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SYMPOSIUM PROCEEDINGS: INVITATIONAL CONFERENCE ON STATUS OF JOB PERFORMANCE AIDS TECHNOLOGY

February 23-25, 1977

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This report includes seven papers assessing the state-of-the-art in job performance aids (JPA) technology presented at an invitational conference on 23-25 February 1977. The papers cover, respectively, perspectives in JPA technology base; selection of formats and media for presenting maintenance information; problems in procuring, producing, and evaluating JPAs; user problems in JPA utilization; new directions for information transfer research;

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FOREWORD

The proceedings and papers that comprise this report were prepared in support of Navy Decision Coordinating Paper, Performance Aids Test and Evaluation (NDCP-Z0828-PN) under the sponsorship of the Director of Education and Training. The papers were presented by specialists in job performance aid (JPA) technology at the Invitational Conference on the Status of JPA Technology held February 23-25, 1977 by the Navy Personnel Research and Development Center (NAVPERSRANDCEN). The findings of the conference contributed significantly to the planning and conduct of the Advanced Development project.

J. J. CLARKIN
Commanding Officer

SUMMARY AND RECOMMENDATIONS

Summary

An invitational conference was held February 23-25, 1977 at the Navy Personnel Research and Development Center (NAVPERSRANDCEN) to assess the status of the state-of-the-art in job performance aid (JPA) technology. The objectives of the conference were: (1) to define the current state-of-the-art in JPA technology as related to personnel/training implications; (2) to obtain a better conceptualization of problems involved in acceptance and utilization of JPA throughout the personnel, training, and maintenance communities; and (3) to recommend methodologies for integrating JPA technology with the Navy personnel systems for the 1980s. The objective of this report is to publish the six papers presented at the meeting, plus an introduction by Dr. R. E. Blanchard of NAVPERSRANDCEN and a final paper assimilating findings and conclusions drawn from the proceedings.

In the Introduction, Dr. Blanchard describes the current need for approaches to controlling or reducing burgeoning personnel costs in the military. He notes that, although (1) data have been collected on JPAs for over 20 years to demonstrate resultant performance increments and (2) payoffs have been forecasted on the order of $1 to $2 billion annually by each service in personnel, training, and maintenance through the use of JPAs, they have not been implemented in other but piecemeal fashion by any of the military services.

The first paper, presented by Dr. John Collins of the Essex Corporation, which was entitled "Some Perspectives On the Job Performance Aids Technology Base," outlined a generally broad concept of JPA for consideration. His description of major conceptual and methodological developments in such areas as motivation theory, job structure, and learning studies stimulated discussion well beyond the textual, highly proceduralized type of job aid.

The next paper, delivered by Mr. Theodore Post of BioTechnology, Inc., covered a method for matching systems to presentation techniques being considered by the Navy Technical Information Presentations Program (NTIPP). The approach, entitled "Selection of Formats and Media for Presenting Maintenance Information," appeared to be a good start toward that part of a program manager's guide, which would give him tradeoff criteria to use in selecting the best JPA technique for his particular system. It also provides a way of greatly simplifying the number of JPA techniques to consider by using only two basic categories, classified as either the "directive" or the "deductive" type of job aid.

The paper presented by Mr. Frank Johnson of the REM Company, which was entitled "Problems in Procuring, Producing, and Evaluating JPAs," clearly illustrated the need for an integrated approach to the acquisition of training materials and technical data. Also, in showing the difficulties of ensuring error-free technical information, his paper suggests that JPA system designers should not attempt to make the maintenance technician totally dependent on the JPA, particularly if the tasks cover complex troubleshooting of equipment.

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"User Problems in JPA Utilization," the paper presented by Mr. Reid Joyce of Applied Science Associates, provided an excellent status report on the general nonacceptance of JPAs even though almost every experimental evaluation has shown that technicians, both experienced and inexperienced, perform with fewer errors on the job when using a JPA. His report was particularly enlightening because it revealed that almost all of the past nonacceptance of JPAs can be attributed to people in the system who are not direct users of the aid itself. These include the technician's peers and supervisors, nonmaintenance users of the documentation system, and all those connected with hardware and logistics problems at the program manager level.

Dr. Edgar Shriver of Kinton, Incorporated, in his paper "New Directions for Information Transfer Research in Maintenance Jobs," suggests five fundamental elements to be used in assessing the quality of any JPA. Four of the elements are types of content analysis described as "equipment analysis," "functional analysis," "task analysis," and "behavioral task analysis." The fifth fundamental element, "intelligibility," covers all format considerations for text and graphics. His paper also described the approach the Army has initiated toward integrating their training and technical data systems.

Mr. John Klesch, of the Air Force Human Resources Laboratory, presented a paper entitled, "Implementation of the JPA Job-Oriented Training Approach to Maintenance: The Impact on Personnel Systems." The discussion following his presentation addressed how JPA experiments in the past have adversely affected individual careers in the Air Force. It is extremely important, therefore, that JPAs, when introduced into existing logistics support systems, even on a test basis, make necessary corresponding systems changes as well.

The final paper, that of Dr. Harold Booher of NAVPERSRANDCEN, concerned "Status of JPA Technology: Analysis and Conclusions." Dr. Booher concluded that, although there are only a limited number of JPA techniques ready for implementation into Navy Weapon Systems, these are quite powerful and well documented. Thus, if they are introduced with corresponding changes in personnel and training systems, they can be expected to produce the payoffs anticipated. There are still a large number of considerations in personnel and training, however, which will have to be addressed and solved within a totally new personnel system concept before the full potential of JPA technology can be realized.

Recommendations

In Dr. Booher's paper, the following recommendations or guidelines were drawn as a result of conference proceedings.

JPA Technology Applications

1. Select JPA test cases for maintenance technical information presentation using both troubleshooting and nontroubleshooting tasks.

2. Conduct longitudinal demonstration (1-5 years) of each test case to determine extent of system life cycle cost payoffs and positive influence on personnel careers.

3. For nontroubleshooting tasks, utilize the fully proceduralized job performance aid for format/content technique with paper as the information transfer medium.

4. For troubleshooting tasks, utilize a combination of directive and deductive JPA formats/content techniques with paper as the information transfer medium.

5. Select troubleshooting test cases to represent (a) complex task electronics systems, (b) not-so-complex task but complex system electronics, (c) mechanical systems, and (d) integrated mechanical/complex-digital electronics systems.

6. Coordinate R&D efforts with NTIPP program for design of optimum JPA selection methodology and procurement of JPA technical data test cases.

7. Consider development of total life cycle tradeoff model for JPAs, training, job design, technical documentation, maintenance design, and equipment design.

8. Review Human Factors Engineering Integration Project of NSRDC, Annapolis and NAVPERSRANDCEN proposed study on Communications Network for Personnel R&D Products and assess applicability to total JPA system implementation model.

9. Determine and initiate development of policies and procedures required to integrate Navy training and technical data for major weapon systems.

10. Consider development of DoD-wide JPA technology standards and specifications.

Methodological Studies

1. Conduct tradeoff study to determine most cost-effective combination of JPA and job-based training for developing skills in "deductive" troubleshooting.

2. Develop methodology for integrating job-based training with JPA technology.

3. Perform study on the implications of JPA technology for job design, personnel careers, and job satisfaction.

4. Develop a JPA-based personnel system concept integrated across personnel, training, and job design.

5. Develop methodology and collect data for costs criteria to be used in tradeoffs among (a) JPA techniques, (b) JPAs, training, and job design, and (c) JPAs and automatic test equipment.

Future R&D

1. Initiate research and development efforts to fill performance data gaps in the JPA technology base and to explore the feasibility of new concepts for JPAs.

2. Develop a scientific and technical approach for identifying, developing, testing, and/or evaluating principles and methodology applicable to the implementation of advanced technology into Navy weapon and logistics support systems.

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INTRODUCTION

Robert E. Blanchard
Navy Personnel Research and Development Center

Problem and Background

Currently, the Navy (as well as other services) is faced with burgeoning personnel costs accompanied by decreasing personnel force levels and declining entry-level skills. Maintaining required operational readiness levels under strict budget limitations is an ever-increasing problem.

A substantial amount of data, collected over the past 20 years by the Army, Navy, Coast Guard, and particularly the Air Force, suggest that job performance aids can be employed to enhance performance of lesser-trained or lesser-skilled individuals, and to reduce training and maintenance costs.

For example, in a study of low-cost ownership for the Army, Shriver and Hart (1975) estimated that savings approaching $1.7 billion annually could be realized in Army personnel, training, and maintenance costs through the use of JPAs. In a study for the Advanced Research Projects Agency, Rowan (1973) estimated that the use of spares in electronic maintenance could be reduced by 30 percent through JPAs. The study completed for the Navy by Post and Brooks (1970) showed a 25 percent reduction in aircraft maintenance waiting time through a change in maintenance workload permitted through use of JPAs.

Although potential payoffs in performance increments and cost avoidance appear to be readily available from JPA technology for the most part, JPAs have been implemented only in piece-meal fashion by any of the military services. Recently, the Army initiated a single program involving concurrent development of training materials and job performance aids, which is called "Improved Technical Documentation and Training" (ITDT). More significantly, the program could have been labeled "Integrated Technical Documentation and Training," which would be more descriptive of the impact the study could have in military personnel and training. Conversely, the Navy and Air Force to date have been reluctant to modify current policy with respect to integration of training design and job performance aids and have chosen to seek further evidence of JPA payoffs and potential impact on current personnel systems.

Although most of the previous research shows positive results with use of JPA technology, several criticisms have been raised. Rowan (1973), for example, was critical of the experimental designs and statistical analyses used in many of the studies; however, he agreed with the conclusions drawn regarding the performance-enhancing and cost-saving properties of the JPAs tested. Another complaint is that there have been few studies that compare one JPA to another, and since there are literally hundreds of systems that claim JPA-like features, a program manager or other decision maker has little data at hand to aid him in selecting a particular JPA approach.

Purpose

NAVPERSRANDCEN currently is conducting a major effort concerning the test and evaluation of job performance aids per se and their integration with current Navy personnel and training systems. Although a thorough literature review and critique were performed, it was felt that full understanding of the current state-of-the-art with respect to JPA technique applicability and potential negative impact effects was not at hand. Further, there were insufficient data upon which to base the always critical decisions regarding maximum payoff for R&D time and funds invested; that is, what approach do we take to get the most of our time and money?

Approach

As one approach toward resolving this dilemma, an invitational conference was organized to which a limited number of nationally recognized experts within the field of JPAs were invited. Each was asked to prepare a technical paper on an assigned topic. Informal discussion among the group was planned following each paper.

One major area addressed concerned defining the current state-of-the-art in JPA technology, particularly as regards personnel and training implications. There is a host of JPA techniques and approaches apparently ready and available for use. However, insufficient guidelines are provided for selecting the optimum approach, considering such factors as personnel characteristics, job tasks, environment, procurement resources, and so forth. The very first step, then, that of selecting optimum JPA approaches for demonstration, was not readily available as part of the JPA technology base. Also, issues concerning the potential impact on personnel and training from JPA applications could not be addressed directly without a better definition of the JPA technology base.

A second area concerned obtaining a better overall conceptualization of job aiding; problems in procuring, producing and evaluating JPAs; and major considerations in obtaining acceptance by both procurement officials and operational users to ensure JPA utilization. This topic was intended to bring together the experiences and views of individuals in the logistics, technical data, production, and research and development communities.

Finally, conference participants were asked to identify and/or recommend approaches for integrating JPA technology into the Navy personnel and training system for the 1980s. Attention here was also devoted to the various types of training and delivery systems that would be involved. Also, perceived problems in integrating JPAs into existing personnel systems were noted, particularly those concerning career structuring, advancement in rank, assignment procedures, and recruiting and retention. It would seem that, to the extent the objectives of integrated JPAs are met, the military services will be that much closer to realizing the full, potential benefits of JPA technology.

