Mark IVA Project Training Evaluation

S. N. Stephenson
TDA Mission Support and DSN Operations Office

The article describes a participant evaluation of a DSN technical training program. The Mark IVA project is an implementation to upgrade the tracking and data acquisition systems of the DSN. Approximately six hundred DSN operations and engineering maintenance personnel were surveyed. The survey obtained a convenience sample including trained people within the population in order to learn what training had taken place and to what effect. The survey questionnaire used modifications of standard rating scales to evaluate over one hundred items in four training dimensions. The scope of the evaluation included Mark IVA vendor training, a systems familiarization training seminar, engineering training classes, and on-the-job training. Measures of central tendency were made from participant rating responses. Chi square tests of statistical significance were performed on the data. The evaluation results indicated that the effects of different Mark IVA training methods could be measured according to certain ratings of technical training effectiveness, and that the Mark IVA technical training has exhibited positive effects on the abilities of DSN personnel to operate and maintain new Mark IVA equipment systems.

I. Introduction

The DSN Mark IVA Project is a multiyear, multimillion dollar implementation effort to upgrade telecommunications and data acquisition systems of the DSN (Ref. 1). The actions taken to establish training requirements and budgets, organize training resources, plan and supervise training activities, and evaluate training results are a Mark IVA project responsibility. The scope of Mark IVA project training includes four types of training: 1) vendor training, 2) a systems familiarization training seminar, 3) engineering training classes, and 4) on-the-job training (OJT) experiences. Vendor training is associated with generic units of equipment which form basic components of Network systems, such as a minicomputer or a microprocessor. Seminar training is oriented primarily to description and discussion of new and modified Network subsystem groups of equipment, and the engineering classes are focused upon individual major assemblies within these subsystem equipment groups. OJT training occurs for all Network personnel who use elements of Network systems to perform telecommunications and data acquisition functions.

The trainers are customer engineers of equipment manufacturers, JPL system designers of hardware and software capabilities, and the JPL development engineers and computer programmers who have built or modified the DSN data systems. The trainees are field engineers, technicians, and operators who work at the DSN Deep Space Communications Complexes (DSCCs) located in Goldstone, California; Canberra, Australia; and Madrid, Spain; and at the DSN Network Operations Control Center (NOCC) in Pasadena, California. The training instruction consists of theoretical concepts associated with each major equipment assembly, subsystem, and system, plus a variety of techniques and procedures needed for installing, configuring, testing, operating, and maintaining Mark IVA hardware and software capabilities.

The research objective was to complete a participant evaluation of the effects of Mark IVA project training in rapidly changing DSN work environments through a training survey designed to identify the outcomes of various Mark IVA training experiences. Key terms are defined below.

Vendor training is any commercially available class or learning device employed to communicate structured product information or to teach well-defined skills associated with maintenance of generic equipment units.

Seminar training refers specifically to a five-week DSCC Implementation Seminar held at JPL in November 1983 to inform and familiarize DSN personnel with Mark IVA subsystems.

Cognizant development engineer (CDE) training refers to the theoretical and practical instruction provided on Mark IVA equipment assemblies by JPL design and development engineers during or after initial installation and testing periods at the DSCC.

On-the-job training (OJT) is the unregulated learning activities that take place through self study programs under actual field engineering, test, operation, or maintenance conditions at the Goldstone, Canberra, and Madrid DSCC; at the NOCC; and within other DSN facilities and groups.

System refers to the interacting parts of a functional whole consisting of Mark IVA equipment assemblies and computer programs grouped according to purpose for deep-space telecommunications and data acquisition.

Operations is configuring and activating DSN equipment systems to produce end-to-end data flow from the DSCC to the NOCC.

Maintenance is testing, isolating, and correcting faults in equipment systems in order to restore malfunctioning hardware or software to operational service.

Effect refers to a consequence or a result of some action or process attributable to Mark IVA training experience; e.g., the ability to load and initialize a new computer program.

Evaluation means assessing a Mark IVA training experience to determine whether training has been technically accurate, clearly presented, and applicable to participant needs.

The research questions were a) whether the effects of different Mark IVA training methods can be measured according to certain ratings of technical training effectiveness; and b) whether the Mark IVA training, inclusive of vendor, seminar, CDE and OJT training experiences, has affected the abilities of DSN personnel to operate and maintain new Mark IVA equipment systems. The significance of the study is that it has been of value in assessing the impact of Mark IVA training in terms of decisions about additional expenditure and use of dedicated project resources and funds for training purposes. The training evaluation was wanted to characterize Mark IVA training results for JPL DSN managers who are presently working to resolve major issues of Mark IVA operability. A study of training effects was useful to uncover discrepancies between intended and actual training outcomes so that corrective action can be taken to modify training design or delivery problems.

As evaluation research, the chief limitation of the study is that the research is retrospective. The participant response data are based upon self report and subjective opinion measures. In order to employ quasi-experimental pretest or posttest measures, or even to make timely trainee performance appraisals, formal training evaluation methodology would have to have been funded and incorporated as part of the original Mark IVA training program design. The original training plan made the assumption that the value of Mark IVA training would be inherent in achieving levels of acceptable system performance by trained people at the DSCC and the NOCC. It was because system performance issues had arisen that it was appropriate to conduct a formal retrospective participant evaluation of Mark IVA training. Results of the Mark IVA training evaluation were presented at the biennial DSN operations and engineering conference of JPL managers held on 20-24 May 1985 in Palm Springs, California, where it was reported that the effects of different Mark IVA training methods had been measured, and that positive effects had been identified for the Mark IVA technical training on the abilities of DSN personnel to operate and maintain new Mark IVA equipment systems.

II. Method

The approach of the study was to evaluate the impact of Mark IVA training in the context of the individual participant's perceptions of the training program. A Mark IVA Network survey was designed to gather four kinds of data: basic biographical information, training evaluation ratings, training needs, and general comments about training. The Mark IVA training program consisted of four types of training presentations: vendor schools, seminar sessions, engineering tutorials, and OJT training. Data were collected from a sample of trained and untrained DSN operations and engineering maintenance personnel. The survey obtained a large quantity of individual participant training evaluations, which have been descriptively analyzed, plus information about training experiences and respondent views, which has been qualitatively analyzed.

A. Network Survey Plan

There is a population of approximately six hundred operations and engineering maintenance personnel in the DSN and an estimated one-quarter of this population has received some Mark IVA project training in the form of vendor classes, seminar sessions, and engineering tutorials. An additional number of individuals have watched video tapes of the vendor, seminar, and engineering training, and have received on-the-job training (OJT) in the use of Mark IVA hardware and software. There was no simple way to identify the trained people or to obtain a random sample. Accordingly, the population of DSN operations and engineering maintenance personnel was surveyed to obtain a convenience sample. Individual self reports identified which people were trained, what training had taken place, and to what effect. The Network survey which was developed also provided an opportunity for poorly trained or untrained personnel to express training concerns and preferences, and for training deficiencies and omissions to be detected.

The Network survey was released throughout the Network in late February 1985. Questionnaire returns were requested by the first week in April 1985. The timing of the survey was important relative to Mark IVA project implementation progress. The DSN could be viewed as being two-thirds implemented in March 1985. Training transfer was well underway in most facilities but not concluded. The training process was sensitive to problem solving and corrective action while project training resources could still be made available to the DSN operations organization. The Network survey was accompanied by an internal delivery return envelope and was bulk mailed through the JPL and overseas organizational mail system to DSN facility and section managers, who were asked to assure that copies of the questionnaire were given to all technical persons employed in the target facilities and groups. A survey cover letter was signed by the DSN operations organization office manager requesting but not requiring the cooperation of DSN operations and engineering maintenance personnel in completing the survey. Questionnaire response was anonymous and entirely voluntary, which was made clear in the letter and on the survey.

The Network survey measured participant reaction to Mark IVA project training. The respondent was identified only by his or her facility, the nature of his or her job, and whether he or she had participated in any of the Mark IVA training activities. If not, the respondent was invited to respond to a series of items about interest in training. If the respondent had received training, he or she was asked to evaluate each type of training: 1) vendor classes, 2) seminar sessions, 3) engineering tutorials, and 4) OJT training. Each respondent was asked to identify his or her training experiences and to rate these experiences on a scale of positive to negative effects according to the degree to which the training received was technically accurate, clearly presented, and applicable to the respondent's needs. Each dimension contained a different array of training items. Many of the training subjects were identical. The respondents who had participated in training activities were asked on a different scale to agree or disagree as to whether Mark IVA training had helped respondents to perform Mark IVA related work. Finally, each respondent was asked if more training was wanted, and was invited to make comments relative to training.

B. Mode of Inquiry

The Network survey was conducted using questions that employ a standard opinion response rating scale, and a five-category, single-column response format with all choice points defined was developed for the Mark IVA training evaluation questionnaire (Refs. 2, 3). The rationale guiding the scale format decision was related to the necessity for respondents to assign ratings from among more than one hundred items in four separate training dimensions. The questionnaire had to minimize ambiguity and reduce the effort required by respondents to complete the survey, even at the cost of some discriminating power, in order to maximize the number of survey questionnaires returned. Five categories were felt to be easier to choose from than six categories. Single-column responses were felt to be less demanding than double-column responses when numerous items were to be read, considered, and rated. Defining all choice points instead of requiring abstract thought about possible alternatives avoided time consuming conceptual dilemmas for respondents.

The Network survey used ordinal response measures in four dimensional groups to obtain scores in five response categories which are identical across dimensions. There were 20 to 30 items for each dimension. The same technical subjects occurred in more than one training dimension. The units of analysis were the rating responses. Every completed survey from a person who had been trained produced rating responses in one or more groups of training items. Questionnaire rating scores in each response category were accumulated to arrive at frequency counts and arithmetic means for individual items, and a composite mean of the scores for each group of training items. Selected score frequencies of like training items in each training dimension were compared, and comparisons provided a useful check on the reliability of the measurement procedure. Since most of the respondents who received training supplied ratings in more than one training dimension, no group of training items obtained an independent N for use in correlating rating scores of one training dimension with those of another dimension, or with training effectiveness scores. Although association between training dimension rating response scores and opinions about training effectiveness in Mark IVA job performance could not be statistically established with correlation coefficients, a relationship was inferred using nonparametric techniques.

Data presentations included tables and figures showing measures of central tendency, including the calculation of item score frequencies, arithmetic means, frequency curve and percentage distributions of response scores. Results of chi square tests of statistical significance were computed. The chi square test of statistical significance was performed on Network survey data, given the first null hypothesis ($H0$) that there is no difference in types of Mark IVA training received by DSN technical personnel, and the first alternative hypothesis ($H1$) that there is a difference in types of Mark IVA training received by DSN technical personnel; and the second null hypothesis ($H0$) that there is no effect of Mark IVA technical training on the ability of DSN personnel to perform Mark IVA related work, and the second alternative hypothesis ($H1$) that there is an effect of Mark IVA technical training on the ability of DSN personnel to perform Mark IVA related work. Replies to an open-ended (comments) question were compiled for content analysis. Examples of respondent comment are presented and interpreted in connection with Mark IVA project training effectiveness or resource allocation issues.

The Network survey did not measure psychological state-change variables (Refs. 4, 5) suggested by the participant reaction to stimulus other than training, such as experiences of flawed Mark IVA equipment system performance. Variables associated primarily with OJT training may have interfered with training effectiveness ratings, which are vulnerable to mixed stimuli. Some people found it difficult to separate their OJT training experiences and their training opinions from their problematic experiences of Mark IVA equipment performance. Unrelated psychological state-change variables may have biased the training evaluation and influenced training effectiveness opinions, with a possible result that some OJT training responses may have reflected change which would be difficult to connect with training or to compare with ratings and opinions associated with other training dimensions. Another source of potential bias in the evaluation research is an unknown response-shift effect (Ref. 6) which would have to be measured using pretest and post-test research designs. Although response-shift bias may have occurred, it has not been possible under these retrospective evaluation conditions to identify a response-shift effect in the statistical analysis of Mark IVA training survey data.

III. Data Analysis

Six hundred twenty survey questionnaires and return mailing envelopes were sent out in lot shipments to managers of target facilities and groups during the last week in February 1985. The survey sample interval lasted six weeks until April 5, 1985 to allow time for responses from internationals, vacationers, and rotating shift workers. It was assumed that there are 620 DSN operations and engineering maintenance personnel, that each individual received a survey questionnaire and return mailing envelope, and that every person was given an equal chance to answer the survey questions. The 221 survey respondents provided a 35.6% return rate of the survey questionnaires distributed. Table 1 and Fig. 1 show training survey responses from DSN facilities and groups. The distribution of respondents by training received is indicated for each DSN facility and group in Table 2 and Fig. 2.

