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A RAND NOTE

Assessment of Communications Operator Proficiency: Design Issues

John D. Winkler, Judith C. Fernandez,
J. Michael Polich

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PREFACE

This Note contains a research design developed by RAND to assess the performance of Signal Corps personnel at operating and troubleshooting Army communications equipment and installing antennas. The purpose of the research is to improve the ability of the U.S. Army Training and Doctrine Command (TRADOC) to set appropriate performance standards, determine training resource needs, and respond to congressional requests for quantitative evidence linking personnel quality with Army operational performance.

This study is one of several TRADOC-sponsored research efforts on the determinants of soldier performance. RAND is conducting related studies in the areas of air defense and electronic system maintenance. TRADOC, the U.S. Military Academy, and the U.S. Army Research Institute are organizing similar studies examining the performance of personnel involved with the operation of armored vehicles and artillery.

This Note is intended to document the design of a study in progress. As data become available, it will be supplemented with RAND analytic reports, including statistical estimates of relationships between personnel quality and performance, as well as models of the implications of those relationships for battlefield operations.

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Stephen M. Drezner is Vice President for the Army Research Division and Director of the Arroyo Center. Those interested in further information concerning the Arroyo Center should contact his office directly:

Stephen M. Drezner
The RAND Corporation
1700 Main Street
P.O. Box 2138
Santa Monica CA 90406–2138

SUMMARY

The U.S. Army Signal Corps provides the means for establishing essential communications between units on the battlefield. Within the various Signal Military Occupational Specialties (MOSs), a key role is played by MOS 31M, which is responsible for operating the tactical communications equipment used in units. This Note describes a research design to assess the ability of such Signal Corps communications operators to perform their principal duties:

- Installing and operating communications equipment as is necessary for a division or corps to communicate,
- Isolating "bugs" and identifying corrective steps in troubleshooting communications systems, and
- Installing antennas effectively and safely.

The study is one of several research efforts sponsored by TRADOC to develop quantitative analyses based on objective measurement of soluier and unit performance. The purpose is to improve the Army's ability to set appropriate performance standards and training resource needs and to respond to congressional requests for quantitative evidence linking personnel quality with Army operational performance.

Personnel in MOS 31M are responsible for successfully establishing, at division and corps levels, the communication links necessary for battlefield command, control, and coordination of subordinate elements. The object of the research is to determine how differences in personnel quality and training background affect the execution of these functions.

This study uses the Reactive Electronic Equipment Simulator (REES), a high-fidelity, computer-controlled simulation facility consisting of four signal nodes and 28 training positions (assemblages). Each node represents a signal center with multiple assemblages, operated by communications personnel. Each assemblage can operate independently or as one component of an integrated tactical communications network. Division or corps communications facilities are represented by particular combinations of equipment within each node. The REES tabulates all of the actions taken by each

operator on each piece of equipment and records these data on a disk that may be used later for analysis of individual and team performance.

Using the REES, RAND has designed a test of communications system operation and troubleshooting, representing critical command and control networks that would be established in wartime. We are employing a configuration that represents division headquarters to division artillery through a relay system. In addition, teams of 31Ms will be required to install an antenna, and their performance will be tested using evaluation methods developed by the Signal Center.

Examinees will be drawn from two sources: Advanced Individual Training (AIT) graduates and active-duty personnel. The test will involve all 31M personnel graduating from AIT during the test period; in addition, active-duty personnel will be brought in from Fort Bragg, Fort Stewart, and Fort Campbell for testing. We plan to preassign examinees to teams of three persons, using a method that will allow us to predict how the performance of teams and individuals would be affected by alternative policies affecting the quality of junior personnel in the Army.

We estimate that up to 80 AIT students per month will be available for testing. We expect to run the test for at least six months, from September 1988 through February 1989, providing an AIT sample size of 480 students, configured into approximately 160 teams. We further estimate that approximately 360 31Ms could be made available from units at the three candidate posts.

Each team of participants will receive an initial 10-minute briefing and perform the required functions on the REES. Active-duty personnel will also complete a short background questionnaire to assess their experience in units. The REES will test their ability to establish an operating communications network and to identify system malfunctions that require troubleshooting skills. Teams will then rotate to an adjacent area for a hands-on test of antenna installation. Outcome data will be obtained from the computerized REES records and from observer assessments. For the system operation functions, outcome measures will include the ability to install the network (for individuals and teams), the time to install, and the occurrence of hazardous conditions. For the troubleshooting functions, measures will include the ability to isolate the fault (within the system and within the assemblage), the time to isolate the fault, and hazardous conditions. Measures of team success, total errors and errors at critical steps, and time to install will be obtained from the test of antenna installation.

We will estimate statistical relationships among personnel quality, training background, and performance for teams and for individuals using general regression models. The analyses will use functional forms such as ordinary least-squares or logistic regression as appropriate to the performance measure. For teams, we will also estimate compositional effects, including having a person of particularly high ability or experience in the "control" terminal or antenna "team chief" position; having individuals drawn from various categories of the Armed Forces Qualification Test (AFQT) in other positions (e.g., relay): and varying levels of aggregate team quality.

ACKNOWLEDGMENTS

This study was made possible by the support and interest of the offices of the Commanding General and the Deputy Chief of Staff for Resource Management, U.S. Army Training and Doctrine Command. Particular thanks are due to General Maxwell Thurman, Brigadier General Theodore Stroup, Lieutenant Colonel David Block, and Major Robert Donoho for their encouragement. We are also grateful to the U.S. Army Signal Center for support and counsel in the design of this study, particularly Major General Leo Childs, Commanding General; Brigadier General Alfred Mallette, Deputy Commanding General; and Colonel Eddie Wheelock and Mr. Glenn Swan of the Office of the Chief of Signal. Necessary subject matter expertise was also provided by Sergeant First Class Bobby Waters, Sergeant First Class Raymond Baker, Ms. Jean Delapenia, and Mr. James Steward. At RAND, Jennifer Hawes shared her expertise in the design of data collection instruments, Alvin Ludwig offered capable communications analysis, and James Kahan provided a thoughtful technical review. Preparation of the document was handled by Bea Cohn and Kerrie Avery.

