PTTI SYSTEMS ON THE EASTERN TEST RANGE

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ABSTRACT

Since August of 1954 the Range Contractor, Pan Am World Services, together with its subcontractor, RCA Service Company, has operated and maintained all equipment and systems at the Eastern Test Range (ETR) for the Air Force and has performed Data Reduction and Engineering Development services. During this period missile development has been phenomenal, from the relatively simple Matador missiles to the very complex Atlas, Titan, Delta, and Trident vehicles. The development of accurate PTTI systems has had to keep pace, until today the ETR timing system accuracy requirements are specified in fractions of microseconds. This paper will describe PTTI systems at the Eastern Space and Missile Center (ESMC) and what is being done to meet the present and future requirements.

BACKGROUND

Figure 1 is a functional ESMC organization chart, showing only that which is germane to this paper. The principal users of PTTI are the launch sites at Cape Canaveral Air Force Station (CCAFS) and the downrange tracking stations at Grand Bahama Island (GBI), Antigua, Ascension, the *USNS* Redstone, and the newest tracking station located at the Jonathan Dickinson Instrumentation Facility (JDIF), Florida (See Figure 2). The ESMC agency responsible for providing PTTI systems to the users is the Air Force Systems Development group. Through tasking of the Range Contractor and Subcontractor, specifications are written for procuring many types of equipment used to interface PTTI systems with the radar, telemetry, command/control, optics, and communications areas. Range Contractor engineers are also responsible for the design, development, fabrication, installation, and testing of unique equipment which is not available from the private sector.

In order to satisfactorily accomplish its mission and to support Range customers with their programs, the ETR has numerous PTTI requirements. These requirements range from providing a single time-of-year display in an aircraft control tower, to a highly reliable system with over 160 output PTTI signals and synchronized within 500 nanoseconds to the DOD Master Clock. Each PTTI system is designed to meet both the dependability and accuracy requirements of the using system. To accomplish these objectives in the most cost effective manner, a hierarchy of "clocks", each closely synchronized to the next higher level, has been established. Each user of PTTI on the ETR will benefit from high quality clocks without incurring the expense of building independent timing systems.

