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Air Force Eastern Test Range Central Telemetry Station (TEL-IV)

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AIR FORCE EASTERN TEST RANGE CENTRAL TELEMETRY STATION (TEL-IV)

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Introduction

We have had a vast increase in the amount and rate of data telemetered back to the Eastern Test Range from both missiles and manned and unmanned space vehicles over the past few years.

In 1961, as a major part of the Eastern Test Range Telemetry Modernization Program, development of a new Central Telemetry Station at Kennedy Space Center was initiated. It was designated Telemetry Station IV (TEL-IV). The objectives of the new Central Telemetry Station (TEL-IV) have been established as:

1. Provide simultaneous multiple mission capability for both pre-launch and launch support.
2. Serve as a central telemetry station for receiving, processing, and distributing the telemetered data from remote mobile and landbased stations.
3. Provide minimum turn around time between mission setups and permit rapid equipment changes in the event of failures.
4. Provide real time and non - real time capability to meet all program requirements.

In order to achieve these objectives, the integrated systems design departed from the traditional ground station concept of hard wire or manual patching. Instead, the station was designed and based on a central control technique. The system setup and equipment assignment for a given mission's support is accomplished automatically by a launch coordinator through a special-purpose, wired-program digital data processor and a cross-bar switching network.

Background

The Need

A statistical workload analysis was initiated in 1960 to predict the telemetry data handling requirements through 1970. Factors included in this analysis were:

1. Maximum number of launch attempts to be supported in one day.
2. The maximum number of radio frequency links to be received from each vehicle.
3. The modulation type and number of channels to be separated, processed, and displayed in real time and for quick look (within 30 minutes after launch).
4. The maximum number of pre-launch tests to be supported in one day.

The predicted launch schedules for each existing and planned program were used to determine the number of times each program must be supported by year and quarter.

A study was also made to assess the entire ETR telemetry capability. This included the effect of the DOD directive to vacate the VHF bands by 1970, as well as the effect of the Range User requests for more data of improved quality.

The results of these studies clearly indicated the need for a larger launch area telemetry station and a new central telemetry data processing center. The decision to place the moonport at Merritt Island only increased and re-confirmed this need. Air Force plans for a new Central Telemetry Station were closely coordinated with the National Aeronautics and Space Administration (NASA). These plans called for a new 25,000 square-foot facility to be located at the south end of NASA's John F. Kennedy Space Center. This new Central Telemetry Station was designated as TEL-IV.

The added workload due to the Apollo Program, the conversion to UHF bands, and the need to modernize all ETR telemetry stations dictated a manifold increase in the quantities of equipment to be bought. A receiver site was planned for Vero Beach, because of the aspect angle, to overcome flame attenuation. Later studies and tests revealed that High-gain antennas at Grand Bahama Island (GBI) in conjunction with the launch area coverage were adequate to maintain coverage during first-stage burn even for large boosters. The plans for the Vero Beach site were cancelled to conserve funds.

The Implementation

The decision to modernize all the Eastern Test Range telemetry meant a multi-million-dollar equipment buy and a major instrumentation effort. For cost effectiveness and single-point technical control, the telemetry modernization program was placed under Air Force management, with overall system design, integration, and site activation responsibility assigned to the Range Contractor. Since the contemplated new equipment purchases represented a broad spectrum of technology, it was decided that each class of equipment would be procured by selecting technically qualified vendors on a competitive basis. In order to overcome interface problems associated with a multi-source equipment buy, common design criteria were pre-established and general specifications were prepared to cover common mechanical and electrical interface requirements. These general specifications were incorporated into each contract to assure subsystem compatibility. A digital common language, for example, was designed to assure that all digital equipments could talk to each other.

Through USAF/NASA agreement, a site at the south end of the NASA Merritt Island Space Center was selected for the Central Telemetry Station. The building, antenna pads, access roads, and a portion of the telemetry equipment were provided or funded by NASA.

