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Technical Manual
Tonopah Test Range Capabilities

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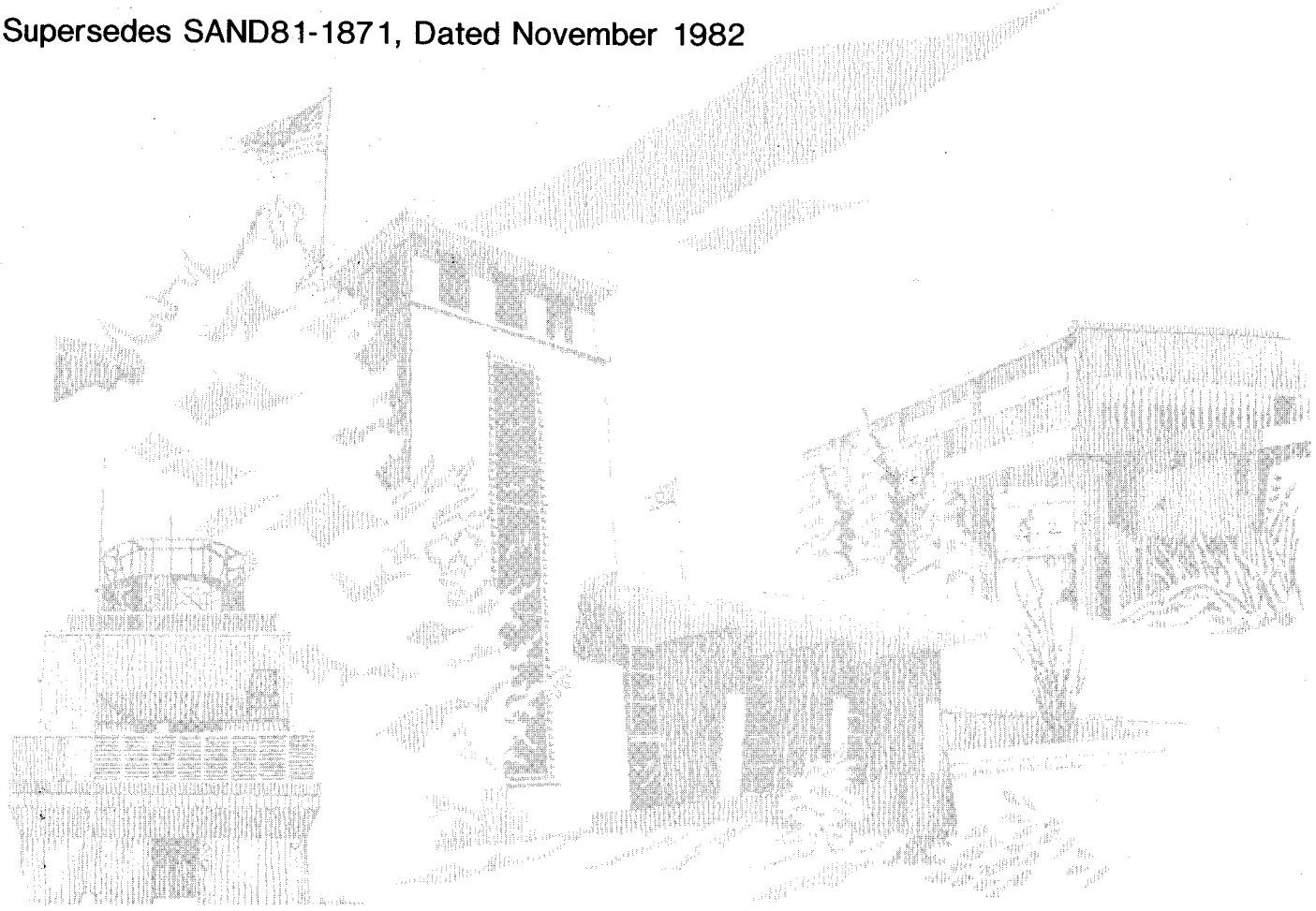

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FRONTISPIECE

Operations Center, Tonopah Test Range

Technical Manual
Tonopah Test Range Capabilities

SECTION 1

INTRODUCTION

This manual describes Tonopah Test Range (TTR), defines its testing capabilities, and outlines the steps necessary for users to schedule tests on the Range.

Operated by Sandia National Laboratories for the US Dept of Energy, TTR is a major Test Facility for DOE-funded weapon programs. The range provides an integrated system for ballistic test vehicle tracking and data acquisition. Multiple radars, optical trackers, telemetry stations, a central computer complex, and combined landline/RF communications systems assure full range coverage for any type of test.

Range operations are conducted by a department within Sandia's Field Engineering Directorate. While the overall range functions as a complete system, it is operationally divided into the Test Measurements, Data Systems, and Range Operations divisions.

Although specific Range operation and management are the responsibilities of Sandia, many support Services are provided by the Reynolds Electrical and Engineering Co., Inc. (REECo), EG&G, Inc., and Advance Security, Inc., under separate contracts.

The primary mission of TTR is to provide test support for DOE weapons development activities. DOE and Sandia management, however, encourage other government agencies and their contractors to schedule tests on the Range which can make effective use of its capabilities. See Section 7 for information concerning Range use by organizations outside of DOE.

This manual describes Range instrumentation, test operations, and support facilities. The test equipment and operating systems represent the current state-of-the-art and reflect a continuing commitment by TTR management to field the most effective tracking and data acquisition systems available.

SECTION 2

RANGE DESCRIPTION

TTR is located on the north end of the Nellis Bombing and Gunnery Range, about 148 air miles northwest of Las Vegas, Nevada, and 40 road miles southeast of the town of Tonopah. It is bounded on three sides by the Nellis Bombing and Gunnery Range, and on the north side by public lands administered by the US Forest Service and the Bureau of Land Management.

The Range (Figure 2-1) is about 26 mi wide and 24 mi long, an area covering 525 square mi. The ground targets are located on dry lake beds averaging about 5350 ft mean sea level (msl). The Cactus Range, a string of low, rocky mountains whose highest peak is 7482 ft msl, borders the Range on the west. The Kawich Range, with peaks up to 9400 ft msl, extends along the east side. Vegetation on the Range varies from sparse to none.

Because of its high desert location, TTR receives little precipitation (averaging only about 5 in/yr), and therefore has infrequent cloud cover and generally good year-round visibility. Relative humidity ranges from 14% to 77%. Average temperatures run from 40°F in winter to 86°F in summer, with extremes of −24°F and 102°F. Storms that reach TTR are usually of short duration and carry little moisture.

Six permanently defined targets are spaced along a flight line through the Range on a heading of 347° true (Figure 2-1). Soil composition and target construction offer users a variety of surface conditions including sandy soil, hard-packed clay base, or concrete. Gravel and rocky or solid rock impact areas are also available when required. Three of the targets are shown as seen from an approaching drop aircraft are shown in Figure 2-2. Target map coordinates and characteristics are given in Table 2-1.

Instrumentation sites and facilities locations are shown in Figure 2-1. All equipment sites have been surveyed to assure accurate placement in relation to the Main Lake reference point, and many have concrete pads to provide stable surfaces. To meet varying test requirements, mobile instrumentation is available to supplement the fixed facilities.

Air traffic to the Range is served by the TTR airfield which has a 12,000-ft-long, 150-ft-wide asphalt and concrete runway. The runway, on a 320° heading (designated 14 and 32), with station elevation at 5,540 ft msl, is equipped with ILS and TACAN.

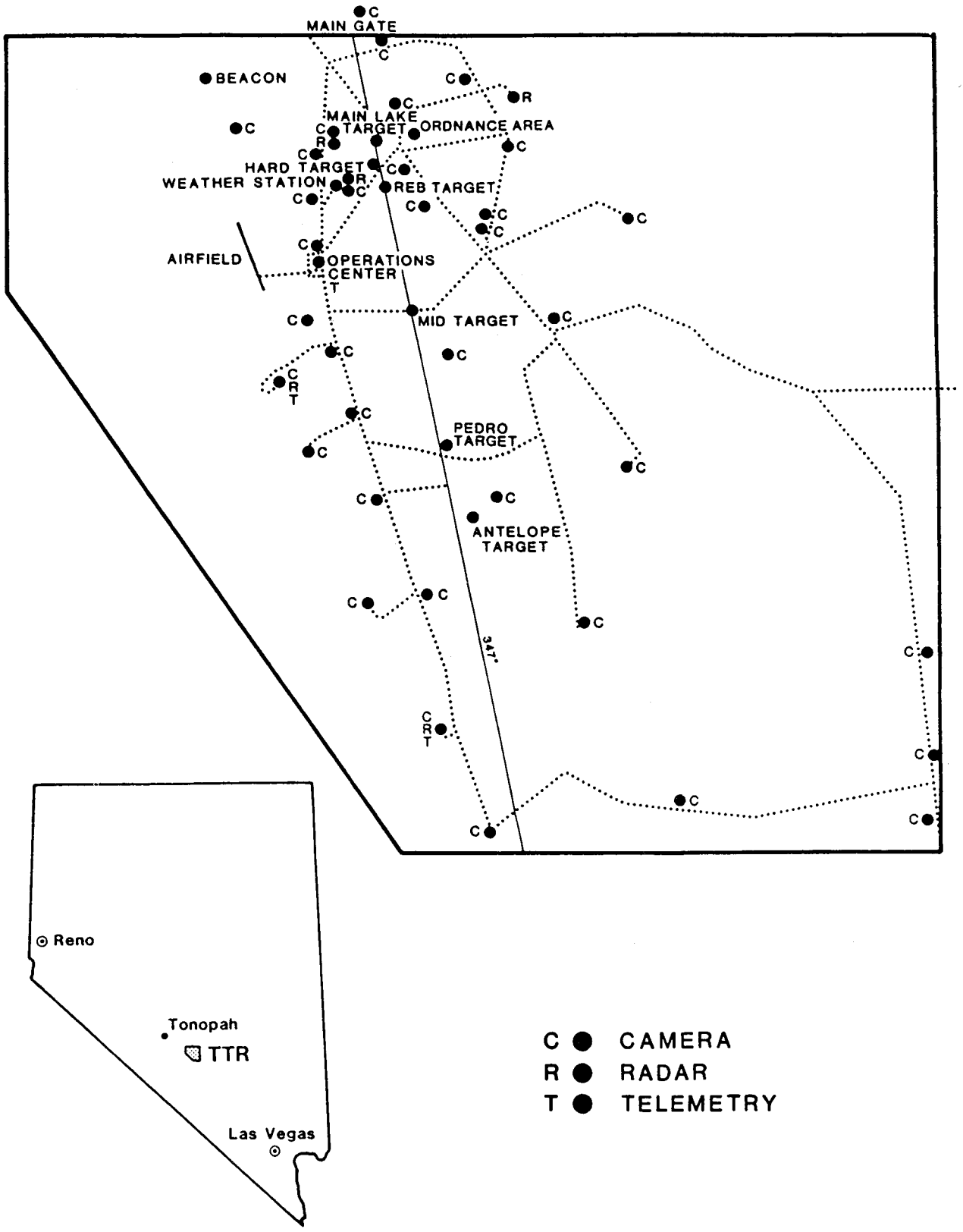


Figure 2-1. Range Location Maps

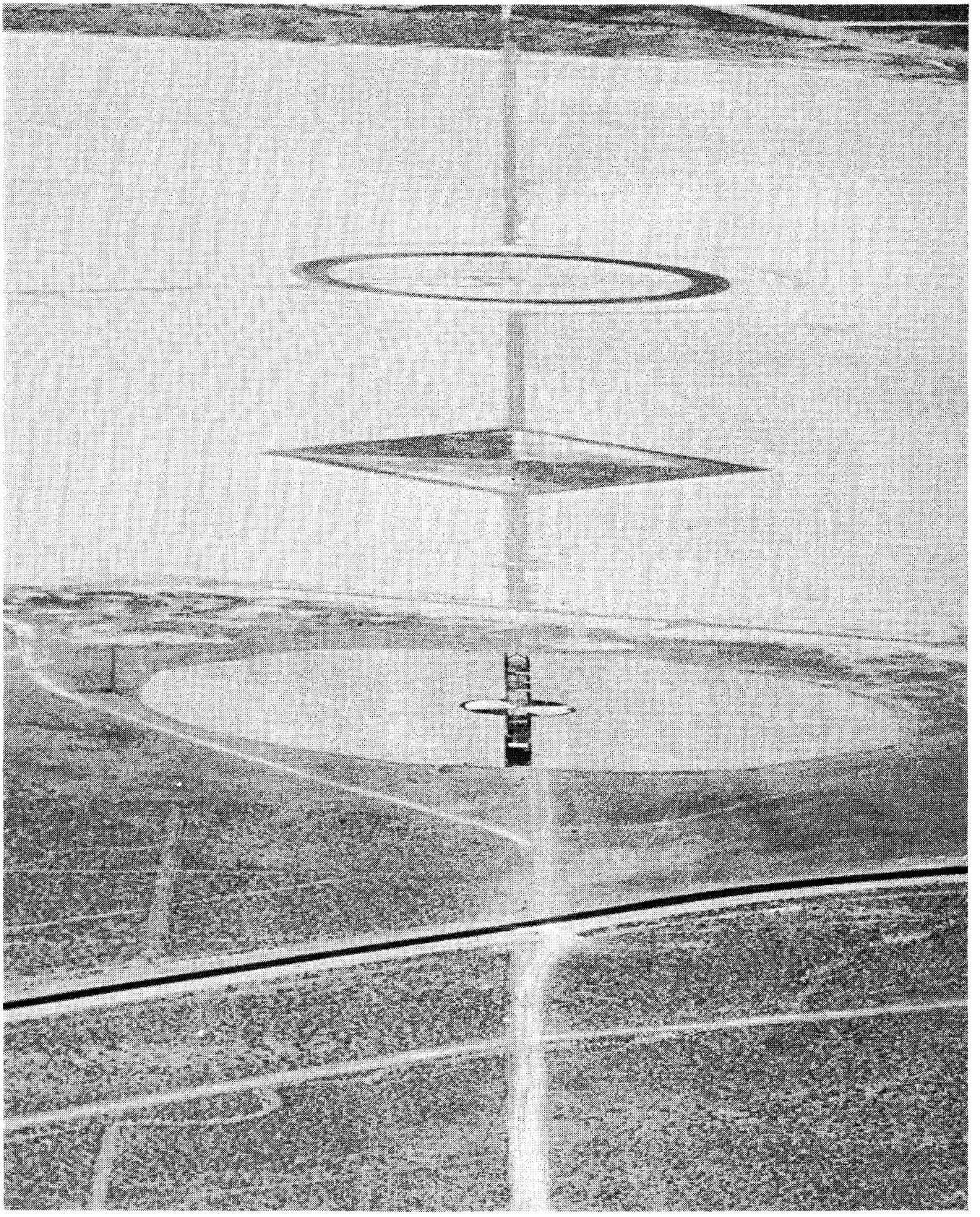


Figure 2-2. Aerial View of Hard, Reb, and Main Lake Targets

Table 2-1. Target Characteristics

Target	Coordinates	Elevation (ft)	Area (sq ft)	Surface Characteristics
Main Lake	37° 50′ 37″N 116° 43′ 44″W	5331	385,000	Dry lake bed
Reb	37° 50′ 19″N 116° 43′ 39″W	5331	125,000	Dry lake bed with NW and SE triangles oiled
Hard	37° 50′ 01″N 116° 43′ 34″W	5335	438,000	Concrete, 1 ft thick, 4000-psi strength, 750-ft diameter
Mid	37° 46′ 56″N 116° 42′ 40″W	5364	1,500,000	Desert turf with checkerboard pattern of 100-ft squares
Pedro	37° 42′ 58″N 116° 41′ 12″W	5371	Can be defined as required	Dry lake bed
Antelope	37° 41′ 13″N 116° 40′ 24″W	5360	272,600	Dry lake bed

SECTION 3

RANGE OPERATION

GENERAL

Successful test operations at TTR depend on the integration of individual instruments, equipment, and personnel into a functional system that yields all required test data. The following overview of this integrated function, as applied to a typical air-drop test, is given as an aid in understanding how the Range conducts these operations. The example is only one of many test configurations available.

The test operation described in the following paragraphs and depicted in Figure 3-1 is a typical sequence for an aircraft-delivered gravity bomb with approach and release directed by a ground-based test controller.

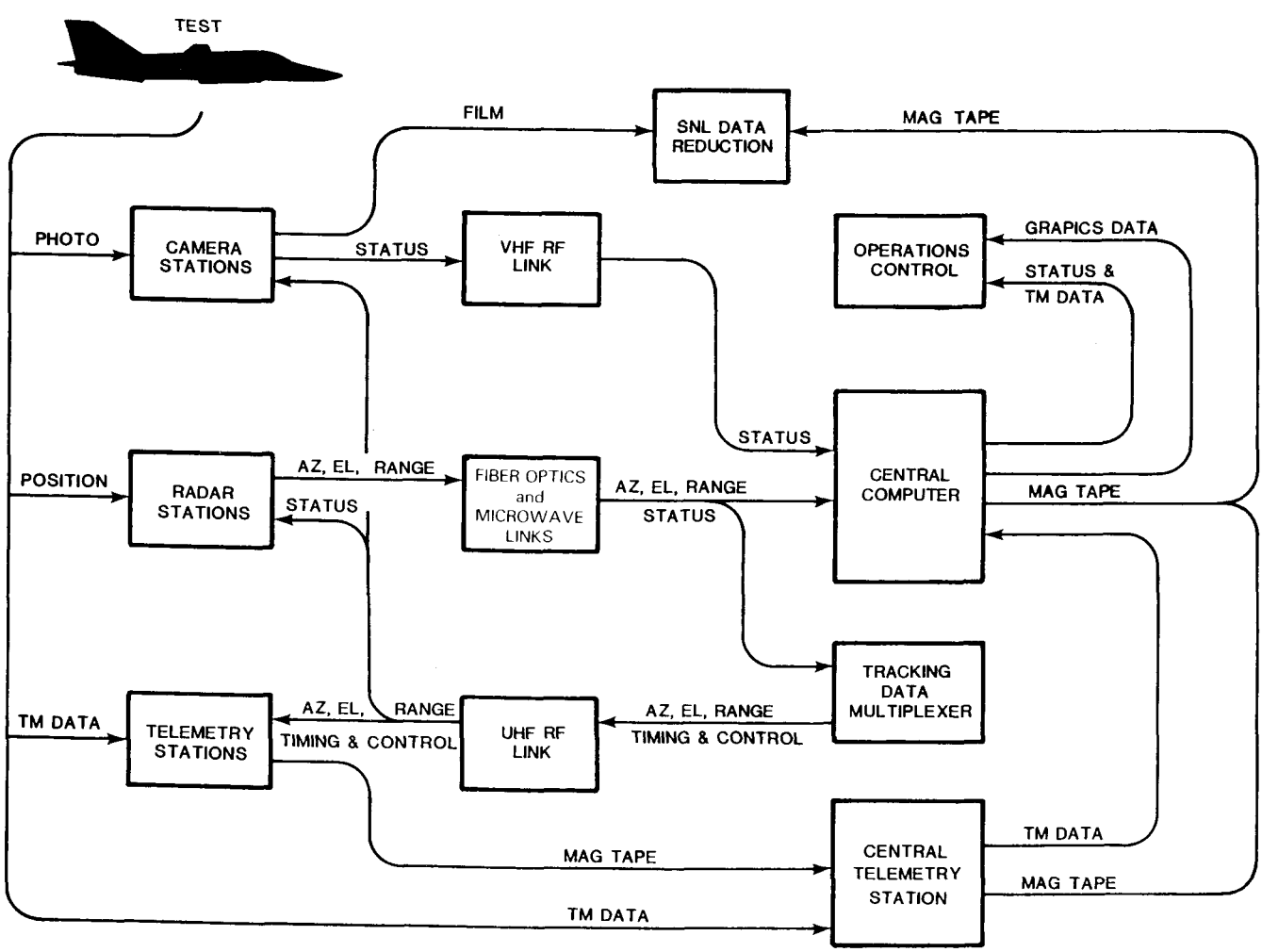


Figure 3-1. Functional Block Diagram, TTR Operations

First contact with the delivery aircraft is by ground-to-air radio from the TTR Control Center. The aircraft commander informs the test controller of his course heading, altitude, and expected arrival time at the point where the test run will begin. The controller then transmits the aircraft position data to all active radars to aid initial target acquisition.

The first radar station to acquire the delivery aircraft immediately transmits the position data via fiber optic lines and microwave to a centrally located multiplexer. The multiplexer combines the data with information it may receive from other radars and applies the output to the Range Tracking Vector Translation System (TVTS). The TVTS transmits the raw positon data over a UHF link to all radars, optical tracking mounts, and telemery stations equipped with TVTS controllers. Each controller calculates the acquisition vectors to the delivery aircraft from its specific location, then automatically points the tracking instrumentation in that direction. When acquisition is accomplished, tracking station operators assume individual control and track independently for the remainder of the operation, using the TVTS again only if a target track is lost. The TVTS output is used continuously by the telemetry stations to point their antennas, and by optical trackers to control camera focus throughout the test.

As shown in Figure 3-1, the radar tracking data also are transmitted to the Central Computer facility in the Operations Center. The computers analyze the data in real-time and also record it on magnetic tape for posttest processing. The real-time tracking data, including target position, altitude, velocity, heading, and glide slope, are presented on an interactive CRT graphic system used by the Range control personnel to assure that correct test flight parameters are achieved while observing all Range safety requirements.

As the aircraft controller vectors the test aircraft through its delivery profile, the TTR test director, test project engineer, and Range safety officer monitor the graphic plot, real-time analysis of telemetered data, and status of all tracking stations, provided as output from the computer facility. When all displayed data indicate that test requirements are being met, the unit is cleared for delivery. Both the test director and safety officer maintain abort capability until the bomb is actually released.

Upon completion of the test, a limited data quick-look capability gives test personnel an opportunity to view video tapes, tab runs, strip charts, and course and trajectory plots. Final data reduction for the test is usually performed either by Sandia National Laboratories in Albuquerque or Livermore, or at other using agency's facility.

TTR recovery crews, equipped with trucks, mobile cranes, winches, backhoes, and other appropriate equipment, locate and retrieve the expended test vehicle for posttest analysis, when required.

CONTROL CENTER

Located on the fourth floor of the Operations Center building, the Control Center (Figure 3-2) is the focal point of all Range test functions. Large, outward-sloping windows provide 360° vision from the Center. Miniblinds and rheostat-regulated lighting control light levels. Operators' consoles are grouped functionally for maximum efficiency.

Console positions in the Center are provided for a test project engineer, test director, safety officer, camera controller, and Range communicator. All console positions have telephone and radio sets for both on-Range and remote communications. Additionally, all positions have closed-circuit TV (CCTV) receivers with input video provided by CCTV cameras mounted on and boresighted with radar antennas and at other strategic locations on the Range. Console locations and equipment are laid out as shown in Figure 3-3.

The Range test director conducts all test operations from this center, except artillery and earth-penetrator firings, which are controlled on-site. However, even on-site-controlled tests are coordinated

through the Control Center. The test director is aided by the aircraft controller, camera controller, communicator, and on hazardous tests, by a Range safety officer. Located on the test director's console is a set of switches that control the aircraft release tone enable circuitry, test-abort system, and command destruct system. The director also has hotline telephone service to Nellis Air Force Base and direct radio links with other facilities participating in test operations for emergency use.

The Range safety officer's console contains communications and video equipment identical to the test director's station, including the test-abort and command-destruct systems. The safety officer also monitors the graphic plotting system to observe test vehicle and aircraft line of flight and other space position data.