The actual number of DSN operations and engineering maintenance personnel in the population, including JPL employees, contractors, and internationals, changed several times during the long survey sampling interval. Also, the definition of a technical person was not precisely specified in the letter accompanying the survey. The technical state was interpreted somewhat differently from one facility or group to another, and in some instances, the appropriate individuals may not have received questionnaires. Other members of the population may have had no opportunity to participate. One of the managers decided to administer the survey only to technical persons who had attended training classes, possibly excluding from the survey individuals who might have seen training video tapes, or who might have had OJT training experience to rate, or those untrained technical personnel who might have been numbered among survey respondents. The sampling procedure irregularities mean that the 221 survey respondents could not represent true DSN population parameters. The survey obtained a sample of convenience which approximates certain population characteristics that may be verified by other means. Proportions of survey questionnaire returns from different facilities and groups can not be directly related to actual numbers of technical personnel employed in these DSN facilities and groups, but appear to be representative for training evaluation purposes.

The Deep Space Communications Complex (DSCC) percentages seen in Figs. 1 and 2 are larger than those from all other DSN organizations. Mark IVA implementation training was focused on the hardware and software capabilities which have been designed for tracking stations. Most new Mark IVA physical equipment system elements are installed, configured, operated, tested, and maintained by the DSCC personnel. The three DSCCs have been target facilities of first importance in Mark IVA implementation training and to the Mark IVA training evaluation although the technical training of other

DSN facilities and support groups is certainly of equivalent programmatic significance.

Mark IVA project training evaluation was directed at the concentration of Mark IVA training resource investments reflecting new hardware and software maintenance and operation functions and priorities. The survey did not thoroughly evaluate training which may have occurred in connection with Mark IVA induced changes in DSN personnel job duties at all points in DSN organizations. Key DSN facilities and groups were part of the Mark IVA training survey because selective Mark IVA project training access and training materials have been offered to and utilized by most if not all DSN organizations. Seminar and OJT training ratings, for example, were received from survey respondents all over the Network. Composite comments provided by the respondents from each facility and group are valuable Network training status indicators.

The Ground Communications Facility (GCF), System Cognizant Operations Engineers (SCOE) group, and Performance Analysis Group (PAG) data presented in Tables 1 and 2 indicate that these organizations may contain a larger proportion of untrained people than of trained people. Network Operations Control Center (NOCC) facility data indicate that almost equal proportions of trained and untrained individuals may be present in that facility. While these numbers can not be accurately used to make representations about population conditions, they may be interpreted to suggest limited classroom training access, low utilization of available Mark IVA training materials (e.g., seminar video tapes), or a range of OJT training experiences which may not have been reported adequately.

The comments of respondents from these organizations point toward a pattern of unstructured reactive Mark IVA training accomplished through documentation self study programs, which is discussed further in this section. By contrast, the data associated with the Complex Maintenance Facility (CMF) and Compatability Test Area (CTA-21) facilities and with the Cognizant Operations Engineers (COE) group indicate that larger proportions of trained personnel may exist within these organizations. These personnel have participated as students in vendor classes, seminar sessions, and engineering tutorials, and their training has included hands-on equipment OJT training experiences. (CMF survey statistics contain questionnaire returns from only two of the three complex maintenance facilities.)

The Network survey returns produced a convenience sample consisting of nearly twice as many trained people (143) as untrained people (78) among the survey respondents. The data suggest that people who received some Mark IVA training are twice as likely to respond to a survey that evaluates Mark IVA training than people who have not received Mark IVA training. Another interpretation of survey sample proportions could be that fewer technical personnel may presently require Mark IVA training than have already been trained. This is an attractive way to look at the data from an organization manager's perspective, but does not account for almost one hundred comments from trained and untrained survey respondents that suggest some, or more, or better Mark IVA training.

Following the presentation and discussion of Mark IVA training evaluation results at the May 1985 DSN operations and engineering conference of JPL managers, \$115K in TDA implementation organization funds were allocated for supplemental microprocessor and minicomputer vendor schools to be attended by DSN engineering maintenance personnel. Assurances were given that JPL technical division engineering resources would also be committed to the DSN operations organization in support of additional JPL unique equipment technical training which was required and appropriately funded through the TDA implementation organization. Conference minutes record a formal action item assigned to the TDA implementation organization to develop and fund an ongoing training program that involves the support of the Deep Space Communications Complexes by the cognizant development engineers in technical divisions.

The central focus of the Network survey was to obtain participants' assessments of the Mark IVA project training which had been accomplished and to learn whether Mark IVA training requirements had been met or if additional Mark IVA maintenance and operations training in DSN facilities and groups was needed. Figure 3 is a graph of the types of work performed by survey respondents, some of whom are working in more than one kind of job (e.g., in both engineering and supervision categories, or in both operations and analysis categories). Note that "operations" and "maintenance" were dominant DSN job categories of the survey respondents. This information was collected to assure that training assessments obtained from the survey sample arose from authentic DSN maintenance and operations work experiences. The following paragraphs review dimensions of Mark IVA training which have been evaluated.

A. Vendor Training

DSN training on the Mark IVA generic equipment units was purchased almost entirely from the commercial certification training course offerings of the manufacturer and equipment suppliers. Many product-based companies, such as Control Data Corporation (CDC), Intel Corp., and Modular Computer Systems (Modcomp), build up professionally staffed training facilities to support user maintenance and operations programs for the company's main product lines. During the Mark IVA project, it is estimated that $300K in tuition fees were invested in commercial training (maintenance) courses on microprocessors and minicomputers, clocks, discs, peripherals, programming, receivers, synthesizers, tape units, and television display systems for DSN engineers and technicians.

Generic equipment units were procured in lot quantities for installing and sparing at a dozen DSN locations, so it was necessary to train individuals from several DSN facilities and groups. Student transportation and sustenance costs became a significant factor in DSN organization training budgets for major equipment procurements because international travel expenses are involved. DSN organizations preferred to send the students to vendor schools rather than bring commercial equipment instructors to DSN locations because it was cheaper. Vendors usually have superior laboratory facilities and test equipment for student hands-on maintenance training practice.

Table 3 shows the participant evaluations of vendor training classes by the respondents who either attended the vendor schools or watched commercial course video tapes. Of the twenty-four vendor classes, seven classes were rated "good" with mean values ranging from 4.40 to 4.00. The most successful vendor training classes, in descending order of student ratings, were high-density magnetic tape unit class, high-density disc class, Classic minicomputer central processing unit (CPU) and memory class, frequency and timing master clock class, IAPX 86, 88, 186 microprocessor class, synthesizer class, and microsystems equipment troubleshooting class. The survey evaluations of these vendor training classes confirm earlier participant feedback received in interviews with individual students returning from vendor schools.

The seven "good" vendor classes are followed by fourteen vendor classes that were rated in the 3.85 to 3.00 range, which indicates that these vendor training classes have been evaluated as technically accurate, clearly presented, and applicable to respondent needs at the "satisfactory" level. Refer to Table 3 for vendor school subjects, levels of participation, and positive mean values associated with these successful vendor training experiences. The Lark disc class and the microbus structures (video tape) class received "poor" ratings, and the minicomputer 13.5, 256 Mbyte discs class was evaluated as "terrible."

It is interesting to note that the negative participant feedback about the minicomputer discs class caused a top priority purchase of two disc classes from the disc manufacturer, only one of which appears to have been an unqualified training success. Both disc manufacturer classes were presented one after the other during a two-week time period at the same place to the same student group. The Lark disc class followed the high-density disc class, and the Lark disc class participant evaluation may have suffered by comparison with high-density disc class participant evaluation. If the Lark disc class had been the single vendor disc training experience that occurred, it is possible that ratings of the Lark disc training would have been more favorable. Participant feedback about the Lark disc class indicated that JPL obtained some valuable information leading to a disc design change, which may have been worth the price of the Lark disc training regardless of participant ratings. The microbus structure video tapes were a recent purchase and more participant feedback about these training materials would be desirable. Students described the problems with the original minicomputer discs class to be inadequate instruction plus a lack of proper equipment and materials at the vendor's facility. Survey evaluations confirmed the original negative participant feedback.

Some characteristics that successful DSN vendor maintenance training class experiences appear to share are instructor expertise in the product line, well-prepared technical documentation, suitable laboratory test fixtures, and training environments with controlled access to practice equipment units. DSCC maintenance engineers have formed the majority of the DSN attendees at vendor schools. They were handpicked for commercial course opportunities, and they tend to be observant of vendor shortcomings in meeting the conditions for successful training. There seemed to be less concern about vendor aptitude for polished training performances than about the extent to which hands-on equipment learning experiences are supported by the commercial course design. It may be as important for DSCC maintenance engineers to be able to learn effectively by themselves within the vendor environment as it is for the vendor to provide the appropriate level of competent instruction.

Survey respondents' comments include descriptions of the need for additional microprocessor maintenance vendor training, and it seems important to fund a 1985-1986 DSN microprocessor training program. Based on participant feedback, emphasis and priority have been placed on vendor microprocessor training for DSCC personnel assigned to antenna and RF subsystem maintenance, CMF personnel repairing lowest replaceable elements (LREs) with microelectronic components and modern test fixtures, CTA-21 personnel maintaining new microprocessor based RF and digital equipment groups, and COE personnel specializing in microprocessor equipment maintenance program support.

DSCC maintenance engineers have asked for Classic minicomputer maintenance training in asynchronous data communication controllers which are part of the Classic minicomputer assemblies procured by JPL and for which maintenance training has never been provided. Assembly language programming with the Classic operating system and maintenance troubleshooting with diagnostics applications executive software also have been suggested as candidate classes for 1985-1986 vendor minicomputer training. Operating system and diagnostics applications capability were an integral part of the JPL DSN Classic minicomputer assembly procurements, but vendor training classes were not provided. DSCC, CMF, CTA-21, and COE equipment maintenance engineers are key candidates for Classic programming schools.

B. Seminar Training

The DSCC Implementation Seminar was characterized by the Mark IVA implementation manager as the centerpiece of Mark IVA project training. This program of subsystem familiarization training events was created to respond to Mark IVA operations and maintenance training needs of engineers, technicians, and operators at Goldstone, Canberra, and Madrid DSCC, and to the Mark IVA technical information needs of seminar participants from local JPL DSN operational facilities and support groups. Subsystem training presented by Mark IVA designers, development engineers and programmers from implementation organizations was video taped at JPL's von Karman auditorium television studio annex as a permanent training resource for the DSCC and other DSN facilities. Video tape sets were also supplied to the engineering groups for archival purposes and for new employee training.

The seminar had Mark III era precedents as a training vehicle. The original Mark IVA project training plan envisioned a 1983 training seminar that would provide videotaped high-level technical introductions to Mark IVA systems. Funding allocated on the basis of Mark III cost records was possibly an order of magnitude off in accuracy for estimating the cost of a Mark IVA seminar involving ten times as many hardware and software training issues. Engineering organizations absorbed large charges as unestimated seminar training expenditures, including the significant cost of engineering man-hours invested in seminar technical presentations which had not been a Mark IVA line item called training in 1983-1984 engineering budgets.

If the hidden cost of man-hours which were expended by the engineering groups plus the travel and sustenance expenses billed to DSCC budgets had actually been debited to the Mark IVA training account, half a million dollars might not have been enough to pay for the DSCC Implementation Seminar. The training account and engineering account overruns associated with the training seminar support were a seminar training evaluation issue to the extent that the miscalculations reflected a notion that training comes free, that using DSN internal resources for technical training represents just another one of the intangible costs associated with a major implementation. There are no free, or invisible, training lunches. Engineering organization budgets have to acknowledge the requirements for technical training in order to forecast the internal resource obligations needed to support technical training on the same basis as any other DSN implementation requirement.

Training should be assigned a priority that gives the function enough visibility to compete for available resources. DSN organization managers ought to be able to assess a training priority in all of their decisions affecting hardware and software deliverables. Future Mark IVA training account allocations should be based on provable estimates. Past expenditures traceable in the organization's records may be taken as guidelines, but technical training cost estimates, like other expensive organization investments, ought to start with current figures and comparisons of training delivery methods, comparisons available in the literature (Refs. 7, 8).

Over one hundred engineering presenters, fifty DSCC engineers and another fifty to sixty local DSN attendees were committed to a seminar program of training events held at the von Karman auditorium television studio from October 31 through December 2, 1983. Implementation organizations chose individual presenters based on their technical design expertise or range of developmental responsibilities. Many designers and development engineers elected to offer material in team presentation formats which gave more people the opportunity to contribute to a seminar knowledge base, to gain organization visibility and recognition through television appearances, and to stimulate discussions between speakers and the audiences. DSCC managers chose the DSCC personnel who traveled to JPL for the five-week seminar. Mark IVA complex implementation coordinators led station teams of mature experienced engineers with staying power for five weeks of Mark IVA technical presentations and with the ability to ask important, interesting questions for video tape training purposes.

Table 4 contains the evaluations of nineteen seminar training events which include the technical presentations and the dialogues that occurred among the engineering presenters and the seminar participants. In examining the frequency and mean values associated with each subsystem training item, recall that seminar events which were recorded on unedited video tapes were personal human experiences, not glossy packaged training products. The seminar was a series of formal structured presentations interleaved with question and answer exchanges punctuated by video tape breaks, coffee breaks, equipment crashes, anecdotes and arguments from the floor. It was intended to be like that. Dialogue and discussion were training objectives, and the survey statistics should not be interpreted to mean that presentations did not achieve the intended technical training goal of the seminar.