SOME PERSPECTIVES ON THE JOB PERFORMANCE AIDS TECHNOLOGY BASE

John J. Collins
Essex Corporation

Introduction

It appears desirable to begin our discussion of the JPA technology base with a statement of the principal elements of that base. In this paper, I will be including theories, principles, methods and techniques, data, and applications experience related to JPA development and utilization when I refer to the technology base. In this context, the literature on job performance aids indicates to me that the technology base is still very much in an emerging and developing stage. It seems to be undergoing a metamorphosis at this time, which is providing an opportunity to capitalize on the accomplishments of the past in being responsive to the demands of the present and the future. It is within this general premise that I wish to direct my comments today. It is not my objective to try to address all of the elements of the technology base or to focus on specific elements in a comprehensive way. Rather, I will try to provide some perspectives on selected developments that are influencing the evolution of the technology, to examine some of the issues relevant to the purposes of this symposium, and to suggest some research and development needed to continue progress in JPA development and applications.

Some General Characteristics of JPA Field

First, let us look at some general characteristics of the field of job performance aids. Ayoub and his colleagues (Ayoub, Cole, Sakala, & Smillie, 1974) have reviewed several aspects of the status of job performance aids development and utilization and provide some interesting insights. For example, they found that 78 percent of authors made no more than a single contribution in the last 20 years. They conclude that this clearly indicates a small rate of retention of JPA researchers and practitioners in the field. They also found that state-of-the-art JPA developments have centered on the efforts of single individuals rather than groups of individuals. Another measure they used is the number and distribution of publications. From their data, they concluded that the growth in the state-of-the-art is rather slow. The statistics cited are that only 23 percent of the JPA literature appears in scientific and technical journals, and that there has been a drop in the number of publications from a high of 40 in 1971 to 4 in 1974. However, a different perspective can be gained by further analyses of their data. Grouping the data by decades, we find that the averages for 1950-1959, 1960-1969, and 1970-1974 were 4.7, 14.3 and 19.6 publications per year, respectively. From this grouping of data, one might well conclude that the rate of growth is increasing rather than decreasing. Determining whether the growth rate is slow, moderate, or fast requires a more definitive analysis and collection of relevant measures than is contained in this study.

Major Conceptual and Theoretical Trends in Work and Work Situations

Next, let us look very briefly at some of the directions and emphases in work and the work situation developments and their significance for JPA developments. We have moved during the past 100 years through a series of conceptual and theoretical developments (Barrett & Dambrot, 1975; Barrett, Dambrot, & Smith, 1975). The concern during the last century was on physical exertion and how much physical work a man can perform in a stated period of time. In the early 1900s, this concern with physical capacity was extended to include simplification of the task and the "one best method" to perform each individual job. Later, factors of fatigue and rest and their relationship to productivity were emphasized. From that orientation, we moved to improvement of equipment, tools, work space, and body movement--the industrial engineering approach. These early models assumed that productivity could be maximized by designing jobs for the persons with minimal ability and motivation. Work simplification and detailed specifications of task requirements were believed to reduce the importance of ability and motivational levels. Other assumptions included the absence of any consequential interactions between individual attributes and work characteristics that would influence performance.

The emphasis shifted during the early 1940s from this concern with physical work to mental work; that is, sensory, perceptual, and decision-making abilities required in complex man-machine systems. Simultaneously, the shift from the work simplification and work specialization emphasis to work motivation concepts took place, and theoretical and empirical studies relating to various forms of motivation increased. The basic theoretical framework for much of this emphasis came from Maslow's Hierarchical Theory of Motivation and Hertzberg's theory of intrinsic-extrinsic motivation, the orientation in these theories again being to minimize interaction between individual abilities and attributes and job structuring. A sociological approach focusing on groups and group differences and interactions with jobs and group membership also appeared. This was the first explicit statement of the interaction effects of cultural values but only at the group level.

Motivation theory has provided the framework for much of the recent attention to individual worker needs, motives, and perceptions. Theories of job enrichment, job enlargement, vertical and horizontal loading, etc. consider factors of job content, various psychological states, and productivity that are moderated by workers' growth need strength. Models have developed with consideration not only of individual perceptions and motives but also ability to perform a job and other individual attributes as they interact with job design and performance. Still other approaches encompass concepts of organizational development or management by objectives. Early work in small group research has brought about models that view jobs as a complex field involving organizational, technical, and personal aspects. This theoretical orientation focuses on the relationship among technology, organizational structure, and human interactions in work groups, and on the goals of satisfying both organizational task requirements and human requirements.

New conceptual approaches to job structuring that have developed include: (1) a behaviorally descriptive approach, (2) a task requirements approach using behaviorally-oriented dimensions, (3) an approach labeled "task-qua-task" that focuses on the physical properties of the task, and (4) an abilities requirements approach. New methods and techniques have also been developed for defining and measuring tasks in a variety of ways. These methodologies include a rational approach to task taxonomy, observation and rating scales by experts, ability reference tests, and quantification of the physical properties of a task. Especially significant are the renewed and increasing developments in the areas of group performance and productivity. All of these techniques represent capabilities that can be applied or adapted for application to meet various requirements for JPA developments.

Briefly, we might state that we have witnessed the development of a technology base in work and work environments with shifts in emphasis from the machine to the human element, from work tools and methods to work context or the work itself, and from management goals of profit and loss to joint organizational and human goals. In the process, numerous and diverse theories, concepts, and approaches have been developed and are being tried. Applications can be found in all sections of the society including the military establishments at the present time. Thought is also being given to the future, and an interesting and original set of papers on work and nonwork in the year 2001 was recently published by Dunnette (1973).

Recent developments and emphases in work design and work environments on the quality of life have some parallels in learning theory. For example, the experiential learning model and its practical counterpart, the action research method, has its foundation also in Lewinian theory (Kolb & Fry, 1975). The underlying concept is that learning, change, and growth are best facilitated by an integrated process involving immediate experience, validation of that experience, modification of that behavior, and the choice of new experiences. Without presenting an in-depth description of this theory, I would point out that the theory (1) provides a framework for the integration of the cognitive and socioemotional perspectives in the learning process, (2) allows for the recognition and description of individual differences in learning styles that shape behavior not only in traditional educational settings but also in the individual's basic mode of adaptation to the world around him, and (3) describes the life cycle of human development through various stages with their differentiating learning styles.

These two brief looks at major conceptual and methodological developments in the work and learning areas suggest to me some general criteria or requirements for the further developments of job performance aid technology. Perhaps it would be useful at this point to pose these in the form of questions that might be further examined in this paper and in our discussions--questions that appear helpful in establishing a capacity to store information for later retrieval in connection with the performance of a job. The aid facilitates performance by reducing the memory and possibly training requirements imposed upon the performer. Joyce (1975) has advocated the integration of a JPA/Job-oriented training approach. Folley (1961) also defined JPAs as aiding in information handling.

Wulff and Berry (1962) stress the guidance aspects of job aids rather than their use as reference materials. That is, an aid is something that guides an individual's performance so as to do something he was not previously able to do. To these authors, achieving stimulus control is essential in good job aid design. Rowan (1973) has emphasized the guidance role of JPAs and believes the aids are people rather than equipment-oriented. Chalupsky and Kopf (1967) address the information content and instruction aspects of aids and the facilitating effect on performance by relieving certain job demands. Lewis and Cook (1969) provide a different information approach entitled "Theory of Telling," a unidirectional communication between man (user) and a JPA. Since there is no feedback from the user, they point out that the design of JPAs must be responsive to a model of the user's abilities, limitations, and processing functions. Pictorial and linguistic channels are the primary means of telling. Algorithms in the form of question-and-answer flow charts and question lists are used as improvements over traditional prose. Wolfe (1975) at NAVPERSRANDCEN has been developing a related capability as an aid for independent study through automatic question generation (AUTOQUEST).

Another perspective on the technology base can be gained from a look at two analyses of job performance aid developments by Main, Harrigan, and Hooprich in 1971 and Rowan in 1973. Main et al. have been interested in identifying methods for furthering job aid development and especially implementation (Main et al., 1971; Main, 1974). In the 1971 study, they point out, from their review of the literature, three limiting influences on JPA developments and utilization. The first is a lack of conceptual development as a class of devices; the second is the narrowness of research; and the third is the failure to establish effective methods of implementation. Main's recent report (1974) used a mail-out questionnaire approach to determine the adequacy of current uses of JPAs, to identify the requirements for increased utilization of aids, and to elicit suggestions for JPA applications. He concluded that there is a recognized need for expansion of the implementation of JPAs and general dissatisfaction with the distribution of available devices. Main also found that the three types of assistance desired most frequently by respondents were in (1) equipment operation, (2) reducing time requirements, and (3) utilizing inexperienced personnel. These latter findings provide insight into both satisfactions and expectations of users, approaches in job aid development.

A final example of an analysis of job performance aid developments is the study by Rowan (1973). His report presents the results of a comparison of innovative job aids versus conventional documentation. The concepts examined were developed between 1958-1972 and included aids such as FORECAST, JOBTRAIN, SIMMS, PIMO, FPJPA, SAFEGUARD, and nontroubleshooting JPAs. While citing concerns about some of the evaluation approaches used, Rowan points out the many positive results reported in the literature in the development and application of these performance aids. The results include large reductions in training time; significant increases in performance as measured by number of faults located, time to complete tasks, number of errors, etc.; and effective use of performance aids by inexperienced personnel. Other positive assessments of new concepts in maintenance performance aids are contained in the proceedings of the 1975 Naval Training Equipment Center symposium on this subject (King & Duva, 1975, U.S. Navy, 1976) and the Second Annual Job Information Presentation Conference (Rowan & Genovese, 1976). In the summary of the King and Duva report King states:

> In summary, it is apparent from papers presented in this volume and in the discussions held during the 3-day workshop that the technologies required for significant improvements in maintenance are ready and available. What seems to be needed are adequate demonstrations to the user communities of those cost reductions and training benefits that are likely to accrue from use of these newer technologies.

In discussing the technology base definitions, concepts, and methodologies in the context of an analytical framework, there is the danger in a short paper of this kind that the more positive aspects might not be given adequate representation. There is a large body of information, well known to all of the participants in this symposium, in areas such as planning for JPAs, principles and techniques of development, design characteristics and specifications, classification and categorizing systems, production and implementation, and test and evaluation, including criteria of cost, accuracy, and time. This technology base supports the well-documented objective of all JPA approaches of providing in a single package complete and current information to the user with minimal need for cross-referencing and retention.

Suggested Areas of Research and Development

I would suggest, however, that there are several research and development problems needing resolutions to improve this technology base as well as to meet the demands of broader objectives that have been proposed for the use of JPAs. These objectives require new capabilities that, in some instances, are conceptually and methodologically more complex and more sophisticated than the existing technology base will support. For example, the objective of fully integrating job performance aids into the mainstream of manpower, personnel, and training systems requires not only refinements and improvements of present capabilities but also additions to the technology base that are consistent with supportive theoretical, methodological, and operational developments. This objective requires a dual strategy of improving the known and searching for the unknown--or at least the yet undeveloped.

With this strategy suggestion in mind, let me end this brief presentation by enumerating some JPA capabilities requiring research and development. These areas of needed research are presented without comment for possible discussion during the symposium.

1. A general method for assessing and evaluating JPAs.

2. An improved data base developed through experimental investigations and field data collection for designing and producing JPAs.

3. Specific quantitatively-oriented rules and guidelines for developing and producing JPAs.

4. Improved distribution and delivery systems for available and future JPAs.

5. Techniques for collecting and processing detailed requirements information for JPAs.

6. Cost-effective approaches to JPAs.

7. JPAs keyed to group performance requirements.

8. Alternative uses of JPAs, e.g., for feedback and system updating.

9. Principles and techniques for designing JPAs to fit previous learning, job, and life style.

10. Approaches for integrating JPAs early into the system planning and acquisition cycle.

11. Approaches suited to the more complex dimensions of job performance requirements.

12. Decision criteria and tradeoff techniques for determining optimum JPA uses.

SELECTION OF FORMATS AND MEDIA FOR PRESENTING MAINTENANCE INFORMATION

Theodore Post
BioTechnology, Inc.

