TRACKING RADIOACTIVE SHIPMENTS USING RADIO-NAVIGATION AND SATELLITE TELECOMMUNICATION SYSTEMS A TRANSCOM UPDATE

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ABSTRACT

The United States Department of Energy (USDOE) Waste Transportation Management Division (WMTD) has commissioned the development of a transportation tracking management and communication system to monitor movement of radioactive material shipments throughout the United States. The system, TRANSCOM, is being developed to enhance DOE's management oversight and operational control over the transport of sensitive materials (e.g., spent fuel, highlevel waste, transuranic waste etc.) and to address state and local government concerns regarding public safety. These goals will be accomplished through providing a near real time tracking and communication system complete with information database management to support emergency response capabilities.

INTRODUCTION

TRANSCOM, in full operation, provides position location determination information and two way messaging capability between the TRANSCOM Control Center (TCC) and the vehicle. The system combines the technologies of navigation, satellite communication, computerized database management, user networks, and ground communication with enroute shipments of radioactive materials.

Components of the TRANSCOM system include: the TRANSCOM Control Center with its database and a designated user community equipped with TRANSCOM configuration hardware and software; the U.S. Coast Guard LORAN-C Navigation System; transport vehicles with integrated on board electronic package (IOBEP); antenna assembly; satellite(s); satellite earth station, and a commercial communication service database (see Fig. 1).

TRANSCOM Control Center (TCC) is currently being established in Oak Ridge Tennessee by Scientific Application International Corporation (SAIC) under the guidance of the Oak Ridge Area Office. The TCC will serve as the central location for all access and interaction with the TRANSCOM system. Six categories of users have been identified as needing access to TCC: DOE Headquarters; DOE Field Offices; Shipping Facilities; Regional Emergency Operation Centers, transit State governments and transit state Indian Tribal governments.

User interface with TCC will be through standard off the shelf computer hardware obtained by the individual user. This hardware consists of an IBM PC/AT w/2mb memory and 30 mb internal storage; an EGA-type monitor, a multi-port I/O board, standard serial I/O board; and a Hayes Smart modem. TRANSCOM software; developed by Systems Research Application (SRA), will be provided by DOE to all users.

TRANSCOM SOFTWARE

The TRANSCOM software has been designed to provide users with immediate access to critical information for monitoring the movement of sensitive materials across the United States. TRANSCOM software as described in Satellite Tracking of Radioactive Shipments - High Technology Solution to Tough Institutional Problems, Lawrence H. Harmon and Paul D. Grimm, USDOE , 1987 (1). "The system will provide a real time map location as well as detailed bill of lading and routing information on all shipments. Access to this information significantly enhances emergency preparedness posture for both DOE and State and local officials. It also allows DOE to improve the dispatching and efficient use of its packaging Fleet.