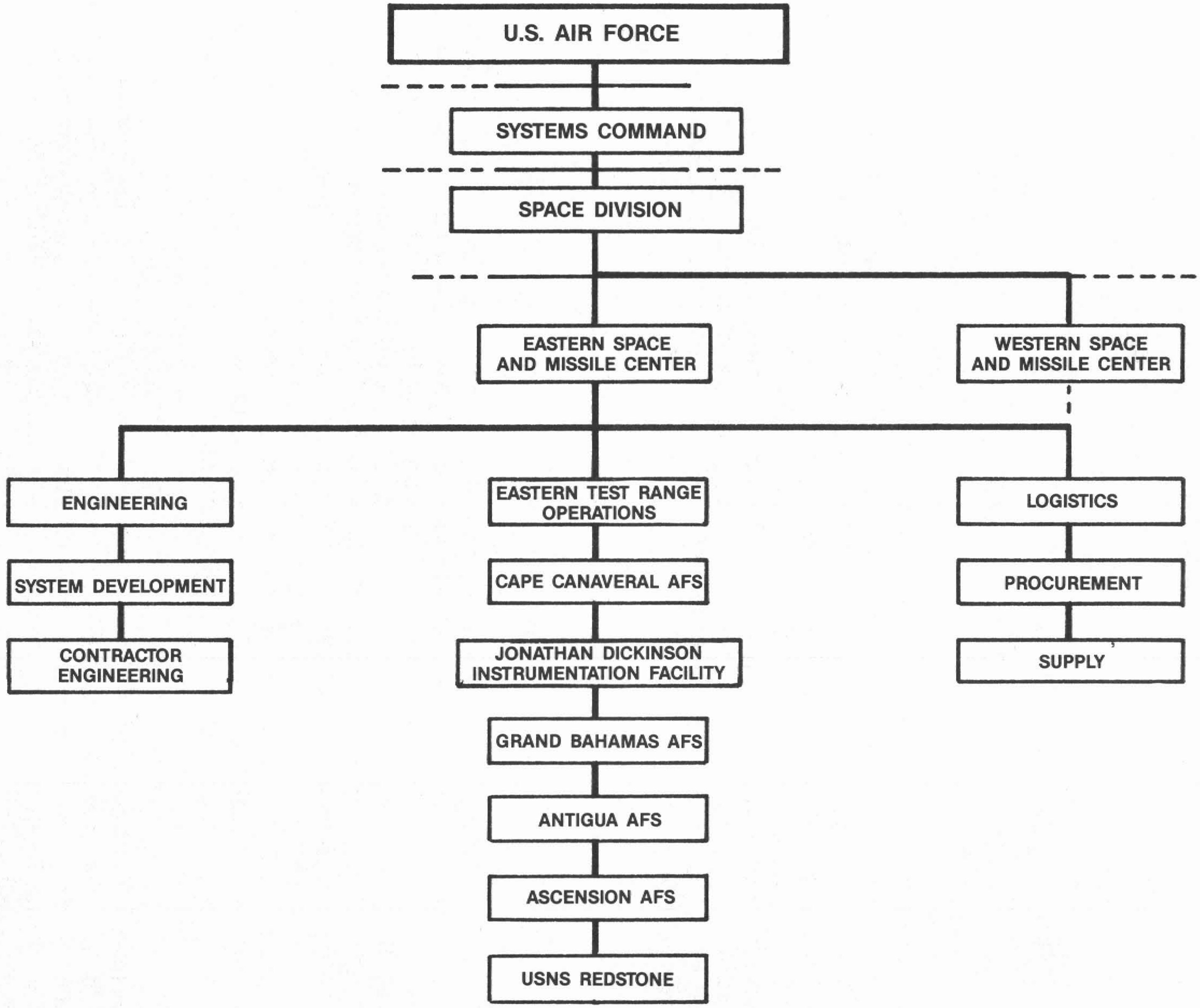

Figure 1. Functional ESMC Organization Chart

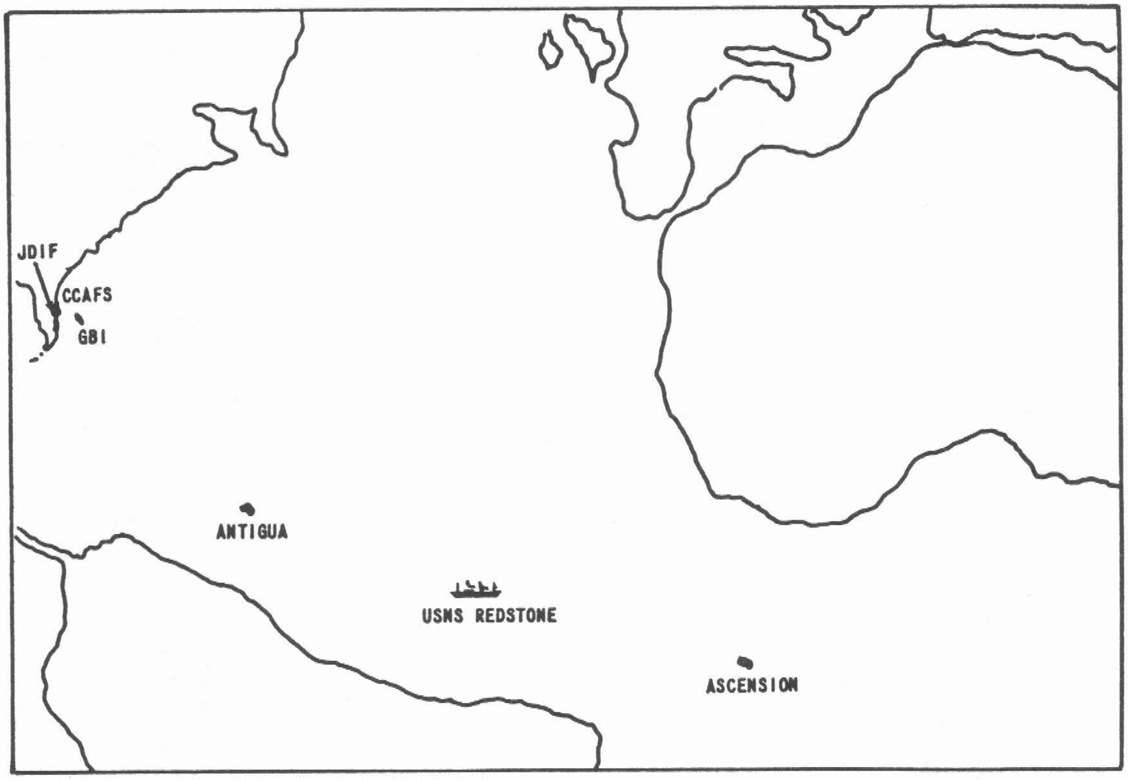

Figure 2. Eastern Test Range Baseline Configuration

SYNCHRONIZATION HIERARCHY

Each ETR facility where PTTI services are provided is traceable to the DOD Master Clock. The Range Clock, collocated with the Station Clock at the Cape, is synchronized and traceable to the DOD Master Clock to within 250 nanoseconds. Each Station Clock is synchronized and traceable to the Range Clock to within 500 nanoseconds. Site requirements determine the synchronization accuracy and traceability of each Site Clock to its local Station Clock. Until recent support of the Trident D-5 Program, the most stringent support requirement had been 50 microseconds synchronization to the DOD Master Clock. However, many of the sites have benefitted from 5-microsecond synchronization for 10 years at the Cape and 5 years at Antigua and GBI. Now, with the recent installation of GPS receivers at each Station Clock (except GBI), many sites have sub-microsecond synchronization capability. Figure 3 provides a composite synchronization diagram.

RANGE CLOCK

The Range Clock is located in the CCAFS PTTI Center, Range Control Center, Cape Canaveral Air Force Station, Florida. The Range Clock serves as the reference for all time and frequency on the ETR. Its major components are four high performance Cesium Beam Frequency Standards, three Microsteppers, seven Digital Clocks, two GPS Receivers, and two Loran-C Receivers. Three Microsteppers are utilized to correct the output frequencies from three of the Cesiums