Problem/Current Situation

To convey the idea of the format and medium selection problem, Figure 1 lists some hypothetical hardware systems and a few available specifications. The problem is to choose one or more of the "TM Specs" on the right to meet the maintenance information needs of the systems on the left. At present, the Navy has no consistent method for guiding component engineers or Program Managers in making this choice. As a consequence, the decision maker usually chooses: (1) the safe spec (15071G), (2) the spec he used last time, or (3) the spec that was touted by the last visiting salesman.

I contend that this inconsistent approach to choosing technical manual (TM) information can have adverse effects on TM usage. This type of selection process can have unfavorable effects on costs, training effectiveness, manpower utilization, and system effectiveness. However, a number of these TM problems can be avoided during the selection process.

One unfavorable effect is that TMs are not getting the utilization we expect. The lack of use is evident in the data presented in Table 1. (Only columns 1, 3, and 5 are relevant to the point being made here.) The amount of man time (MT) spent using the "tech orders" (column 3) compared to elapsed time (column 1) varies from 0 to 24 percent, the mean being 3.5 percent. Scant use of TM information obviously. However, the number of minutes of procedural problems (column 5) is also quite small. This implies that maintenance actions (MAs) are completed acceptably. Maybe underutilization of TMs is not really a problem.

Table 2 provides information to address the quality of performance question. The table presents the results of a survey of workcenter chiefs who were asked which of their men could perform the workcenter's MA (for F4Js). Only non-troubleshooting MAs were included and, even so, the average man could perform only 65 percent of the necessary MAs. If troubleshooting MAs were included, the figure would undoubtedly drop below 50 percent. These same chiefs were asked earlier what they thought contributed to their men's poor performance capability and the vast majority said poor retention. Thus, there is some evidence that TMs receive little use and personnel capability is suspect.

The Warrants Approach

Objectives

The warrants concept hypothesizes that TMs are not used because of mismatches between TM characteristics and conditions within the system being supported. Thus, TM potential to improve technician performance and maintenance effectiveness is not maximized.

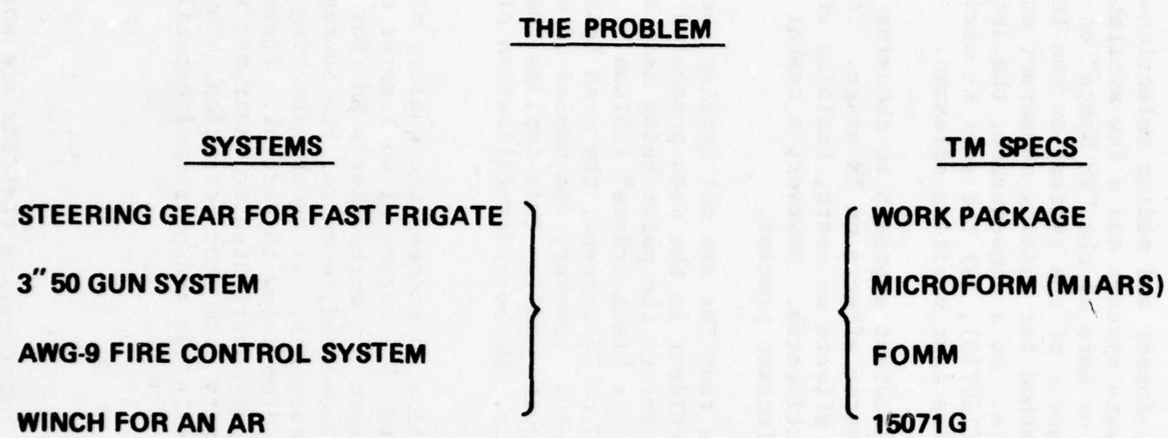

Figure 1. Format Selection Problem.

Table 1.

Maintenance Man Time, by Maintenance Actions. (in minutes)

Function	(1) Elapsed Time	(2) Total Performance Man Time	(3) Tech Orders MT	(4) Tool Search MT	(5) Procedural Problems MT	(6) Misc. MT
Install Sync Elev	20.5	37.0	3.3	3.7		
Remove Sync Elev	18.5	13.5	1.7	2.2	5.0	1.0
Remove Lower Cabin Window	31.2	57.4		5.5	8.0	
Install Lower Cabin Window	53.3	97.6			2.0	
Install Landing Gear Assy.	48.3	103.9	1.0	2.2	13.4	
Remove-Install Servo Syb-Assy.	135.7	100.5	32.7	7.5	35.2	
Remove Main Rotor Assy.	43.0	93.3	0.7	16.3	11.3	
Track Main Rotor Blade	67.0	78.0		5.0		66.0
Replace Rotor Blade Assy. Bolts	109.7	157.8	3.7	14.3	4.0	2.0
Install Engine	81.8	130.8	15.3	15.2		3.3
Remove Engine	96.8	233.0		4.5	2.0	
Remove Fuel Control Assy.	64.8	110.3		7.3	2.5	0.7
Install Engine	47.5	153.3		0.7	10.0	3.0
Rig Throttle	43.7	42.8	11.8	5.7	2.2	
Install Engine	85.8	189.6		38.8	6.5	4.8
Remove Starter Relay Assy.	20.7	27.7		2.5	3.7	
Install Starter Relay Assy.	84.0	80.2	19.3	5.2	16.2	0.8
11th Phase Insp.	63.8	32.5	1.0	2.3	29.8	10.0
12th Phase Insp.	207.7	899.1	27.5	6.3	7.0	1.2
15th Phase Insp.	85.2	379.4	5.3	2.0		
TOTALS		3017.7	123.3	147.2	158.8	92.8
% of Total Maint. Man Time (3539.8 min.)		85.2	3.5	4.2	4.5	2.8

Table 2.

Personnel Performance Capability for a Maintenance Workcenter (Typical)

ELECTRICAL WORKCENTER

Maintenance Action	Personnel									
	AE1	AE2	AE2	AE2	AE3	AE3	AE3	AN	AN	AN
Auxiliary Air Door										
operational check	X	–	X	–	–	–	–	–	–	–
troubleshooting	X	–	X	–	–	–	–	–	–	–
remove/install	X	–	X	X	–	–	–	–	–	–
Hydraulic Indicating System										
operational check	X	X	X	–	X	X	X	–	–	–
troubleshooting	X	–	–	X	X	–	–	–	–	–
remove/install	X	–	–	X	X	–	–	–	–	–

X = capability to perform independent of experienced supervision.

NOTE: Average technician is capable of performing satisfactorly on 65% of his workcenter's non-troubleshooting action.

The conditions under which MAs are performed change, sometimes even within one system, and, to provide best support, the TM must be compatible with these conditions. For example, some maintenance requires that the prime system be "down," not operationally ready. Other maintenance has no immediate effect on the readiness of the prime system. The warrants approach attempts to consider differences such as these in selecting formats and media for presenting a system's maintenance information.

Figure 2 depicts in a general way the range of outcomes that can be expected from a good and a poor match between TM characteristics and system conditions. The rays from "good match" and "poor match" flare out to indicate that, even with the best or worst of matches, there will be variation in both usage and performance effectiveness, due to factors such as morale, type of mission, and hardware design. The point is that, with a poor match, highest usage levels are not likely to be attained, and task performance and maintenance effectiveness will be short of their potential. The objective then is to match the characteristics of TMs to relevant conditions of the maintenance situation.

The number of TM options available for application to various systems is bewildering (Figure 3). Many of these options have been tested and indicate promising results; others have not been tested but are supported by research principles; and still others are merely ideas of interested persons. With few exceptions, notably those listed in Figure 1, these TM options have one thing in common--none of the services have adopted them for any but experimental applications. When examined closely for meaningful differences, most of the TM options fall into relatively few categories. In fact, a beginning can be made by considering TM options as variations of (1) proceduralized or (2) deductive aid formats.

It should be noted that the TM options vary in both format and medium (viz., recording mode, display mode, and access). The warrants concept contends that formats and media can be selected for each system on the basis of conditions within that system.

System Conditions and Methodology

Table 3 lists the current set of system conditions considered useful in selecting formats and media. Inasmuch as selection of TM options occurs early in the system development process, it is necessary to have system conditions that are identifiable early, and that are reasonably easy for a Program Manager to define. A major objective of the warrants approach is that we want to affect TMs when they are selected by a Program Manager, early in system development.

In addition to their ability to suggest TM formats and media, each condition affects one or more aspect of system performance (see Table 3). For example, if the TM format is selected to accommodate a certain rate of personnel turnover, the effect anticipated is that personnel cost-effectiveness will improve, as the technician will then have technical information matched to his performance capabilities. As shown in Figure 4, personnel turnover can occur in either of two states, each of which suggests a particular type of format. The format-medium indications of a single condition are not necessarily conclusive. However, the case becomes stronger if enough other conditions relating to the same TM decision are in agreement; or, if the other conditions disagree, tradeoffs are set up.

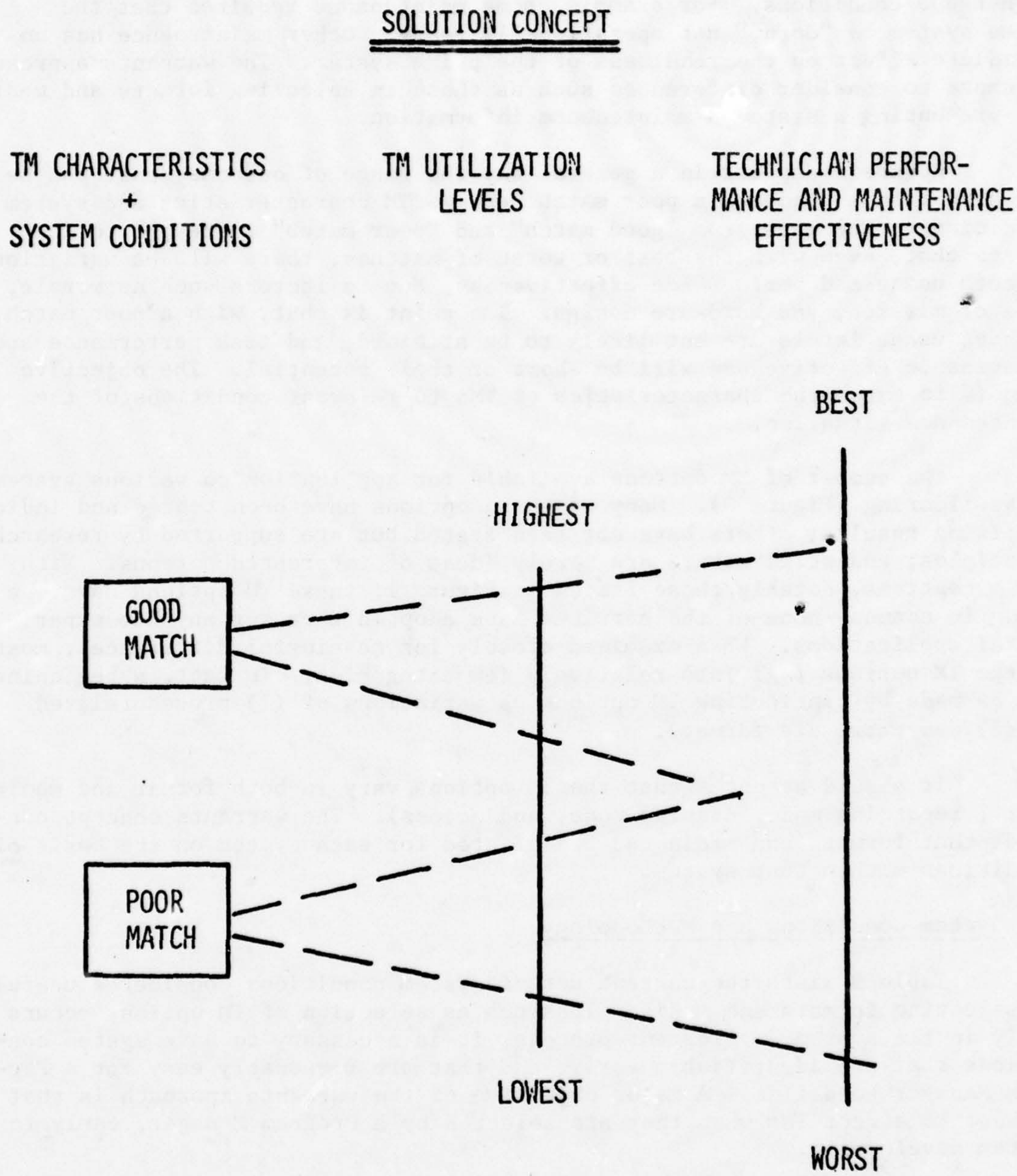

Figure 2. Solution Concept.