Figure 3-2. Interior View, Control Center

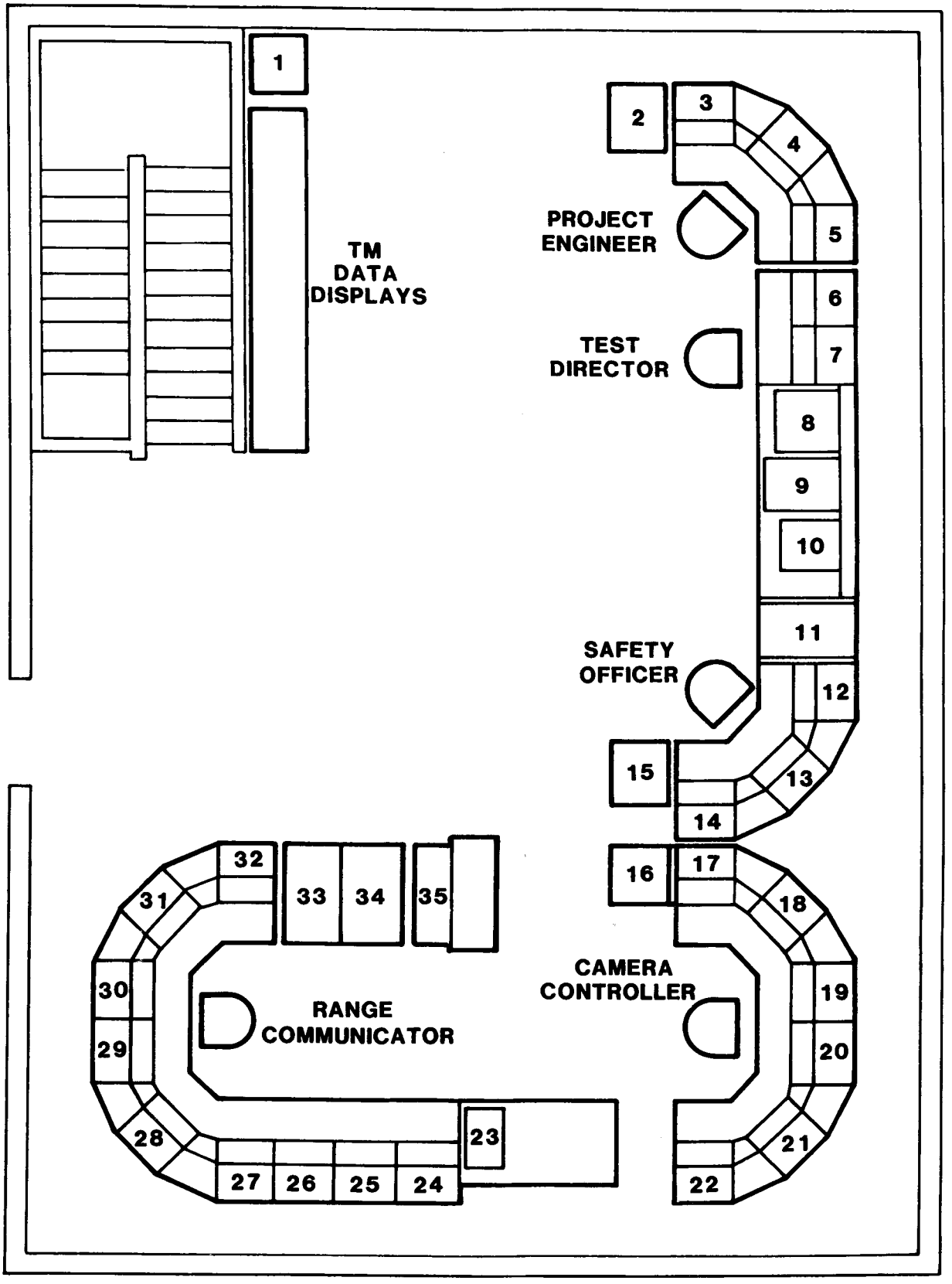


Figure 3-3. Control Center Console Layout (1 of 2)

1. Video Tape Recorder (VTR) and Weather Chart Recorders
2. CCTV Monitor
3. Range Communications Panel
4. Telephone Panel, Communications Net Receiver, and Remote Control for VTR
5. Dual CCTV Monitors and Test Abort Panel
6. Command Transmitter Panel and Communications Panel
7. Base Unit and Hard Copy Device, Tektronix 4081 Graphics System
8. 4081 Graphics Terminal
9. Graphics Map Select System
10. Tektronix 618 Terminal
11. Command Transmitter Panel and Communications Panel
12. Dual CCTV Monitors, Telephone Panel, and Remote Status Panel
13 Communications Panels
14. Tektronix 4031 Printer
15. LaserFax Weather Satellite Recorder
16. Remote Camera Controls
17. CCTV Monitor
18. Dual CCTV Monitor, CCTV Select Panel, Timing Display (IRIG–B), and Remote Status Panel
19. Tracking Controller, Camera Operations Control, Communications Switch, and Telephone Select Switch
20. Cinematographic Light Intensity Translator and Microprocessor
21. Ticon Panel and Communications Panel
22. Datamedia Elite 3000 Terminal to Central Computer
23. Not Used
24. Control Center Weather Indicator Panel and Two–Net Land Line Monitor Panel
25. Two–Net Land Line Monitor and Weather Station Panel
26. TTR Log Tape Control, Communications Net Local/Remote Panel, and Remote Monitor Control
27. Dual CCTV Monitors and Local/Remote Base Station Site Selector
28. Hard Target Weather Station Readout, CCTV Select Panel, Remote Status Panel, and Communications Panel
29. Dual CCTV Monitors, Timing Display (IRIG–B), and CCTV Select Panel
30. Airport Weather Readout and Communications Panel
31. 300–ft Tower Weather Readout, Aircraft Guard Channel Radio, and Time Code Generator
32. AMS Radar Control
33. AMS Video
34. Fax Machine

Figure 3-3. Control Center Console Layout (2 of 2)

The camera controller's console contains the instrumentation to control and coordinate all Range optical tracking systems during test operations. From this station the camera controller establishes camera frame rates, start and stop times, shutter openings, and f/stops. The controller also defines critical parts of tests requiring special photo coverage, then transmits these data over the RF Camera Net to tracker operators. The controller can start and stop any or all cameras on the net, although most are controlled by individual operators. A computer-based system with remote sensor establishes light exposure values and computes f/stops or shutter angles and other pertinent photographic data for each optical tracker in use.

The Range communicator's console is connected to all Range radio nets: HF, UHF, and VHF ground-to-air radio; the Air Force guard channel; and Net 12 from the Nevada Test Site. The console also has telephone panels with direct lines to NAFB and the Salt Lake City FAA Air Route Traffic Control Center. The console additionally contains a weather station readout panel with display inputs from various monitoring stations on the Range. A transponder interrogation radar provides locations of aircraft on or adjacent to the Range.

COMMUNICATIONS SYSTEM

The Range has a fully integrated communications system of ground-to-ground and ground-to-air links using both RF and landline equipment that assures full support of test projects, Range administration, and emergencies. Access to the communications links is available to visiting test personnel.

In addition, the Operations Center contains designated areas where visitors may monitor the test communications nets. Key personnel, such as project engineers, test engineers, and controllers, may be assigned a console or an area with a remote communications package for test operations.

Ground-to-Air Nets

The primary purpose of the ground-to-air system is to communicate with delivery aircraft during air-launched test operations. All ground-to-air nets consist of multiple channel selections: UHF, VHF, and HF single-sideband equipment. Fixed, mobile, and portable radio units are available, as are hand-held pocket pager units that simultaneously monitor two ground-to-air nets with priority on the primary net.

Although all the ground-to-air equipment is multichannel, normal TTR operating frequencies are listed in Table 3-1.

Table 3-1. Assigned Ground-to-Air Frequencies

Band	Frequency	Function
UHF	384.800 MHz	Primary
UHF	257.000 MHz	Secondary
UHF	243.000 MHz	Guard
VHF	118.700 MHz	Primary
VHF	122.800 MHz	Secondary
VHF	121.500 MHz	Guard
HF	8964 kHz USB	Daytime
HF	4600 kHz USB	Nighttime

The Range VHF and UHF equipment have primary and secondary assigned frequencies. Some tests involving multiple aircraft require the use of both frequencies. Also, the secondary frequency provides a backup in case of equipment failure. The use of test aircraft with HF capability is encouraged as an additional operational option and backup system.

Depending on the altitude of the test delivery aircraft, the VHF and UHF radios are reliable up to ~200 mi from TTR. When the aircraft descends to lower altitudes, the effective range decreases and may become spotty because of the terrain profile. When aircraft have HF equipment, communications up to 1000 mi can be obtained. The HF single-sideband is also an effective communications link with aircraft flying at low altitudes over uncertain terrain profiles.

Functional characteristics of the UHF, VHF, and HF systems are as follows:

a. UHF System

Both primary and secondary systems are AN/GRC-171 multichannel transceivers. Each of the four units has 7000 channels with 25-kHz spacing. The transceivers are connected to all consoles and monitors. All have log-tape recording with time annotations and phone patch capability.

b. VHF System

Both primary and secondary VHF systems are Model VHF-400 multichannel transceivers. Each of the four units has 7000 channels with 25-kHz spacing. The transceivers are connected to all consoles and monitors. Both systems have log-tape recording with time annotations and phone patch capabiltiy.

c. HF System

The HF transceiver is a Northern Radio Co. Model N850/N860. The single-sideband unit has lower and upper sideband capability with 150 W PEP RF power, and a frequency range of 1.6 to 18 MHz. The HF system is also connected to all consoles and monitors and has phone patch capability.

The HF system has a conventional phone patch system that can be controlled by a radio operator. Also connected to the HF system is a Baron Communications Model RT-13 automatic telephone interconnect switching system for reliable long-range signalling. It processes calls from the HF/SSB and VHF mobile radios to a dedicated telephone number (phone patch), as well as calls between the HF/SSB and VHF mobile radios through a cross-patch, without requiring the aid of a radio operator.

Ground-to-Ground Nets

Voice communications between individuals at remote locations on the Range and the Control Center and the Administration building use the Sandia net. This is a VHF/FM system with a maximum range of ~100 mi. Mobile, hand-held, and portable radio units are available and should be requested from the test director in advance of need.

The VHF/FM system incorporates an autopatch net that gives users in remote areas of the Range the capability to interconnect directly to FTS and commercial telephone service. Also, an off-range calling party may dial an autopatch number and communicate directly with field users on the Range. The remote autopatch radios are assigned as needed.

Special point-to-point communications systems are available to accommodate special test requirements. These systems are used when test conditions require users to be hundreds of miles apart. Pretest notification is required and is to be coordinated with the Test Director and the Radio Laboratory.

Table 3-2. Ground-to-Ground Nets

Communication System	Net	Purpose
HF		Sandia operations, communications with USAF, military, and state emergency nets
VHF/FM	Sandia	TTR operations, test countdown
	Autopatch	TTR operations, telephone patch
	Operator C	Pager-type monitor, ground-to-air links
	Security	Security and emergencies
	REECo	Range crafts support
	Camera	Camera operations, routine tasks
	Nevada/EMS net (Medical)	Medical emergencies
	Nevada State Patrol and Mutual Aid	Security, emergencies
	Nye County Sheriff	Security, emergencies
	USAF Fox 2/Fox 4	Operational, emergencies
	USAF Disaster/Crash	Emergency
	Net 12 Public Health	Operational, emergencies
Landlines	TM	Telemetry operations, routine tasks
	Test Operations	Range operations
	Ordnance	Area 9 operations, routine tasks
	Edwards AFB/Point Mugu	Operational information between TTR, Edwards AFB and Pacific Missile Test Center
	PA	Operations, information, telephone paging
	Radar	Radar operations, routine tasks

RF Usage Conditions and Regulations

Certain conditions and rules must be observed by visitors or users who wish to use their own communications equipment on TTR. Prior written approval by the Range Manager is required before any RF equipment can be used on the Range. In emergency situations threatening to life or property, visitors are permitted to operate their communications equipment, but must notify TTR Operations or Security as soon as possible. Section 7 contains information on how to obtain RF-use approvals.

TTR/NAFB OPLAN Response to Aircraft Accidents

Emergency response teams from TTR will provide paramedical, security, and communications services at aircraft crash sites on Range. Complete responsibilities and procedures are outlined in NAFB OPLAN 355-1 and TTR Emergency Procedures.

Sandia Navigational Air System

A low-frequency radio navigation beacon at TTR aids aircraft during their approach and landing under adverse weather conditions. The facility is FAA-approved and approach plates are available. The beacon transmitter frequency is 278 kHz, and the call sign is XSD.

Emergency Communications

All radio nets at TTR can provide support for emergencies. The available nets and the type of support each can provide are as follows:

243.0-MHz Guard Channel provides direct communications with military aircraft for safety, airspace control, and emergencies. It is log-taped and monitored 24 h/day.

121.5-MHz VHF Guard Channel is used for emergencies and emergency locator transmitter (ELT) alarms. It is log-taped and monitored 24 h/day.

The Nevada State Patrol and Mutual Aid net provides direct communications to the Nye County Sheriff's Office and the Nevada State Highway Patrol, for safety, security, and emergencies. This channel is monitored 24 h/day, but not log-taped.

The EMS net is a direct communication link between the TTR paramedic and the hospitals and doctors in Nevada and California. The radio is installed in the TTR ambulance and is not log-taped.

USAF HF 4742-kHz USB is a direct link to NAFB and to aircraft with HF equipment. It is used for safety, airspace control, and emergencies. The net is monitored during Sandia working hours.

The Autopatch Autonet connect systems enable direct connection into the FTS and commercial telephone systems to provide paramedic and emergency response teams with telephone capability. With Autonet connect, any of 10 RF nets may be connected with mobile and hand-held units in the field.

Nevada Civil Defense nets are HF radio frequencies for emergency communications within the state.

Net 12, the Public Health Service net, provides health, safety, and emergency communications.

Direction-Finding Equipment

Portable direction-finding equipment is available to assist in locating aircraft with ELTs operating on any frequency that TTR is capable of receiving. An additional direction finder is located in the Security building.

E-Equipment

E-equipment consists of RF voice scramblers that are used when sensitive voice messages must be sent. General net users and public monitor radios do not have eavesdropping capability. E-equipment is installed in consoles for the range communicator, security dispatcher, and communications lab. It is also installed in vehicles used by communications, security, and medical personnel.

Telephones

Centel Business Systems provides telephone service to the Range. Calls off the Range are routed through an SL-100 remote electronic switch on TTR and then linked by microwave to the SL-100 host switch at DOE Headquarters in Las Vegas. From that point connections can be made to tielines, FTS, and the commercial phone network. Several Autovon circuits are also available.

Tests in process can be phone-patched to users in a listen-only mode to monitor voice communications between the TTR controller and aircraft commander. Patches may also be made through the FTS and commercial telephone systems, and a two-way phone patch is available on all ground-to-air links.

Services generally available include:

FTS, incoming and outgoing

Access to commercial telephone services

Secure telephone for classified conversations

Autopatch net to allow VHF and HF radio access to telephone system

Conventional phone-patch capability for VHF, UHF, and HF radios

Facsimile service

Secure data line to Sandia National Laboratories, Albuquerque, which provides access to SACNET for transmission and reception of classified messages

COMPUTER FACILITY

Equipment

The Range Central Computer Facility (Figure 3-4) consists of two Perkin-Elmer 8/32D computers with shared peripherals. Figures 3-5 and 3-6 define system function. The 8/32D computers have full 32-bit parallel architecture with 1024 kbytes of 750-ns core memory, floating point hardware with single- and double-precision arithmetic for up to 15-digit precision and 8 sets of sixteen, 32-bit general purpose registers. Peripherals currently include a 300-Mbyte disk, two 80-Mbyte disks, three 9-track magnetic tape machines, two 600-line-per-minute printers, an electrostatic printer/plotter, and 16 user terminals. All peripherals are on bus switches to allow rapid reconfiguration of each computer.

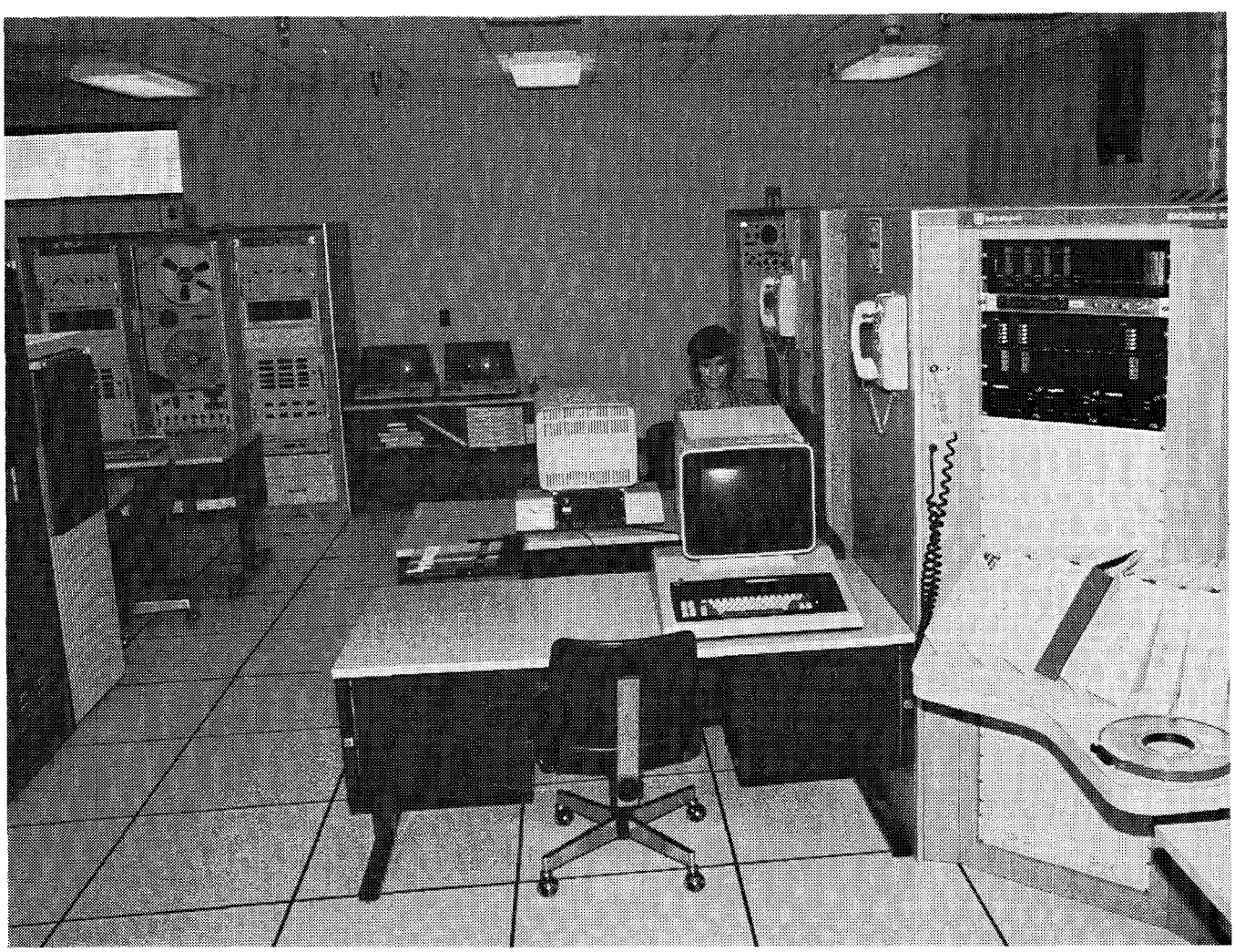


Figure 3-4. Central Computer Facility

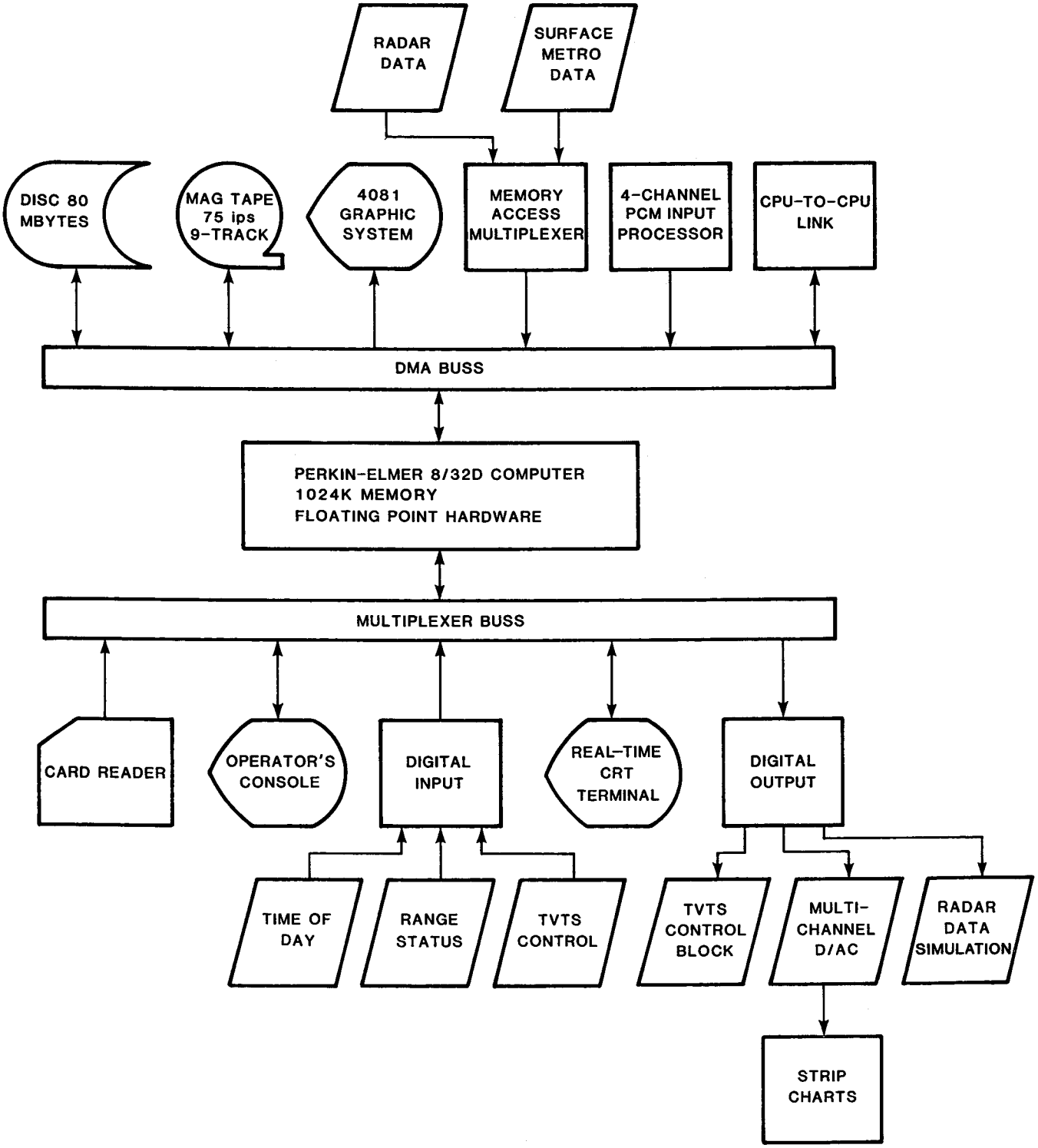


Figure 3-5. Functional Block Diagram, 8/32 Computer Real-Time Operation

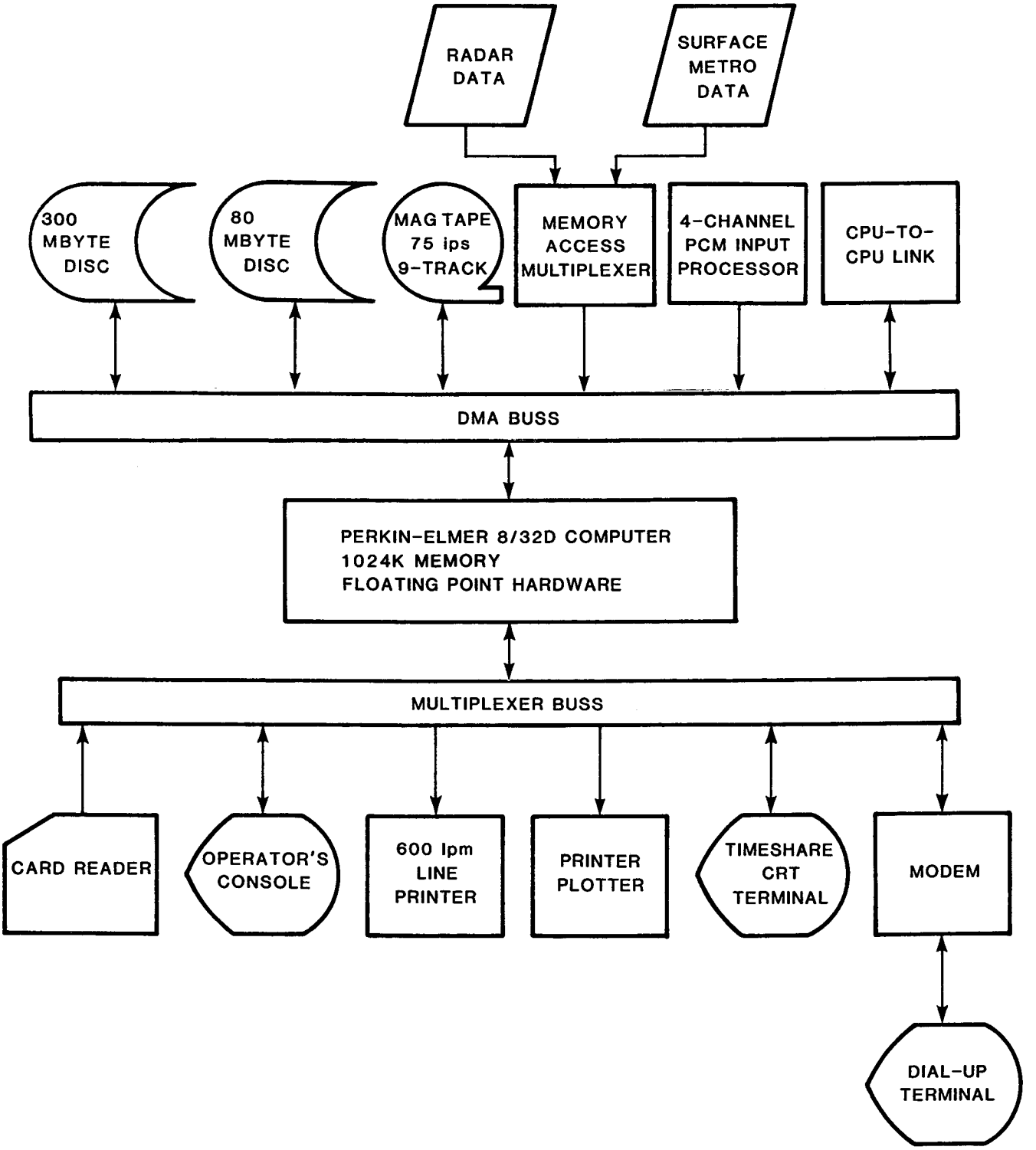


Figure 3-6. Functional Block Diagram, 8/32 Computer Time-Share Operation

A real-time program, written in FORTRAN and assembly language, is run on one computer. The second computer supports the posttest data presentation and software development. Either function can be run on both computers, providing operational redundancy.