Pan American's Guided Missile Range Division, in July 1963, initiated a three-phase Central Telemetry Station integration program. Phase I was a study contract to design TEL-IV Systems as an automated telemetry station. This phase also included the design study of an automatic test and calibration system. Phase II was implementation of the station systems-integration portion of Phase I. Phase III was to be implementation of the automatic test and calibration system.

The Convair Division of General Dynamics Corporation (GD/C) was selected for Phase I and later for Phase II. The integration contract gave GD/C responsibility for the integration of TEL-IV Systems to meet specific performance and operational requirements.

Systems Design Concept

The Objectives

The principal objectives of the Central Telemetry Station in meeting the need have been established as:

1. Provide simultaneous multiple mission capability for both pre-launch and launch support.
2. Serve as a central telemetry station for receiving, processing, and distributing the telemetered data from remote mobile, and land-based stations.
3. Provide minimum turn-around time between mission setups and permit rapid equipment changes in the event of failure.
4. Provide real time and non-real time capability to meet all program requirements.

These objectives have governed, to a large extent, the design concepts of the system.

The System's Design

In order to achieve these objectives, the integrated systems design departed from the traditional ground station concept of hard wire or manual patching. Instead, the station was designed and based on a central control technique. The system setup and equipment assignment for a given mission's support is accomplished automatically by a launch coordinator through a special-purpose data processor and a cross bar switching network. This basic concept has been expanded into the Central Telemetry Station.

Figure 1 shows the five basic telemetry subsystems of TEL-IV and the normal flow of data through them. The interconnection of these functional subsystems for a given mission configuration is accomplished by the automatic patching subsystem (except that the receive/record subsystems, TRKI-12's, are patched manually). Figure 2 depicts the complete station block diagram and shows how the automatic patching subsystem fits into the basic subsystems of Figure 1. Central Control is implemented operationally by the Master Controller and the Launch Control Coordinator.

Automatic Patching System

The heart of the automatic patching system is the special-purpose, wired-program digital processor which employs a memory drum with a capacity of 6,144 34-bit words in the main memory section, eight 34-bit recirculating registers, and control logic. The memory drum, figuratively speaking, contains a library of all subsystems which can be called up by the remote patch control (RPC). The information is processed at a rate of 250 kc. The RPC receives the input commands (up to 16 commands) from the Control Console either mannually through a ten-digit keyboard or automatically through the pre-programmed paper tape. The commands enable the RPC to interconnect, through the cross bar switching matrix, all addressable functional subsystems required for a given mission configuration. In addition to controlling the cross bar switching matrix, the RPC output also controls the status display unit, line printer, and paper tape punch for making permanent records of the station configuration for any mission.

Switching Matrices. The normal signal flow and the signal characteristics suggest a logical division into three primary switching matrices; namely, the Video Remote Patch (VRP), Digital Remote Patch (DRP), and the Analog Remote Patch (ARP). An additional secondary remote patch system is provided to insert interpolation filters into the digital-to-analog converter output lines for data reconstruction. To use the "common equipment pool" effeciently, the switching matrix is designed to interconnect any one of the source devices to a maximum of 30 selected load devices, depending on the requirement and type of equipment involved. Stringent channel isolation requirements have been imposed to preserve high data quality. Figures 3 and 4 depict typical real time and post-mission signal flow, respectively.

Video Remote Patch. The VRP is a three-stage switching matrix and is designed to interconnect any of 150 groups of video sources (up to a two megacycle bandwidth) to any of 170 groups of loads. Up to four load devices can be paralleled from a single video source. The noise and crosstalk contributed by this system measures -60db.

Digital Remote Patch. The DRP is a single-stage switching matrix and is designed to interconnect any of 40 source devices to any of 95 load devices. It has a paralleling capability of up to 30 loads from a single source. The net interference noise and crosstalk contributed by the DRP is less than -40db.

Analog Remote Patch. The ARP is a three-stage matrix designed to interconnect any of 450 input groups to any of 630 output groups. Up to ten loads can be paralleled to a single source. The measured noise and crosstalk resulting from the ARP is -60db.

