WHITE SANDS MISSILE RANGE MODERNIZATION

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INTRODUCTION

The White Sands Missile Range (WSMR), as the only overland National Missile Range, has established an extensive instrumentation capability. This capability must be updated, improved, and expanded to keep up with progress in missile and weapon technology. WSMR has an aggressive modernization program based on sound system planning. It is this program for the 1966 to 1970 period with emphasis on telemetry modernization that is discussed in this paper.

RANGE WORKLOAD

A look at the type of Range workload would be helpful at this point. Over 2,600 hot firings and as many as 4,000 test operations are supported by the Range in a year. These firings and tests are sponsored by the Army, Navy, Air Force, NASA, other U. S. government agencies, and, in some instances, foreign governments. To accomplish the heavy workload, there are two or more hot firings or test operations in progress approximately 75 per cent of the time during a working day. A wide variety of objects, such as missiles (one inch to six feet in diameter and one foot to sixty feet in length), aircraft, balloons, bombs, parachutes, and spheres are employed in tests. A single hot firing may present up to seven targets (boosters, payload, and aircraft) for instrumentation. Land over which tests are conducted includes the 40-by-100-mile area within WSMR boundaries, a 40-by-40-mile Northern Extension, and adjacent flight corridors, such as those from Blanding and Green River, Utah, to WSMR. Data coverage, in terms of space volume, is about five million cubic miles. Length of flights varies from a few hundred feet up to five hundred miles. Approximately seven hundred instrumentation sites provide data coverage. For some of the firings, selected trajectory and telemetry data are processed through the computer in real time for controlling test vehicles and for flight safety monitoring. Data collected with the instrumentation represent a considerable workload for data reduction. Approximately ten million data units were processed in the past year. (A data unit is equivalent to the amount of work required to reduce one point in space from Askania cinetheodolite raw data.) Another indication of the workload is that over one million feet of black-and-white and color film are processed each month. The complexity, variety, coverage, and large quantity of Range tests provide many challenging problems to be solved with instrumentation.

SYSTEMS ENGINEERING APPROACH

Like all missile ranges, WSMR grew by adding new instrumentation for each new project. Today, 135 projects are active at WSMR, and a project oriented growth is no longer practical. New growth and modernization of the Range is now based on a system engineering approach, and the instrumentation is more of a "general purpose" type. With the system engineering approach, as applied by WSMR, future requirements for Range testing are analyzed to estimate the type of work the Range should be doing in the future. Then, concepts and a unified system design are developed and implemented, based on the requirements analysis. The Advanced Range Testing, Reporting and Control (ARTRAC), started in 1958, represents the major system engineering task at WSMR and will be discussed in the following paragraphs.

INSTRUMENTATION MODERNIZATION PROGRAM

All types of range instrumentation and test support functions are considered in the modernization program. Major elements of the program are discussed under ARTRAC, Telemetry, and Sensors (electronic and optical).

Advanced Range Testing, Reporting and Control (ARTRAC)

In the present configuration, most of the instrumentation systems have unique and often inadequate data handling, data processing, communications, timing, pointing (acquisition) data, operations control, and performance evaluation subsystems. ARTRAC integrates these subsystems to provide standard interfaces with instruments and to correct instrumentation deficiencies.

Integration of the instrumentation is accomplished through the use of control and data centers, as shown in the artist's concept in Figure 1. Information, to and from the sites, is routed through Area Data Centers (ADC's) to the Data Processing Center (DPC) and the Range Control Center. ARTRAC can best be visualized when divided into two categories -- Control System and Data System.

Control System. Operation Control Centers (OCC's) have been established both on- and off-Range. Operation of these centers will be subordinate to a Range Control Center located near the WSMR headquarters. Operators in the OCC's coordinate tests with Range customers. To assist instrumentation operators, certain reporting aides will be provided in the ARTRAC Program. A simplified diagram of the automated reporting system is shown in Figure 2. Major elements are operation status reporting and readiness reporting.

Operation status information consists of operation identity, current state of operation (scheduled, running, standby, hold, etc.), and either the running countdown or the time of day when the operation is scheduled to occur. This information is determined and entered into the system on consoles in the OCC's and is distributed through the ADC's to the instrumentation sites and to Range customers. The status of up to ten operations can be entered in the system, but display capabilities for most sites will be limited to two operations.

Readiness reporting information is determined and entered into the system by the instrumentation site operator. Readiness information consists of identity of reporting unit, identity of the operation, one of four readiness levels, and a trouble index in case of "NOT READY." This information is displayed on consoles in the OCC's.