Twelve seminar sessions were rated as technically accurate, clearly presented, and applicable to respondent needs at the "satisfactory" level. These sessions were considered successful seminar training experiences. The highest frequency and mean values in seminar events responses were assigned to the local area network (LAN) training session. The LAN training was given by an exceptional presenter who brought terminal equipment to the seminar and by chance or by design, swept the seminar participants into exciting exercises with LAN programs. Skilled camera work captured this unusual seminar training experience on the video tapes. In addition to high task competence, the LAN presenter also exhibited strong leader position behavior which may have influenced the survey respondent perceptions. That combination of trainer qualities may have enhanced LAN seminar training effecttiveness (Ref. 9).

Seven seminar sessions have mean values ranging from 2.95 to 2.42, meaning that survey respondents did not give full marks for technical accuracy, clarity, or fit with respondent needs to these seminar training experiences. Baseband assembly (BBA) seminar training, for example, got off to a poor start when presenters appeared to be unwilling to respond to BBA questions, which could have had some effect on ratings for applicability of training to respondent needs. Although the BBA seminar training was an engineering development team event, most of the technical material was prepared and presented by a Madrid DSCC engineer working at JPL on a Mark IVA project implementation assignment. Survey respondent ratings for clarity may have been affected by differences in English language enunciation which are natural for this individual and for the two other engineers from the Madrid DSCC who presented the precision power monitor (PPM) material. The Mark IVA systems presentations were made by the DSN system engineers. In contrast with the presenters from implementation organizations, the system engineers did not invest as much time or effort in preparing for the seminar. Network support subsystem (NSS) presentations were given as brief instructive talks and a panel discussion by several teams of individuals. Limited DSCC audience participation during the NSS presentations may point to an effect on the ratings for applicability of training to respondent needs.

The less than satisfactory mean value assigned to the receiver subsystem seminar training was a surpise. Considerable effort was invested in the receiver subsystem seminar presentations, which were led by a person with teaching credentials, one of the rare presenters with a background and skills in adult education. Test support subsystem seminar presentations included speakers for the maintenance support assembly (MSA) and for the telemetry simulation assembly (TSA). By accident, the TSA presentation master video tapes were reloaded into the television studio video tape decks and overwritten during a subsequent seminar event. When the tape problem was discovered, the TSA presentation was reconvened, but the second session fell short in technical information content and audience involvement through no fault of the presenters. The disservice done to TSA seminar training by the tape accident may have affected the survey respondent ratings and mean value assigned to test support subsystem.

One problem with the DSCC Implementation Seminar video tapes as a permanent DSN training resource is the technical changes which have occurred in Mark IVA subsystems since the November 1983 presentations given by the implementation organizations. Several survey respondents commented about large differences between seminar training information and prevailing Mark IVA equipment subsystem realities. While it is not likely or even desirable that another Mark IVA seminar will be organized for training purposes, the 1983 seminar training presentations can be selectively updated with 1985-1986 technical status information. Based on participant feedback, some candidates for updated or amended technical presentations on changed equipment are the antenna, command, monitor and control, network support, telemetry (including baseband assembly), and test support subsystems. The cognizant development engineers for antenna firmware and the monitor and control software have experimented with updated seminar format video tape training presentations, and have gotten good results with informal videotaping sessions held at the Goldstone DSCC.

C. Cognizant Development Engineer (CDE) Training

CDE training is a traditional JPL engineering activity associated with first installations of JPL unique hardware assemblies or major software packages. It is customary for a JPL designer or implementer to accompany the equipment into the field when it makes its first appearance in a DSN facility system environment. Development engineers have responsibility for overseeing the new equipment integration into the operational subsystems within which it will be expected to function. The training idea is that while the development engineers are in the field, they can show the facility engineers what to do with the equipment, assuming that it works when it arrives and that it has been properly supported with spares and documentation.

Formal CDE training for the Mark IVA equipment was negotiated with the engineering organizations in January 1984 following the DSCC Implementation Seminar. Mark IVA CDE training classes took place during the initial Mark IVA implementation phase at the Goldstone DSCC, where field engineers from all three DSCCs were gathered to assist with the first equipment installations. Selected CDE training classes were repeated at overseas DSCCs. Mark IVA capabilities at other DSN facilities were also supported with training by CDEs, but not with formal classes like those which were planned and organized for the DSCC.

The initial training expectations of DSN facility personnel are often thwarted because JPL designers and implementers tend to view first installations as another milestone in the development cycle rather than as completed equipment deliveries. Protracted cycles of phased Mark IVA hardware and software deliveries meant that the CDE training was replete with technical information inconsistencies which added confusion to learning experiences for DSN maintenance and operations personnel. The CDE training process lacks instructional rigor. Classes were defined and scheduled according to the characteristics of what was being delivered, not by any rational application of training design standards to DSN instructional needs. Requirements for the CDE training were that CDEs would provide, to the best of their individual abilities, the technical instruction needed to install, operate, and maintain the delivered Mark IVA equipment capability, including theory of operations information.

The goal of the CDE training was to bridge the gap between the seminar training and on-the-job training experiences of the DSN technical personnel. When the Goldstone DSCC CDE training classes began, the decision was made to restrict CDE training access to facility engineers and technicians who were responsible for installing and maintaining the new equipment. Operations personnel were represented in the CDE training classes by DSCC operations individuals who were committed to the crew training for rotating shift operations. There were reasons for the decision to hold down operator participation, reasons associated with effective utilization of CDE training time during the Goldstone equipment installation phase lasting from March to November 1984.

CDEs were delivering unfinished hardware and incomplete software packages. Engineers and technicians had to learn everything that they could absorb from the CDEs quickly in order to help make the Mark IVA equipment systems operable. Operations was considered to be something that engineers would learn as they discovered how to make equipment work. Also, operations information would change each time the equipment capabilities changed. The CDE training classes were recorded on video tapes for later viewing by station personnel. Station trainers and engineers rather than CDEs appeared to be the logical choice for distilling accurate data and teaching station operators how to use the new equipment. CDE training classes were to address urgent operability issues for the engineers and technicians. The operator training was to be deferred until a later time in the Mark IVA integration and test phase when properly functioning hardware and software could be dedicated to operator training use.

The catch for the Goldstone DSCC and the Canberra DSCC was that these complexes had to be committed to spacecraft tracking operations before that time arrived. A similiar outcome was in store for the Madrid DSCC. All of the DSCC operations crews have had to take the equipment as they find it. They have had to learn to operate the hard way through the OJT training experiences. Although CDE training class video tapes are available and have been used by the DSCC operators, these tapes require engineering interpretation and do not always represent the actual state of the Mark IVA hardware and software. DSCC engineers appear to have been too busy to give training to DSCC operators.

Pre-survey participant feedback indicated that operator crews were unhappy about exclusion as a group from the CDE training experiences. The operators' attitudes appeared to have been negatively influenced by lost opportunities for CDE training participation. Aversive approach behaviors toward the Mark IVA equipment (Ref. 10) may have been formed among DSCC operators at least partly as a consequence of CDE training access restrictions which meant that the operator learning process had to occur through OJT training augmented by seminar or CDE training class video tapes. More operator participation in CDE training classes probably should have been tolerated despite the danger of sidetracking CDEs from engineering operability issues and the risk of technical misinformation.

Table 5 contains the frequency and mean values assigned by survey respondents to the CDE training classes. Low frequency values for some CDE tutorials may mean that a number of trainees have not responded to the survey. Alternatively, class sizes were determined by Mark IVA equipment delivery conditions, restricted participation, and crowded work spaces. Of the twenty-five CDE training classes held, the mean values for fifteen classes range from 4.40 to 3.00. Most of the fifteen tutorials were assessed as technically accurate, clearly presented, and applicable to the respondents' needs. These classes were considered successful engineering training experiences at the "satisfactory" level. One CDE tutorial was rated as "good." The digital spectrum processor (DSP) software training class which achieved the highest CDE training mean score of 4.40 was eulogized in survey respondents' comments, where the CDE was praised as an "excellent" and "pragmatic" instructor.

According to survey respondents, ten CDE training classes did not fully measure up to the evaluation criteria for successful Mark IVA project training. One of the ten CDE tutorials was rated very close to a Mark IVA training failure attributed to the embryonic state of antenna-pointing software prematurely introduced into the field. In contrast to mean values of the DSCC Implementation Seminar training, survey respondent ratings were lower for LAN, maser, and telemetry CDE training experiences, while CDE training scores were higher for antenna drive assembly equipment, DSCC monitor and control (DMC), frequency and timing, microwave, receivers, transmitter, MSA and TSA test support equipment, and very long baseline interferometry (VLBI) receiver training experiences.

One interpretation of the increases in mean values was supported by participant feedback which suggested that seminar training had been an authentic learning experience for the CDEs. As cited in Carlsson *et al.* (Ref. 11, p. 2) individual experiential learning has been defined by the Kolb learning model in these terms: "Immediate concrete experience is the basis for observation and reflection. These observations are assimilated . . . then serve as guides in acting to create new experiences." Higher means for CDE training than were achieved for seminar training may be related to the efforts of the individual CDEs to adapt their Mark IVA technical instruction presentations to the perceived needs of real maintenance and operations people encountered at the seminar and in the field. The Mark IVA CDE learning experience might be considered as an encouraging step toward a better communications network (Ref. 12) between engineering and operations that would enhance Mark IV follow on development work and Mark V project designs and training.

D. On The Job Training

The OJT training process of learning how to do a job by actually performing the work is a time honored way to conduct DSN technical training. Survey responses from DSN people who have rated Mark IVA OJT training experiences describe perceptions of Mark IVA equipment environments and job training tools available within these work settings. Technical documents are the principal resource that supports learning in Mark IVA environments under OJT training conditions. Engineers, technicians, programmers, operators, analysts, supervisors, and support personnel obtain OJT training through extensive use of the written word in self study programs leading to job or equipment knowledge of a major implementation.

Technical documentation makes it possible to enter the hands-on equipment operation and maintenance work places with a set of meaningful actions to perform. If an individual does what the book says to do and produces results that are consistent with the job or equipment performance specified by the book, OJT learning processes have been reinforced and the books become significant elements of OJT training experiences. Successful Mark IVA OJT training means that the technical reference documents delivered with the Mark IVA equipment systems achieved standards comparable to other technical information presentations used for training DSN people. The information contained in all Mark IVA document deliverables should be technically accurate, clearly presented, and applicable to respondents' needs.

Document deliverables that accompany new hardware and software are key source materials used to prepare abridged training presentations for different DSN groups and to develop equipment procedures for operations and maintenance activity in DSN environments. System procedures were rarely available in advance of hardware or software deliveries, even with good preliminary source materials, because systems-level procedure instructions have to be designed to mirror the actual behavior of interfaced equipment under program control. DSN technical personnel have had to rely on Mark IVA engineering source documents for firsthand information, particularly in real-time operations, about ways of performing Mark IVA related work.

Table 6 contains frequency and mean values provided by respondents with OJT training experiences. Means range from 3.33 to 1.66 and many of these values indicated trouble with Mark IVA OJT training. Participant feedback described the OJT training as a trial and error learning process of trying things that may not lead to repeatable results, suggesting that Mark IVA documentation insufficiencies may account for some of the poor OJT training results. The symbiotic relationship between Mark IVA technical documentation and OJT training may be new to some readers, and to illustrate the perceptions of association, typical comments are reproduced in these excerpts from Network survey data:

> Documentation is only now starting to catch up to the changes that have been implemented in the hardware and software for Mark IVA. The first six months of OJT training were made difficult because hardware and software were changing on an almost daily basis. Operator OCIs could work one day and not the next, and there was little or no documentation of what was being changed. There are still multiple areas of software and hardware with no documentation, and what little is available is extremely confusing and difficult to interpret or understand.

> Training and documentation are so poor that theory of operation is a word of mouth learning experience with everybody expressing their own theories.

> I needed proper training. Proper means training with good procedures that work right. You can't tell whether the procedure is bad or the equipment is bad. Things should be standard. So far, nothing is standard. Mark IVA needs to be standardized with proven procedures.

> Documentation is poor. There really isn't anything resembling training available.

The most beneficial training has been from reading SOMs and hands-on experience.

