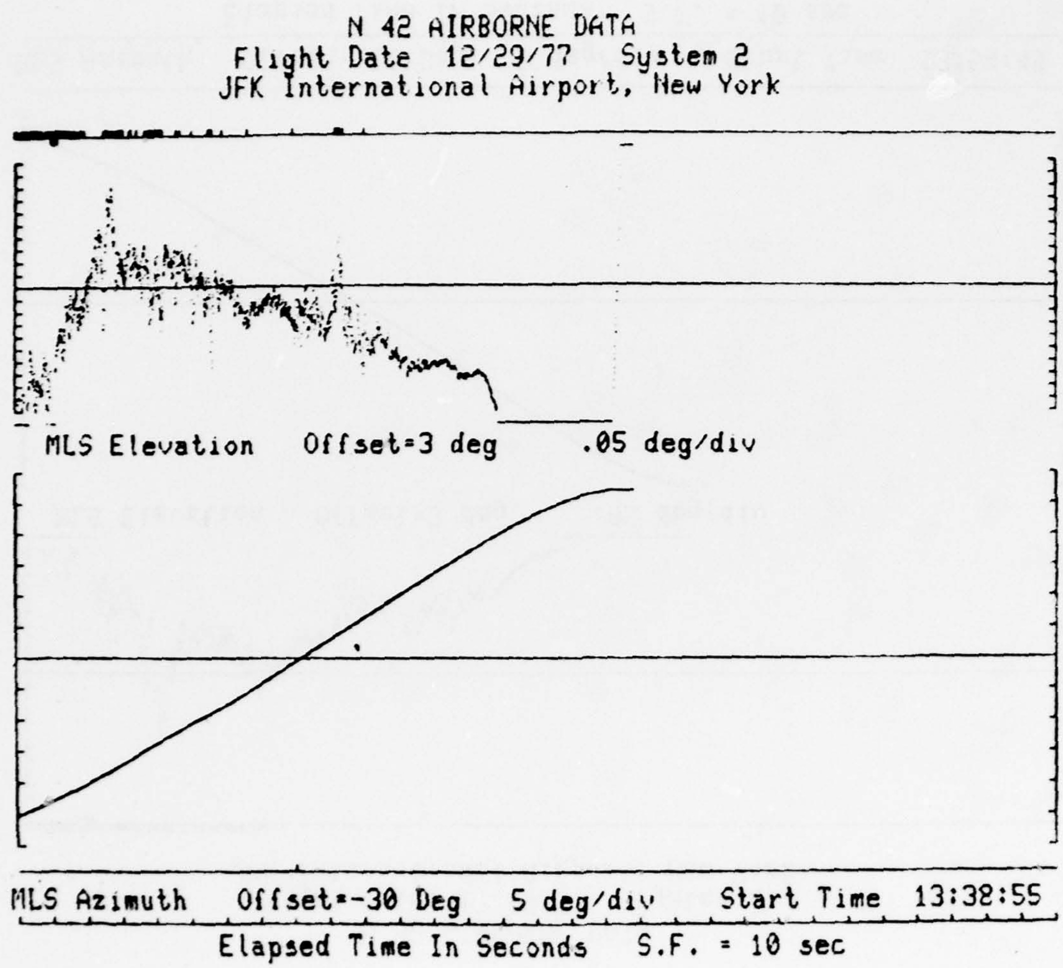

N 42 AIRBORNE DATA
Flight Date 12/29/77 System 2
JFK International Airport, New York
MLS Elevation Offset=3 deg .05 deg/div
MLS Azimuth Offset=-30 Deg 5 deg/div Start Time 12:27: 3
Elapsed Time In Seconds S.F. = 10 sec