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I. INTRODUCTION

This Note describes plans for research to assess the proficiency of enlisted personnel who install, operate, and troubleshoot multichannel communications equipment. The research involves personnel in Military Occupational Specialty (MOS) 31M, Multichannel Communications Equipment Operator, which is a key occupation in the Signal Corps. The tasks performed by these personnel, as teams, are necessary to establish essential communications between divisions and corps during combat.[1]

The reasons for assessing unit communications systems operations are twofold:

- To derive statistical estimates of effects of personnel quality and training background on the operation of combat communications systems, and
- To link operators' proficiency at systems operations and troubleshooting to the availability of communications facilities to commanders at division and corps level.

BACKGROUND AND OBJECTIVE

In the past few years, the U.S. Army has acquired modernized equipment with the potential to greatly expand unit combat capability. Realizing that potential, however, depends on the quality of the Army's people and the training opportunities that they receive. In this decade, the Army has enjoyed unprecedented levels of quality among recruits and increased levels of seniority, experience, and training among its more senior personnel.[2] But emerging constraints on Defense budgets are likely to limit the Army's future ability to secure the numbers of high-quality recruits to which it has become accustomed and to maintain current levels of training resources.

Indeed, recruiting and training budgets are now being scrutinized increasingly by decisionmakers in the Army, the Office of the Secretary of Defense, and the

[1]Department of the Army, 1978, describes the structure of the signal brigade that supports the corps, the means of communications used, and how signal assets are deployed.

[2]Department of Defense, 1985.

Congress.[3] To establish resource needs credibly, and to most effectively utilize the resources that are allocated, the Army needs reliable and quantitative analyses of soldier performance and its determinants, including such broad categories of training resources as personnel quality, opportunity to train on tactical equipment, and access to training devices and simulators.

The U.S. Army Training and Doctrine Command (TRADOC) has primary responsibility for setting the standards for unit and individual training and for determining the required levels of aptitude and performance among trainees.[4] To set these standards, TRADOC needs improved measures of soldier performance, based on objective, quantified assessments of individual and unit mission achievement in wartime-related functions.

In the past, TRADOC schools have carried out most analyses of personnel quality requirements. These have been based on the minimum aptitude levels that recruits need to pass initial skill training courses.[5] The Army's long-range job performance measurement project (called "Project A") seeks to provide more definite connections between various recruit characteristics and certain performance measures on specific critical tasks.[6] However, no effort to date has attempted to measure actual performance in realistic situations directly linked to wartime conditions and outcomes and to relate that performance to the educational background, aptitude, and training history of personnel.

This study aims to develop improved databases and analyses for such broad-based performance assessment. The objective is to produce empirically based, quantitative estimates of the relationships among training resources, soldier characteristics, and the

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[3]For example, in its report accompanying the FY 88 military authorization bill, the House Appropriations Committee directed the Department of Defense to develop new methods of linking the educational background and aptitudes of recruits to the ability of units to perform their operational missions (Department of Defense, 1987).

[4]Training standards are established in various TRADOC-published Soldier's Manuals, ARTEPS (Army Training and Evaluation Programs), and related publications. TRADOC schools set minimum aptitude entry standards for their MOS courses, and TRADOC Pamphlet 601-1 establishes "distribution of quality" criteria for allocating high-quality recruits across functional areas.

[5]Recent school submissions to the TRADOC Distribution of Quality program, which requires schools to justify their quality needs, indicate that this type of analysis continues to predominate.

[6]See, for example, Eaton, Hanser, and Shields, 1987.

job performance of crews and small units. This Note describes such a study in the area of Army communications, one of several special research efforts in different functional areas. Other areas in the series of studies include air defense, electronic system maintenance, armored vehicle operation, and artillery operations.[7]

BASIC APPROACH

This study examines the primary work of MOS 31M, whose members operate communications systems for division and corps level command and control. The research will test three principal functions:

- *The operation of communications systems*—the ability to establish an operating communications network, a task that requires interaction between individuals at different communications facilities,
- *Troubleshooting communications systems*—skill at troubleshooting multichannel communications systems, also a team task, and
- *Installation of antennas*—the proficiency of teams at installing antennas.

On all three functions we will examine both graduates of Advanced Individual Training (AIT) at the Army Signal Center, Fort Gordon, Georgia, and personnel from Active Army Signal units from Fort Bragg (50th and 82nd Signal Battalions), Fort Stewart (24th Signal Battalion), and Fort Campbell (501st Signal Battalion).

Operator performance will be tested in a high-fidelity communications simulator located at the Army Signal Center, called the Reactive Electronic Equipment Simulator (REES). This simulator has four signal nodes; each node represents a signal center like that found at a division or corps headquarters. The REES's simulation capabilities provide a realistic environment for evaluating operators' performance; in addition, its computer system provides a mechanism for recording student data for subsequent analysis. Antenna installation will be tested at an adjacent site.

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[7]RAND is conducting the studies of air defense (Orvis, Childress, and Polich, 1989) and electronic system maintenance. Studies in the other areas are being carried out by TRADOC, the U.S. Military Academy, and the Army Research Institute.

OUTLINE

The remainder of this Note presents the research approach and design for the test of operation and troubleshooting of communications systems and installation of antennas. The next section describes the approach to be taken in the research, including the specialty examined and the high-fidelity simulator from which performance measures are drawn. The final section describes the scope of tasks tested; it presents the specific research design, including the detailed procedures for testing and the approach taken in selecting individuals and forming teams for testing.

II. RESEARCH APPROACH

The research will examine the efficiency and effectiveness with which teams of communications operators are able to perform three of their primary duty tasks:

- Install and operate multichannel communications equipment as necessary for a division or corps to communicate,
- Isolate "bugs" and identify corrective steps in troubleshooting communications systems, and
- Install an antenna for the appropriate multichannel communications system.