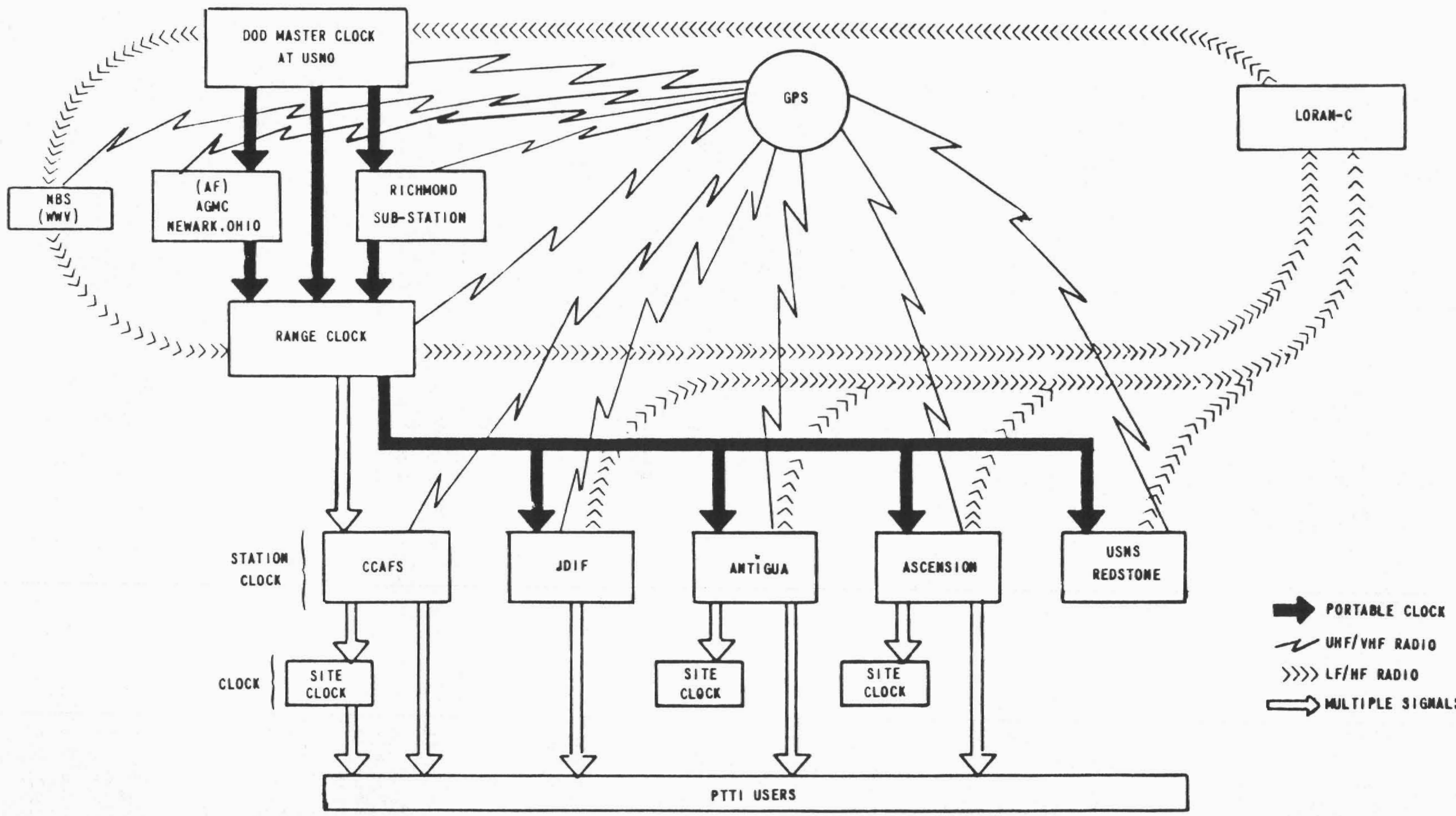

Figure 3. ETR PTTI Synchronization and Traceability

so that the resultant frequency is more nearly that of the DOD Master Clock. The Digital Clocks provide time derived from each frequency source (Cesium and Microstepper). The GPS and Loran-C Receivers provide frequent time transfer information from the DOD Master Clock, which is used in conjunction with Portable Clock data to derive the long term corrections employed by the Microsteppers.

PTTI VAULT

Figure 4 is a photograph of the PTTI Vault where much of the Range Clock equipment is installed. This is an environmentally controlled area where the equipment is installed on low-frequency shock mounts, and the temperature and humidity are closely monitored. Currently temperature is controlled to approximately ± 1.5 degrees Celsius. Later, if performance dictates and Air Force funding is available, tighter temperature controls will be implemented. Chart recorders are used to show the phase relationships of the various frequency sources.

The performance history of a frequency standard can be used to predict its near future time only when it has continuously operated in a controlled environment and without adjustments. For this reason extensive precautions are taken to ensure that the environment is constant and power is always present to all equipment in the PTTI Vault. No adjustments are made to the oscillators and frequency corrections are made using only the exacting digital features of the Microsteppers.

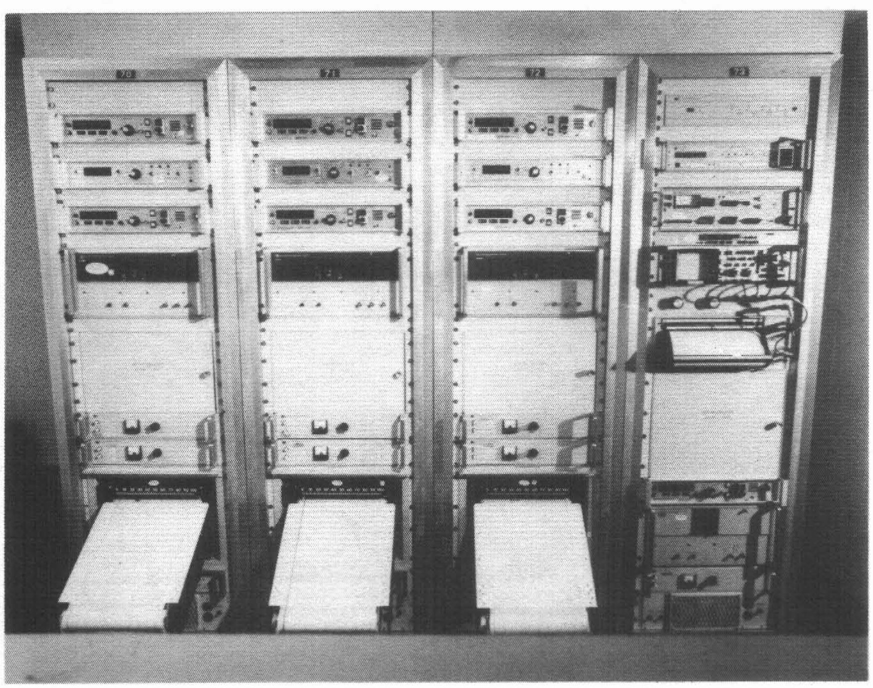

Figure 4. PTTI Vault

The entire PTTI Vault is operated from an uninterruptible power source (UPS). If the UPS fails, all equipment is battery backed-up for approximately 4 hours. (Modifications are currently in progress to extend this period to 48 hours.) Microsteppers are used to implement all changes to the resultant time and frequency outputs from the PTTI Vault. Changes in output frequency are predictably achieved with the Microstepper and are very easily verified with phase plots and time interval measurements.

