A FLEXIBLE VOICE COMMUNICATION SYSTEM FOR A REAL-TIME MISSION CONTROL FACILITY

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ABSTRACT

Due to the complexity of real-time missions, an increasing number of participants, and the critical nature of test missions, providing a reliable, versatile voice communication network for mission support entities has become essential. A voice communication system has a direct impact on the effectiveness of every mission and the safety of mission personnel. Each participant must satisfy unique functional and operational communication requirements. This paper addresses the functional, operational, and ergonomic aspects associated with a voice communication system for the Central Control Facility (CCF) at the Air Force Development Test Center (AFDTC), Eglin AFB, Florida. The communication system was purchased from an Edwards AFB Digital Switch requirements contract.

INTRODUCTION

Control functions required to support real-time testing at the AFDTC and involve aircraft, munitions or multiple range facilities have been consolidated into the CCF. This arrangement allows test engineers to be collocated with personnel who direct test aircraft and control range instrumentation resources. CCF mission control rooms consist of control and analysis consoles, test item and range instrumentation video displays, processed telemetry and Time and Space Position Information (TSPI) data displays, and communication links to range facilities. The CCF also houses a reliable and versatile communications network for a variety of users, and is designed to support a diverse spectrum of projects. The CCF generally supports eight to 15 missions a day and can be completely reconfigured for dissimilar projects within 15 minutes.
The control console supports an aircraft controller and a range instrumentation director (the mission director). The analysis console provides communication support for the lead test engineer, the project officer, and either range safety personnel or other test engineers. Each person has a dedicated user station and requires a unique setup and configuration.

CENTRAL CONTROL FACILITY COMMUNICATION INFRASTRUCTURE

Voice circuits are bridged and routed to the CCF through the telephone central office and a microwave communications facility. The current method used to transmit the signals is baseband over multi-twisted pair trunk cables. Future plans include utilizing D4 channel banks for time division multiplexing of voice circuits to the DS-1 and DS-3 line signal standards. The signals will be converted from electrical to light fiber at the DS-3 level. A single DS-3 light fiber circuit will provide 672 time division multiplexed signals.

Two AT&T Digital Access and Crossconnect Switches (DACS II) make up the core switching system. The Eglin system configuration consists of one switch for routing and bridging unsecure (BLACK) communications and one switch for secure (RED) communications. The digital switch supplies all bridge, broadcast, and point-to-point circuit connectivity to the CCF. Telephone, radio, and full duplex voice circuits are converted from analog signals into digital DSO signals in Programmable Line Interface Unit (PLIU) channel banks and then multiplexed into a T1 signal before entering the DACS II switch. The switch is non-blocking. A PC based computer provides a menu driven control system for the system operations personnel. The system control software is C code running under a UNIX operating system.

All voice communication hardware is located in and operated from a dedicated communication control room. The intermediate wiring distribution frame (IDF), voice recorders, test equipment, RED and BLACK DACS II core switches, and communication system control consoles are all located in this room. Riser cables connect other rooms in the facility to the main communications room. Figure 1 provides a block diagram of the communication system.

The primary interface to the user is an all-digital keyset, referred to as a Subscriber Terminal Unit (STU). The STU consists of a 19" chassis and a separate 19"W x 3.5"H x 1.5"D panel containing the STU control interface to the user. The STU provides 18 separate communication circuits, one intercom, a DTMF keypad for telephone dialing, and user station functional control buttons. Figure 2 illustrates the front panel.

A number of different STU physical and operational configurations are available. Eglin’s STU configuration provides 15 BLACK and three RED communication circuit interfaces. STU functional and operational goals were designed not only to satisfy Edwards and Eglin
requirements, but provide the versatility needed to satisfy communication requirements at other major test range facilities. The STUs are connected directly to the digital switch by a copper and a fiber optic bidirectional TI circuit. Copper is used for the BLACK T1 and light fiber is used for the RED T1.

