BRINGING UP TRANSCOM - U.S. DEPARTMENT OF ENERGY'S TRANSPORTATION COMMUNICATION SYSTEM

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ABSTRACT

A transportation tracking system (designated TRANSCOM) has been developed under the direction of the Department of Energy (DOE) in response to three institutional concerns about shipments of large quantities of radioactive materials: routing, prenotification, and emergency response. This tracking system consists of a geographical location system, a system for communicating with the vehicle operator while en route, and an information management system that appropriately distributes shipment information to DOE headquarters, field offices, and key state officials.

The TRANSCOM system has moved from the developmental stage to the fully operational stage through the efforts of a number of DOE contractors and subcontractors, namely, Argonne National Laboratory, Oak Ridge Operations Office, Systems Research and Applications Corporation, Westinghouse Waste Isolation Division, Science Applications International Corporation, and Analyses Corporation.

This paper presents the development, testing, and demonstration efforts undertaken to bring the prototype system to a fully operational status. The LORAN-C locating system has proved to be acceptable as a geographical location system for TRANSCOM equipped vehicles. The satellite communications technology employed has demonstrated timely radio transmission regarding location and communication with the vehicle operator.

This paper also discusses the interim developmental TRANSCOM Control Center, the Oak Ridge Operations TRANSCOM Control Center, software, hardware, operational issues, and the tracking of a WIPP TRUPACT-II demonstration trailer.

INTRODUCTION

A tracking, management, and digital messaging communication system has been developed under the direction of the U.S. Department of Energy (DOE) Transportation Management Division in response to concerns about the shipment of radioactive materials throughout the country. State and local *government* concerns about prenotification, routing, and emergency response are being addressed by providing these agencies with access to the transportation communication (TRANSCOM) system.

The TRANSCOM system combines the technologies of the United States Coast Guard's long-range navigation (LORAN-C) system, satellite communications, database management, user networks, and commercial telephone service.

The TRANSCOM system (1,2) was developed to enhance management oversight and operational control of the transport of designated radioactive materials. These materials include spent fuel, high-level waste, and transuranic (TRU) waste. Enhanced management oversight and adherence to this control is accomplished by providing a near real-time tracking and communication system between the vehicle and DOE management (3,4).

BACKGROUND

The technical effort required to demonstrate the tracking and messaging capabilities, and bring the TRANSCOM system to operational status, involved several independent organizations working as a team. Their goal was to provide operational experience and expert input to the project. The members of this team were:

The DOE - Transportation Management Division, which provided overall direction and funding for the project; Argonne National Laboratory (ANL) Materials and Components Technology Division, which initiated the developmental contracts and provided contract monitoring, technical evaluation, system testing with actual vehicles, and team coordination;

Systems Research and Applications Corporation, which provided the software development expertise and performed the initial field tests that led to the testing on actual transport vehicles;

Westinghouse Waste Isolation Division provided major user input and the use of the TRUPACT-II trailer for more extensive field testing;

Science Applications International Corporation/Analysas Corporation, which supplied technical recommendations on several systems control features and now are responsible for the day-to-day operation of TRANSCOM Control Center (TCC).

The development of the TRANSCOM system progressed through several phases. Recognition of the need to provide this service, definition of the concept, proof of the principle, and interim field tests. It culminated in a viable service for DOE management oversight and public reassurance.

Phase I - Initial Feasibility Study, 1986

The feasibility of implementing an affordable continuous tracking system for designated DOE radioactive shipments was first established in early 1986. It was determined that there were practical, cost-effective means to provide the desired managerial oversight capabilities for the DOE and its subcontractors. This effort established the basic system design philosophy that mandated the use of typical computer equipment most likely to be found in government offices, and the configuration of a minimum central database which could be expanded upon as needs developed.

Three user classifications were established: a full user with access to all system functions for maintenance of the TRANSCOM database; a DOE field office user (shippers/receivers) with restricted edit and modification capabilities; and other government agencies classified (OGAs). OGAs include State and Indian tribal government users with access to tracking, advanced notification, emergency response, and bill of lading functions.