PTTI MONITOR AND CONTROL SYSTEM

Figure 5 is a photograph of the PTTI Monitor and Control System and various PTTI receivers. The computer-based monitor system automatically collects time interval measurements made among various equipments in the PTTI Vault, the PTTI receivers, and the local Station Clock. Measurements are made daily at 1800 UTC, upon restoration of ac power, and upon operator demand. Provisions are also available for an operator to set up a "Special Measurement Set" where several measurements can be made more frequently and/or at specified times. The operator also may enter narrative information pertinent to the operation of PTTI on the ETR into a "Daily Log" file. Currently this system is used only to collect and store data, and to assist the operators in determining the Microstepper values.

Figure 6 is a diagram of the PTTI Monitor and Control System, as it is now and as it will be when completed. Modifications currently in progress include extending the Monitor and Con-

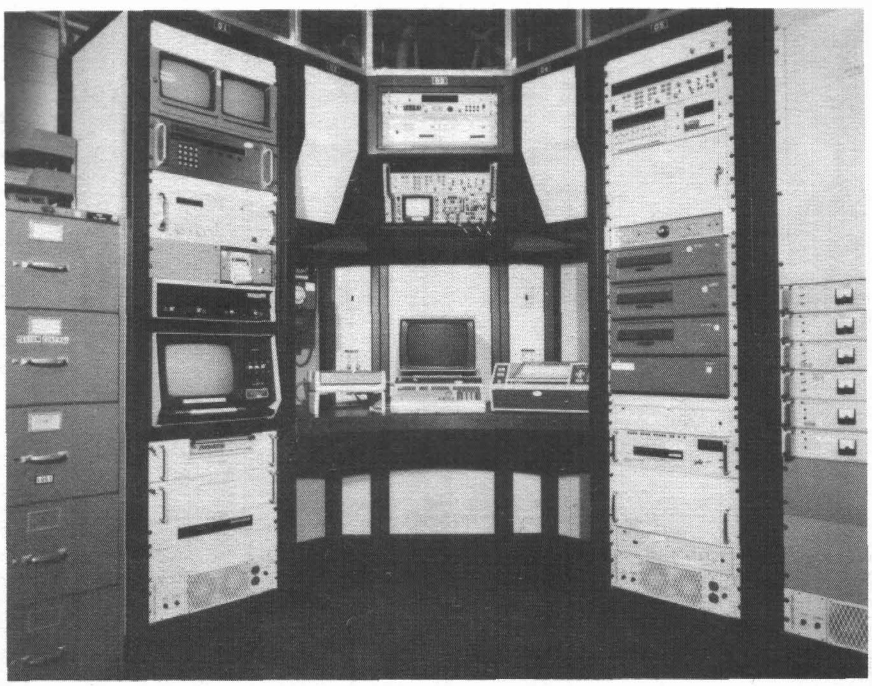

Figure 5. PTTI Monitor and Control System

trol System to all Station Clocks and selected Site Clocks, and automatically deriving "Paper Clocks" at locations where three or more undisturbed Cesiums reside. The first "Paper Clock" algorithm will be very similar to the one being used at the USNO Substation, Richmond Heights, Florida.

A partial extension of the monitor system was implemented at the Antigua PTTI Station Clock several years ago. Until recently the only sub 10-microsecond time transfer system available was Loran-C. However, Antigua is in a fringe reception area for Loran-C and thus correct cycle tracking is unreliable. The best way to ensure proper timing at the unmanned Station Clocks and Site Clocks is to validate continuous operation of the clocks by taking frequent time interval measurements between various timing sources after the correct time has been validated by a Portable Clock. At Antigua, 1-pps signals from the Site Clock Loran-C Receiver and Time Signal Generator are transmitted to the Station Clock where they are compared with 1-pps signals from the Station Clock Cesiums (two each), Time Signal Generators (two each), Loran-C Receiver, and Satellite Receiver (recently changed from Transit to GPS). Measurements, taken every 6 hours, are transmitted back to the PTTI Center where operators validate proper performance of both the Station and Site Clocks, and develop Microstepper values used to slowly slew the Time Signal Generators. One set of measurements is made simultaneously with measurements made at the Range Clock (1800 UTC) so that Site and Station Clock synchronization is verified using Loran-C common view techniques.