USER REQUIREMENTS

Considerable effort has been invested to satisfy a wide range of user requirements. Resident test engineers, range safety officers, and mission controllers frequently use the facility, but other customers, such as contractors or government personnel who have a requirement to run a single series of tests, do not use the CCF often enough to be adept in
complex console operation. In order to satisfy both types of users, the system must be user friendly. Simplicity, ease of control, and assessment of the mode of operation are primary issues. The consoles are heavily populated with keyboards, displays, and control switches, so the less complicated the communication panel the happier the user (as long as requirements are satisfied!)

A large number of controls are required due to the complexity of the user station. Extreme care must be taken to ensure that all of the critical functions are either hardkeys or primary functions on softkeys. Critical functions such as circuit selection and control have dedicated hardkeys for choosing talk, listen, and off conditions for each circuit. Analog rotation knobs control volume in headsets and the speaker system. The operator has direct physical control (rotational) vs an automated push-button, resulting in greater sensitivity. The DTMF keypad mimics a standard telephone instrument keypad and provides a telephone and intercom dialing function. An adjacent keypad provides control of the STU operational configuration. All user station functions are prioritized to determine which functions should be primary/secondary softkeys or dedicated hardkeys.

The safety of test aircraft and mission personnel depend on the ability of the test director to immediately assess the user station’s mode of operation and quickly select the circuits required to control the mission. Each circuit at the user station contains dedicated displays and indicators. The mode of transmit, receive, and off operation is indicated by light-emitting diodes (LEDs), which function much like a multi-button telephone instrument. In addition to indicating the mode, the LEDs blink to indicate voice activity on the circuit and incoming ring activity. The blinking repetition rate differs for voice activity and rings. Each circuit name is identified by a programmable eight character display, which can be assigned circuit labels meaningful to the user.

COMMUNICATION SYSTEM IN A MISSION SUPPORT ENVIRONMENT

System issues such as versatile program control, system configuration assessment, signal quality, and fault recovery are critical in a real-time environment. The system software must provide a real-time command execution capability as well as an off-line mode that will allow the system operators to generate command files for system setup. The command file contents are coordinated with the project personnel and are generated prior to the mission, providing setup validation and eliminating premission wiring errors. The command file is available for lengthy or complex setup tasks.

The ability to execute real-time (RT) commands is also important and must provide a speedy mechanism for modifying the operational characteristics of the user station and route/bridge/disconnect circuits. RT commands permit users to make simple changes in the system switching and operational configuration. The RT command mode must promptly
satisfy requests for last minute changes in the setup configuration, and control the operational characteristics of the user station and the PLIU interface cards. The RT commands also provide a work-around for hardware failures.

Due to a large number of circuits, complex bridging capabilities, and versatile user station modes of operation, the system control software must easily assess system configuration. It is essential for operation and maintenance personnel to know at all times the exact operational configuration and health situation of each component in the system. The network control system must provide status displays that give detailed information for the operational program for each user station. In turn, these displays must provide information concerning the programmed mode of operation for all of the hardware interfaces to the radios and trunk. Status displays must also provide information concerning the routing of circuits in the digital switch and the assignment of circuits into the bridges. The system must provide health alarm indicators for loss of data links, loss of power, and box level failures.

After the signal has been routed and bridged correctly, the next critical factor is signal quality. The transmitted signal and the received signal must not be corrupted by the room environment, switching and distribution mechanism, circuit bridging, or user stations. The old rule “any breakdown in quality effects the overall effectiveness of the system” applies. Fortunately, technological advancements in the digital audio switch have eliminated many of the problems associated with analog switches. Analog perturbations such as crosstalk, signal distortion, or level control have been eliminated by digitized circuitry.

All signals are automatic gain controlled (AGC) and adjusted to a common voice level before they are converted to a digital signal in order to equalize volume levels. The bridging of circuits is performed with special digital signal processing algorithms, providing an excellent quality composite. Another signal quality enhancement feature is idle noise suppression, which mutes the circuit if no voice is present. The result is a noiseless network totally independent of the number of circuits in the bridge or the number of channels enabled at the user station.