SPECIALTY TESTED

The Signal Corps provides the means for establishing essential communications between units on the battlefield. As described in Army Field Manual 11-50,[1] each division has an associated Signal Battalion whose job is to provide internal communications within the division and link the division to its subordinate units.[2] Units of a division, such as brigade and division artillery or tank and other combat battalions, each have an assigned communications element that moves with them, as does division headquarters. Although the size and capability of the associated communications organizations may vary, in all instances, the people and equipment constituting the communications teams are responsible for successfully establishing and maintaining the communication links that provide commanders with the ability to command, control, and coordinate their subordinate combat, combat support, and combat service support elements.

Among the various communications-related MOSs, Career Management Field (CMF) 31 provides the personnel who install and operate the tactical communications equipment used in units. CMF 31 is one of four career management fields in Army communications and provides almost 50,000, or 75 percent, of the nearly 67,000

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[1]Department of the Army, 1977a.

[2]The Signal Brigade provides the analogous function for the Signal Corps.

authorized enlisted spaces in the entire Signal Corps.[3] Within CMF 31, there are currently 14 beginning-level MOSs and five additional advanced supervisory MOSs.

This study examines the performance of operators in a key MOS, 31M, at tasks essential to their wartime mission. These personnel provide critical communications functions within the division and the corps. As described in FM 11-92,[4] 31M personnel hold important positions at command posts and area signal nodes within the corps radio battalion and area signal battalion. It is their job (among others) to link command posts at corps/division with adjacent corps/divisions, subordinate headquarters, and other important elements, such as division artillery and air defense batteries. In addition, the functions of MOS 31M can be tested at the REES. As will be seen, the REES provides the systematic testing environment essential for a valid test of operator proficiency.

The members of MOS 31M install, operate, and perform preventive maintenance checks and services and unit level maintenance on multichannel communications equipment and related equipment such as antennas and generators.[5] The initial skill level (31M10) emphasizes installation, operation, and maintenance of equipment. At higher levels (e.g., 31M20 and 31M30), these personnel are also responsible for supervising and assisting other team members.

The equipment used by MOS 31M is arrayed as individual components (e.g., radio transmitters, receivers, communications security devices), "assemblages" of integrated components, and "shelters," consisting of assemblages within their assigned vehicles. The major categories of assemblages used by 31Ms include so-called "high-capacity," "medium-capacity," and "low-capacity" equipment.[6] Among the most frequently used is the "low-capacity" assemblage, AN/TRC-145, found in the REES. The AN/TRC-145 is a radio terminal set containing (most commonly) two 12-channel terminals, each consisting of a radio transmitter and receiver, signal converter, security device, and two multiplexers (a device that combines or decouples two or more signals on a single channel).[7]

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[3]Office of the Chief of Signal, 1988.

[4]Department of the Army, 1978.

[5]U.S. Army Signal Center, 1987.

[6]The "capacity" of equipment denotes the number of different individual channels, or bands of frequencies, on which communication can be established. Higher capacity equipment is usually concentrated at the highest echelons of command.

[7]Department of the Army, 1977b.

Members of MOS 31M are ordinarily assigned to all echelons. The number of enlisted personnel in the Army inventory, along with the number of AIT training seats for FY 87 (actual) and FY 88 (programmed), is shown in Table 1.

THE REACTIVE ELECTRONIC EQUIPMENT SIMULATOR

Description of the REES

The REES is a computer-controlled, high-fidelity simulation facility located at the U.S. Army Signal Center, Fort Gordon, Georgia. It consists of four signal nodes and 28 training positions (assemblages). Each node represents a signal center with multiple assemblages operated by communications personnel and contains the following assemblages: one AN/TRC-145 and AN/TRC-151 (each operated by a 31M), one AN/TRC-138 (operated by a 31Q) and three AN/TCC-73s (each operated by a 31Q or a 31M), and one AN/TSQ-84 (operated by a 31N).

Each assemblage can operate independently or as one component of an integrated tactical communications network. Division or corps communications facilities are represented by particular combinations of equipment within each node. Several overall configurations of the nodes are possible; they represent the networks that would be found in alternative tactical environments. A typical network configuration employs the four nodes to simulate a communication network between one armored division, two infantry

Table 1

INVENTORY AND TRAINING REQUIREMENTS

Item	Number
Inventory	
(by grade and skill)	
E1 (Level 1)	166
E2 (Level 1)	672
E3 (Level 1)	1725
E4 (Level 1)	3010
E5 (Level 2)	1659
E6 (Level 3)	1130
Total	8362
AIT training seats	
FY 87 (actual)	1970
FY 88 (programmed)	1562

SOURCE: *Figures are from the Enlisted Personnel Management Directorate, Enlisted Distribution Division, Total Army Personnel Agency; they are current as of March 1988.*

divisions, and one corps headquarters.[8] The configuration chosen for this test is described in the next section.

The REES duplicates the front panels and simulates the functions of the equipment. The REES is driven by a master computer; using a real-time interface, it tabulates all of the individual actions taken by each operator on each piece of equipment. These data are recorded on a hard disk; a tape drive transcribes the data that are the basis for later analysis. Software developed at the REES tabulates measures of individual performance, including errors made during a procedure, time used, and whether conditions hazardous to the individual or equipment were created. These data can be used to develop measures of team performance—e.g., through derived measures of the time needed before the entire network is "up."

The REES also contains a central instructor console from which actions can be monitored and the system controlled. From this panel, instructors are able to insert faults in the system for testing troubleshooting.

We have designed a test of communications system operation and troubleshooting that is based on experience with the REES for individual performance assessment.[9] This test examines how differences in personnel quality and, for active personnel, training background affect performance of teams of communications operators. We will preassign individuals to teams, and to assemblages within nodes, based on comparisons of interest. Our test uses the REES to test teams of three soldiers at a time.

Rationale for Using the REES

The REES offers several important advantages for assessing the performance of teams at installing, operating, and troubleshooting communications systems:

- The REES provides a realistic simulation of communications assemblages and networks, where success at the task implies availability of division/corps command and control facilities.
- The REES can be used to provide an objective test that can be administered consistently and under controlled conditions. The difficulty of some features

[8] Gould, Inc., 1981.

[9] Winkler and Polich, unpublished RAND research.

of the test (the selection of troubleshooting bugs) can be manipulated so as to provide desirable statistical variation in outcomes.