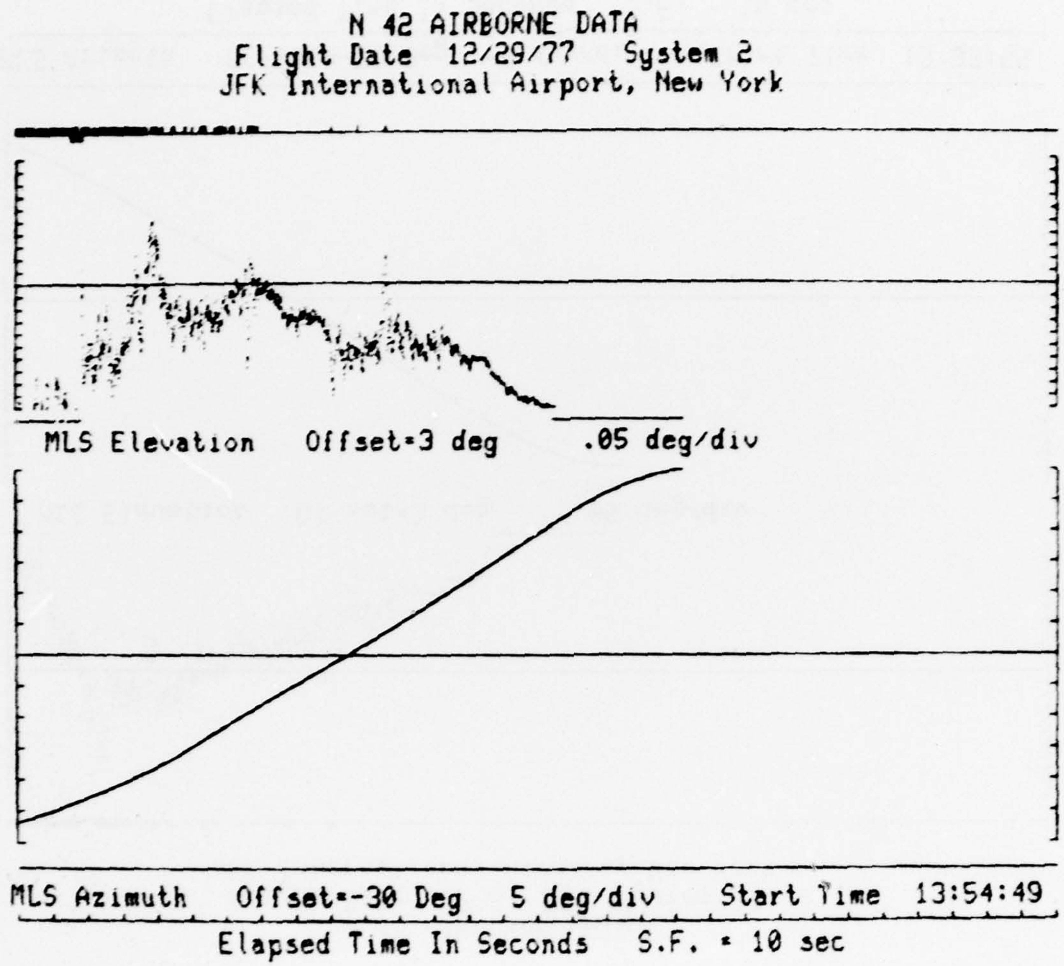
N 42 AIRBORNE DATA
Flight Date 12/29/77 System 2
JFK International Airport, New York



N 42 AIRBORNE DATA
Flight Date 12/29/77 System 2
JFK International Airport, New York

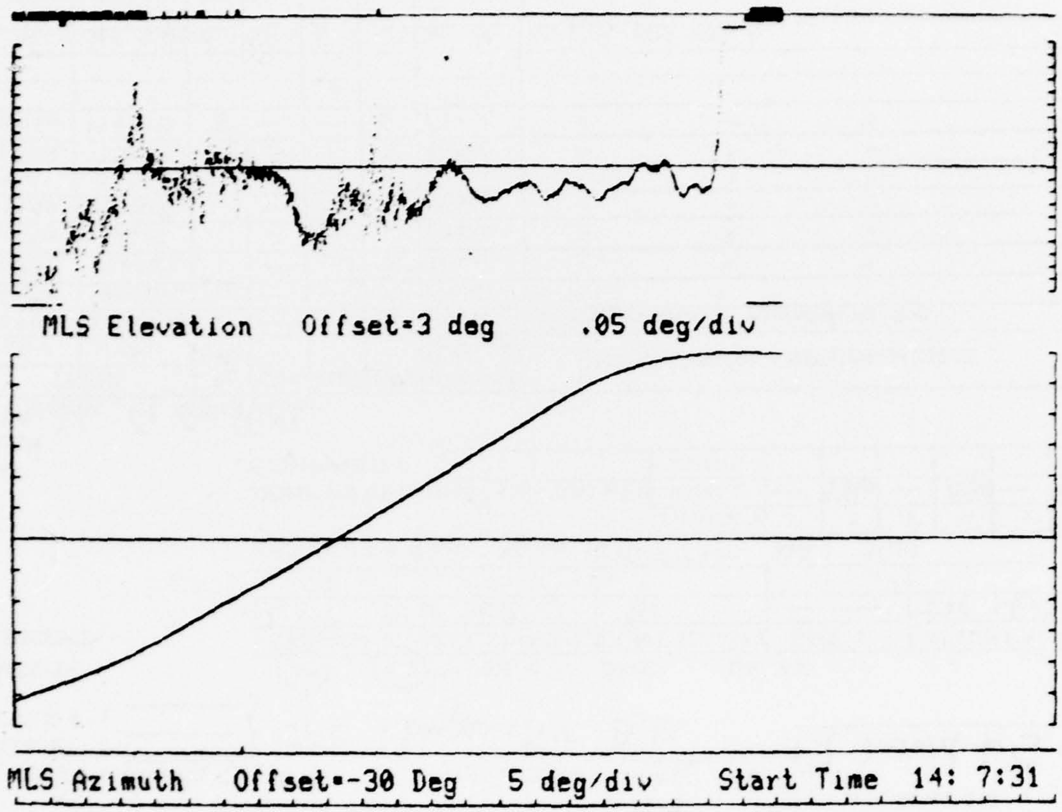



N 42 AIRBORNE DATA
Flight Date 12/29/77 System 2
JFK International Airport, New York
MLS Elevation Offset=3 deg .05 deg/div
MLS Azimuth Offset=-30 Deg 5 deg/div Start Time 13:38:55
Elapsed Time In Seconds S.F. = 10 sec