Data System. Data handling interfaces, data processing, data display, communications, timing, instrument pointing information (acquisition), and assessment of instrumentation capability are provided with the Data System. A simplified diagram of the Data System is shown in Figure 3. At the instrumentation sites (sensor), an Instrument Data Converter (IDC) interfaces the instrument with communication facilities. The IDC receives and demodulates data messages; synchronizes internal instrument functions to timing; energizes audible and visual fault alarms; adjusts sample rates (upon command); provides pointing data and pointing data error outputs; enters data quality tags into output messages; formats output messages; and performs instrument diagnostics. At the ADC's communications channel switching and data recording are provided. The Data Processing Center (DPC) is the heart of the Data System. In the DPC, instrument data are processed for the Range user and real-time control of missiles and other targets during the tests. Also, pointing data for control of optical instruments and tracking antennas are computed. Data processed in the DPC are displayed in the OCC's. Provisions will be included for immediate assessment of Range instrumentation capability and its performance during a test.

Large portions of the ARTRAC System are on procurement now, and the system is expected to be complete in 1970. An IBM 7044-7094 Direct Coupled System (DCS) will be used in the interim system. A larger, more flexible computer system will be acquired for the final system. Telemetry information, because of high data rates and the need to preserve data accuracy, is handled separately, as will be described later. However, telemetry stations will be included in the Control System reporting elements and will use pointing data from the DPC.

Telemetry

The requirements for missile telemetry support have increased tremendously since the first V2 rocket was fired at WSMR. Today, there are requirements for missile assembly checkout and prelaunch checkout utilizing closed-loop techniques. Real-time telemetry data are required for launch, mid-trajectory flight, and impact, both on-Range and off-Range. Quick-look records provide immediate postflight analysis. In many instances, the information required to determine missile performance can only be obtained from telemetry data. As newer and more complex missiles are developed and tested, the need for better telemetry data has become critical, resulting in telemetry equipment becoming more sophisticated and expensive.

In the past, to support the increases in test requirements, additional telemetry stations were installed throughout the Range and operated independently. Each station contained equipment to support -needs in the areas of acquisition, receiving, demodulation, recording, and display. This resulted in the overlapping of equipment, manpower, and capabilities. Also, missile telemetry frequencies in the past were almost exclusively in the 216- to 260-Mc band. Telemetry transmission must be transferred to the L- (1435 to 1540 Mcs) and S- (2200 to 2300 Mcs) bands by 1970. These changes will require new acquisition and tracking methods and new receiving equipment.

The telemetry modernization program changes the concept of independently operated stations to an integrated system as shown in Figure 4. The scope of the new system is sufficiently universal to support any formats which comply with the RCC (IRIG) Document 106-66, Telemetry Standards. The system will include equipment for demodulating and demultiplexing all FM/FM (both proportional and constant bandwidth), PAM, PDM, and PCM telemetry signals. The modernized telemetry complex will be composed of an acquisition system, a microwave relay system, and a data handling, recording, and display system. The Telemetry Acquisition System receives and automatically tracks telemetry RF sources and provides conditioned signals to the microwave relay system. The microwave relay system transfers data from the remote stations to a centralized data handling and processing center. The Telemetry Data Center will demultiplex the telemetry signals received on the microwave relay, then digitize, display, record, reproduce, edit, linearize, and scale the telemetry data in both real time and deferred time.

Telemetry Acquisition System. The primary purpose of the Telemetry Acquisition System will be the simultaneous reception of RF signals in any or all of the designated telemetry bands. A simplified block diagram of the Telemetry Acquisition System is shown in Figure 5. Antenna tracking performance and tracking accuracies are equally important but are considered to be secondary in purpose and intent.

The antennas will operate in automatic tracking, slaved tracking, sector scan for search, and manual tracking modes. A tracking memory provides continuous tracking in the same direction and at the same rate for a period of at least ten seconds after loss of signal. A portion of the RF equipment will convert the UHF bands to the VHF band. A multicoupler will distribute signals to eight telemetry receivers. Patch panels provide outputs for predetection recording and for transfer to the microwave relay system.

Fixed telemetry stations cannot always provide adequate coverage of a missile firing during the entire flight, because of geographical locations. To augment the fixed station capabilities, the telemetry modernization program includes mobile equipment. The mobile stations acquire, receive, and record telemetry data. This data will then be transmitted to a centralized processing and display center by microwave relay.

Microwave Relay System. The microwave relay system is the means of transferring data from remote acquisition stations to the TDC. A block diagram of the system presently in operation is shown in Figure 6. The system operates in the 7125 to 8400 Mcs band and employs frequency diversity techniques. Up to eight multiplexed channels can be accepted simultaneously for continuous transmission. The 10-megacycle intermediate frequency output of the eight telemetry receivers are converted by an acquisition converter to frequencies suitable for application to the microwave baseband. Filters for each converted channel provide selectable bandwidths of 100 KC, 500 KC, or 1500 KC. Eight multiplexed channels can be relayed simultaneously at either the 100-KC or 500-KC bandwidths; however, only five channels can be relayed at the 1500-KC bandwidth.

At the fixed stations, the incoming telemetry multiplexed channels from mobile stations are separated and each channel is applied to a selector switch. A second set of eight telemetry multiplexed channels acquired locally are connected to the same selector switch on a channel-to-channel basis. Eight of the 16 channels are then selected for relay to the TDC. Best channel selection can be accomplished manually or automatically. The automatic control of best channel selection is based on a comparison of the AGC voltages. After the best signal is selected, only that telemetry channel is relayed to the TDC. At the fixed stations, all telemetry channels are recorded on predetection recorders to preserve the data in the event of a malfunction elsewhere in the system or for use at a later time. The TDC relay receiver equipment converts the multiplexed channels to frequencies suitable for demodulation and for predetection recording.

