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Several Navy projects have examined the technological feasibility and practicality of establishing a secure satellite-based communications system between maintenance personnel at sea and expert repair technicians on shore for remotely diagnosing and repairing casualties to shipboard machinery and combat systems. These projects have, however, provided only limited information concerning (1) the extent to which such a remote communications system could meet the technical assistance needs of ships at sea, and (2) the level of telecommunications equipment support needed to provide troubleshooting assistance and repair guidance at a distance. This report describes research that was conducted to determine the applications problem solving capabilities of this maintenance-aiding concept in general and the effective and efficiency of alternative telecommunications equipment configurations for delive remote technical assistance in particular.

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FOREWORD

This research and development was conducted in support of exploratory development task RF63.522.801.014 (Relating Training and Readiness) work unit 03.02 (Remote Expertise for Maintenance). The sponsor was the Chief of Naval Operations (OP-01B7). The project was designed to extend earlier research from independent exploratory development task ZF66.512.001.070 (Methods for Improving Maintenance Procedures) that examined the feasibility of employing remote telecommunications between highly qualified shore-based technicians and maintenance personnel at sea for use in the diagnosis and repair of Navy equipment casualties.

Appreciation is expressed to the following for providing the Navy enlisted and civilian personnel who supported the present effort: Commanding Officer, Naval Sea Support Center, Pacific, San Diego; Commanding Officer, Naval Electronic Systems Engineering Center (NAVELEXSYSENGCEN), San Diego; Commanding Officer, Submarine Training Facility, San Diego; Commanding Officer, Fleet Combat Training Center, Pacific, San Diego; Commanding Officer, USS REEVES (CG 24); Commanding Officer, USS LONG BEACH (CGN 9); Commander, Fleet Anti-Submarine Warfare Training Center, Pacific, San Diego; Officer in Charge, Mobile Technical Unit FIVE, San Diego; and Officer in Charge, Mobile Technical Unit NINE, Treasure Island, California.

This Center also wishes to acknowledge the outstanding support provided by members of the Fleet Liaison Office (Code 05), NAVELEXSYSENGCEN; Facilities Operations and Engineering Department (Code 03), Integrated Combat Systems Test Facility (INTCOMBATSYSTESTFAC); and Weapon Control and Sonar Department (Code 62), Naval Ocean Systems Center (NAVOCEANSYSCEN), who provided access to the equipment and facilities used during the land-based demonstration studies.

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This report is intended for the use of military and civilian personnel concerned with developing or implementing a remote communications maintenance assistance capability.

J. W. RENARD
Captain, U.S. Navy
Commanding Officer

JAMES W. TWEEDDALE
Technical Director

SUMMARY

Background

The operational readiness of deployed Navy ships may be seriously degraded by delays in obtaining off-ship technical assistance to diagnose and repair casualties to mission-essential equipment. This problem can be particularly acute for the Navy because of the world-wide deployment of its surface units. One possible way to reduce the time that a ship at sea spends in a state of degraded equipment readiness is to link it to an expert repair technician on shore by using modern telecommunications satellite technology. The present effort examined several issues related to the feasibility and practicality of establishing such a capability for the surface fleet.

Objectives

The objectives of this effort were (1) to identify Navy equipments whose corrective maintenance at sea could be addressed by the remote expertise for maintenance (REM) concept and (2) to determine the effectiveness of alternative telecommunications modes (e.g., voice communications only vs. voice supplemented with visual and/or graphic equipment) in providing shore-based technical advisory assistance and repair guidance at a distance.

Approach

Three separate research phases were conducted: (1) identifying Navy equipments whose number of downtime hours awaiting off-ship technical assistance might be significantly reduced through the use of the REM concept; (2) identifying and selecting telecommunications accessory devices that shore-based expert maintenance technicians considered applicable for remote site troubleshooting; and (3) conducting studies to determine the problem-solving capabilities of the REM concept in general and the level of telecommunications devices needed to facilitate the delivery of remote technical assistance in particular.

Results

Regardless of the telecommunications modes used for the remote technical assistance consultations, expert maintenance technicians solved all troubleshooting problems administered in three separate land-based demonstration studies. In addition, no statistically significant differences were found among alternative telecommunications modes in terms of time-to-solution and the number and types of corrective maintenance actions that were ordered by the remotely located expert technicians. Moreover, several experts used fewer telecommunications accessory devices than the experimental design specified. In cases where visual information was used (i.e., slow-scan or full-motion television), the experts were only interested in viewing limited portions of the Navy equipment undergoing repair and/or supporting test equipment. The REM experts did not use the interactive graphic devices (i.e., hard-copy facsimile and electronic telewriter) to any great extent primarily because they could see no tangible troubleshooting applications for either device. It was also found that actual conversation time between the expert and shipboard technicians accounted for only a limited amount of the total time spend in troubleshooting each problem.

Conclusions

1. To the extent that the demonstration studies simulated the conditions under which remote technical assistance would be provided, the feasibility of the REM concept was demonstrated for diverse Navy equipments and corresponding troubleshooting problems.

2. Diagnostic and repair accuracy, time-to-solution, and the number and types of troubleshooting tests and repair actions the expert technicians ordered were found to be clearly independent of the telecommunications mode used for the remote technical assistance consultation. Therefore, the least equipment-intensive interactive telecommunications systems (e.g., voice-grade telephone, radio, or satellite links) are effective and efficient substitutes for in-person contact between expert technicians ashore and maintenance technicians in deployed units of the surface fleet.

3. The large amount of time not spent in conversation for the troubleshooting problems suggests that the telecommunications link need not be available continuously during the course of a remote telecommunications maintenance assistance event.

Recommendations

1. The design and implementation of a formal REM capability for the surface fleet should focus on a secure, voice-grade telecommunications link.

2. The feasibility and practicality of a time-sharing arrangement over an operational REM network should be investigated. Such an arrangement could enable shore-based technicians to provide either assistance to several deployed units over a single telecommunications channel or incidental on-the-job training to the unit that requested shore-based assistance.

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INTRODUCTION

Problem

A ship usually requests shore-based technical assistance when its own personnel are unable to diagnose and repair an equipment casualty. Although casualties requiring such assistance may constitute only a limited portion of the maintenance problems encountered in the fleet, they may be especially detrimental to overall operational readiness because lengthy delays are usually encountered before technical assistance is provided. One possible way to reduce the time that a ship at spends in a degraded state of equipment readiness is to link it to an expert technician on shore by using modern telecommunications satellite technology.

This method, hereinafter referred to as remote expertise for maintenance (REM), has been the focus of several recent Navy projects that have examined its technological feasibility and practicality. While the findings from these projects are indeed encouraging, each has provided only limited information concerning (1) the extent to which a REM capability could meet the technical assistance needs of ships at sea, and (2) the level of telecommunications equipment support needed to provide troubleshooting advice and repair guidance at a distance. Given the interest and attention that this maintenance-aiding concept has generated, definitive information needs to be obtained to address these deficiencies.

Objectives

The objectives of this effort were to (1) identify Navy equipments whose corrective maintenance at sea could be addressed by the REM concept and (2) determine the effectiveness and efficiency of alternative telecommunications modes (e.g., voice communications only vs. voice supplemented with visual and/or graphic equipment) in providing shore-based technical advisory assistance and repair guidance at a distance.

Background

The Navy has implemented several methods to provide more responsive delivery of shore-based technical assistance to deployed units of the fleet. Perhaps the most widely-used method at the present time for substituting in-person contact between technical experts on shore and deployed Navy ships is the use of "hard copy" message traffic. In this method, the ship and shore site exchange written messages to document the symptoms of an equipment casualty and to recommend a course of troubleshooting and repair actions respectively. While moderately effective, the efficiency of this method is often seriously impaired by lengthy delays in processing messages through formal chains of command and, more importantly, by imprecise descriptions of casualty symptoms and/or recommended corrective maintenance procedures.

Two-way voice communications by means of long distance radio or telephone can also be used to deliver shore-based technical assistance to remote sites. Although this method avoids most of the limitations associated with conventional message traffic, its use is precluded whenever secure (i.e., encrypted) transmission lines are not available to the port or geographic area in which a ship is located.[1]

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[1]Navy casualty reports (CASPERs) and other communications detailing shipboard equipment problems are classified and thus require encrypted transmission.

These examples demonstrate the need for improving the delivery of shore-based technical assistance to deployed surface ships. One method that shows considerable promise calls for the establishment of a secure, satellite-based telecommunications system that allows maintenance personnel at sea to communicate interactively with expert repair technicians on shore for assistance in diagnosing and correcting casualties to shipboard equipment. The Navy has begun to examine the feasibility and practicality of implementing such a system for the surface fleet. The following paragraphs provide a general overview of the findings, to date, obtained from this work.

Technological Feasibility

The technological feasibility of establishing a satellite-based telecommunications link for remote site troubleshooting was examined in a project entitled shipboard engineering assistance for system test and repair via satellite (SEASTARS) (American Management Systems, 1980). A SEASTARS project team, under the direction of NAVSEA 62C, addressed several equipment-related issues in evaluating the technological feasibility of the REM concept.

1. Determining the most suitable telecommunications system delivery vehicle with which to conduct an operational test of SEASTARS on a Navy combatant ship.

2. Identifying various telecommunications accessory devices (e.g., slow-scan television, facsimile processor, teletype) that would provide a range of interactive services to facilitate the delivery of remote technical assistance.

3. Examining the feasibility of encoding voice and other telecommunications accessory equipment transmissions using a standard Navy encryption device, as well as examining the inter- and intrasystem electromagnetic compatibility.

Although the SEASTARS project team demonstrated the feasibility and technological compatibility of various equipments that would support a REM network, it did not demonstrate (either directly or through simulation) the problem-solving capabilities of this maintenance concept.