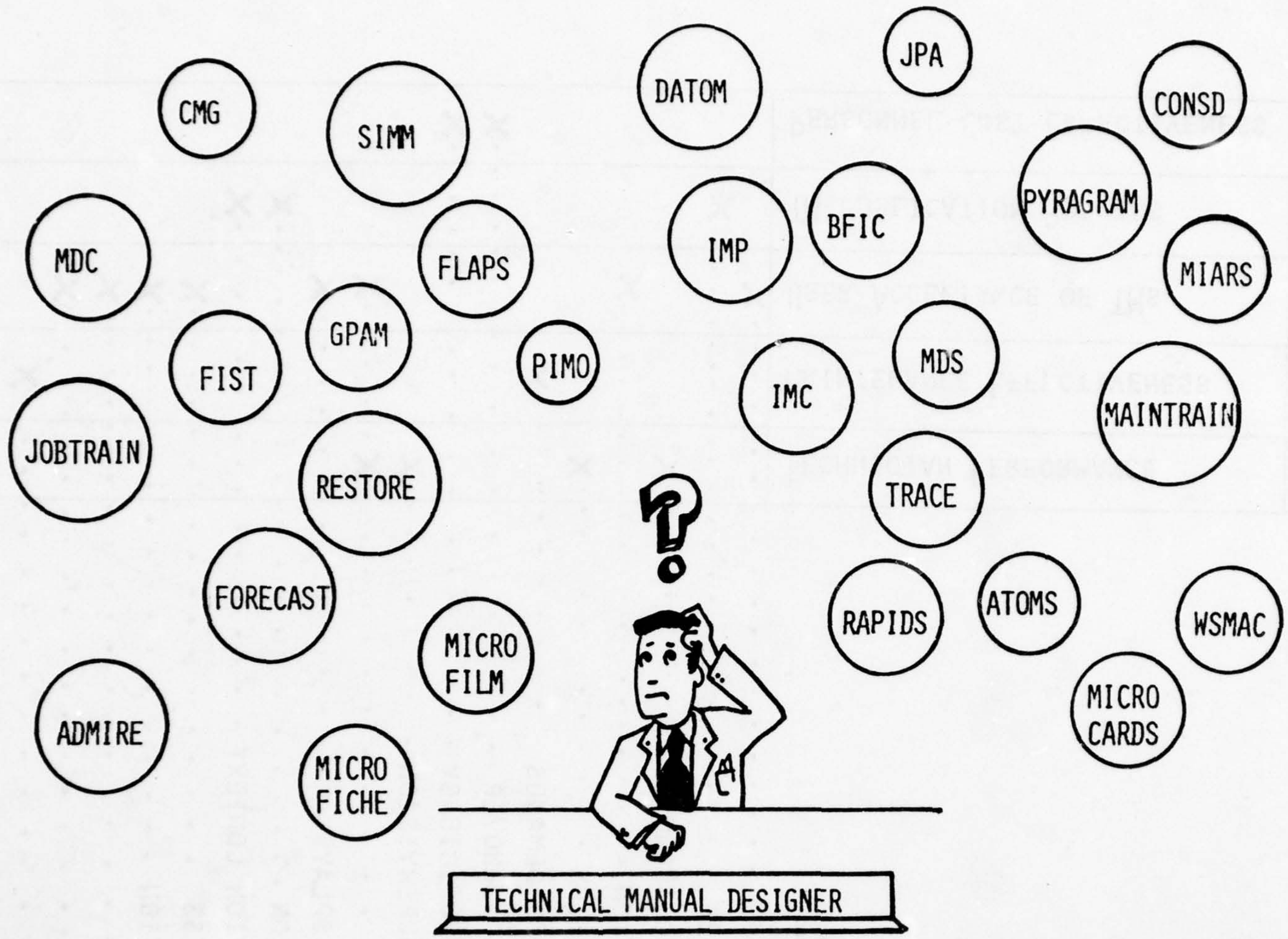

Figure 3. Some Available Format-Media Choices.

Table 3.

Impact of Maintenance Conditions

CONDITIONS	Benefit Area: Technician Performance	Maintenance Effectiveness	User Acceptance of TMs	TM Publication Process	Personnel Cost-Effectiveness
ATE			X		
System Size				X	
Diagnostic Technique	X				
Distribution			X		
Subordination	X				
Maintenance Demands		X			
Personnel Turnover					X
Time to Proficiency					X
Span of Supervision	X				
GCT	X		X		
Status Displays			X		
Replication				X	
Installation Context				X	
Cleanliness			X		
Illumination			X		
Workspace			X		
Elements			X		
Hierarchy		X			
Personnel Qualification System					X

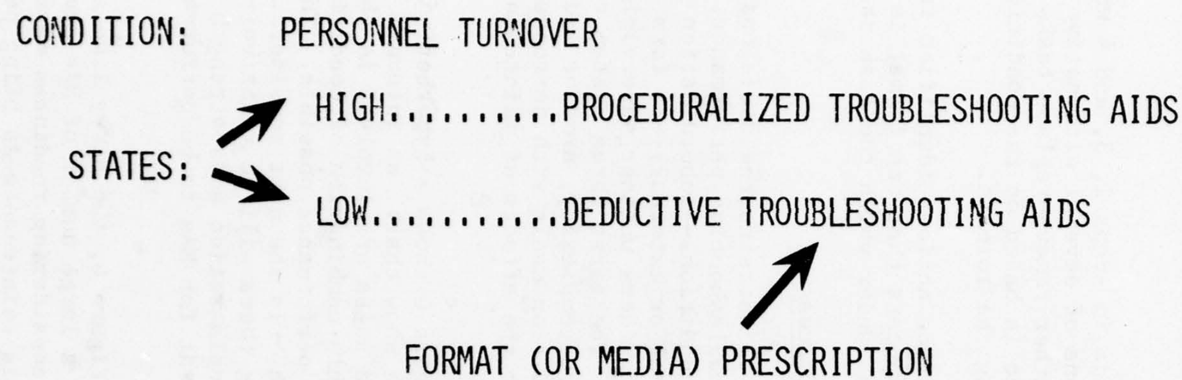

Figure 4. Format Choice as Indicated by Personnel Turnover.

The preliminary version of the warrants process relies on the 19 conditions of Table 3 to help select formats and media. These conditions are considered in a five-step methodology summarized in Figure 5. Step 1 of the process is a review of the Task Identification Matrix (TIM). The purpose of this review is to group tasks into sets that will economize on the number of format and medium decisions that have to be made. In this step also, information is gathered to defined the conditions of the system under development.

Format selections are made in steps 2, 3, and 4 while step 5 selects the medium. In steps 3 and 4, one of several alternative formats is chosen to support the performance of either remove-replace tasks (MAs) or troubleshooting tasks (MAs). The choice is based on the conditions referred to earlier and the cost of preparing the formats.

The special case maintenance actions identified in step 2 are unique types of tasks where it appears that one format is the most effective regardless of the conditions under which the task is performed.

Flow Chart of the Warrants Process

The Figure 6 flow chart illustrates the decisions to be made in selecting formats to support troubleshooting performance. The first choice in the chart uses two hardware conditions--subordination (high or low), and diagnostic technique (internal or external)--to form four possible combinations. The second choice considers whether supervision is available to support technician performance. The first three system conditions are intended to define task performance complexity, a major indicator of the type of format needed. The next condition deals with personnel turnover, while the last two conditions consider the effects of maintenance demands and system criticality.

The heavy outline of Figure 6 shows a hypothetical situation in which the first three conditions show that: an internal diagnostic technique is required, many hardware units are involved in the diagnosis, and no supervision is available. This combination of conditions is felt to represent the most complex task performance possible. This tends to suggest a proceduralized format approach. In the next consideration, personnel turnover is shown as "high," meaning there will be relatively few experienced technicians available. This consideration adds strength to the argument for use of a proceduralized format for MAs to be performed under these conditions.

Continuing to refer to Figure 6, the heavy line shows that maintenance demands are "batch" (i.e., a large number of MAs occur in near simultaneous fashion). The result of considering readiness impact indicates that prime systems are down while this maintenance is being performed. The need for the proceduralized format is at its highest, under these conditions (i.e., the proceduralized format has the best chance of allowing the inexperienced technicians to cope with the complex MAs without incurring backlogs that, in turn, cause readiness problems). All other possible condition combinations can be followed through to see how they become somewhat less critical.

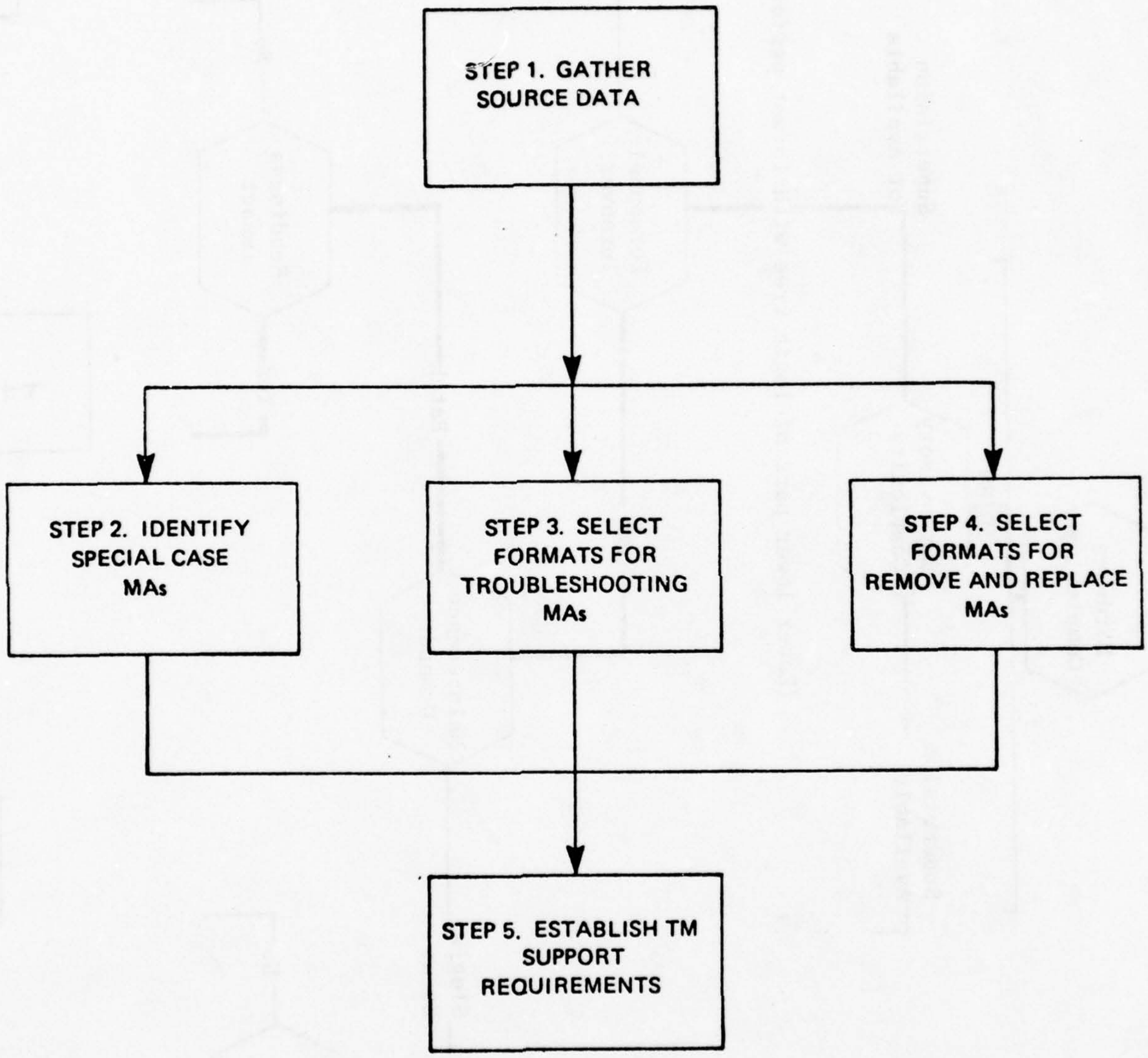

Figure 5. Warrants Methodology.

