# CANADIAN FORCES
# PCM TELEMETRY PROCESSING AND DISPLAY SYSTEM

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## ABSTRACT

Canadian Forces (CF) flight test facilities were recently updated to support testing of the CF-18 aircraft by the development of a new ground based PCM telemetry processing and display system (TPADS). Additional enhancements to this system are currently underway, or being considered, to further improve flight test mission control and data processing functions and produce a system capable of meeting CF flight test requirements into the 1990's.

## INTRODUCTION

When the CF-18 aircraft was acquired by the CF, a requirement arose to conduct immediate and ongoing test programs on these aircraft to clear and evaluate the performance of unique CF modifications and systems. Two fully instrumented aircraft were included in the procurement program. However the existing telemetry acquisition and display system was not capable of supporting the new instrumented aircraft. Rather than modify the existing system, it was decided to develop a new system which would not only satisfy the CF-18 requirements but also substantially enhance overall test capabilities.

Budget restraints and time limitations dictated by the delivery schedule for the new aircraft necessitated a two stage development plan; the basic system was installed for initial weapon testing followed by enhancements and modifications as time and resources permitted. This paper will outline the system requirements, detail the present configuration and describe the planned enhancements. Changes to the standard system and in-house developments required to meet specific requirements or resolve existing problems will be emphasized. As well, limitations of the present system and associated plans to resolve these limitations and enhance overall flight test capabilities will be discussed.

## CF FLIGHT TEST FACILITIES

The CF Flight Test Facilities consist of the Aerospace Engineering Test Establishment (AETE) which includes the 200 square mile Primrose Lake Evaluation Range (PLER). These facilities are located at CFB Cold Lake, which is situated approximately 300 Km east/northeast of Edmonton, Alberta, Canada (Figure 1).

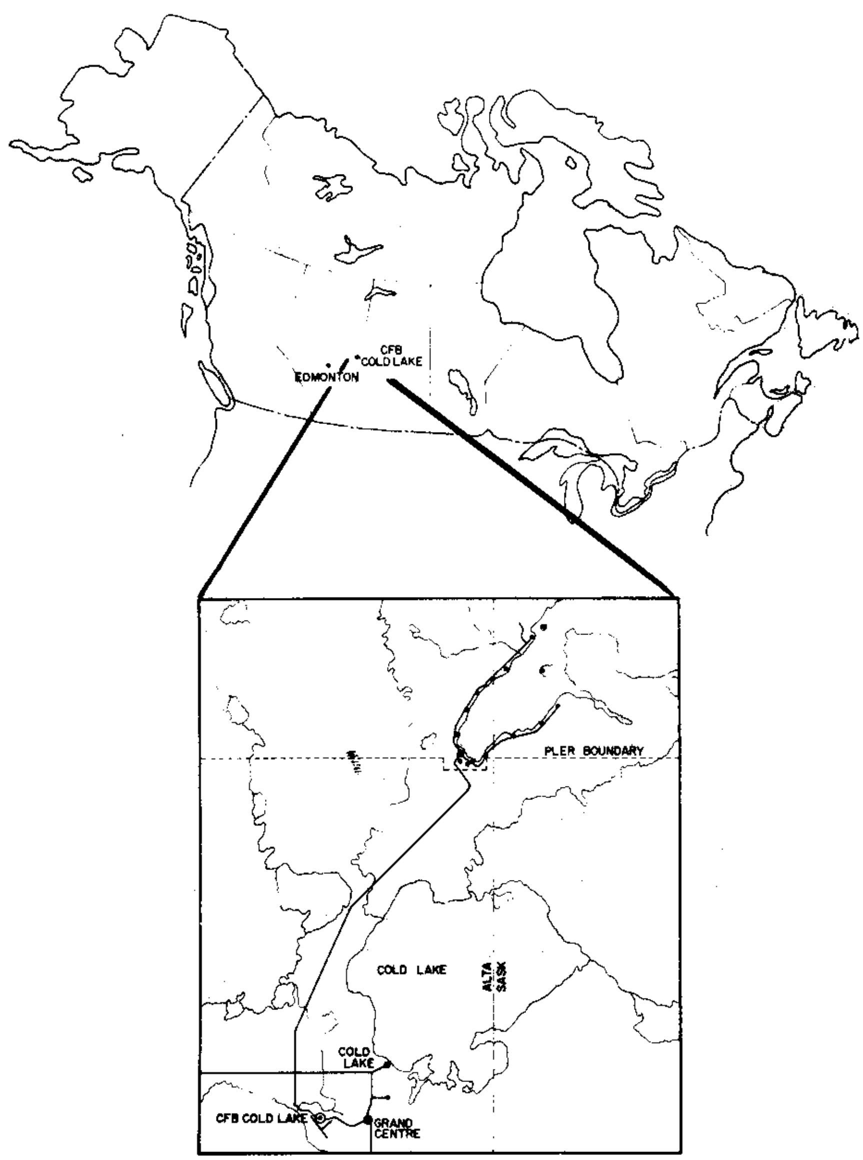


**Figure 1: Canadian Forces Base Cold Lake**

The facilities at PLER include nine phototheodolites, a telemetry tracking and receiving station, a meteorological station, command and control centres, and a microwave and L-Band telemetry link to the main AETE facilities 50 Km to the south. AETE consists of 350 technical, operational and administrative staff.

