Transmission Monitoring and Control of Strategic Communication Systems

JOSEPH E. FARROW AND RICHARD E. SKERJANEC, MEMBER, IEEE

Abstract—This paper discusses a minicomputer-based communication system monitor used by the U.S. Department of Defense to improve the service availability and reduce the operating costs of the new multichannel digital transmission systems. A brief history of the development of the monitor and a general description of the present-generation hardware and software are included.

Introduction

As plans for the upgrade of the long-haul U.S. military communications network in Europe were being made, the advantages of digital transmission became more and more apparent. Long-haul voice channel quality could be improved, integrated medium-speed data transmission could be made more efficient, and bulk encryption of wide-band transmission could improve communication security. For these reasons, military communication planners decided to emphasize digital transmission techniques for all future main-line communication facility upgrades to be a part of the Digital European Backbone.

The conversion of the Defense Communications System's European wide-band communication system to an all-digital communication scheme started with the installation in 1975 of the Frankfurt–Koenigstuhl–Vaihingen (FKV) microwave links that carried a digital baseband signal on frequency-modulated analog radio equipment. The next step in the conversion was the installation of the Digital European Backbone, Phase I (DEB-I), that used the same technology. Current plans are to convert the entire European wide-band system to digital transmission over the next several years.

The planning and development of these first two digital microwave systems indicated that an improvement in system effectiveness and a decrease in operating costs could be realized by reexamining the traditional methods of communication system control. In the past, each radio site in a system had a number of people assigned to operate the site 24 hours a day. This practice was recognized as being wasteful of both money and trained personnel. Furthermore, modern communication equipment is reliable enough that continuity of service can be assured by installing redundant electronic equipment with automatic switching. This makes reduction or complete elimination of the personnel at repeater sites practical. As a consequence, both the FKV and DEB-I systems were commissioned with certain relay sites that were not staffed. Maintenance and restoral at these sites were to be performed by dispatch of trained, skilled maintenance personnel from one or more central locations. In order to permit system operators to know the status of the equipment at these unstaffed sites, an alarm monitoring system was installed to report site conditions to the location of the responsible system operator.

The initial alarm remoting equipment was a wired-logic, poll-response type system. A master unit requested information from the remote sensing unit and displayed the conditions of the remote radio site as an array of alarm and status indicator lights at the master location.

In order to make the remote site information more complete and accessible to the human operators, the Air Force system engineers decided to use a minicomputer to do some data processing and put the information in a more useful format for presentation to the operators. The development of this improved alarm remoting system, called the Enhanced Fault Alarm System, or EFAS, was begun in 1977.

The EFAS development consisted of preparing hardware and software to allow the minicomputer to replace a master fault alarm terminal. The computer sent poll messages to the remote units and received and decoded the responses. The information in the responses was analyzed and used to generate displays on a CRT terminal. These displays presented the alarm, status, and parameter data gathered from the remote sites in English text designed to show site and entire system conditions on easily understood displays.

The deployment of the minicomputer master units of the Enhanced Fault Alarm System was done in parallel with the DEB-I installations in southern Germany and northern Italy during early 1979. The DEB-I EFAS consisted of 13 remote data acquisition units and 3 minicomputer-based master units. Each communication site, even those where a master unit was located, was equipped with one of the remote data acquisition units.

The next major development in the Transmission Monitoring and Control (TRAMCON) concept was the decision

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The authors are with the Institute for Telecommunication Sciences, National Telecommunications and Information Administration, U.S. Department of Commerce, Boulder, CO 80303.

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to deploy a second-generation minicomputer with a fully revised software package in support of the next two stages of the Digital European Backbone, namely, the DEB-IIA segment and the Frankfurt North-Berlin troposcatter segment. This was an opportune time for a change since these later DEB stages will use a completely new digital multiplex, a new digital line-of-sight link radio, and a new digital troposcatter link radio.