The 8/32D computer runs under control of the OS/32 Multi-Terminal Monitor (MTM) operating system that supports a multiprogramming capability for up to 255 user tasks written in FORTRAN, BASIC, or assembly language. The MTM option provides a time-spliced interactive programming capability for up to 16 concurrent terminal users.

Sandia-designed interfaces include five radar data input controllers, a four-channel, high-speed telemery PCM data input controller, a meteorological input controller, an IRIG-B time-of-day interface, and a range status input interface. Output devices include a network of alphanumeric CRT terminals, two CRT graphic display stations, and a multichannel digital-to-analog converter (DAC).

Real-Time Program

The real-time program performs specific functions for acquiring test data, recording it in mass storage, and displaying it for test control. Tasks are grouped by priority and are executed on time- and event-triggered interrupts. Range data are formatted and displayed in real-time on up to eight alphanumeric CRT terminals for use by the test director, safety officer, and project engineer.

Radar tracking data is translated to a common origin, and trajectory parameters are calculated and passed to the two graphic CRT display stations. Telemetry PCM data is decommutated, scaled to engineering units, and displayed in real-time on alphanumeric CRT terminals and up to 24 strip-chart recorder channels. Radar data is read and logged on magnetic tape at rates up to 100 frames per second, and meteorological data is read and logged once per second

Data on the displays are updated once per second and several options, such as radar selection and range in feet or meters, may be selected at any time. The telemetry display allows for 36 different sets of data pages with up to 16 channels per page. Page formats are defined prior to the operation.

Posttest Data Presentation

The posttest data presentation system has been configured to quickly handle a limited amount of data. The system is a collection of program modules that may be executed individually or linked together automatically to perform a prescribed analysis and output. Input program modules select and scale data channels to engineering units and write results into a TTR Standard Data File. Analysis program modules read the TTR Standard Data Files, perform the analysis, and write the results onto another TTR Standard Data File. Output program modules list the data in tabular form, plot it on X-Y plots, or write it onto a digital magnetic tape for use at another facility. Several major program modules described below typify the existing capability at TTR.

Program REFO

This program module reads the raw radar digital tape and makes a separate file containing time, azimuth, elevation, range, and status for each radar and a file for the meteorological data.

Program RADAR

This program module reads a REFO radar file, calculates trajectory parameters from a specified origin, and writes the results onto the RADAR file. Trajectory parameters include target position in X,Y,Z; A,E,R; or LAT, LON, HGH; target velocity; target acceleration; azimuth heading angle; tangential angle; and status.

Program MERGE

This program module merges selected parameters from one file with selected parameters from another file and writes the results onto the MERGE file. Input files must have a common time interval.

Program PRINT

This program module reads any standard TTR data file and lists selected data point parameters in tabular form. Up to 10 parameters per data point and 50 data points per page are printed. A summary page is provided at the beginning which describes the data file. An example of a typical output is shown in Figure 3-7.

Program PLOT

This program module reads any standard TTR data file and plots any two parameters. Plot limits may be specified or self-scaling, additional labeling may be added, and up to three dependent parameters may be plotted against the common independent parameter as long as they have the same scale. An example of a plot is shown in Figure 3-8.

Telemetry Data Programs

There are four program modules that process telemetry data. The first module defines each data channel and assigns it a number. Channel definition includes position in the frame, recycle count, name, units, comments, and scale factor. The next module defines the pages of the real-time PCM alphanumeric display. The third module records telemetry data onto digital magnetic tape, and the fourth module reads this tape and selects up to 16 data channels per pass, scales each channel and writes an output TTR data file. Data from this file can then be printed and plotted.

TTR DATA FILE PRINTOUT
(FILE SUMMARY PAGE)

THIS FILE HAS BEEN PROCESSED BY THE FOLLOWING PROGRAMS:

FILE IDENTIFICATION ---------- HDL STANDARD ATMOSPHERE TABLE
IRIG CODED TIME OF FILE ZERO TIME (ZT) ----- HR MIN . SEC

FILE START TIME (SECONDS RELATIVE TO CODED ZERO TIME) -- 0.000
FILE STOP TIME (SECONDS RELATIVE TO CODED ZERO TIME) --- 0.000

TITLE INFORMATION :

FILE VARIABLES:

NO.	NAME	UNITS	REMARKS
1	ALTITUDE	FEET	
2	TEMP	DEG C	
3	PRESSURE	LB/SQ IN	
4	SOUND	FT/SEC	

FILE SOURCE PROGRAM: HDLTAB FILE ID: HDL STANDARD ATMOSPHERE TABLE

ALTITUDE FEET	TEMP DEG C	PRESSURE LB/SQ IN	SOUND FT/SEC
0.	15.000	14.69583	1117.
1000.	14.133	14.17292	1113.
2000.	11.039	13.66458	1109.
3000.	9.061	13.17153	1105.
4000.	7.078	12.69236	1102.
5000.	5.100	12.22778	1098.
6000.	3.122	11.77778	1094.
7000.	1.139	11.34028	1090.
8000.	-0.839	10.91597	1086.
9000.	-2.822	10.50556	1082.
10000.	-4.800	10.10694	1078.
11000.	-6.778	9.72083	1074.
12000.	-8.761	9.34653	1070.
13000.	-10.739	8.98403	1066.
14000.	-12.722	8.63333	1062.
15000.	-14.700	8.29375	1058.
16000.	-16.678	7.96528	1054.
17000.	-18.661	7.64453	1050.
18000.	-20.639	7.33956	1046.
19000.	-22.622	7.04167	1041.
20000.	-24.600	6.75417	1037.
21000.	-26.578	6.47569	1033.
22000.	-28.561	6.20694	1029.
23000.	-30.539	5.94722	1025.
24000.	-32.522	5.69653	1021.
25000.	-34.500	5.45347	1017.
26000.	-36.478	5.22014	1012.
27000.	-38.461	4.99444	1008.
28000.	-40.439	4.77708	1004.
29000.	-42.422	4.56667	999.
30000.	-44.400	4.36458	995.
31000.	-46.378	4.16944	991.
32000.	-48.361	3.98125	987.
33000.	-50.339	3.80069	982.
34000.	-52.322	3.62639	978.
35000.	-54.300	3.45833	973.
35332.	-55.333	3.40139	971.
36000.	-55.333	3.29722	971.
37000.	-55.333	3.14236	971.
38000.	-55.333	2.99444	971.
39000.	-55.333	2.85417	971.
40000.	-55.333	2.72083	971.
41000.	-55.333	2.59306	971.
42000.	-55.333	2.47083	971.
43000.	-55.333	2.35486	971.
44000.	-55.333	2.24444	971.
45000.	-55.333	2.13889	971.
46000.	-55.333	2.03889	971.
47000.	-55.333	1.94306	971.
48000.	-55.333	1.85139	971.
49000.	-55.333	1.76458	971.
50000.	-55.333	1.68194	971.
60000.	-55.333	1.04792	971.
70000.	-55.333	0.64931	971.
80000.	-55.333	0.40278	971.
90000.	-55.333	0.25000	971.
100000.	-55.333	0.15556	971.
104987.	-55.333	0.12215	971.
110000.	-44.111	0.13139	996.
120000.	-21.778	0.06268	1043.
130000.	0.556	0.04216	1089.
140000.	22.944	0.02926	1132.
150000.	45.278	0.02085	1174.
160000.	67.611	0.01521	1215.
164042.	76.667	0.01346	1231.
170000.	76.667	0.01128	1231.
180000.	76.667	0.00837	1231.
190000.	76.667	0.00622	1231.
196850.	76.667	0.00507	1231.
200000.	70.778	0.00461	1220.
210000.	52.167	0.00338	1187.
220000.	33.556	0.00243	1152.
230000.	14.944	0.00172	1117.
240000.	-3.722	0.00118	1080.
250000.	-22.333	0.00079	1042.
255905.	-33.333	0.00062	1019.
260000.	-33.333	0.00052	1019.

ENCOUNTERED FILL WORD IN RECORD NO. 1

Figure 3-7. Typical Output of Meteorological Data From Program PRINT

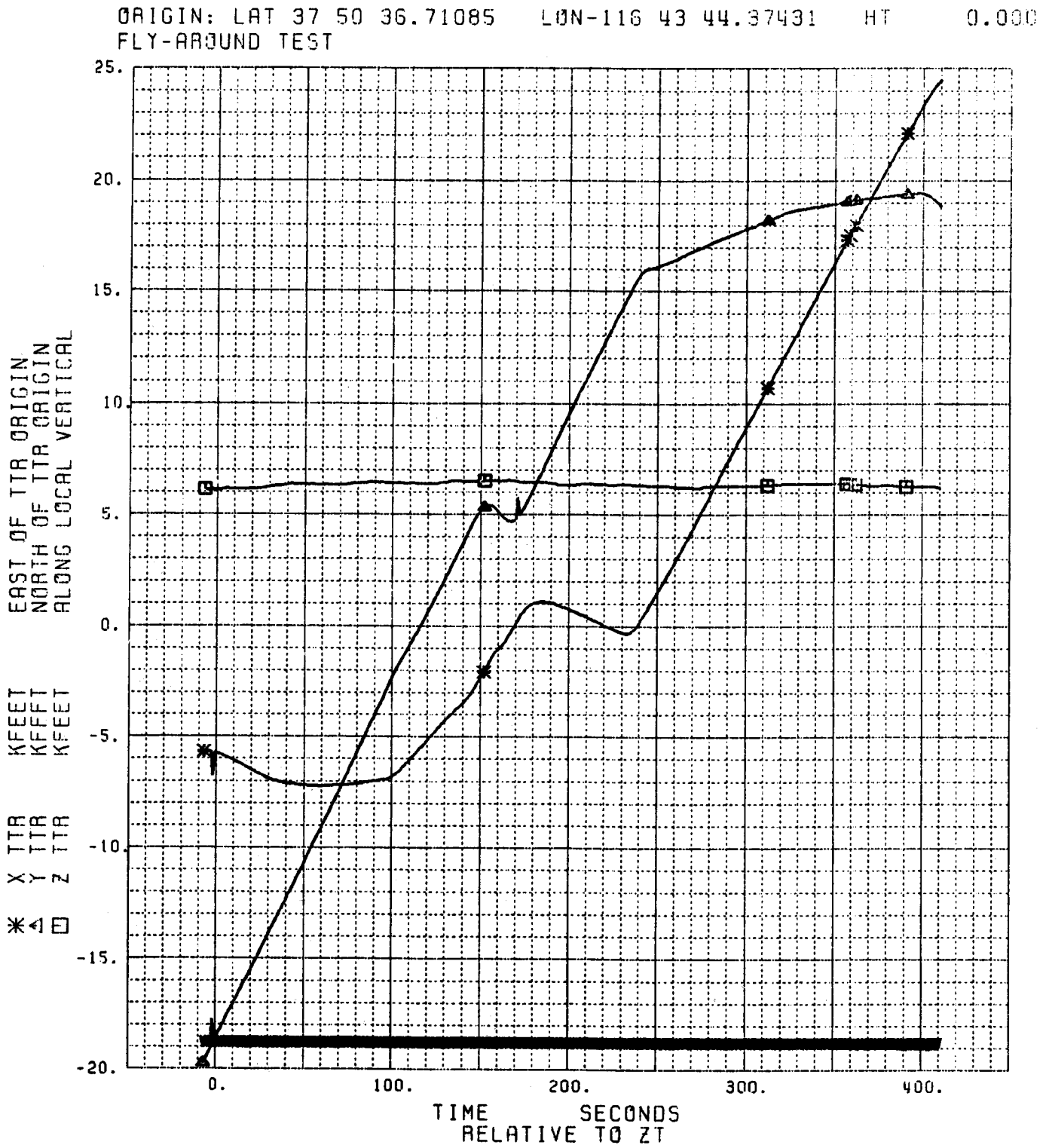


Figure 3-8. Typical Three-Axis Plot Output From Program PLOT

Software Development

The computer facility has the peripherals for in-house or remote software development. There are eight terminal interfaces of which four are connected to answer-only modems. This provides the capability of receiving software development support from Sandia National Laboratories, Albuquerque and Livermore or from other remote locations.

PLOTTING SYSTEMS

Two identical but independent CRT graphics systems and two similar but independent mechanical plotting board systems are used for real-time data presentation.

Graphic Systems

The Tektronix 4081 Graphic Systems (Figure 3-9) have been integrated into the range tracking system through Sandia-designed interfaces and software. Each system has a microcomputer with 64 kbytes of memory and is capable of stand-alone operation. The microcomputer has a 16-bit central processor that supports 16- and 32-bit integer arithmetic and hardware that supports 32- and 64-bit floating point arithmetic.

Each of the systems has a 10-Mbyte hard disk drive and dual 8-in floppy disk drives. The floppy disk provides a convenient means of transferring programs and map files between systems. The graphics

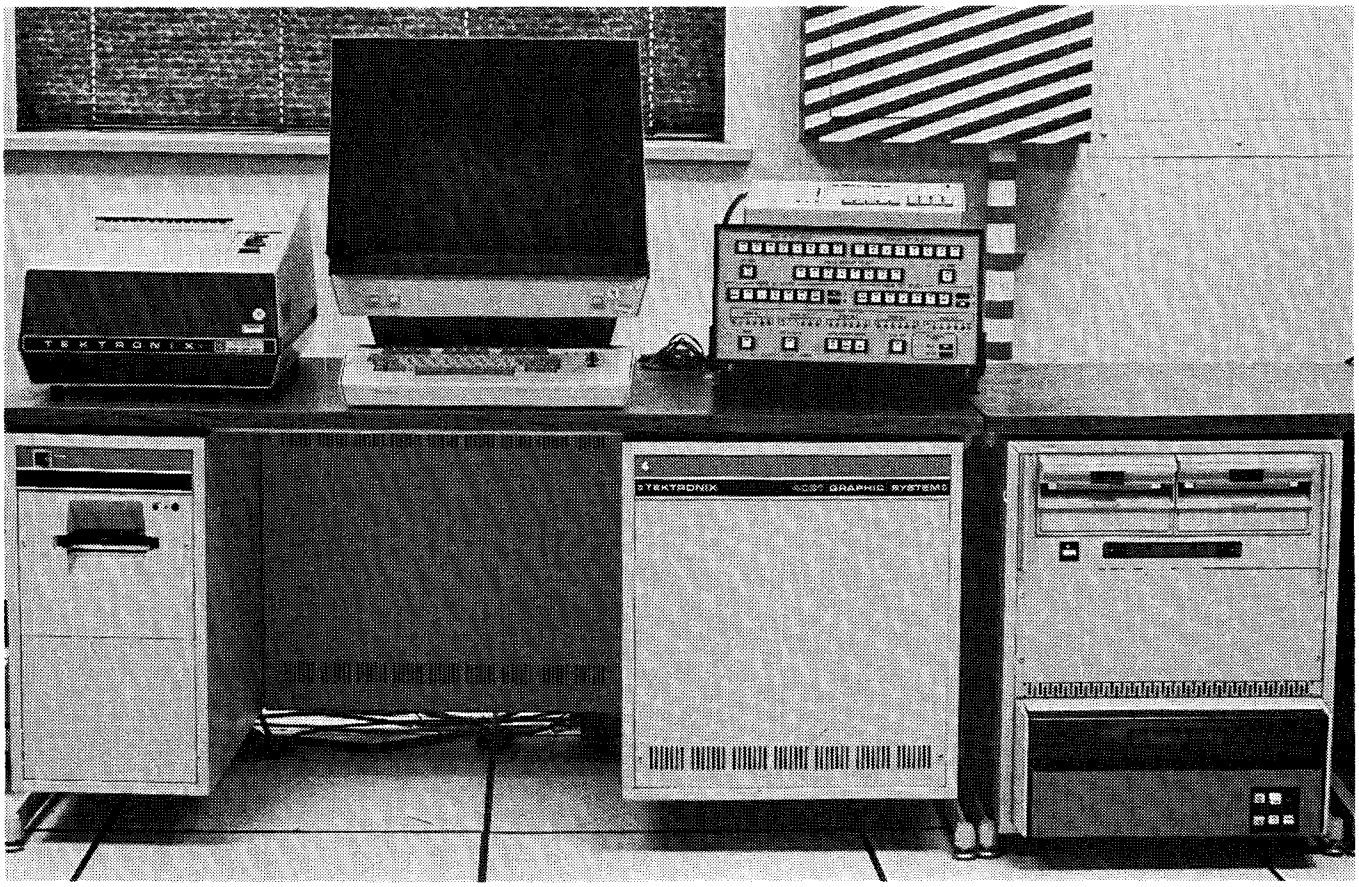


Figure 3-9. Graphic Plotting System, Including Printer, CRT, Keyboard, Map Select System, and Hexadecimal Display

display device is a stroke writer that employs both storage graphics and refresh graphics. In operation, maps are displayed in storage mode. Dynamically changing data such as alphanumerics and target position cursors are displayed in the refresh mode. Each of the two graphic systems can drive three display monitors.

One graphic system, located in the Control Center, primarily serves the TTR test director and test project engineer. The second system, located on the third floor, serves the range aircraft controller or visiting test conductor. Since the systems are identical, but independent, these roles may be reversed or shared to meet test support requirements. Figure 3-10 is a sample of real-time graphics plot in hard copy.

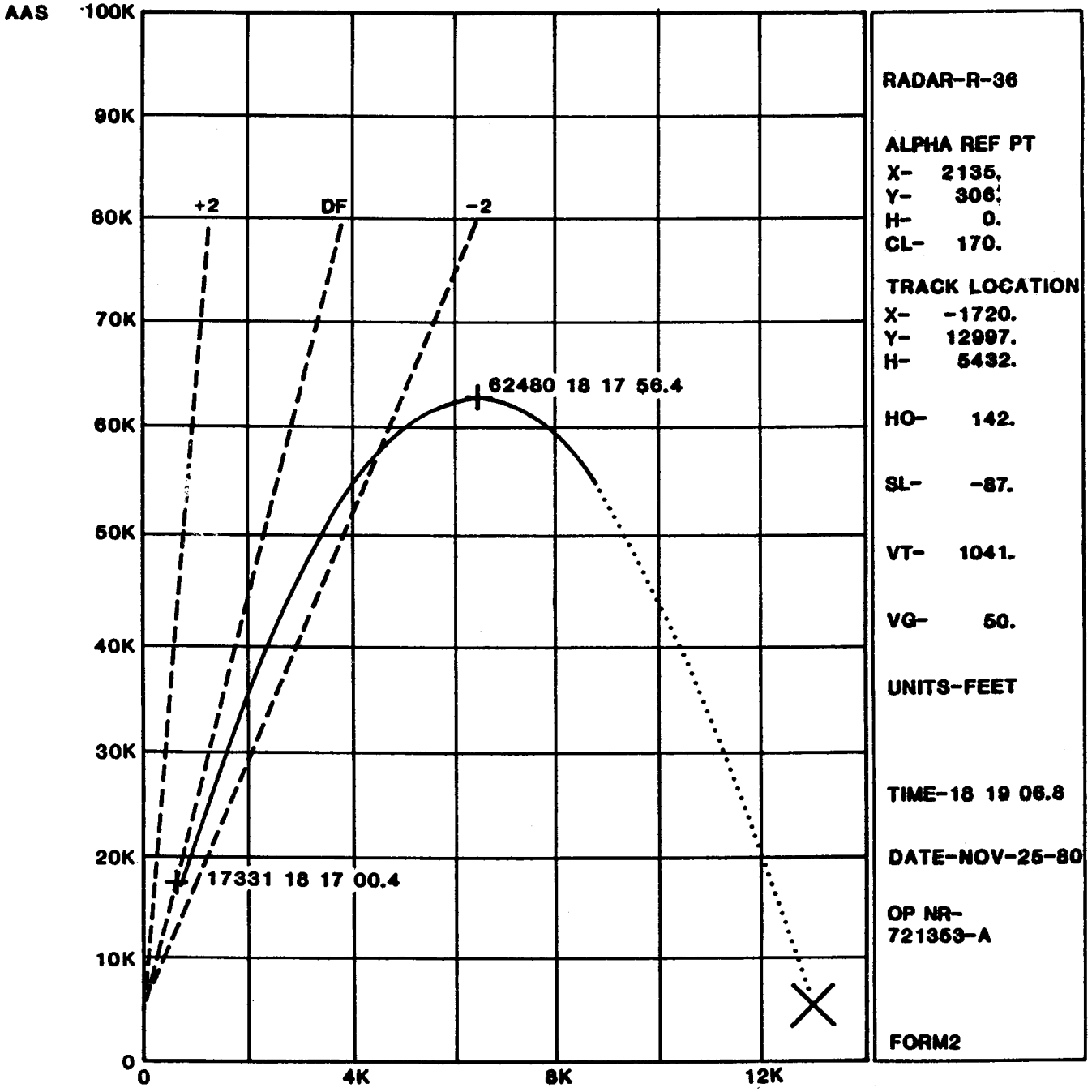


Figure 3-10. Real-Time Graphics Plot, Hard Copy

Graphic Real-Time Program

The graphic real-time program runs under a modified version of the Tektronix Graphics Operating System (GOS). The real-time program allows the operator to interact with the system for map selection, radar source selection, engineering units selection (feet, meters, or nautical miles), trail/no-trail option, and hard copy initiation. The real-time program also controls the high-speed parallel interface that transfers tracking data from the 8/32D computer. The 8/32D also provides a simulation function that allows the graphic systems to plot recorded data files in playback mode. This permits multiple passes on a data set so that the data can be plotted in different viewing environments.

The frame rate and the picture update rate of the graphics system is either 10 per second or 5 per second, depending on picture complexity.

Two sources of radar tracking data can be displayed simultaneously in a two-dimensional mode.

A wind-run option in the program computes and lists wind velocity and direction, based on the radar track of a weather balloon. Meteorological conditions aloft are also listed if the balloon is equipped with a rawinsonde.