The primary role of PLER is to provide a controlled and instrumented airspace for flight tests. Spatial positioning data on test aircraft is provided by the nine phototheodolites and two PRELORT C-Band tracking radars capable of operating in skin or transponder mode. Test vehicle spatial position information from the radars is displayed on two CRT terminals located in the main control room. A camera installed on one of the phototheodolites transmits video signals to the control room. The phototheodolites can be slaved to the radar to facilitate target acquisition. Phototheodolite slaving and processing of spatial positioning data is accomplished with a DEC PDP 11/34 computer. Telemetry data is received on a Tecom auto-tracking antenna and sent to the FTCR via a dedicated microwave link, or using L-Band rebroadcast equipment. Timing information is provided by a VLF receiver tuned to WWVB in Boulder, Colorado. An illustration of the PLER facilities and data links to the FTCR is presented in Figure 2.

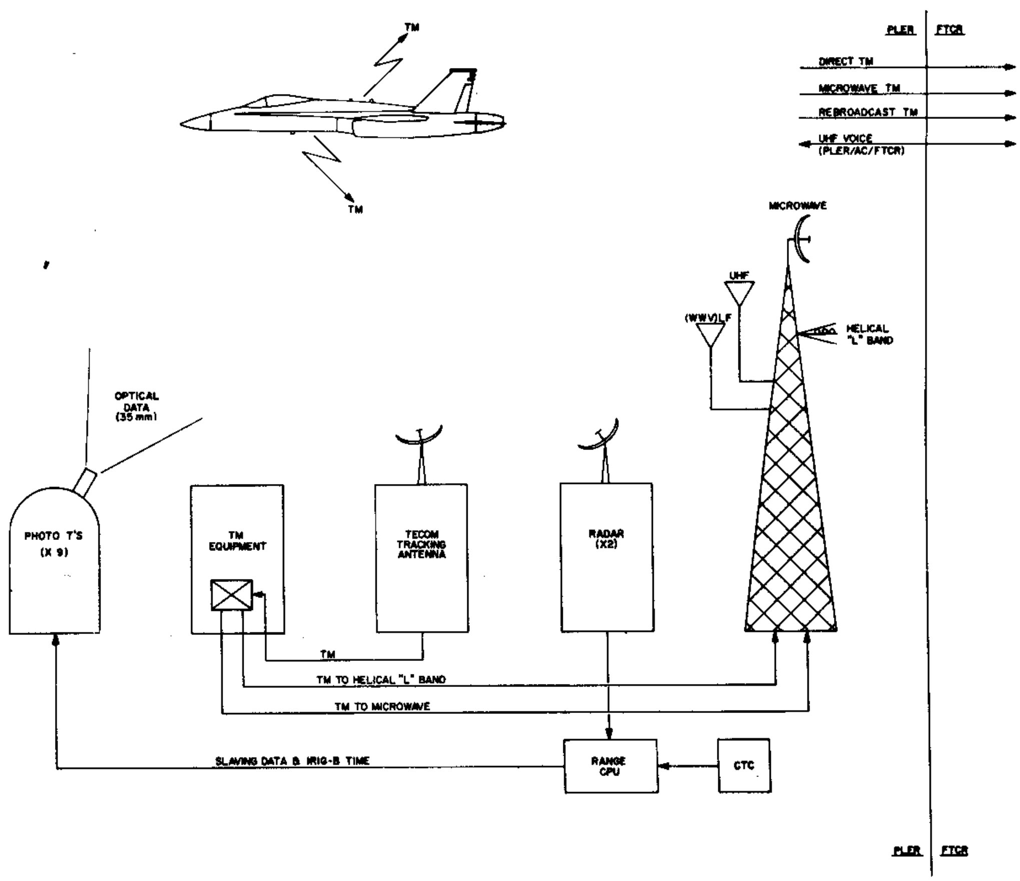


**Figure 2: PLER Facilities and PLER/FTCR Data Links**

## FLIGHT TEST CONTROL ROOM (FTCR)

The primary role of the FTCR is real-time data acquisition, processing and display. It also provides some test control capability, but currently that function is largely handled at the PLER Mission Control centre.

For a typical project, the test team members assemble in the FTCR, which has been configured to provide the necessary data displays. A pre-flight check is carried out on PCM telemetered data received directly from the test aircraft prior to take-off. Once the test aircraft is airborne and telemetry data acquisition has been achieved at PLER, the data are re-transmitted to the FTCR where they are recorded on magnetic tape for post-flight processing, and also processed in real-time for the various displays. The real-time processing and display capability is the heart of the system, since it permits the project team to continually monitor test conditions and quickly modify test parameters to obtain maximum benefit from each sortie and minimize flight safety risks.