The basic network operation was defined with the selection of a suitable operating system and file management software that would function on the class of equipment where the TRANSCOM system would reside. The initial study of available tracking/location techniques available or planned in the near future ended with the selection of the Geostar Link/One system, and LORAN-C radio location equipment.

Phase II - Initial Software Development, 1986

A prototype tracking system was developed from the specifications established in the Phase I work. Identification of satellite services and remote user control and data transfer protocol resulted in a software package capable of simulating input from satellite services via modem link. Data was simulated by a suitable microcomputer. There was no actual testing or tracking of shipments.

Phase III - Hardware Testing and Reliability, 1987

Real-time demonstration "shipments,3 using an engineering model satellite communications electronics package, collected data on a portable PC, and later on both a portable PC and a satellite-TCC modem link. Early tests only collected data on accuracy and limitations of the LORAN-C. Data collected during this phase effectively showed that shipments could be tracked with reasonable accuracy, and that satellite services could provide necessary position update intervals. Initial multiple user access was demonstrated during this period. This version, which was open to all users, could be accessed simultaneously by the maximum of four to five users who could then examine routing, contents, and movement dates on all shipments.

During this phase, a second satellite service was selected and tested. This service, OmniTRACS (a service provided by the Qualcomm Corporation), provided two-way communications/messaging capabilities which greatly enhanced the control aspect of hazardous shipments.

Two cross-country trips provided day and night LORAN-C tracking comparisons in virtually all kinds of weather conditions. One daytime and one nighttime train trip provided some interesting clear weather information on typical radio location anomalies. Details regarding these trips have been reported previously (4).

Phase IV - Software Enhancements and Debugging, 1988

In early 1988, the site and prime contractor/operator were selected for day-to-day operation of the TCC. A project status review was held with Analysas Corporation prior to transferring the technology. Recommendations for TCC equipment were based upon refined user equipment configuration and overall system performance requirements. System requirements were redefined and enhanced by the TRANSCOM Working Group. The goal of this group was to bring TRANSCOM to a fully operational status in support of the opening and operation of the WIPP in Carlsbad, NM. A program readiness review was held in late 1988 to expedite matters of concern on the operational status of TRANSCOM. Initial "multiple user" operation of the TCC occurred at Oak Ridge, Tenn., in late 1988.

TRANSCOM RESEARCH AND DEVELOPMENT

Interim TRANSCOM System Hardware and Software

An interim TRANSCOM central computer (ITCC) was operated at ANL for phase III and IV testing and development. Figure 1 shows the ITCC screen, as well as the tracking and message screens. The ITCC consisted of a database and control computer (DBAC) and a local user control computer (LUCC).

The DBAC was composed of a pair of 16 Mhz Advanced Logic Research 386-2 microcomputers utilizing the SCO Xenix System V operating system. These machines ran the ITCC software and controlled all user and satellite communications.

The LUCC consisted of a 16 Mhz Standard Brand 386-2 microcomputer utilizing the MS-DOS 3.2 operating system. This machine performed the maintenance functions for the TRANSCOM active and archived databases.

An IBM-XT was used to monitor certain tracking tests.. This machine also served to test interaction between multiple users during software development.

The local machines and all remote user machines employed PC-DOS or MS-DOS operating systems, version 3.1 or later.

Database file management was accomplished with the Btrieve Relational Database File Manager, versions 4.10 for Xenix and 4.11 for DOS.

The satellite services employed for all phases of development were Geostar Corporation, Washington, D.C., and Qualcomm Incorporated, San Diego, CA. Both services offered users custom software for access to their respective systems. However, this software did not meet the TRANSCOM system requirements for prenotification, route control, shipment contents, emergency response, or lading, route, and message archiving. The equipment for both systems consisted of an electronics module that performed the LORAN-C acquisition and mobile subsystem control functions, an external transmitter/antenna, and a remote control head containing the operator keyboard, message display, and subsystem performance indicators. The detailed function of each of these major components differs from one manufacturer to the other.