- The REES computer can provide precise measurement of the performance of individuals and teams. Such measurements are less prone to bias or error than similar measures made by human observers.

We believe that the REES can provide an objective and realistic test that is likely to produce *reliable* and *valid* measures of individual and team proficiency. By reliability, we mean measurement of performance that is consistent from test administration to test administration; by validity, we mean measurement of outcomes that are accurate with respect to "true" success or failure at communications systems operations and troubleshooting. Were our protocol to be followed consistently, the conditions of testing and measurement should not vary from examinee to examinee. Because the REES uses the actual faceplates of the equipment, and because the tasks are identical to those performed with actual equipment, we believe that one's ability to perform in the REES should be highly related to one's ability to perform in a shelter outside the REES. Indeed, given the data collection capabilities of the REES (not present in the actual equipment), we believe that testing in the REES is actually preferable to a test involving actual equipment, which would of necessity require some subjective assessment of performance.

III. RESEARCH DESIGN

TESTING ENVIRONMENT

We have designed procedures to represent critical tasks that would be performed within a typical command and control communication network such as would be established in wartime.

Simulated Configuration

The testing environment consists of a simulated network configuration of two terminals connected by two relays. The terminals represent two communications nodes: the "endpoint" of a network such as those that might be found at the division or corps main command post (Terminal A) and division artillery (Terminal B). These are connected by a radio relay system where the signals from Terminal A and Terminal B are received and retransmitted at intermediate nodes.

The system configuration to be used is shown in Fig. 1. The communications network simulated in this configuration consists of two separate systems managed by each terminal. Each terminal provides two 12-channel systems. In the relay positions, the equipment is used to receive the retransmitted signals in one system from one terminal to the other; thus, each relay is responsible for only one 12-channel system.

The test in the REES employs three-person "teams," representing an operator in three of the nodes. Two persons will be assigned to the terminal positions, and the remaining team member will be assigned to one of the relay positions. The other relay position will be placed by the REES computer in "override" position, meaning that it will be transparent in the network. The task will consist of installing one system through a manned relay and a second system direct from terminal to terminal.

Equipment

Each node in the REES contains an AN/TRC-145 and an AN/TRC-151, which are the principal pieces of radio equipment used by 31Ms. We decided to test 31Ms on the AN/TRC-145 because, according to subject matter experts at the Signal School, it is used more widely in the field than is the AN/TRC-151, which is used only at corps and higher

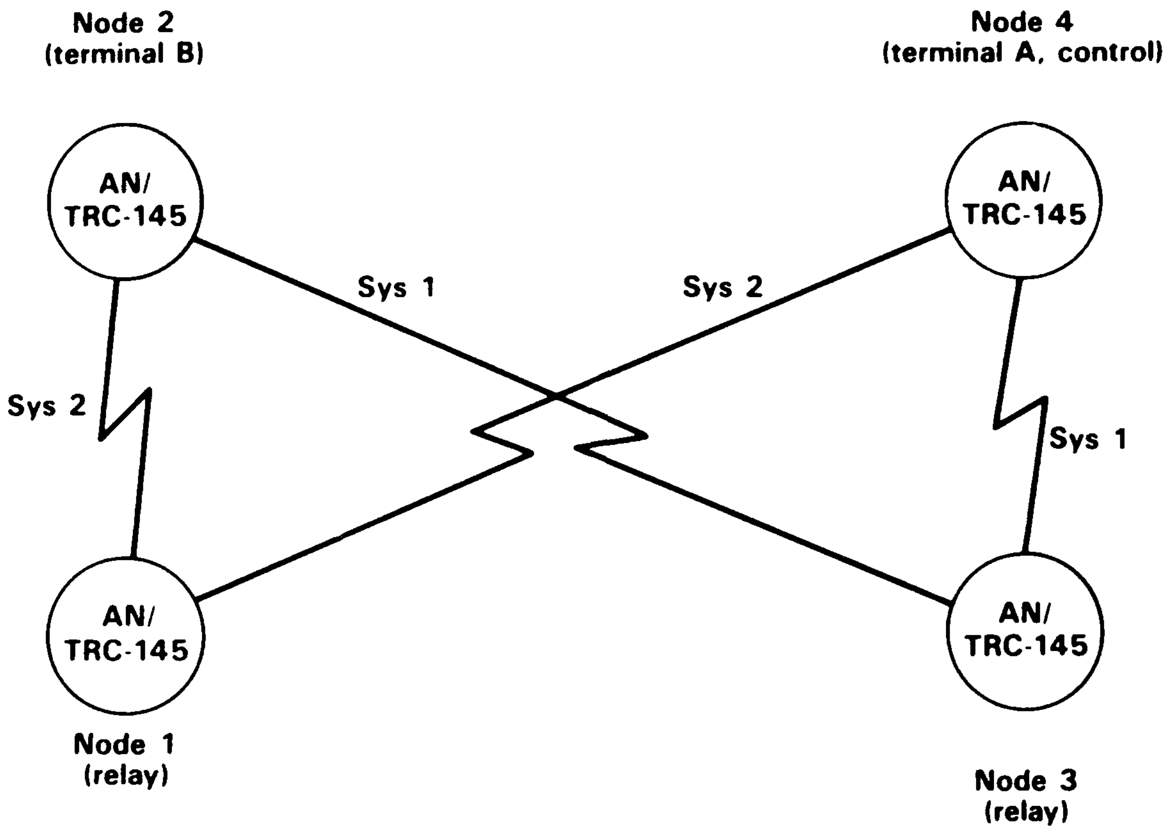

Fig. 1—Test configuration

echelons. This permits a larger number of active personnel to be tested on applicable equipment.

Tasks Tested

System Operation. Examinees will receive separate tests of their performance at system operation and system troubleshooting. System operation involves, first, the individual task of equipment installation and, second, the team task of establishing communication between nodes. The individual at each assemblage must correctly interconnect the individual components in his assemblage, preset and perform operational checks of the individual components, align and adjust his own equipment, and establish initial communication with the "distant end." The relay is the first to complete his part of the system installation. After the relay establishes communication with each terminal, the individuals at each of the two terminals perform the necessary alignments and adjustments of their equipment to ensure adequate communication.