A service channel in the microwave relay system is used for voice communications between stations and for relaying AGC, monitor, and control signals.

Telemetry Data Center. The Telemetry Data Center is the central station for handling and processing all telemetry data for White Sands Missile Range. A block diagram of the

TDC is shown in Figure 7. The Telemetry Data Center will perform the following major functions:

a. Demultiplex raw data, assigning appropriate identification and time to each datum point.
b. Condition, convert, and record all telemetry data in a common digital language format.
c. Select and edit data for display and processing.
d. Remove from the normalized data all errors and nonlinearities that are a function of the original transducers or telemetry system.
e. Present the selected processed data in real time to a Central Processing Facility.
f. Prepare computer compatible digital magnetic tapes containing data for further off-line processing or distribution to data users.
g. Present both raw and processed data for quick-look display.
h. Perform off-line functions, including post-test data processing and sorting of data on magnetic tape, mission checkout, and calibration.
i. Accommodate up to three asynchronous time bases simultaneously.
j. Provide complete simulated telemetry information for system checkout and calibration.

The system performs in three widely varying configurations:

a. For real-time support, the multiplexed telemetry channels from the microwave relay are processed in the TDC for entry into the DPC computer facility and for visual display to the operation controllers, missile flight safety controllers, and Range users. This output of the TDC is used for determining automatic and manual control actions during hot firings and tests. Data processed in real time is available for quick-look display and post-test analysis.
b. For post-test processing, the TDC processes data recorded on predetection and digital magnetic tapes during hot firings and tests. This data is then further processed by the WSMR data reduction personnel or provided to the Range user on computer compatible magnetic tapes, strip charts, oscillograph recordings, or listings.
c. For the system checkout and calibration function, the TDC will use simulated data and signals to calibrate and perform checkout of equipment. Also, the TDC will provide simulated signals for checkout of the entire telemetry instrumentation system.

The Telemetry Data Center can operate in all three configurations simultaneously and may be rapidly reconfigured to meet varying mission requirements.

The Telemetry Data Center will be composed of six major subsystems.

a. Telemetry Data Handling Subsystem (TDHS)
b. Digital Data Handling Subsystem (DDHS)
c. Recorder/Reproducer Subsystem (RRS)
d. Timing Subsystem (TS)
e. Display and Quick-Look Subsystem (DQLS)
f. Test, Calibrate, Control, and Status Subsystem (TCCSS)

The Telemetry Data Handling Subsystem (TDHS) conditions, demultiplexes, digitizes, and formats in common digital language, all types of multiplexed telemetry channels from the microwave relay and predetection recorders. The digital format contains the data value word, an identification word, and time word. Subassemblies within the TDHS can handle 2 PCM, 4 PAM-PDM, 2 PAM, and 4 FM/FM multiplexed channels simultaneously. The maximum capability of each subassembly is as follows:

a. PCM - 800,000 bits per second (NRZ).
b. PAM-PDM - 3,600 pulses per second.
c. PAM - 36,000 pulses per second.
d. FM/FM - 50,000 (12-bit) words per second, 18 subcarrier discriminators (Standard IRIG 106-66) in each of 4 subassemblies.

Output capability of the TDHS is 520,000 (12-bit) words per second. FM subcarrier discriminator analog outputs are provided for display. From the TDHS, the digital data are sent to the RRS and the DDHS.

The Digital Data Handling Subsystem (DDHS) selects, processes, formats, and time tags data for output to the quick-look recorders and displays, the computer compatible tape recorders, and the DPC computer. Telemetry data inputs to the DDHS are available from the TDHS in real time and from the digital tapes (high density and computer compatible) in deferred time. Program selection data parameters can be entered in the DDHS by operators on a console typewriter, a card reader, or magnetic tape. Modification of the DDHS program by the DPC computer is possible during real-time operation. Data from as many as 256 sources (transducers or sensors) may be processed at a combined rate of up to 50,000 words per second. Processing of data by the DDHS includes editing, normalizing, scaling, linearizing and computation of derivative data.

The Recorder/Reproducer Subsystem (RRS) has two assemblies-High Density Digital Magnetic Tape Assembly and Computer Compatible Digital Magnetic Tape Assembly. The High Density Digital Magnetic Tape Assembly records all TDHS outputs in real time for reproduction in deferred time. The Computer Compatible Digital Magnetic Tape

Assembly records the entire output of the DDHS. This latter assembly can reproduce data in deferred time for reentry into the DDHS or for use in the DPC computer.

The Timing Subsystem (TS) receives IRIG A and B timing as its time source. Timing may be direct from the Range timing system or from data tapes. The TS generates all timing and clock signals required in the TDC for three simultaneous, asynchronous operations. Provisions for tape search of predetection recordings are included in the subsystem.