The most important changes in the TRAMCON system will not affect the display of information, but rather the way information is stored in the computer. The changes will enable TRAMCON to monitor any type of communication link, either terrestrial radio, satellite, fiber optic, or metallic cable technology, carrying traffic in either analog or digital form.

This paper deals primarily with the development of the second-generation system and includes a description of both hardware and software.

Objectives

The basic reason for the establishment and continuation of the system monitoring project is to reduce the per-channel-mile cost of communication services by increasing the productivity of the communication operation and maintenance personnel. The increase in productivity is expected to occur as a result of requiring fewer operation and maintenance workers to provide the increased communication capacity being provided by the installation of the Digital European Backbone. To make this improvement in productivity possible, the communication system operators need new tools and techniques to permit them to monitor and control entire segments of a communication network and to isolate problems at any site quickly and accurately so that remedial action can be taken before total communication outage or failure occurs. The TRAMCON system is seen as the tool that will make the improvement possible and support the development of new operation and maintenance doctrines and techniques.

The intent of TRAMCON is not to displace or reduce the responsibility of human operators, but rather to increase their span of control by placing information of a more refined quality at their disposal to allow them to make better control and troubleshooting decisions.

The success of the transmission monitoring and control systems up to this time can be ascribed in no small part to the fact that a well-defined objective was set out and that a system was designed to move in evolutionary steps toward that objective.

TRAMCON System Capabilities

The basic purpose of the transmission monitoring and control system is to gather information on communication equipment status from a number of sites and present this information in a useful format to a communication system operator. The information is presented to the operator in the form of displays on a CRT terminal. These displays report the functioning of the communication system in English text and can present data from a single communication terminal within a station or can present an overview of the operation of an entire transmission segment.

The monitoring process starts when the controlling master unit sends an addressed poll message to each of its remote units in turn. The remote unit replies with a formatted message that contains all of the alarm, status, and parameter information about its communication site. The master unit disassembles this message and places the information in local data files. The CRT terminal displays are generated from these data files at the request of the operator. Some of the data are processed for long-term archival storage. Examples are received signal level measurements, other parameter measurements, and the occurrence of alarms of major significance.

Another function the TRAMCON equipment performs is remote control switching of certain equipment at the remote sites. To perform a remote switching function, the system operator enters the request on the CRT terminal keyboard.

In addition, the master unit performs a number of other functions that support the TRAMCON mission. These involve maintaining information on communication system configuration, information on the status of communication system elements, and the necessary calibration and threshold tables for processing the input data from the remote communication sites. These databases are established specifically for operation of the TRAMCON system, but such data can be obtained from the computer so that other analyses can be performed.

A new capability of the TRAMCON system is for the connection of a number of CRT terminals in addition to the system console. These extra terminals, called remote displays or maintenance dispatch terminals, will be used to provide communication system monitor information to other than the system operator.

The TRAMCON system includes both master and remote units. To improve the reliability of the monitoring system, at least two master units are able to monitor each segment or group of communication sites. The polling master will actually control the remote units on a segment while any other masters will operate in a listen-only mode. The polling line is broken at segment boundaries so that only polling messages intended for a particular segment's remote units appear on the segment poll line.

Fig. 1 is a functional block diagram that shows some of the capabilities of a TRAMCON master unit. The master software includes a real-time operating system, file-handling utilities, various language compilers, and communication handlers and drivers for the various input/output devices. The TRAMCON data acquisition, manipulation, storage, and display programs that were written at ITS will be described in detail in a forthcoming NTIA report.

All data acquisition performed by the TRAMCON system is handled through the wired-logic remote units, which also implement the remote switching mentioned previously. Fig. 2 is a functional block diagram of a remote unit. As shown, three types of input can be accommodated, namely,

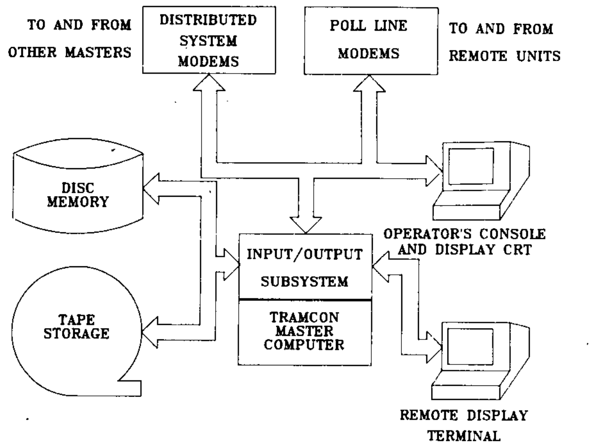

Fig. 1. Functional block diagram of a TRAMCON master.