Land-based Demonstrations

To provide such a demonstration and to identify factors that might affect use of such a procedure when troubleshooting Navy equipment casualties, Nugent (1982) conducted a controlled land-based test of the REM concept using the AN/SQR-17 sonar detecting-ranging set. Three troubleshooting problems representative of those requiring outside technical assistance were inserted in the SQR-17 in two demonstration sessions. These casualties had been identified in earlier research as too difficult for fleet second and third class sonar technicians (surface) (STG2s and STG3s) to diagnose and repair on their own. For each session, an SQR-17 maintenance instructor served as the remote maintenance technician (or expert), while STG2s and STG3s from the fleet served in the roles of at sea maintenance personnel. The two telecommunications linkage configurations tested in this study were audio plus video and audio with video as needed.

Regardless of the telecommunications linkage used, the expert technicians solved five of the six troubleshooting problems. The unsolved problem was terminated due to time limitations imposed by the testing schedule. These findings demonstrated the problem solving capability of the REM concept.

Operational Tests

Project SEASTARS. An operational test of a prototype SEASTARS equipment network was conducted aboard USS EISENHOWER (CVN 69) between August 1981 and January 1982 using a commercial marine satellite (MARISAT) system. The principal findings (American Management Systems, 1982) were as follows:

1. Conventional MARISAT operations were not materially affected by electromagnetic interference from other Navy shipboard electronic equipment or vice versa.

2. MARISAT proved to have wider potential than was anticipated as the link was used extensively for periodic logistic updates both to and from shore-based commands.

This operational test of SEASTARS provided only limited information about its primary intended use; namely, to provide shore-based technical advisory assistance to deployed Navy ships. For example, only 2 of the 95 MARISAT calls made when EISENHOWER was at sea were made for purposes of Navy equipment maintenance. An explanation offered for this infrequent use of MARISAT to obtain such assistance was the nonavailability of a secure circuit for encrypting MARISAT voice and teletype transmissions. Hence, while the test confirmed the operational compatibility of a prototype SEASTARS telecommunications link, it did not provide sufficient information to validate operationally the problem-solving capabilities of the REM concept.

Remote technical assistance (RTA) program. Perhaps the most clear-cut evidence that the REM concept is operationally feasible and practical has been obtained from a program[2] being conducted at the Naval Electronic Systems Engineering Center (NAVELEXSYSENGCEN), Portsmouth, Virginia. RTA is comprised of existing Navy secure voice-telecommunications assets (e.g., satellite, radio, telephone) and operational system test beds (i.e., complete electronic system mockups) that enable NAVELEXSYSENGCEN, Portsmouth technicians to duplicate actual fleet-reported equipment casualties. Preliminary results indicate that RTA has achieved an 80-percent success rate in correcting casualties to certain electronic equipments installed aboard Navy ships and at remote locations on shore. Appendix A provides examples of the equipment problems resolved and the geographic locations served by RTA.

APPROACH

The present effort was conducted in the following three phases:

1. Identifying the Navy equipments whose number of hours of downtime while awaiting off-ship technical assistance might be significantly reduced through the use of the REM concept.

2. Identifying and selecting telecommunications accessory devices for remote site troubleshooting.

3. Determining the problem solving capabilities of the REM concept in general and the level of telecommunications equipment support needed to facilitate the delivery of remote technical assistance in particular.

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[2]A general overview of the RTA program was obtained from briefing materials prepared by the Naval Electronics Systems Command (undated), because only limited documentation is currently available for this effort.

Identification of Candidate Navy Equipments

Preliminary Selection

Information on operational Navy equipments that incurred lengthly periods of downtime awaiting off-ship technical assistance was obtained from a computerized listing of Navy casualty reports (CASREPs) prepared by the Navy Ships Parts Control Center, Mechanicsburg, Pennsylvania. This listing summarized the number of maintenance downtime hours by equipment identification codes[3] (EICs) for calendar years 1980 to 1981 for operating units of the surface fleet. The number of downtime hours reflected only the time that an equipment remained in a casualty status awaiting off-ship technical assistance and did not include time awaiting parts.

For each EIC, the number of downtime hours incurred awaiting off-ship technical assistance was summed for the 2-year time period. The results were then ranked from highest to lowest.[4] The following criteria were established for selecting an appropriate and representative sample of Navy equipments from the 1,417 ranked EICs for follow-on efforts:

1. The equipments selected must represent a significant proportion of the number of maintenance downtime hours reported in CASREP data base for calendar years 1980 to 1981.

2. The number of equipments selected must permit a meaningful assessment of their potential for application of the REM concept.

3. The types of equipment selected must represent a broad cross section of major shipboard system-level divisions (e.g., engineering, weapons, and operations).

Using these criteria, the preliminary sample of 280 shipboard equipments was selected from the CASREP data base. Although these equipments accounted for only 20 percent of all the equipments for which CASREPs were submitted, they accounted for 75 percent of the overall number of maintenance downtime hours reported. Moreover, these 280 equipments represented 22 of the 28 major shipboard system-level divisions listed in the EIC Master Index (see footnote 3).

Two of the six divisions not represented in the sample contained equipments for which no casualties were reported; the remaining four divisions contained equipments whose composite downtime was at or below the 25th percentile for the overall distribution of maintenance downtime hours.

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[3]The EIC is the primary source used to identify shipboard systems, subsystems, and equipments when documenting maintenance actions. For further information refer to: Equipment Identification Code Master Index (NAMSO 4790 E2597). Mechanicsburg, PA: Navy Maintenance Support Office, November 1982.

[4]The downtimes reported for 33 EICs were excluded from the calculation of 2-year composite scores because the maintenance downtimes reported for these EICs (in separate calendar years) equalled the 9,999-hour upper limit established by the CASREP system.

Final Selection

To rely exclusively on the CASREP data base for selecting a final list of candidate equipments was problematic in the following respects.

1. Some of the 280 equipments identified might no longer be operational in the Navy during the projected time period for which a REM capability could be formally implemented in the surface fleet (i.e., 1985 to 1990). As a result, any efforts to demonstrate the feasibility and practicality of troubleshooting casualties these equipments by means of satellite telecommunications would have limited, if any, future payoff.

2. Some of the equipments included in the preliminary sample, such as deep fat fryers, laundry, and dishwashing machines, were of limited importance to the conduct of primary naval warfare missions.

With these considerations in mind, representatives from the Navy's shore-based technical assistance community were asked to screen the preliminary list of equipments for relevance and timeliness.

Needs Assessment Survey

Purpose and Scope

Navy equipment maintenance experts were surveyed concerning the potential usefulness of various telecommunications accessory devices in addition to voice communications for delivering shore-based technical assistance to deployed Navy ships. The experts rated the usefulness of each accessory device in relation to the potential types of casualties that could occur among the candidate equipments selected in the preceding research phase. A summary of the procedures used to develop and administer the needs assessment survey, together with its principal findings obtained is provided in the following paragraphs.

Development

Potential telecommunications accessory devices were identified through an extensive literature review and interviews with specialists in this area. From this, seven telecommunications accessory devices, under the general headings of visual, graphic, and computer, were included in the survey for evaluation by the experts. Although some of these devices have not yet been fully developed, the prototypes that are available appear to be operationally feasible. For example, electronic signals from most of these devices are capable of being encoded and deciphered using existing Navy cryptographic equipment.

To obtain information concerning the specific area(s) in which malfunctions could occur to the Navy equipments in the survey, the following five component categories were identified: Mechanical, electrical, digital, analog, and hydraulic/pneumatic. This categorization scheme provided a means for localizing major problem areas on an inter-as well as intraequipment basis.

The final section of the survey asked the respondent for (1) background information including his experience in the maintenance of Navy equipment, (2) any additional telecommunications accessory devices that might be useful for providing remote technical assistance, and (3) any problems that might rule out the feasibility of troubleshooting shipboard equipment casualties by means of satellite telecommunications.

Administration

To ensure that respondents would make their assessments based on equipments with which they were personally experienced and familiar, the survey forms listed only those equipments for which the respondent's department or command had cognizance. Furthermore, the forms contained spaces for the respondents to enter any additional Navy equipments that they thought should be included in the survey.

Respondents estimated the percentage of each equipment's casualties that were accounted for in each of the five component categories described above. For example, if a respondent estimated that 15 percent of the casualties to a particular equipment were attributable to malfunctions in electrical components and 85 percent to digital components, then these two percentage estimates were entered in the survey form for that equipment. In all cases, the estimates were based on the respondent's actual equipment maintenance experience and were required to total 100 percent. Moreover, respondents were also asked to evaluate the potential usefulness of the seven telecommunications accessory devices using the following scale: 1 = not applicable, 2 = helpful, 3 = essential. These ratings were requested only for those component categories for which the respondent had estimated a casualty percentage.

Examples of the needs assessment survey forms and standardized instructions for completing it are provided in Appendices B and C respectively.

Survey Sample and Data

Survey forms were completed by 25 Navy enlisted and 89 Navy civilian personnel from four shore-based technical assistance commands. Table 1 provides the number of survey respondents from each command by department.

Of the 273 Navy equipments evaluated in the survey, 202 (or 80%) were from the list of 254 equipments on which the survey was based and 71 were added by the respondents. The overall survey data base contained 1,090 records of which 997 were retained for subsequent analysis. Nine respondents indicated that none of the telecommunications accessory devices were applicable for remote site troubleshooting; hence, their data, which did not help to discriminate among the various alternatives for which assessments were sought, were excluded from subsequent analysis.

Selection of Accessory Devices

Analyses of the survey data focused on identifying those telecommunications accessory devices that the experts indicated they would be most likely to use in facilitating delivery of remote technical assistance to deployed Navy ships. To accomplish this, an applicability score was calculated for each accessory device both within and across the equipment component categories in which the experts made judgments. These scores, presented in Table 2, reflect the percentage of experts who rated a given accessory device as either helpful or essential for remote site troubleshooting.

Table 2 shows that the range of applicability scores for the accessory devices varies considerably among the categories of equipment components (i.e., 14% to 69%). Nevertheless, the applicability scores listed for the first four accessory devices tend to be noticeably higher than those listed for the last three. Accordingly, two nonparametric statistical tests were performed on these data to determine the magnitude of the difference in this observed pattern of relationships.