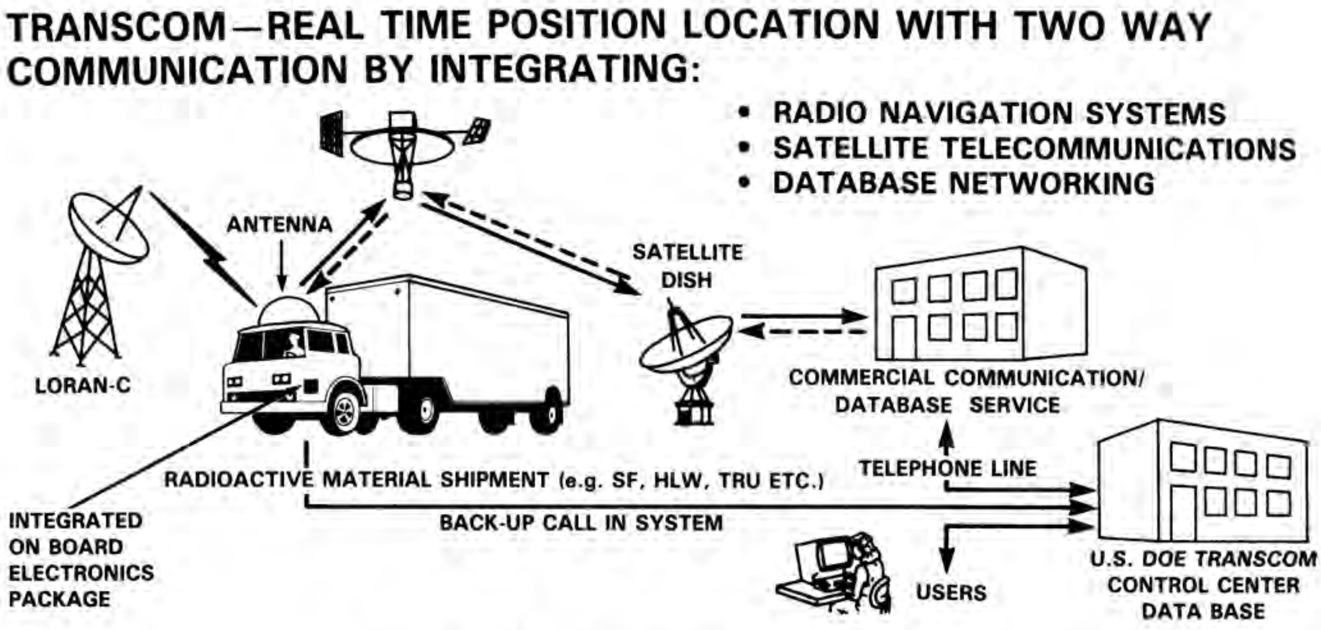

Fig. 1. Transcom Tracking and Communications System.

Vehicle Location

The TRANSCOM system uses advanced technology in navigation and telecommunication to track the location and status of sensitive DOE shipments. This technology is used to determine the latitude and longitude coordinates of shipments and provide two way communication capability between the vehicle and the TCC. TRANSCOM has the capability of tracking these shipments throughout the continental United States (CONUS). CONUS tracking is accomplished using a map of the 48 states projected on a computer monitor. A general overview of all shipments underway is indicated on the map by color coded icons designating shipment location and status. Green, yellow or red icons inform the TRANSCOM operator of normal shipping, abnormal shipping or emergency states. The TRANSCOM mapping system displays U.S. interstate roads, state highway roads and the U.S. railroad routes. Status of the vehicle can be indicated by the driver of the vehicle or by automatic on board monitors or locally by the cognizant TRANSCOM operator.

Advance Shipment Notification

Notification of an advanced shipment can be entered into the database at least 45 days prior to shipment. This allows all monitoring agencies to pre-plan shipment coordination.

Bill of Lading Information

Data can be entered to provide designated officials with information about current and near term shipments. For each planned shipment, specific data such as the schedule, planned routes, and type of radioactive material is available. All the information carried on the truck or rail manifest and required by Department of Transportation (DOT) regulations will be available.

DOT Emergency Response Procedures

System users will be able to select emergency response information from the DOT Guidebook for Hazardous Materials Incidents, (1987) (2). The scope of this file includes all the regulatory categories of nuclear materials that can be expected to be shipped and tracked using TRANSCOM. DOE or States can use this function in case of an accident to quickly determine what response measures are needed for the shipment in question.

Federal/State Points of Contact

The emergency information includes the key emergency response contacts at DOE Headquarters, the originating field office, and the shipper. The contacts for the State and the field office closest to the accident are also available.

Shipment Schedules

An accounting of planned shipment activities will be available through the TCC. This will allow states to efficiently monitor shipments relative to their geographic locations.

OPERATIONAL AVAILABILITY

The task of assuring availability of the TRANSCOM system for operation by the fourth quarter of fiscal year 1988 requires the expertise of several organizations. Research and development activities are being conducted by the Argonne National Laboratory (ANL) and its technical support contractor Systems Research and Application Corporation

(SRA). R and D contractual arrangements are being handled through the Chicago Operations Office. System implementation activities are the responsibility of Scientific

Application International Corporation (SAIC) through the Oak Ridge Operations Office. These organizations, under the guidance of the DOE/HQ, are developing the TRANSCOM system around state of the art tracking and communication technology offered by the Geostar and the Omninet corporations.