Map Generation

Maps are generated on the graphic system in local stand-alone mode. A data base that can be accessed interactively contains range boundaries, restricted area boundaries, tracking station locations, and TACAN station locations. Data items that are unique for a given test, such as predicted X-Y track and run-in lines, are merged with selected elements from the data base to provide a tailored data file. This input file may be scaled and translated by the operator with the zoom and pan capability. When the operator is satisfied with a picture, it may be saved in a library on the hard disk so that a series of different pictures can be created and saved. In real-time mode, pictures and corresponding tracking data transformation constants are retrieved from the library as needed. A calibration utility program verifies the validity of the maps by simulating radar targets along the predicted trajectory. Test parameters for map generation for a specific test are obtained from a Range Instrumentation Order (RIO), a waypoint list, or simply a set of geodetic latitude, longitude, and elevation points defining the required mapping features. Programs on the 4081 system convert the input data into the TTR local coordinate system, and then into a graphics-compatible format.

Plotting Boards

Two modified Milgo Model 2149, 30- × 30-in plotting boards serve as backup or independent real-time displays. One plotting board is in a fixed location in the Plotting and Graphics room in the Operations Center building. The second plotter is mounted in a trailer to provide limited mobile control point capability. Each plotting board is driven by its own microcomputer. A terminal allows the operator to interact with the system to set up scale factor arrays, define radar space points for map calibration, and choose from a number of CRT data presentation formats. Once initiated, the CRT displays tracking parameters alphanumerically and updates them once per second. The plot, however, is updated at a 10-per-second frame rate. A control panel that is scanned by the microcomputer permits the operator to interactively set scale factors and axis rotation, and to select source data from one of five tracking radars.

Input data for the plotting board systems are acquired from the TVTS acquisition system, which is independent of the central computer. The plotting system thus serves as a backup for the graphics system in the event of central computer malfunction. The plotting board systems allow tracking data to be plotted on user-provided maps. Scale factors can be adjusted to meet user map requirements.

TIMING AND CONTROL SYSTEM

An IRIG-B time code, generated at the telemetry master ground station in the Operations Center building, synchronizes all range operations. The time-code generating system is based on a Hewlett-Packard Model 5061A Cesium Beam Frequency Standard that provides the basic stable frequency input to a Datum Model 9110 Time Code Generator. An Austron, Inc. Model 2100 LORAN C Receiver synchronizes the time-code generator with Coordinated Universal Time referenced to the National Bureau of Standards, Boulder, CO. Control functions are inserted in the time code to provide a countdown/countup clock, start/stop and frame rate commands to cinetheodolites, and start/stop signals to all camera stations. Figure 3-11 depicts the standard IRIG-B and Timing and Control (TICON) codes in use on the Range.

Land lines and a radio link in the 400- to 425-MHz band transmit the modified IRIG-B code to all instrumentation sites. Optical instruments and telemetry stations use the modulated 1000-Hz code format directly from the land line or receiver. At each radar site, a Datum Model 9100 Synchronized Time Code Generator reads the incoming serial time, compensates for propagation delays, and outputs parallel time data and pulse trains to synchronize radar data with range time. Timing offsets in data records using this distribution system are shown in Figure 3-12.

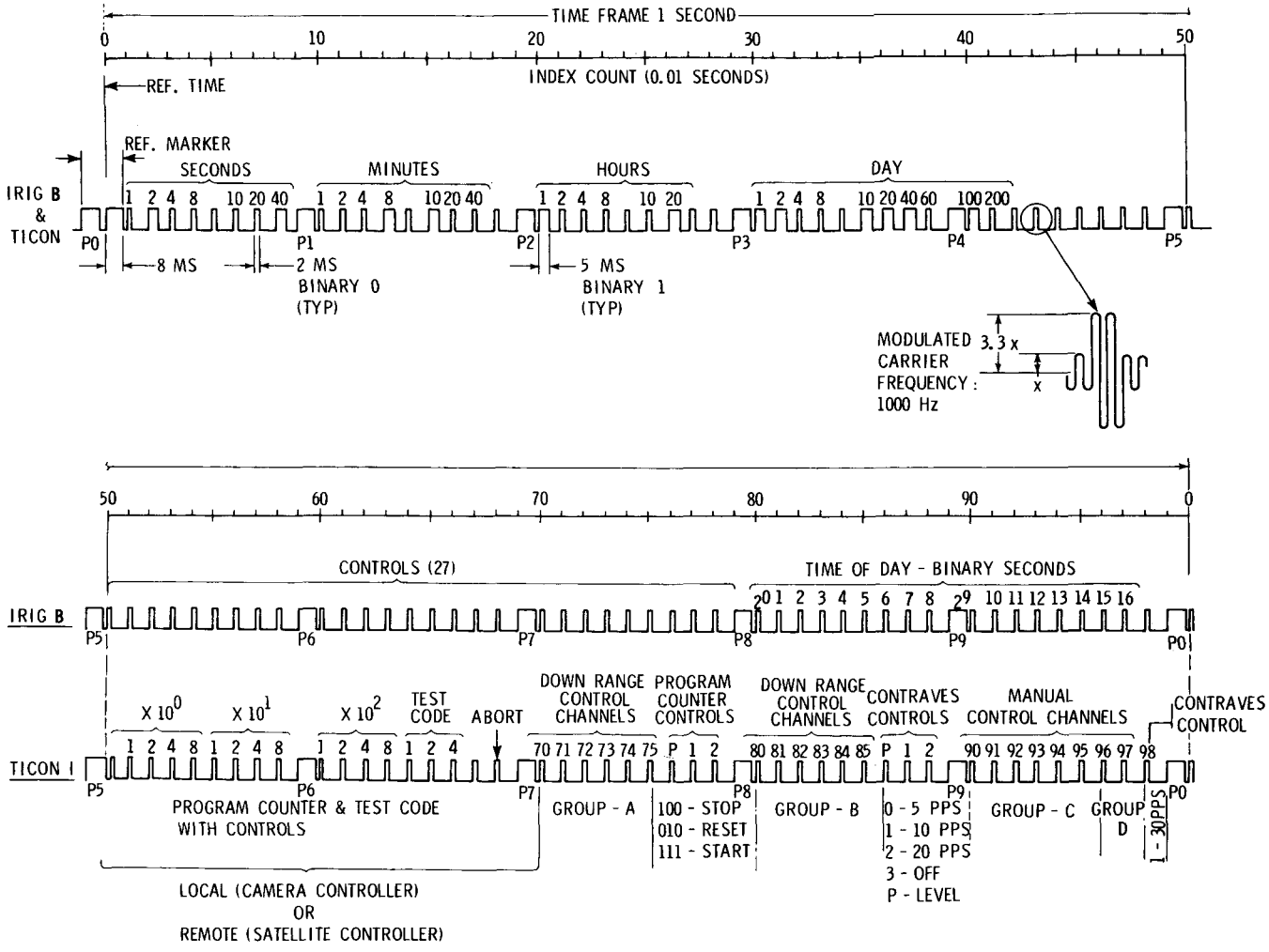


Figure 3-11. Timing and Control (TICON) and IRIG-B Range Time Codes

When a higher resolution time code is required by a specific instrumentation site, it can be generated on-site by a time-code generator sychronized to the incoming IRIG-B range timing. IRIG-A, generated by the master time-code generator, can be transmitted over a second RF link in the 400- to 425-MHz band when required.

A 100-W transmitter, tunable over the 400- to 430-MHz band, can send command/control/destruct signals to test vehicles throughout the range-operating area. A matrix switching system and an IRIG tone generator provide selectable tone combinations. Complex time multiplexers or digital encoders are not available, but customer-furnished units can be accommodated.

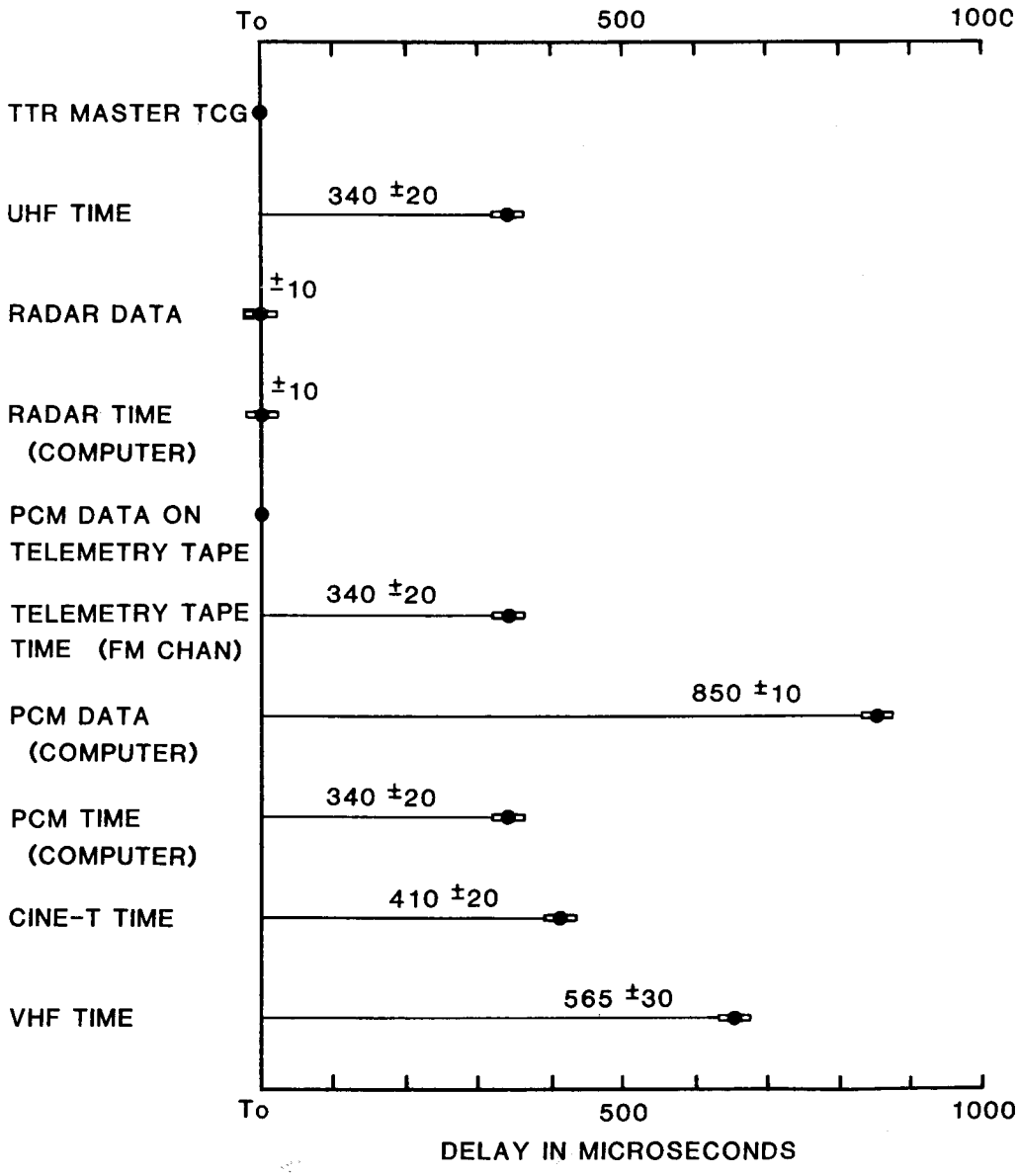


Figure 3-12. Timing Distribution System and Data Handling Delays

TRACKING VECTOR TRANSLATION SYSTEM

The Tracking Vector Translation System (TVTS) acquires, processes, and distributes radar data to aid other tracking instrumentation in target acquisition. The functional block diagram in Figure 3-13 depicts simplified operation of the TVTS.

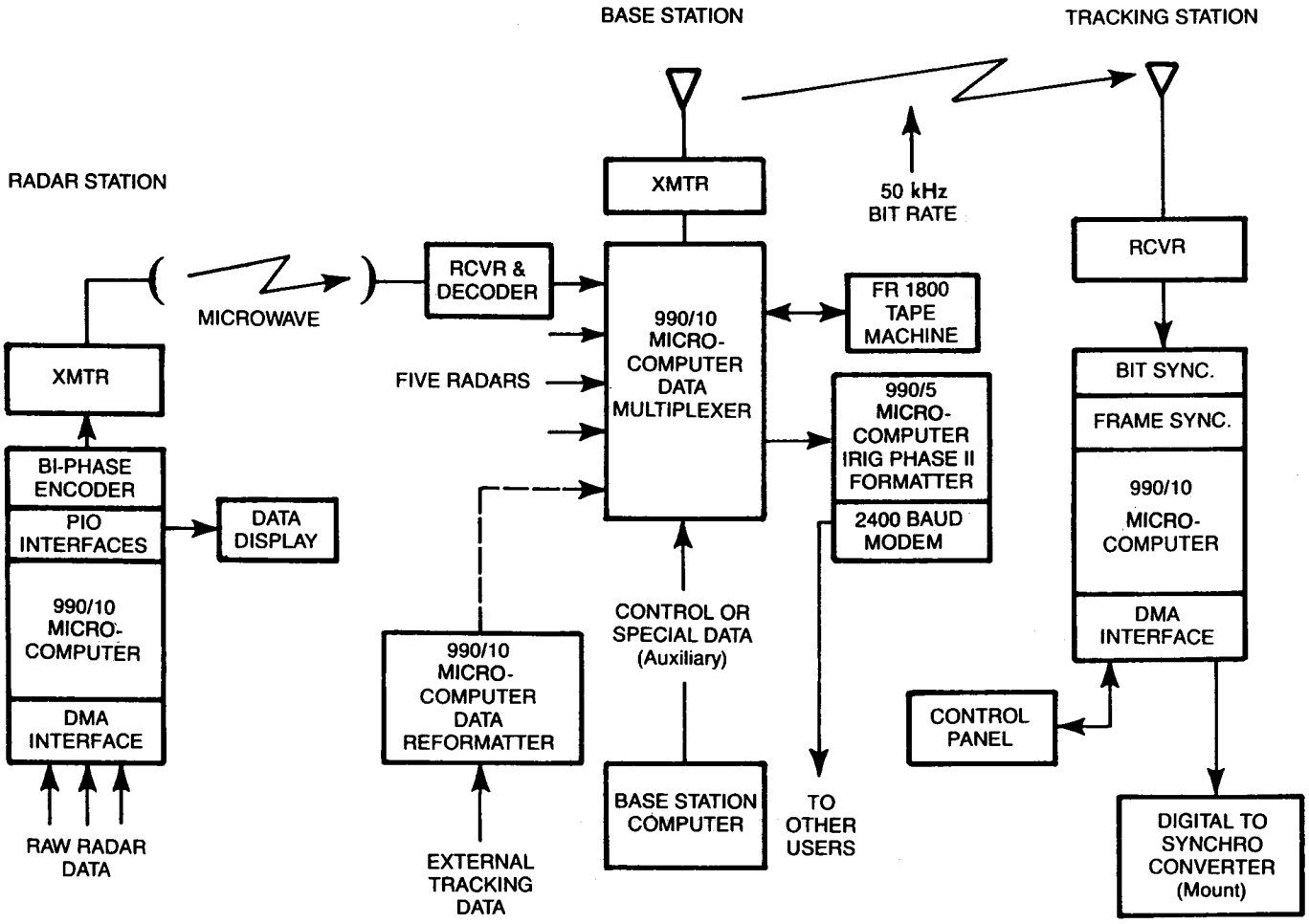


Figure 3-13. Functional Block Diagram, Tracking Vector Translation System

Sandia-modified Texas Instruments' Model 990/10 microcomputers have been used exclusively to perform this function. At each radar station, a 990/10 samples target information, formats the data into a 50-kbit serial data stream, and relays the data to the Operations Center via microwave link. At the Operations Center a 990/10 multiplexes tracking information from up to five radars and applies input controls or special tracking data from the Central Computer facility. This microcomputer outputs the data in a serial 50-kbit stream, which is distributed to all tracking stations over a single RF carrier. At a receiving station, another 990/10 decodes the multiplexed information and calculates the azimuth, elevation, and range to the target vehicle referenced to the station location.

Spherical transformation equations are used to calculate target location which is accurate to within one foot of those calculated with a geodetic formula. Each tracking station can select any one of the five radars as the source of its tracking data, allowing multiple targets to be tracked simultaneously. The selection can be made manually at the tracking station or automatically from the Operations Center. In either case, the radar data must be valid before the tracking computer will use the data. This automatic radar selection also allows selection of up to three radars on a priority basis as the source of data for a

tracking station. In this mode, the tracking stations will automatically select the highest priority radar with valid data for its tracking information.

TVTS modules at each tracking station provide digital readout data, calibration points for setup and alignment of the tracking mount, focus information for optical trackers, and space points for radars.

Another feature of TVTS is an analog magnetic tape machine that records the tracking data from the radars at the Operations Center in real-time, thus providing a backup for the Central Computer's real-time data reduction and recording system. Since all tracking data must pass through the multiplexer and transmitter at the Control Center, this equipment must be operational at all times; therefore a redundant system is used. In the event of hardware failure of the on-line system, the backup system can be placed on-line in a few minutes.

Tracking data from up to two radars can be reformatted to a 2400 b/s IRIG PHASE II data format for transmission to other tracking systems external to TTR. A Texas Instruments Model 990/5 microcomputer is used for this function with the outputs normally connected to the user through a dedicated phone line. There is an additional dedicated land line for transfer of tracking data to Edwards Air Force Base.

Tracking data from sources external to TTR that are not directly compatible with TVTS can be entered into a 990/10 microcomputer, which acts as a special programmable interface to TVTS. This allows tracking stations at the Range to receive acquisition data from other test ranges or locations.

All Range operations are synchronized by using an IRIG-B time code generated in the telemetry ground station located at the Operations Center. This timing signal is provided to all tracking stations by the same RF carrier as TVTS, but on a separate subcarrier frequency.

The TVTS system of distributed processing accomplishes several functions:

It enhances the tracking-control characteristics of the raw radar data by filtering and smoothing techniques. A look-ahead operation compensates for the time involved in measurement, transmission, calculation, and use of data.

It includes corrections for the earth's curvature since the radars and remote stations are leveled with respect to the center of the earth.

It computes tracking vectors 100 times a second to support high-speed tracking mount slew rates.

It permits the use of an unlimited number of remote tracking stations since the target vector calculations are made at each station independent of the other stations. Range operational reliability was substantially improved through the use of this distributed system.

It expands the capacity for independent off-range operations since individual tracking stations perform their own parallax corrections. The system easily adapts to allow direct communications from a radar to the tracking stations and thus establishes local ranges where required.

RANGE SAFETY

The Range Operations Division is responsible for ensuring that all operations at TTR are conducted in a safe manner, consistent with operational objectives and national priorities. To meet these requirements, Range users must consider the safety aspects of their test well in advance of scheduled operations.

The following are minimum safety requirements for tests to be conducted at TTR:

A written safe operating procedure (SOP) is required for all hazardous test units on TTR. This SOP will include a description of the hazards in the unit, procedures to be followed in pre/posttest work on the unit and any information required for explosive ordnance disposal (EOD). It must be approved by TTR management.

A pretest assessment of the risk involved must be made whenever possible. This assessment will include an estimate of the probability of personal injury or property damage. It will be performed by TTR Range Safety personnel but requires considerable input from the Range user.

Operations that present unusual hazards may require review and approval by the Sandia Ad Hoc Test Operational Hazards Committee.

High-altitude rocket tests require detailed trajectory analysis. The analysis is usually reviewed by the Sandia Aeroballistics Project Division prior to TTR Range Safety approval. If a Range user cannot provide this analysis, it can be provided by Sandia's Aeroballistics Projects Division on a reimbursable basis.

Test units that present unusual hazards may be required to include a radar transponder and a command destruction capability. Both the Range Test Director and Safety Officer have test abort and command destruct transmitters on their test consoles in the Control Center.

METEOROLOGY

System

The meteorological data gathering system at TTR consists primarily of two surface weather stations and an upper atmosphere sounding system. Normally, meterological data is gathered and recorded only when it is required by a specific test program. The data gathering system provides the degree of accuracy and resolution defined in Table 3-3.

Weather forecasts for the Range and adjacent areas are obtained from the NTS weather station or from Air Force weather services.

Table 3-3. Metorological Data System Accuracy and Resolution

Measurement	Accuracy	Resolution
Tower Station (3 Levels)		
Wind Direction	±2°	1°
Wind Speed	±1 kn	1 kn
Temperature	±1°F	1°F
Lake Station		
Temperature	±0.5°F	1°F
Dew Point	±2°F	1°F
Pressure	±0.015″ Hg*	0.01″ Hg
Wind Direction	±2°	1°
Wind Speed	±1 kn	1 kn
Radiosonde		
Temperature	±2°F	±1°F
Relative Humidity	±5%	±1%

*0.015″ Hg = 0.5 mb

Ground Stations

The primary surface weather station is located near the Hard Target. It measures windspeed and direction, atmospheric pressure, temperature, and dewpoint. A 50-ft wind tower is also located near the Hard Target. The tower data and the data from the ground station are transmitted by landline to the Operations Control building, where it is recorded by the Central Computer and displayed in both the Graphics room and the Control Center.

An instrumented 300-ft tower, located in the rocket and gun firing area, measures wind speed and direction, and temperature at the 50-ft, 150-ft, and 300-ft levels. These data are transmitted to the Rocket Firing Bunker for display and to the Operations Control building for recording by the Central Computer and display in the Control Center.

Both of the surface stations are equipped with high-accuracy Teledyne Geotech sensors and linear data processors. Their analog data are digitized and transmitted to the Control Center building for decoding, recording, and display.

Any of the surface meterological data recorded by the Central Computer is available for real-time graphic display over the Range closed circuit television system.

Upper Air Sounding System

Balloons are used for determining upper atmosphere wind speeds and direction. When equipped with radiosondes (Figure 3-14), they also measure temperature, humidity and pressure, and can be tracked by any of the five range tracking radars. The radar and radiosonde data are recoded by the Central Computer for posttest reduction and printout. In addition, a real-time printout of all upper air data is available in the Graphics room.

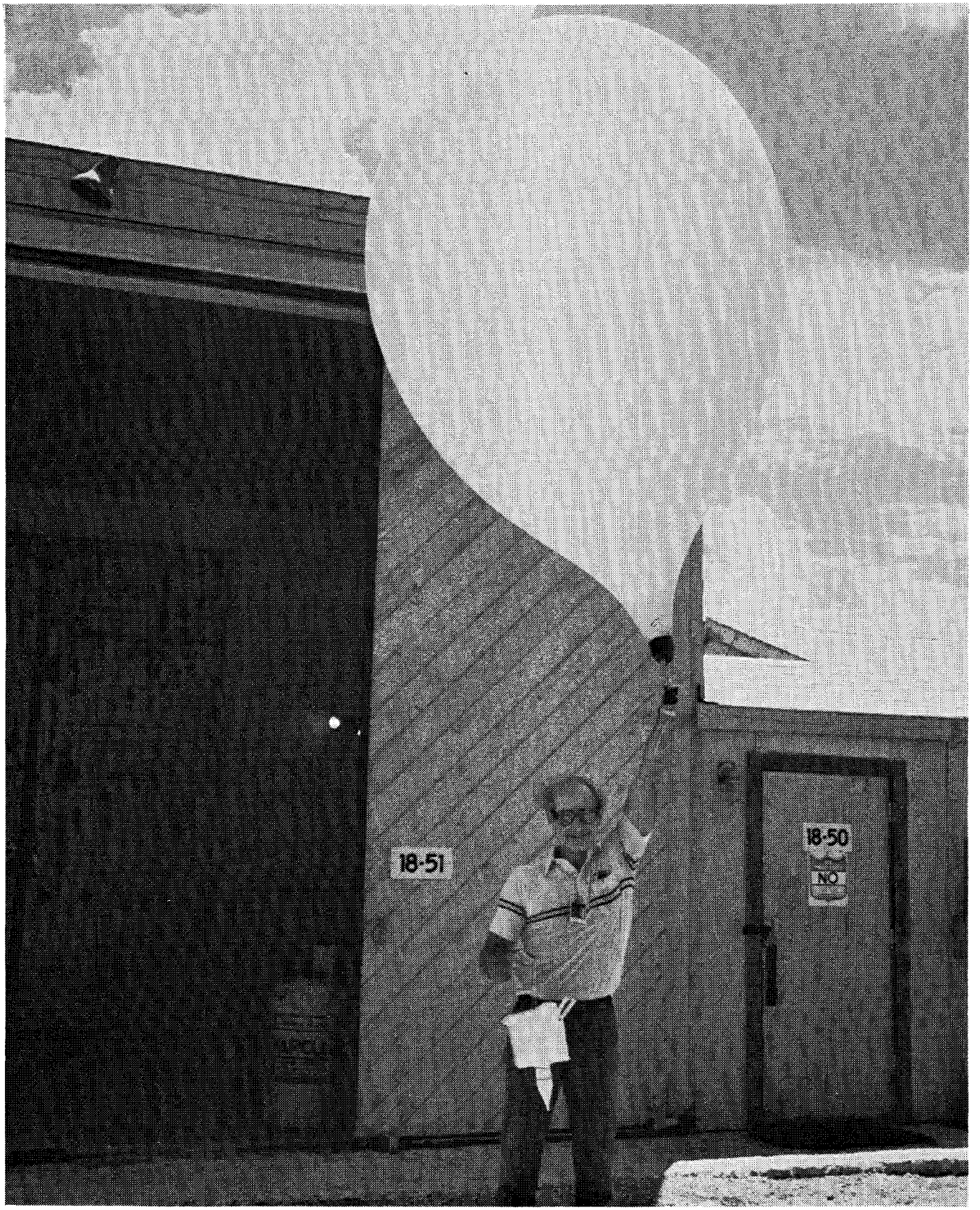


Figure 3-14. Rawindsonde Launch

Data Reduction Facility

The Data Systems Department, located at SNLA, operates the data reduction facility using a network of Data General MV/10000 computers which receive their input data from a telemetry processor controlled by a PDP 11/44. This complex provides scientific data analysis and telemetry playback support for TTR test activities. Overall function of the facility is shown in Figure 3-15. It accepts raw data input from both analog and digital magnetic tapes, tape cassettes, film in widths from 16 mm through 140 mm, Polaroid film, transparencies, paper charts, strip charts, floppy disks, and modem-transmitted direct digital data.