Table 1

Needs Assessment Survey Respondents

Command, Location	Department	Number of Respondents (N)
Naval Sea Support Center Pacific, San Diego (N = 67)	Surface Ordnance & Electronics Systems	12
	Surface Missile Systems	19
	Surface Underseas Systems	7
	Ship Systems	29
NAVELEXSYSENGCEN, San Diego (N = 11)	Communications Systems	7
	NAVAIDS & SATNAV Systems	4
Mobile Technical Unit FIVE, San Diego (N = 28)	Communications & NAVAIDS Systems	4
	Data Systems	8
	Electronic Countermeasures Systems	1
	Interior Communications Systems	2
	Radar & IFF Systems	6
	Sonar Systems	4
	Weapons & Gun Systems	3
Mobile Technical Unit NINE, Treasure Island (N = 8)	Communications & NAVAIDS Systems	2
	Data Systems	1
	Electronic Countermeasures Systems	1
	Interior Communications Systems	1
	Radar & IFF Systems	1
	Sonar Systems	1
	Weapons & Gun Systems	1
Overall Total		114

Table 2

Applicability Scores for Telecommunications Accessory Devices Within and Across Categories of Equipment Components

Equipment Component Category	No. Expert Judgments	Telecommunications Accessory Devices (%)						
		Slow-scan Television	Full-motion Television	Hard-copy Facsimile	Electronic Telewriter	Three-dimensional Display	Automated Trouble-shooting Routines	Remote Sensing Unit
Mechanical	691	60.9	65.6	52.3	56.0	33.7	38.2	22.7
Electrical	717	47.7	65.0	59.8	58.1	16.5	38.1	35.4
Digital	427	55.7	65.8	69.3	67.0	19.2	63.9	49.6
Analog	641	46.5	58.2	51.8	64.1	14.0	43.2	37.9
Hydraulic/ Pneumatic	279	55.2	68.8	54.5	56.6	31.2	35.5	29.0
Overall	2,755	52.7	64.1	57.0	60.5	22.1	43.0	34.4

Note. Applicability scores (expressed in percent) were derived by combining the number of expert judgments in which a given accessory device was rated either helpful or essential for remote site troubleshooting and dividing that sum by the total number of expert judgments per equipment component category.

The first test, which provided a measure for the significance of difference between proportions (Bruning & Kintz, 1977, p. 212), involved calculating the values of two proportions for each of the six row variables (five equipment component categories and overall) listed in Table 2. One proportion was based on the average applicability score for the first four accessory devices; the other, on the average for the last three. Results showed that the values of the two proportions differed significantly in all cases (average $z = 10.2$, $p<.001$ for the six row-wise comparisons). Thus, it can be concluded that the average applicability scores for the first four accessory devices were significantly larger than the average for the last three on both an inter- as well as intraequipment component basis.

For the second test, applicability scores for each accessory device were first ranked from highest to lowest within the five categories of equipment components (i.e., row-wise) and then submitted to the Friedman two-way analysis-of-variance-by-ranks procedure described in Hays (1973, pp. 785-786). Results yielded a significant Chi-square statistic ($\chi r^2 = 25.6$, 6df, $p<.005$), thus rejecting the null hypothesis that any given rank was as likely to be found with one accessory device as another. Stated another way, this finding indicates that the rankings of applicability scores for the accessory devices were highly consistent among the categories of equipment components in which the experts made judgments.

Based on these findings, the four following telecommunications accessory devices were selected for testing in the final phase of this research effort: Two visual accessory devices (i.e., slow-scan and full-motion television) and two interactive graphic devices (i.e., hard-copy facsimile and electronic telewriter). More detailed information concerning each of these devices is presented in Appendix D.

Secondary Analyses

Additional analyses were performed on the survey data to determine whether the applicability score assigned to each of the telecommunications accessory devices (i.e., within each of the five equipment component categories) differed as a function of the respondents' years of maintenance experience, number of off-ship technical assistance visits rendered, and Navy activity to which assigned. Although significant main effects were found for these independent variables in relation to the applicability scores assigned by the respondents, the overall results were equivocal. For example, one analysis showed a particular pattern of differences for the applicability scores assigned to the five categories of equipment components based on the respondents' number of years of maintenance experience, but the patterns based on the number of off-ship technical assistance visits rendered and Navy commands to which the respondents were assigned were entirely different.

Difficulties were also encountered in the analysis of the open-ended survey questions in that: (1) A majority of experts surveyed did not respond to the open-ended questions and (2) those who did respond typically paraphased the same types of problems and issues that were raised in the questions themselves. For these reasons, secondary analyses of the survey data were abandoned.

Demonstration Studies

The final phase of this effort consisted of determining the level of telecommunications equipment support needed to provide a REM capability for the surface fleet. A series of studies were conducted to compare the effectiveness and efficiency of alternative telecommunications linkage configurations in delivering remote technical advisory assistance and repair guidance.

Troubleshooting Problems

A comprehensive survey was conducted among Navy laboratory, maintenance, and Fleet training commands to determine the availability of equipments that could serve as test vehicles for the demonstration studies. The general criteria used in selecting test vehicles were:

1. The equipment must be among the prospective candidates for application of the REM concept identified in the first phase of the effort.

2. The faults developed for the equipment must provide realistic troubleshooting tasks and equipment component malfunctions.

3. The equipment must be available for use during conventional working hours (e.g., 0800-1700).

Using these criteria, three Navy equipments were selected as test vehicles for the demonstration studies: AN/WRN-5 satellite navigation (SATNAV) set, AN/SPS-10G surface search radar set, and MK 53 Mod 0 attack console of the MK 114 antisubmarine rocket (ASROC) fire control system. Navy maintenance experts developed four separate troubleshooting problems for each of the three test vehicles. The 12 problems were representative of those for which some form of off-ship technical assistance historically has been required and included four of the five major equipment component categories listed in the needs assessment survey (no faults were developed for the category of hydraulic/pneumatic components). Table 3 presents the troubleshooting tasks and equipment component malfunctions included in the 12 problems.

Subjects

The subjects in the demonstration studies were 15 enlisted and 7 civilian personnel from Navy activities in San Diego with one half (4 enlisted and 7 civilian) serving as remote technical assistance advisors (or experts); and the other half serving as at-sea maintenance personnel (termed shipboard technicians). Each of the 11 experts had extensive training and experience in maintaining the equipments selected as test vehicles. Five experts were from the Naval Sea Support Center, Pacific; three, from Mobile Technical Unit FIVE; two, from the NAVELEXSYSENGCEN; and one, from the Submarine Training Facility (SUBTRAFAC).

The equipment-maintenance proficiency level of the 11 shipboard technicians varied. Four were surface search radar trainees from the Fleet Combat Training Center, Pacific (all second class electronics technicians (ET2s)); three, WRN-5 SATNAV maintenance trainees from SUBTRAFAC (one ET1, two ET2s); and four, MK 114 fire control system maintenance instructors from the Fleet Anti-Submarine Warfare Training Center, Pacific (all STG1s).

Experimental Design

The needs assessment survey identified the following four telecommunications accessory devices as potentially applicable for delivering remote technical assistance: slow-scan and full-motion television, hard-copy facsimile device, and electronic telewriter. To

Table 3

Summary of Troubleshooting Problems Administered in Demonstration Studies

Test Vehicle		Casualty Inserted	Major Symptom(s)	Required Corrective Action
AN/WRN-5 Navigation System, Satellite	1.	Mechanical. Potentiometers (R-7, R-18) improperly adjusted on tape read board (Card A3A16) in receiver section.	Unit unable to load OPNAV navigational program and/or diagnostic program tape.	Adjust both potentiometers to proper tolerance and monitor output at Test Point 6 with an oscilloscope. Load and run OPNAV navigational program tape.
	2.	Electronic (analog). Shorted contacts on multiplexer board (Card A3A9) in receiver section.	Unit unable to load OPNAV navigational program; front panel video monitor shows scrambled display; SYSTEM ERROR and HALT lamps illuminated.	Isolate fault to module level and replace with spare A3A9 card. Load and run OPNAV navigational program tape.
	3.	Electronic (digital). Faulty chip on memory board (Card A2A18) in computer section.	Unit loads OPNAV navigational program; however, unit does not operate in RUN mode.	Isolate fault to module level and replace with spare A2A18 memory board. Load and run OPNAV navigational program tape.
	4.	Electrical. Broken electrical connectors (i.e., bus bars) on input/output board (Card A2A3) in computer section.	Unit loads and runs OPNAV navigational program; however, HALT and SYSTEM ERROR lamps flash continuously.	Isolate fault to broken bus bars and replace with spare A2A3 card. Monitor front panel indicators with unit placed in RUN mode.
AN/SPS-10 Surface Search Radar Set	1.	Electrical. Jumper removed from crystal gate shutter motor (lead F102) at terminal board E3010 in receiver-transmitter section.	Crystal gate shutter motor stuck in closed position; no long-distance targets; poor ring time; low minimum discernable signal (MDS).	Isolate fault to missing jumper on F102 and replace. Energize radar to determine if unit operates properly.
	2.	Electrical. Plate cap removed on high voltage charging diode (V103) in modulator section.	Unit does not radiate; no magnetron current.	Isolate fault to diode V103 and replace plate cap. Energize radar to determine if unit operates properly.
	3.	Mechanical. Relay armature removed on box interlock (Microswitch S0034) in receiver-transmitter section.	Unit does not radiate; no magnetron current; relay K102 does not energize.	Isolate fault to pulse box interlock and replace microswitch assembly. Energize radar to determine if unit operates properly.
	4.	Electrical. One of two (F102) leads removed at terminal board E207 in power supply section.	No sweep or video display at Plan Position Indicator (PPI); however, good video output when monitored "locally" with an oscilloscope.	Isolate fault to missing lead on F102 and reconnect. Energize radar determine if sweep and video display is present at the PPI.
MK 53 Attack Console; part of MK 114 ASROC Fire Control System	1.	Electrical. Opened shield between terminal board TB-102 pin 3 and transformer T-2 in back of A2 section.	Erroneous readings in bearing and range during Position Keeping (PK) test; bearing dial does not drive at all.	Isolate fault to opened shield on TB-102-3 and resolder broken lead connection. Run PK test to determine if unit operates properly.
	2.	Electrical. Connector for 45-volt power supply plug (P-4) disconnected in A5A4 power supply section.	Horizontal Range to Past Position (RHP) readings in error during ballistic static test; no torque on RHP dial when set in automatic.	Isolate fault to 45-volt DC power supply and reconnect plug P-4. Run ballistic static test to determine if unit operates properly.
	3.	Electrical. Opened shield on return side resister R-12 at transformer T-3 in back of 12A2 section.	Erroneous readings in bearing and range during PK test; bearing drives to a particular point but does not move thereafter.	Isolate fault to opened shield on transformer T-3, pin 3 and resolder broken lead connection. Run PK test to determine if unit operates properly.
	4.	Electronic (digital). Opened diode (CR1) on Scale Change Generation Board at terminal board TB-10 in plotter section.	Target does not automatically recenter as range scale is changed; other plotter functions operate properly using target-to-center push-button.	Isolate fault to CR1 diode and replace with spare. Verify that unit recenters target automatically as range scale is changed.