The Display and Quick-Look Subsystem (DQLS) accepts 150 digital data sources in any combination of raw and processed data from the DDHS and 72 analog data sources in any combination from the FM subassembly in the TDHS for local recording and display and for distribution to other centers. Recording and display capabilities are:

a. 48 data sources on oscillographs
b. 80 data sources on strip chart recorders
c. 16 data sources on alphanumeric displays
d. 64 data sources on analog meters

Recording and displays in the DQLS are used for quick-look purposes during tests by the Range user and Range operators and also for post-test analysis.

The Test, Calibrate, Control and Status Subsystem (TCCSS) is the central control point for operation of the Telemetry Data Center. The control console contains visual displays of readiness and operation status; provides controls for switching data, making tests, and calibration of equipment within the TDC; and provides a means for verification of proper operation.

Mobile Checkout Vans. These vans are used for preflight checkout of Range user missile telemetry equipment in the assembly areas or on the launcher. Receiving, demultiplexing (FM/FM, PCM, PDM, or PAM), as well as recording and display (oscillographs, strip chart, and magnetic tape) of data are provided for in the vans. If necessary, these vans can be equipped with antennas and located in remote areas for support of firings.

Major portions of the new telemetry system are in operation or being prepared for the Range. Two fixed Telemetry Acquisition stations are now being fabricated. Most of the microwave relay system is in operation on the Range. An interim telemetry data handling system will be completed this year and the TDC described in this paper will be complete in 1969. Modernization of the telemetry system and the change from VHF to UHF will be accomplished before 1970.

Sensors (Electronic and Optical)

The ARTRAC System will provide an improvement in the handling and processing of data for the electronic and optical systems. WSMR plans many improvements in its capability to collect trajectory, attitude, and event data. Major improvements in radar, CW, and optical systems are as follows:

Radar Systems. The AN/FPS-16 radars are being modernized to improve accuracy and reliability. Modernization includes the addition of coherent Doppler kits, digital range trackers, and binary shaft-angle encoders. Existing AN/FPS-16 type radars will be supplemented by the addition of modern mobile medium-precision radars in the next four years. A modern air surveillance radar system will be installed on the Range in the next few years. Major improvements in the utilization of surveillance radar information are expected by processing and displaying data automatically in the ARTRAC System.

CW Systems. A real-time digital data output has been added to the DOVAP (Doppler, Velocity, and Position) System. New CW systems to be added will provide highly-precise trajectory data in the launch phase for high-acceleration missiles and highly-accurate range and range-rate data for missiles that can carry transponders. In the next few years, considerable attention will be given to the problems in measurement of trajectory, attitude, and miss distance on multiple targets and low trajectory missiles.

Optical Systems. Development and procurement of new telescopes and cinetheodolites, as well as modification of existing instruments, will be a major part of the modernization program. Some of the most significant areas are:

a. Development and implementation of the WSMR cinetheodolite system which represents a departure from conventional cinetheodolite technology. Uncertainty of cinetheodolite data will be reduced by a factor of ten.
b. Askania and Contraves cinetheodolites are being modified to improve optics, mounts, and servo systems. Most of the instruments will be mounted in special trailers for mobility.
c. LASER ranging instruments are being developed for special applications.
d. Mobile telescopes are being added to improve attitude and event coverage. New telescopes are being developed to provide optical attitude and event coverage up to 500,000 feet.

SUMMARY

WSMR expects to make major advances in range instrumentation in the next four years and to be able to provide much better support to its customers. A summary of improvements and advantages inherent in the modernization program is given below:

a. Greater flexibility by using more mobile (transportable) instruments.
b. Improvement of coordination and service to customers.
c. Eliminate expensive duplication of equipment and retire obsolete equipment.
d. An order of magnitude improvement in trajectory measurement.
e. Increase the volume of coverage for all types of measurements (telemetry, trajectory, attitude and events).
f. Better compliance with IRIG standards.
g. Capability to handle UHF telemetry.
h. Less turn-around time between tests.
i. Faster delivery of data from all types of instrumentation to user. The goal is quick-look data within two hours and final reports in one to three days.
j. Better flight safety control and monitoring.

By improved planning and reliance on the application of system engineering principles, WSMR will be modernized in a highly efficient manner and be capable of providing even better support to the nation’s missile and space programs.