System Troubleshooting. System troubleshooting is a team task. Several malfunctions or "bugs" will be introduced by computer. The bugs are selected to simulate the existence of a malfunction at some point in the system; the symptoms may appear at more than one node of the network and could in fact be at any of the indicated locations. The individuals must work together to determine the component containing the malfunction, by communicating over the radio if possible, or else by the orderwire (an auxiliary cable circuit used in installing and maintaining the system). The individual with the "true" malfunction must correctly identify the source of the problem and determine the appropriate corrective action. Interaction of team members is needed to isolate the bug under direction of the higher-echelon "control" terminal.

Antenna Installation. Using the same individuals who are tested in the REES, we also plan a subsequent test outside of the REES facility of proficiency at installing an antenna. One individual serves as the "team chief" who directs the others. The team follows several steps, selecting the site, assembling the launcher tower and antenna element, guying and raising the antenna, and obtaining the proper orientation.

EXAMINEES

Examinees will be drawn from AIT graduates from the 31M course at the Signal Center, and from active-duty personnel. In preassignment, examinees will be configured in teams of three persons and assigned to three nodes in the REES.[1]

The teams will be composed by RAND to allow simulation of performance with varying team quality and experience levels. One to two classes of AIT 31M graduates will be tested weekly. Our plan encompasses testing all graduates during the course of the study. Active-duty unit personnel will be brought in from Fort Bragg, Fort Stewart, and Fort Campbell for testing. Candidate units include the 24th Signal Battalion (Fort Stewart), the 50th and 82nd Signal Battalion (Fort Bragg), and the 501st Signal Battalion (Fort Campbell).

[1]For this test, we use Nodes 2, 3, and 4.

FORMATION OF TEAMS

Logic of Team Formation

We have developed a method for composing teams that will allow us to predict how the performance of teams and individuals would be affected by alternative policies affecting the quality of junior Army personnel. The policies would produce teams that represent:

(a) the current distribution of quality in the MOS (the baseline condition);
(b) the distribution of quality that is likely to be found should average quality be reduced (were the recruiting budget to be cut, for example); and
(c) the distribution of quality that is likely to be found should average quality be raised (for example, to support the fielding of Mobile Subscriber Equipment, the Army's new generation of more technically sophisticated communications equipment).

We will specify the composition of three-man teams such that the teams represent the distributions of quality that are possible under (a), (b), and (c), by assigning members to teams based on individual AFQT (Armed Forces Qualification Test). We recognize, howeve that some combinations are impractical or improbable (e.g., teams of all high- or all low-AFQT categories). The nature of the communications task we are testing also constrains our team composition. If a communications chain is as strong as its weakest link, then we desire to test that effect by including some teams with no soldiers from low-AFQT categories. Also, the marginal effect of adding too many lower AFQT soldiers is likely to be small.

As a first step, we investigated the distribution of AFQT categories within teams for teams composed at random from a population of soldiers with an underlying distribution of quality among FY 88 31M non-prior service accessions. The Defense Manpower Data Center in Monterey, California. ovided these figures for active-duty accessions in FY 88 (through June), which are shown in Table 2.

How are these individuals likely to be formed into teams? If commanders' information and control were perfect, one might imagine that the most capable or experienced individuals would be placed in strategically important locations, so that individual nodes and the network would be formed to maximize the system's

Table 2

DISTRIBUTION OF QUALITY IN MOS 31M:
ACTIVE-DUTY ACCESSIONS, FY 88

AFQT Score Range, Percentiles	Percentage of 31Ms
65–99 (high)	38
50–64 (medium)	29
0–49 (low)	33

performance. We suspect, however, that the exigencies of battle would preclude any such systematic assignment. In an actual tactical situation (during armed conflict), individual specialists would be spread out over an extended geographic area. Each small group of communications operators would move frequently as the combat units maneuver across the battlefield area; over time, a given team could find itself in different geographic locations or perform a different network function (e.g., terminal one day, relay the next). The specific role played by any single specialist would probably be determined by a process that would be much more random and less predictable than in peacetime exercises.

If a random process governs the composition of teams, we can use the binomial function to represent the number of teams that would be observed in a large sample of teams. Table 3 shows the distribution of teams according to the number of low-quality and high-quality personnel based on the binomial process where the underlying population is 33 percent low-quality.

Table 3

PROBABLE DISTRIBUTION OF QUALITY IN
THREE-PERSON TEAMS

Team Composition	Percentage of Teams
No low members	30
One low member	44
Two low members	22
Three low members	4

Thus, given the distribution of quality in the current incoming population of 31Ms, any randomly drawn set of three 31Ms is likely to have the following characteristics: 70 percent of the teams will have at least one 31M from low-AFQT categories, and 30 percent of the teams will have no 31Ms from low-AFQT categories. Therefore, a random assignment mechanism should be sufficient to provide a reasonable number of teams of each quality level, except the very lowest.

Team Assignment

The above results suggest that a random assignment of individuals to teams would reflect current actual patterns of assignment and would produce substantial variability in team quality (as indicated by the number of "low quality" members). Given a sufficient sample size, we would be likely to have enough cases at the extremes of the distributions to be able to predict the marginal effect of raising or lowering quality characteristics of the teams. During the initial stages of the study, we are using such a method to form our teams.[2] In later stages of the test, however, we will consider methods to form teams whose characteristics will permit more statistical precision for comparisons of interest. We should have enough statistical power to test certain hypotheses about minimum quality levels in the composition of the crews. If we believe the hypothesis that the network is as strong as its weakest link, for example, we would want to avoid testing many teams containing only individuals in low-AFQT categories in favor of teams with more variation at the high end of the distribution (very high quality versus less high quality teams).

A second concern is the intra-team assignment to specific node. Subject matter experts state that for both installation and troubleshooting, the terminals have tougher jobs than the relays; in addition, the quality of personnel at the higher-echelon "control terminal" is important to the success of the team tasks. If true, then ensuring an adequate distribution of individuals in "high-" and "low-" AFQT categories to the "control terminal" is important. During the test, we will examine the distribution of team

[2]The procedure requires that (a) RAND obtains lists of potential examinees in advance of the testing and allocates individuals at random to teams of three and to REES nodes within teams; (b) remaining individuals are designated as alternates to replace any team members who do not appear at the prescribed time; (c) one individual on each team is randomly selected as team chief for the antenna installation test; and (d) teams are tested in a preestablished random order.

characteristics and team members according to these criteria. If small sample sizes or other problems contribute to improper distributions, we will impose stratified sampling or controlled assignment methods to ensure that the above issues can be addressed.