Output from the data reduction system can be provided as computer listings, plots, punched cards, and digital magnetic tapes. Special analog and digital outputs may be generated from telemetry data, including analog tape dubs, oscillograph quick-look charts, tape cassettes, floppy disks, and removable disk recordings.

Information for Range users who wish to use Sandia's data reduction services is contained in Section 7.

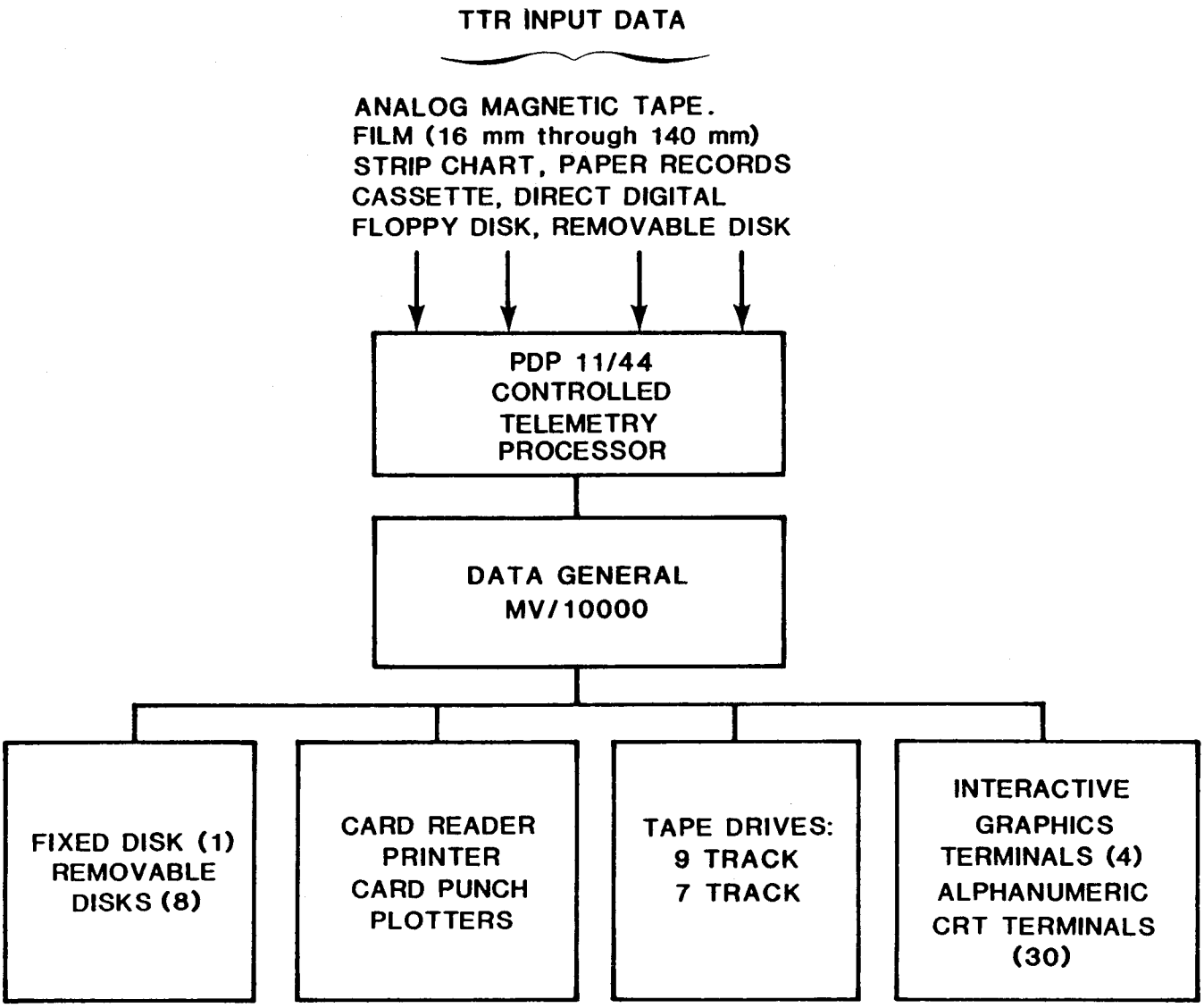


Figure 3-15. Data Reduction Facility

SECTION 4

INSTRUMENTATION

GENERAL

The tracking and data acquisition systems, including optical trackers, radars, and telemetry, at TTR provide both versatility and high accuracy for maximum test results. The variety of tests conducted at the Range requires systems capable of gathering large volumes of information under diverse, and sometimes unfavorable, test conditions. To achieve this capability, much of the equipment was custom-designed and built by Sandia, and the balance (built to TTR specifications) was purchased from commercial vendors and manufacturers.

OPTICAL TRACKERS

Optical trackers provide two categories of test data: test documentation and target vehicle space position data. Currently four fixed-location trackers and 17 mobile trackers are in use. All stations are equipped with landline or RF links for communications, and for receiving timing and target acquisition information. Trackers can be deployed at any of the locations shown in Figure 2-1.

Tracking Telescopes

The principal equipment used to obtain sequential photographic engineering records are the ME-16, LA-24, and SM-mount tracking telescopes. Most of these units were designed and built, or modified by Sandia. The Range has 11 of these telescopes, although the number in use at any one time varies with test requirements. The mobile units are positioned on surveyed sites as specifically required by the test operation.

The ME-16 (Figure 4-1) and the LA-24 are similar in design. Each model is built around a Newtonian telescope with a prime focal length of 117.5 in. The telescope is installed in a high-accuracy mount that permits simultaneous azimuth and elevation tracking.

The basic differences between the two instruments are the size of the primary mirror, the turret mount, and the effective length. The ME-16 uses a 16-in-diameter primary, and the LA-24 uses a 24-in-diameter primary. The additional size and weight of the 24-in telescope require a larger supporting turret. A Sandia-designed amplifying lens doubles the effective focal length of the LA-24 to 235-in, producing a geometrical optical speed of f/10, compared to f/7.4 for the ME-16. These lenses with a greater focal length have temperature correction and are kept in focus with radar digital range data that assures high resolution target images at all distances of 1000 yd or more.

Most of the telescopes use 35-mm Photosonic 4E pin-registered cameras, which run at rates of 6 to 360 fps. Two of the permanent stations use Mitchell cameras, which run at speeds of 48 or 96 fps. The LA-24 has a Photosonic 10A pin-registered 70-mm camera, which has frame rates of 20 to 80 fps. Maximum tracking velocity for the ME-16's and LA-24's is about 18°/s.

The SM-mounts are small, highly mobile trackers. Figure 4-2 illustrates the newest type in use at the Range, an ABA Lightweight Optical Tracking System (LOTS). These units are capable of much higher

tracking velocity rates than the telescopes, about 57°/s. Two mounts carry 12-in Newtonian telescopes with 60-in focal lengths. The SM mounts also feature special photographic instrumentation for high velocity impact data. Additional azimuth-only cameras on two mounts are Photosonic 4C rotary prism cameras with variable frame rates up to 2000 fps, using 12-in Newtonian telescopes with 60-in focal lengths. Two of the mounts have video cameras that are boresighted with the cameras for video displays of the field of view and either mount may be used for remote tracking control through the microwave link. In this mode either of the mounts can be located in hazardous locations and all camera and tracking functions can be controlled remotely. An additional camera, usually a 16-mm, can also be mounted on the tracking axis for supplemental coverage. Both the azimuth-elevation tracking telescope and the azimuth-only (impact) telescope are kept in focus with radar range data and are temperature corrected.

The LOTS SM-mount uses a Photosonic 4E camera with a 60-in F/8 hyperstabilized catadioptric lens. It also has a Redlake LOCAM camera which can be set from 2 to 500 fps.

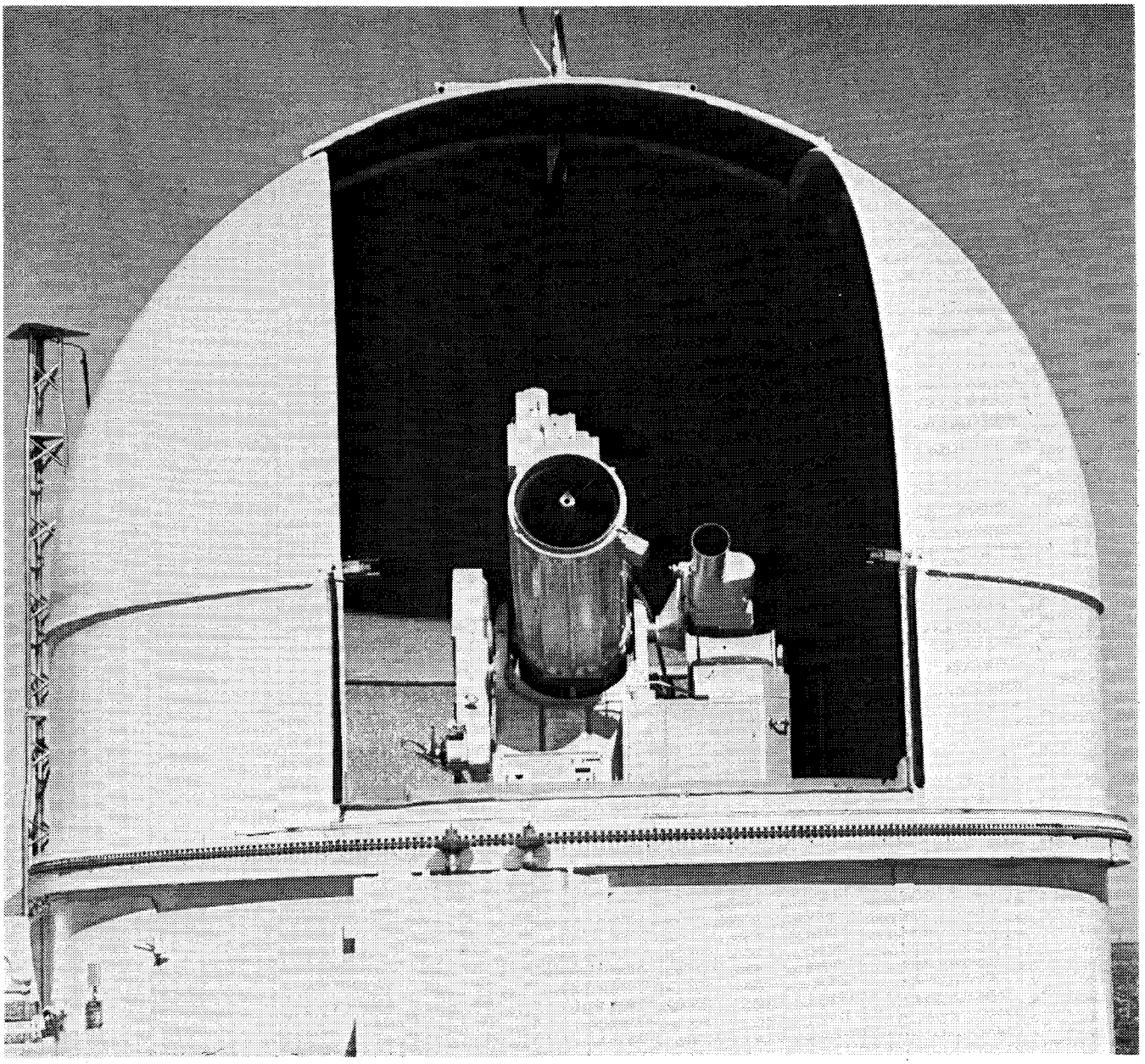


Figure 4-1. Fixed ME-16 Tracking Telescope

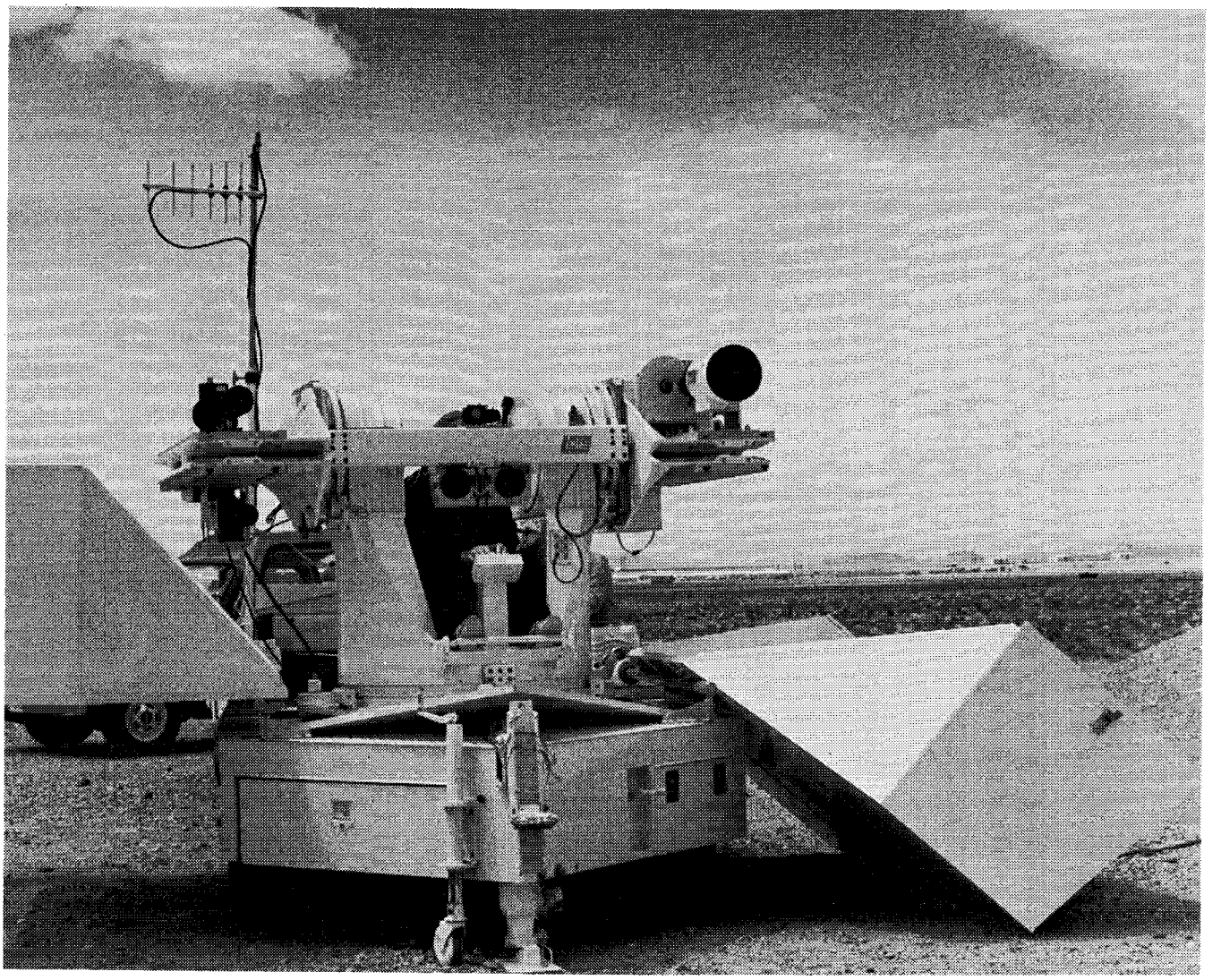


Figure 4-2. LOTS SM Mount Tracking Telescope

A number of video cameras can be installed on the SM trackers to meet specific test requirements. Figure 4-3 shows a typical video camera installation on the LOTS SM tracker. Quick-release video mounts enable rapid change-out of camera units when required.

Contraves Cinetheodolites

Contraves cinetheodolites (seven Model EOTS F, Sandia-modified, and one EOTS-C/F) are used to obtain metric photo data. These mobile tracking instruments are mounted on Parabam trailers and protected by astrodomes (Figure 4-4). There are 29 locations where cinetheodolites may be positioned, depending on the optical tracking requirements (Figure 2-1). New locations can be constructed with about 120 days lead time.

The Contraves cinetheodolites have been modified to allow one-man operation and to permit target acquisition with radar assistance through use of the TVTS. They use a 60-in focal length, or 120-in catadioptric, folded lens system, and have frame rates of 5, 10, 20, or 30 fps. Three cinetheodolites are equipped with a G-Band radar ranging system which, along with the azimuth and elevation data,

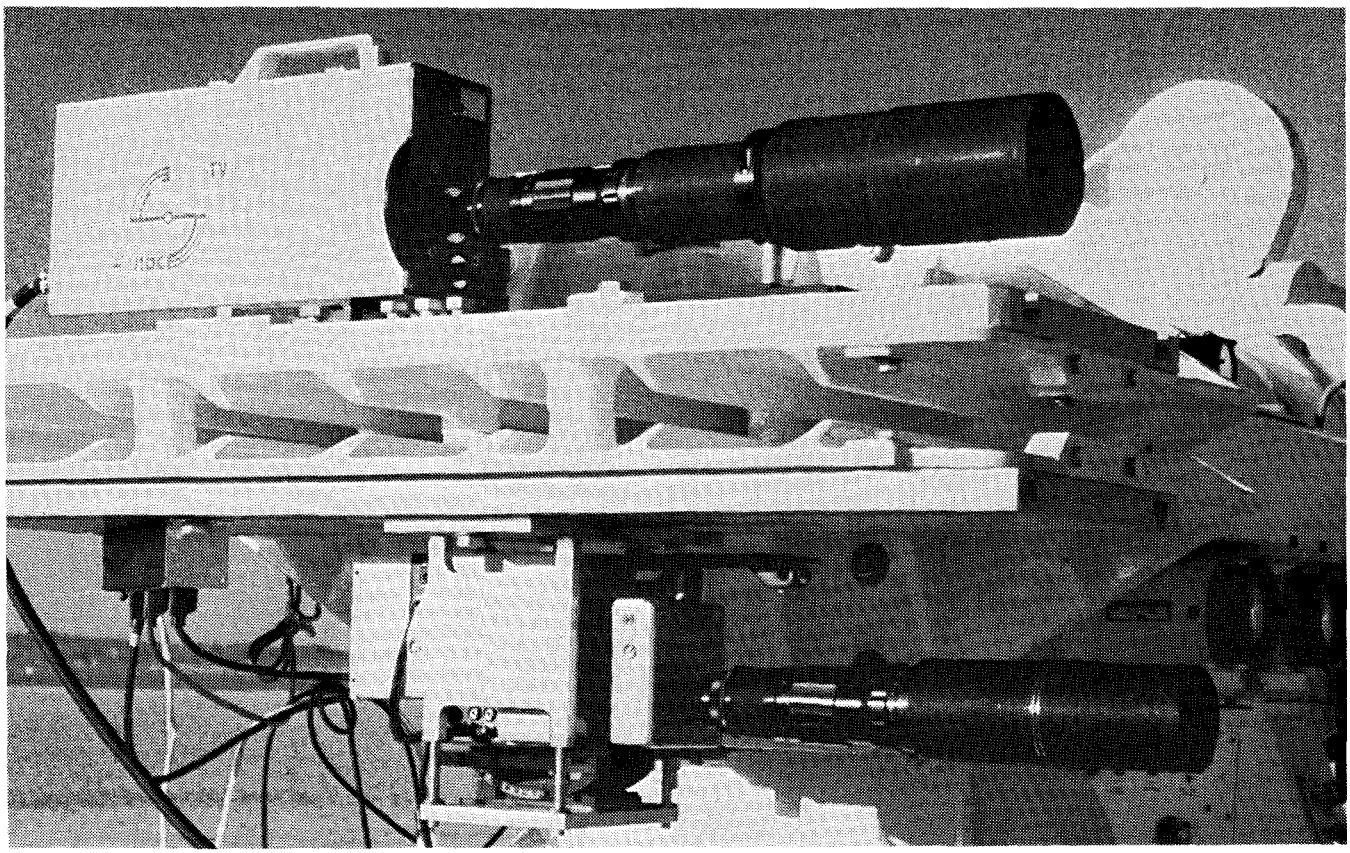


Figure 4-3. Typical Video Camera Installation on SM Tracker

provides a one-station space position solution for any incoming test vehicle that is equipped with a 5400- to 5900-MHz radar transponder. One of the units also has a video camera mounted and boresighted with the film camera.

Cameras on these mounts are synchronized to expose like frames simultaneously. Recorded on each picture frame are target image, plus IRIG time, and elevation and azimuth angle annotations. Data reduction of these films provides position vs time (primary source), velocity (primary source), acceleration (primary for some tests), and altitude data.

The space position data, obtained from an optimized cinetheodolite solution and translated to the TTR rectilinear coordinate system, is accurate to within ±1 ft.

The largest source of error is the readability of the target image and reference point. Correction data for known errors in collimation, orientation, level, and refraction are introduced in the data reduction solution but accuracy is limited to ±15 ft unless the following criteria are observed.

Minimizing the distance from electro-optical tracking system to the target and to a selected reference point

Scheduling the test during prime time (½ h after sunrise or ½ h before sunset) to minimize the effects of changing air density (scintillation)

Front-lighting the target images

Painting targets fluorescent orange or red

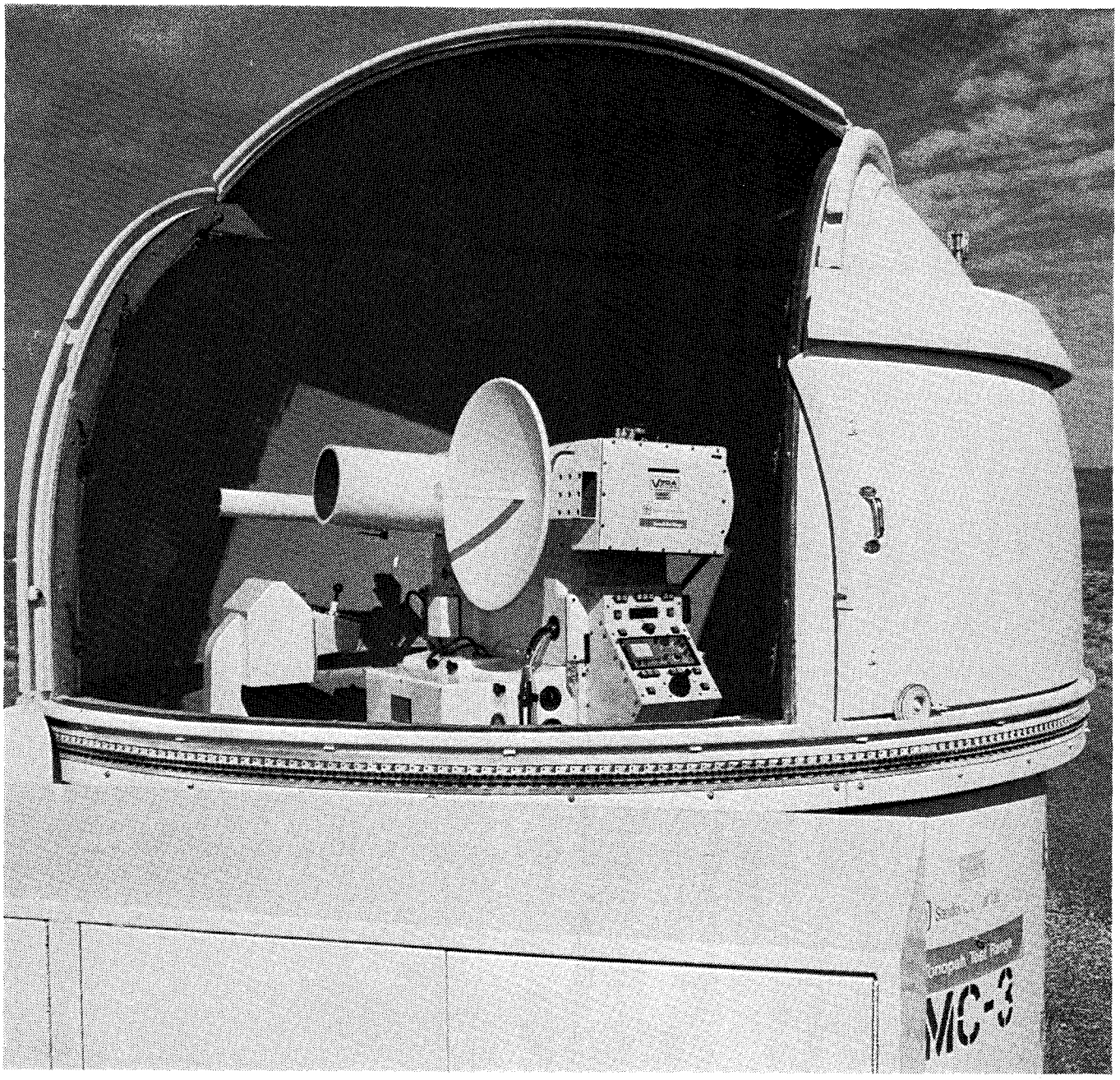


Figure 4-4. Contraves Cinetheodolite With G-Band Radar Ranging System

If the above criteria are observed, space position accuracy improves to within 3 to 5 ft and velocity accuracy to within 0.5%.