Recorder Remote Control

To gain operational flexibility and to permit simultaneous initiation of recording devices, all magnetic recorders, direct-write recorders, and oscillograph recorders are centrally controlled by the launch coordinators. The recorders are assigned in pre-programmed groups to the Control Console assigned a given mission. The launch coordinator can also initiate speed changes, within pre-selected ranges, remotely from his console. The recorder status display panel provides him with necessary recorder status.

Real Time Telemetry Data System

Continuous geographical coverage of certain missions necessitates re-transmission of telemetered data from remote sites (mobile and land-based stations) to the Central Telemetry Station for processing, evaluation, and distribution to ETR support activities and various Users.

To meet this need, a Real Time Telemetry Data System is presently being implemented. This system consists of central receiving equipment located at the Central Telemetry Station and remote units located at downrange and mobile (ship) stations. Due to the limitations of the data bandwidth of communication circuits (subcable or H.F. radio link), the Real Time Telemetry Data System at remote sites selects data from multiple asynchronous RF links and formats the selected data in serial PCM train for re-transmission to the Central Telemetry Station. Under the present program the Central Telemetry Station is equipped to simultaneously process inputs from two (out of 8 scheduled) remote stations, plus up to nine links of locally-received telemetry data. The Central Distribution Programmer is designed to extract specific parameters, in accordance with a stored program, and compile seven output formats for special distribution by the Cape Kennedy Real Time Computer Center.

Facility

The system design concept described above has greatly influenced the station configuration. The facility is designed to support the planned instrumentation system layout. Two principal design features which depart from conventional instrumentation facility designs are:

1. The "equipment pool" concept, which dictates the grouping of instrumentation subsystems by functional groups. Instrumentation space is basically divided into: (a) RF acquisition, receive, and record area, (b) display area, (c) control and status display area, and (d) data separation, processing and off-line subsystems. This integrated facility aids in maintenance, operation and future expansion.

2. A walk-in type access layer between the two instrumentation floors is designed to house approximately 23,000 cables, 700 cross bar switches and other passive devices. The access layer also serves as a plenum chamber for the return of conditioned air.

Systems Characteristics

Since the Central Telemetry Station is designed primarily to cover all pre-launch and support tests of the launch area, the selection of each class of functional subsystems, in terms of performance characteristics and capacities, is based on known program requirements and projected workloads resulting from the continuing statistical workload analysis.

Data Acquisition

Two automatic tracking antennas are being provided for simultaneous reception from two vehicles. One 85-foot parabolic antenna covers the frequency range from 130 to 2300 mc divided into seven discrete frequency bands. The 30-foot medium-gain parabolic antenna covers a frequency range from 225 to 2300 mc divided into six discrete bands. Both antennas employ polarization diversity and are capable of receiving signals from any two frequency bands simultaneously. Three broadbeam disc-on-rod antennas (TAM-1's) are provided exclusively for multiple coverage of pre-launch support. The TAM-1 antenna is designed to receive signals from seven frequency bands simultaneously in the range of 130 to 2300 mcs.

Receive/Record

The receive/record subsystems will accommodate standard IRIG and most non-standard signals of frequency, phase, or amplitude modulated RF carriers with FM, AM, PAM, PDM, PCM, and SSB/AM intelligence between 130 and 2300 mcs with a carrier bandwidth between 10 kc and 3.3 mc. The received signals are magnetically recorded either in pre-detected or post-detected form or demodulated for real time data separation, display and record. TEL-IV is equipped with seven receive/record subsystems, each with 12 receivers. Thus, a maximum of 84 RF links or 42 RF links with polarization diversity can be received.

Data Separation

For frequency division multiplex signals, fixed and tunable solid state discriminators are provided to separate the standard IRIG and non-standard subcarrier frequencies (300 cps to 300 kc) and bandwidths.