Both Geostar and Omninet have demonstrated systems that can be applied to the needs of DOE. Omninet, however; is offering tracking and two-way communication (vehicle to control center and back) capability on a more timely schedule than is currently shown by the Geostar program. Geostar is scheduled to offer tracking and two-way communication but not prior to the early 1990's. The Geostar interim operation is scheduled to offer tracking and one-way communication in May 1988. The major difference between the two systems is when fully implemented Geostar will not be dependent upon the LORAN-C for position location. It will be able to perform this function through two-way ranging from its satellites. Omninet will still require the use of LORAN-C for position location determination. Since the U.S. Coast Guard is planning to augment the LORAN-C coverage in the mid-continent with the construction of four more transmitter sites the Omninet method remains a viable solution.

Full service operation of Geostar or Omninet is dependent upon activities yet to be completed. Geostar is awaiting the successful launch of the first of a series of satellites that will provide communication services. Omninet has leased transponders from existing communication satellites and therefore is not dependent on satellite launches for full operation. It is currently operating under an FCC experimental license while awaiting FCC approval of an operational license. However, Omninet has informed DOE that limited commercial service can be offered under the experimental license.

In the event that neither commercial system is available, DOE has elected to use a proven back-up system demonstrated during R and D testing (refer to summary of R and D test report in the following section).

TESTING

Demonstration of TRANSCOM in full operation requires testing of the adequacy of the navigation and communication elements. The adequacy of the navigation system involves the testing of both its accuracy as well as CONUS coverage. Testing of the communication system requires a satellite link to a mobile vehicle. Since the Geostar satellite launch is delayed until spring of 1988 and the Omninet system availability is not scheduled prior to spring of 1988 alternative methods for testing the LORAN-C navigation technique were developed. Testing of the navigation system with both communication services is currently scheduled for mid spring 1988. LORAN-C navigation tests were successfully conducted in late October 1987. Techniques and test results are discussed below.

Transcontinental Navigation Test

A transcontinental test, originating in Oak Ridge, Tennessee and terminating in Idaho Falls, Idaho was conducted. The route represented actual routes travelled by DOE radioactive material shipment carriers. The purpose of the transcontinental test of TRANSCOM was to evaluate the accuracy and coverage of the LORAN-C position locating subsystem (navigation subsystem) contained in the test unit and to demonstrate the TRANSCOM field office transport carrier management and tracking software. This report addresses the performance evaluation of the vehicular equipment, and in particular, the LORAN-C subsystem of the test unit.

The purpose of the transcontinental test of TRANSCOM was to evaluate the accuracy and coverage of the LORAN-C position locating subsystem (navigation subsystem) contained in the test unit and to demonstrate the TRANSCOM field office transport carrier management and tracking software. This report addresses the performance evaluation of the vehicular equipment, and in particular, the LORAN-C subsystem of the test unit. Prior to the transcontinental test two preliminary test runs were made to confirm the proper installation and operation of all of the equipment. One test was conducted in the near vicinity of Washington, D.C. and the second test was a four hundred mile circuit encompassing the states of Virginia, West Virginia, Pennsylvania and Maryland. These tests also confirmed procedures used on the transcontinental test. Figures. 2, 3 and 4 show routes travelled during the preliminary tests.

Equipment

The test TRANSCOM configuration consists of vehicle position determination equipment (LORAN-C subsystem and antenna), vehicle to TRANSCOM control center communications equipment (MA/COM test satellite transmitter and antenna), the Geostar communications satellite, the Geostar control center (including ground station), the TRANSCOM control center, and DOE field offices (shipment handling and tracking hardware\software). At the time of these tests, the Geostar satellite was not available to complete the communications link between the vehicle and the TRANSCOM control center. A vehicle mounted data logging system was therefore designed and implemented to be used in place of the satellite communications . This consisted of a Zenith laptop computer with two hard disk units, a printer and appropriately created software. Instead of transmitting data through the satellite, the data was trans-