FTCR post-flight capabilities include the ability to re-process the data tape and display selected parameters, as well as the capabiliy to reformat the analog PCM data tape recorded on-board the aircraft onto a digital magnetic tape. This tape can then be loaded into the main data processing computer (VAX 11/780) for detailed post-flight analysis and production of graphs, cross plots, etc. A block diagram of the FTCR equipment is illustrated in Figure 3.

## REAL TIME AND POST FLIGHT DATA ACQUISITION AND RECORDING

Real-time and post-flight data acquisition and recording is provided by an Aydin Monitor system consisting of a bit synchronizer, decommutator, and the Aydin Telemetry Acquisition Control Console (ATACC). PCM Bi-phase data are received either directly on an L-Band helical antenna or via the dedicated microwave link. These data are then routed through the appropriate receivers and interfaces to the bit synchronizer, and finally to the decommutator.

The ATACC is a DEC LSI 11/23 based microcomputer terminal with a 12 inch CRT, 64K x 16 bit RAM and dual eight inch floppy disk drives providing a total of 2M Bytes off-line storage for programs and set-up files. The ATACC uses Aydin Monitor’s Telemetry System Integrated Software (TELSIS) for the set up and control of the telemetry data acquisition and processing equipment and for the acquisition, processing, and display of real time data. The ATACC/TELSIS system provides the user with the following capabilities :

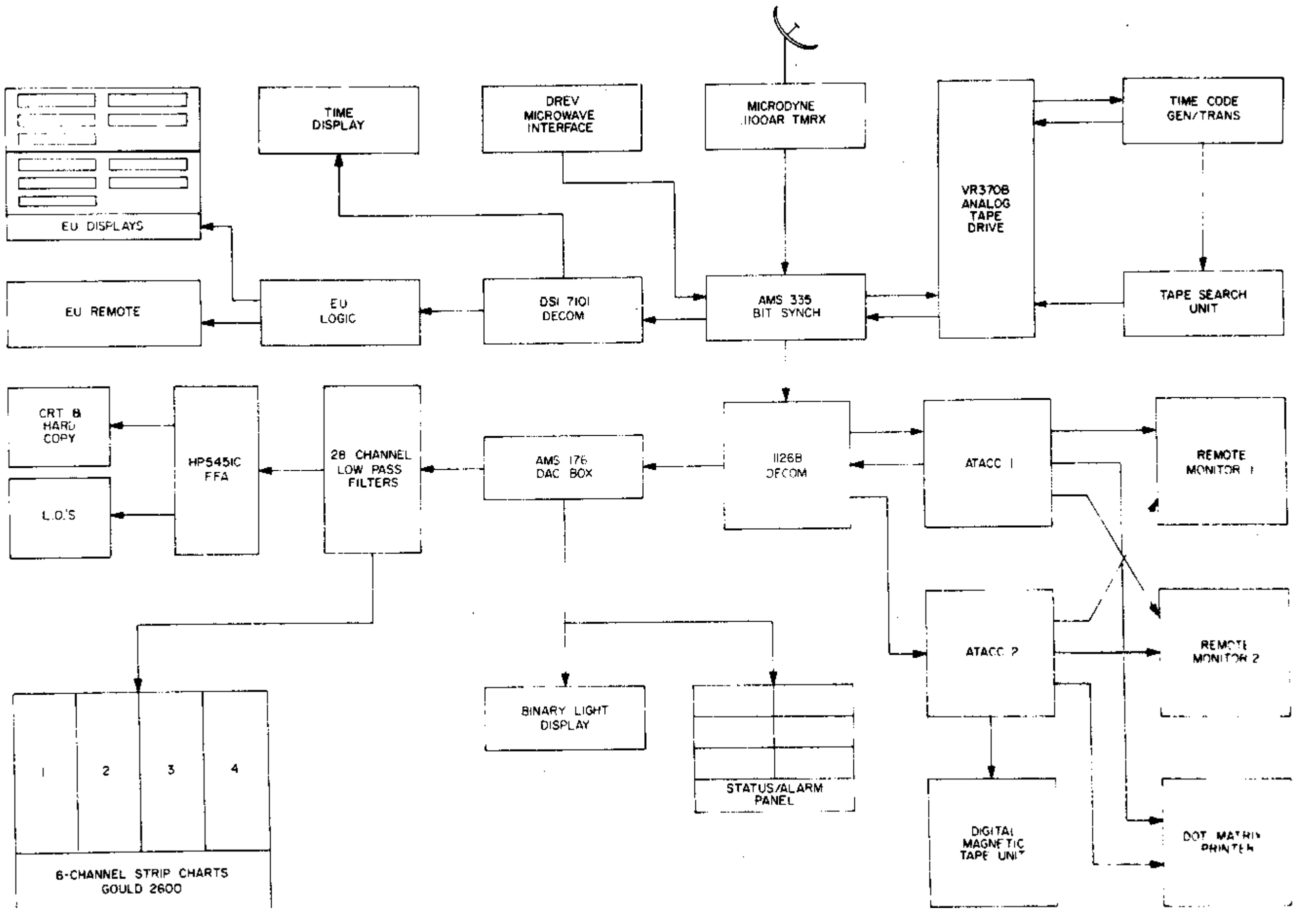


**Figure 3: FTCR Equipment**

a. Pre-Test: The system facilitates complete set-up and storage of signal processing parameters to initialize the telemetry front end (TFE) equipment for a mission and editing of existing set-ups.

b. Real Time: The system is capable of monitoring data from up to 128 telemetry channels and providing, in real time:

- soft and hard copy alarm messages on limit failures for user programmed limits,

- derived measurements based on up to 64 user defined equations of up to 12 terms each,

- up to 32 user defined channels may be displayed on up to 32 different display pages consisting of any mix of the following display types: Limit Alarm List, Raw Data List, EU Data List, Bar Graph, Strip Chart, or a Custom Display which provides a user programmable format.