determine whether these devices provided a significant advantage over voice communications alone, each was used to supplement a two-way audio intercommunications system, either separately or in various combinations. Accordingly, nine alternative telecommunications modes were selected for testing: one single-channel mode, four 2-channel modes, and four 3-channel modes. More detailed information concerning these modes is presented in Table 4.

Table 4

Telecommunications Modes Used in Demonstration Studies

Mode Number	No. of Channels	Equipment Configuration
1	1	Audio intercom only
2	2	Audio plus slow-scan TV
3	2	Audio plus full-motion TV
4[a]	2	Audio plus hard-copy facsimile device
5	2	Audio plus electronic telewriter
6[a]	3	Audio plus slow-scan TV and hard-copy facsimile device
7	3	Audio plus slow-scan TV and telewriter
8[a]	3	Audio plus full-motion TV and hard-copy facsimile device
9	3	Audio plus full-motion TV and telewriter

Note. Mode numbers were assigned for convenience only; they do not reflect an ordinal ranking.

[a]Due to unresolved technical difficulties at the time of testing, the equipment modes involving the hard-copy facsimile device were not available for use in the WRN-5 SATNAV demonstration study.

Multiple sessions were conducted in three separate laboratory facilities. Four separate sessions were conducted for the SPS-10 radar and MK 53 attack console. The WRN-5 SATNAV study was limited to three sessions due to the unanticipated absence of a scheduled expert. For each session, the four separate troubleshooting problems were administered to a team that consisted of an expert and a shipboard technician. The order in which the problems were inserted in each test vehicle was identical in all cases, but the various telecommunications modes (i.e., 1-, 2-, or 3-channel) were presented in a counterbalanced order across problems.

Procedures

Upon arrival at the testing site, each troubleshooting team was briefed on the purpose and scope of the REM concept in general and the principal research objective of the demonstration studies in particular. Next, the subjects were introduced to the safety monitors, who were highly qualified Navy technicians assigned to the activity where the vehicles were located. The safety monitors were responsible for inserting the troubleshooting problems and for ensuring that safety precautions were observed throughout the test. The troubleshooting team was then briefed on the purpose and standard operating procedures for the telecommunications equipment to be used in their particular session.

Following this orientation, the shipboard technician was stationed at the equipment site. Due to time limitations imposed by the testing schedule, the shipboard technician was instructed not to perform any troubleshooting or repair actions on his own prior to establishing the telecommunications link with the expert. Instead, the safety monitor provided the shipboard technician with an explanation of the major symptoms for each equipment casualty before each problem started. The shipboard technician was then instructed to report the symptoms associated with each casualty to the expert technician. In addition, he was also responsible for performing various fault isolation tests and removing and replacing equipment components as directed by the expert.

The expert technician was stationed in an area remote from the actual equipment site. He directed the shipboard technician verbally in troubleshooting and correcting the equipment casualties using, as applicable, the various telecommunications accessory devices provided for the troubleshooting problems. Although the experimental design specified the telecommunications accessory equipments available for any given troubleshooting problem, the actual selection of which equipment to use was left to the discretion of the expert technician. This procedure provided a means for assessing the user acceptance of the various telecommunications modes.

For all sessions, complete sets of equipment maintenance manuals and schematic diagrams were provided to the expert and shipboard technicians. In addition, conversations between members of the troubleshooting team were tape-recorded and the telecommunications equipments used and total time spent in troubleshooting each problem noted. Although no formal time limits were established for completing each troubleshooting problem, the expert and shipboard technicians were only available for a limited time period (4 to 6 hours) for each session. As a result, when troubleshooting had exceeded 1 hour for any given problem, the team was given the option to continue or terminate that problem. This option was given 13 times among the 44 total problems administered; in each case, the teams elected to continue the problem.

Measures

Comparisons among the alternative telecommunications modes focused on two principal measures: effectiveness and efficiency. The effectiveness measure was simply whether or not the troubleshooting team diagnosed and corrected a given equipment casualty by using a particular telecommunications mode. The efficiency measures, on the other hand, were more detailed and included comparisons of the various telecommunications modes in terms of:

1. The total time spent in troubleshooting and repairing each equipment casualty.

2. The amount of time the telecommunications link was actually in use in relation to the time-to-solution for each troubleshooting problem.

3. The number of troubleshooting tests and repair actions that the expert technicians ordered for each troubleshooting problem.

While the first of these efficiency measures is self-explanatory, criteria were established for obtaining measures of efficiency in the other areas. With respect to the second measure, termed communications efficiency, audio recordings between the expert and shipboard technicians were analyzed to determine: (1) the amount of time spent in active conservation, defined as essentially uninterrupted dialog with pauses or other hesitations not exceeding 15 seconds, and (2) time periods characterized by delays that were clearly of a nonconversational, "dead-air" nature--those in excess of 15 seconds during which casualty symptoms were written down, technical manuals were consulted, various troubleshooting tests were performed, and so on.

For the third measure, termed troubleshooting efficiency, audio recordings of the expert technicians' communications were analyzed to determine the number and type of corrective maintenance actions that the experts ordered for troubleshooting and repairing each equipment casualty. The three general categories of corrective maintenance actions used to obtain this measure of efficiency are summarized as follows:

1. Nonintrusive checks. Observation and/or manipulation of externally located hardware on the equipment undergoing repair. Examples include:

a. Monitoring front panel indications (e.g., lamps, dials, meters).

b. Performing standard operating procedures (e.g., control panel adjustments, and calibrations, light-off/power down).

c. Utilizing built-in test (BIT) features (e.g., computer-based diagnostic program tapes or sequences, comparison-to-standard tests).

2. Internal troubleshooting. Testing and/or inspecting of internally located hardware on the equipment undergoing repair. Examples included:

a. Taking various measurements at test points, card pins terminal boards using standard Navy test equipment (e.g., volt-ohm-milliammeter, oscilloscope, digital voltmeter).

b. Visually or physically inspecting modules, components, or component parts for signs of corrosion, improper or missing connections, breakage, etc.

c. Exchanging interchangeable modules, components, or component parts from within the unit itself (i.e., actions that do not require replacement units to be drawn from ship's supply).

3. Removals and replacements. Removing suspected faulty components from the equipment and replacing them with identical spares from ship's supply. Examples of these components include printed circuit boards (PCBs), diodes, amplifiers, microswitch assemblies, and so forth.

Several factors should be noted concerning both the independent and dependent variables that were used to analyze the demonstration study data. The first of these dealt with the telecommunications modes. When the expert elected not to use one or more of the accessory equipments provided for a given troubleshooting problem, the measures of effectiveness and efficiency were based on the telecommunications mode that was actually used for the consultation. Second, because only a limited number of digital and analog casualties were developed for the test vehicles, these two classes of equipment malfunctions were collapsed into a single category of problem type--termed electronic--which reduced the number of levels of this independent variable from four to three.

The final factor concerned the number of audio recordings for which measures of communications and troubleshooting efficiency were obtained. Due to a malfunction in the audio tape recorder, conversations between the expert and shipboard technicians were either partially or completely erased for 9 of the 44 problems administered (3 and 6 problems for the WRN-5 and SPS-10 demonstration studies respectively); hence, comparisons involving these measures were based on 35 observations.

RESULTS

Identification of Candidate Navy Equipments

Representatives from the Navy's shore-based technical assistance community selected 191 (or 68%) of the original 280 equipments as prospective candidates for the application of the REM concept. They also recommended adding to the list 63 equipments that had only recently become operational in the fleet but whose actual or projected maintenance histories indicated a high demand for off-ship technical assistance. The final 254 candidate Navy equipments sample represented 18 of the 28 major shipboard divisions.

Demonstration Studies

Utilization of Telecommunications Modes

Table 5 summarizes the nine telecommunications modes used in the demonstration studies. The experts used mode 1--single channel, voice-only--most frequently. The four 2-channel modes (numbers 2, 3, 5, and 4 in that order) were associated with the next highest levels of usage, while only a limited number of the expert technicians used the 3-channel modes (numbers 6 through 9). Moreover, in 11 cases, the expert technicians deviated from the particular mode specified by the experimental design and used fewer telecommunications channels. Five experts used only the two-way voice telecommunications link despite having access to interactive graphic equipment (i.e., hard-copy facsimile or electronic telewriter). Five used a combination of voice and video channels (i.e., slow-scan or full-motion television), but not the graphic equipment that was also available. One expert used only the voice link even though both video and graphic equipments were available to him.