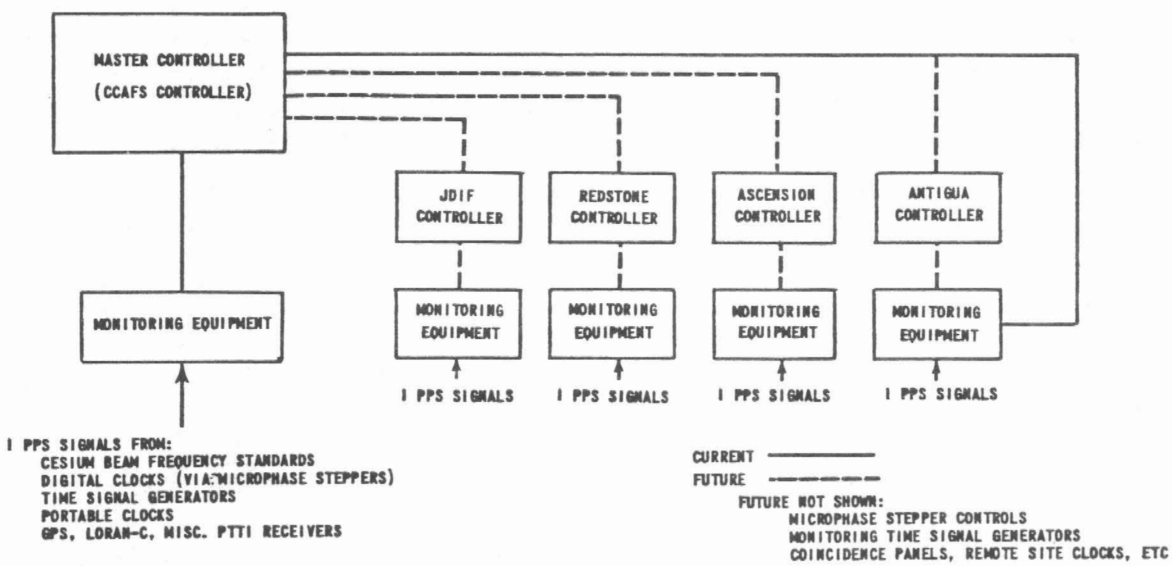

Figure 6. PTTI Monitor and Control System Block Diagram

CCAFS STATION CLOCK

The Cape Station Clock obtains its sense of time and frequency from the Range Clock; both clocks are collocated in the PTTI Center. Two Time Signal Generators are synchronized to the Range Clock and are driven from the corrected (Microsteppered) frequencies of the Range Clock. These Time Signal Generators are capable of producing all IRIG serial codes, decade pulse repetition rates (1 pulse-per-day through 100 kpps). In addition they generate various non-standard time codes which are required by customers not yet totally in compliance with IRIG standards. Like outputs from each generator are compared in a Coincidence Monitor Panel, where any synchronization difference greater than 2 microseconds or disagreement in code content activates an audible alarm and illuminates individual lamps to indicate which signal pair is in disagreement. Outputs of the manually selected Time Signal Generator are conditioned and then provided to Range communications for distribution to authorized users within a 40-mile radius. Major procurement activity is in progress to replace this redundant system with a modernized triplicated system. The new Station Clock will employ coincidence monitoring, voting, and automatic selection of signal source.

Other major PTTI systems located at the Cape Station Clock are the USNO Monitor System, the Count Sequencing System, and several Time Annotators. The USNO Monitor System employs the Data Acquisition System (DAS) described in the Automation of Precise Time Reference Stations (PTRS) paper presented by Paul J. Wheeler at the Fifteenth Annual PTTI Applications and Planning Meeting. With the USNO Monitor System, the Naval Observatory obtains GPS data from a Naval Research Laboratory GPS Receiver and time interval measurements made between the Station Clock, the vault Cesiums, and the Loran-C Receiver 1-pps signals. The Naval Observatory compares readings from this system with those simultaneously made against Loran-C at their site in Washington, D.C., and provides a real-time time transfer measurement utilizing common-view Loran-C techniques. The results of the USNO data analysis are transmitted to the Range Clock for use in coordinating and steering the local time scale.