The Time Division Multiplex decommutators differ from conventional decommutators in that the output data of the decommutators is converted into an identical digital binary format "Digital Common Language" to improve station flexibility and minimize the complexity of data interface. Three types of TDM decommutators are provided with varying degrees of sophistication. The TDM III is a simple decommutator which handles standard IRIG PAM and PDM data. The TDM Type I and II handle PAM, PDM. and PCM data with frames and subframes of 512 words and word lengths from 3 to 64 bits. In addition, the TDM Type II contains two synchronizers and two main frame recognizers which provide independent bit, word, and frame synchronization. Special provisions of the Type II also include: (1) an automatic adaptive switch-over which enables the decommutator to switch over and maintain synchronization lock on data with varying bit rates, (2) stored program control and manual and external control, and (3) an adaptive signal detector which ensures meeting real time and play-back requirements.

TDM decommutators will handle PCM data rates of up to 1,000,000 bps NRZ, PAM up to 100,000 pps RZ, and PDM up to 6,000 pps.

Data Processing

To provide complete data processing flexibility, a complement of D/A's, A/D's, interpolation filters, computer formatters, and a data corrector are provided at the Central Telemetry Station to meet real time and post-mission data processing needs. The data processing subsystems provide five basic functions:

1. Convert the analog signal into digital common language for computer entry.
2. Convert the digital common language into analog form for display or record.
3. Filter and integrate the signal output from the D/A Converter into a reconstructed analog signal.
4. Format the digital data train into a 7 bit parallel format suitable for IBM 7090 and CDC 3600 entry.
5. Accept digital common language data and perform necessary linearizing, scaling, and offset corrections.

The digital to analog converter subsystems each convert fifty channels of common language data to analog form for recording and display. The frequency response of the D/A Converter is DC to 30 kc with linearity better than 0.1% B.S.L. The analog to digital converters each accept up to 48 analog outputs from the discriminators and convert the analog data into "common language" digital data at a rate up to 20,000 words per second, with conversion accuracy of better than .1% and linearity better than $\pm$.05%.

Display and Record

For real time monitoring or post-mission analysis, a complement of display devices, both analog and digital, is provided. In addition, there is a family of direct-write recorders and oscillograph recorders for quick look and permanent records. Over four hundred channels of oscillograph recording capability is furnished at the Central Telemetry Station. The frequency response of the new oscillograph is rated at DC to 5 kc with extended frequency capability.

The Direct-Write Recorder Subsystem accepts up to sixteen low frequency DC to 55 cps analog signals and provides a permanent record chart. This recorder subsystem exhibits DC and AC linearity of ±.5% full scale with a system stability of .5% full scale within an eight hour period.

The Analog Bargraph is designed to display forty channels of continuous analog data with a frequency response of DC to 2,000 cps and accuracy on the order of 2.5%.

The Digital Bargraph is designed to display forty channels of digital telemetry data in analog form. Data words from the time division multiplex signal are selectable from the front thumbwheel switches of the Digital Bargraph. The measuring accuracy of the oscilloscope is on the order of ±.2%.

Ancillary Subsystems

Ancillary equipments have been provided at the Central Telemetry Station for the recording of telemetry data from remote sites and for playback and copying of real time and post-mission magnetic tape.

The Tape Playback Subsystem is used for the playback of tape recordings of pre-detected and post-detected data. The Telemetry Remote Signal Recorder Subsystem provides for the recording of primary telemetry data from a remote site. This subsystem is primarily designed to record post-detected telemetry signals transmitted over a communications link from remote acquisition sites. In addition, the subsystem is equipped to playback post-detected signals.

The Tape Copy Subsystem will make up to three copies of primary telemetry data tapes. The subsystem is basically designed to copy post-detected telemetry tapes. In addition, it also has the capability to play back post-detected signals and to record pre-detected telemetry signals.

Support Capability

Acquisition and Tracking

Pre-launch. The three TAM-1 antennas give TEL-IV the capability to participate in three simultaneous pre-launch countdowns and pad checkout tests. Although three countdowns normally will not be in progress at the same time, it will be necessary at times to support some pad checkout operations for two weeks or longer. With three antennas assigned for this purpose, there will be no need to interrupt a pad checkout to support a countdown on another pad.