Table 5

Frequency of Usage for Telecommunications Modes

Test Vehicle	Mode Number 1	2	3	4	5	6	7	8	9
WRN-5 SATNAV	5	1	2	0	2	0	1	0	1
SPS-10 RADAR	6	4	2	1	1	0	0	1	1
MK 53 CONSOLE	6	3	3	2	1	0	0	1	0
Total	17	8	7	3	4	0	1	2	2

Note. Table 4 describes each of the nine modes.

During postsession debriefings, the general consensus among the six experts who used only the two-way voice communications link was that the extra audio devices "would not have helped" in troubleshooting and correcting the particular equipment casualties for which these devices had been provided. Similarly, the five experts who used the voice link supplemented with video indicated that they could see no practical application for the interactive graphic devices in the context of troubleshooting the problems for which this equipment was available.

Effectiveness and Efficiency Measures

A primary concern in the demonstration studies was to determine if, and to what extent, the alternative telecommunications modes differed in terms of their effectiveness in delivering remote technical assistance. Each of the 44 total troubleshooting problems administered was solved by the remotely located expert technicians regardless of the telecommunications mode used for the consultation. Therefore, the accuracy of the experts in diagnosing and repairing the equipment casualties inserted in each test vehicle was independent of the various telecommunications modes used.

With respect to efficiency, dependent variable scores were obtained for each of the three measures (time-to-solution, communications efficiency, and troubleshooting efficiency) and separate, mode-by-problem-type by equipment-type analyses of variance (ANOVA) were conducted. ANOVA results showed that the main effect for telecommunications mode (8 levels) and the type of troubleshooting problem administered (3 levels: mechanical, electrical, electronic) failed to reach statistical significance in relation to the total time-to-solution as well as the troubleshooting efficiency measure (i.e., both for separate subcategories of corrective maintenance actions and overall--summed across subcategories).

Statistically significant main effects were found, however, for telecommunications mode and type of problem administered in relation to the measure of communications efficiency: $F(7,23) = 2.92$, $p<.05$ and $F(2,23) = 3.96$, $p<.05$ respectively. Using Tukey's (1949) post-hoc analysis procedure for comparing group means in the ANOVA, it was found that more time was spent in active conversation for the electrical-type problems than for the mechanical-type problems ($p<.05$). Even though a statistically significant main effect was found for telecommunications mode in terms of the communications efficiency measure, results of the Tukey procedure showed no significant differences among the mean values for the various modes based on this category of dependent variable.

ANOVA results also showed a significant main effect for the Navy equipments used in the demonstration studies for all three efficiency measures: time-to-solution ($F(2,32) = 8.47$, $p<.001$); communications efficiency ($F(2,23) = 4.47$, $p<.05$); and the composite troubleshooting efficiency score ($F(2,23) = 4.39$, $p<.05$). Tukey (1949) post-hoc analyses for these data showed that, on the average:

1. MK 53 attack console problems took significantly longer to solve than did WRN-5 SATNAV or SPS-10 radar problems ($p<.05$ and $p<.01$ respectively).

2. More time was spent in active conversation for the MK 53 problems than for the SPS-10 problems ($p<.01$).

3. The expert technicians ordered more overall troubleshooting tests and repair actions for the WRN-5 problems than for the SPS-10 ($p<.01$).

Interaction effects could not be estimated in the ANOVAs calculated for each category of efficiency measure due to the number of empty cells that were present among the independent variables of interest.

Table 6 presents a summary of the means and standard deviations for 1-, 2-, and 3-channel telecommunications modes relative to the three efficiency measures. Although ANOVA results indicated that the telecommunications modes did not account for any substantive portion of the variance (at least in statistical sense) among these measures of efficiency, on a more practical level, Table 6 shows genuine differences for the various modes. For example, the mean values for each of the three dependent variable measures rise consistently as the number of telecommunications channels increases. These findings suggest that, insofar as efficiency measures are concerned, the 2- and 3-channel modes may have actually impeded, rather than facilitated, delivery of remote technical assistance. Moreover, because a range of alternative telecommunications modes was used for any given troubleshooting problem (i.e., from two to four), the differences found among the various modes in relation to the efficiency measures are probably not attributable to the difficulty level of the problems themselves.

Table 6

Means and Standard Deviations for 1-,2-, and 3-channel Modes for Three Efficiency Measures

Telecommunications Mode	Time-to-solution (minutes)			Conversation Time[a] (minutes)			Number of Troubleshooting & Repair Actions[a]		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
1-channel (voice only)	17	41.3	24.5	13	10.5	6.4	13	14.3	7.4
2-channel (voice + video)	15	49.0	30.6	12	15.7	10.1	12	20.9	10.8
2-channel (voice + graphic)	7	57.8	27.4	6	16.0	11.0	6	20.7	7.0
3-channel (voice + video + graphic)	5	57.7	26.7	4	18.3	18.9	4	21.3	8.7
Overall	44	48.4	27.3	35	14.1	10.3	35	18.4	9.0

Note. Due to the small sample sizes obtained for certain telecommunications modes, data were collapsed across generically equivalent conditions for the 2-channel modes and across all 3-channel modes.

[a]Because the audio tape recorder malfunctioned, comparisons are based on 35 observations.

Finally, on an overall basis, the average time-to-solution for the 44 troubleshooting problems was slightly more than 48 minutes (Table 6). Actual conversation time, in contrast, accounted for only a limited amount of the total time spent in troubleshooting. It averaged 14 minutes across the 35 problems for which these data were available. In addition, the remotely located expert technicians ordered an average of 18 (combined) troubleshooting tests and repair actions to effect the casualty diagnosis and repair (based on the 35 troubleshooting problems for which these data were obtained).

Qualitative Findings

A general pattern was established in each of the demonstration sessions with respect to the types of interactions that occurred between the expert and shipboard technicians. First, the shipboard technician provided a verbal description of the symptoms associated with each equipment casualty in various operational modes. When the expert had confirmed these symptoms (either verbally, visually, or in some cases, graphically), the interaction changed. The expert began directing the shipboard technician's behavior by either asking him specific questions or giving him explicit instructions concerning the troubleshooting procedure to be performed.

With respect to the utilization of video information, the expert technicians were only interested in viewing limited portions of the equipment undergoing repair (e.g., CRT displays, front panel indications, suspected faulty components) as well as supporting test equipment (e.g., waveforms on oscilloscopes, meter readings from digital voltmeters, volt-ohm-milliammeters, etc.). This video information was most often used by the expert to confirm the casualty symptoms and was not usually requested for other aspects of troubleshooting at the equipment site (e.g., removing and replacing components, verifying that measurements were being taken from correct test points, and the like). The expert technicians used the interactive graphic equipments even less and then mostly to transmit hand-drawn schematics and not portions of maintenance manuals and schematics as had been anticipated.

DISCUSSION

The present effort demonstrated the feasibility and practicality of the REM concept for several Navy equipments, troubleshooting problems, and telecommunications modes. As such, the results from this effort should be generalizable to a much broader range of Navy equipments and corrective maintenance actions than were examined in earlier feasibility studies (e.g., American Management Systems, 1982; Nugent, 1982) and in on-going operational tests of the REM concept (i.e., RTA program (see footnote 2)).

Perhaps the most striking finding of the present research effort was that the empirical evidence failed to disclose any significant advantage for the ability of telecommunications accessory devices to facilitate the delivery of remote technical assistance. Diagnostic accuracy, time-to-solution, and the number and type of corrective maintenance actions ordered by the remotely located expert technicians were all found to be clearly independent of the telecommunications mode used for the consultations. These findings are of considerable significance in view of the large cost disparities and potential fleet implementation problems that the alternative telecommunications modes tested could present. Time spent in active conversation was the only dependent variable measure found to be mode dependent; nevertheless, post-hoc data comparisons showed no statistically reliable differences among the group mean values in relation to this measure.

In addition to confirming the results of earlier research on the REM concept (Nugent, 1982), strong support for the present findings has been obtained in other studies that have compared the effectiveness and efficiency of alternative telecommunications modes in entirely different contexts. For example, a series of studies in the field of telemedicine (Conrath, Buckingham, Dunn, & Swanson, 1975; Conrath, Dunn, Swanson, & Buckingham, 1975; Conrath, Dunn, Bloor, & Tranquada, 1977), compared the use of alternative telecommunications systems for delivering primary health care to medically underserved, remote populations in northern Canada.

In one of these studies (Conrath et al., 1977), more than 1,000 patients who came to a clinic seeking medical attention were examined remotely by physicians using one of four interactive telecommunications systems: a hands-free telephone link only; a telephone with full-motion color television; a telephone with full-motion black and white television; and a telephone with still frame (i.e., slow-scan) black and white television. Each patient was also examined independently in the physical presence of doctor at the clinic. The diagnoses and patient management/treatment programs of the in-person clinic physicians were compared to those provided by physicians who used the four alternative telecommunications systems. Results of this study showed no significant differences among the four modes tested in relation to (1) overall diagnostic accuracy, (2) proportion of supporting investigations requested by the remotely located physicians (e.g., laboratory tests, X-rays, etc.), (3) time taken to complete the diagnostic consultations, and (4) effectiveness of the patient management/treatment programs. Furthermore, the remotely located physician's behavior across the four telecommunications modes was significantly similar in several instances. The cross-check reliability of diagnosis between the remote and in-person physicians (i.e., 61%) was actually higher than the same reliability figures calculated between two attending (in-person) physicians.