- on operator command up to eight CRT images can be captured on each ATACC and spooled to a graphics printer, without interrupting display updates or data processing, and

- a hardcopy printout of all monitored and derived measurements can be obtained on command.

c. Off Line: When not being used for data acquisition, analysis, or display, the ATACC terminal can be used to produce digital magnetic tapes for post-flight data analysis or as a general purpose computer capable of running all DEC LSI 11/23 compatible software.

The heart of the TPADS is the 1126B Programmable Decommutator. It is a remote control, stored program synchronizer/decommutator module capable of receiving PCM data in any standard format at data rates up to 5 MBits. It can assign user-selected ID tags to any of the data syllables in the frame and pass selected ones to the computer. Other features available include processing of formats requiring word, sub-frame, and sub-sub-frame synchronization as well as arithmetic/logic operations on words up to 16 bits long. A major feature of the 1126B is the Computation Module. This module receives parallel decommutated data and, via the associated ID tags, accesses the appropriate processing programs which have been set up with the ATACC and stored in the Computation Module’s 8K x 24 bit RAM. Processing operations which can be programmed into the Computation Module include scaling, offset, DAC output, limit tests, binary code conversions, logic operations, etc.

**ANALOG AND DIGITAL DISPLAY SUB-SYSTEM**

In addition to the ATACC displays, the following display systems are available:

a. Engineering Unit Display System (EUDS);

b. Time Display Unit (TDU);

c. Strip Charts (SC); and

d. Binary Light Display (BLD) and Status and Alarm Panel (STALP).

The EUDS is a hard wired logic system developed at AETE specifically for the initial CF-18 Weapons Clearance Program (WCP). It reconstructs the 12-bit PCM words from the data stream into the 16-bit word format representative of the original onboard data taken off the CF-18 MUX BUS (MIL STD 1553 data). These data are then displayed on the ten digital displays in real time. A control is available to select the update rate for either individual samples or an average of a specified number of samples. Two of the displays, centre of gravity and gross weight, are derived in the logic module as a combination of several parameters. Because it is a hard wired system, the EUDS can only be used for CF-18 testing; major hardware modifications would be required to adapt it to the specific data formats of other telemetry systems.

The TDU provides an indication of the following: imbedded PCM IRIG-B time from the onboard TCG; IRIG-B time from a time code receiver tuned to WWVB in Boulder, Colorado; and the difference between the two. The difference is typically kept within ± 1 millisecond by synchronizing the onboard time code generator with the IRIG-B signal via the UHF radio in the FTCR both before flight and during flight if required.

The Aydin Monitor 176 Digital-to-Analog Convertor (DAC) provides 64 analog channels from 12-bit DACs, and 192 digital event lines to the input/output (I/O) panel. The digital outputs are sent to the BLD and STALP, and the analog outputs are sent through a 28 channel filter assembly to the HP5451C Fast Fourier Analyzer (FFA), Lossajous oscilloscopes, and the strip charts. Four six channel Gould 2600 pen recorders are used to display 24 EU scaled measurands with a Bandwidth up to 80 Hz, and a high speed Gould 2600S recorder is used to display six channels of high frequency (DC to 50KHz) data. The selection of strip chart measurands, scaling, etc is all done in the 1126B Decom, under ATACC software control.

The BLD provides LED indicators for up to 64 discrete status indicators or up to four 16-bit words, or any mix of these two types of indications, under software control. These displays are used to monitor the status of data represented by one or more bits in the PCM stream to indicate system servicability, and to verify correlation between binary and EU representations of selected measurands. The STALP displays the status of up to six selected measurands under software control. It is driven by either limit check computations performed within the decommutator, or by status bits gathered from the PCM stream. When designated events occur or limits are exceeded the Digital Event Registers in the AMS DAC 176 box are used to illuminate colored panels, and an intermittent audio tone is transmitted to each headset as well as over the PA system (if desired).

## FLUTTER DATA PROCESSING AND DISPLAY SUB-SYSTEM

This system, which includes the Flutter Exciter Display Unit (FEDU) HP5451C Fast Fourier Analyzer (FFA), Tektronix 4012 terminal, Tektronix 2611 hard copy unit, and eight Lissajous displays, is mainly used to conduct wing flutter test on aircraft configured with various types of ordnance. However, it is also useful for conducting frequency spectrum analysis of any analog test data.