Signal quality can be affected by a high level of ambient noise, particularly that caused by computer hardware cooling fans. A special headset microphone with a built-in noise canceling circuit rejects background sound, significantly reducing noise transmitted over the circuit.

System reliability and maintainability is crucial. Due to the critical nature and cost of real-time testing performed at Eglin, the system must provide continuous fault-free operation. An automated diagnostic ability to assess the health of the system must be provided at all times. In order for the diagnostics to be operative, the system components
must be modular and replaceable without affecting other components and must not require removing unit power. The system must not interfere with real-time support and should provide confidence in identifying defective components. A true real-time support system should also provide redundant hardware with automatic switch-over to a second power source when a fault occurs. The DACs II design is redundant and is ideal for the real-time environment.

SYSTEM INTEGRATION

Integration of a new communication system into a real-time mission support facility is a delicate matter and must be executed without interruption to daily mission support. Facility wiring, system cutover, and mission control console modification must all be considered.

The wiring support package will ultimately make the difference in ease of system installation. If effort is invested in designing a simple wiring scheme, the benefits will be reaped during installation. A good wiring scheme minimizes the complexity in wiring cross connections on the distribution frame. To simplify cross connections, all hardware must employ a common connector style and pin out. Connectorized terminal blocks, patch panels, interface hardware, and the core switch all use fifty position champ connectors with the standard pinout wiring. The aforementioned system is optimal for use of off-the-shelf pre-made cables.

Changing an existing communication system to a new communication system is not a small task. The cutover must not degrade signal quality, or interfere with or cause downtime to the existing system. A number of different methods are available for system cutover. The old system can drive the new system as if it were the feeder trunk for the new system, or the new system could drive the old system. The incoming trunk circuits can be actively or passively bridged to feed both systems. The method used to cutover the CCF incorporated a transformer coupled active bridge, providing the least risk of mission support interference.

Integration of the user station into the control room consoles is a challenge. The ergonomic considerations dictated user station location. In Figure 3, the user station is located in the angled section between the horizontal writing surface and the vertical face that contains the CRT displays. This location satisfies accessibility and viewer requirements and does not interfere with any other controls of the console. The wedge is designed so that the angle is incident with the user’s viewing angle. The STU front panel dimensions are ideal for locations with limited space.
The secure communication requirements at Eglin consist of circuits to aircraft, ships, and test range support facilities. All secure communications are transmitted using GRC-171 UHF radios. A KY-58 is the most common device used for encryption and decryption of voice frequency communications. It is not feasible for the CCF to maintain a dedicated KY-58 for each KY-58 on the range, so a switching configuration has been developed to support secure communications. Figure 4 illustrates the connectivity between the RED and BLACK systems.

The 171 radios provide two ports-wideband and narrowband. The narrowband port functions exclusively for BLACK voice communications and connects to a four wire interface in a PLIU channel bank on the BLACK switch. The wideband port passes cipher text through the BLACK switch and routes the signal to the KY-58 located between the RED and BLACK switch. The KY-58 accepts the cipher text and converts it into baseband RED audio. The RED audio then is routed through the RED switch to the STUs. A typical
mission support configuration would be a STU BLACK channel connected to the narrowband port and a STU RED channel connected to the KY-58 output. This arrangement provides normal communication over the STU BLACK channel while the circuit is in the clear mode and communication over the STU RED channel when the circuit is secure. Since all of the range cipher text circuits are routed through the black switch before it connects to the KY-58s, only the number of KY-58 units that are in use at one time are maintained, thus minimizing the number of units required.

**CONCLUSION**

A communication system is an extremely critical component in a real-time mission support facility. In order to satisfy the requirements of users and systems operational and maintenance personnel, extensive interaction during the development phase must take place to ensure that all requirements are satisfied within the system’s capabilities. The key components of the system are ease of operation, flexibility, reliability, and maintainability. The EDS system is based on established telecommunication standards. The core switch is used extensively in commercial telephone industry, thus increasing the probability of a
long support life cycle from the equipment manufacturer. The adherence to industry standards ensures ease of interfacing with external devices and provides a wide variety of commercially available peripheral devices.

REFERENCES