Another series of studies compared human performance over alternative communications modes (Chapanis, 1973; Chapanis, Ochsman, Parrish, & Weeks, 1972; Ochsman & Chapanis, 1974). Ochsman and Chapanis (1974) presented 60 teams of two college students each with credible "real-world" problems (e.g., a class scheduling problem, a fault finding problem involving an automobile ignition system, a part identification problem) whose structure required the cooperative efforts of both team members to solve them. In all cases, the members of each team were physically separated and were asked to carry out their interactions using one of ten communications modes. These ranged from an "impoverished" mode in which the subjects could only communicate by typewriting to a "rich" mode that approached natural, fact-to-face communications (i.e., voice supplemented with video and hard-copy devices as well visual contact through a sound-insulated glass panel). All problems were solved using the various communications modes; however, the hard-copy modes (i.e., typewriting or hand writing only) did not even approach the speed or efficiency with which the problems were solved by using voice communications alone or, alternatively, voice supplemented with hard copy and/or video devices. Further, no evidence was found in this study that the addition of a video channel had any significant effects on communications times or on communications behavior. Finally and, perhaps, most importantly, results showed virtually no differences between the rich communications mode and other modes having a voice channel. Based on these findings, Ochsman and Chapanis (1974) concluded that:

> It is abundantly clear that for the kinds of problems we used, face-to-face communications is not demonstrably better than a simple voice channel. This confirms what decades of practical experience seem to have shown: the telephone is an extremely effective communication device. . . . The single most important decision in the design of a

> telecommunications link should center on the inclusion of a voice channel. In the solution of factual, real-world problems, little else seems to make a demonstrable difference. (p. 618)

Beyond these confirmatory findings, the data presented in Table 6 indicate that the 2- and 3-channel telecommunications modes were, for all practical purposes, less efficient in delivering remote technical assistance than was the single channel, voice-only, telecommunications mode. An explanation for these findings in terms of one efficiency measure, time-to-solution, is simple enough: It is far easier to speak and do other things simultaneously (e.g., consult schematic diagrams, technical manuals, etc.) than it is to to write, to draw, or to observe video presentations and engage in such activities. It is entirely possible, therefore, that the experts in the voice-only condition used their troubleshooting time more efficiently than did the experts who used the 2- and 3-channel modes because they had to concentrate on other forms of information exchange concurrently with the troubleshooting task.

The findings obtained for the communications and troubleshooting efficiency measures are somewhat harder to explain. In regard to the communications measure, it may be that, with the addition of video and/or graphic devices, the expert and shipboard technicians simply spent more time in active conversation discussing the information that was being presented by these devices. Thus, in these cases, the old adage "a picture is worth a thousand words" was true in a more literal than figurative sense!

For similar reasons, the increased overall number of corrective maintenance actions ordered by the experts who used the multichannel modes might be explained by the fact that the experts had more sources of information with which to confirm (or rule out) casualty symptoms and/or steps of the troubleshooting procedure. This may have been especially true in those cases where the experts used video equipment (e.g., "Show me what you get when you press the {program} load button . . . . Okay, now hit the run button and let's see what happens.") This explanation should be interpreted cautiously, however, because a significant main effect was found for the types of Navy equipments that served as test vehicles in these demonstration studies for the troubleshooting efficiency measure.

Finally, the relatively large amount of time not spent in conversation for the troubleshooting problems as a whole suggests that some sort of time-sharing arrangement should be considered in further exploration of the REM concept. Such an arrangement could, for example, enable shore-based technicians to provide simultaneous services to a number of deployed units using a single telecommunications channel. Should such an arrangement prove feasible, further research is needed to determine the load that an expert technician could tolerate; that is, the number of separate equipment casualties that an expert could handle simultaneously. Alternatively, significant portions of nonconversation time over the telecommunications link could be used to deliver incidental on-the-job training to shipboard technicians during remote technical assistance event.

CONCLUSIONS

1. To the extent that the demonstration studies simulated the conditions under which remote technical assistance would be provided, the feasibility and practicality of the REM concept was demonstrated for diverse Navy equipments and corresponding troubleshooting problems.

2. Diagnostic and repair accuracy, time-to-solution, and the number and types of troubleshooting tests and repair actions the expert technicians ordered were found to be clearly independent of the telecommunications mode used for the remote technical assistance consultation. Therefore, the least equipment-intensive interactive telecommunications systems (e.g., voice-grade telephone, radio, or satellite links) are effective and efficient substitutes for in-person contact between expert technicians ashore and maintenance technicians in deployed units of the surface fleet.

3. The large amount of time not spent in conversation for the troubleshooting problems suggests that the telecommunications link need not be available continuously during the course of a remote telecommunications maintenance assistance event.

RECOMMENDATIONS

1. The design and implementation of a formal REM capability for the surface fleet should focus on a secure, voice telecommunications link.

2. The feasibility and practicality of a time-sharing arrangement over an operational REM network should be investigated. Such an arrangement could enable shore-based technicians to provide either assistance to several deployed units over a single telecommunications channel or incidental on-job-training to the unit that requested shore-based assistance.

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APPENDIX A

REMOTE FLEET TECH ASSIST--RECENT EXAMPLES

(After NAVELEX Life Cycle Fleet Support briefing materials, Naval Electronics Systems Command, Washington, DC)

REMOTE FLEET TECH ASSIST
RECENT EXAMPLES

NAVELEX LIFE CYCLE FLEET SUPPORT

SHIP	LOCATION	PROBLEM	CORRECTION TIME
USS O'BRIEN	INDIAN OCEAN	HARD DOWN SECURE VOICE (BAD COMSEC GROUP CABLE)	24 HRS
USS FT SNELLING	CARIBBEAN	HARD DOWN SECURE VOICE (KY-75) (WSC-3 INTERFACE PROBLEM)	4 HRS
USS PUGET SOUND	MEDITERRANEAN	HARD DOWN PSSPC (ALL FLEET COMMS INCL SEC VOICE) (BAD MODEM IN NAPLES)	1 DAY
USS CORONADO	ARABIAN SEA	SECURE VOICE HARD DOWN (CABLE PULLED LOOSE) (PICKED UP ON CASREP)	2 HRS
ROTA, SPAIN	SPAIN	PARKHILL CIRCUIT INOP (DEFECTIVE LAND LINE)	1 DAY

REMOTE FLEET TECH ASSIST RECENT EXAMPLES (CONTINUED)

SHIP	LOCATION	PROBLEM	CORRECTION TIME
NCSO BAHREIN	BAHREIN	ALL AUTOVON COMMS DOWN (INTERFACE PROBLEM WITH NEW SWITCHBOARD)	1 DAY
NISO EASTCOTE	ENGLAND	INOP AUTOSEVOCOM STATION (LOCATED PROBLEM CONNECTION STATION GROUND TO LINE INTERFACE UNIT)	9 HRS
USS SIMON LAKE	KINGS BAY GEORGIA	INOP AUTOSEVOCOM DOWN HARD (DEFECTIVE PINS ON CARD IN KG-13 KEY GEN)	6 HRS
USS NITRO	MAYPORT	KY-75 PARKHILL INOP (SHORT IN WIRING)	1 DAY

APPENDIX B

NEEDS ASSESSMENT SURVEY FORMS FOR RADAR AND IFF SYSTEMS/EQUIPMENTS

EXAMPLE OF NEEDS ASSESSMENT SURVEY FORM FOR RADAR AND IFF SYSTEMS/EQUIPMENTS

REMOTE EXPERTISE FOR MAINTENANCE: NEEDS ASSESSMENT SURVEY

CANDIDATE OPERATIONAL SYSTEMS/EQUIPMENTS			TELECOMMUNICATIONS EQUIPMENT OPTIONS						
			VISUAL		GRAPHIC			COMPUTER	
NOMENCLATURE/DESCRIPTION	MAJOR COMPONENT GROUPINGS	PERCENT OF EQUIPMENT CASUALTIES	SLOW SCAN VIDEO	FULL MOTION VIDEO	HARD COPY FACSIMILE	ELECTRONIC TELE-WRITER	3-D DISPLAY	AUTO. T/S ROUTINES	REMOTE SENSING UNIT
RADAR, SURFACE SEARCH • LN-66 Radar Set	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
• AN/SPS-10 (Series) Radar Set includes SPS-10A thru SPS-10F	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
• AN/SPS-53L Radar Set	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
• AN/SPS-55 Radar Set	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
• AN/SPS-67 Radar Set	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
RADAR, AIR SEARCH • AN/SPS-40 (Series) Radar Set includes SPS-40B,C,D	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								

SCALE: 1 = NOT APPLICABLE 2 = HELPFUL 3 = ESSENTIAL

REMOTE EXPERTISE FOR MAINTENANCE: NEEDS ASSESSMENT SURVEY

CANDIDATE OPERATIONAL SYSTEMS/EQUIPMENTS

TELECOMMUNICATIONS EQUIPMENT OPTIONS

NOMENCLATURE/DESCRIPTION	MAJOR COMPONENT GROUPINGS	PERCENT OF EQUIPMENT CASUALTIES	VISUAL: SLOW SCAN VIDEO	VISUAL: FULL MOTION VIDEO	GRAPHIC: HARD COPY FACSIMILE	GRAPHIC: ELECTRONIC TELE-WRITER	GRAPHIC: 3-D DISPLAY	COMPUTER: AUTO. T/S ROUTINES	COMPUTER: REMOTE SENSING UNIT
RADAR, AIR SEARCH (cont'd) • AN/SPS-49 (Series) Radar Set includes SPS-49(V),(V)1, (V)4	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
RADAR, HEIGHT FINDER • AN/SPS-48 (Series) Radar Set includes SPS-48A(V) and SPS-48C(V)	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
• AN/SPS-39A Radar Set	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
• AN/SPS-52 (Series) Radar Set	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
DISPLAYS, RADAR • AN/SPA-4 (Series) Indicator, Range-Azimuth -- includes SPA-4, SPA-4A thru SPA-4F	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
• AN/SPA-25 (Series) Indicator Group -- includes SPA-25B, SPA-25D, SPA-25F	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								