The one-station solution utilizing the G-Band radar ranging system is accurate to approximately ±10 ft.

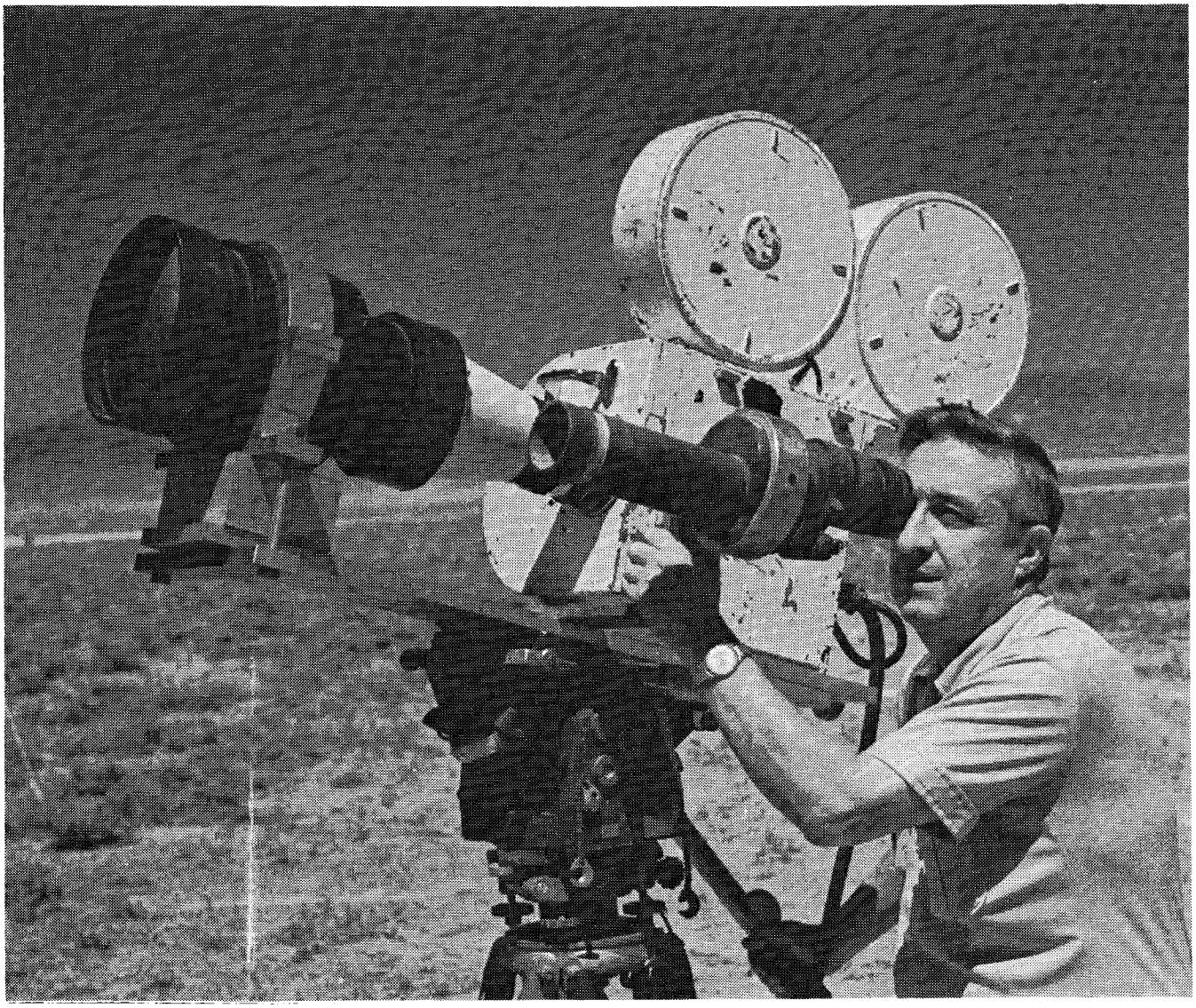


Figure 4-5. Mobile Hand Tracker With Photosonic 10A Camera

Hand-Tracking Instrumentation

To gather sequential engineering photographic records in isolated locations or when instrumentation must be placed close to impact areas, TTR has another family of mobile tracking instruments. These are smaller and less sophisticated than the ME-16 and the SM-mounts. Mobile hand trackers (Figure 4-5) are either tripod-mounted or pedestal-mounted on trailers, and use Photosonic 10A, 70-mm cameras equipped with variable lenses and operated at 6 to 360 fps. Other cameras can be used if higher frame rates are needed. A single operator hand-tracks the target in both azimuth and elevation, and a fixed focus is used. This equipment can be taken to a location and prepared for use within an hour by a single operator. The equipment includes mobile generators, and the trailer units are equipped with satellite IRIG-B timing receivers and mobile radio equipment. Figure 4-6 is a set of sequential photos of a B83 test drop from a B1 bomber. The photos were taken with the 10A camera at 60 fps, with a 20-in focal length at f/4.5. Subject distance was 1500 to 3500 ft.

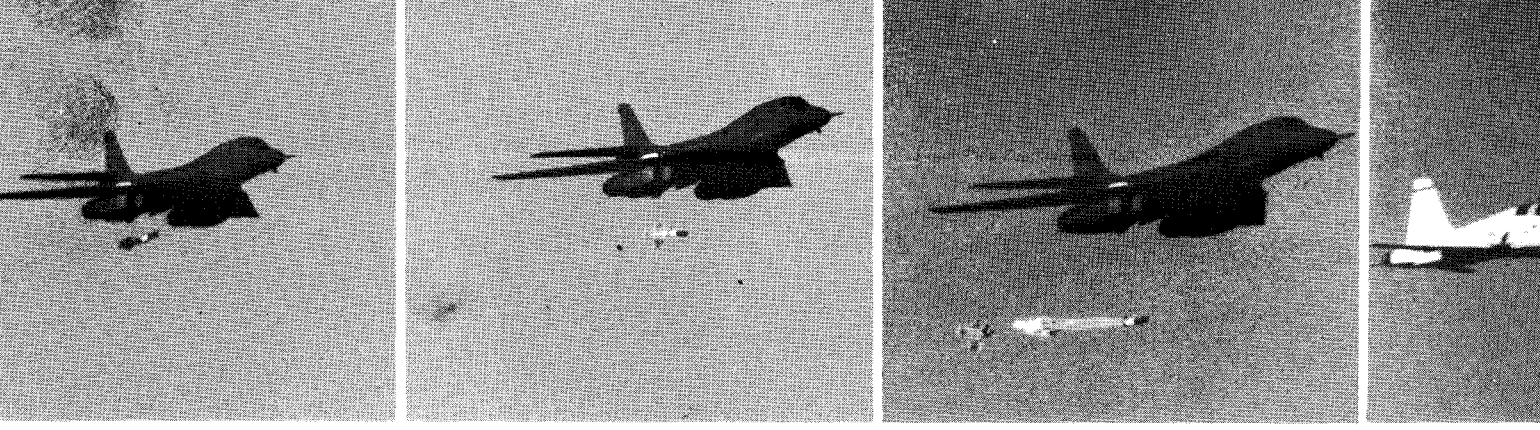


Figure 4-6. Photographic Sequence of B83 Drop from B1 Bomber

Photography, Photometrics, and Radiography

A wide range of photographic equipment and services are available to users through the Photography, Photometrics, and Radiography Laboratory.

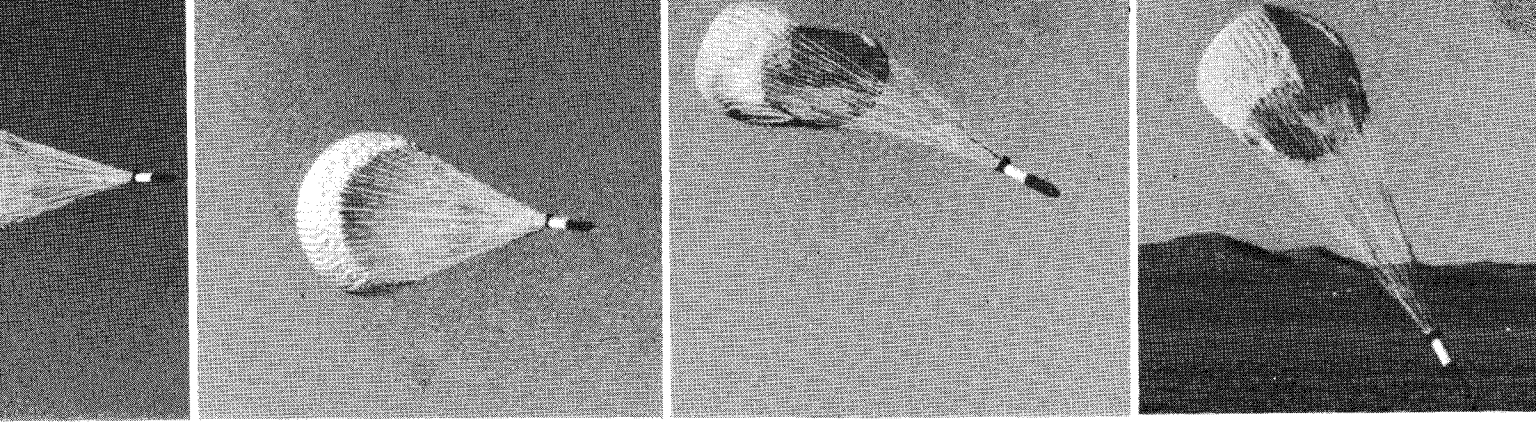
The high-speed and special purpose cameras (Table 4-1) operated by trained specialists can readily fulfill most Range requirements. Many of the cameras can be mounted on tripods or platforms and operated either locally or remotely. Portable steel camera buildings, each of which may contain a battery of up to four cameras, may be positioned close to hazardous test operations and operated remotely. These cameras can provide excellent data on test vehicle velocity, impact attitude, projectile velocity and spin rates, crack propagation from explosions, and streak records (Figure 4-7).

More conventional camera equipment is available for routine range use and industrial photography. These include 35-mm Pentax and Nikon, Mamiya 6x7 and 6x5, Pentax 6x7, Graflex 4x5, and Polaroid cameras. Polaroid backs, motor drives, and a large assortment of lenses are available for the above cameras.

A radiography system for test vehicle postmortems and other industrial applications is also available at the Range. The projector is a Tech/Ops Model 616 Gamma Ray system with a Model A58101-8 Iridium[192] source which produces 200 Ci. The unit weighs 45 lb, including the depleted uranium shield. The Tech/Ops Model 694 vacuum-type Control Unit with 50 ft of hose weighs an additional 16 lb. The light weight of the system enables rapid setup time. Kodak industrial x-ray film normally stocked for Range use includes AA, T, M, and R in 14x17 in size.

Table 4-1. Range High-Speed Cameras

Manufacturer	Model	Qty	Film Size (mm)	Frame Rate (pps)	Shutter	Lens Range (mm)
Redlake	Fastax II	3	16	100 – 7000	Rotating prism	13 – 254
Redlake	Fastax 210	3	16	200 – 10000	Rotating prism	13 – 254
Milliken	DBM-44	3	16	10 – 400	Interchangable	15 – 500
Photonic	Photec IV	2	16	200 – 10000	Rotating Prism	24 – 600
Redlake	Hytax	7	35	35 – 250 ft/s	Streak	13 – 500
Fastax	RF-5 1/2 Frame	2	35	100 – 6000	Rotating prism	13 – 254
Photosonic	4M	3	35	10 – 180	Variable	80 – 200 zoom
Photosonic	4C	6	35	100 – 2000	Rotating prism interchangable	80 – 150
Mitchell	GC	4	35	48 and 96	Variable	13 – 254
Photosonic	10A	2	70	20 – 80	Variable	105 – 210 zoom



The Range photo lab has facilities for processing 16- and 35-mm black and white motion picture film. The lab can also process and print still photos, with enlargements up to 8x10 for black and white, and 16x20 for color.

Black and white motion picture film can usually be ready for viewing within 4 h. Polaroid prints for pre/posttest requirements can, of course, be available immediately. Still prints and enlargements can also be obtained within a few hours. Developed radiographic plates can be available about 1 h after completion of exposures.

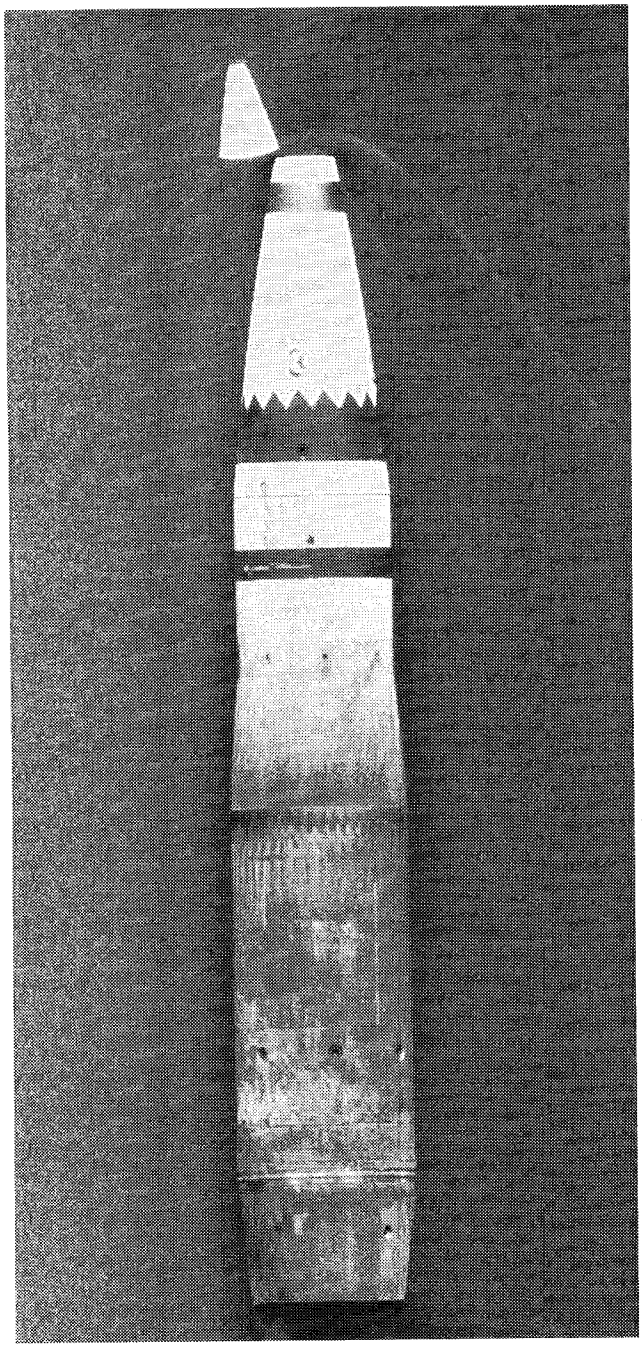


Figure 4-7. High-Velocity Gun Round Stop-Motion Photograph

RADARS

TTR is equipped with five tracking radars: two G-Band (5400 to 5900 MHz) and three I-Band (8900 to 9600 MHz). These units are strategically located to cover of all Range targets and aircraft or ballistic vehicle entry paths. The three I-Band radars are all portable or mobile and can be easily moved to fill any gap in coverage that might occur because of a special test. The I-Band radars are also used to support off-Range tests. Radar R18 is also the primary unit for tracking rawindsondes. Figure 4-8 shows the 12-foot diameter antenna and pedestal of the MPS-25, one of the two largest radars on Range. High-resolution video cameras system is mounted at right.

All of the radars have been designed or modified to meet specific Range operational requirements and to improve precision and reliability. Major modifications have included conversion from vacuum tube to solid-state electronics.

Closed circuit television cameras mounted on the pedestals are boresighted with the antennas to provide real-time television coverage of the radar targets. The video is used by radar operators for angle tracking when ground clutter or test conditions require it. Digital annotations are superimposed on the TV signals that provide time of day, azimuth, elevation, and range data. The video is transmitted via microwave to the Computer Center for observation both during and after the test.

Digital data are transmitted from each radar to the Control Center and the Central Computer facility. These digital signals provide real-time trajectory data to drive plotting boards and graphics displays. All radar data are recorded in the Central Computer for posttest analysis of space position and trajectory.

Additionally, tracking data from all operational radars are multiplexed and transmitted by RF link to all other tracking stations on the range. A microcomputer at each receiving station receives the data and computes azimuth and elevation pointing angles and Range data for target acquisition and camera focusing.

Virtually all Range tests are supported by the radars, including high-speed aircraft bomb drops, rocket launches, and artillery round firings.

Table 4-2 gives specifications and performance data for all five radar systems.

Figures 4-9 and 4-10 show range and coverage profiles for the two fixed-location G-Band radars, the MPS-25, and the MPS-36.

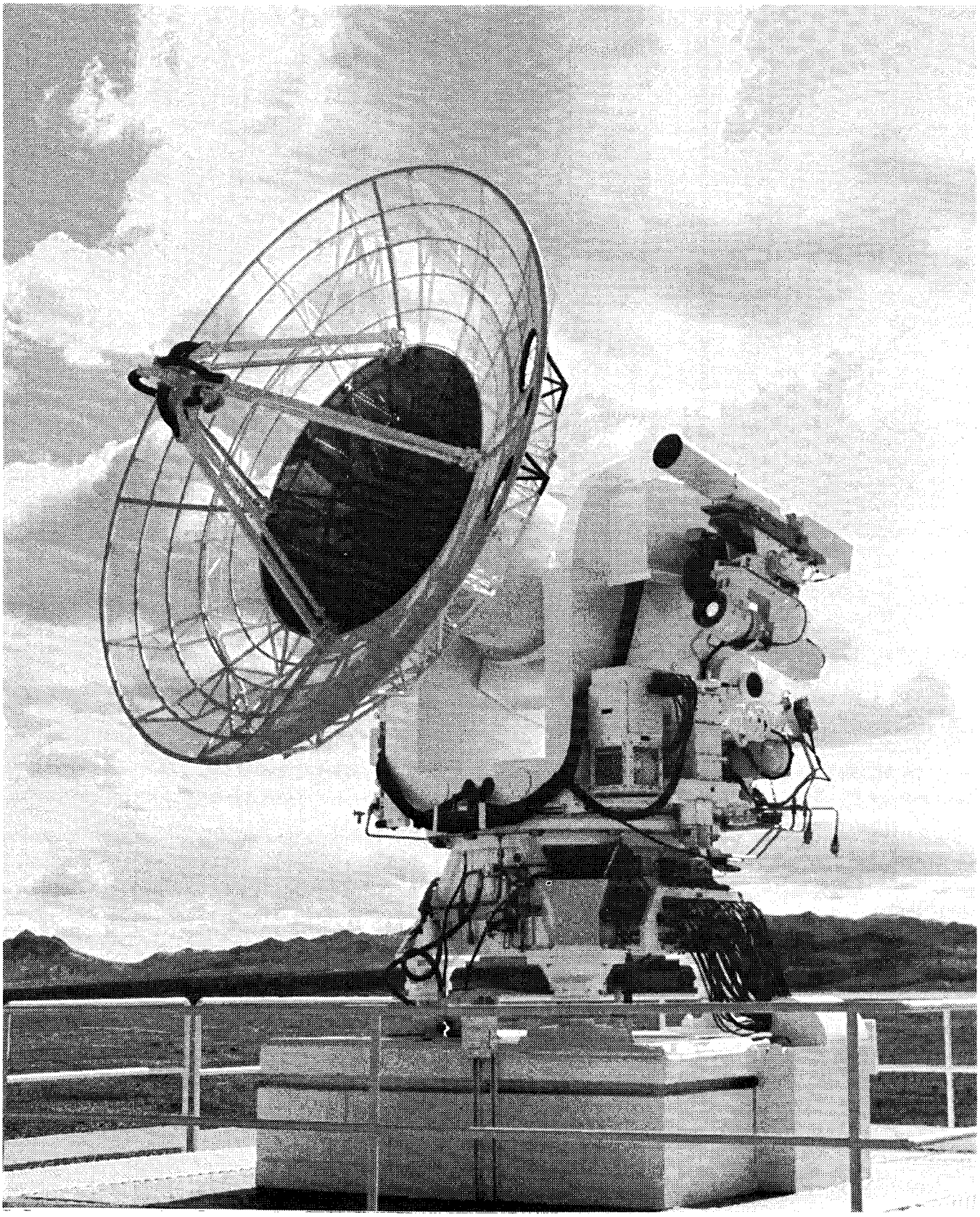


Figure 4-8. MPS-25 Radar Antenna and Pedestal With High-Resolution Video System

Table 4-2. Specifications and Performance Data for Radar Systems

Radar Type	M-33 Modified Conical Scan	DIR Monopulse	MPS-25 Monopulse	MPS-36 Monopulse	R18 Conical Scan
Transmitter					
PRF	700	156, 312, 625	160, 320, 640	160, 320, 640	500
Pulse width	0.25 μs	1.0, 0.25 μs	1.0, 0.5, 0.25 μs	1.0, 0.5, 0.25 μs	1.0, 0.25 μs
Multiple pulse	No	Yes	Yes	Yes	No
Peak power output	250 kW	250 kW	1.0 MW	1.0 MW	200 kW
Final stage	Coaxial magnetron I-Band (8.4-9.6 GHz)	Coaxial magnetron I-Band (8.4-9.6 GHz)	Coaxial magnetron G-Band (5.4-5.95 GHz)	Crossed-field amplifier (coherent) G-Band (5.4-5.95 GHz)	Coaxial magnetron I-Band (9.1-9.6 GHz)
Pedestal					
Prime mover	Electric motor	Electric motor	Hydraulic	PM torquer	Dual DC motors
Maximum velocity	700 mil/s azimuth 500 mil/s elevation	700 mil/s azimuth 500 mil/s elevation	800 mil/s azimuth 500 mil/s elevation	800 mil/s azimuth 500 mil/s elevation	266 mil/s azimuth and elevation
Antenna					
Type	Lens	Cassegrain parabolic	Parabolic	Parabolic	Parabolic
Size	6 ft	8 ft	12 ft	12 ft	8 ft
Gain	37 dB	43 dB	44 dB	43 dB	43 dB
Polarization	vertical	vertical	vertical	vertical, horizontal, right or left circular	vertical
Receiver (Solid-State)					
Type	One channel	Three channel	Three channel	Two channel	One channel
Mode	Skin	Skin/beacon	Skin/beacon	Skin/beacon	Skin/beacon
Range Tracking					
Type	Digital	Digital	Digital	Digital	Digital
Mode	Skin	Skin/beacon	Skin/beacon	Skin/beacon	Skin/beacon (single pulse)
Maximum Tracking Rate	10,000 yd/s	10,000 yd/s	20,000 yd/s	20,000 yd/s	2500 m/s
Data granularity	1 yd	1 yd	1 yd	1 yd	2 m
Angle Tracking					
Tracking precision for 20-dB s/n target	±0.5-mil rms	±0.15-mil rms	±0.1-mil rms	±0.2-mil rms	±0.5-mil rms
Digital Data System					
Angle encoders	16-bit synchron/digital	16-bit synchron/digital	18-bit optical	20-bit optical	16-bit synchron/digital
Data output	16-bit angles 20-bit range	16-bit angles 20-bit range	18-bit angles 24-bit range	20-bit angles 24-bit range	16-bit angles 18-bit range
Date rate	100 frames/s	100 frames/s	100 frames/s	100 frames/s	100 frames/s
Closed Circuit Television					
Lens (focal length)	40 in	20/60 in 7-70 in zoom	40/120 in	40/120 in	7-70 in 200 m
Annotation	Time of day, azimuth elevation, range	Time of day, azimuth elevation, range	Time of day, azimuth elevation, range	Time of day, azimuth elevation, range	Time of day, azimuth elevation, range, altitude