LOCAL TEST THROUGH METROPOLITAN AREA

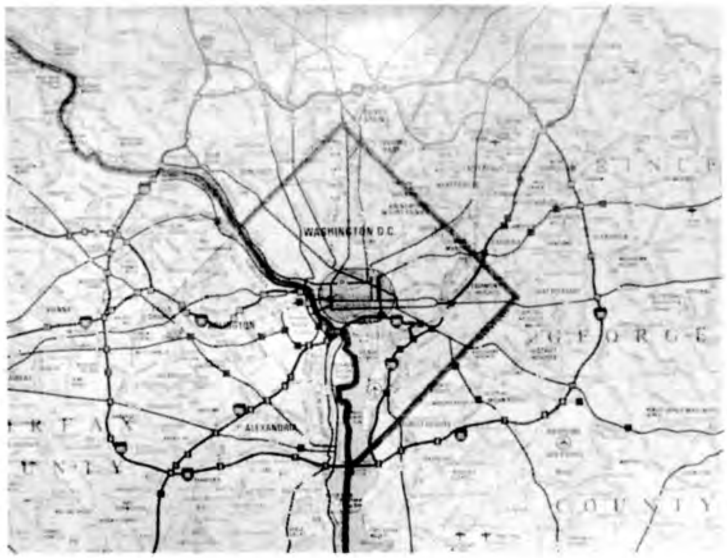

Fig. 2. Local Test Through Metropolitan Area.

400 MILE TEST MOUNTAINOUS TERRAIN

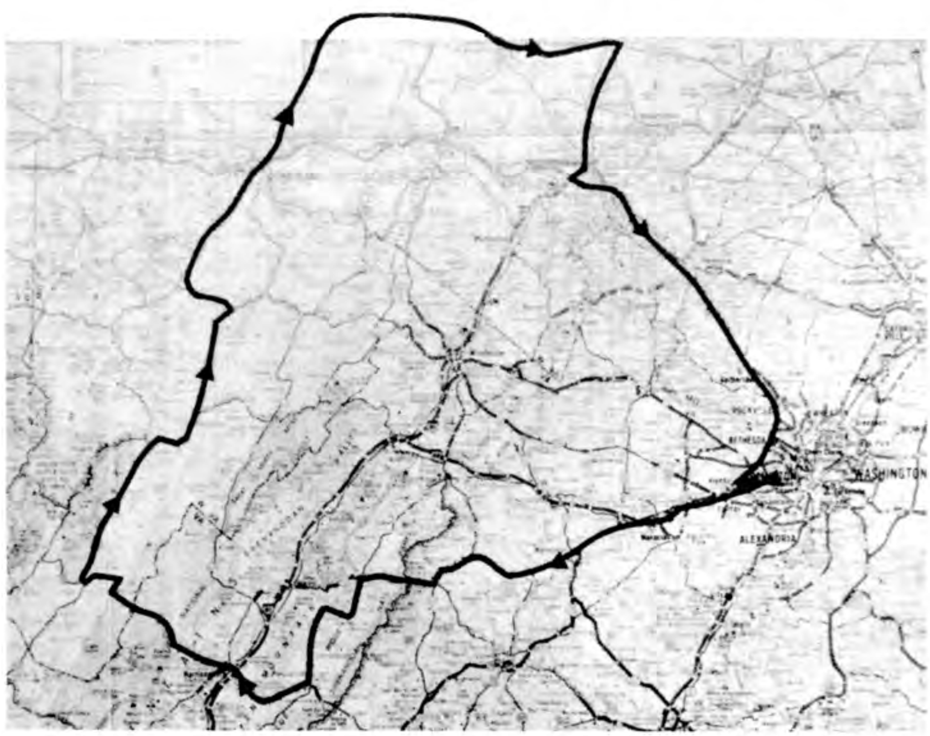

Fig. 3. 400 Mile Test Mountainous Terrain.

CROSS COUNTRY TEST--SAVANNAH RIVER (SC)
IDAHO FALLS (ID)--FOLLOWED ACTUAL SHIPPING ROUTE

Fig. 4. Cross Country Test--Savnnah River (SC) Idaho Falls (ID)--Followed Actual Shipping Route.

ferred to the laptop computer and in turn recorded onto the hard diskettes (note: this configuration could be used as a backup system). The special software was used to query the LORAN-C subsystem of the test unit at regular intervals and record position and status information onto both the disk and paper. Normally, only the position information is sent from the vehicle to the Geostar ground station via the Geostar satellite. Once received by the ground station, the information is then time-stamped, converted into proper format, and placed in a TRANSCOM "mailbox." In order to simulate this process, information from each query by the laptop computer was converted into a form identical to that used when placing information into the TRANSCOM "mailbox" and stored onto the hard disk. Each evening, this information was transmitted via standard phone lines to SRA (location of simulated TRANSCOM Control Center, TCC). The next day they were entered into the TCC computer at regular intervals to simulate real-time reception of the packets.