SCALE: 1 = NOT APPLICABLE 2 = HELPFUL 3 = ESSENTIAL

REMOTE EXPERTISE FOR MAINTENANCE: NEEDS ASSESSMENT SURVEY

CANDIDATE OPERATIONAL SYSTEMS/EQUIPMENTS			TELECOMMUNICATIONS EQUIPMENT OPTIONS						
			VISUAL		GRAPHIC			COMPUTER	
NOMENCLATURE/DESCRIPTION	MAJOR COMPONENT GROUPINGS	PERCENT OF EQUIPMENT CASUALTIES	SLOW SCAN VIDEO	FULL MOTION VIDEO	HARD COPY FACSIMILE	ELECTRONIC TELE-WRITER	3-D DISPLAY	AUTO. T/S ROUTINES	REMOTE SENSING UNIT
RADAR, DISPLAYS (cont'd) • AN/SPA-50 (Series) Radar Repeater-- includes SPA-50B, SPA-50C	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
• AN/SPA-66 (Series) Indicator Group-- includes SPA-66, SPA-66A,B	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
• Radar Switchboard/Display System Interface (e.g, SB-1505 interconnect)	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
IFF EQUIPMENT • MK 12 Interrogator System-- includes AN/UPX-27 Interrogator Set	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
• AN/APX-72 Transponder System	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
• MK 12 AIMS System, IFF -- "Full" System	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								

SCALE: 1 = NOT APPLICABLE 2 = HELPFUL 3 = ESSENTIAL

REMOTE EXPERTISE FOR MAINTENANCE: NEEDS ASSESSMENT SURVEY

CANDIDATE OPERATIONAL SYSTEMS/EQUIPMENTS

TELECOMMUNICATIONS EQUIPMENT OPTIONS

			VISUAL		GRAPHIC			COMPUTER	
NOMENCLATURE/DESCRIPTION	MAJOR COMPONENT GROUPINGS	PERCENT OF EQUIPMENT CASUALTIES	SLOW SCAN VIDEO	FULL MOTION VIDEO	HARD COPY FACSIMILE	ELECTRONIC TELE-WRITER	3-D DISPLAY	AUTO. T/S ROUTINES	REMOTE SENSING UNIT
DISPLAYS, NTDS • AN/SYA-4 %V ☐ , Display Group Radar	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
CCA/GCA EQUIPMENT • AN/SPN-6 Radar, Carrier Control Approach	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
• AN/SPN-35A, Aircraft Control Approach, Central	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
• AN/SPN-42A, Landing Control, Central	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
• AN/SPN-44 Radar Set	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								
	MECHANICAL								
	ELECTRICAL								
	ELECTRONIC--DIGITAL								
	ELECTRONIC--ANALOG								
	HYDRAULIC/PNEUMATIC								

SCALE: 1 = NOT APPLICABLE 2 = HELPFUL 3 = ESSENTIAL

APPENDIX C

STANDARDIZED INSTRUCTIONS FOR COMPLETING NEEDS ASSESSMENT SURVEY FORMS

REMOTE EXPERTISE FOR MAINTENANCE: NEEDS ASSESSMENT SURVEY

INTRODUCTION

Operational readiness of deployed Navy surface ships may be seriously degraded by extended delays in obtaining needed off-ship technical assistance to diagnose and correct casualties to mission-essential equipment.

One possible solution to this problem is to provide shore-based technical assistance to the ship by means of satellite telecommunications rather than the personal presence of the off-ship technician.

To determine if this may be a feasible solution to the problem, it is necessary to determine what kinds of troubleshooting facilities shore-based technicians would need to effect casualty diagnosis and repair actions by means of satellite telecommunications.

Candidate Navy systems and equipments with large amounts of downtime have been identified by screening CASREPs and other maintenance records. Analyses have also resulted in the identification of five general categories of system/equipment components in which casualties can occur.

There are two tasks to accomplish for purposes of this survey. The first is to determine, on the basis of your experience, the percentage of each system or equipment's casualities accounted for by malfunctions in each of five major categories of components. The second task is to identify how useful to you, as a shore-based technician, each of seven telecommunications capability options would be for diagnosing and correcting shipboard casualties in each of the five component-level categories.

The following pages describe the way in which this survey is structured, in addition to detailed instructions for completing it. Therefore, before making entries on the survey form it is important that you read through these introductory pages to get a frame of reference for completing the Needs Assessment Survey.

SURVEY FORM DESCRIPTION

The Survey Form consists of two major sections, labeled Candidate Operational Systems/Equipments and Telecommunication Equipment Options. Brief descriptions of the column headings contained in each of these sections are presented below.

CANDIDATE OPERATIONAL SYSTEMS/EQUIPMENTS

Nomenclature/Description

Identifications are given for systems and equipments whose histories suggest their downtimes might be significantly reduced by use of the proposed satellite telecommunication system. Some systems encompassing several MKs or Mods have been grouped together as a "series". The total list of systems and equipments of interest have been grouped so that your forms should contain only, or primarily, those Navy systems and equipments with which you are most likely to be familiar.

Major Component Groupings

A system is made up of a variety of "parts" which can be categorized in a variety of ways. The five categories of major component groupings used for this survey are defined below. While fairly crude, these categories have been found to be satisfactorily meaningful to technical experts. Although a specific system/equipment component may not neatly fall into one of these categories (for example, it might "really" be electro-mechanical), it should be thought of as belonging to the one most appropriate category.

Description of System/Equipment Component Grouping Terminology

(1) *Mechanical* -- Those equipments and devices which transmit mechanical forces or change the direction of forces.
Examples include:

- Engines
- Turbines
- Levers/Winches/Pulleys
- Gears/Gear Trains/Synchros
- Shafting/Couplings/Linkages/Connecting Rods

(2) *Electrical* -- Those equipments and devices which generate, transmit, transform, or distribute electrical energy
Examples include:

- Generators
- Motors
- Transformers/Regulators/Inverters
- Busses/Relays
- Switches/Switchboards
- Rotating Machinery

(3) *Electronic* -- Those equipments and devices which provide control functions, feedback loops, or servo mechanisms. Two basic distinctions include:

- Digital -- Devices that operate by means of discrete, binary, or stepping functions (e.g., diodes, chips)
- Analog -- Devices that operate by means of continuous electron flow (e.g., vacuum tubes, hard-wired circuits)

(4) *Hydraulic/Pneumatic* -- Those equipments and devices which have fluid or air-powered sources.
Examples include:

- Pumps/Compressors
- Catapults/Launchers/Rams
- Cooling Systems
- Valves/Piping/Lines
- Fire Mains/Sprinklers/Washdown Systems

Percent of Equipment Casualties

This column is where we begin to tap your expertness and experience. We'll get back to it under the heading of specific Instructions.

TELECOMMUNICATION EQUIPMENT OPTIONS

The remaining seven columns identify specific types of capabilities, ***in addition to a voice link***, that might be useful for remote, shore-based assistance in shipboard casualty diagnosis by means of satellite telecommunications. These have been grouped, for convenience, under the headings of Visual, Graphic, and Computer. Brief descriptions of these options are presented below. Note that although some of the equipment options are not yet fully developed, at least prototypes are available and appear to be operationally feasible. (For example, electronic signals from these devices are capable of being encrypted and deciphered using existing Navy crypto gear).

Slow Scan Video

This is a portable, high resolution video system which would be set up at the equipment casualty or troubleshooting site(s) aboard ship and its picture(s) monitored ashore. Rather than a conventional continuous scan, however, it would provide a series of still "snapshots" somewhat akin to an automatic slide projector presentation, with delays of about 10 to 30 seconds between "shots".

Full Motion Video

Like slow scan video, this is a portable video system which would be set up at the shipboard casualty or troubleshooting site(s) and monitored ashore. For stationary objects/static displays, its resolution is equal to that of slow scan; moreover, it offers the advantage of relaying images of dynamic motion in real time.

> Note: For both slow scan and full motion video, requests for specific visual information would be controlled by shore-based technicians through verbal instructions passed to shipboard personnel over the voice link. In addition, the possibility exists for shore-based technicians to receive multiple, split-sceen images for those systems/equipments whose components are physically separated. In these cases, two or more television cameras could be set up in the shipboard spaces where physically separate, but functionally interrelated, system/equipment components are located. Still another possibility would be an interactive video capability such that the technician ashore could control a cursor (which would appear on the shipboard televsion monitor) to highlight, point out, or otherwise identify a particular component or area on the system/equipment undergoing repair.

Hard Copy Facsimile

This is a familiar equipment for the transmission of hard copy materials (e.g., text, graphics, etc.) by electronic means. It would be a two-way system which could be used, for example, to transmit a copy of schematics being used aboard ship to be corrected or updated ashore and sent back.

Electronic Telewriter

This is a new, two-way communication equipment consisting of an ordinary video display and a telewriter pad. The telewriter pad permits the shipboard technician to sketch a part, circuit path, etc., which is displayed on both a shipboard and shore-based screen. By use of his telewriter pad, the shore-based technician can correct, emphasize, delete, or otherwise alter the common display. Use of two colors permits the contributions of the two users to be differentiated. The interactive capability makes this equipment somewhat like a dynamic, on-line version of a static, hard copy facsimile device.

3-D Display

This is an equipment which provides CRT-generated images which present a virtual image of a solid object that can be rotated, manipulated, etc., as if it were a real object. With compatible installations both aboard ship and ashore, the technicians could manipulate a "model" to display a problem encountered and/or the correction required.

Automated Troubleshooting Routines

This is a stand-alone computer-based system located at the shore facility which would integrate the past maintenance history of particular systems or equipments to arrive at the probable cause(s) of "unique" casualties, in addition to providing diagnostic actions to successively eliminate the alternatives.

Remote Sensing Unit

This consists of a capability for a shore-based computer system either to (1) interrogate sensors embedded in or temporarily attached to shipboard equipment as an aid to fault isolation, or (2) process data collected from shipboard equipments which have automated, "self-test"/diagnostic routines by having these data telemetered directly to shore-based facilities for analysis; in effect, circumventing the current practice of delivering these data by surface or air mail.

INSTRUCTIONS

Provide requested information only for those systems or equipments with which you are personally experienced and familiar. It is unlikely that any one person will be thoroughly experienced with *all* the equipments listed. Therefore, draw a diagonal line through the left hand block identifying any system or equipment with which you are not personally familiar, then proceed to the next equipment listed.