## FTCR DIGITAL COMMUNICATION SYSTEM

Figure 4 illustrates the block diagram of a complete communication system for the FTCR which was designed and built at AETE. This system supports up to 32 stations. The terminals at each station are all identical except the master. All terminals have access to four networks (intercom, radios, recorders, or public address (PA) and event), and each can be set up as an interface for one of these networks. It is a digital system with all the terminals daisy-chained together by two digital buses, each of which handle sixteen stations. A general description of the operation and features of the system is presented in the following paragraphs. This system has provided far superior versatility, control and audio quality compared to the analog communication system it replaced.

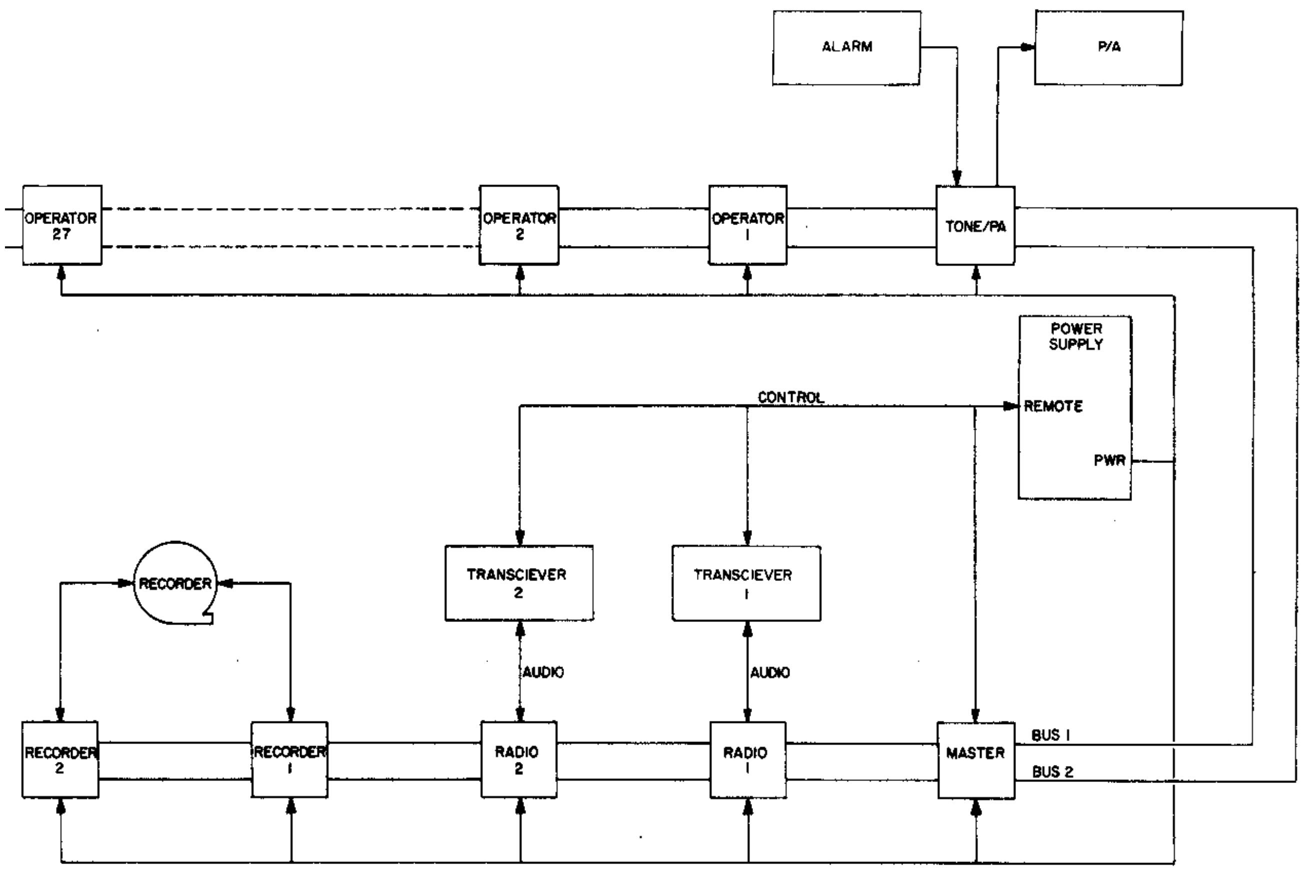


**Figure 4: Digital Communication System Block Diagram**

The intercom network has a total of seven channels selected by a thumbwheel switch on the front panel. All terminals that have the same intercom channel selected can communicate with each other. The radio network has three radio channels. All terminals can hear the selected radio and may also communicate with each other if their radio switch is on. However, only the terminals selected by the master terminal can transmit over the radios. Each terminal has a tone enable switch which permits it to hear event tones transmitted from the aircraft in the telemetry stream. Each terminal also has an override switch which enables it to transmit over the PA system and to all other terminals regardless of their switch selections. The master terminal provides system synchronization and enables up to four other terminals to control radio transmission on any of the three radio channels. Power for the entire system is provided by a common power supply which draws 115VAC at 4 amps. The current configuration used in the FTCR is illustrated in Figure 5.