N 42 AIRBORNE DATA
Flight Date 12/29/77 System 2
JFK International Airport, New York
MLS Elevation Offset=3 deg .05 deg/div
MLS Azimuth Offset=-30 Deg 5 deg/div Start Time 13:54:49
Elapsed Time In Seconds S.F. = 10 sec

N 42 AIRBORNE DATA
Flight Date 12/29/77 System 2
JFK International Airport, New York



Elapsed Time In Seconds S.F. = 10 sec

AIRBORNE DATA LOG
MLS PHASE III

SYSTEM UNDER TEST : BW Az BN El
TEST PLAN TABLE # : ____ } JFK Comparative Data
PATTERN # : ____

RUNWAY # : JFK 13L

DATE : 1/9/78
FLIGHT # :
AIRCRAFT # : N49

El moved to S. side Rwy

GROUND EQUIPMENT: (AZ) (EL) EL 2 DME BK AZ
AIRBORNE EQUIPMENT:

SYSTEM #	RECEIVER #	CONT HEAD #	DME #	INTERFACE #
1	102	111	——	TM Mod[illegible]
2				

WIND: 210 C8
TEMP.: 29°F
CEILING: Unl
VISIB: 10+ mi
PILOT: G. Decker
COPILOT: R. Powell
OBSERVERS: C. Mockin, G. Griffith

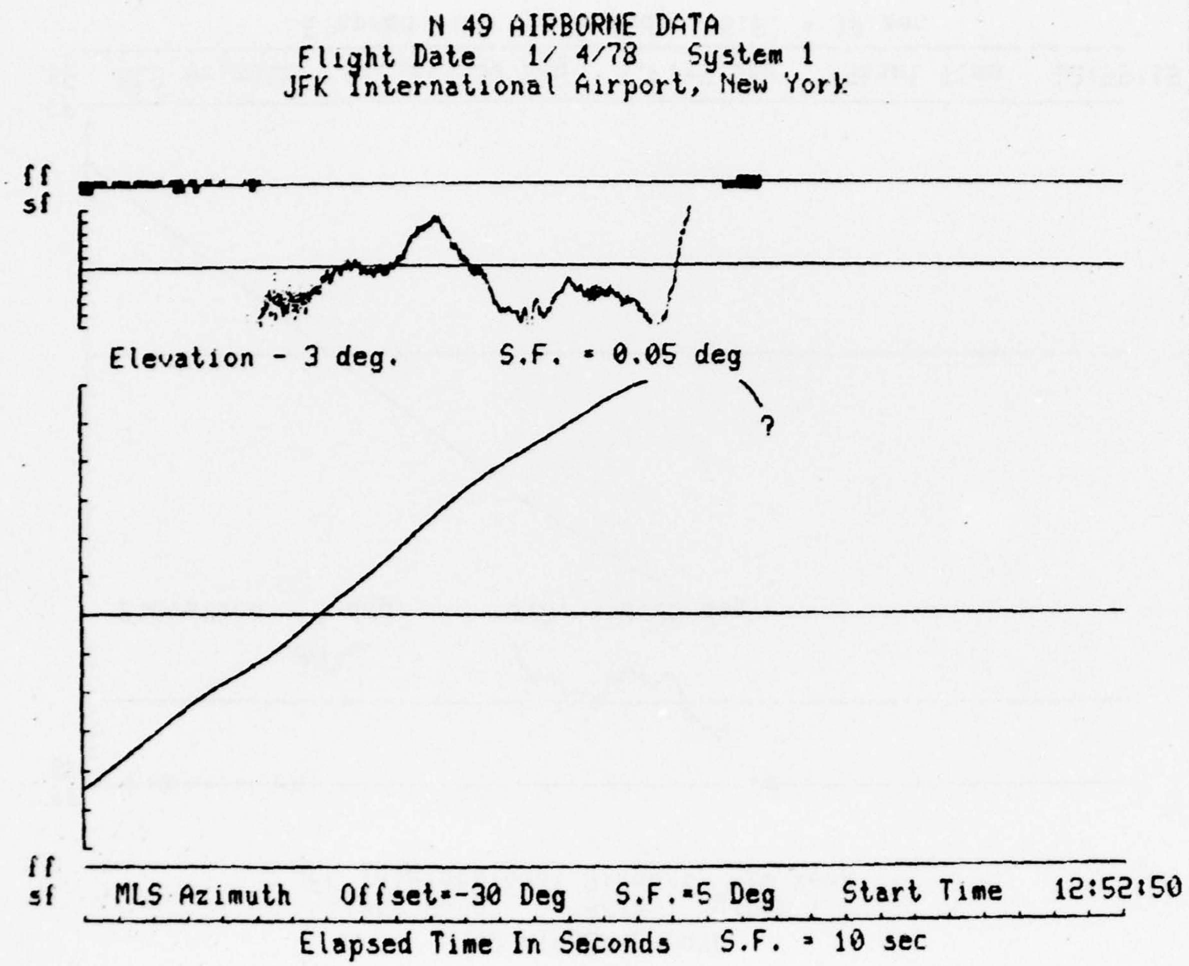
KENNEDY # 9trk 9800 WIP #7450 NA2 2917
HONEYWELL # WIP # 5700 NAO 6510
STRIP REC #