Percent Equipment Casualties

For the systems/equipments identified in the leftmost column, indicate your estimate of the percentage of all its casualties which are attributable to failures in each of the five categories of components. Your estimates need only be "ballpark" accurate, however ***the total for each system/equipment should always equal one hundred percent.***

Telecommunication Equipment Options

Consider each of the telecommunication equipment options in relation to the types of casualties occurring in each of the major component categories for which you have provided percentage estimates. How useful would that option be to you, as a shore-based technician, in providing remote technical advisory assistance to shipboard personnel for diagnosing and correcting casualties in that type of component? If the option would be ***not applicable*** , place a "1" in the block. If the option would be ***helpful*** to you, place a "2" in the block. If you would find the option *essential* to you, place a "3" in the block. When you are done, there should be a 1, 2, or 3 in each of the Telecommunications Equipment Option blocks for each component category you have indicated to account for some percentage of casualties to the identifed system or equipment.

Remember, all options are to be considered to be *in addition to voice link communications*. Cost-benefit analyses will be conducted separately. Therefore, do not be concerned with the cost of installing the options but only how useful they would be to you for that type of casualty on the specified system or equipment. If an option would be merely "nice-to-have" for a given component category, do *not* give it a 2 or 3 rating.

If there are any additional systems/equipments which you feel should be included in the list, write in the description of those equipments and complete the requested information for each on the blank forms provided at the end of the survey.

The final section of this survey contains some questions for you to answer. These questions deal with (1) additional telecommunication equipment which you might suggest, (2) any problems that you can see that might rule-out the feasibility of remote technical assistance via a ship-to-shore telecommunication network, and (3) your background and experience in providing shore-based technical assistance.

1. If there are any additional telecommunication equipments or capabilities, other than the seven listed in the survey, which might be useful for you to perform a remote technical assist, please identify or describe it and also indicate the system/equipments and the component category for which it would be useful.

2. If, in your opinion, there are any technical, operational, or facility problems (other than supply support) that would *rule-out the overall feasibility* of the remote technical assistance network, briefly describe what they are and identify the system/equipments to which they apply.

3. If, in your opinion, there are any technical or other problems (other than supply support) that would rule-out the feasibility of the remote technical assist network for a *particular troubleshooting or repair action*, please descibe.

4. If, in your opinion, there are any *conditions* aboard ship (e.g., noise, vibration, low light levels, space limitations) that would *limit or rule-out the use of any of the telecommunication equipments options described*, please identify what they are and the option(s) to which they apply.

5. Background Information

Your name will not be used and your survey responses will not be singled out for anyone outside the Remote Expertise For Maintenance Project staff. This information will be used by project staff to make any necessary follow-up contacts with you to clarify survey responses and to identify the qualifications of shore-based technicians who provided judgments.

Name: ______________________________

Rating/Civilian Occupational Title: ______________________________

Paygrade (Military Only): ______________________________

Navy Command: ______________________________

Department Code and Name: ______________________________

Bldg: ________________ Room: ____________ Phone: __________

SYSTEM/EQUIPMENT MAINTENANCE EXPERIENCE

In the spaces below, we would like you to provide the following:

1). Navy systems/equipments for which you currently provide technical assistance services,

2). Navy Enlisted Classification (NEC)/ Navy Officer Billet Code (NOBC) which you hold for any of the systems/equipments you have listed,

3). approximate number of years of maintenance experience which you have accumulated on the systems/ equipments which you have listed, and

4). number of technical assistance visits (outside CONUS) that you have *ever* provided for the systems/equipments which you have listed.

System/Equipment Description	NEC/NOBC Skill Code(s)	Yrs. Maint. Experience	Number Tech. Assists (Outside CONUS)

Thank you for completing this survey. Your expert assistance in providing this essential information is appreciated.

APPENDIX D

DESCRIPTIONS OF TELECOMMUNICATIONS ACCESSORY DEVICES USED IN DEMONSTRATION STUDIES

DESCRIPTIONS OF TELECOMMUNICATIONS ACCESSORY DEVICES USED IN DEMONSTRATION STUDIES

In accordance with the needs assessment survey results, the four extra-audio telecommunications devices that shore-based expert repair technicians considered most applicable for integration with a two-way voice communications link were selected for testing in the demonstration studies. Detailed descriptions of each of these equipments follows:

Slow-scan Television

1. Description and capabilities. This device is a portable, high-resolution video system that allows transmisison of a video signal over voice-grade telephone lines or satellite channels. To transmit the complex television signal, a single video image must be photographed, stored, broken down into discrete elements, transmitted, then reassembled bit-by-bit at a rate compatible with the transmission media. Thus, rather than a conventional, continuous scan, this device provides a series of still "snapshot" images. Delays from 30 to 90 seconds are typical between successive "shots"--depending on the quality of the transmission line and the complexity of the signal (color is more complex than monochrome). As part of the technological feasibility study for the shipboard engineering assistance for system test and repair via satellite (SEASTARS) project (American Management Systems, 1980), signals from this device were encoded successfully using existing Navy cryptographic equipment.[1]

2. Apparatus and procedures. Due to the nonavailability of dedicated telephone lines between the equipment site and expert technician's station in the laboratory facilities where the demonstration studies were conducted, it was not possible to use conventional slow-scan television equipment. Instead, an alternative system was devised to simulate slow-scan video presentations. This system consisted of two color television monitors[2] (Sony model PVM 8000), a closed-circuit television camera and video interface unit (Sony models DXC and EIAJ-8 respectively), and a standard video cassette recorder (VCR) (Sony model V02860 A, U-matic).

The following procedure was used to produce simulated slow-scan television images for the expert technicians who requested them. First, the transmission cable to the expert's television monitor was disconnected and a full-motion television image was recorded on the VCR for the requested shot. Next, the cassette tape was rewound and a "frozen-frame" image was obtained by depressing the PAUSE button on the VCR. (The shipboard technician's television monitor served as the point of reference for evaluating the clarity of the simulated slow-scan images.) When a clear picture was obtained, the transmission cable from the VCR to the remote station was reconnected and the recorded image appeared instantaneously on the expert's television monitor. The entire process, which generally took 1 or 2 minutes to complete, was repeated for additional shots as requested by the expert technicians.

---

[1]In addition to encoding slow-scan television signals, the SEASTARS project team also demonstrated the feasibility of encrypting signals from hard-copy facsimile and electronic telewriter devices, which were also used in the present research effort.

[2]Identification of the equipment is for documentation only and does not imply endorsement.

Full-motion Television

1. Description and capabilities. Like slow-scan video, this is a portable (i.e., "mini-cam") video system that could be set up at the equipment casualty or troubleshooting site and its pictures monitored ashore. For stationary objects or static displays, its resolution is somewhat poorer than slow-scan; however, it offers the distinct advantage of relaying images of dynamic motion in real time. Because the transmission frequency bands required for full-motion television signals are an order of magnitude greater than those required for slow-scan (i.e., 5.2 to 6 megahertz vs. 2.5 to 3 kilohertz), its signals cannot be readily encoded by existing Navy cryptographic equipment. Nevertheless, prototype bandwidth compression devices are being developed at the present time that, when perfected, should enable encoding of broad-band (full-motion) television signals.

2. Apparatus and procedures. The same closed-circuit television system that was used to produce simulated slow-scan images (less the VCR) was used to relay full-motion pictures to the expert technicians who requested them. Because the procedures for delivering this form of video support were considerably less involved that were those for slow-scan, the experts frequently requested the camera operator to provide a series of views (e.g., sweeps, panoramic shoots, "zooms," etc.) of the equipment undergoing repair and/or supporting test equipment during any given viewing period.

Hard-copy Facsimile Device

1. Description and capabilities. A hard-copy facsimile device electronically sends an original document to a remote location where it is reproduced as a "facsimile" of the original. Facsimile devices are generally used to transmit text or graphic data to distant sites by means of ordinary telephone lines, private transmission lines, or satellite relay systems.

2. Apparatus and procedures. Two facsimile units (Rapicom model 3300/RDI) were provided for use by the troubleshooting teams in the SPS-10 radar and MK 53 attack console demonstration studies. This device was not used in the WRN-5 satellite navigation (SATNAV) study because a "stand-alone" interface capability for interconnecting these units (i.e., independent of conventional telephone lines) was not available at the time that study was conducted. This problem was circumvented by obtaining a modem/channel simulator (International Data Sciences model 9150) with necessary cabling, which enabled the units to be connected in tandem and operated at varying speeds (e.g., 1200, 2400, or 4800 baud rates). To transmit text and/or graphic information, the expert or shipboard technicians simply placed an original document in the machine, pressed the SEND button, and instructed the receiving party (via the intercom) to press the RECEIVE button on his facsimile unit. This process generally took from 30 seconds to 1 minute to complete.

Electronic Telewriter

1. Description and capabilities. A telewriter is an interactive graphics device that consists of an ordinary video display monitor and a telewriter pad. A graphics processor (microcomputer) links the video display to the telewriter pad on which users can write or sketch. The transmission of telewriter drawings or writings from one terminal to another makes this device somewhat like dynamic (on-line) version of a static hard-copy facsimile device. That is, two separate inputs--the one created at a distance and the one created locally--can be superimposed on both users' video monitors. Additional features include

(1) an assortment of drawing colors (i.e., red-green, white-gray) that enables remotely located users to differentiate between their respective inputs, and (2) a video overlay option that enables users to write or superimpose graphic comments on slow-scan or full-motion images projected on the video display monitor. (The latter option has been used for nationally-televised broadcasts of college and professional football games.)

2. Apparatus and procedures. Two electronic telewriter units (French Telecommunications Services model Telewriter II Eelectronic Graphics Tablet System) were used in the demonstration studies. The units were connected in tandem by a 150-foot coaxial cable. For each session in which this equipment was available to the troubleshooting teams, the experimenter demonstrated its standard operating procedures before and, in some cases, during the troubleshooting problems for which it was used.

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