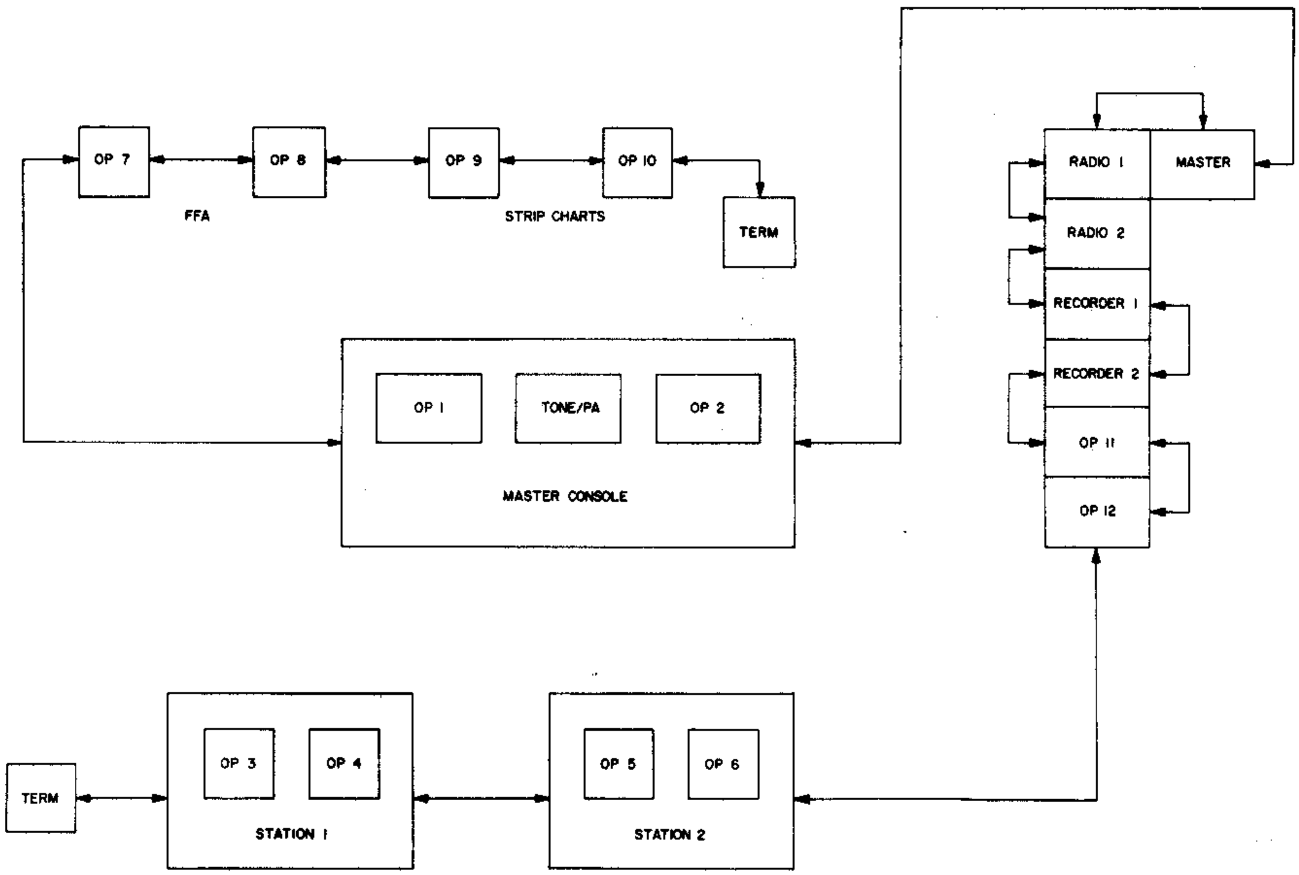


**Figure 5: FTCR Communication System Configuration**

The system is based on a time division multiplexing (TDM) scheme. The master terminal contains a 320 KHz clock which is used to establish 16 time slots for each of the two buses. Thus each bus can accomodate 16 channels sampled at 20 KHZ. For every 16 clock pulses, a reference synch pulse is generated which occurs at the first multiplex position of bus 1 or position 17 of bus 2. This synch pulse is used by all terminals to insert or remove data to or from the digital buses at the correct time. All terminals, whether configured for intercom, recording, radio or event tone/PA operation, are assigned a unique time slot via internal jumpers. The buses are two way differential systems which use twisted wire pairs terminated at both ends to hold the lines in a low (zero) state when not driven. Each terminal digitizes and multiplexes its audio output onto the digital bus in its own assigned time slot, along with the associated control information, and each terminal can receive data from any number of other terminals which have selected the same channel. These data are then mixed and converted to analog form for listening, recording, PA, or radio transmission.