The Count Sequencing System provides the Count (both countdown and plus count) for each launch site and is capable of providing "functions" (voltages or dry closures) relative to Count or UTC. These functions are used to start and stop documentary and metric cameras, to initiate prelaunch controls and checks, and to actually launch some vehicles. Built into this system are automatic holdfires, manual holdfires, and remote operator controls. PTTI signals are used to sequence the Count and to time-tag (both in UTC and Count) each output and input to this system.

The Time Annotators located at the Cape Station Clock provide aural time in several formats, including the "WWV format." These systems are used in operational areas where sound recordings are used to document events, and also are used by personnel who wish to obtain the time via the telephone.

CCAFS SITE CLOCKS

Timing signals are distributed to outlying instrumentation sites (Site Clocks) via standard telephone cable plant, video cables, and UHF radio. Most signals are transmitted in bipolar pulse form to the Site Clocks where the signals are reconstructed into standard dc level shift or amplitude modulated formats. Newer Site Clocks now employ Synchronized Time Signal Generators which input IRIG B120, compensate for transmission delay, and output required IRIG standard codes, decade repetition rates (1 pps through 100 kpps), and decade frequencies (100 Hz through 100 kHz).

Site Clocks within a 40-mile radius of the Cape Station Clock can also obtain time via the UHF radio system. Timing signals from the Station Clock are time division multiplexed and transmitted 1-millisecond early on a 1750-MHz carrier. Site Clocks with receiver and decoder equipment demultiplex and output the required signals "on-time" (within the 1-microsecond resolution of the delay compensation equipment). This system is now over 20 years old and is currently under consideration for upgrade and replacement. The multiplexed timing signal is also transmitted, via video cable from the Station Clock, to Site Clocks which have requirements for redundant transmission paths from the Station Clock.

Each timing signal is provided to the requiring user from a separate buffered amplifier. Signal levels are adjustable from 0 to 10 volts (peak-to-peak or base-to-peak, depending on signal type). Thus each user is unperturbed by other users collocated at the instrumentation site.

Other timing equipment at Site Clocks often includes time-of-year displays and terminal Count Sequencing equipment.

DOWNRANGE STATION CLOCKS

Station Clocks at each of the downrange stations employ redundant timing systems similar to those currently employed by the CCAFS Station Clock. However, unlike the Cape Station Clock which is driven directly from the Range Clock frequency standards, Downrange Station Clock systems are driven from local Cesiums (only Antigua also employs Microsteppers). Downrange Station Clocks obtain time transfers from semiannual portable clock calibrations from the Range Clock and from GPS, Loran-C, Transit, and WWV timing receivers.

Modernization programs are now in progress to upgrade each Station Clock to a triplicated system. Major attributes of the new Station Clocks are improved accuracy, automated self monitoring and data transfer to the CCAFS PTTI Monitor and Control System, and lower costs for operaton and maintenance. Each Station Clock will operate in an ensemble configuration with at least three Cesiums contributing to a station "paper clock". Data will be automatically collected by a local computer. Health of the local PTTI equipment will be determined, adjustments will be made to local Microsteppers, and status information will be transferred to the Cape PTTI Center operators. Fewer requirements will be demanded of downrange Station Clock operators since they will be assisted in failure identification and will be relieved of nearly all monitoring and timekeeping chores.

DOWNRANGE SITE CLOCKS

Downrange Site Clocks obtain PTTI signals from the local Station Clock and provide signals to users in a manner similar to that of the Cape Site Clocks. The only differences are that UHF distribution is no longer operational (although the Time Division Multiplex system is used via video cables) and very little terminal Count Sequencing equipment is employed.

SUMMARY

The ETR PTTI systems are continuously being upgraded to meet current and projected requirements. Major considerations for each of the Range PTTI systems are accuracy, traceability, dependability, and low costs for implementation and operation. Generally these systems are built using commercially available equipment, perform in various field environments, and are operated and maintained at low costs.

QUESTIONS AND ANSWERS

SAMUEL WARD, JET PROPULSION LABORATORY: I noticed in one of your slide that there were three displays, 10, 11 and 12 that were in green and all read different times. What were those displays?

MR. WRIGHT: Those were count-down indicators. We have three count sequencing systems and the PTTI timer. At that time we were supporting three different tests on the range, and showed various counts for each test.