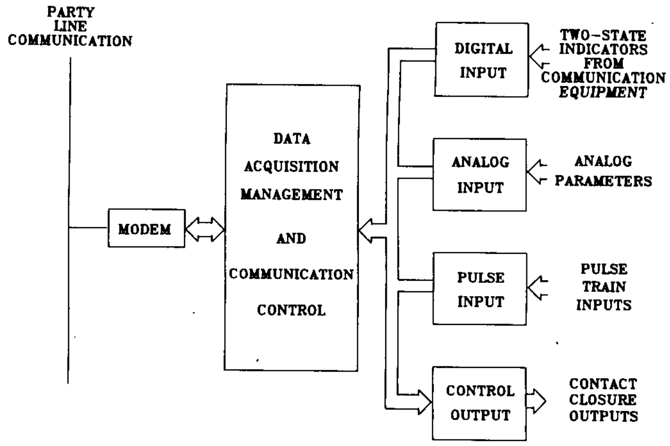

Fig. 2. Functional block diagram of a TRAMCON remote.

two-state status or alarm indications, continuously varying voltages that correspond to analog parameters, and pulse train or random pulse occurrences. In addition, the remote unit provides for contact closures, either momentary or latching as required, to perform the remote switching functions. As the TRAMCON remote units are now designed, all of the functions they drive or monitor are those that are built into the communication equipment as status and alarm indicators and remote switching points.

One type of signal monitored—the two-state indicators—are the status and alarm conditions used by an operator or maintenance person to assist in diagnosing problems with the communication equipment.

A second type of signal the remote unit is equipped to monitor is a slowly varying dc voltage. The communication equipment generates these voltages as analogs of parameters of interest to the operators, such as radio received signal level and mission traffic signal-to-noise ratio. The remote unit samples and measures the voltage and sends the measurement to the TRAMCON master for conversion to a value in the units of the parameter being monitored for display and for further analysis or archiving.

A third type of signal monitored by the remote unit is the pulse or pulse train. The remote unit collects these data in two ways. The first is simply to count the number of pulses during the interval between poll messages from the master and to report the number in the poll response (up to the maximum count capability of the remote). The second way is to count the number of seconds between poll messages during which one or more pulses were detected. This second measure, called the number of "errored seconds," is also sent to the master unit for processing and display.

The control outputs of the remote unit that will be used to control the communication equipment are metallic relay contacts, both normally open and normally closed, without any voltage on the contacts that originates in the remote unit. Either latching or momentary contact closure is available so these outputs are able to handle a wide variety of external switch functions.

TRAMCON Master Software

The master unit is a general-purpose minicomputer with a number of peripheral devices for large-scale data storage, information display, and communication. The computer operating system, which is the software that controls the basic functioning of the computer and allows other programs to be run, was purchased from the manufacturer. In addition, high-level language compilers for Fortran and Pascal and a number of other useful software utilities were obtained. Manufacturer-provided software was used to develop application software for polling, data collection, analyses, storage, and display.

Since the TRAMCON system is intended for worldwide application to the Defense Communications System, the communication and data storage programs must be easily adaptable to many different types of communication equipment. This is implemented as a technique for easy field entry of a communication system configuration database. These configuration data will include such segment-peculiar items as segment identifier, number of sites, site names, communication equipment configuration, communication equipment type, trunk identifiers, and any other information needed to define the operational status of the communication system.