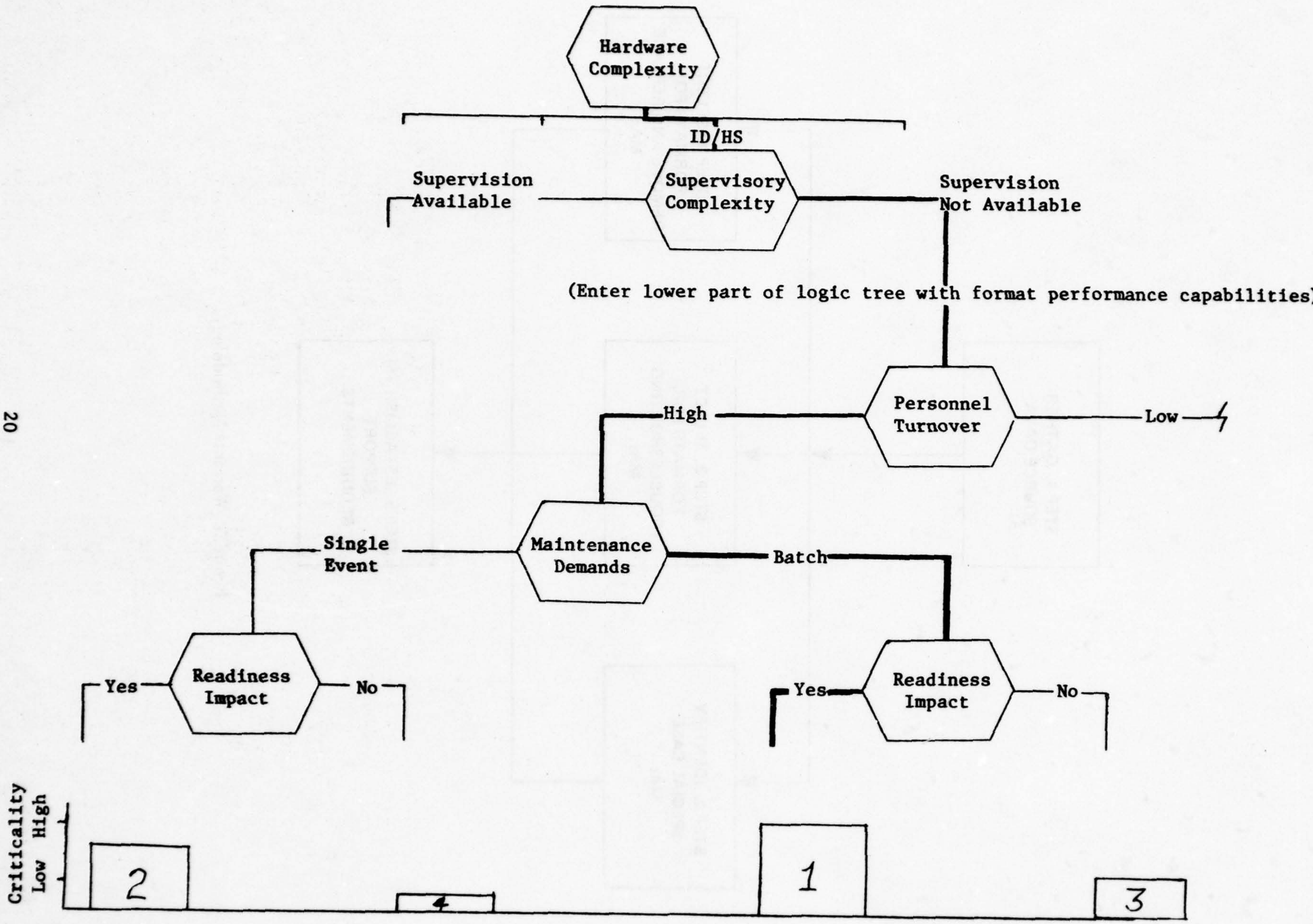

Figure 6. Format Selection Flow Chart.

Conceptually, the warrants approach attempts to structure the process so that the decision maker can base his choice on the type of comparisons shown in Figure 7. The need is to match the performance-fostering power of the TM format to the criticality of the maintenance-personnel situation in which the TM will be used. There is no point in spending money to buy unneeded performance capability (Figure 7, "excess"). Conversely, there is no point in saving money on TMs if performance capability of the format falls short of the need (Figure 7, "shortfall").

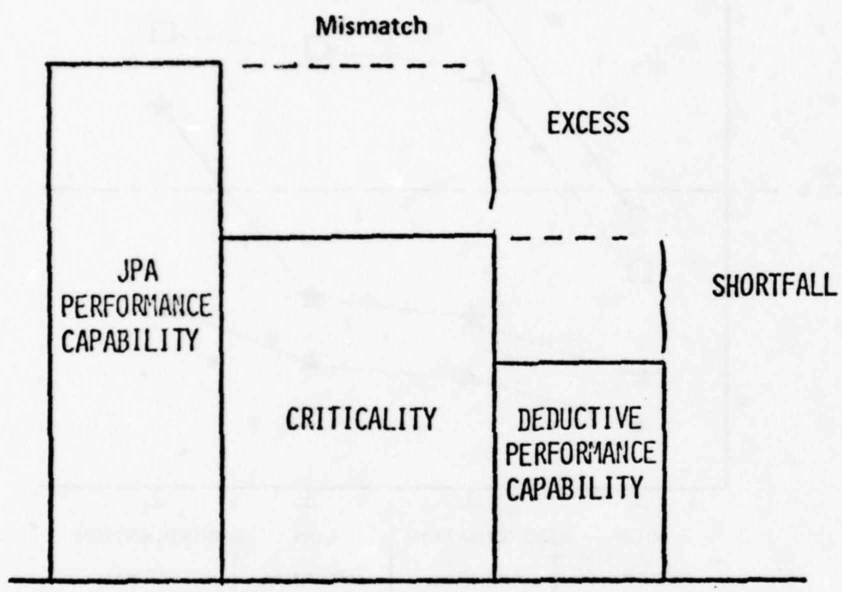

Figure 7. Mis-match of TM to System Criticality.

Demonstrating the concept requires actual data that ranks the relative strength of formats under various task complexities (the first three choices of Figure 6). Figure 8 presents a hypothetical plot of troubleshooting performance on tasks of four complexity levels. Note that the bottom scale of Figure 8 (MA characteristics) is not a continuum but represents roughly decreasing levels of task complexity from left to right. Several assumptions are indicated in this figure:

1. Performance by experienced technicians (open symbols) will be better than by inexperienced (solid symbols).

2. Performance with supervision (○ & ★) will be better than without (□ & ▲).

3. Performance will improve as task complexity decreases.

4. There may be interactions, such as inexperienced technicians with supervision (★) performing much better when the task involves low subordination and external diagnostic technique. The shaded region at the top of the figure indicates the expected range of performance with proceduralized job performance aids.

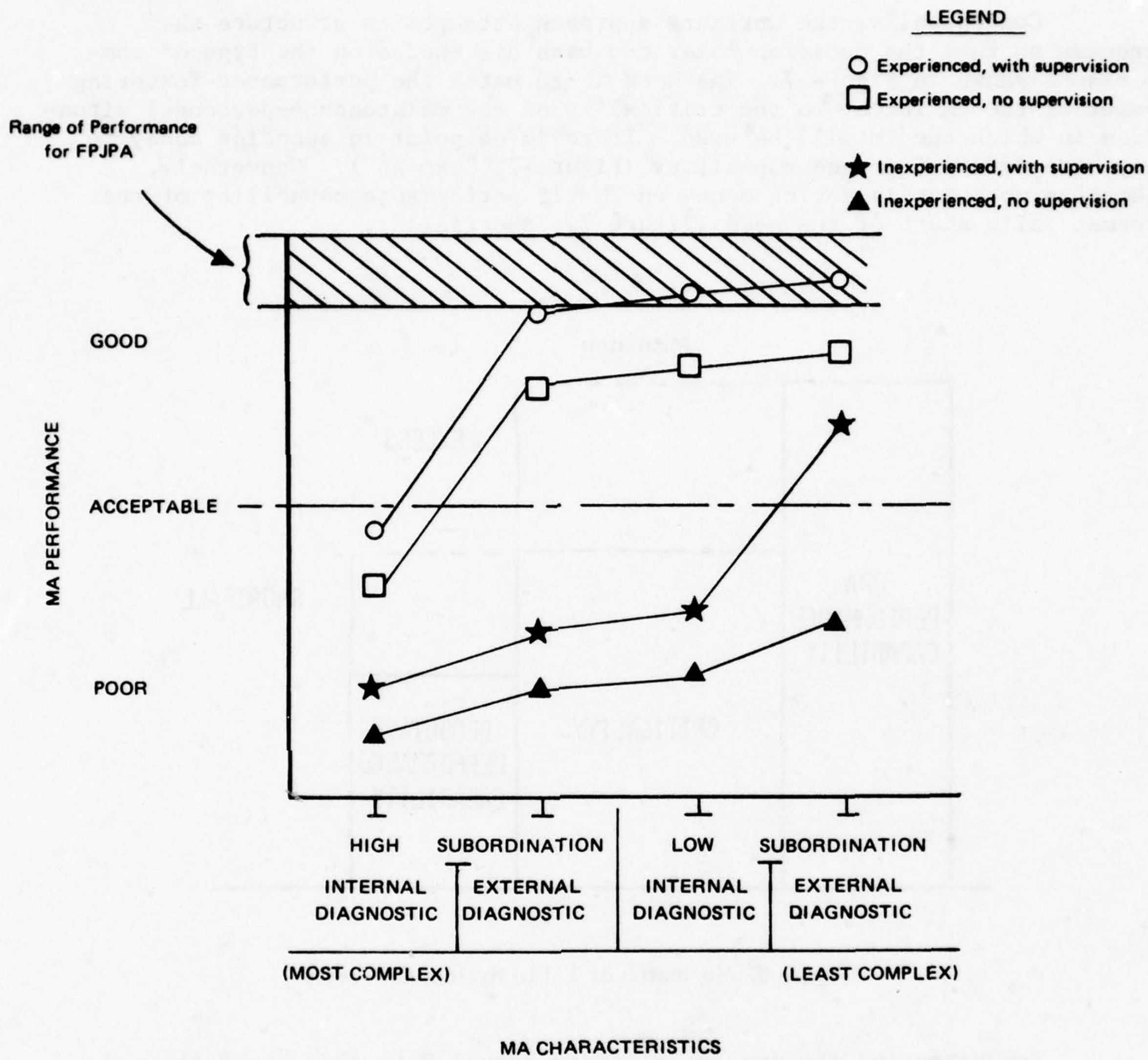

Figure 8. Plot of Troubleshooting Under Various Task Complexities.

Cost Considerations

To indicate how the cost considerations fit into the above picture, turn for a moment to Table 4. The amounts listed were arrived at using cost guidelines which are based largely on subordination (see Post, Price, & Diffley, 1976). Costs for two proceduralized and two deductive formats are shown for three levels of subordination.