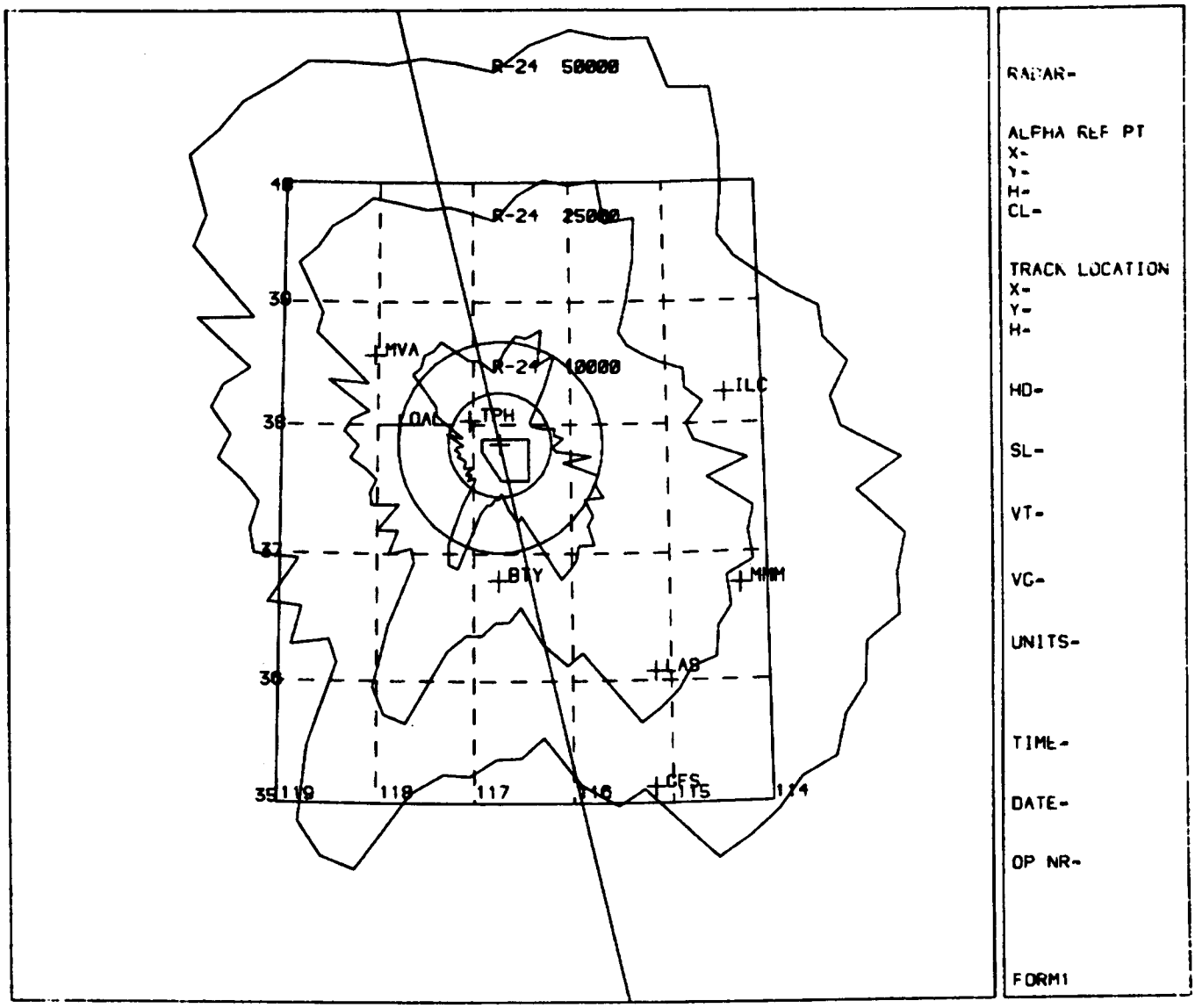


Figure 4-9. Range Coverage Profile vs Target Altitude, MPS-25 Radar

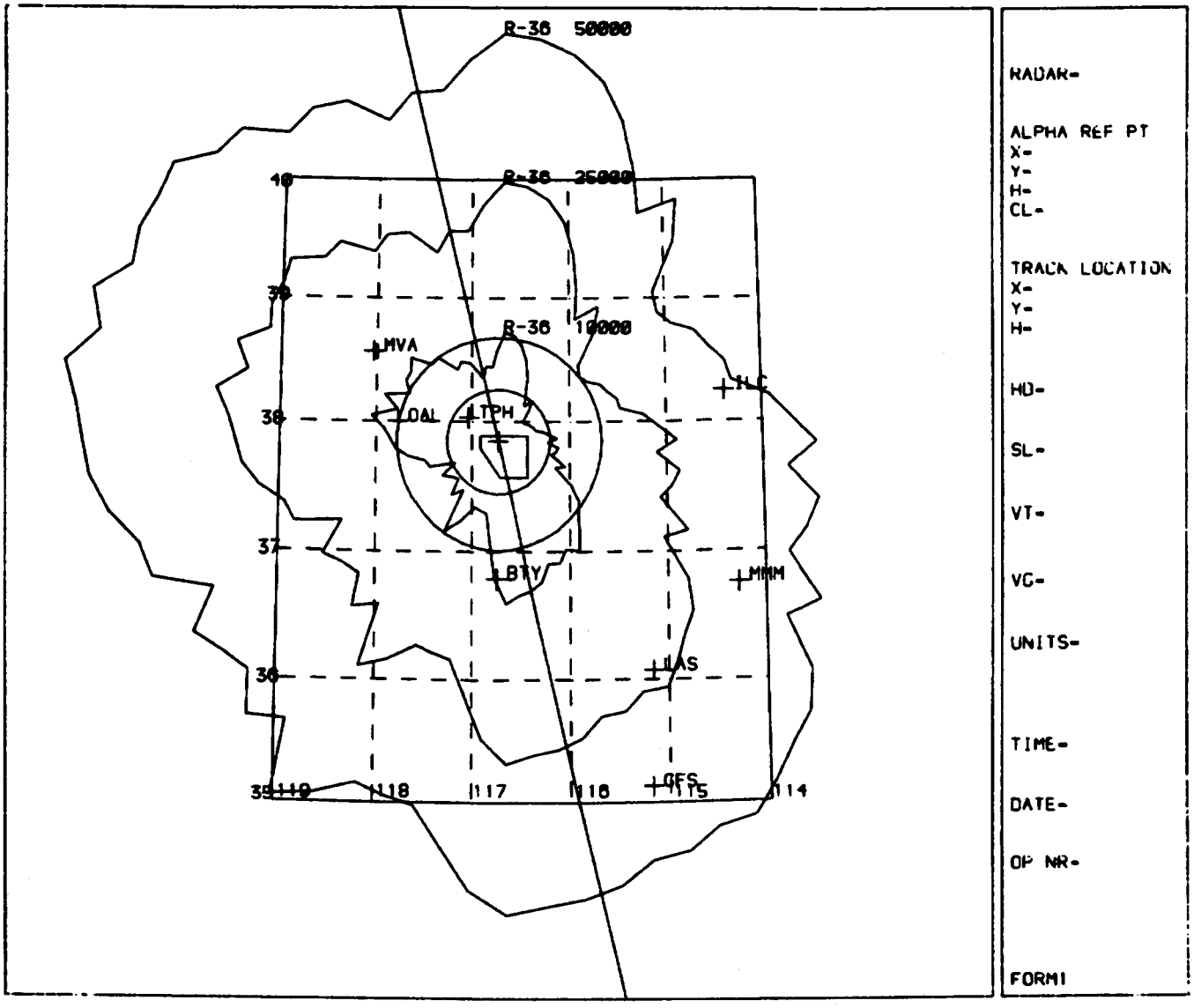


Figure 4-10. Range Coverage Profile vs Target Altitude, MPS-36 Radar

TELEMETRY

General

Two fixed and two mobile ground stations provide complete Range coverage of RF signals in the 1435- to 1535-MHz and 2200- to 2300-MHz telemetry bands. The Master Ground Station (Figure 4-11) is located on the first floor of the Operations Center building and provides receiving, recording, real-time display, and posttest playback of telemetry data. The other fixed ground station, at Station 24, receives and records only. Both of these stations have limited reception capability for P-Band signals (225 to 260 MHz).

The B-67 trailer is a 10x40 ft instrumentation trailer that has receiving, recording, and limited data playback capability. The B-71 trailer (Figure 4-12) is an 8x40 ft instrumentation trailer for receiving and recording telemetry data.

A fifth ground station, located in the gun control bunker in the Ordnance area, is the primary TM station supporting the gun facilities. It uses a pair of fixed antennas and has limited recording, diagnostic, and display instrumentation.

Figure 4-11. Telemetry Master Ground Station

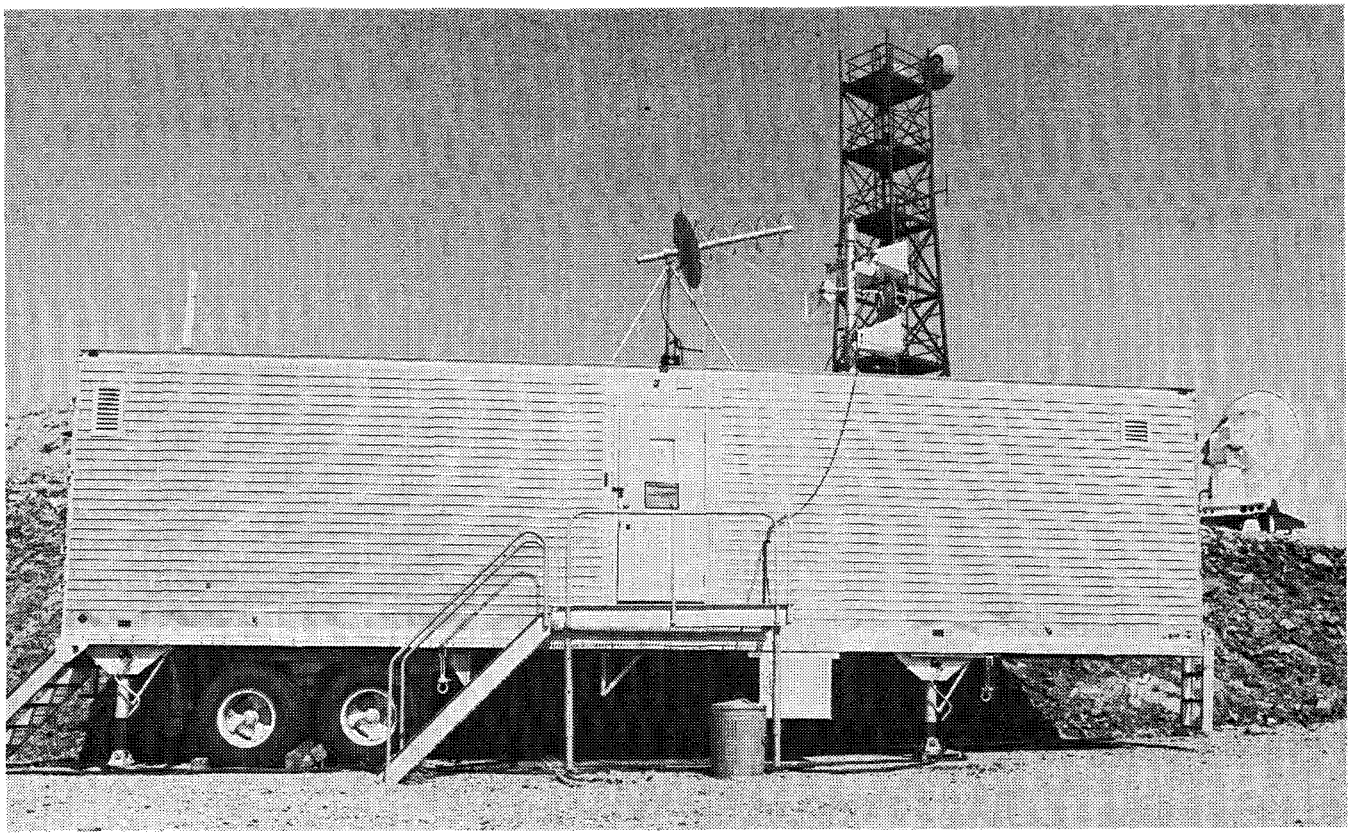


Figure 4-12. Mobile Telemetry Ground Station

Operation

The master ground station is the controlling element for telemetry functions, providing reception, recording, real-time evaluation, and posttest data playback. The other ground stations serve as backup for receiving and recording data. The mobile stations are located where they can assure coverage of critical areas of the test vehicle trajectory. At least two ground stations are operated during any test.

Analog tape recorders record either Pre-D receiver outputs or the receiver video outputs depending on the modulation format or the customer's requirements. IRIG-B timing and a station multiplex containing reference frequencies and receiver AGC signals are also recorded, along with a voice channel with the UHF air-to-ground radio net and a VHF ground-to-ground range operations net. Any of the other range voice networks can be recorded on the telemetry tape when required.

The data needed to make real-time go-no-go decisions are displayed several ways, including analog meters, oscillographs or strip charts, oscilloscopes, spectrum analyzers, computer printouts, and CRT alphanumeric displays. In addition to the display capability in the TM ground station, a separate area in the Operations Control building can accommodate up to six chart recorders and three CRT displays with hard copy printers. Posttest quick-look data are supplied in the form of strip charts or oscillograph records. Any combination of PCM, PAM, and FM/FM data can be put on a strip chart subject to the constraints of number of channels, channel deflection desired, paper width, etc. Analog tape dubs can be provided.

The Central Computer accepts PCM data in real-time and posttest modes, and produces listing, and/or plots in engineering units.

Most playback and quick-look data processing requirements can be fulfilled within 24 h after a test. Unusual requirements for non-IRIG PCM formats, subcarrier frequencies, and RF frequencies, should be coordinated with TTR telemetry engineers as far in advance of a test as possible.

Station Instrumentation

A description of each station's equipment and capabilities is given in Table 4-3. In general, all stations use the same kind of receiving and recording systems except as noted.

Table 4-3. Specifications and Performance Data for Telemetry Station Equipment

Item	Description/Capabilities		
Master Ground Station			
Antenna 1: Scientific-Atlanta 2.4-m Parabola (CORTS)	Frequency	1435 – 1535MHz	2200 – 2300 MHz
	Beamwidth	6°	4°
	Gain	28.5 dB	32 dB
	Preamplifier noise figure	4.8 dB	5.6 dB
	RF outputs	Simultaneous RHC and LHC polarization.	
	Operating mode	Slaved to radar via TVTS.	
Antenna 2: Broadband Horn Array Configuration	Eight broadband (1435 – 2300 MHz) horns; four vertically and four horizontally polarized; individually movable in azimuth and elevation.		
	Horn specifications	Beamwidth: 30° x 32° Gain: 15 dB Preamplifier noise figure: 5.0 dB	
	Operating mode	Horns oriented for overlapping coverage of area of interest to provide medium gain, wide-angle coverage with vertical and horizontal polarization diversity.	
Antenna 3: P-Band Tri-Helix Configuration	Three 4-turn helix antennas (225 – 265 MHz) connected to form a single assembly with a horizontal beamwidth of 180° and a vertical beamwidth of 40°.		
	Preamplifier noise figure	3.5 dB	
	RF output	One	
	Operating mode	Antenna manually pointed to cover area of interest	
Receivers: Raytheon Predetection Diversity Combining System (2 each)	Frequency	1435 – 1535 MHz and 2200 – 2300 MHz	
	Noise figure	11 dB	
	IF bandwidth	1.0 MHz or 3.3 MHz	

Table 4-3. (cont)

Item		Description/Capabilities
	RF inputs	Up to 10 per receiver, depending on how many input modules are used. One receiver in the master ground stations configured to accept up to six inputs – normally two from the 2.4-m dish, and four from the horn array.
	Outputs	Each receiver combines its inputs into a single output. Video and 900 kHz predetection available.
Receivers: Microdyne 1100AR (4 each)	Frequency	225 – 265 MHz, 1435 – 1535 MHz, 2200 – 2300 MHz
	Noise figure	10 dB at 2200 – 2300 MHz
	IF bandwidth	500 kHz, 1.0 MHz, or 3.3 MHz
	RF inputs	One
	Outputs	Video, predetection (225 to 900 kHz)
Combiners: Microdyne 3300(C) (2 each)	Operating mode	Each combiner combines the output of two 1100AR receivers into a combined video or combined predetection output (225 to 900 kHz).
Tape Recorders: Ampex FR3030 (2 each)	Tape size	1 in × 9600 ft
	Number of channels	14
	Frequency response	2 MHz direct, 500 kHz FM at 120 IPS
	Recording Speeds	1.875 to 120 IPS
Discriminators: EMR 4130 (36 each)	Frequencies	All IRIG PBW and CBW channels available.
PAM Decommutation System: EMR 515/516/517 System (2 each)	Outputs	Up to 16 DACs, patchboard selectable from each decommutation. Parallel output for computer interface.
PCM Decommutation System: Data Control Systems 4004 Decom/4211H Word Selector (3 each)	Inputs	All IRIG bi-phase and NRZ formats.
	Bit rate	Up to 800 kb/s bi-phase, 1.6 Mb/s NRZ.
	Outputs	Up to 15 digital-to-analog outputs and one 8-b bi-level output per word selector. Word selectors may be chained for additional outputs. Each decom has a parallel output for a computer interface.

Table 4-3. (cont)

Item	Description/Capabilities	
	Programming	Format selector programmed by punched plastic card. Word selector programmed by punched IBM card.
	Display	Each digital-to-analog channel has a meter display.
PCM/PAM Decommutation System: Loral D/Pad Mk II	Inputs	All IRIG bi-phase and NRZ formats
	Bit rate	Up to 500 kb/s bi-phase and 1M bps NRZ.
	Programming	Programmed by keyboard and CRT display; programs stored on cassette tape.
	Display	Selected words displayed on CRT, up to 12 words per display. Engineering units available.
	Outputs	48 digital-to-analog outputs.
Time Code Translator: Datum Model 9200	Input	IRIG-B on modulated carrier, from tape or station multiplex
	Output	BCD format slow code for oscillographic or hot-pen recorders
Chart Recorder: Gulton Model 888 (6 each)	Number of channels	8 on 12-in-wide paper
	Type of recording	Hot pen
	Frequency response	100 Hz
	Paper speed	0.5 to 100 mm/s
Oscillograph: Bell and Howell Model 2000 (2 each)	Frequency response	Up to 5 kHz
	Number of channels	Up to 18 data channels plus timing
	Paper	12-in-wide × 400-ft-long, direct writing, permanent trace
	Paper speed	0.1 to 160 in/s
Tuneable Discriminator: EMR 410 (2 each)	Frequency	200 Hz to 200 MHz
	Deviation	±1% to ±40%
Computer: Digital Equipment Corp PDP-11/44	Auxilliary equipment	VT 100 Terminal Two each RL 02 removable cartridge disk Houston Instruments line printer RX02 dual floppy disk
	Operating mode	Computer used for real-time pretest evaluation of PAM and PCM telemetry system (block dump and OK check modes available)

Table 4-3. (cont)

Item	Description/Capabilities	
Telemetry Ground Station - Station 24		
Antenna: Scientific-Atlanta 2.4-m Parabola (CORTS)		
Antenna: Canoga Teltrac	Frequency Beamwidth Gain Operating mode	225 – 265 MHz Azimuth: 22.5°, elevation 16° 19 dB Manual or autotracking
Receivers: Raytheon (2 each) Microdyne 1100AR (4 each) with Microdyne 3300(C) combiners (2 each)		
Tape Recorder: Ampex FR3030 (1 each)		
B-67 Telemetry Trailer		
Antenna: Scientific-Atlanta 2.4-m Parabola (CORTS)		
Receivers: Raytheon (2 each) Microdyne 1100AR (4 each) with Microdyne 3300(C) combiner (2 each)		
Tape Recorders: Ampex FR3030 (2 each)		
Discriminators: IRIG CBW and PBW: EMR 410 Tuneable Discriminator		
PAM/PCM Decom System: Loral D/PAD III		
Oscillograph: Bell and Howell Model 5-133 direct writing, 5-kHz frequency response		

Table 4-3. (cont)

Item	Description/Capabilities	
Computer: Digital Equipment Corp PDP-11/44	Auxiliary equipment	VT 100 Terminal Two each RL02 removable cartridge disks Houston Instruments line printer RX02 dual floppy disk
B-71 Telemetry Trailer		
Antenna: Scientific-Atlanta 2.4-m Parabola (CORTS)		
Receivers: Raytheon (12 each) Microdyne 1100AR (4 each) with Microdyne 3300(C) combiner (2 each)		
Tape Recorder: Ampex FR3030 (1 each)		
Telemetry Station - Gun Control Bunker, Area 9		
Antenna: System Dynamics Model 1003 Fan Beam (2 each)	Frequency	1435 - 2300 MHz
	Gain	17 dB (nominal)
	Beamwidth	6° horizontal, 40° vertical
	Outputs	Simultaneous RHC and LHC from each antenna
	Operating mode	Fixed, pointable
Receivers: Raytheon (2 each)		
Tape Recorder: Ampex FR3030 (1 each)		
Discriminators: EMR 4130, CBW (18 each)		
Oscillograph: Bell and Howell Model 2000		

Table 4-3. (cont)

Item	Description/Capabilities
Telemetry Antenna - Trailer-Mounted, Used at any Station	
Antenna: Electromagnetic Processes, Inc. Model 100-788, 2.4-m Parabola	Frequency: 1435 - 2300 MHz Gain: 28-32 dB Beamwidth: 6-4 degrees Preamplifier Noise Figure: 1.5 dB RF Outputs: Simultaneous RHC and LHC Operating Modes: Slaved to Radar or Autotrack
Test and Diagnostic Equipment (All Stations)	
Oscilloscopes	—
RF and Baseband Spectrum Analyzers	—
RF and Audio Frequency Counters	—
RF and Audio Signal Generators	—
Station Multiplex: Receiver AGC, IRIG-B, 100 kHz, 240 kHz	—

Neutron Detector System

The Neutron Detector System (NDS) is set up at the target area with an array of photomultiplier tube neutron detectors, connected by cabling to an instrumentation trailer. The instrumentation trailer contains the power supplies, signal conditioning, and recording equipment to record neutron flux. A remote controller is located at the Operations Center in the telemetry room to operate the system. The detectors are positioned in arrays of 6 to 24, depending on test requirements. Each detector covers a radius of 375 ft and can detect the output of a single neutron generator.

VIDEO SYSTEM

Three of the five radars (R36, R24, and R39) have two each boresighted TV cameras. The R-18 and M-33 radars have one boresighted TV camera mounted to their radar antennas. The video output of each camera is recorded at the radar site and the video output of at least one camera at each radar site is transmitted via microwave link to the Operations Center for display in the control room and plotting room.

Two of the SM-mount telescopes are also equipped with TV cameras, which record the data on site and also transmit it via microwave link to the Operations Center.

Four TV cameras are used at the Ordnance Area for security surveillance, and two TV cameras are used to monitor personnel activity in and around the rocket launcher and guns during operations. The video output of each of these cameras modulates a standard broadcast RF frequency (Channels 2 through 7), and the RF signals are multiplexed and transmitted over cable to the Security Building and to the Operations Center.