Of the thirty-three kinds of OJT training experiences rated, the OJT training area with the highest mean score of 3.33 was GCF software training. Eight OJT training areas with low frequencies and "poor" to "terrible" mean scores were NOCC software training experiences. Twenty-four OJT training areas were rated by DSCC, CMF, CTA-21, COE, and SCOE respondents. High frequency and mean values of 3.27 for link monitor console (LMC) software training, 3.13 for complex monitor console (CMC) software training, and 3.00 for frequency and timing (FTS) hardware training represented successful OJT training experiences that were assumed to have been supported in the DSCC and CTA-21 work environments with documented Mark IVA information which was technically accurate, clearly presented, and applicable to respondents' needs. Twenty of these OJT training areas have high frequency values with somewhat lower means ranging from 2.93 to 2.00, raising the question of how successfully the Mark IVA documentation associated with each of these OJT training experiences supported the learning process in DSCC and CTA-21 work settings. Five OJT training areas (four NOCC software package training experiences and the DSCC phase calibrator training experience) have means below 2.00 and were considered Mark IVA OJT training failures that were assumed to be partly attributable to Mark IVA technical document deficiencies.

It would be inappropriate to ignore the unstable problem-ridden Mark IVA system performance as a locus for variables other than technical documents which may affect OJT training. The difficulty is to isolate and quantify these variables, or their effects, for Mark IVA training evaluation purposes. Inconsistencies between Mark IVA equipment performance and most of the technical information training presentations appear to have influenced Mark IVA training evaluation, particularly in the OJT training dimension, where people were learning real-time operations by trial and error and the Mark IVA documentation became a critical element of Mark IVA OJT training experiences. Participant feedback invites speculation about possible gamma change effects for DSN trainees who appeared to have been experiencing "quantum shift in ways of conceptualizing salient dimensions of reality," versus alpha or beta change effects "occurring along relatively stable dimensions of reality" (Ref. 5, pp. 135-138). However, the Network training evaluation survey research design does not support distinctive interpretations of psychological state change effects which require controlled experimental research designs. Respondents' ratings and comments offer observational evidence, not proof (Ref. 13) that the presence of interfering variables may have been producing psychological change related to Mark IVA work in DSN environments, at least for the participants who have supplied Mark IVA training survey data.

Low mean values associated with Mark IVA OJT training experiences should improve as Mark IVA systems performance stabilizes and operability problems are solved. Better Mark IVA technical document ought to be delivered to the DSN work force as expeditiously as possible. Engineering implementation organizations need to consider the OJT learning aspects of all Mark IVA engineering source documentation, especially the need for a close match between the written word and equipment reality. Mark IVA funds and higher development priorities should be assigned in order to deliver the necessary complement of Mark IVA technical documents for support of real-time operations OJT training on Mark IVA equipment systems in NOCC and DSCC environments.

E. Differences

Table 7 shows clear statistical differences between the four types of Mark IVA training which have just been discussed. One hundred forty-three survey respondents who had received training have supplied the composite rating frequencies and means displayed in Table 7 for vendor schools, seminar sessions, engineering tutorials, and OJT training experiences. Survey data indicate that there is one full rating point's difference between mean values assigned to the vendor schools (3.55) and to the OJT training experiences (2.54). Half of a rating point separates the vendor schools' score from mean values assigned to the seminar sessions (3.00) and the CDE tutorials (3.08). The same difference exists between seminar session and CDE tutorial scores and the mean value for OJT training experiences.

According to the stated evaluation criteria of technical accuracy, clarity of presentation, and applicability to respondent need, vendor schools were the most successful Mark IVA training venture. CDE tutorials and DSCC Implementation Seminar sessions have also met the survey training evaluation criteria for successful Mark IVA training. OJT training experiences, with four exceptions, were not very successful. Training method comparison data graphs for seminar session, CDE tutorial, and OJT training experience rating scores have been prepared on Mark IVA technical subjects which have been covered by all three types of training. Frequency curve comparisons of training survey mean values are provided to assist DSN implementation organizations who want to look at graphic representations of the survey data in connection with their particular areas of technical training responsibility. Refer to Figs. 4 through 21 for these graphs.

The training experience could perhaps represent a million dollar Mark IVA project investment if Mark IVA implementation organization training man-hours had been calculated and charged above the line. Even larger sums could probably be allotted to Mark IVA technical drawing and document costs. As suggested by the Network survey OJT training results, future DSN implementation project training and documentation efforts could be enhanced by priorities and project development resource allocations rigorously maintained from design to first installation stages of the implementation project for successful results in these key DSN support functions.

F. Effects

Survey respondents who had received training were asked to rate the effectiveness of Mark IVA training by expressing opinions as to whether they agreed or disagreed with the statement that Mark IVA training had helped them to perform Mark IVA related work in their jobs. One hundred forty-three people in the survey were qualified to determine whether their job performance abilities were affected by training and to state their opinions about Mark IVA training effectiveness. Table 8 is a breakdown of opinion responses by DSN facility and group. Figure 22 displays the same data as a percentage distribution of rating totals across the five opinion categories of strongly agree, agree, no opinion, disagree, and strongly disagree. A glance at Fig. 2 serves as a reminder that the DSCC respondents are the largest group of trained people in the survey. In Fig. 22, the DSCC led other DSN organizations in Mark IVA training effectiveness ratings.

The percentage distribution in Fig. 22 reveals that 78% of the survey respondents who had received training perceived Mark IVA training to have affected their abilities to perform Mark IVA related work while 22% of survey respondents who had received training had no opinion. Equivalent percentages (7% and 6%) of respondents strongly agreed and strongly disagreed about the effects of Mark IVA training. A larger percentage (55%) consisting of people who strongly agreed and agreed felt that the training had been helpful. A smaller percentage (23%) consisting of people who strongly disagreed and disagreed felt that the training had not been helpful. The fact that thirty one people expressed no opinions is interpreted to mean that these individuals were ambivalent about Mark IVA training effectiveness. They may not be able to perceive that training helps, yet they may not be willing to assert that training does not help.

The effects of Mark IVA training as perceived by survey respondents are more obvious in Fig. 23, where opinion response ratings were combined by DSN facility and group into positive and negative effect classifications, separating these data from the statistics of survey respondents who had no opinion. Positive effect responses consist of all of the ratings in the "strongly agree" and "agree" opinion categories. Negative effect responses consist of all of the ratings in the "strongly disagree" and "disagree" opinion categories. Positive effect rating percentages, particularly for the DSCC, are greater than negative effect rating percentages, except for the percentages reported by NOCC, CTA-21, and PAG respondents. Survey findings suggest that NOCC and PAG respondents had not experienced adequate or satisfactory Mark IVA training.

By contrast, the Mark IVA training which has been made available to the CTA-21 facility was equal in most respects to the DSCC Mark IVA training because CTA-21 functionally resembles a tracking station. Survey findings do not suggest a reason why a larger percentage of the ratings reported by trained CTA-21 respondents indicates negative training effects. Figure 23 percentages derived from one hundred twelve decisive opinion response ratings (excluding the "no opinion" response ratings) indicate that the Mark IVA training has had positive effects for a majority (70%) of the trained survey respondents who have expressed decisive opinions. A minority (30%) of the trained survey respondents who have expressed decisive opinions appear to have felt that the Mark IVA training had not been helpful in its effect on their abilities to perform Mark IVA related work.

G. Significance

The nonparametric chi square test of statistical significance for categorical variables and enumerative data was selected to determine whether measures of association for variables reported in this study can be considered significant. A nonparametric choice acknowledges that conventional probability assumptions have not been satisfied by the sampling design of this research, although the magnitude of χ^2 values obtained by applying chi square distributions to the survey data clearly points toward the operation of nonchance factors at an appropriately conservative level of significance. Table 9 presents the results of a two variable chi square test of the relationship between types of Mark IVA training and training survey rating responses, and Table 10 presents the results of a single variable goodness of fit test of observed and theoretical survey opinion response distribution (Refs. 14, 15). In formal statistical terms, the null hypotheses (*HO*) have been established that there is no difference in types of Mark IVA training received by DSN technical personnel, and there is no effect of Mark IVA technical training on the ability of DSN personnel to perform Mark IVA related work (see Section II: Method). Alternative hypotheses (*H*1) are that there is a difference in types of Mark IVA training received by DSN technical personnel, and there is an effect of Mark IVA technical training on the ability of DSN personnel to perform Mark IVA related work. The significance level for both tests is $\alpha = 0.01$.

The value of χ^2 is calculated for the two variable case from the formula

$$\chi^2 = \sum_{r=1}^{r} \sum_{c=1}^{c} \frac{(f_o - f_e)^2}{f_e}$$

where

f_o = the observed value

f_e = the expected value

$\sum_{r=1}^{r} \sum_{c=1}^{c}$ = sum of the ratio over both rows and columns

The value of χ^2 is calculated for the one variable case from the formula

$$\chi^2 = \sum_{i=1}^{k} \frac{(f_o - f_e)^2}{f_e}$$

where

f_o = the observed value

f_e = the expected value

$\sum_{i=1}^{k}$ = sum of the ratio over k categories

Sampling distributions are the chi square distributions with degrees of freedom (df) equal to $(r - 1)(c - 1)$ for the two variable test. For the one variable test, $df = k - 1$. The two variable test has $df = 12$, and at $\alpha = 0.01$, the critical region consists of all values of $\chi^2 \geqslant 26.217$. The one variable test has $df = 4$, and at $\alpha = 0.01$; the critical region consists of all values of $\chi^2 \geqslant 13.277$. Table 9 shows the obtained χ^2 value of 209.817 for the two variable test case to be greater than the critical value of 26.217 which is required for significance at the 0.01 level. This result means that $H0$ may be rejected and $H1$ may be asserted: there is a statistically significant difference in types of Mark IVA training received by DSN technical personnel. Table 10 shows the obtained χ^2 value of 80.460 for the one variable test case to be greater than the critical value of 13.277 which is required for significance at the 0.01 level. This result means that $H0$ may be rejected and $H1$ may be asserted: there is a statistically significant effect of Mark IVA technical training on the ability of DSN personnel to perform Mark IVA related work.

H. Training Needs

The discussion of survey information up to this point has been concerned with data from survey respondents who received training. The needs of survey respondents who did not receive Mark IVA training or who felt that they had been poorly trained are important to the Mark IVA training evaluation and were not as precisely measured as the dimensions and effects of accomplished training. Survey respondents who received no training make up 35% of the survey sample. They have contributed to the evaluation database and provided many of the survey comments which indicate where Mark IVA training deficiencies and omissions may be found. NOCC and PAG survey respondents, for example, have already been identified in other parts of the evaluation as the sources of information which suggested that these organizations may need attention and more resource assistance to accomplish Mark IVA training.

Quantified Mark IVA training needs are displayed in Figs. 24 and 25, which note the types of training requested by untrained and poorly trained survey respondents and the subjects for training that interested these respondents. The figures show selection frequencies that occurred in training method and subject categories. Those respondents who were untrained and poorly trained and who made the choices usually selected more than one training method or subject. The selection frequencies for the OJT training method and for the subjects of JPL unique equipment and software are larger than the numbers for any other selection categories. The respondents evidently felt that the needs for Mark IVA OJT training and for classes in JPL unique hardware and software outweighed other needs, which is not surprising for respondents who may have been working at their jobs without training in the Mark IVA environments. Commercial equipment and software training classes also have high selection frequencies in the subject categories. Frequencies associated with vendor school, seminar session, and engineering tutorial types of training are on a par with one another in the method categories.

Although Mark IVA technical documents have been characterized earlier in this section as the principal resource for Mark IVA OJT training, the survey comments of the untrained and poorly trained respondents highlighted experiences of being shown what to do and told how to do it as a meaningful (if not always comfortable) form of OJT training. The challenge for managers interested in cultivating this method of training is to identify and assign a sufficient number of trained people who know how to instruct others to serve as resources for individuals who need productive or timely show-and-tell OJT training. It is in every DSN organization's interest to encourage trained people to share Mark IVA knowledge by helping coworkers with no Mark IVA background to develop the capability required for getting the job done. Managers could stimulate some informal Mark IVA training activity by rewarding people who are qualified and willing to teach others. The survey comments suggested that there may be a number of DSN people who would probably do better work if they received some simple show-and-tell training support from knowledgeable members of the organization. The alternative to rewarding competent in-house instructors is to force people to learn the hard way by trial and error, which lowers organization productivity and morale.

Survey comments cited hands-on equipment experience as significant Mark IVA OJT training which would be available only in facility environments under maintenance or operations supervision and special procedural controls. Section and facility managers should be aware of individuals who need or want hands-on Mark IVA experience and would be in the best position to take the appropriate action for providing this form of OJT training. In "other" categories noted on Figs. 24 and 25, the untrained and poorly trained respondents wrote twelve training requests: DSCC-NOCC-MCCC data flow, computer-aided instruction on NSS software, Mark IVA system capabilities, limitations, workarounds, reliable reference materials, antenna control, DSN system flow and configuration, qualified instructors, more classroom work, and better documentation (three items repeated prior statements). The item suggesting NSS software computer-aided instruction may be a useful Mark IV follow on software design input. The remaining items would be local classroom or OJT training options where appropriate resources are available.