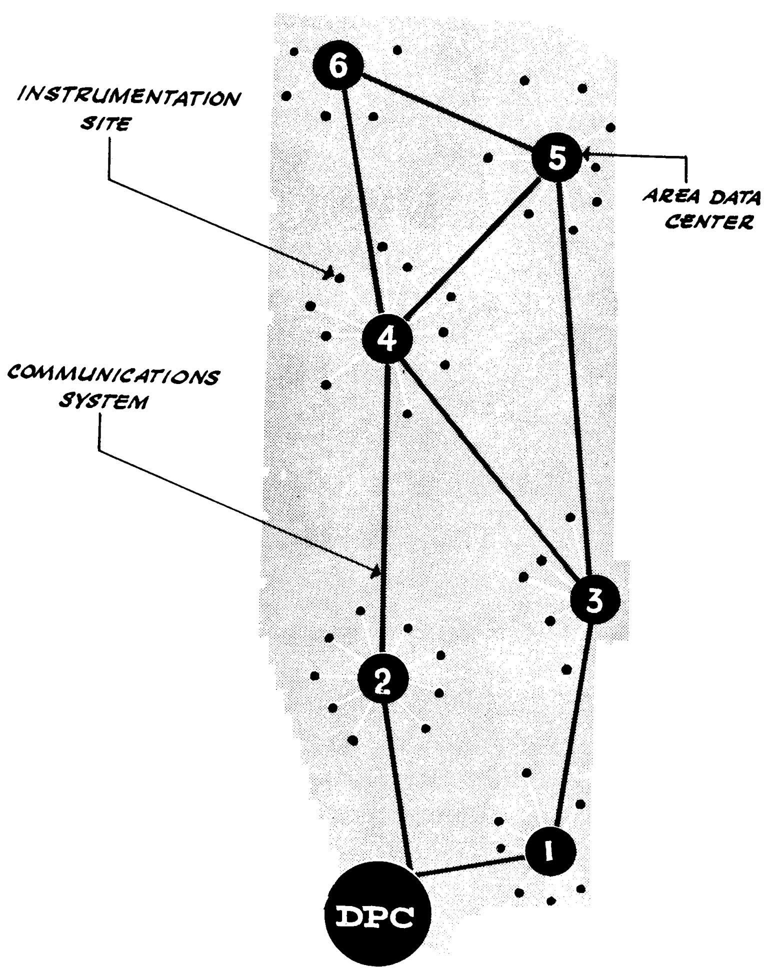

Fig. 1 -ARTRAC System

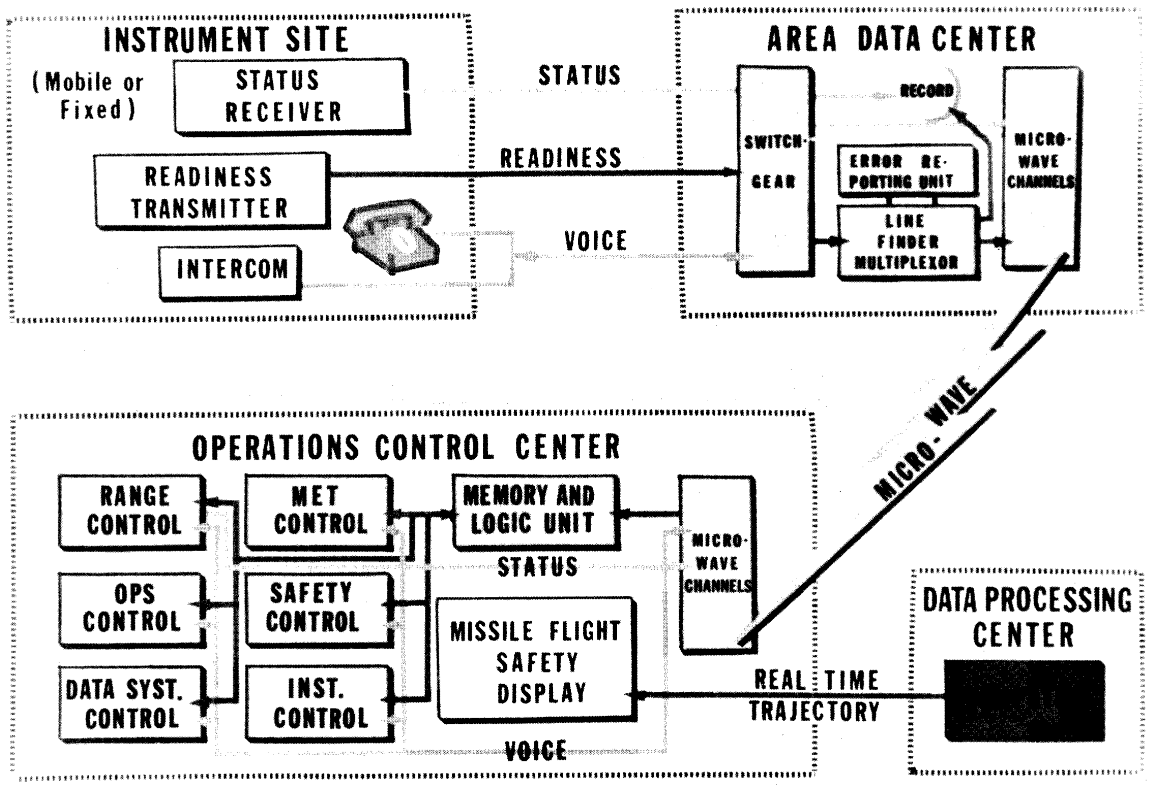

Fig. 2-ARTRAC Control System