Vehicle Installation

Installations to date include Western Star, AutoCar, White-Volvo and White-Freight Liner tractors. Each vehicle has presented unique challenges to installation personnel. Qualcomm provides diagrams, illustrations, and verbal and manual assistance with equipment installation. However, the assistance is oriented toward placement of the tracking system on and within the tractor; it is not oriented toward installation on the trailer. Additionally, it is assumed that the vehicle power is appropriately filtered with devices in the dc power line and the LORAN-C antenna lead to minimize interference with the LORAN-C electronics. The general installation procedure begins with identification of the manufacturer of the transportation vehicle and any special electrical system requirements. Installation, testing, and driver/operator instruction are performed according to written procedures.

Some trailer designs allow modification of the standard power disconnect socket and the use of a spare connector pin to obtain vehicle power for the tracking electronics. Others require the installation of an alternate power distribution scheme. Power and control wiring and disconnects

Fig. 1. Computer Screens in the ITCC Operation.

must accommodate the turning radius requirements of the vehicle.

Truck Tracking Package

A truck tracking package consists of an all aluminum framework supporting both satellite and LORAN-C antennas at about 12 feet above the road. A cross-ventilated aluminum enclosure housing the electronics and backup battery attaches to this framework which is clamped to the trailer frame. Aluminum was selected for the tracking system pack to minimize weight which is a concern with vehicles subject to weight restrictions. The enclosure was isolated from the base by Berry mounts to decouple road vibration above approximately 2 Hz. All power and control cables pass through bulkhead connectors. An external key operated power switch allows shutdown of the tracking system during extended idle periods. No more than two 80 to 100 A-hr batteries are permissible in this configuration, which is shown in Fig. 2.

A rail package consists of dual steel enclosures to house the battery pack and electronics. The auxiliary battery pack, sized to hold up to three 80 to 100 A-hr batteries, provides approximately two to seven days of operation (depending on the satellite service). A guyed, steel mast supports the satellite and LORAN-C antennas about 8 feet above the rail car bed. No external control head is required for unattended transit. Steel was selected to provide a durable containment in a less than favorable environment. An external key-operated power switch and control head and power plugs complete the pack.

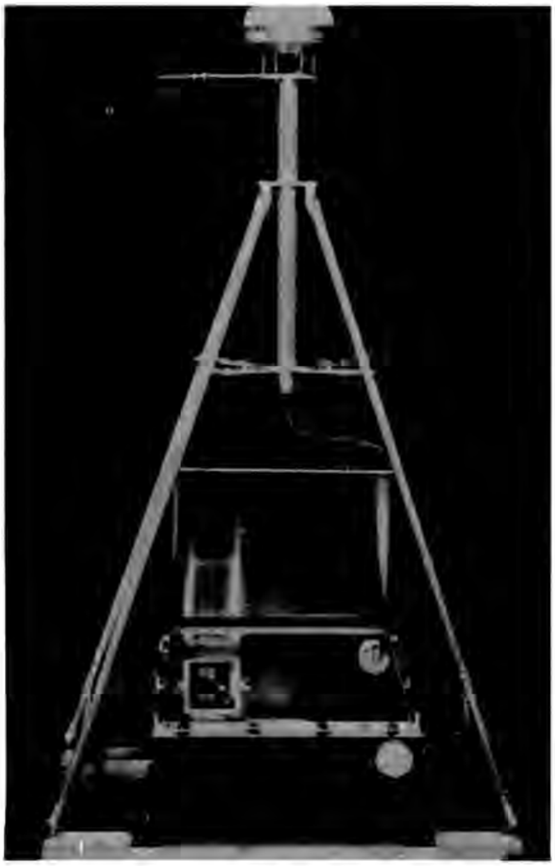

Fig. 2. Truck Package Hardware.

WIPP TRUPACT-II Testing

Westinghouse has designed a custom trailer on a lowboy type frame, with three removable, triple-shell waste containers. Each container has the capacity to accommodate fourteen 55 gallon drums of solid waste. The TRUPACT-II demonstration trailer, outfitted with the truck pack is shown in Fig. 3.