SAMPLE SIZE

Based on current throughput in the courses, we estimate that up to 80 AIT students per month will be available for testing. We expect to run the test for at least six months from September 1988 through February 1989. Overall sample size is estimated at 480 students, configured into approximately 160 three-person teams.

The number of active-duty personnel available for testing will depend upon arrangements to be made between TRADOC and FORSCOM. Figures provided by the Office of the Chief of Signal indicate that in the four candidate Signal battalions, there are approximately 360 31M10s. This would provide a maximum of 120 three-man teams, were all to be tested. There would an additional 188 31M20s, if these personnel were included.

SPECIFIC PROCEDURES

We have developed detailed protocols for testing personnel both in the REES, for communications systems operation and troubleshooting, and outside the REES, for antenna installation. The development of these protocols began in August 1988. They have been modified based on experience during one month of pretesting and are current as of October 1988.

Operation and Troubleshooting in the REES

Each team of participants receives an initial 10-minute briefing describing the operation of the REES. Individuals are then assigned to a node. As discussed earlier, the system configuration represents two terminals connected by one relay. The initial task consists of installation of a radio system using the AN/TRC-145. Individuals are told that they are to install their system as either a radio terminal or relay, as appropriate, and they are assigned frequencies on which to transmit and receive.

Teams are then asked to begin with the first task, the installation of the radio terminal or relay and operation of that system to establish communications with "distant ends" in the network. The teams are assigned 70 minutes in which to accomplish this task.[3] The specific REES tasks are Task 49 (terminals, Nodes 2 and 4) and Task 44 (relay, Node 3).

At the conclusion of this task, the teams continue with troubleshooting. We have chosen the faults to be ones in which teamwork is a significant factor in successful troubleshooting. After preliminary testing with different combinations of faults, we have chosen to perform three troubleshooting trials per team with two faults inserted per trial. Ten minutes are allotted for each troubleshooting trial, and the two faults are located in different nodes. The assignment of faults is counterbalanced, such that each examinee receives an equal number of bugs.

We use the same sets of faults, inserted in a pre-specified order, in testing a given team. The current list of faults includes two malfunctions inserted in a radio transmitter, three in a radio receiver, and one in a multiplexer. The symptoms of the faults range from red alarm lights to incorrect meter readings to audible cues (alarm or buzzer) that fail to sound. In all three trials, a fault cannot be diagnosed unless team members are cooperating with one another. Thus the test emphasizes *system* troubleshooting.

Recording Data About Student Performance

System Operation and Troubleshooting. The primary data used in this study are those recorded by the REES computer. To ensure accurate measurement of errors, data are also taken from written assessments by objective assessors who are unaware of the AFQT category of the examinee. Data are recorded by the operator of the REES simulator (the console operator) and by an assessor who observes the test in the node (the node assessor). The console operator records data on:

- *Spot Checks*: These identify errors of a particular type at the completion of the operations task. They indicate whether the examinee has performed some specified set of steps within the task out of sequence. We record these data in order to identify specific "procedural" errors.
- *Malfunctions*: These include any problems that may lead to a false record of an error on a task or to the abnormal termination of a task (such as broken counters, bad cables, or phantom cables that cause a task to abort).

[3]The time allotted for the test of communications operations is consistent with ARTEP standards.

The center console operator records this information on printed forms entitled "REES Console Daily Activity Record" (see Fig. 2). The console operator notes various identifying information, including, for spot checks, the time the spot check occurred and was cleared and the specific spot check(s) (by number). The console operator also notes and describes other types of malfunctions.

The node assessor records data about students' performance on the AN/TRC-145 in each node, using printed forms entitled "Node Assemblage Record" (see Fig. 3). For all personnel assigned, the assessor records the indicated data, noting whether each person completed his portion of each task and if any spot checks or other equipment malfunctions occurred. Subsequent to clearing the spot check, he also notes whether errors remain.

Installation of Antennas. We have also developed instruments for recording the performance of teams at installing antennas. In conjunction with REES testing, each team will be tested at its proficiency at this task in an open field adjacent to the REES facility, using the AN/GRC-103 antenna. Figure 4 shows the instrument used to record performance. One assessor who is unaware of the AFQT categories of the team members will be responsible for conducting these tests and noting whether teams accomplish the steps necessary to carry out the task.

PERFORMANCE MEASURES AND ANALYSES

Measures of Individual and Team Performance

Performance of teams at communications system operation and troubleshooting will be examined using computerized REES records, with observer assessments used as necessary for interpretation. The REES computer data show, for each individual at each task, whether the individual completed the task successfully, the amount of time used, and whether during the task the examinee created a condition hazardous to himself or the equipment. For troubleshooting, the data also show the number of trials attempted and whether there were errors on each trial. These data will be taken as measures of individual performance.

Measures of team performance are developed by linking the performance of individuals on each team. The team is successful at installing a system if all individuals have completed their tasks correctly; otherwise, the team has failed. The time taken by a