There seem to be pressing local needs for sustained Mark IVA training within DSN organizations, at least as represented by the comments of the respondents who were untrained and poorly trained. Facility and section managers are responsible for establishing structured in-house training programs that report regularly and utilize formal record keeping practices, such as training hours checkoff sheets, lesson plan outlines (LPOs), and posted lists of technical documents, library books, video tapes, commercial course opportunities, resident expert lecture schedules, and the like. Several DSN facilities already have individuals who are accountable for training. Such attention to the training function may help to assure that DSN facility training occurs according to local training plans and schedules of training events.

IV. Conclusions and Recommendations

The research shows that training method differences can be measured through ordinal response ratings of Mark IVA training experiences. Mark IVA technical training is effective for DSN personnel who operate and maintain new Mark IVA equipment systems. Survey data indicate that on balance Mark IVA training helps people perform Mark IVA related operations and maintenance jobs in Mark IVA work environments. Vendor classes have received favorable ratings. Participant feedback for this training dimension indicates good return on commercial course investments. Scores for seminar training sessions did not produce frequent values at positive or negative extremes. The engineering tutorial ratings were mixed and on-the-job training experiences produced values in the satisfactory-to-poor evaluation range because this dimension is where DSN respondents have had difficulty keeping their Mark IVA training experiences separated from their experiences of flawed Mark IVA equipment performance.

Rating mean values associated with successful training experiences are consistent with, but are not necessarily related to, the positive opinion response scores indicating agreement that Mark IVA training helps to perform Mark IVA work. Rating mean values associated with unsuccessful training experiences are consistent with, but are not necessarily related to, the negative opinion response scores indicating disagreement that Mark IVA training helps to perform Mark IVA work. Statistical significance of these data has been tested with chi square distributions. Obtained values permit rejection of the null hypotheses, asserting the alternative hypotheses that there is a difference in types of Mark IVA training, and there is an effect of Mark IVA technical training on the ability of DSN personnel to perform Mark IVA related work.

Recommendations resulting from the Mark IVA project training evaluation are summarized as follows: supplementary Mark IVA training resource allocations including more commercial courses in minicomputer and microprocessor vendor schools; seminar session technical presentation video tape updates; engineering review of unsuccessful CDE tutorial presentations to help determine whether these tutorials should be repeated in the field; higher project priorities and funds for technical training and document delivery improvements; and operations management review of DSN organization local training plans, resources, and schedules in DSN facilities and support groups.

Some future issues in the area of training design and evaluation were suggested by review of related literature as being worthy of DSN research. These issues include simulation training applications (Ref. 16); designing new matches between training materials and technical documents (Refs. 17, 18); isolation of psychological state change variables which affect training (Refs. 4, 5); and use of learning models (Refs. 10, 11) to characterize future training designs and to build better intraproject communication networks (Ref. 12) in anticipation of Mark IV follow on development work, and Mark V engineering implementation projects.

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Table 1. Survey sample

Facility/Group	Number	Percent
DSCC	102	46.2
CMF	16	7.2
NOCC	28	12.7
GCF	16	7.2
CTA-21	14	6.3
COE	15	6.8
SCOE	19	8.6
PAG	11	5.0
Total	221	100.0

Table 2. Respondents of training survey

Facility/Group	Trained		Untrained	
	Number	Percent	Number	Percent
DSCC	78	35.4	24	10.8
CMF	12	5.4	4	1.8
NOCC	15	6.8	13	5.9
GCF	5	2.2	11	5.0
CTA-21	9	4.0	5	2.3
COE	13	5.9	2	0.9
SCOE	7	3.2	12	5.4
PAG	4	1.8	7	3.2
Total	143	64.7	78	35.3

Table 3. Vendor training: frequency and mean values of respondents' ratings[a]

Vendor Classes/Video Tapes	Frequency (f)	Mean ($\bar{X}$)
High-Density Disc	11	4.36
Lark Disc	11	2.81
Surveillance TV	8	3.75
IAPX 86, 88, 186 Microprocessors	13	4.00
IRMS 88, 80 Microprocessor Operating System	4	3.50
IRMX 86 Microprocessor Operating System	7	3.71
Introduction to Microprocessors	7	3.57
MCS 80/85 Microprocessors	11	3.45
Microbus Structures	4	2.75
PL/M Programming	9	3.66
RMX Programming	1	3.00
Synthesizers	8	4.00
Microsystems Equipment/Troubleshooting	7	4.00
Classic Minicomputer CPU and Memory	14	4.21
Classic Minicomputer Extended Arithmetic Unit	13	3.76
Classic Minicomputer Disc Controller	9	3.44
Classic Minicomputer Bus I/O Processor	14	3.85
Minicomputer Diagnostics Applications Executive	4	3.25
Minicomputer Introduction to Microprocessors	10	3.10
Minicomputer 13.5, 256 Mb Discs	8	1.50
Receivers	4	3.50
Console Displays	13	3.53
High-Density Magnetic Tape Units	5	4.40
FTS Master Clock	7	4.14

[a]Excellent = 5.00
Good = 4.00
Satisfactory = 3.00
Poor = 2.00
Terrible = 1.00

Table 4. Seminar training: frequency and mean values of respondents' ratings[a]

Seminar Sessions/Video Tapes	Frequency (f)	Mean (X)
Antenna Subsystem	44	3.04
Baseband Assembly	25	2.92
Block IIA, V Masers	14	3.28
Command Subsystem	25	3.00
DSCC Monitor and Control Subsystem	49	3.10
Digital Spectrum Processing Subsystem	19	3.05
Frequency and Timing Subsystem	30	3.13
Ground Communications Facility Subsystem	29	3.03
Local Area Network	56	3.35
Mark IVA Systems	35	2.82
Microwave Subsystem	15	3.13
Network Support Subsystem	23	2.82
Precision Power Monitor	28	2.89
Receiver Subsystem	36	2.80
Telemetry Subsystem	28	3.00
Test Support Subsystem	21	2.42
Tracking Subsystem	22	2.95
Transmitter Subsystem	22	3.27
VLBI Receiver	25	3.00

[a]Excellent = 5.00
Good = 4.00
Satisfactory = 3.00
Poor = 2.00
Terrible = 1.00

Table 5. CDE training: frequency and mean values of respondents' ratings[a]

CDE Tutorials/Video Tapes	Frequency (f)	Mean (X)
Antenna Drive Assembly	13	3.23
Antenna Pointing Software	15	2.06
Area Routing Assembly Software	9	2.77
BLK III RCVR/EXC/Controllers	23	3.13
BLK IV RCVR/EXC/Controllers	24	3.04
Command Modulator Assembly/Switch	18	2.83
CPA Software	8	2.87
Common Computational Modules	5	3.00
Data Channel Filter	4	2.50
DMC Software	13	3.53
DSP Software	5	4.40
Frequency and Timing	16	3.43
GCF Software	4	3.50
Local Area Network	29	3.13
Maintenance Support Assembly	20	2.85
Masers/S-Band FET/LNA	7	2.57
Microwave/Controller	14	3.71
MDA Software	6	2.66
NSS Software	3	3.00
Phase Calibrator	8	2.75
Portable Development System	8	3.12
Telemetry Simulation Assembly	15	3.26
TPA Software	7	2.71
Transmitter/Controller	13	3.61
VLBI Receiver/Controller	13	3.38

[a]Excellent = 5.00
Good = 4.00
Satisfactory = 3.00
Poor = 2.00
Terrible = 1.00

Table 6. OJT training: frequency and mean values of respondents' ratings[a]

Hardware and Software OJT	Frequency (f)	Mean (X)
Antenna Control Subassembly (ACS)	29	2.89
Antenna Drive Assembly (ADA)	29	2.93
Antenna Pointing Assembly (APA)	25	2.72
Area Routing Assembly (ARA)	26	2.73
Baseband Assembly (BBA)	11	2.00
Block III and Block IV Receivers	31	2.90
Command Modulator Assembly (CMA)	26	2.76
Complex Monitor Console (CMC)	29	3.13
CPA Software	21	2.57
DDP Software	9	2.11
Digital Spectrum Processing (DSP)	9	2.77
Frequency and Timing (FTS)	25	3.00
GCF Software	9	3.33
Local Area Network (LAN)	30	2.86
Link Monitor Console (LMC)	33	3.27
Maintenance Support Assembly (MSA)	16	2.18
Masers	15	2.66
Microwave	21	2.76
MDA Software	21	2.71
NCD Software	6	1.66
NMC Software	7	2.14
NRS Software	7	1.85
NSS Software	10	2.10
NTK Software	9	2.11
NTM Software	7	1.85
Phase Calibrator	9	1.66
Precision Power Monitor (PPM)	22	2.72
Portable Development System (PDS)	11	2.27
Telemetry Simulation Assembly (TSA)	25	2.84
TPA Software	23	2.91
Transmitters	21	2.80
VAP Software	7	1.85
VLBI Receiver	12	2.83

[a]Excellent = 5.00
Good = 4.00
Satisfactory = 3.00
Poor = 2.00
Terrible = 1.00

Table 7. Composite frequency and mean values of respondents' ratings[a]

Training Method	Frequency (f)	Mean (X)
Vendor Schools	202	3.55
Seminar Sessions	546	3.00
CDE Tutorials	300	3.08
OJT Training	591	2.54

[a]Excellent = 5.00
Good = 4.00
Satisfactory = 3.00
Poor = 2.00
Terrible = 1.00

Table 8. Survey opinions of trained people responding to the statement "Mark IVA training has helped me to perform Mark IVA related work in my job"

Facility/ Group	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree
DSCC	8	40	16	12	2
CMF		7	3	2	
NOCC		5	2	4	4
GCF		3	1	1	
CTA-21	1	2	2	2	2
COE	1	7	4	1	
SCOE		4	1	2	
PAG			2	1	1
Total	10	68	31	25	9

Table 9. Chi square two-variable test of significance: relationship between types of training and rating responses

Types of Training	Rating Responses[a]					Total
	Excellent	Good	Satisfactory	Poor	Terrible	
Vendor	10	75	62	20	5	202
	(11.092)	(48.189)	(83.807)	(46.833)	(12.078)	
Seminar	11	134	268	120	13	546
	(29.981)	(130.253)	(226.528)	(126.589)	(32.646)	
CDE	18	92	110	60	20	300
	(16.473)	(71.568)	(124.466)	(69.554)	(17.937)	
OJT	21	90	240	180	60	591
	(32.452)	(140.989)	(245.198)	(137.022)	(35.337)	
Totals	90	391	680	380	98	1,639

[a]Values in parentheses denote expected frequencies; other values denote observed frequencies.

$$\chi^2 = \sum_{r=1}^{r}\sum_{c=1}^{c} \frac{(f_o - f_e)^2}{f_e}$$

$$\chi^2 = 209.817$$

where

f_o = the observed value

f_e = the expected value

$\sum_{r=1}^{r}\sum_{c=1}^{c}$ = sum of the ratio over both rows and columns

degrees of freedom $(df) = (r - 1)(c - 1)$

Test Result: At a significance level of $\alpha = 0.01$, with $df = 12$, the obtained χ^2 value of 209.817 exceeds the critical value of 26.217 and the null hypothesis ($H0$) may be rejected. There is a statistically significant difference in types of Mark IVA training received by DSN technical personnel.

Table 10. Chi square one-variable test of significance: goodness of fit between observed and theoretical opinion response distribution. Statement of opinion: "Mark IVA training has helped me to perform Mark IVA related work in my job."

	Opinion Responses[a]					
	Strongly Agree	Agree	No Opinion	Disagree	Strongly Disagree	Total
Trained Respondents	10 (28.600)	68 (28.600)	31 (28.600)	25 (28.600)	9 (28.600)	143

[a]Values in parentheses denote expected frequencies; other values denote observed frequencies.

$$\chi^2 = 80.460$$

$$\chi^2 = \sum_{i=1}^{k} \frac{(f_o - f_e)^2}{f_e}$$

where

f_o = the observed value

f_e = the expected value

$\sum_{i=1}^{k}$ = sum of the ratio over k categories

degrees of freedom (df) = $(k - 1)$

Test Result: At a significance level of $\alpha = 0.01$, with $df = 4$, the obtained χ^2 value of 80.460 exceeds the critical value of 13.277 and the null hypothesis (H0) may be rejected. There is a statistically significant effect of Mark IVA technical training on DSN personnel ability to perform Mark IVA related work.