This trailer with dual rail packages containing both OmniTRACS and Geostar satellite communication systems was tracked from late June 1988 through January 1989 throughout most of the Western United States and as far east as Oak Ridge, TN. These tests provided information on the TRANSCOM electronics packages and battery backup systems. While dual rail packages were installed originally, the truck package will be used on future installations.

TRANSCOM Control Center Operations

The TCC has been established to monitor the activities of designated radioactive shipments. It is responsible for the overall management of the TRANSCOM under the supervision of the DOE - Information Resources Management Division, Oak Ridge, TN. It is a service organization to TRANSCOM users and supports the transportation management mission of DOE. It is managed by Analysas Corporation with support from Science Applications International Corporation at DOE's Oak Ridge Operations Office.

The heart of the TRANSCOM system is composed of three Compaq "386-class" microcomputers configured as a local area network (LAN) and controlled by the SCO Xenix 386 System V operating system. System power is buffered by an uninterruptable source to protect potentially volatile, active data, and provide an orderly system shutdown in the event commercial power is disrupted. Local access to the system is provided by two AST "AT-class" microcomputers. These machines control the full user and map editing functions of the system. Each microcomputer has an identically configured backup to minimize system down time in the event of hardware failure. Several AST "AT-class" machines serve as training and general administration terminals in addition to providing emergency system backup.

The TCC supports the tracking requirements of various DOE facilities by integrating TRANSCOM into the DOE transportation system with minimum disruption to the existing system. A TRANSCOM roles and responsibilities document defines the TCC functions within the DOE traffic/transportation community. Standard operating procedures (SOPs) developed from this document serve as a functional framework for the day-to-day operation of the TCC. These procedures delineate responsibilities of the various users and form a "living document" that changes as the system matures.

Tracking active shipments can require 24-hour operation. The TCC operators are responsible for ensuring that

Fig. 3. WIPP TRUPACT-II Trailer with Tracking System.

the system is maintained and that the guidelines established in the SOPs are followed.

The TCC is also responsible for overall system maintenance including TCC equipment maintenance, TRANSCOM user and TCC database software, database file backup and integrity, addressing general security issues, and the establishment and maintenance of satellite communication service contracts.

The TCC coordinates all user requests for changes, modifications, and enhancements, and provides recommendations to DOE for inclusion of the most appropriate requests. Modifications will be tested and validated before release to the user community. As the system matures, requests for changes are expected to diminish.

The TCC is designed to accommodate the addition of several machines via an Ethernet LAN, or the addition of serial boards to existing machines, to optimize system throughput as the user load and shipment schedule expands. Planning for eventual hardware expansion in this manner minimizes the funding resources necessary to meet system demands. The TCC software is configured to allow operation with either satellite service.

From time to time, the original map database will require modification to correct, add, or delete misplaced or nonexistent boundaries, roads, labels, and sites. The TCC can alter the database to provide increased accuracy and clarity. Modifications and enhancements have been made to the states of New Mexico, Colorado, Utah, Wyoming, Idaho, North and South Carolina, and Tennessee. This is expected to be a continuing process for the near term. Periodically the modified database is distributed to all users.

The TCC is responsible for training all users in the system and has trained individuals from five western states, including five Pueblo Indian tribal agencies, DOE Headquarters and Field Offices, and several waste generation, receiving, and storage sites.

A Major TRANSCOM User - The WIPP Site

The WIPP is a research and development facility designed to demonstrate safe, long term, deep geological storage of transuranic (TRU) waste generated by the U.S. national defense program. One aspect of the project involves the transportation of contact-handled (CH) and remote-handled (RH) TRU waste to the WIPP site. Currently, these wastes are stored at and/or generated by ten facilities throughout the United States.