Launch. The two independent autotracking antennas at TEL IV give us the capability to support two simultaneous or successive launches. If the second antenna is not required for other support within two hours of a launch, it will be used to backup the prime antenna in tracking a live launch.

On-Orbit. The TAA-2A antenna will normally be employed as the prime tracking antenna for on-orbit support. The tie-in of this antenna with other acquisition sources through the Cape data acquisition buss will enhance its acquisition capability. As is the case with live launches, the TAA-3A will be used for back-up.

Receive/Record

Receive. The eighty-four data receivers normally provide the capability to support forty-two RF links in polarization diversity modes to ensure high data quality. The forty-two link capability is adequate to meet all known and anticipated support requirements. It is expected, however, that all data receivers will be committed for a single mission when it contains twenty-one RF links and 100 percent instrumentation system back-up is requested.

Record. There are sufficient record-reproduce channels to cover each RF link. All data received by TEL-IV will be recorded in the pre-detection mode. The pre-detection tapes will then be played back to provide separated and processed data in the form requested by the Range User. These tapes will also be used for data insurance in that they can be replayed at a later date to separate and reprocess noisy or questionable data if the User so desires.

Pre-detection magnetic tapes normally will not be furnished to Range Users. TEL-IV has the capability to furnish post-mission data in any form needed by most Users.

Data Separation

Control of most missions will require real time or quick-look (launch plus 30 minutes) strip out and display of selected channels of data. All real time and quick-look data from TEL-IV and pre-selected data transmitted from Grand Bahama Island (GBI) will be processed in TEL-IV as required. Each link or serial train of real time or quick-look data will require one data separation system. Thus, the twelve TDM, seven fixed and four tunable FDM, and two SSB subsystems may all be needed to support one mission, particularly if backup is requested for critical data channels. Normally, however, this data separation capability will be sufficient to support up to seven pre-launch, launch, and post-mission programs. Post-mission support will be scheduled around pre-launch and launch support when necessary.

Data Processing

The eight D/A converters can process 400 channels of data, up to 200 of which can be smoothed and reconstructed through the Data Interpolation filters. The two A/D converters will be used with the four digital displays for real-time data and with the Computer Formatters and Data Corrector for post-mission records. The two Computer Formatters and the Data Corrector are designed to supply the Range User with data records, prepared in his format, ready for computer analysis.

All post-mission data, including that from the downrange land-based and mobile stations, will be processed, displayed, and recorded in the Central Telemetry Station. Post-mission data will normally be supplied to the Range User within 24 to 72 hours. Through the Real Time Telemetry Data System (RTTD), selected channels of data from downrange can be processed and displayed in near real-time or formatted and corrected for computer analysis immediately after the mission.

The RTTD System can be patched to the Range User's Control Center through the Central Communication Interface subsystem (CCI). This will supply them with selected channels of digital data from downrange stations in near real-time. Through the CCI, Range Users will also be supplied with video signals and digital data from TEL IV in real-time. For example, video from the Saturn/Apollo will be supplied to the Mission Control Center in Houston through NASA's Central Instrumentation Facility at the Kennedy Space Center.

Display and Record

The two large display rooms in TEL-IV are provided for the use of Range Users. Here they can monitor selected channels of launch activities in real-time, and downrange data in near real-time. Through the TEL-IV MITOC Systems, the User can be patched directly to his mission control center or block house. He can use the display room for his control center in the case of smaller missions such as small satellite programs.

Each large display room can be sub-divided into two separate rooms. Thus, for the smaller missions, four different Range Users have a display room available in TEL-IV.

Over 900 channels or subchannels of data can be displayed at one time on the analog bargraph, digital displays, direct-write pen recorders and oscillographs. The pen recorders and oscillographs provide permanent records of the stripped-out data. The oscillograph paper processor in TEL-IV is capable of processing 200 feet of oscillograph paper per minute.