Return to Figure 8 and consider the ID/HS condition (internal diagnostic/high subordination). Increasing performance above the "acceptable" line will apparently require fully or partially proceduralized JPAs. Performance quality alone, however, is not the sole criterion for this decision. In this example, if there is no readiness impact, maintenance demands are single event, and turnover is low, the need for a proceduralized approach softens. Cost of preparing information in the alternative formats should also be considered in this decision. If we assume a 1 to 12 subordination, we can see that there is a $2300 difference (per MA) between the fully proceduralized and simple logic formats. This large cost difference may combine with the relatively mild personnel and maintenance conditions to suggest the simple logic diagram format. The warrants methodology leaves the final choice to the Program Manager.

As another example, refer again to Figure 8 and consider the ED/LS condition (external diagnostic/low subordination). As indicated, performance with the deductive aid is good for three of the four personnel/task conditions. Referring to Table 4 and assuming a 1 to 4 subordination, the decision not to use a fully proceduralized format in this case could save $900 ($1100 - 200 = $900). Again, the decision is not likely to be this straightforward. There may be compelling reasons for using proceduralized aids even though performance is expected to be good with deductive aids. Personnel and maintenance conditions must also be considered. For example, if personnel turnover is high and maintenance actions occur in batches, there may not be enough qualified, experienced technicians to cope with the workload under a deductive aid situation. A lack of supervision could detract further from technician performance capability, while a prime system involvement would heighten the consequences of this lack. Thus, even though the deductive aid form is suggested by the hypothetical data of Figure 8 and by its relatively low preparation cost, the conditions of personnel turnover, maintenance demands, and readiness impact may show one of the proceduralized aid forms as the most effective in a life cycle sense.

Operational Model

Admittedly, all of these projections are theoretical. The costs, the task performance levels, and the relationships between system and personnel conditions are all subject to experimental verification. Despite the lack of direct empirical evidence, the approach seems credible and practical.

Table 4.
Costs of Format Alternatives

	Format Type			
Subordination	Proceduralized		Deductive	
	FPJPA	PPJPA	System Des.	Simple Logic Diagram
1 to 4	$1100	$860	$700	$200
1 to 8	2200	1720	1400	400
1 to 12	2900	2180	1700	600

To add to this credibility, the following text will use the warrants concepts to interpret some field test data that has been extended by using a simple model to represent the operation of a maintenance work-center (Post & Brooks, 1970). Table 5 shows the results of a field test that compared the performance-fostering capability of job guides with the format included in a conventional manual (viz., partially proceduralized).

Table 5.
Performance Quality with Conventional
Vs. Pictorialized (Job Guides) Presentations

FIRST TRIAL DATA – % SATISFACTORY PERFORMANCE

	Experienced	Inexperienced	Average
Existing Procedures	74%	63%	68%

	Experienced	Inexperienced	Average
Job Guides	100%	94%	97%

The workcenter model included a batch demand situation whose size was based on typical missions and equipment failure rates as defined by 3M data. The ratio of experienced to inexperienced technicians conformed to actual (high turnover) conditions; personnel assignment policy was based on current practice which reflected poor performance capabilities. Two runs were made with this model: one with the performance-fostering power of the conventional manual and one with the performance-fostering power of the job guide. Manpower utilization and maintenance queue comparisons resulting from these runs are shown in Table 6. These comparisons and the following points illustrate how the format selection process might work when fully developed. First, the tasks of the field test were chosen by workcenter chiefs to be those to which inexperienced technicians were not assigned, but if such assignments could be made, the workcenter would function more effectively. Second, the protocol of the field test did not allow the subjects to seek help from their peers or supervisors. On these bases, these tasks were given the highest complexity rating available, comparable to no supervision, internal diagnostic technique, and high subordination.

Table 6.
Potential Manpower Utilization Benefits of the Job Guide Concept

Maintenance Variable	Current Practice	Job Guides	Percent Change and Comments
Experienced Technicians			
Available for complex work	32%	49%	52% increase
Required for non-troubleshooting work	68%	51%	25% decrease
Inexperienced Technicians			
Full responsibility for non-troubleshooting maintenance	0%	83%*	20 of 24 man* hours available during 12-hour shift
Assisting and observing experienced technicians	71%	17%	
Available, but not required by the maintenance workload	29%	0%	
Time awaiting maintenance for lack of technicians	6 hrs.	4.5 hrs.	25% decrease
Number of maintenance actions failing quality assurance check	4	1	75% decrease

The work forces involved in the experiment were experiencing high turnover, meaning that there were relatively few experienced technicians available to process the incoming workload. The model assumed a 16-man work force, eight of whom might be available for unscheduled maintenance. These eight technicians were reduced to five to represent dayshift, non-troubleshooting; and three of the five were considered experienced, a very conservative reflection of the high turnover situation.

In the job-guide run of the model, inexperienced technicians were allowed to perform any tasks while in the conventional run and their use was limited to assisting an experienced technician in a two-man task or to observing an experienced technician performing a one-man task.

Moving into the maintenance conditions portion of the warrants process, the model dealt with system-installed tasks (e.g., removing a faulty component from the prime system, which means the prime system is out of commission during the performance of the tasks), and with batch arrivals of maintenance tasks. Figure 9 shows the particulars of the batch situation.

This combination of task, personnel, and maintenance conditions constitutes the most severe requirements the warrants process can generate. In this situation, we might assume that the fully proceduralized job aid costs some percentage more than its partially proceduralized counterpart and that this premium buys the personnel and maintenance improvements shown.

MAINTENANCE WORKLOAD

MAINTENANCE WORKLOAD GENERATED BY 6-7 LAUNCHES PER DAY.

EACH LAUNCH HAS 4-5 F-4Js AND CONSUMES 1.5 FLIGHT HOURS.

APPROXIMATELY 1.8 "FAILURES" RESULT FROM EACH FLIGHT HOUR.

EACH FAILURE INVOLVES BETWEEN 3 AND 4 MAINTENANCE ACTIONS.

TOTAL MAINTENANCE ACTIONS GENERATED: 185-190.

APPROXIMATELY 21 OF THESE PERFORMED IN THE CNI WORK CENTER.*

*15 OF WHICH ARE PERFORMED DURING THE DAY SHIFT. 5 MAINTENANCE ACTIONS REQUIRE 1 EXPERIENCED TECHNICIAN EACH, THE REMAINING 10 MAINTENANCE ACTIONS ARE 2 MAN JOBS.

Figure 9. Maintenance Workload.

In summary, our objectives in developing the warrants concept are as follows:

1. To make the selection of formats and media more systematic.

2. To match the cost and performance-fostering capability of formats to the needs of the system being supported.

3. To improve level of TM usage (acceptance) by tailoring formats to the needs of the users.

4. To justify premium costs of new formats in terms of maintenance or personnel benefits.

5. To consider task, maintenance, and personnel conditions to arrive at a mix of aid forms required by the system being supported.

What Next?

We are hoping to collect real data to replace the hypothetical and to prepare more specific guidelines for the Program Manager. Ultimately, we would like to have a tradeoff model using weighted system conditions and cost algorithms. We don't envision this model as ever being an "automatic" decision maker. We do envision a heuristic model that could be easily and reliably applied by the decision maker--the Program Manager.

PROBLEMS IN PROCURING, PRODUCING, AND EVALUATING JPAs

Frank Johnson
REM Company

Procurement, production, and evaluation of JPAs should be discussed as a part of the broader technical manual problems. This provides context within the requirements for the logistic support elements and specifically, the function served by technical manuals for maintenance and maintenance training. If we ignore these continuing problems, the potential of JPA effectiveness may never be realized. After all, a JPA is a form or part of a technical manual; it is procured by technical manual people; it is written by technical writers and used by operators and maintainers.

JPA Production and Utility Problems

A survey conducted by the National Security Industrial Association (NSIA) and reported in December 1974 identified problems of importance to the utility and user acceptance of technical manuals. These problems are closely related and directly affect the procurement, production, and evaluation of JPAs for training operators and maintainers. The survey subjects included:

1. Readability--Comprehensibility
2. Reading Grade Level
3. Presentation--Verbal, Graphic, Pictorial
4. User Problems
5. User Skill Level
6. Critical Job Performance Factors

The survey was initiated to develop a data base for recommendations to the Chief of Naval Material. The recommendations addressed problems of writing, training, operating, and maintenance manuals to fit the average level of comprehension of Navy personnel.

The technical manual problems identified and directly related to the Navy Personnel and Training Utilization of Job Performance Aid (JPA) Technology are discussed in the following paragraphs.

Organization of Technical Manuals

The survey, through discussions with users and producers of technical manuals, indicated that the manual organization is equal in importance to factors such as readability and comprehension. The following excerpt from the introduction to NAVTRADEVCEN 69-C-0301-1 is quoted: "Technicians express a great deal of frustration with 'just trying to read (maintenance manuals) . . .' and in 'trying to simply find out what is in them . . .'"

The significance of this problem to the procurement and production of JPAs is that the equipment maintenance or technical manual has in it sections and information used by others than operation and maintenance personnel. For example, "General Description" is a section of importance to planners, users, and others requiring information not covered in the Maintenance Sections. Therefore, the planning and procurement of technical manuals must specify what sections require JPA treatment, what sections do not, where the overlap is, and how they complement each other. Without this kind of systems planning, the benefits of JPAs are lost in the maze of thousands of pages of manuals describing some systems (e.g., F-14 manuals exceed 25,000 pages).

Importance of Maintenance Sections

The terms "Technical Manuals" and "Training, Operating and Maintenance Manuals" are too general. Various studies and reports bear out the conclusion that certain sections of manuals are more important than others in the maintenance of equipment. These are "Action" sections. They include check out, troubleshooting, repair and replacement, and other job-oriented maintenance functions. Sections containing theory, description, parts lists, diagrams, schematics, and drawings are reference material.

JPAs, Job Guides, and Logic Tree Troubleshooting Aids are "Action" maintenance aids. They should be identified by the procurement people for JPA treatment during the initial publications planning stage.

Manuals Contain Too Much Data

The survey indicated that: "Technical manuals contain much more data than is required by the maintainer at lower levels of maintenance. The number of pages could be dramatically reduced if the needs of the maintainer were identified and coordinated with his training."

Manuals are identified and written to a specified level of maintenance. Today's JPAs have been largely devoted to the organizational and intermediate levels. It is the intermediate level that contains a variety of material that is not action type or performance oriented. This material includes diagrams, tables, and drawings not greatly improved by JPA treatment.

To make JPAs where they are not applicable or useful is a waste of time and money. Unfortunately, technical manual specifications leave to the contractor the option as to treatment in many areas without direction from the government.

Utility

The utility of a maintenance manual, or the quality of being useful, depends on several factors. These include organization, format, technical accuracy, the use of illustrations, and many others such as media and technique of presentation. The utility of a maintenance manual also depends on weapon system logistic support interdependencies at each level of maintenance; that is, test equipment and trained personnel (maintainers).

It is in the area of utility that the JPA potential seems to lie; more so, if maintenance training can be conducted using the actual JPA that will be in the technical manual.

Needs of the Maintainer

The utility of the maintenance manual is directly related to the background of the maintainer. It is a tool he may or may not use. If his background includes extensive equipment-related experience in isolating a particular fault, he needs only simple test equipment or limited manual assistance. He is guided by equipment cues and his background. On the other hand, the novice needs all the help he can get. He must be led step-by-step by the maintenance procedures in checking out the equipment and in the use of the test equipment to isolate the faulty component. Ideally, the maintenance manual would complement or make up for deficiencies in the maintainer's education, training, and experience.

The ideal maintenance manual would contain only action information oriented to the maintenance task. It would be entirely job oriented to serve as a maintenance aid to the maintainer. All other data would be reorganized and included in reference data manuals or some other format or media.

Technical Data Development Processes

A recent study conducted by REM Company (Martin & Johnson, 1975) for the Naval Air Development Center (NADC) investigated the Technical Manual and Engineering Data Base Interface. This report was reproduced by the Naval Ships Research and Development Center, Carderock, Maryland for distribution. Pertinent excerpts or comments appropriate to the procurement, production, and evaluation of JPAs are included below.