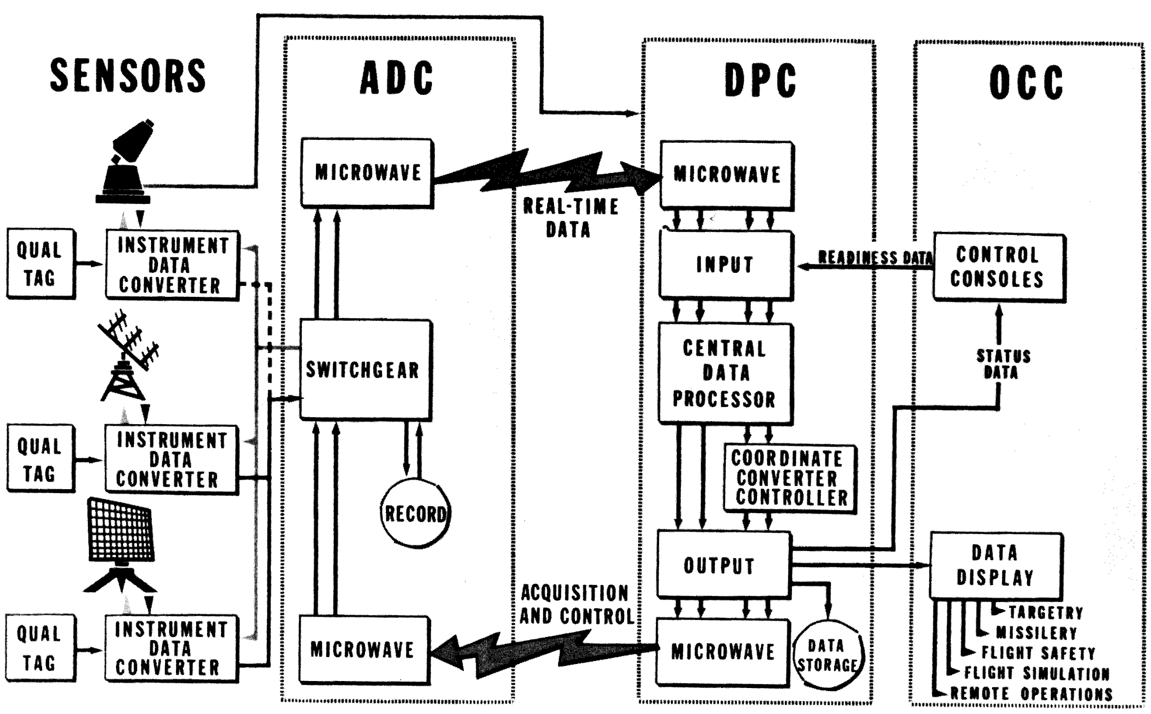

Fig. 3-ARTRAC Data System

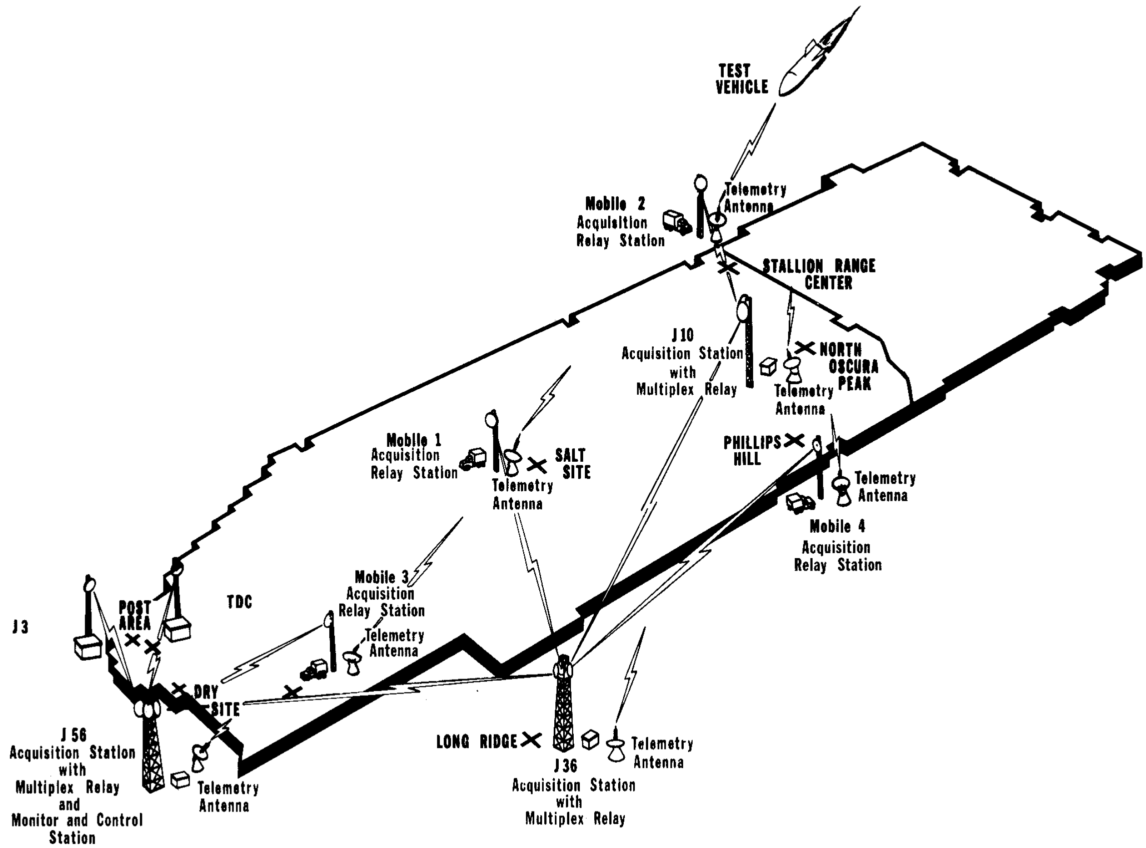