As part of the WIPP public awareness campaign, a tractor trailer carrying the full-scale TRUPACT-II (the package that will be used to transport the CH-TRU waste to WIPP) mock-ups has traveled through most of the western U.S. The TRANSCOM equipment was installed on this "road show" model to demonstrate tracking and communication capabilities under routine and simulated abnormal shipping scenarios. These demonstrations have provided an opportunity to coordinate driver, shipper, receiver, and TCC interaction with en route shipments.

TRANSCOM Demonstrations

During the campaign, TRANSCOM was demonstrated to numerous public interest groups, including the following: WIPP Community Day visitors (approximately 2200 people), Santa Fe and Albuquerque businessmen and media representatives, the Radioactive and Hazardous Waste Legislative Committee, the New Mexico Motor Carriers Association, and the Southern States Energy Board.

The primary focus of the demonstrations was to show the near real-time tracking capabilities of the software (being able to know where the TRUPACT-II trailers are at all times), the ability to communicate weather and hazardous road conditions to the driver, and the enhanced emergency response capabilities that can result from a system of this type. The use of TRANSCOM for WIPP shipments is viewed as an added assurance for those individuals concerned about trucks carrying radioactive materials through their communities.

TRANSCOM User Testing

WIPP has been involved in user testing of the TRANSCOM system. This primarily involved interaction with the TCC in testing the remote log-on capabilities, data entry procedures, assistance in problem identification and resolution, and the live communications process with the WIPP road show vehicle.

The testing process from WIPP's perspective was relatively simple. As problems were encountered, they were communicated to the TCC, addressed and, if not immediately correctable, documented. If programming revisions were required, efforts were made to work around the problem. As long as the limitations were understood, TRANSCOM could be used effectively to track the vehicle and communicate with the driver. The next version of the software would correct many of the problems encountered. The outcome of WIPP's involvement was a list of enhancements to be considered for future versions of the software.

Computer Hardware and Software

WIPP's use of the TRANSCOM system uncovered several significant, though seemingly innocuous, aspects of system operation. The most important aspect was the requirement that TRANSCOM be installed and operated exactly as provided on disk and in the installation instructions. While this may not appear to be a significant discovery, for those involved in determining why the system would at times fail to function, the importance of this cannot be understated.

TRANSCOM has several hardware requirements that must be met. The computer must be a functional, IBM-AT/XT or equivalent, with a full 640 kilobytes of "base system" random access memory (RAM). After loading the file management program, at least 526 kilobytes must be available to the TRANSCOM software. Additionally, the computer must have a hard disk with 10 megabytes of storage available, an EGA monitor, and a 1200 baud Hayes-compatible modem. Finally, the disk operating system (DOS) must be MS-DOS, or PC-DOS, version 3.1 or later. Misunderstanding the software's memory requirements was the most significant impediment to proper operation at user installations.

Although exact instructions were provided for loading and starting TRANSCOM, most users plan to use their computer for other applications. There is a tendency is to modify the start-up files and load other RAM resident programs, thus enabling easy access to other programs. This seemingly innocent move would cause TRANSCOM to exceed the available RAM, and problems would arise that were often difficult to pinpoint. The lessons learned were to stress the importance of not modifying any of the files or procedures provided for system use, and to recognize that varying levels of computer expertise will continue to cause problems of this type as TRANSCOM becomes fully operational.

SUMMARY

TRANSCOM has been shown to be a viable technological means of providing the DOE with near real-time tracking of designated radioactive materials. The system provides two-way digital messaging with the moving shipments, and the security required to ensure that the messages reach the intended destination. The system provides authorized users with advanced notice of intended shipping dates, and appropriate procedures and contacts in the event of an emergency situation.

In addition to the user knowledge gained by testing the TRANSCOM system at WIPP, the TCC personnel have become aware of the types of troubleshooting that will be required as more users come on-line. The WIPP testing also pointed out areas that require extra emphasis during training and initial user operation. While TRANSCOM clearly meets the definition of a "user friendly" system, there are areas in the computer environment that can affect system operation. It is these areas that could consume a large amount of time from an operational standpoint as TRANSCOM becomes fully functional.

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