TRACK #	1	2	3	4	5	6	7
SIGNAL	—	Video	—	A10	—	[illegible]	—
SIGNAL							

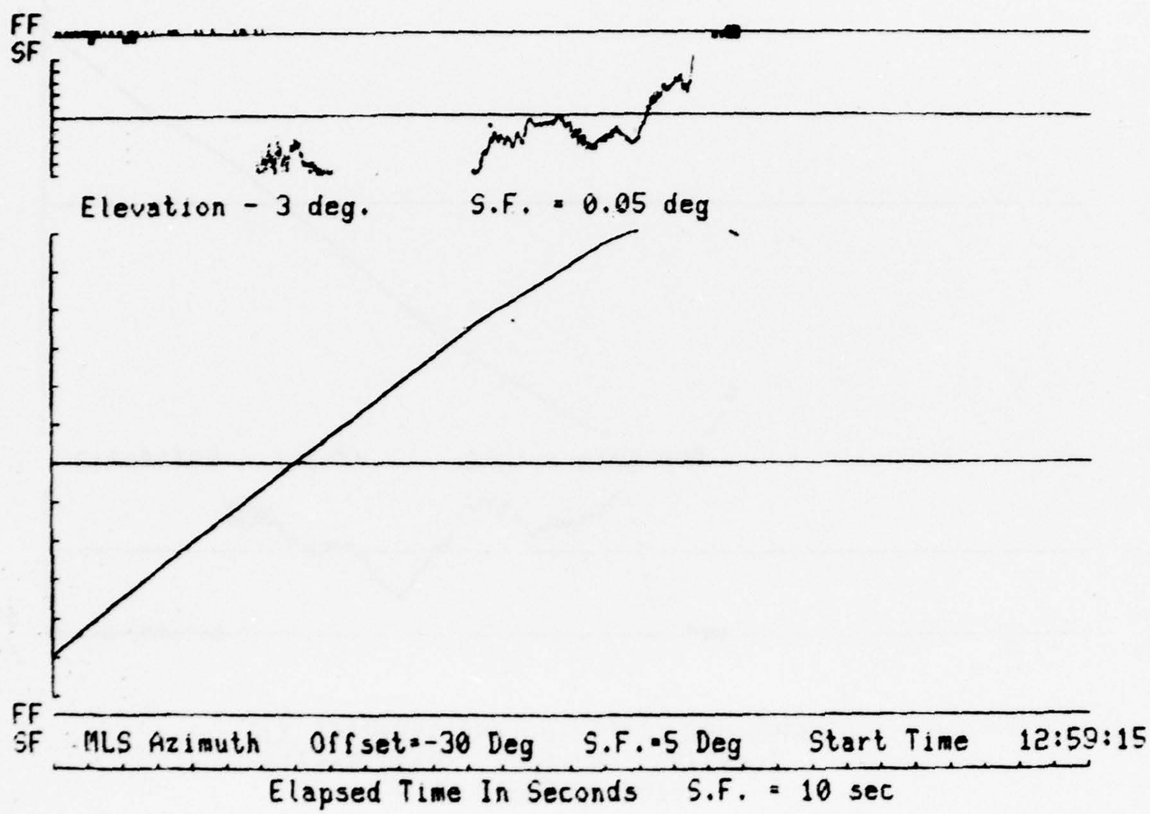
RUN #	TAPE #	FILE #	TIMES START	TIMES STOP	# EDI	FAIR	TIBI	LASER	Aircraft Antenna	DESCRIPTION AND COMMENTS
1*	1	1	125250	125606	1	—	—	X	Horn	3° GS Canarsie Approach to 300'
2*	1	2	125915	130235	1	—	—	X	Omni	" " "
3*	1	3	130558	130852	1	—	—	X	Horn	" " "
4*	1	4	131240	131615	1	—	—	X	Omni	" " "
5	1	5	131940	132315	1	—	—	X	Horn	" " "
6	1	6	132641	132945	1	—	—	X	Omni	" " "
7	1	7	133329	133635	1	—	—	X	Horn	" " "
8	1	8	134030	134415	5	—	—	X	Omni	" " "