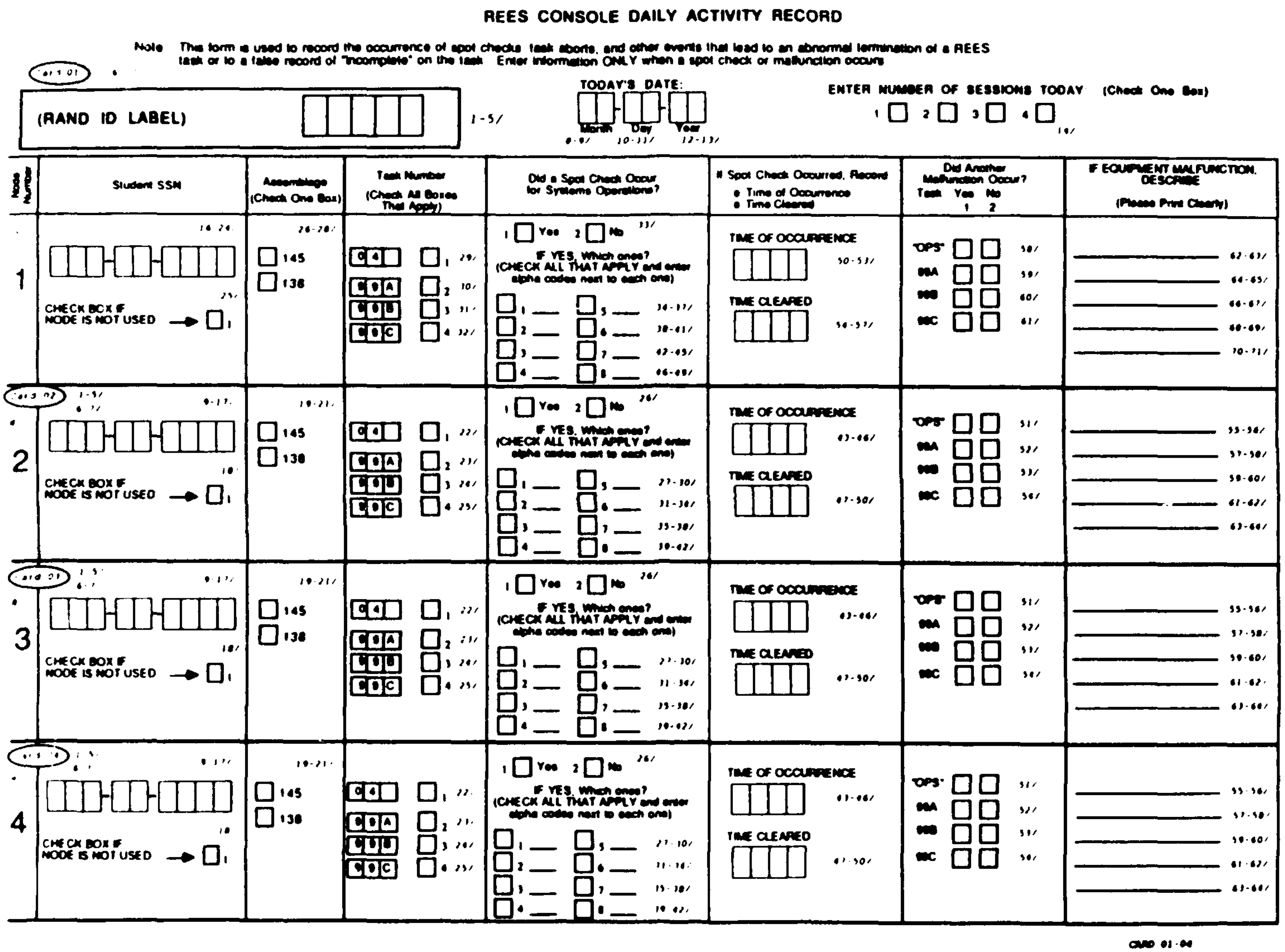

Fig. 2—REES console activity record

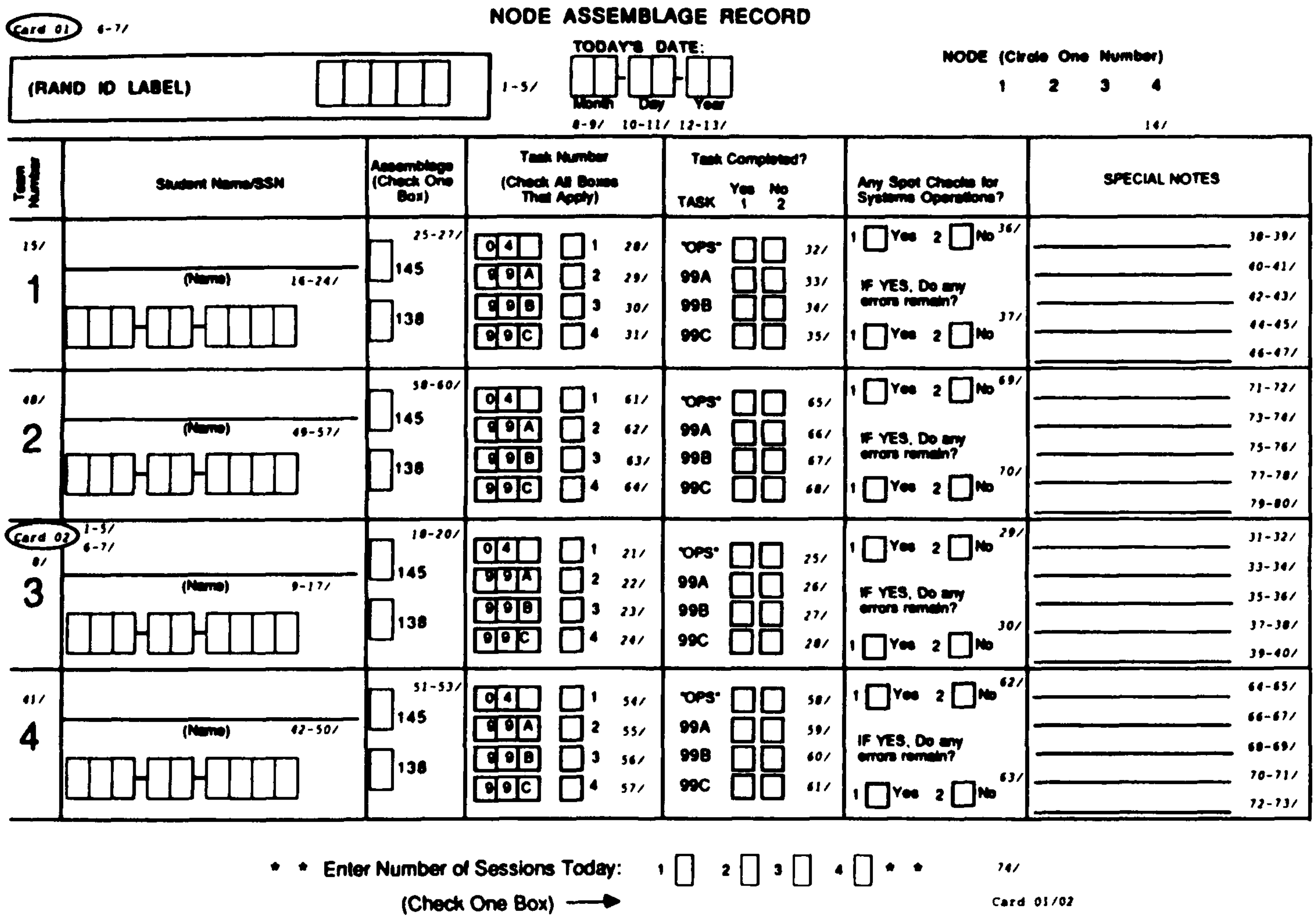

Fig. 3—Node assemblage record

INSTALL THE AN/GRC-103 ANTENNA SYSTEM (31M) (Card 01) 6-7/

RAND ID LABEL [ ][ ][ ][ ][ ] 1-5/

DATE [ ][ ]-[ ][ ]-[ ][ ] (Month 8-9/, Day 10-11/, Year 12-13/)

GROUP: [ ][ ] 14-15/

TEAM CHIEF: NAME: ____________ SSN [ ][ ][ ]-[ ][ ]-[ ][ ][ ][ ] 16-24/

TEAM MEMBER: NAME: ____________ SSN [ ][ ][ ]-[ ][ ]-[ ][ ][ ][ ] 25-33/

TEAM MEMBER: NAME: ____________ SSN [ ][ ][ ]-[ ][ ]-[ ][ ][ ][ ] 34-42/

START TIME: [ ][ ][ ][ ] 43-46/ STOP TIME: [ ][ ][ ][ ] 47-50/ TOTAL TIME: [ ][ ] Minutes 51-52/

	Circle Rating Go	No-Go		Check Box If Out of Time		Remarks	
1 SITE LAYOUT AND STAKE PLACEMENT	1	2	53/	[ ]1	54/	______	55-56/
2. ASSEMBLY OF LAUNCHER AND ANTENNA	1	2	57/	[ ]1	58/	______	59-60/
3 REFLECTOR ADJUSTMENT	1	2	61/	[ ]1	62/	______	63-64/
4 ATTACH COAX CABLES	1	2	65/	[ ]1	66/	______	67-68/
5 ATTACH GUY LINES	1	2	69/	[ ]1	70/	______	71-72/
6 RAISE AND LEVEL THE LAUNCHER	1	2	73/	[ ]1	74/	______	75-76/ (CARD 02) 1-5/ 6-7/
7 RAISE THE MAST SECTIONS	1	2	8/	[ ]1	9/	______	10-11/
8 GUY TENSION ADJUSTMENT	1	2	12/	[ ]1	13/	______	14-15/
9 ANTENNA ORIENTATION	1	2	16/	[ ]1	17/	______	18-19/
10 SAFETY PRECAUTIONS	1	2	20/	[ ]1	21/	______	22-23/

FINAL INSTALLATION: 1 [ ] GO 24/
2 [ ] NO-GO

CARD 01/02

Fig. 4—Install the AN/GRC-103 antenna system (31M)

successful team is determined by the last individual to complete his task. We will also examine the occurrence and frequency of hazardous conditions.

For the troubleshooting functions, measures will include the individual's and the team's ability to isolate the fault (within the system and within each affected assemblage), the time to isolate the fault, and hazardous conditions. We expect to aggregate the measures of individual trials and errors to indicate individual and team effort. Measures of team success, total errors and errors at critical steps, and time to install will be obtained from the test of antenna installation.

Analytic Approach

We will estimate statistical relationships between performance at operating and troubleshooting communications systems and at installing antennas, using as predictors a broad range of measures of the quality and training background of examinees. Measures will include the following:

- AFQT Category
- Scores on test components of the Armed Services Vocational Aptitude Battery (ASVAB), such as Electronics (EL) and Surveillance Communication (SC)
- High school diploma status and years of post-high school education completed
- Demographic characteristics