The use of the laptop computer as well as the software written specifically for this test allowed access to much more information than is normally available through the normal operating configuration of the test unit. Some of the extra capabilities available are: direct access to information concerning the status of the LORAN-C unit within the test unit; the ability to automatically check status at any interval or on demand; and the ability to record all information in a disk file and/or on paper.

The vehicle used was a rented four-door sedan. The antenna, one for receiving the LORAN-C signals and one for transmission to the satellite, were mounted together and enclosed in a radome on the roof. The test unit, laptop computer, and printer were located inside the automobile. Spares for the test unit, its antenna assembly, the laptop computer and printer were stored in the trunk. A portable cellular phone was also carried in the vehicle to test it's capability to establish communication to the TCC. The power for all systems was supplied through a specially built power distribution box. A noise filter was connected to the vehicles alternator.

The Test Unit

The test unit consisted of two separate assemblies, an electronics unit assembly and an antenna assembly. The electronic unit contained the LORAN-C receiver, the Geostar satellite transmitter, an on board microprocessor, power supply and backup battery. The antenna assembly contained both the LORAN-C antenna and the satellite transmitter antenna.

Two identical test units with antenna were supplied, one was used for testing and the other kept as spare. The operating test unit was configured to run exactly as it would in a standard installation. Although the Geostar satellite was unavailable, the test hardware was configured to automatically transmit a message packet out into space every 15 minutes as in a normal operation.

The antenna assembly was protected by a radome which acted primarily as a weather shield. Inside of the dome was both the LORAN-C antenna with its preamplifier and the Geostar satellite antenna. Two separate coaxial cables connected the LORAN-C and satellite antennas to the test unit's front panel. The supplied antenna assemblies were prototypes. The final configuration, while being functionally equivalent, is expected to be substantially smaller.

Data Logging Computer System

There are two classes of data obtained. These are data taken every minute of time while the vehicle is in motion and data taken when the vehicle passes a predetermined reference point (checkpoint). Each checkpoint is an identified landmark with a previously determined latitude and longitude from geodetic survey maps.

The data logging system consisted of a ZENITH model 181 IBM compatible laptop computer and a DICONIX portable inkjet printer. The data logging software programs used on the laptop computer, were written and compiled in Turbo Pascal by SRA to specifically control and query the test. No modifications to the test unit were necessary. The connection to the test unit was by cable through one of the two RS232 ports supplied on the unit's front panel.

The software provided the ability to obtain the basic latitude and longitude data while allowing collection of other ancillary information such as the LORAN-C stations used in the position determination, received signal level, the signal to noise ratio of each received signal and much more. This data was time stamped, merged with operator entered notes and recorded on disk for later analysis.

The software was designed to minimize the need to type, since the operator was responsible for navigation and checkpoint identification tasks conducted while the vehicle was in motion. An automatic logging (autolog) feature allowed data to be taken at preset intervals. During this test the interval was set at one minute and was identified by the note AUTOLOG in the message field.

When a checkpoint was reached depression of one key entered all identifying information into the logged data file. Each time data is logged it is simultaneously displayed on the screen, printed on the printer, and recorded on disk.

At the end of each day the data logged to the computer was transmitted to the test TCC (SRA Arlington) via modem. During the following day, software at TRANSCOM central would extract the packets individually from the file and play them back at preset time intervals to create the illusion of tracking the vehicle in real time via the Geostar satellite.

Power Distribution Unit

The power distribution unit was built to filter and distribute the power to the various electronic devices. A converter is also provided within this box to supply 9VDC to the printer. The supply wire plugs into the accessory outlet on the dashboard.