## ASSESSMENT OF FTCR CAPABILITIES AND LIMITATIONS

During the past year the FTCR has been successfully used to support more than 150 missions on a variety of test vehicles. The CF-18 WCP, for which the FTCR was initially designed and optimized, was effectively supported with few problems, and the system is currently providing a full range of pre-flight, real time and post-flight test support for all test programs. However, the following deficiencies have been identified:

a. All measurands selected for real-time analysis must also be included in the post-flight data unless an entirely new set-up is created - an arduous task.

b. Because of the hard-wired logic configuration of the EUDS necessitated by the severe time constraints imposed by the original CF-18 test requirements, this unit cannot be readily reconfigured for different aircraft and/or different PCM formats.

c. Due to the requirement to format PCM data into 9-track computer compatible digital tapes, which must then be manually loaded into the VAX 11/780 data processing computer for post-flight processing, the transfer of data between the FTCR and the data processing computer is a cumbersome and time consuming procedure.

d. The current system lacks the capability to carry out a post-flight search of airborne TM data tape and produce a list of event times. This limits the ability of the project engineers to identify the specific event times of interest for post flight analysis in the FTCR, and for production of the digital tape for post flight data processing.

e. The lack of real-time video data to supplement the telemetry data and radio communications in the FTCR during real time test monitoring has proved to be a serious problem which has led to confusion prior to missions as well as a degradation in mission control. In particular, it would be very beneficial for the test personnel in the FTCR to have access to visual information of the flight line activity prior to each mission launch, the orientation of the test vehicle within the range airspace, and events occurring on the test vehicle (eg rocket firing, bomb drops, separation and jettisoning tests etc.),

f. Audio communications between the FTCR and PLER are currently inadequate.

g. The current configuration can only support one PCM data link between FTCR and PLER thus limiting range utilization to one real-time mission at a time.

## PLANNED ENHANCEMENTS TO PLER/FTCR

Plans are under development to eliminate or alleviate the problems outlined above, as well as other minor problems. Essentially these plans entail: the addition of a data compression capability; a major redesign of the EUDM; the addition of a VAX 11/785 minicomputer to the FTCR; design and construction of an event time search unit; the addition of ground and air video systems and installation of a CRT to display test vehicle orientation within the range airspace from RADAR data transmitted from PLER; an upgrading of the PLER/FTCR communication link; and the addition of a second PCM data link.

One option being discussed with the contractor is the design of a data compressor module for the 1126B Decommutator. This module would provide the capability to select specific measurands from the PCM telemetry data stream in real-time according to limit criteria set by the operator, selection of every Nth sample, time averaging of N data samples, and the capability to select different measurand lists for real time and postflight processing, etc. The advantage of the system are two fold: less data is passed to the post-flight data processing computer thereby decreasing it’s workload and data turnaround time, and real time plot/cross-plot capabilities are facilitated by freeing up the VAX 11/785 processing time during the periods when TM data is being rejected.

The replacement of the hard wired logic in the EUDS with a system which would utilize the programmable capabilities of the Computation module in the 1126B Decommutator is being investigated. Under this scheme all word selection, scaling, and conversion to required format (ie. word reconstruction, 2’s complement to binary conversion, etc.) which is currently done within the EUDM would be accomplished under software (TELSIS) control. The desired parameters could then be output in 16 bit binary format via the digital event registers through an interface to the EUDM display modules. With this system any combination of measurands could be selected and displayed for each mission simply by reprogramming the Computation Module.

To provide automated digital reformatting of PCM data into 9 track computer compatible digital data, the acquisition of a VAX 11/785 minicomputer along with an Aydin Monitor Systems GPD-004 VAX Unibus interface and associated TELBASE software is being considered. This equipment would eliminate the requirement to produce 9 track digital tapes since, under TELBASE, data may be routed directly from the telemetry front end (TFE) hardware to the VAX memory and then written to either disk or magnetic tape. With the addition of two color graphics CRT terminals and a hard copy unit this system could also provide an interactive real-time plotting and cross-plotting facility since the

GPD-004 interface and TELBASE can provide telemetered data to the VAX 11/785 for processing and display. The VAX 11/785 is fully compatible with the VAX 11/780 currently used for post-flight data processing, so these two computers could be networked into a system which would share peripherals. Since the VAX 11/785's processor is 50% faster than the one in the VAX 11/780, this system would significantly increase overall data processing cabability thereby alleviating the data bottleneck problem currently existing in this area.

In-house design of an event time search unit which will produce a hard copy list of all event times from a PCM data tape in a post-flight playback mode is currently underway. This system will provide the project engineers with the exact time of each event tone generated on-board the test vehicle, and permit them to readily identify the precise data time slices desired for post-flight analysis and display.

Two systems are under consideration to provide visual data to the FTCR: a real time airborne and ground-based video system, and a CRT for representatin of test vehicle location within the range airspace.

The major components of a real time video system are illustrated in Figure 6. This system would provide pre-flight monitoring of the flight line, system would provide pre-flight monitoring of the flight line, visual coverage of the test vehicle from three different angles (as seen from three phototheodolite sites), and airborne data from video cameras mounted in the cockpit and/or externally. Shuttered video systems would be used to provide adequate displays of dynamic events and IRIG time code data would be inserted into the video data stream for time correlation. The airborne camera would operate at 200 frames/second for maximum dynamic response. The data would then be recorded on-board at 200 frames/second, but would be reduced to 60 frames/second for transmission to the ground for real time display using a standard video transmiter with 10MHz BW. The bandwidth limitation of 60 frames/second for telemetered video data will limit the resolution of the system in the real-time mode, but should enable the test directors to ascertain current mission status and identify serious problems such as undesirable separation characteristics during stores separation tests. Post-flight analysis of the 200 frames/second video from the on-board video recorder will provide more detailed information ti augment the real time data.