> The methods the defense industry typically employs to develop technical manuals and training aids for maintenance are obtained from four sources:
>
> 1. The published state-of-the-art
> 2. Historical data on similar systems
> 3. Engineering data on the system
> 4. Professional expertise of technical writer
>
> The range of professionalism in technical manual organizations is described. Because innovations are deemed to have minimal effects below a certain level of professionalism, this task report uses data and draws conclusions based on the methodology of companies with technical manual departments ranking high on the range of professionalism and ranging from large to small in size.

Both the substantial, and the time-phase, relations between technical manuals and training aids and their primary data base (engineering data) are charted and described. It is noted that the development process for both technical manuals and training aids begins with the generation of some kind of an intermediate data base from the primary base of engineering data and the professional knowledge, skill, and experience of the technical manual writer and/or training aid writer.

The vital role of engineering data in the development of technical manuals and training aids is described. It is demonstrated that engineering drawings are a type, form, or precise and detailed model of the equipment. When properly made and available in a timely manner, the engineering drawing model can be examined, analyzed, manipulated, and exercised to develop maintenance information for technical manuals and training aids with much of the work completed before the first hardware is available.

Engineering drawing schedules coincide closely with hardware manufacturing schedules. Seldom are technical manuals and training schedules contractually reconciled with each other and with the schedules for engineering and manufacturing. There are management practices and techniques that can be taken to minimize these difficulties and some companies utilize them when not contractually inhibited.

Use of Technical Manuals in Training

The DoD customer continues to raise the question, "Why can't technical manuals be used in training?" The NADC report indicates that only 39 percent of companies surveyed coordinate training manuals with training requirements. The reasons cited below apply to problems in usage of the JPAs in maintenance training:

1. Training tends to overtraining by teaching many prerequisite courses which are not coordinated with technical manuals.

2. Customer schedule requirements for equipment, training, and technical manuals are not structured to optimize technical manual availability based on engineering data release and on validation; and training programs are not scheduled to coincide with technical manual availability.

3. Customer quality requirements are not the same for technical manuals and training. Training can be, and is, conducted with data and material that lags considerably behind the hardware configuration to be delivered. On the other hand, technical manuals must be accurate and configuration accountable. Because of the dialog in face-to-face confrontation between instructor and pupil, many shortcomings in training material can be easily compensated; something that is not possible with technical manuals. This quality gap tends always to keep technical manuals in lagging phase with respect to training.

4. Technical manuals emphasize theory too much and diagnostics and repair too little.

CDRL Interdependencies

DoD requirements are specified in a Contract Data Requirements List (DD-1423). These data items are shown in Figure 10. Common to every element is engineering data.

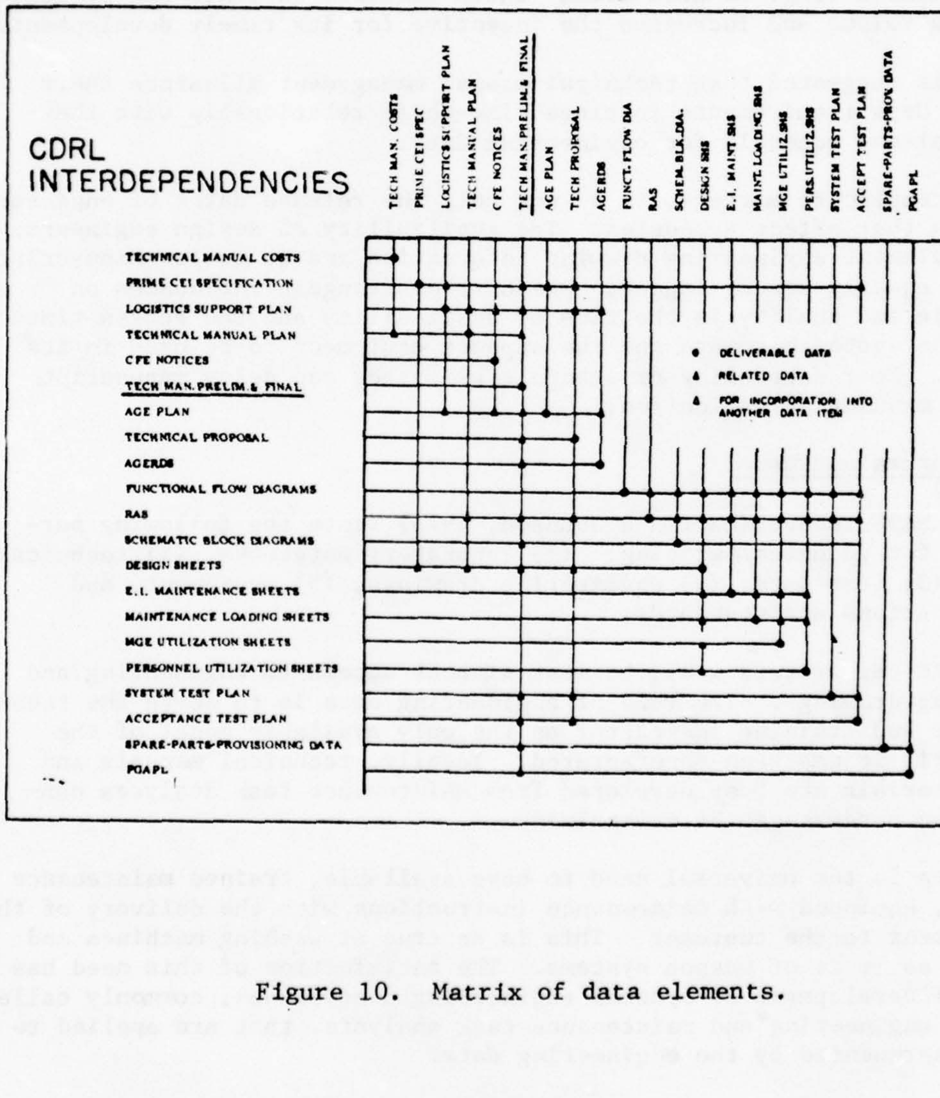

Figure 10. Matrix of data elements.

In dealing with the timeliness of data, suggestions are made concerning those actions that both the military customer and the contractor can make to assure timeliness of data. Contributing to timeliness is common usage of data items by functional organizations of the customer and the contractor, especially the latter. Where common data item usage is not imposed, each functional organization of the contractor will respond to schedule pressures by developing (insofar as possible) its own band of engineering data. This practice can be costly and sometimes does not permit even a low quality product or service to be delivered on time because final delivery is contingent on release of the authorized engineering data. Common usage of data items (which requires customer acquiescence) reduces data volume and increases the incentive for its timely development.

It is suggested that technical manual management milestone their engineering data requirements in close time-phase relationship with the realistic release schedule for engineering data.

To complicate matters, it is not only the release dates of engineering drawings that affect schedules. The availability of design engineers, both to supplement engineering drawing information and to review manuscript, can have an equally strong impact. One of the strongest influences on both schedule and quality is the time of availability and the access times to the weapon system hardware and the support equipment to be used in its maintenance. Poor scheduling or schedule slippages can delay manuscript writing and manuscript validation.

Data Sources and Uses

The NADC report (Martin & Johnson, 1975) lists the following pertinent data for technical writing: (1) laboratory notebooks, (2) technical memoranda, (3) test data, (4) engineering drawings, (5) equipment, and (6) specifications and standards.

Technical writers would be lost without access to engineering and manufacturing drawings. The role of engineering data is to serve the technical writer and training instructor as the only available model of the hardware until it has been manufactured. Ideally, technical manuals and training materials are best developed from maintenance task analyses conducted on the hardware to be maintained.

There is the universal need to have available, trained maintenance technicians, equipped with maintenance instructions with the delivery of the first equipment to the customer. This is as true of washing machines and automobiles as it is of weapon systems. The satisfaction of this need has entailed the development of special engineering disciplines, commonly called maintenance engineering and maintenance task analysis, that are applied to the model represented by the engineering data.

The role of engineering data in this process is often misunderstood. Many laymen think that engineering drawings contain all the knowledge to be imparted in training and technical manuals and that it only needs to be extracted and reformatted for training and technical manuals. This belief is wholly incorrect. Engineering drawings contain a wealth of information about the equipment that is essential to the content of training courses and technical manuals. But engineering drawings do not explain how anything works; they do not specify what can fail or how to troubleshoot failures; and they do not contain procedures for maintenance.

In short, engineering drawings portray what is to be manufactured but they do not, as a rule, tell how to manufacture or how to maintain. Contractors have process specifications and other documented manufacturing procedures usually referenced on engineering drawings or else required by operations manuals. These documents, when supplemented with Manufacturing Information developed for each set of engineering drawings, make them capable to direct the manufacturing process. No such data bank exists for training materials and technical manuals. Thus, all of this kind of information must be developed based on analyses of the engineering drawings.

Production and Evaluation of JPAs

The processes involved in producing technical manuals or JPAs are extremely complex and human error is possible at each step. There are, for example, over 50 major work steps between the time the contractor receives the work statement and authorization from ILS manager and the final negatives of a JPA are shipped to the printer. A flow chart of a typical development process for technical manuals and training materials is contained in the NADC report.

The validation and verification of technical manuals and JPAs must be planned and implemented from the outset of planning. Validation, in the strict meaning of the word, is the contractor's evaluation of his written maintenance procedures by performing them on the actual hardware. Simulation and desk-top substitutes for 100 percent hands-on validation have a very low yield (if any at all) in benefits. Not only does the hardware have to be available for validation but it must also have the deliverable configuration and it must be completely operable. In addition, and of equal importance, all GFE, all support and test equipment, tools, and spare parts must be available. Hardware availability for validation must occur about two-thirds of the way through a program for concurrent delivery of adequate technical manuals and for their effective use as a training aid for the first class trained by the contractor.

It is possible, of course, to produce some kind of technical manual from the engineering data and use it without validation and verification. This has frequently been done and the practice is one of the major causes for generally poor technical manual quality. But the ease with which this approach can be taken is probably responsible for the failure of government to schedule realistically.

Obviously, if a good validation is to be performed, planning and the logistical work to make hardware available and accessible must begin early and continue unabated until validation is accomplished. Of equal importance is the need to have access to the equipment in reasonable states of assembly for 100 percent hands-on task analysis (performance of and critical behavioral evaluation of each maintenance procedure) in the writing phase. If this cannot be done, there are only two recourses known to the industry at this time. One is to delay all procedural writing and do it at validation. The other is to write to the best judgment of the technical writer and rewrite (usually 70%) at validation. Neither approach is really acceptable but the latter must be firmly avoided to avoid major budget overruns. Neither approach is calculated to produce a good technical manual for the timely use of training.

USER PROBLEMS IN JPA UTILIZATION

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Introduction

Almost exactly 10 years ago, the Air Force hosted a performance-aids symposium much like the present one. Most of the attendees were familiar with each other's work, so the assigned topics were dealt with quite rapidly, and the bulk of the discussion focused on a common concern: frustration with the difficulties of getting our research findings implemented. There followed a period of several years of zealous, hard-sell activity during which the JPA community made quite a variety of enemies among military publications and logistic-support organizations, and few of our JPA concepts were adopted. Finally, within the last 4 or 5 years, accompanied by little or no fanfare, there has been a quiet infusion of JPA-like features into the maintenance documentation systems of most of the services. Although it is gratifying to see some of our ideas finally getting into the field, the satisfaction is a bit hollow: some technical manuals look more like JPAs now, but relatively few of the potential benefits of JPAs are actually being realized.

One of the areas extensively researched over the years has been that of "user acceptance." We explored many features of tech data and its presentation that affect the extent to which a user "likes" his performance aids. Audiovisual presentations have been compared with books. Books have been varied in size, shape, color, contrast, and format. Content has been varied from fully procedural to nonprocedural. We discovered that people who have to move around a lot like portable aids, and that people who work in dim, dark environments need bigger printing. And we discovered that people with hardly any training at all can solve very complicated problems, and enjoy doing it, if they are given enough information in their performance aids. We established all of these things quite conclusively through a long series of studies and experiments of which we can be justifiably proud. I believe that today's JPA technology base provides us with a good collection of solutions to the problems of building performance aids that the user <u>can</u> use, and that he will <u>want</u> to use.