RESULTS

Over three thousand data points were collected during the transcontinental test. These are divided into two classes. They were taken every minute of time while the vehicle was in motion for the entire trip. Data was also taken whenever the vehicle passed a predetermined reference point. Each reference point (checkpoint) was an identifiable landmark with a previously determined latitude and longitude from the geodetic survey maps. The checkpoints, 145 in all, are further subdivided into validated and ambiguous sets. There are 121 checkpoints in the validated set and 24 in the ambiguous set.

Table I shows the checkpoints error in miles as the percentage and number of points that fall into the indicated range. The validated set contains only points both verified by the LORAN-C and the operator. The set of all points includes all checkpoints logged.

Table II displays the overall average error in feet of the previous two sets of checkpoints. The third column shows the average error of the validated checkpoints excluding one checkpoint which had an error of over 20 miles. It is believed that this position was determined by the LORAN-C unit while locked onto a skywave reception (as opposed to the preferred ground wave). Tables III and IV divide the trip at Oklahoma (checkpoint 60) to show a comparison between the west and east.

CONCLUSIONS

The results of the test confirmed that there is accurate LORAN-C coverage over the complete route traveled. There was some degradation in performance in the west, particularly in Wyoming, but the anomalies that appeared were intermittent and accurate position data could still be obtained. This is evident from the detail in the graph of the trip route included at the end plotting all of one minute interval data as well as the checkpoint data.

It is interesting to note that the LORAN-C readings were extremely useful in anticipating the arrival of a checkpoint. Since all the maps were marked with the coordinates of the checkpoints, the navigator could follow the position change on the automatic logs on the computer screen and anticipate very closely the coming of a checkpoint. If the coordinates were missed the navigator could easily determine whether the vehicle was off the planned course or if the checkpoint had changed since the last revision of the maps. Twice the navigator passed the checkpoint's longitude value but the latitude value showed the vehicle was well away from the checkpoint. A check of the coordinates on the map put the vehicle on another road paralleling the marked route and from there the vehicle returned to the planned route.

TABLE I

Transcontinental Test Data Sample Showing Checkpoints Error in Miles

RANGE IN MILES POINTS	CHECKPOINT ERROR IN MILES ALL POINTS		VALIDATED	
0 <-> 0.5	124	85.5%	110	90.9%
1 <-> 2	13	9.0%	5	4.2%
2 <-> 3	4	2.7%	3	2.5%
3 <-> 4	2	1.4%	1	0.8%
4 <-> 5	1	0.7%	1	0.8%
5 ->	1	0.7%	1	0.8%
	145	100.0%	121	100.0%

TABLE II

Transcontinental Test Data Sample Showing Overall Average In Feet

	ALL POINTS (145 points)	VALIDATED (121 points)	VALIDATED MINUS WILD POINT (120 points)
AVERAGE ERROR IN FEET	2698	2001	1804

TABLE III

Transcontinental Test Data Showing Eastern United States Checkpoints Error in Feet

	UP TO CHECKPOINT 60 ONLY ALL POINTS (60 points)	VALIDATED (56 points)	VALIDATED MINUS WILD POINT (56 points)
AVERAGE ERROR IN FEET	972	876	N/A

TABLE IV

Transcontinental Test Data Showing Western United States Checkpoints Error in Feet

	FROM CHECKPOINT 62 TO END ALL POINTS (85 points)	VALIDATED (65 points)	VALIDATED MINUS WILD POINT (64 points)
AVERAGE ERROR IN FEET	3997	4268	2618

The transmitting interval of the Geostar data packets should probably be reduced from 15 to 5 minutes in certain areas to improve chances of receiving enough accurate position information.

The performance of the LORAN-C subsystem is greatly dependent on proper installation, with particular attention necessary for grounding, antenna mounting and elimination of vehicular electrical noise sources. Future tests planned for the trucks and trains should closely consider these factors.

REFERENCES

1. L. H. Harmon, P. D. Grimm, Satellite Tracking of Radioactive Shipments -- High Technology Solution to Tough Institutional Problems, U.S. Department of- Energy, Washington, D.C. 20545 (1987).

2. Guidebook for Hazardous Materials Incidents, U.S. Department of Transportation (1987).