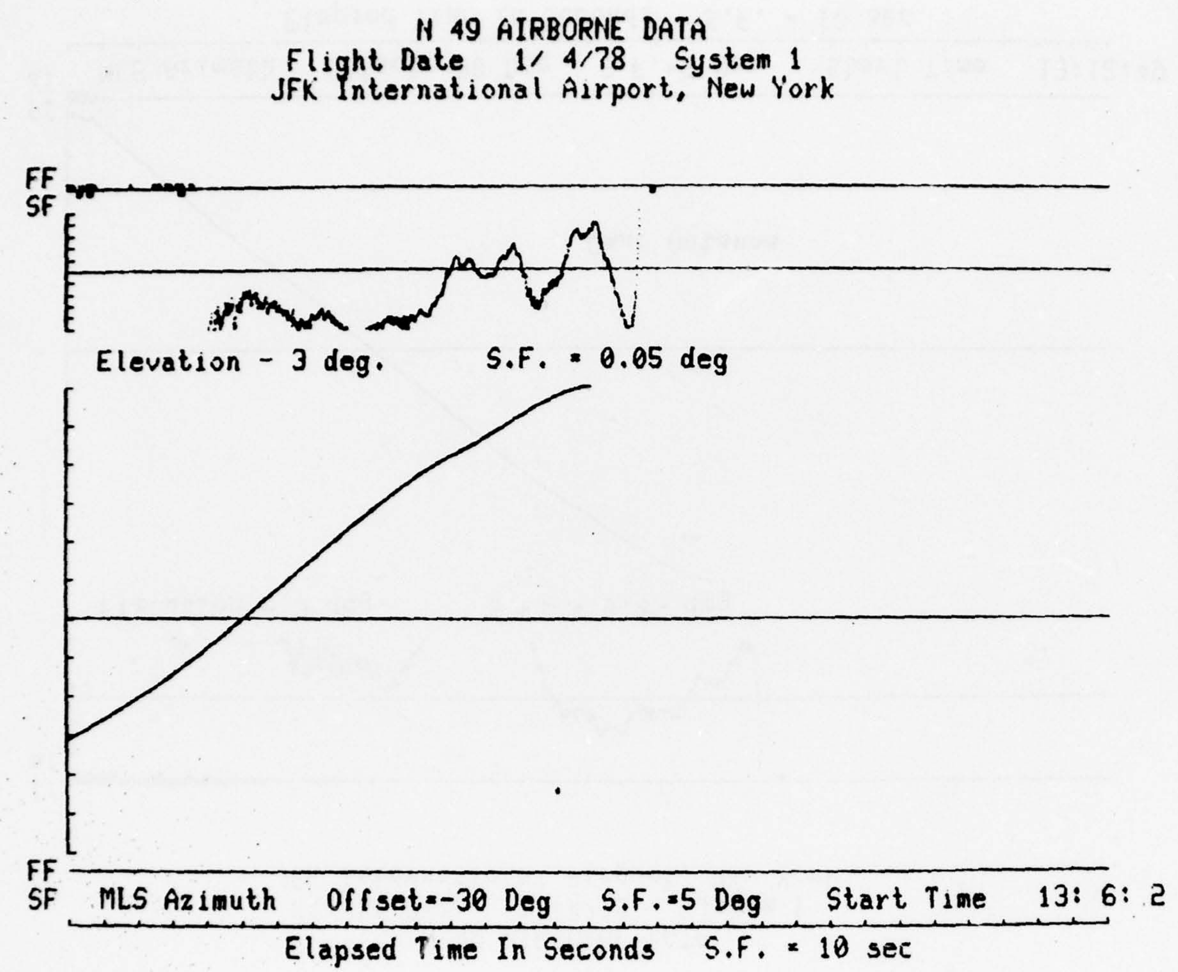
* Honeywell recorder speed 15ips ; changed to 30 ips mid run 4

No exc[illegible]ometer or Angle recorder installed in project rack for this flight