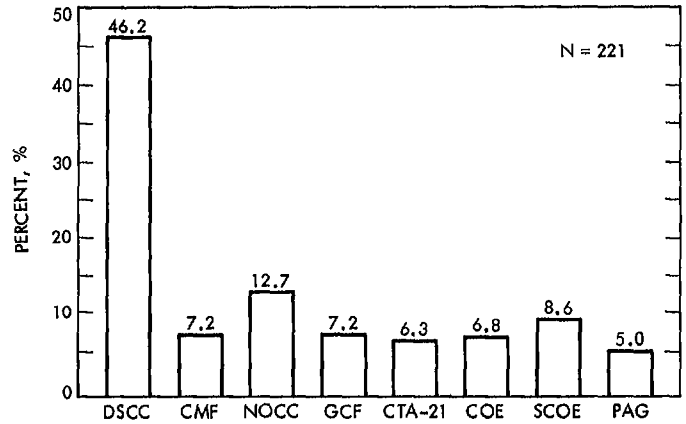

Fig. 1. Percentage distribution of training survey responses: facility/group

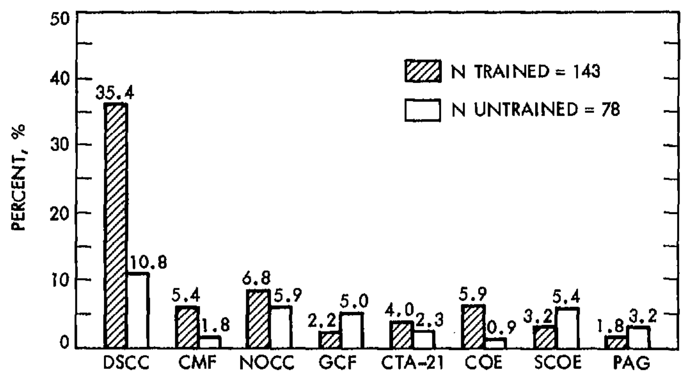

Fig. 2. Percentage distribution of trained vs untrained survey respondents: facility/group