Evaluation and Analysis

Evaluation

Each class or type of functional subsystem has been independently tested and evaluated (under the original procurement contract) to determine its respective capability and limitations. During the system integration phase at the Central Telemetry Station, the integrated systems underwent a series of integration tests in a progressive manner to ascertain the system compatibility and to examine the data quality of signals being routed through various combinations of switching matrices. Qualitative comparisons were made during these tests between data collected when the functional subsystems were interconnected through the switching matrices, and data collected when the functional subsystems were interconnected directly, eliminating the switching matrices. Immediately following systems integration tests, a series of systems tests are scheduled to evaluate (under various systems configurations) the overall systems' capabilities and limitations.

The capability of the Central Telemetry Station will be determined in terms of the quality of the recorded or processed data. This requires examination of pre-detection and post-detection recording plus demodulating and processing of various RF carriers modulated with FM, PAM, PDM, PCM, and SSB/AM intelligence in the range of 130 to 2300 mcs. The systems testing will involve a series of tests designed to measure the performance limits of the most significant characteristics of each typical system configuration. For example, the FM improvement threshold, the RF signal threshold for frame synchronization, and the amount of data degradation caused by subsystem nonlinearity, noise, or crosstalk as in the case of analog data or bit failure rate and loss of synchronization with reference to digital data will be measured.

Since the technique employed for the integration of the Central Telemetry Station (switching matrix) represents a new concept for large telemetry facilities, operationally oriented tests are planned and designed to closely examine and pinpoint any possible restrictions. These tests will supplement the integration tests by establishing confidence in the repeatability of results. The tests will cover time required for system patching for a single mission or multiple missions concurrently, for replacement of mal-functioned subsystems, and on the effectiveness of the Remote Control of the Magnetic Tape Recorders, Direct Write Recorders, and Oscillographic Recorders. In addition, detailed tests will be conducted to measure the minimum "turn around" time between two consecutive missions.

Operational Analysis

In the next six months we plan to undertake an extensive program to conduct an operational analysis of the Central Telemetry Station with the objective of establishing the maximum effectiveness of the station in terms of its ability to meet mission support requirements. The plan incorporates the mathematical models developed through Systems Performance Tests and the models developed and verified for various operational elements, such as scheduling, reliability, maintainability and logistics.

The Future

Although TEL-IV is adequate to support all present missile and space vehicle programs, continuing advances in telemetering techniques and the continuing demand for more and higher quality data require an almost constant modification and expansion program. Space has been provided in the TEL-IV facility for additional equipment as it is needed for increased data handling capacity, new types of equipment, and improved processing techniques. Many minor modifications are already scheduled or planned to improve existing equipment to fulfill the latest requirements.

The National Range Division (NRD) is now planning to tie TEL-IV into the Satellite Control Facility (SCF) in California. Thus, NRD will indeed have a global range which will provide world wide coverage for the support of orbital and interplanetary space vehicles.

We expect TEL-IV, with minor equipment modifications and additions, will meet all Range User requirements for many years to come.

Conclusion

TEL-IV can support a total of seven missions simultaneously, including pre-launch, launch, orbital, and post-mission data processing. With the Remote Patch Control subsystem, turn-around time to set up for a new mission is limited only by the time required to set up and check out the various subsystems. The Automatic Test and Calibration System was planned to make it possible to turn-around for a new mission within 30 minutes. Recent analysis of workload requirements by NRD indicate insufficient requirements to justify this system.

Sufficient telemetry equipment is available in TEL-IV to meet all known and planned Range User schedules and requirements. The display rooms, with the large number of display channels available, will provide Range Users, large and small, with sufficient information to meet any need. This should eliminate the cost, to Eastern Test Range Users, of procuring their own data separation, data processing, and display equipment.