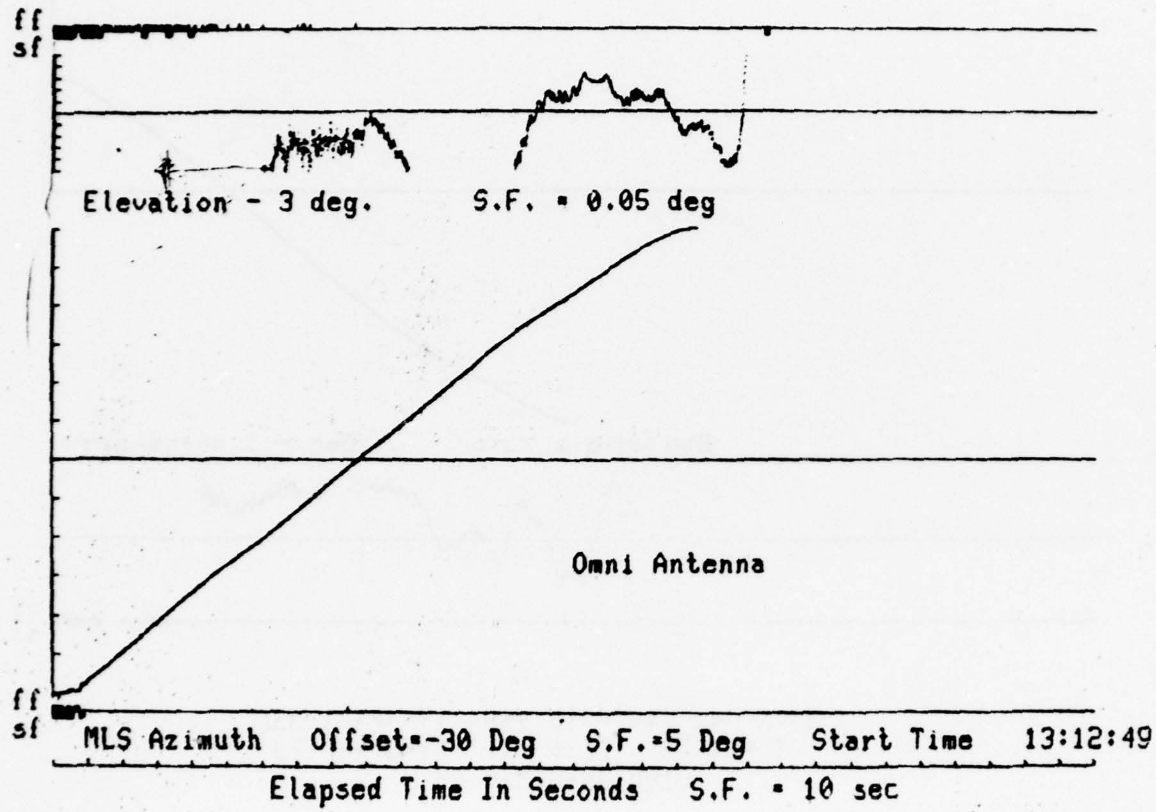

N 49 AIRBORNE DATA
Flight Date 1/ 4/78 System 1
JFK International Airport, New York
ff
sf
Elevation - 3 deg. S.F. = 0.05 deg
?
ff
sf
MLS Azimuth Offset=-30 Deg S.F.=5 Deg Start Time 12:52:50
Elapsed Time In Seconds S.F. = 10 sec

N 49 AIRBORNE DATA
Flight Date 1/ 4/78 System 1
JFK International Airport, New York