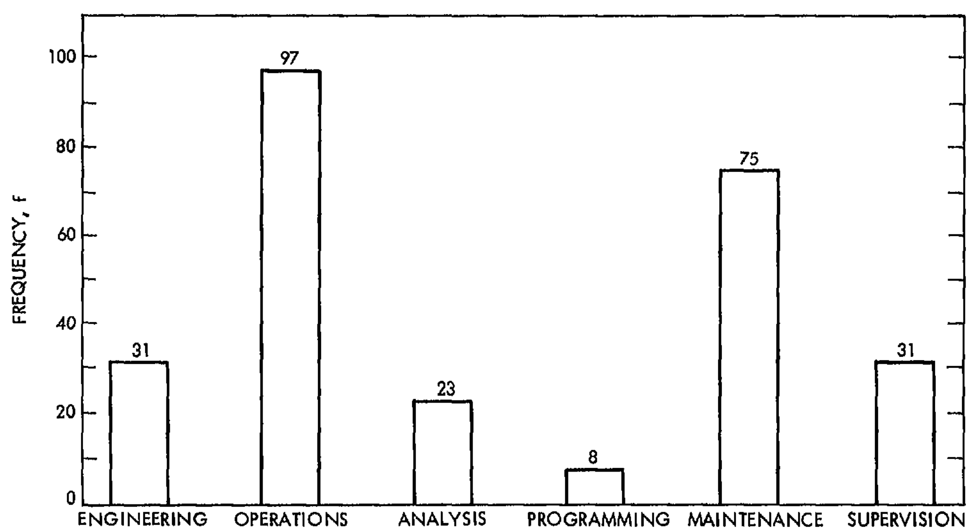

Fig. 3. Types of work performed by survey respondents: job categories

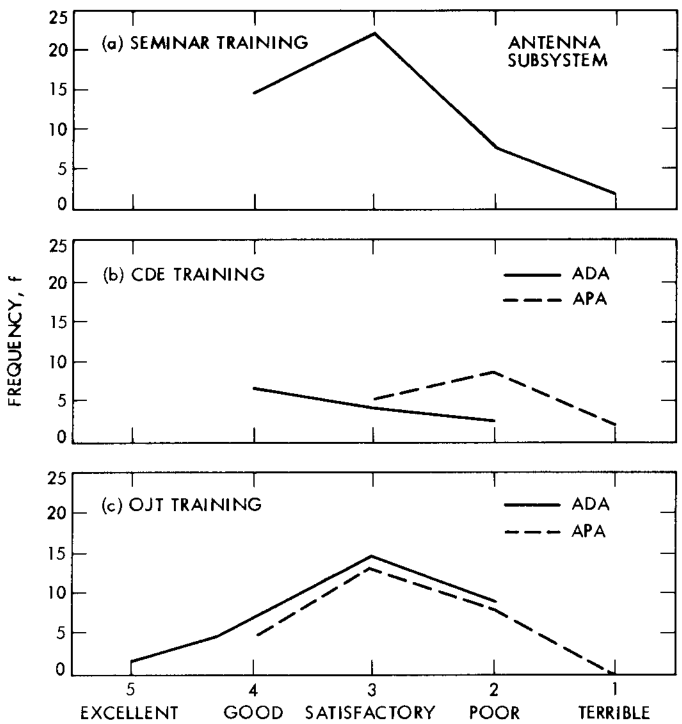

Fig. 4. Frequency curve comparison of antenna rating scores

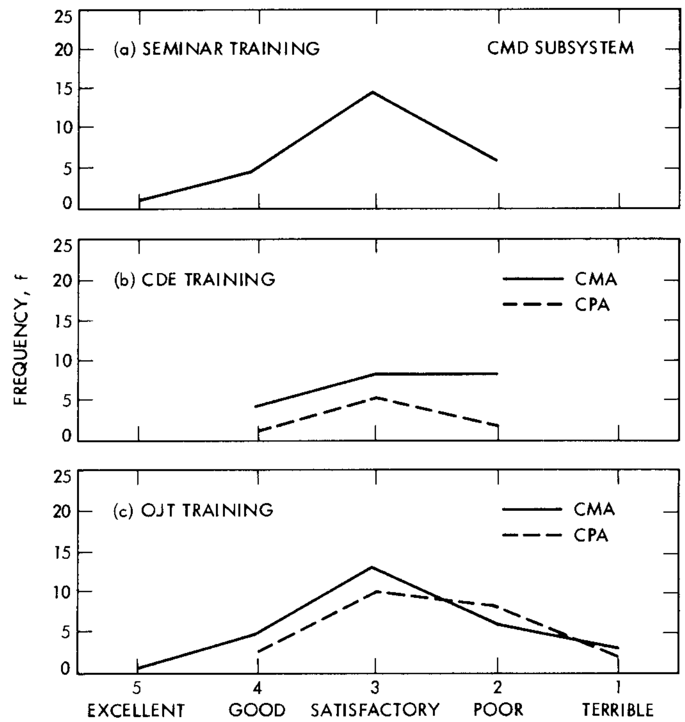

Fig. 6. Frequency curve comparison of command rating scores

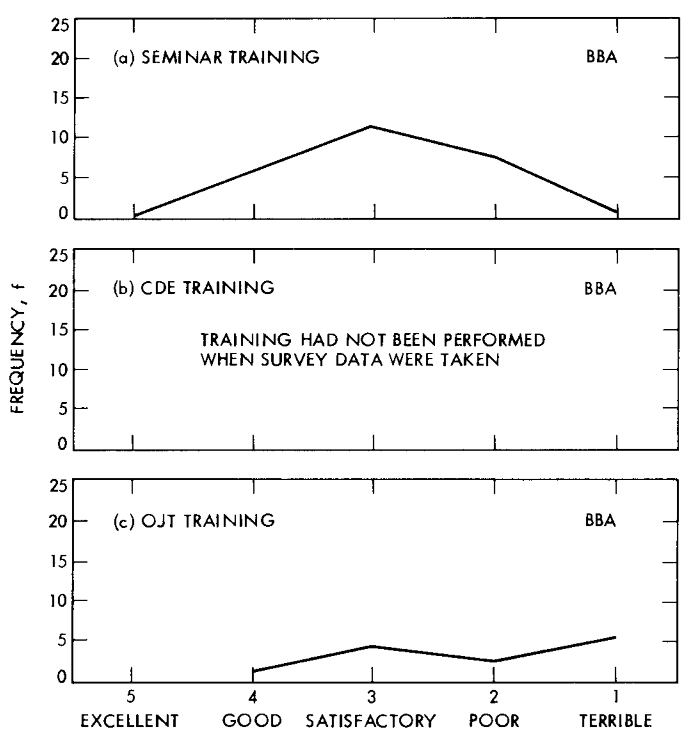

Fig. 5. Frequency curve comparison of baseband assembly rating scores

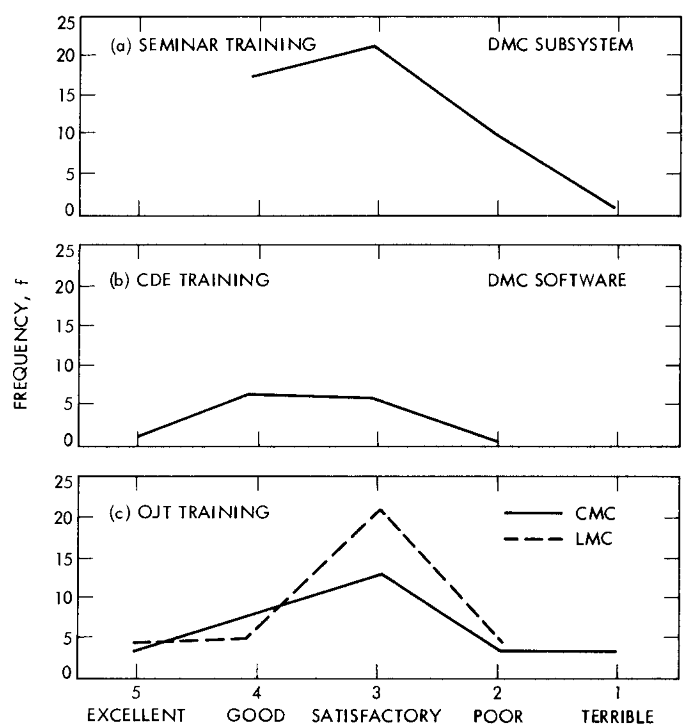

Fig. 7. Frequency curve comparison of monitor and control rating scores

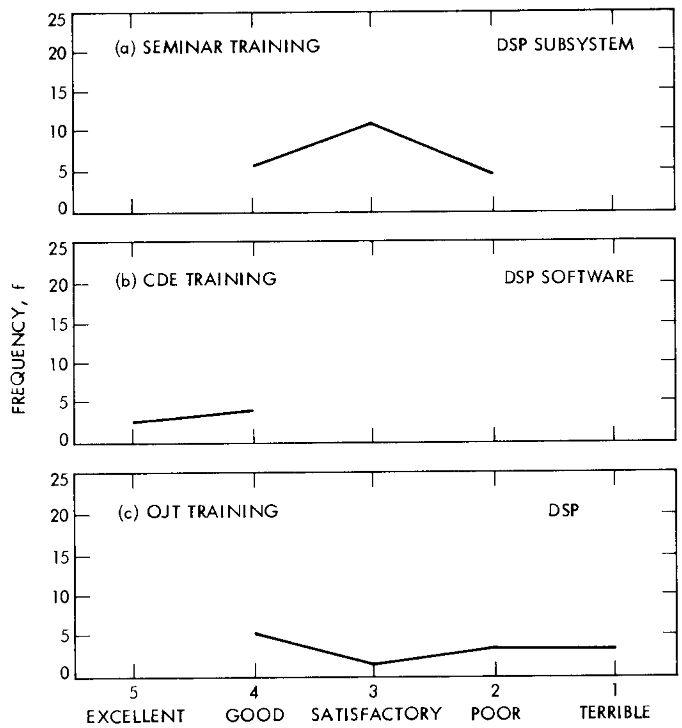

Fig. 8. Frequency curve comparison of digital spectrum processing rating scores

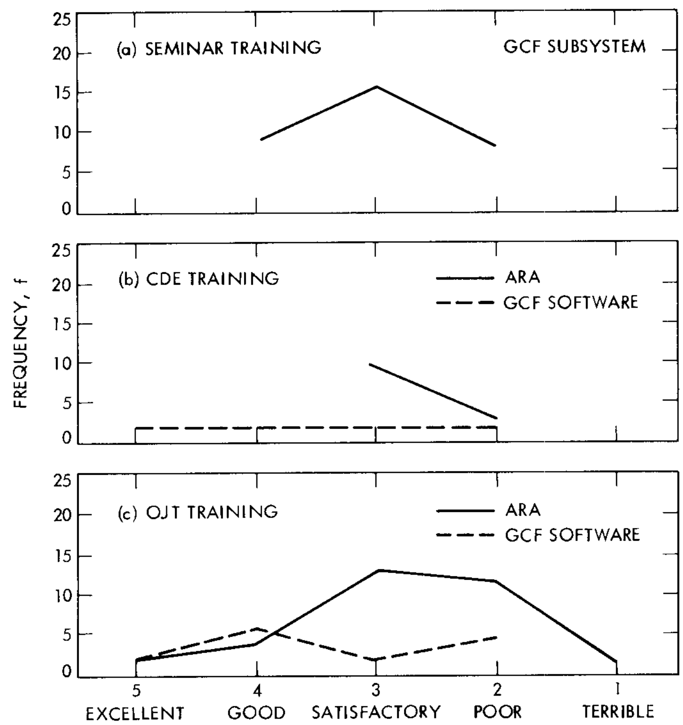

Fig. 10. Frequency curve comparison of ground communications rating scores

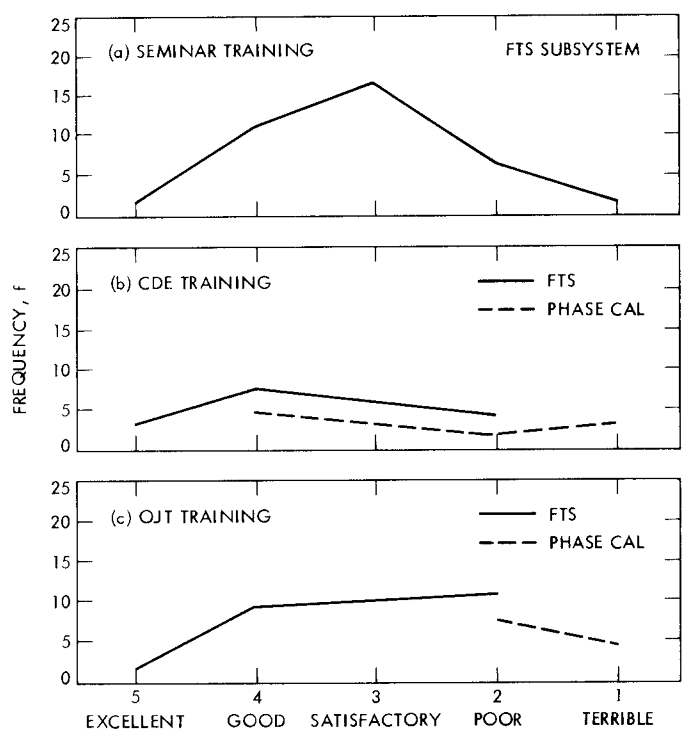

Fig. 9. Frequency curve comparison of frequency and timing rating scores

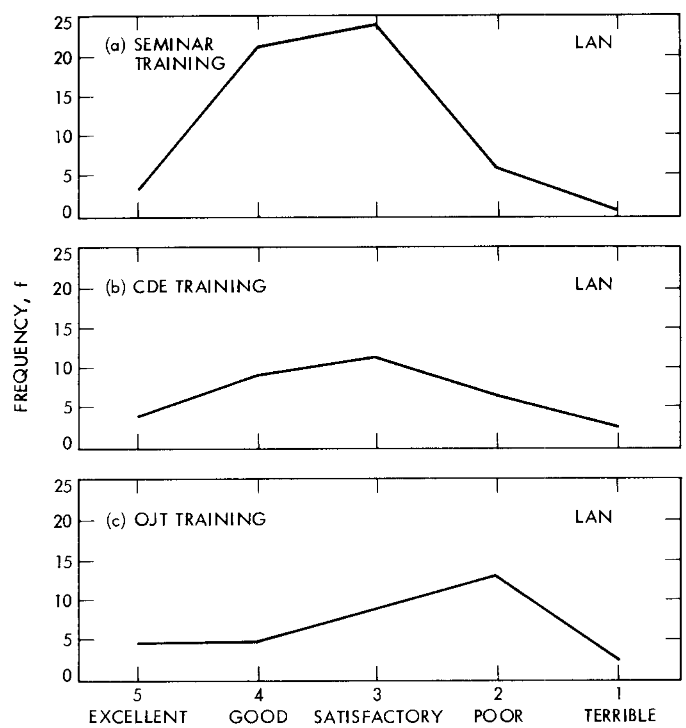

Fig. 11. Frequency curve comparison of local area network rating scores

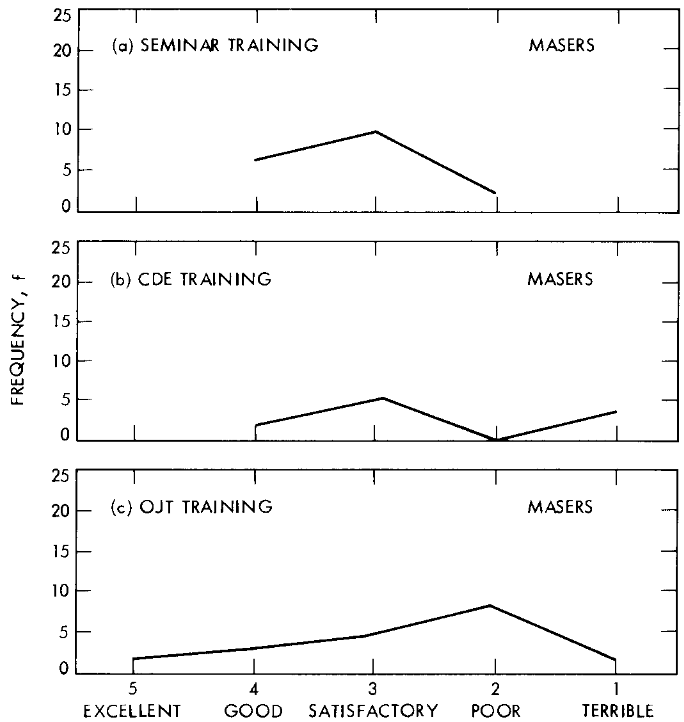

Fig. 12. Frequency curve comparison of maser rating scores

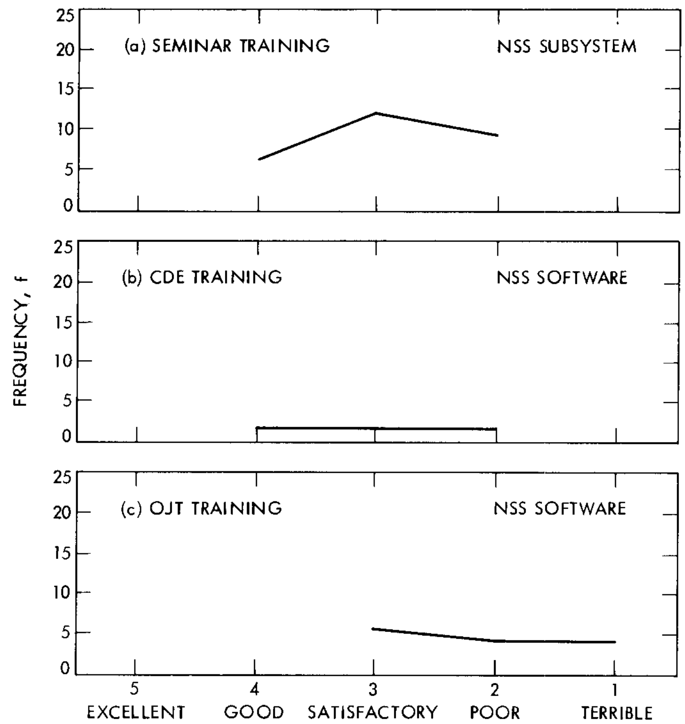

Fig. 14. Frequency curve comparison of network support subsystem rating scores

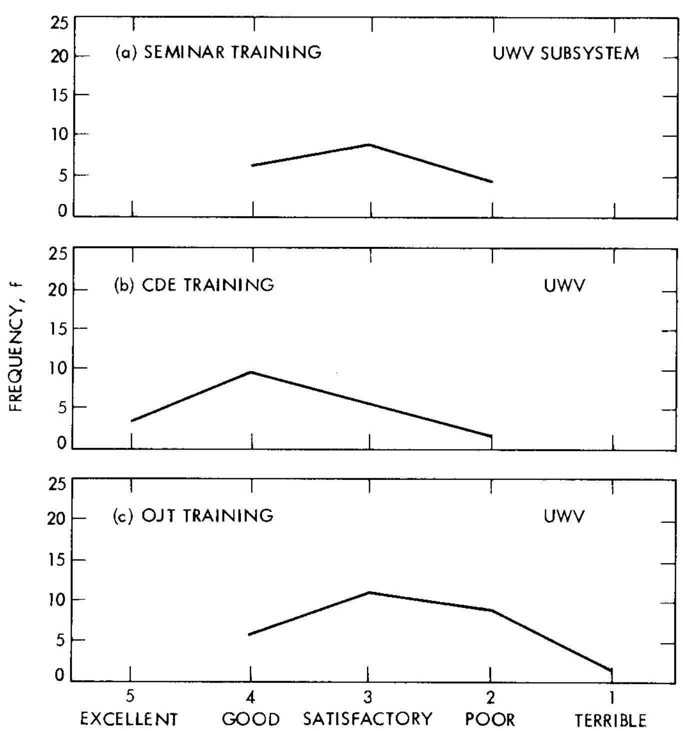

Fig. 13. Frequency curve comparison of microwave rating scores