As TRAMCON is more widely used, there will be further evolution of the software and displays to enhance the usefulness of the system. To make trend analysis easier for the operator, display software is planned that will summarize system performance on an hourly and daily basis. This summary will be updated each hour and the oldest hour's data will be deleted. The software will also provide for displaying any of the data on more than one terminal and for making any data available for use by other elements of network control.

The primary device for providing assistance to the communication system operator is the CRT terminal and hard-copy device. For this reason, a great deal of planning and testing has been done to make the formatted data displayed on the CRT terminal informative and understandable. The data displays were provided to system

TABLE I
DISPLAY AND NONDISPLAY COMMANDS

DISPLAY COMMANDS	
AL	ALARM/STATUS DISPLAY FOR ONE OR MORE REMOTES
AR	ARCHIVE RECORD REVIEW FOR SINGLE REMOTE
CC	CALIBRATION CURVE ENTRY FOR SINGLE LINK END
CN	COUNTED TWO-STATE ALARM OR STATUS OCCURRENCE
CO	CONFIGURATION DATA BASE CHANGE FOR SEGMENT
CR	CRT STATUS FOR THIS TRAMCON MASTER UNIT
DI	DIAGNOSTIC ROUTINE, TURN ON OR OFF
DT	DATA TRANSFER TO ANOTHER REMOTE
HE	HELP WITH TRAMCON OPERATING PROCEDURES
HI	HISTOGRAMS OF A/D AND COUNT DATA FOR ONE REMOTE
LS	LIST ALARM/STATUS DEFINITIONS FOR SINGLE REMOTE
MA	MAP DISPLAY OR SEGMENT STATUS, ALL REMOTES
ME	MENU OF OPERATOR COMMANDS
MS	MESSAGE ENTRY, FOR ANOTHER TRAMCON OPERATOR
NM	NETWORK MAP SHOWING MANY SEGMENTS
PA	PARAMETER DISPLAY OF A/D AND COUNT DATA
PC	PCM ALARM SUMMARY
PM	POLLER/MONITOR/INACTIVE SELECTION FOR THIS MASTER
SC	SCENARIO MODE START FOR TRAINING
SD	SITE DIAGRAM OF COMMUNICATION SIGNAL FLOW
SE	SEGMENT NAMES IN SHORT FORM FOR COMMAND ENTRY
SS	SEGMENT STATUS TABULAR DISPLAY, ALL REMOTES
SW	SWITCHING DISPLAY FOR REMOTE RELAYS FOR ONE REMOTE
TH	THRESHOLD SET FOR A/D AND COUNT ALARM LEVELS
TR	T-1 DIGROUP FAULT MAP FOR SEGMENT
TS	SEGMENT ALARM HISTORY, SHORT TERM
NONDISPLAY COMMANDS	
AC	ACKNOWLEDGE ALARMS FOR ONE OR MORE REMOTES
DE	DEFAULT DISPLAY SELECTION
EN	ENABLE ALARM NOTIFICATION FOR SINGLE REMOTE
IN	INHIBIT ALARM NOTIFICATION FOR SINGLE REMOTE
OL	ON-LINE/OFF-LINE TOGGLE COMMAND, THIS TERMINAL
OP	OPERATOR IDENTIFICATION ENTRY, THIS TERMINAL
PO	POLLING SEQUENCE CHANGE ON SEGMENT
PR	PRINT CONTENTS OF CURRENT CRT DISPLAY
SI	SIMULATOR COMMAND ENTRY FOR TRAINING
SR	SYNCHRONIZE CLOCK WITH NETWORK TIME
ST	STOP TRAMCON PROGRAMS AT THIS MASTER UNIT

operators with the request that any suggestions for improvement or simplification to make the data display more easily understood be sent to the programmers for consideration. Most of the displays have been revised a number of times, and the current formats are the result of considerable operating experience. In subsequent sections of this paper, the formatted data presentations will be referred to simply as displays.

The menu has a list of 37 commands, most of which evoke the various displays. Some of these commands, however, perform a specific action without regard to what display is on the screen. Table I shows which commands call up displays and which commands do not.