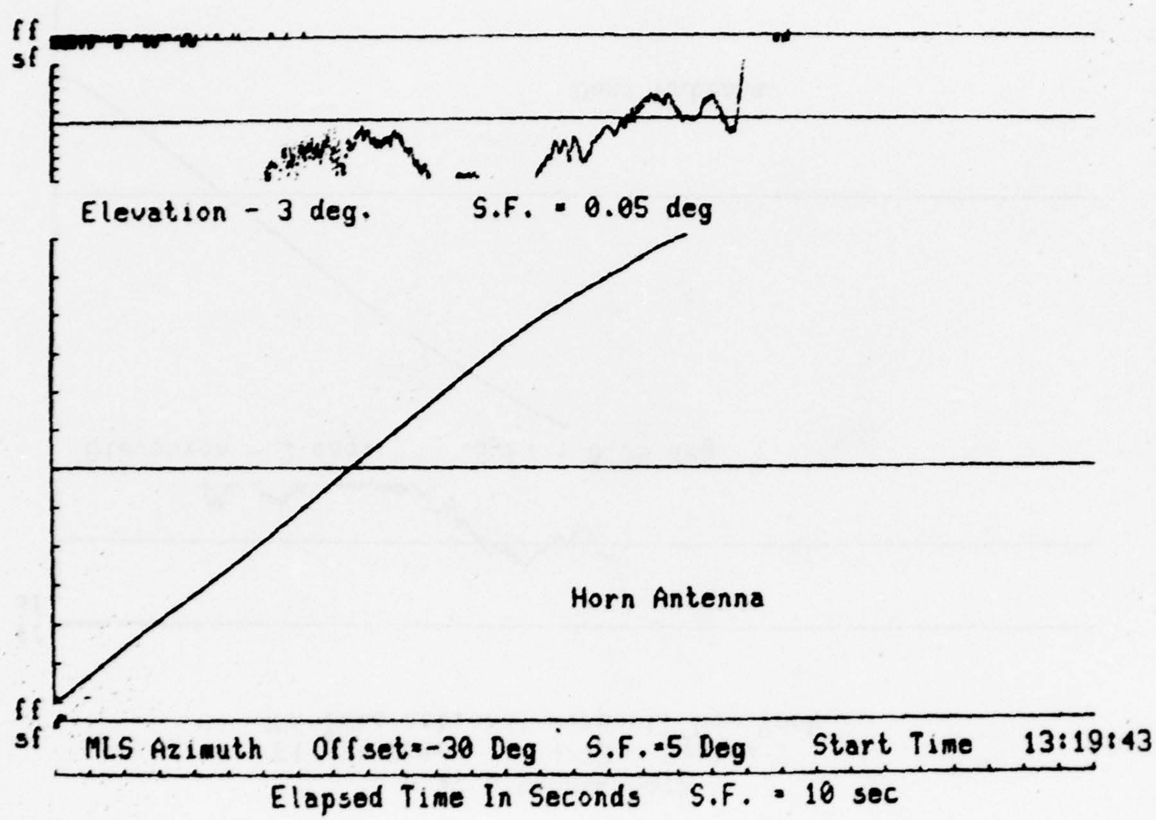



N 49 AIRBORNE DATA
Flight Date 1/ 4/78 System 1
JFK International Airport, New York
FF
SF
Elevation - 3 deg.
S.F. = 0.05 deg
FF
SF
MLS Azimuth
Offset=-30 Deg
S.F.=5 Deg
Start Time 13: 6: 2
Elapsed Time In Seconds S.F. = 10 sec

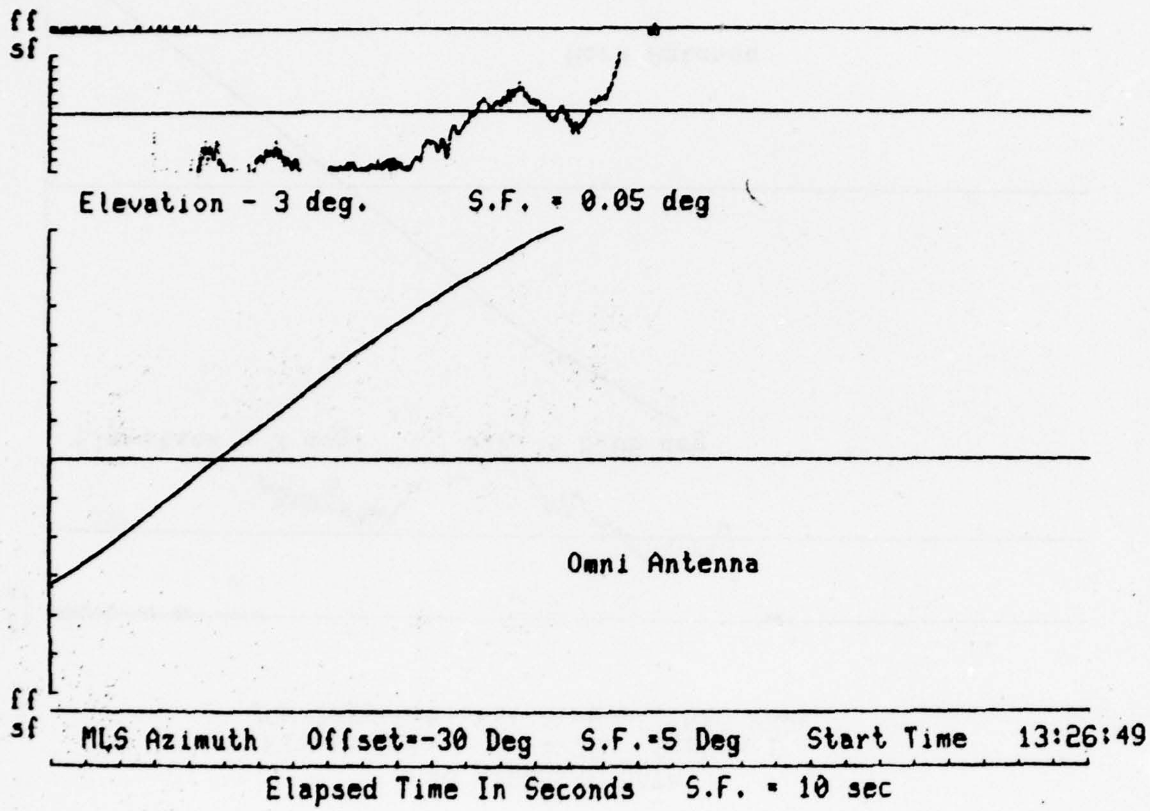
N 49 AIRBORNE DATA
Flight Date 1/ 4/78 System 1
JFK International Airport, New York