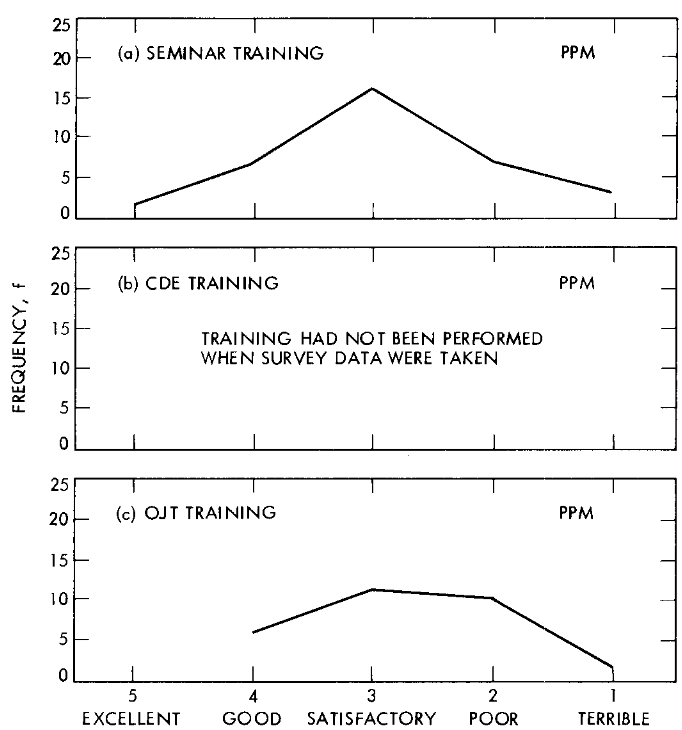

Fig. 15. Frequency curve comparison of precision power monitor rating scores

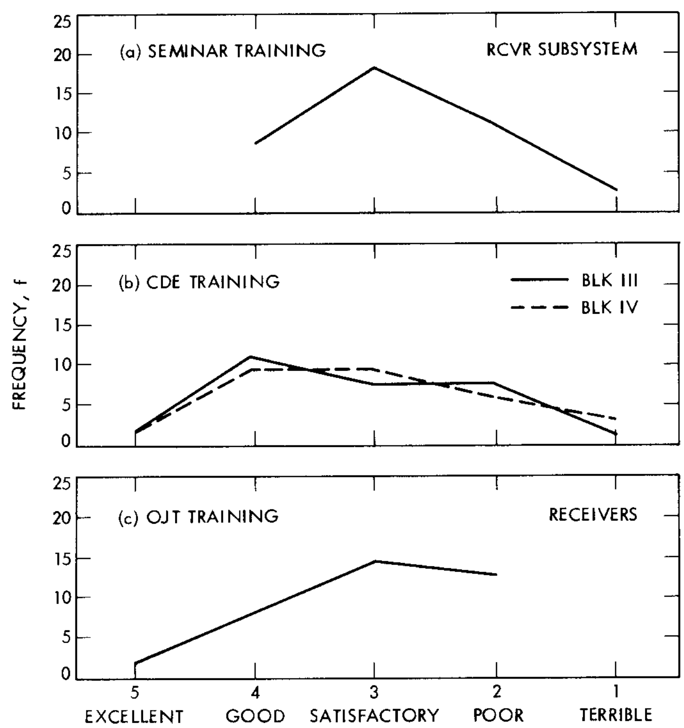

Fig. 16. Frequency curve comparison of receiver rating scores

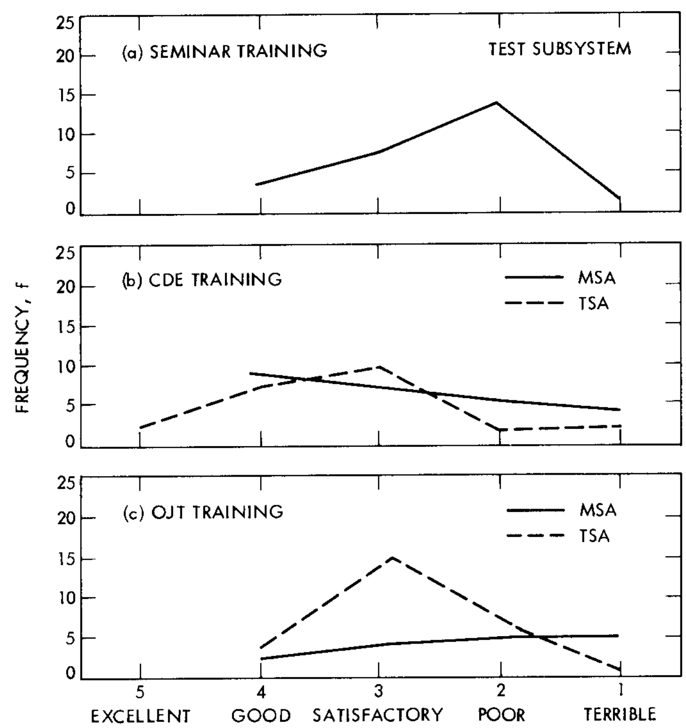

Fig. 18. Frequency curve comparison of test support subsystem rating scores

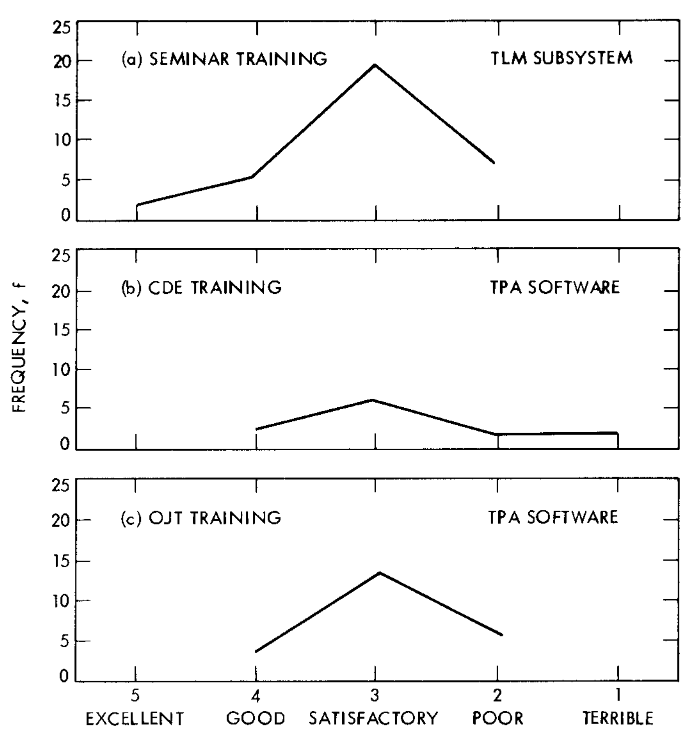

Fig. 17. Frequency curve comparison of telemetry rating scores

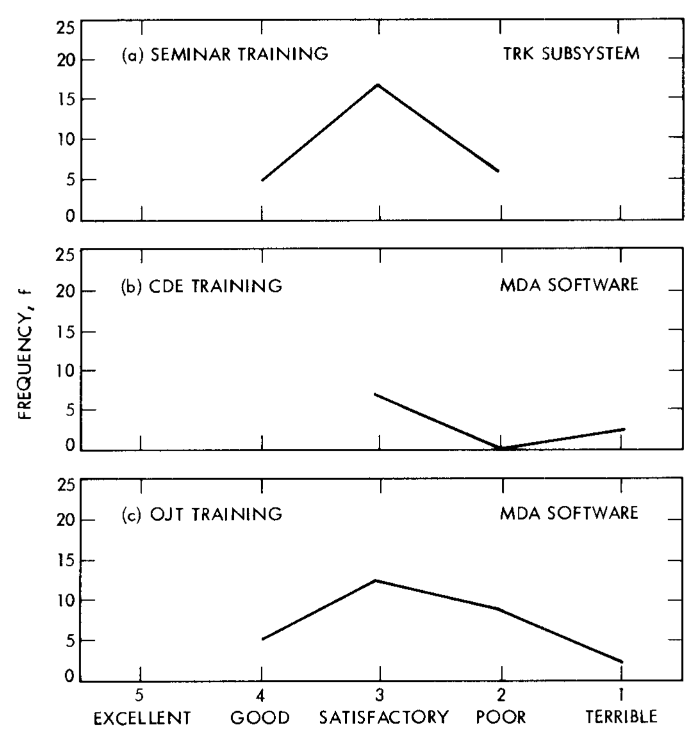

Fig. 19. Frequency curve comparison of tracking rating scores

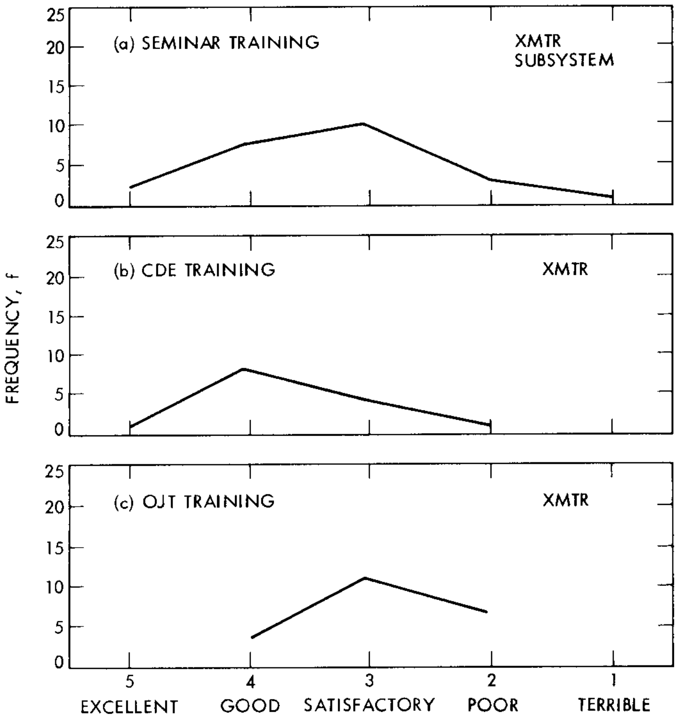

Fig. 20. Frequency curve comparison of transmitter rating scores

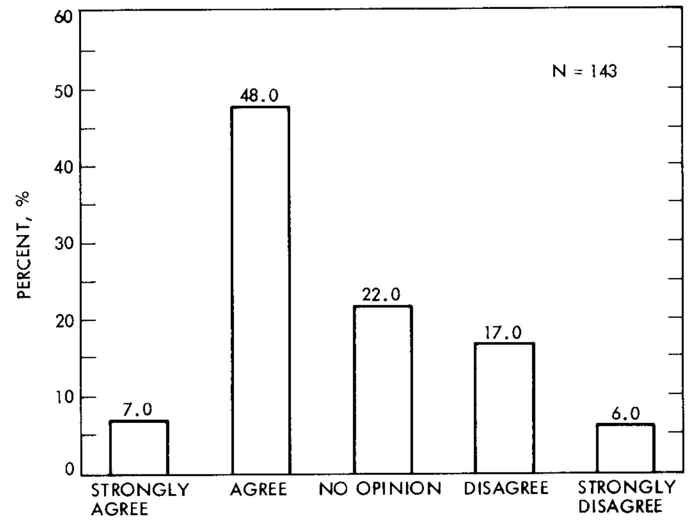

Fig. 22. Percentage distribution of training effectiveness opinion scores: opinion categories

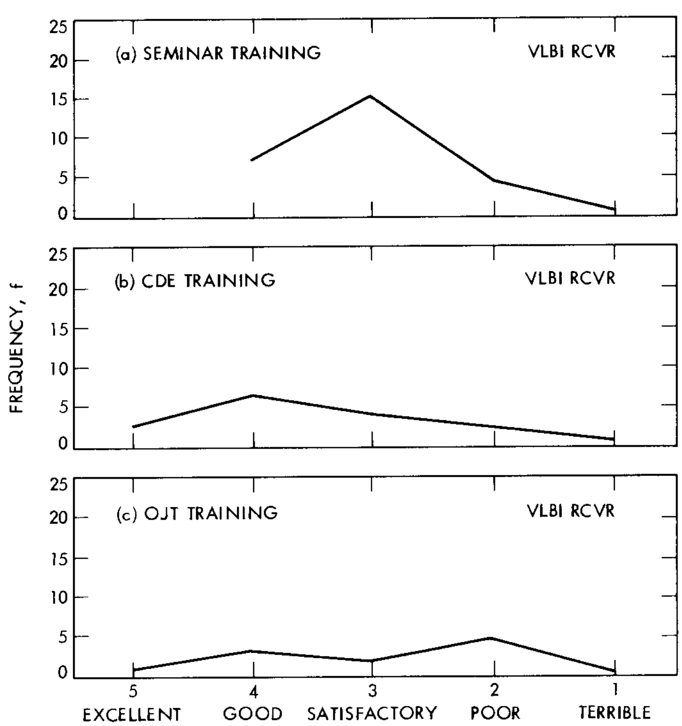

Fig. 21. Frequency curve comparison of VLBI receiver rating scores

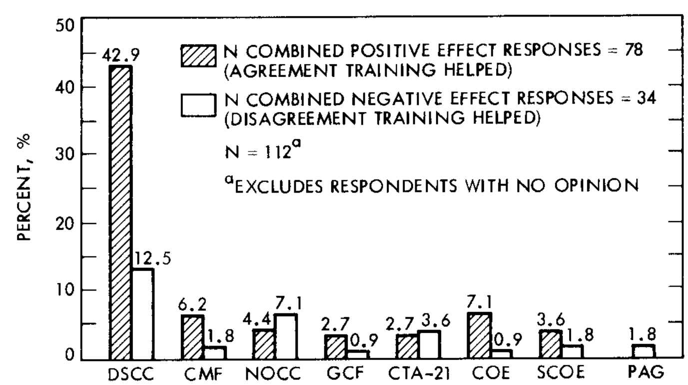

Fig. 23. Percentage distribution of positive/negative training effect responses

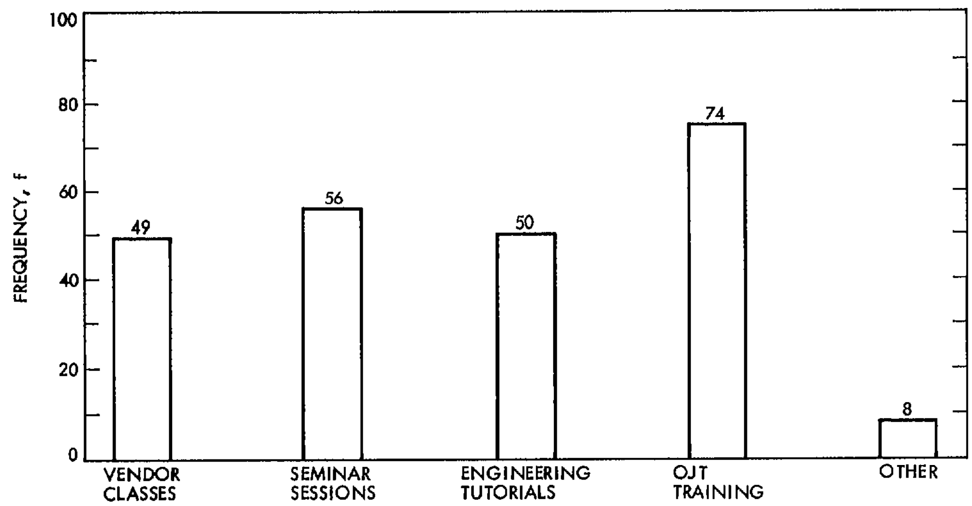

Fig. 24. Types of training requested by untrained/poorly trained respondents: method categories

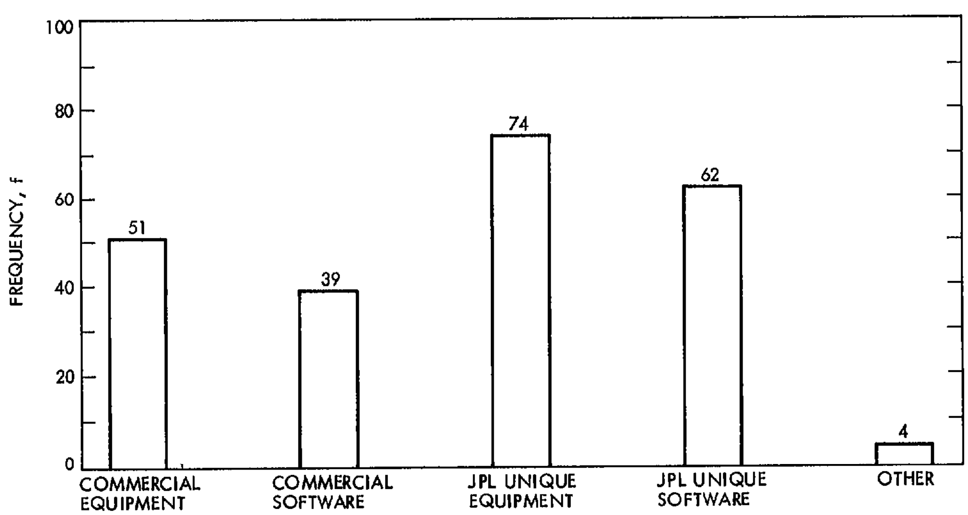

Fig. 25. Training classes requested by untrained/poorly trained respondents: subject categories