All of the TV signals received at the Operations Center are applied to a video switcher and distributed throughout the Center. In addition to the TV picture being distributed throughout the Operations Center, a number of computer terminal outputs are tied into the video switcher and distributed. A TV camera is set up to take a picture of the graphics display used by the aircraft controller, and the video is distributed throughout the Operations Center.

A high-speed, shuttered color video system adds to TTR's stop motion photometric capability. The FHS-200 video camera accommodates any C-mount lens from 12 to 500 mm and operates at 200 pps with shutter speeds of 1/1000 s, 1/2000 s, 1/5000 s, and 1/10000 s, which assures pictures with no motion blur. The VHS cassettes in NTSC format can be played back on any VHS system. The system provides tapes with annotated IRIG-B timing. The accompanying recorder/monitor has still-frame capability and will hold one frame up to 45 s. A continuously variable speed playback permits slow-motion viewing forward and reverse. A complete video editing system permits pretest, test, and posttest data on one tape. The camera may be hand-held or operated from a tripod or other SM mount.

Highly portable black and white video capability is made possible with a Sony RSC-1010 camera with SVM-1010 recorder/power supply. This minicamera-type system operates on ac/dc with integral power pack. The camera has a shutter speed of 1/1500 s. The disc will record for 10 s and will hold the image indefinitely.

An Eigen 5820 color video disc recorder with 20-s recording time is available with continuously variable speed forward and reverse and stop-frame capability. Video system integration is shown in Figure 4-13.

A portable TV camera (color or black and white) can be set up at any station on the Range and from most stations the video signal can be transmitted by microwave to the Operations Center or recorded on site.

Video cameras currently available for Range use include:

RCA Model TC1005/01 with 40 and 120 in lens, black and white; installed on pedestals of radars R24, R36, and R39.

JVC Model NV-1800V with 40 and 120 in lens, three-tube color camera installed on pedestal of radar R39.

RCA Model TC1005/V20 with 50 and 75 mm auto iris lens, black and white camera for use in low-light levels, usually security surveillance.

RCA Model TC1005/V20 with 16 to 120 mm zoom lens, black and white camera for use in low-light levels, usually security surveillance.

Sony BVP-110 color video camera with 10 mm to 120 mm zoom lens for documentary use.

Present video recording capability consists of the following:

1/2-in video cassette recorders, VHS format

3/4-in video cassette recorders, U-Matic

Video motion analyzer Sony Model SVM-1010 (10-s recording capability)

3/4-in Sony Model BVU-110 portable U-matic cassette recorder

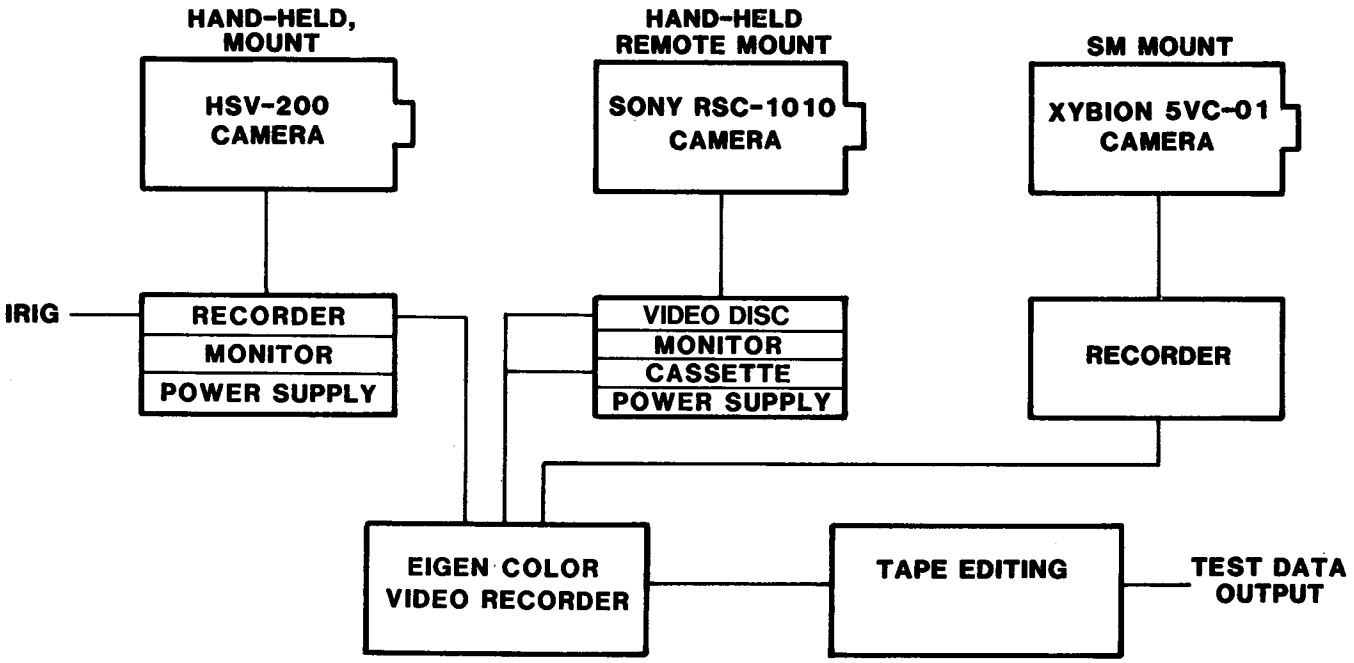


Figure 4-13. Functional Block Diagram, Stop-Action Video System Integration

SECTION 5

ORDNANCE AREA

GENERAL

The Range Ordnance Area, located east of the Main Lake target, is centered around a field of four rocket launchers and two heavy fixed-gun emplacements. Support buildings, munitions storage bunkers, and instrumentation structures complete the complex.

SUPPORT FACILITIES

Four support buildings house the ordnance assembly, checkout, and environmental conditioning facilities. The largest building, usually used for assembly and checkout of nonexplosive components, contains two work bays. The main bay and work area contains a 10-ton-capacity bridge crane; the second bay has a 2-ton-capacity hoist. In addition to test vehicle handling and checkout equipment, the work bays contain a few machine tools, including a bandsaw, drill press, belt sander, grinder, and small arc welder.

Each of two remaining support buildings can accommodate test assemblies up to approximately 30 ft long, with one building containing a 5-ton bridge crane and the other a 1-ton U-rail hoist. Both explosive assembly buildings are rated for 2500 lb of Class B and 100 lb of Class A explosives. One building is equipped with washdown and containment facilities for use in the event of a dispersion of hazardous materials.

Three environmental conditioning chambers in the fourth building are used to temperature-condition both projectiles and propellants to any temperature from $+185°$ to $-65°$F. Inside dimensions of two chambers are $4 \times 4 \times 4$ ft, and the third is $3 \times 3 \times 5$ ft. Adjacent facilities are also available for weighing and packing propellants and explosives.

The explosives storage area, adjacent to the Ordnance Area, has three large bunkers (each with a capacity of 50,000 lb) and 10 small bunkers (each with a capacity of 250 lb).

A secure storage area is also available for classified test items and hardware.

A static sensing system continuously monitors the potential gradient and activates automatic alarms when the gradient exceeds safe explosives handling limits.

Material handling and transportation equipment includes two 3/4-ton pickup trucks specially equipped for carrying explosives, a 3000-lb-capacity forklift, and a 5000-lb-capacity hydraulic boom truck.

A 300-ft meteorological tower provides wind, temperature, and humidity data from stations 50, 150, and 300 ft AGL to support gun and rocket operations.

GUN TEST FACILITY

The gun test installation (Figure 5-1) provides the means for firing artillery projectiles in standard military gun barrels under closely controlled and instrumented conditions. The two custom-designed emplacements are built around standard M158/173 recoil mechanisms, and can accommodate barrels up to the size of an 8-in howitzer. Barrels with adaptive hardware currently available on the Range include both 155 mm and 8 in. Several barrels are available for each gun. Both gun mounts can be elevated from 0° to 90°, and azimuths are fixed at 147° and 170°.

An underground bunker near the gun emplacements provides protection for operating personnel and observers. The bunker also contains the firing console and telemetry station. A CCTV system enables bunker personnel and others at remote locations to observe the gun installations. The telemetry receiving system records ballistic and performance data transmitted from in-flight projectiles.

A 45-ft tower near the gun emplacements provides a fixed platform for cameras with accompanying flash arrays for image-motion photography of the fired projectiles. Projectile velocity and spin rate can be accurately measured with the photographic system. Additional instrumentation yields breech dynamic and peak pressure measurements, and muzzle velocity is acquired with a doppler radar.

A Davis gun (Figure 5-2), available at the Ordnance Area, is a recoilless, smoothbore, earth-penetrator test device. The gun has a 35-ft-long barrel with a 12-in bore and operates on the reaction

Figure 5-1. Ordnance Area Fixed-Gun Emplacements

mass principle; that is, it fires projectiles from both ends of the barrel. The reaction mass is usually about four times the weight of the penetrator projectile. The maximum velocities that can be obtained are dependent on projectile weights. However, as an example, a 300-lb projectile can be fired at 3000 ft/s and a 400-lb unit at 2400 ft/s. The gun can be fired at any desired angle. Since the gun is mounted on a specially designed trailer, it may be transported to areas that have the desired soil or rock conditions.

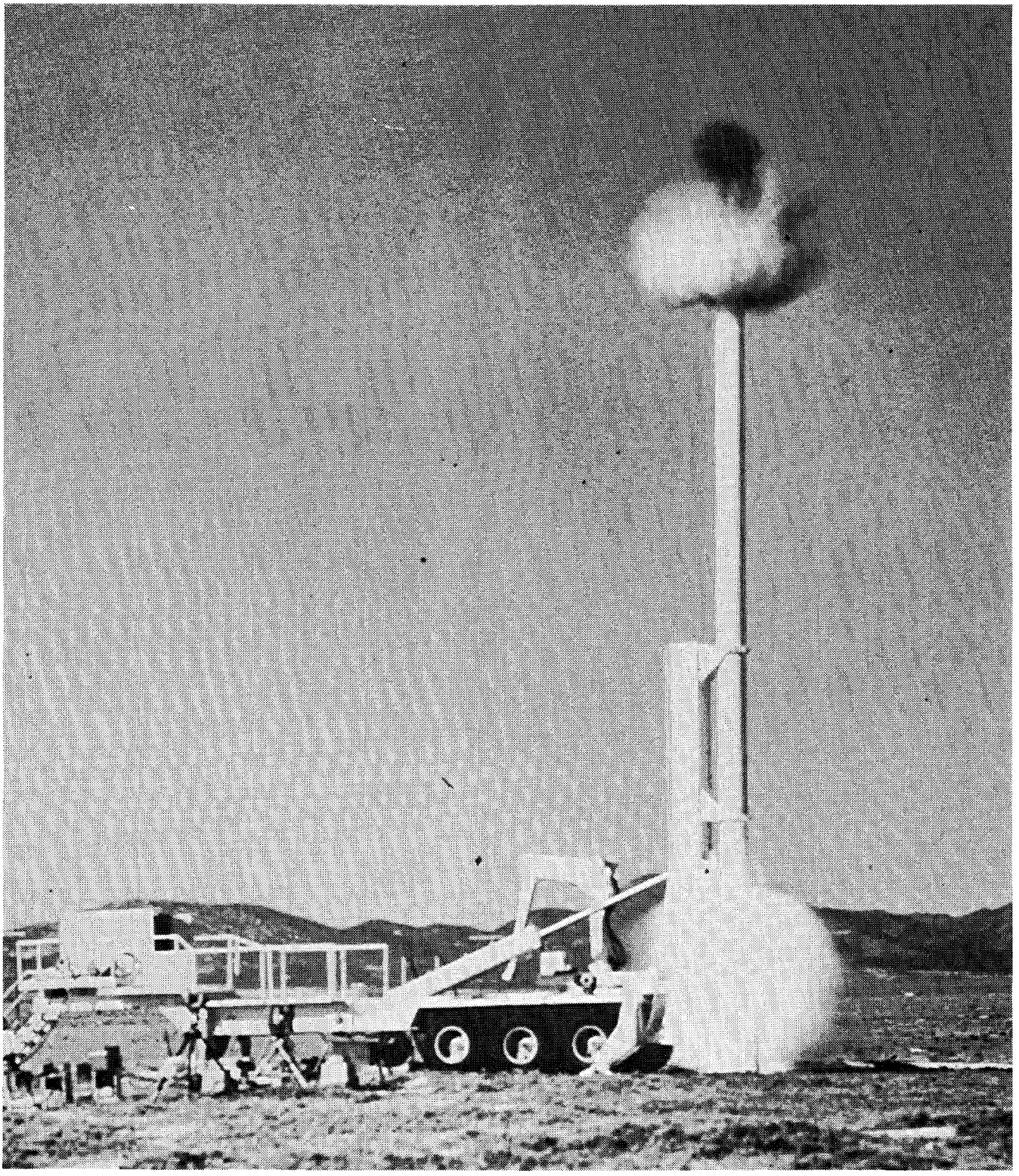


Figure 5-2. Davis Gun Earth Penetrator

ROCKET LAUNCHER FACILITY

Four rocket launchers and a control blockhouse make up the rocket launching installation. The launchers and support equipment were selected and modified by Sandia to assure operational flexibility, safety, and reliability. The two high altitude diagnostic (HAD) launchers will accommodate rocket systems weighing up to 8000 lb, and the two Universal launchers (Figure 5-3) will accept rockets weighting up to 15,350 lb. Typically, the HAD launcher is used for Nike-Tomahawk and Zap class rockets, while the Universal is used for rockets in the Honest John and Strypi classes.

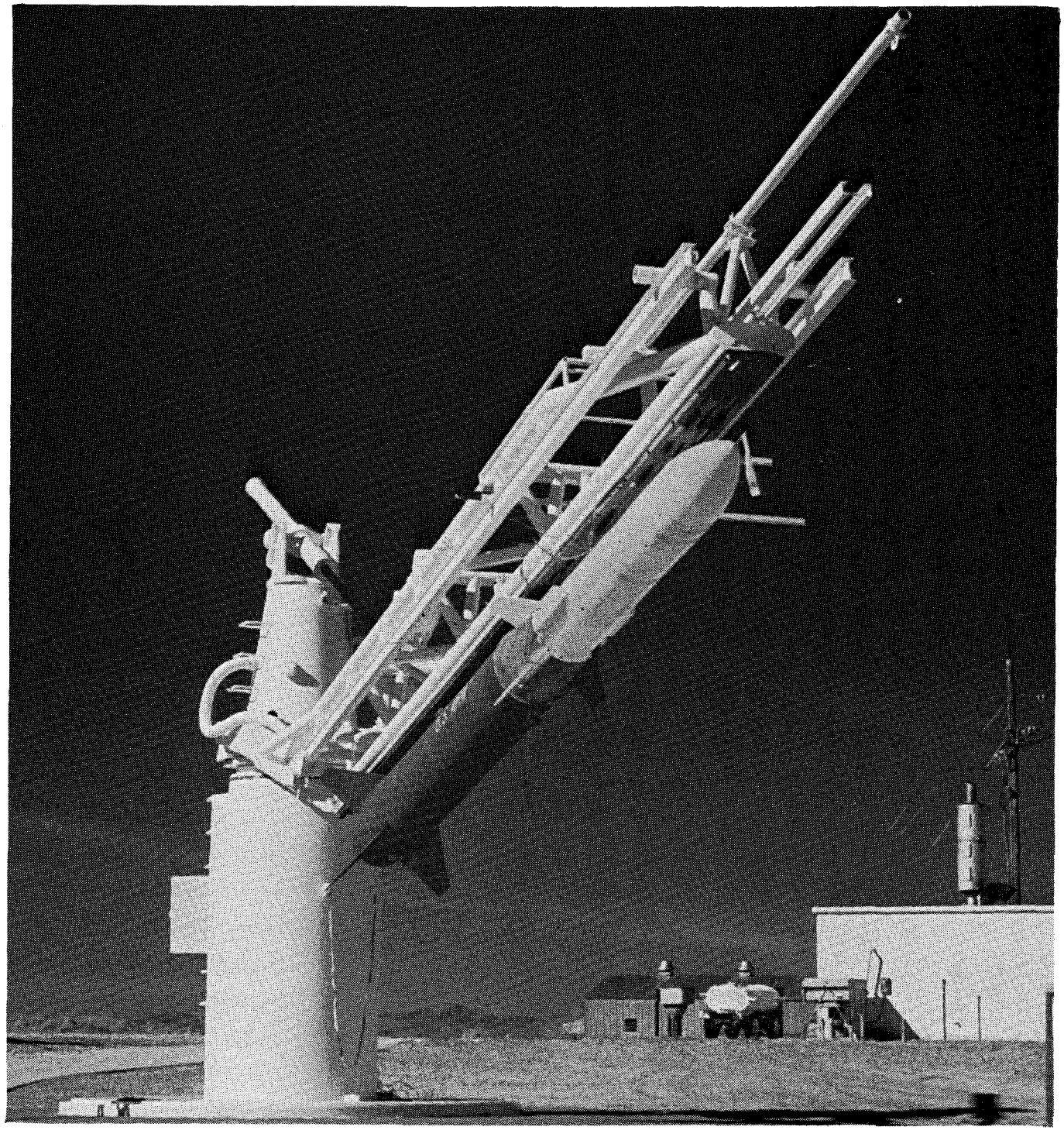


Figure 5-3. Universal Launcher With Test Rocket Installed

All of the launchers are locally and remotely settable from 0° to 360° in azimuth and from 0° to 90° elevation. The launchers are individually controlled to permit multiple firing applications. The blockhouse at the launch area contains the launcher control panels and firing consoles.

TEST UNIT RECOVERY AND EOD

Recovery and EOD

A fully trained and equipped recovery and EOD team is available to recover test vehicles and devices. Test items that present a particular hazard may be rendered safe or destroyed in situ with explosives by the team. The Ordnance Area has a full complement of recovery equipment, including specialized tools, trucks, cranes, backhoes, drilling rigs, forklifts, flatbed trailers, and explosives.

Projectile Impact Location System

A geophone array provides impact locations for 155MM and 8-in artillery rounds fired from the Area 9 gun site. Twenty-four geophones implaced within a 6-square-mile area cover both normal and anomalous impacts. Signals from the geophones are hard-wired to the gun bunker and recorded on analog tape. Relative times-of-arrival are entered into a computer program which calculates the impact locations that best fit the input data. Accuracies of 300 ft have been demonstrated.

SECTION 6

SUPPORT FACILITIES AND SERVICES

MEDICAL

A medical aid station, manned by a trained paramedic, is located in the Security building at the main entrance to the Range Administrative and Control Area. A fully-equipped ambulance is also stationed on the Range. A modern, full-service hospital is located in the town of Tonopah, about 40 mi from the Range. Additional medical assistance can be summoned by using the available emergency radio channels.

SECURITY

Q-cleared security inspectors, provided under contract with Advance Security, Inc., supplemented by electronic surveillance systems, assure security of Range facilities and materials. Secure storage areas and repositories are available for classified hardware and documents.

FIRE PROTECTION

An integrated fire protection system protects Range buildings, facilities, and personnel. The system includes automatic sprinkler systems or Halon extinguishing systems in most buildings, along with fire extinguishers, alarms, fire plugs at strategic locations, and a 5000-gal pumper truck manned by trained personnel.

SHOPS AND CRAFTS

Range maintenance and support activities are performed by a crew of skilled tradesmen provided under contract by Reynolds Electric and Engineering Co. The work force includes machinists, welders, mechanics, electricians, carpenters, cement finishers, painters, pipefitters, and equipment operators. Specialized shops provide a full range of equipment and tools to meet range needs.

The machine and welding shops have the equipment and machine tools to perform most metal-working and machining operations required by the Range. The machinists and welders have at their disposal industrial-grade lathes, mills, surface grinder, drill presses, heat treating furnace, metal-forming and metal-cutting equipment, welders (heliarc, gas, and electric), hydraulic presses, and metal-cutting power saws. The shops also maintain a substantial inventory of aluminum, brass, phenolic, and stainless-steel raw stock.

RF AND RADIO LABORATORIES

The RF and Radio Laboratories support the RF emitting/receiving equipment in use at the Range.

RF Laboratory

Located in the Administrative and Control Area, the RF lab is equipped with the latest state-of-the-art equipment for testing, monitoring, and calibrating RF equipment in frequencies ranging from 500 kHz to 18 GHz. Primary functions of the lab are to:

Aid in the troubleshooting, maintenance, and calibration of transmitters and receivers on the Range

Monitor and aid in the frequency adjustment of the G-Band and I-Band radars

Detect and define the source of interference from unauthorized RF transmissions on or near the Range.

Develop new RF systems

Test newly acquired equipment for adherence to Sandia specifications.

Radio Laboratory

A fully equipped and staffed radio lab supports the varied communications systems in use on the Range. Specifically, the lab is responsible for the development, modification, upgrading, and maintenance of TTR radio systems.

Frequency management is an essential function of the lab. It coordinates RF use with other users, including the Air Force and NTS, to assure electromagnetic compatability. It also monitors all frequencies in use to detect and eliminate sources of RF interference. Lab personnel work with range users to provide special communications links, when required, and to accommodate user-provided RF equipment when dictated by test requirements. The lab technicans, equipped with the latest diagnostic and test equipment, maintain operational capability of the RF communications system.

GROUND TRANSPORTATION AND MATERIAL HANDLING EQUIPMENT

A limited number of cars, trucks, and vans are available for Range use. Official visitors and Range users may have use of vehicles when such use does not interfere with regular operations. Personnel who will need extensive transportation are encouraged to rent appropriate transportation in Las Vegas and drive to TTR.

Heavy equipment available for Range operations include hydraulic and diesel-operated cranes, crawler tractors, backhoes, front loaders, cherry pickers, forklift trucks, flatbed tractor-trailers, and heavy-duty trucks. In addition to routine material handling tasks, this equipment is used for Range construction and maintenance projects, target preparation, and test vehicle recovery.

AIR TRANSPORTATION

A DC-9 aircraft (Figure 6-1) operated under contract with Ross Aviation, Inc, transports Range employees and official visitors between Las Vegas and TTR. It also carries limited amounts of nonhazardous cargo. Section 7 contains information for visitors wishing to travel on the aircraft.

A small two-place L-19 aircraft (Figure 6-2), operated by a certified Ross Aviation pilot, is also stationed at TTR for test operations and general utility use.

Figure 6-1. DC-9 Transports Personnel and Cargo to and From TTR

Figure 6-2. L-19 Observation and Utility Aircraft

SECTION 7

VISITOR/USER INFORMATION

FACILITIES ON RANGE

There is a limited amount of office space for visiting test personnel. Facilities which may be used by visitors are the Control Center building conference room furnished with desks, chairs, tables, and telephones, an Administration building conference room with CCTV and motion picture projection equipment, and a lunch room stocked with a variety of frozen meals, canned foods, snacks, and beverages and equipped with microwave ovens and other food-warming equipment.

Visitors may use Range vehicles when they are available. However, those who require extensive transportation should rent cars in Las Vegas and drive to the Range, a distance of 250 miles. Official visitors may travel on the contractor-operated DC-9 aircraft on a space-available basis. Individuals who wish to fly to the Range should contact Range Operations on 702 295-8221 (FTS 575-8221) for reservations. Aircraft departure time from Las Vegas may be obtained by calling 295-0220 in Las Vegas.

FACILITIES OFF RANGE

Visitors with their own transportation can find adequate food and lodging in the town of Tonopah. Individuals flying the DC-9 have a wide choice of accommodations in Las Vegas. In both cases, advance reservations for both lodging and rental cars are recommended.

USE BY ORGANIZATIONS OUTSIDE OF DOE

Preliminary Contact

Government agencies and their contractors who wish to conduct tests on the Range should contact the Test Director for preliminary discussion of technical requirements and tentative schedules.

Test Director
Tonopah Test Range
PO Box 871
Tonopah, NV 89049
Telephone 702 295-8235
FTS 575-8235

Request for Use

Formal requests for Range use should be submitted to:

US Department of Energy
Albuquerque Operations Office
PO Box 5800
Albuquerque, NM 87185

Request for Data Reduction Services

Users who will need data reduction services should make arrangements two to three weeks in advance for routine data reduction, and several weeks in advance if special software is required. Address inquiries to:

Test Data Analysis Division, 7522
Sandia National Laboratories
PO Box 5800
Albuquerque, NM 87185
505 844-4948

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