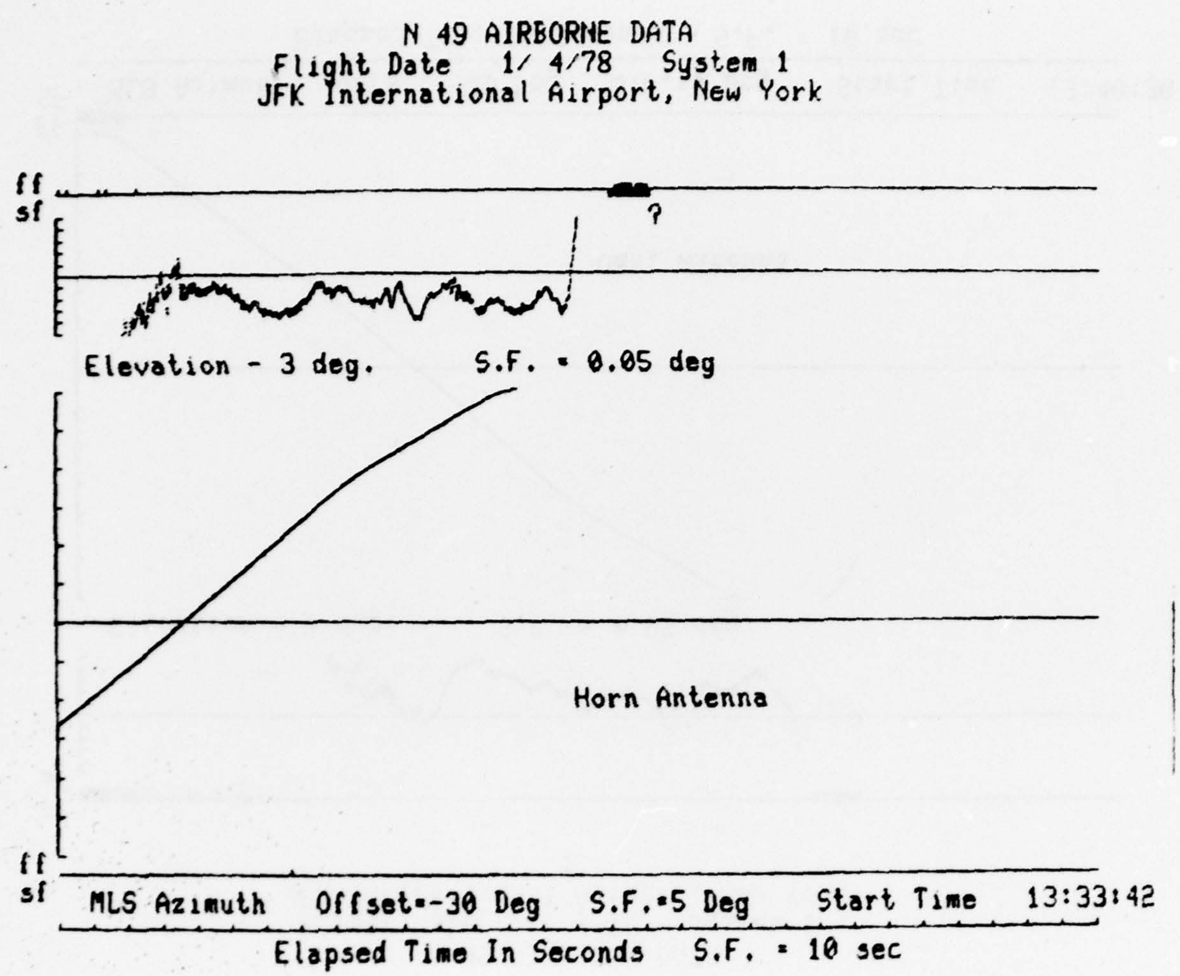


N 49 AIRBORNE DATA
Flight Date 1/ 4/78 System 1
JFK International Airport, New York



N 49 AIRBORNE DATA
Flight Date 1/ 4/78 System 1
JFK International Airport, New York





N 49 AIRBORNE DATA
Flight Date 1/ 4/78 System 1
JFK International Airport, New York
ff
sf
?
Elevation - 3 deg. S.F. = 0.05 deg
Horn Antenna
ff
sf
MLS Azimuth Offset=-30 Deg S.F.=5 Deg Start Time 13:33:42
Elapsed Time In Seconds S.F. = 10 sec

N 49 AIRBORNE DATA
Flight Date 1/ 4/78 System 1
JFK International Airport, New York