Fig. 4-Telemetry System

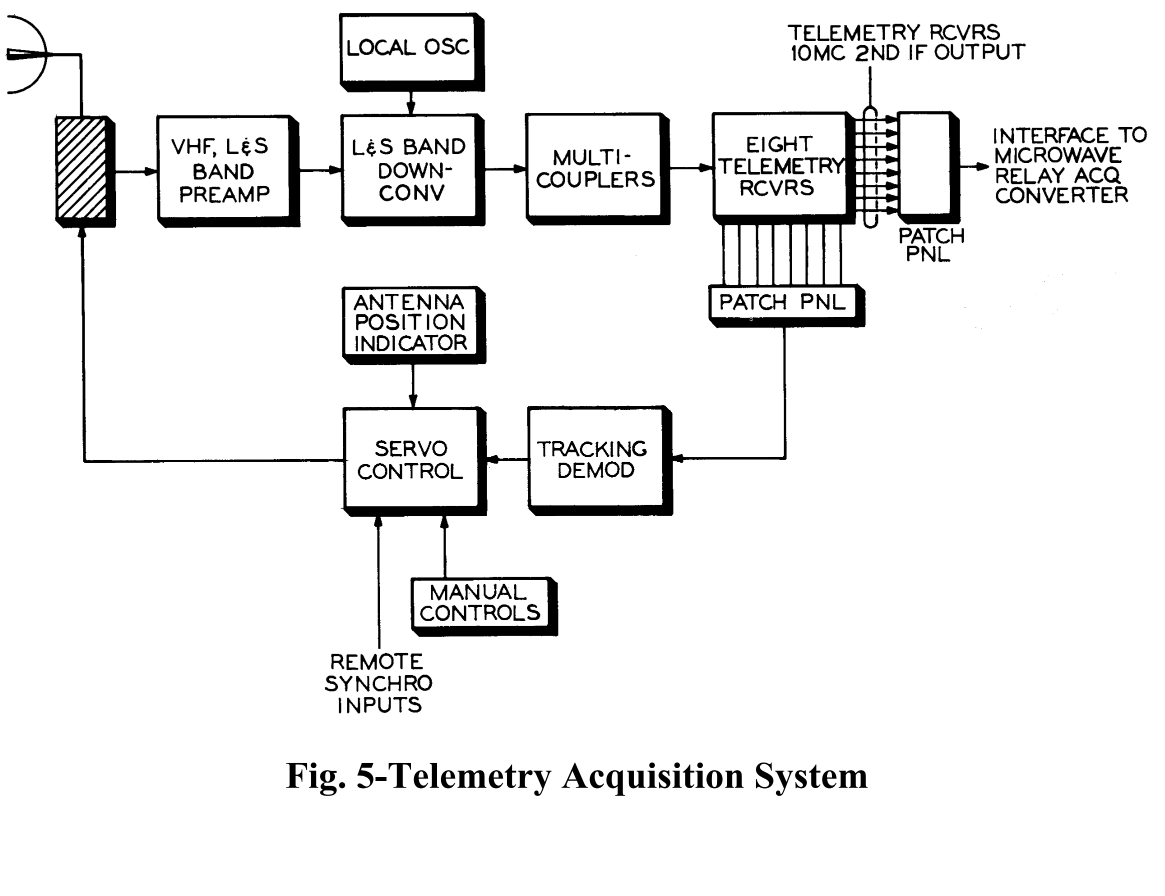

Fig. 5-Telemetry Acquisition System