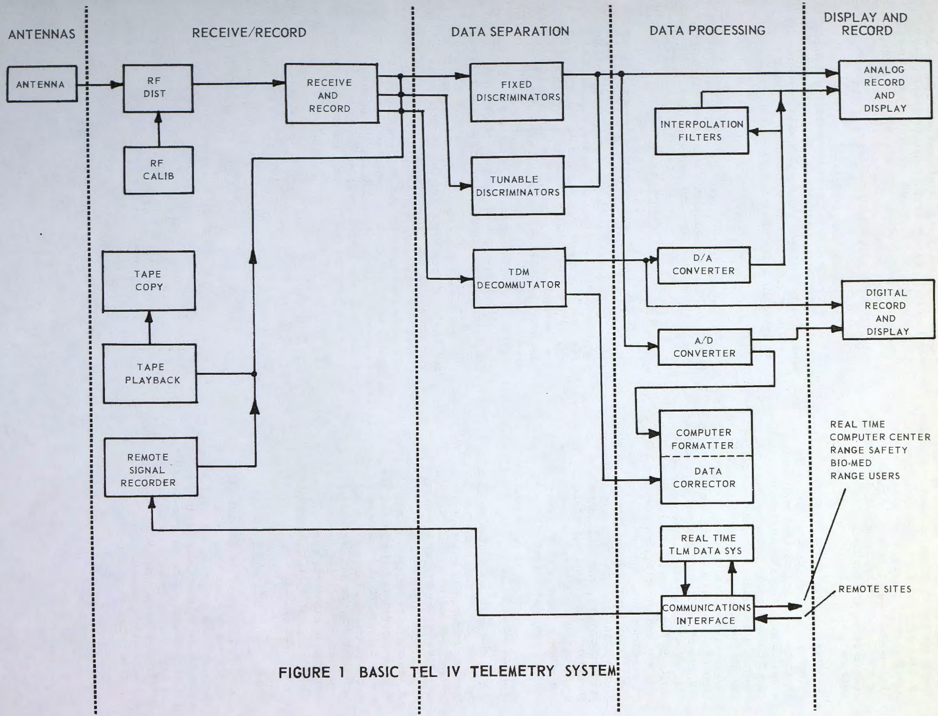
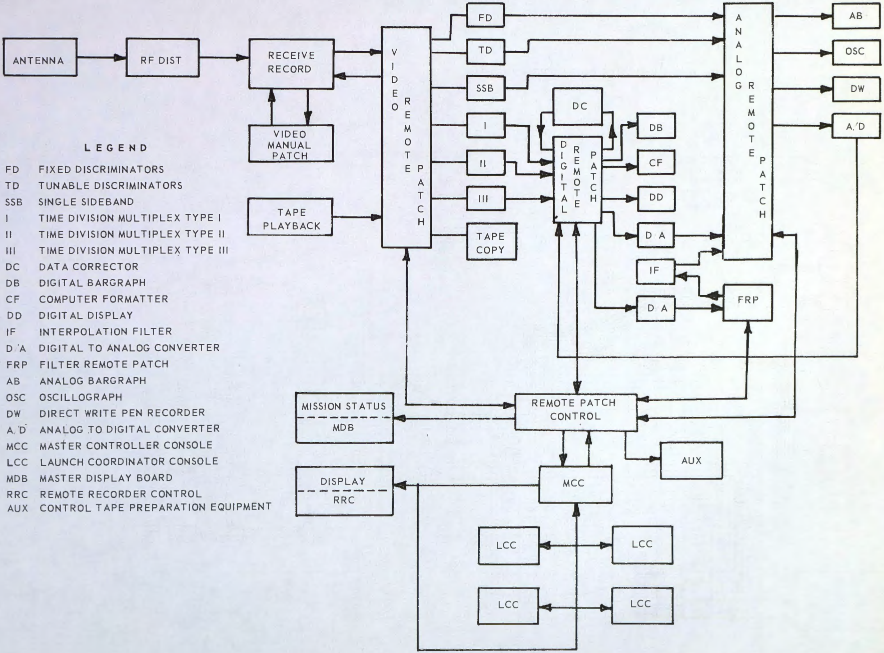