The commands can also be divided into five categories, depending on the purpose and effect of the command. The first category includes those commands that are intended to assist the operator in using the TRAMCON system. The MENU and HELP commands fit this description. The next category includes those commands that directly show or influence communication system operation. These commands would include the map, the segment status, the remote unit status alarm, and the switch commands, among others. The third category comprises a set of utility commands that support the communication system operation commands. Examples of this category are the calibration curve and operator identification commands. The fourth category includes those that request information about the communication system or TRAMCON configuration, such as list or CRT status. The fifth (and final) category includes all other commands. These are commands to set the clock and to run the diagnostic and simulator functions. Details of each display and command are given in NTIA Technical Report 84-147.

OPERATIONAL EXPERIENCE

The initial EFAS (now TRAMCON) installations were made in 1978, so some experience with the system has been gained. The primary users of the DEB-I TRAMCON have been the technical control personnel on the sites where the master units are located. In late 1981, a maintenance dispatch terminal was added to a site with no master unit, but from which maintenance teams are dispatched to several unstaffed sites in the area. The purpose of this installation was to learn some of the problems and possibilities of a remote terminal and to permit the maintenance dispatch personnel to use the remote terminal to develop operating procedures. As the TRAMCON program has developed, the military personnel who are and will be using the system have had a definite formal channel to assist in the design and development of the displays, the operator input commands, and the operating doctrines and procedures.

The TRAMCON concept emerged from the realization that first, the type of communication equipment now being installed, particularly for line-of-sight links, does not require constant attention and, second, that providing full staffing at all sites, including relay sites with no voice break-outs, was an expensive and inefficient use of trained operators. The opportunity for centralized control and maintenance dispatch over limited segments of the system was recognized. However, a prerequisite for taking advantage of the opportunity was a means for gathering information quickly from each site in the segment and presenting the information to a technical controller in a format that would allow one segment operator to monitor, control, and dispatch maintenance for all sites in a segment. The technique developed has allowed reduced staffing at many sites, particularly those difficult to reach in winter or collocated with other United States or NATO military functions. Maintenance teams are dispatched from central locations at the request of the segment operator to sites from which reports of faults or failures have been collected by the TRAMCON system. While this system has been in operation on the DEB-I segment, no observed decrease in communication channel availability has accompanied the reduced levels of operation and maintenance personnel. That is a testimonial to the equipment selection, link design, and installation, as well as a justification for the faith the military departments placed in the idea.

The introduction of computers into the operation and management of military wide-band strategic communication systems permits a new alignment of resources to perform the primary task of the communicator—namely, to provide the best quality of communication service to the customer user at the lowest cost consistent with the established constraints of required service availability and existing physical plant.

As the field experience with the DEB-I TRAMCON developed, it became apparent that the computer could provide a degree of fault isolation. The alarm data were already being collected, the fairly simple fault isolation algorithms could be developed to isolate equipment faults to major modules. This function will be part of the final TRAMCON software.

The original DEB-I CRT terminals were simple alphanumeric screens and all information was shown in that format. Suggestions were received from the users to the effect that graphic presentations might make the information easier for operators to grasp at a glance. An initial effort in this direction was a map display showing the segment status that was made up of ASCII characters such as hyphens, dashes, and slashes. This was so well received that the new TRAMCON terminals have full graphic capability and new displays that present information in either text or graphic format at the choice of the operator.

The fact that each computer has available complete and current data on the segment it is monitoring suggests that such data could be gathered for many segments and collated to provide status information on communication system operation on a much wider geographical basis than a single segment. This would allow a network control technique to be developed that could permit much more rapid restoral of critical communications and improved operating procedures. The new TRAMCON computers will have a dedicated data port to which such a network monitoring system could be connected if this is desired.

Another enhancement of the TRAMCON system under consideration is the replacement of the wired-logic data-acquisition equipment by a microprocessor-controlled unit that would permit some data processing to be done at each site to reduce the volume of information sent to the TRAMCON master during each poll cycle.