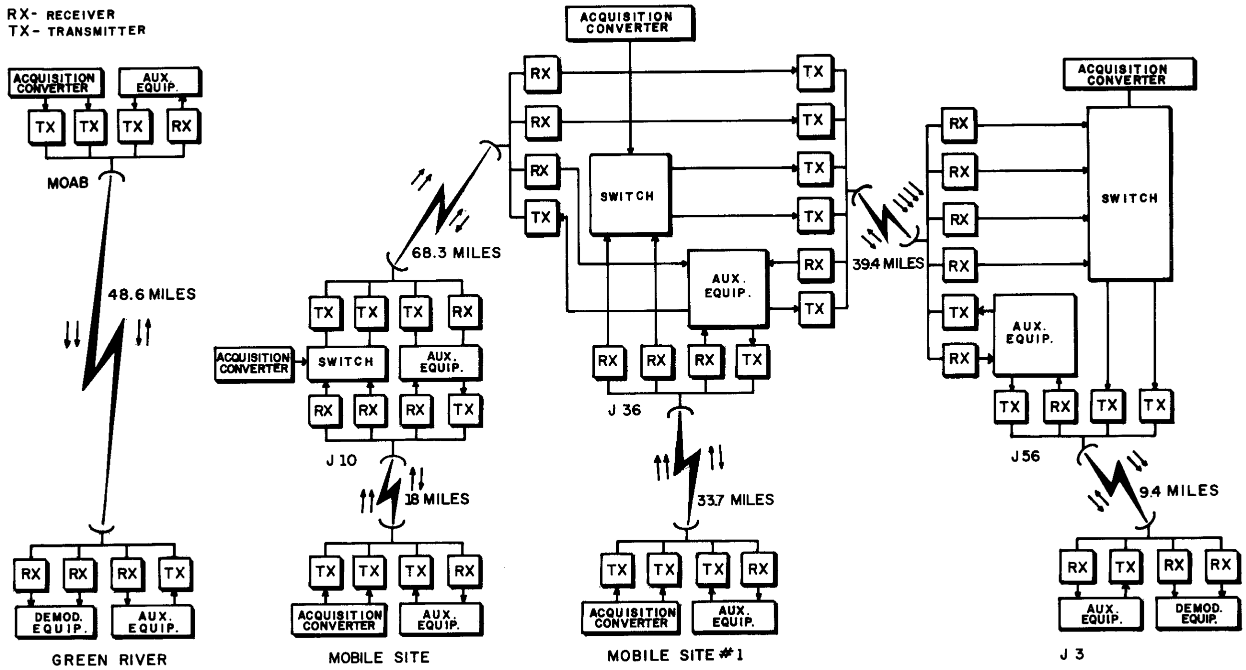

Fig. 6-Microwave Relay System

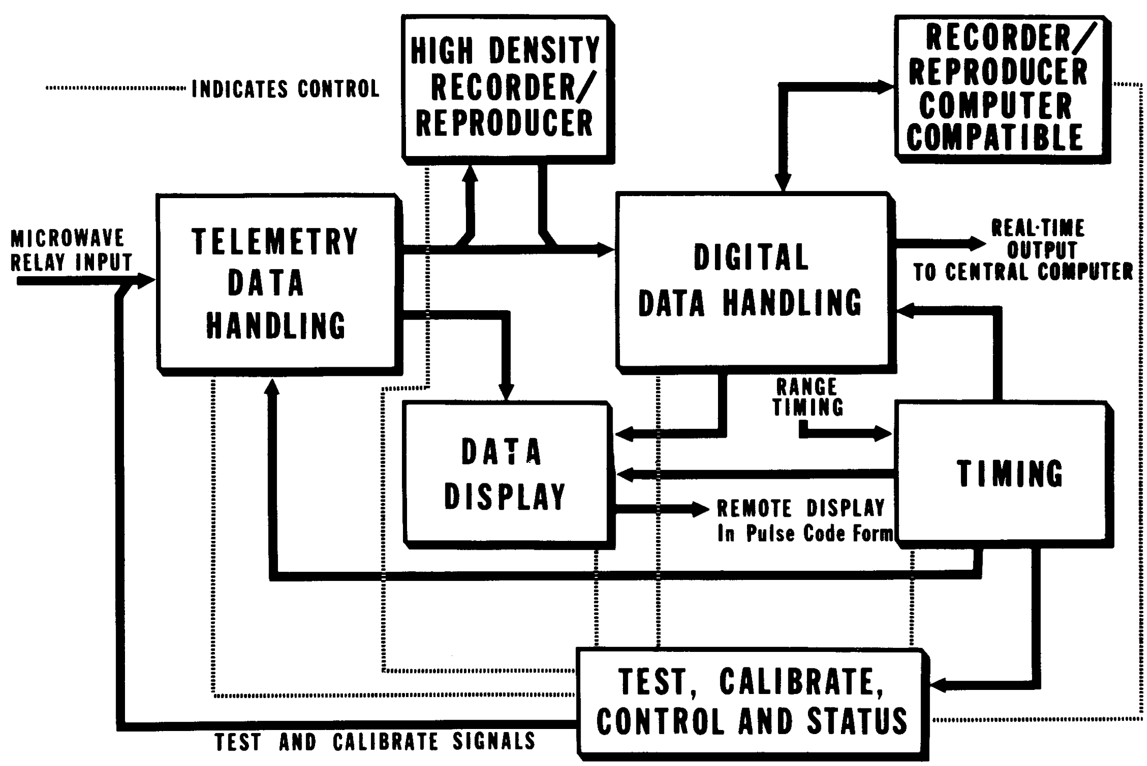

Fig. 7-Telemetry Data Center