PLER currently use an ORCA Model 1000 graphics CRT to display the position of the test vehicle over the range during test missions. This system operates by displaying positional data from the Range CPU and superimposing this data over an image of the test range. It is planned to transmit this data to the FTCR via the microwave link and display it using an identical CRT display to provide the test director at FTCR with the same positional information available to the PLER mission controller.

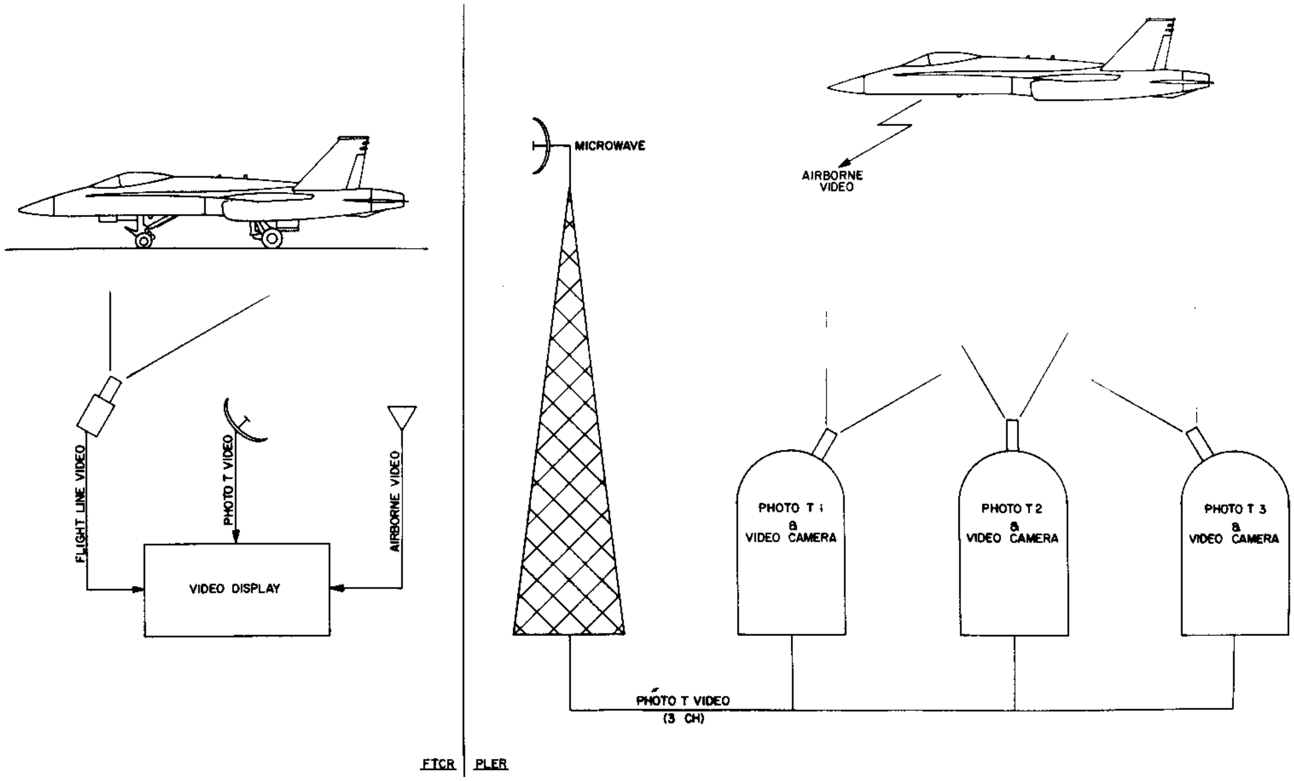


**Figure 6: Real-Time Video System**

Another enhancement currently under consideration is to extend the Digital Communication System to include several stations at PLER using the existing microwave link. This will complete the communication link between the FTCR and PLER by providing uninterrupted and clear voice communications between the two sites, thus greatly improving overall test coordination and control.

The addition of the capability to add a separate PCM channel to simultaneously support two missions reguiring PCM telemetered data is a long range goal. Although it will represent a significant increase in test capability, installation of this system is not fully justified at this time since many current test requirements can be adequately met using on-board data recorders only with no telemetry.

## CONCLUSION

During the past year, approximately 150 real-time test missions have been conducted, a substantial amount of post-flight data analysis has been carried out, and hundreds of digital magnetic tapes have been produced for post-flight analysis. Despite the limitations outlined above, the overall performance of the FTCR has been excellent, equipment reliability has been outstanding, and most of the assigned roles have been successfully executed. When the planned improvements are implemented, it is anticipated that the facility will be able to meet CF flight test requirements into the 1990’s.