The TRAMCON project started in a small way with limited objectives. As these were met, other desirable features were added, but only in an orderly way so that adding some new feature would not cause TRAMCON system failure. During the development, the users were consulted frequently to get their reactions to the actual operation of TRAMCON and the information it provided. The result of this steady development is a monitoring scheme that is easy to use and has permitted savings in personnel costs.

Acknowledgment

The authors wish to thank Col. T. Pickens (ret.) whose efforts brought TRAMCON into being, as well as the U.S. Army Communication Command (now the Information Systems Command) for supplying the original computers and The MITRE Corporation for their assistance and cooperation. Finally, we acknowledge our debt to the many members of the Air Force and Army technical control staff for their assistance, their patience, and their valuable suggestions.

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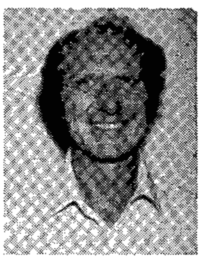
Joseph E. Farrow was born in Boulder, CO, in 1936. He received the B.S. degree in electrical engineering from the University of Colorado, Boulder, in 1959.

He joined the Department of Commerce while a student at the University of Colorado in 1957. Following graduation, he became a full-time staff member of the Central Radio Propagation Laboratory and has remained with the group through its morphoses from NBS to ESSA and the Office of Telecommunications, and finally, NTIA. He has engaged in research on obstacle diffraction paths, troposheric scatter paths, and line-of-sight microwave paths and has worked on the acceptance of wide-band tropospheric radio systems throughout the world and has assisted the Defense Communication Agency and the U.S. Air Force in rewriting the standards for tropospheric communication equipment types, radio links, and systems. He has directed the preparation and presentation of a course of instructions in communication system test and analysis. He has conducted studies of the conversion of analog radios to digital service and of a system to provide communication over a large area for conducting equipment tests. Recently, he has been involved with the conversion of the DCS to digital transmission and has participated in the design, implementation, and installation of a minicomputer-based microwave transmission monitor and control system. He has continued to be involved in research on tropospheric communication links, and has adapted minicomputer systems to gather propagation data and to analyze it. He continues to contribute to the development of communications system, link, and equipment standards, and is engaged in the detailed analysis of telecommunication problems and in providing explicit solutions for other government telecommunication users.



Richard E. Skerjanec (S'60–M'60) was born in Canon City, CO, in 1937. He received the B.S. and M.S. degrees from the University of Colorado, Boulder, in 1960 and 1962.

He worked with the Radio Astronomy Group of the High Altitude Observatory, University of Colorado until 1963 when he joined the National Bureau of Standards, Central Radio Propagation Laboratory (CRPL) which later became a part of Environmental Science Services Administration, then the Office of Telecommunications (OT), and recently National Telecommunications and Information Administration. He has done research work in the field of microwave tropospheric telecommunications since joining the Department of Commerce, and has studied rain attenuation effects on 15 GHz propagation, space and frequency diversity performance measurements on line-of-sight microwave circuits, and the effects of other phenomena on microwave propagation and system performance. In addition, he has assisted in rewriting the line-of-sight and beyond-the-horizon troposcatter standards for the Defense Communication Agency, assisted in test and evaluation of new microwave systems for DOD, has written microwave system test plans and procedures, and has participated in writing line-of-sight and beyond-the-horizon microwave system engineering handbooks that are now part of the military handbook series. More recently, he has been involved in the evaluation of a pilot digital microwave transmission system and, as a sequel, organized, defined, and implemented, with other individuals, an automated computer-based alarm monitor and control system now in use on a multihop microwave digital communication system. He has also recently been active in the area of telecommunication system assessment and planning, including data communications requirements. Multiple technical solutions have been examined on a cost and performance basis and several alternatives provided to the sponsoring agency. Systems examined include a complete integrated telecommunication evaluation to satisfy Forest Service requirements for a large national forest and satellite systems for the public distribution of NOAA information products.