- Component, grade, and relevant military experience

We will conduct analyses separately for teams and for individuals. The analyses will use general regression models in their appropriate functional form, such as ordinary least-squares regression for performance measures taken on an interval scale of measurement (e.g., time to install a system) or logistic regression for nominal measures (e.g., success or failure at installation). For teams, we will estimate compositional effects, including the effects of having a person of particularly high ability or experience in the "control" terminal or antenna "team chief" position; the effects of having individuals drawn from various AFQT categories in other positions (e.g., relay); and effects of varying levels of aggregate team quality (e.g., average AFQT). We will also develop models of individual performance using individual characteristics as predictors, along with characteristics of other team members.

DATA COLLECTION, ADMINISTRATION, AND SCHEDULE

In its role as a research and analysis center for the Army, RAND is providing technical assistance for the study, research design expertise, an observer to support data collection, data analysis, and written reports and briefings of results. TRADOC Headquarters is providing support for temporary duty (TDY) expenses of Signal students and personnel used in this test and certain other expenses, including funding of stockpile spare parts for the REES.

The Signal Center is providing expert advice from resident subject matter experts on tactical communications functions, equipment used, appropriate configurations of nodes and assemblages in the REES, troubleshooting bugs, and appropriate measures of communications performance; availability of the REES facility and all AIT graduates at Fort Gordon from MOS during the study period; and assignment of the three REES instructors, one to oversee the instructor console, one to oversee the nodes, and one to oversee the associated test of antenna installation.

The schedule for the study is shown in Table 4. The study will begin with AIT graduates; phase-in of personnel from active units will depend on dates to be negotiated between TRADOC and FORSCOM. RAND expects to provide briefings and documents with interim results to TRADOC and the Signal Center periodically during the study, and to publish final results at its conclusion.

Table 4

EXPECTED SCHEDULE FOR THE STUDY

Pretest and revisions	August–September 1988
Testing start date	September 1988
Testing end date	May 1989

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