FIGURE 1 BASIC TEL IV TELEMETRY SYSTEM



LEGEND

FD	FIXED DISCRIMINATORS
TD	TUNABLE DISCRIMINATORS
SSB	SINGLE SIDEBAND
I	TIME DIVISION MULTIPLEX TYPE I
II	TIME DIVISION MULTIPLEX TYPE II
III	TIME DIVISION MULTIPLEX TYPE III
DC	DATA CORRECTOR
DB	DIGITAL BARGRAPH
CF	COMPUTER FORMATTER
DD	DIGITAL DISPLAY
IF	INTERPOLATION FILTER
D/A	DIGITAL TO ANALOG CONVERTER
FRP	FILTER REMOTE PATCH
AB	ANALOG BARGRAPH
OSC	OSCILLOGRAPH
DW	DIRECT WRITE PEN RECORDER
A/D	ANALOG TO DIGITAL CONVERTER
MCC	MASTER CONTROLLER CONSOLE
LCC	LAUNCH COORDINATOR CONSOLE
MDB	MASTER DISPLAY BOARD
RRC	REMOTE RECORDER CONTROL
AUX	CONTROL TAPE PREPARATION EQUIPMENT

FIGURE 2 TEL IV SYSTEMS BLOCK DIAGRAM

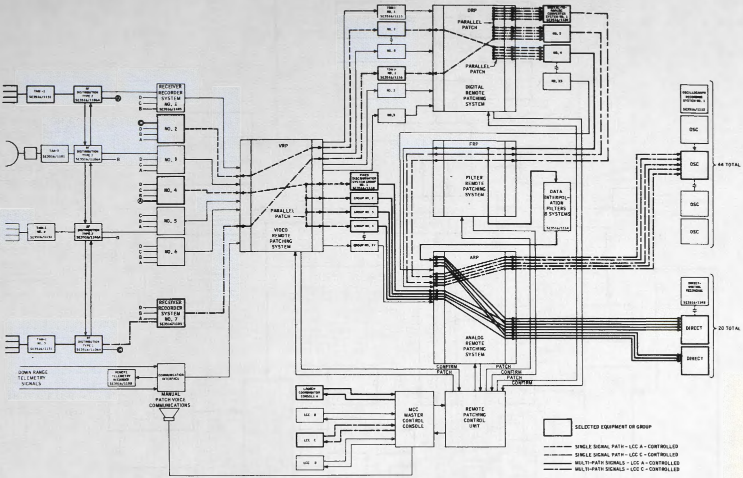


Figure 3 Typical Real Time Signal Flow

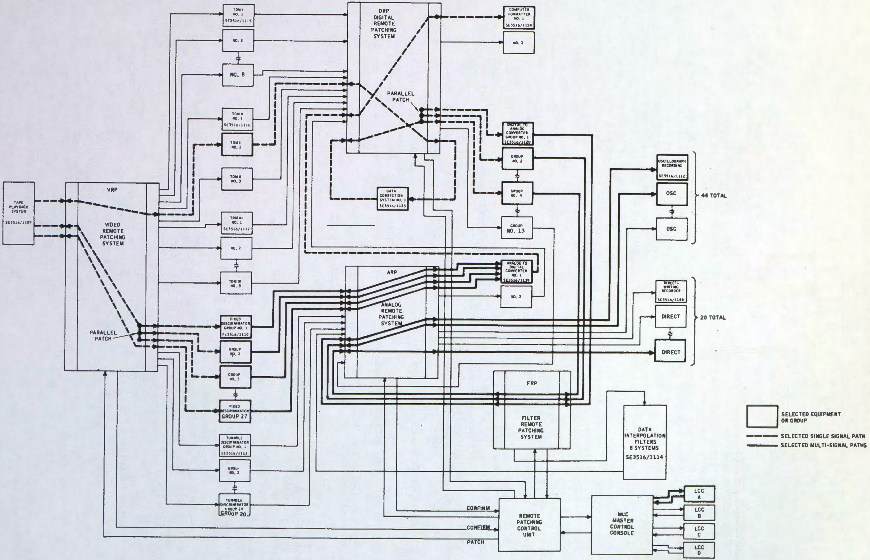


Figure 4 Typical Post-Mission Signal Flow