So what is the problem? Why isn't everyone using JPAs? It's because the man who uses a JPA on the job is only a small part of a much larger system of support people and organizations, and we haven't yet shown the world just where JPAs fit in that system. Even worse, some of our experiments have left some people with the feeling that JPAs are more of a monkey wrench than a panacea. The subjects of many of our studies have performed admirably in the lab and the field; but, after we've made our point and gone away, it's become clear to our hosts that they are stuck with some rather peculiar people, for whom there is no place in the system.

Clearly, we have reached a point where we have to shift our focus a bit when we consider "user problems," and the list of topics for the present symposium reflects that shift. <u>Integration</u> is now the name of the game, and the "user" who needs our attention most is the system itself, not just the guy with the book. If we want to see JPA concepts pay off, we have to conceptualize a system in which JPAs and their users have a clearly defined role, one that is compatible with the rest of the system. The problem areas that make up the rest of this paper consequently tend to address the needs of the using system more than the using individual.

Program Management Level Problems

Program managers have had the authority to select, during system development, from a limited range of technical documentation alternatives. Those who stick strictly with tradition are seldom criticized; those who innovate have sometimes been burned. Even a manager who is knowledgeable about both traditional and innovative performance aids still has little in the way of hard data and clear-cut guidance upon which to base a comfortable decision about the best mix of tech data for his system. He has even less information available to him, and less real authority, to specify the best personnel system--especially training and career patterns--to complement the performance aids he wants.

Specifications are Incomplete

Although some of the services have incorporated some JPA features into tech data specifications, we have yet to construct a spec that goes beyond the JPAs to show the manager a good "impedance match" between the JPAs and the rest of the system. Some of the draft specs include specification of certain parts of the JPA development process. Many of us believe that the procurement activity must monitor--and have some authority over--the development process in order to assure completeness and accuracy in JPAs, but this tends to spook some managers, who aren't used to meddling much in the tech data until pretty far downstream.

The perceptive manager contemplating an existing JPA spec will recognize that:

1. If he implements JPAs without finding the proper niche for them, he won't get much extra benefit for the money he spends.

2. The spec provides little or no guidance to help him decide what kind of niche to make or how to exercise the necessary quality control.

Procurement and Updating Costs are High

A manager who has been around for a while has probably heard some horror stories about huge costs associated with JPAs, especially those that include extensively proceduralized troubleshooting. The fact that we haven't yet defined the optimum system role for such aids makes their admittedly high cost understandably hard to swallow. Furthermore, we haven't gone far enough in describing updating procedures. Logistics people, who have a hard enough time keeping conventional publications current, recognize the potentially massive impact that even relatively small hardware changes can have on a collection of JPAs. Again, recognizing the potential benefits of JPAs used on the job just isn't enough to prevent managers and logistics people from being scared away by vague and mostly incomplete guidance in acquisition and control of the JPAs over the life of the system.

Tradition is Hard to Beat

The conventional technical manual in most of the military services carries with it the weight of tradition and the inertia of long-term familiarity within large logistic-support organizations. Even when it isn't rationally-based, the use of tradition as an argument for the status quo will be much harder to counter until we can show the world a complete new system that describes all of the differences from the traditional one. As long as we persist in providing a kit with some of the essential pieces missing, we'll continue to have trouble even getting the traditionalists' attention.

What About Backup?

To the extent that JPAs are either incomplete or inaccurate, the system must have alternate means to heal itself. An unfortunate flaw in the early JPA sales pitch was that it pretty much ignored this question. JPA was sold as a panacea in fully-proceduralized form, but thoughtful managers recognized that if fully proceduralized aids were the only system documentation available, if they failed to solve a problem (regardless of the reason), and if the technicians were wholly dependent on the JPAs, unable to apply some "creative" troubleshooting, the whole system would shortly collapse. Studies conducted to date reinforce the feasibility of integration of the JPA approach into the documentation system, but not replacement of the entire existing system with JPAs--an intent that we allowed many people to erroneously infer from our early enthusiasm. Other papers presented at this symposium have described in more detail some of the currently-proposed solutions to this problem, including restructuring career fields and personnel-advancement schemes. The ultimate solution will probably include JPAs used by inexpensively-trained early-enlistment people, and more conventional aids used by more experienced people who have received supplemental training along the way, or who go to another completely different resident school, perhaps at the beginning of their next enlistment. A fairly large group of the former kind, and a smaller (through attrition) group of the latter kind could probably cover all bases, fairly economically.

What About Nonmaintenance Users?

Another reason why program managers have been frightened away from JPAs is their recognition of the fact that some JPA specs completely ignore nonmaintenance users of the documentation system. Again, we failed to make it clear that most of our innovative maintenance aids were intended to replace or supplement only those portions of conventional manuals that technicians use, rather than to supplant the entire system. Supply and transportation people, operators, design and service engineers, and curriculum planners, to name a few, all have legitimate interests in information about the system that might not be included in JPAs for maintenance, yet some of the JPA specs have provided little or no guidance to the manager in choosing the right mix of conventional and JPA-type material.

Field User Level Problems

As mentioned earlier, most of the problems we have seen in recent years with rejection of JPAs by users seem to derive more from organizational and social features than from unsolved technical difficulties with the aids themselves. If people lose confidence in their performance aids, or if they feel that their jobs are somehow demeaning, then they're in trouble no matter how good the aids actually are.

JPAs Need a Proper Introduction

We have probably all seen examples of a good idea being defeated even before it gets started. The two most common pieces of scuttlebutt that are likely to precede a JPA-implementation exercise are:

1. They're so full of errors that you can't use them--even worse than conventional manuals.

2. They're designed for use by dummies, so if you get them, it means they think you're not smart enough to figure it out for yourself.

Little wonder that people are at least suspicious, and that they tend to nit-pick a bit. The only countermeasure we can apply is a carefully presented introduction that explains that our aids don't have the errors that earlier experimental models had, and that shows everyone how the JPA-user fits into the organization and what his future options are. All this presupposes, of course, that the organization really does have a place for him, and that his career field isn't planned to be a dead-end slot for dummies. People who are exposed to JPAs right after tech school, as Mr. Klesch will describe later, are painfully aware of how little they have really been taught to _do_, and they are extremely receptive to procedural aids. They see the aids as giving them the ability to do productive work right away, rather than depending on an extensive period of hand-holding by their experienced co-workers.

It may be a fairly fine distinction, but we've discovered that even experienced people tend to accept procedural aids quite readily if they are billed as something to make the job _easier--not simpler_. People in supervisory positions get uneasy when something comes along that tends to minimize the complexity of their operations. Shop chiefs pride themselves in being able to say that they possess the very finest technicians, and only through superhuman effort are they able to keep their incredibly complex gear on line. As long as that makes a good story, we're better off to appear to be fighting the battle against complexity, _not_ reducing troubleshooting to child's play.

Users Must be Trained in JPA Use

This is really no different from introducing people to JPAs, but we have occasionally stopped short. People need not only to hear about what the aids do, but they must also practice using them properly. This practice should be followed up in the field to assure that later questions get answered, and that the aids don't fall into disuse because the users never quite caught on to all the tricks before the salesman left. I've seen SIMM-type documentation lying around completely unused, simply because the technicians admit that they never really learned how to use them. These aids are pretty to look at, and they impress the visitors, but the users just don't feel that they have the time to teach themselves how to use them.

Similarly, even modestly-experienced technicians have a tendency not to believe that a fully-proceduralized troubleshooting book is, as its name imples, a thing that must be followed to the letter. They tend to omit steps that appear to be unnecessary and to try to take other shortcuts. When the procedures subsequently bomb, the technicians conclude that it's the procedures' fault, and they discontinue using them. It is a relatively simple task to demonstrate the devastating effect of trying to ad lib with such procedures, but we often fail to do so.

Supervisor and Peer Acceptance of JPA Users

We've gotten ourselves into this bag repeatedly with some of our field studies, and the problem will not get better until we get the rest of the system revised. We have had a tendency to demonstrate some of our principles by dragging people out of boot camp, showing them how to solder without hurting themselves, giving them a package of experimental JPAs, and measuring their performance. In at least a couple of instances, these people have somehow managed to stay in the system, at least for a while, after the study was over. It doesn't take long for supervisors and peers to peg these folks as the "dummies," because they just don't talk like "real" technicians, even though they may perform every bit as well with their JPAs. The kicker comes when it's time to qualify for the next skill level. Not only do they have lower supervisor ratings (because they talk funny), but they find that they can't possibly compete with their conventionally trained peers. Most career-progression ladders are based on advancement criteria that discriminate against the JPA user by testing for "knowledge" that has not been conveyed by his schooling, because he doesn't need the knowledge to do the job with JPAs.

Ex-students who could see this problem coming have actually gotten to the point of conferring with their congressmen about the effect that such an experiment has had on their careers.

Generalizability of Skills

Certainly, people learn as they use JPAs, particularly from non-troubleshooting procedural material. Some tasks can be learned fairly quickly, and some JPA formats provide a dual-level presentation that allows the inexperienced man to follow every step but cues the experienced man at a somewhat higher level. Because the principles of mechanical and electrical assembly and repair tend to be reflected in a fairly consistent way within most systems, some JPA users find that they can figure out how to do a variety of things that are similar to ones for which they've used JPA procedures. In this sense, then, some of the specific operations that a user practices as he follows a procedure can generalize to other tasks for which he does not have--or doesn't choose to use--a written procedure.

Although some kinds of semi-procedural or nonprocedural troubleshooting aids can foster the development of troubleshooting skills (an essentially cognitive activity), fully proceduralized troubleshooting does not. Troubleshooting procedures typically provide neither a map through the data flow nor reasons for the checks. The troubleshooter who is wholly dependent upon the procedure is unlikely to learn anything at all about the principles behind the procedural sequence. We know how to build both kinds of aids, so the choice must be made on the grounds of how much we wish to spend on training, and what kind of personnel system and career advancement structure we wish to have.

NEW DIRECTIONS FOR INFORMATION TRANSFER
RESEARCH IN MAINTENANCE JOBS

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Introduction

Maintenance personnel need information to get their jobs done. Traditionally, information has been subdivided into compartments called training and technical manuals. The traditional philosophy is that personnel should be trained in the fundamentals and that manuals should contain the system specifics. It is assumed that personnel will then apply their fundamental knowledge and skills to specific technical information and deduce what actions should be taken in each situation on the job.

Twenty years of research, development, and some implementation have eroded the distinction between these compartments. Today, there is a new philosophy for producing documentation. It holds that training documents should tell maintenance personnel what actions to take on specific equipment under various conditions. This new technical documentation takes over a large percentage of what training and training devices were expected to mediate, and the test standard and conditions also are built into the book.

This paper will review what has been found to be effective, what the life cycle cost implications are, what remains to be determined, and where the field must go to achieve maximum payoff in the operational world.

First, let's look at costs. One-third of all personnel in the Armed Services are in full-time maintenance jobs. This does not include equipment operators who also do some maintenance. The cost of an enlisted person varies with rank and with support costs (e.g., food, housing, health care, and retirement). We use a figure of $30,000 per year as an estimate, though $25,000 or $35,000 or even $40,000 are also used as estimates by others. There are about two and one-half million enlisted personnel in the services. With one-third of them in maintenance jobs at $30,000 per year, this amounts to more than 18 billion dollars per year in maintenance personnel costs. This is about six billion dollars for each of the three services. The cost of all technical documentation operations is no more than 3 percent of this cost in each service per year.

About one-fourth of the maintenance personnel is new to the service each year. An average of 20 weeks is spent in nonproductive maintenance training before these personnel do any productive work on the job. For some 6 months on the job, their productivity is low. The student/instructor ratios for training are on the order of 1-to-1 or 3-to-1. There is steady Congressional pressure to reduce this ratio. The cost of maintenance training for first enlistment personnel is on the order of a half billion dollars per year per service. Another billion per year per service is attributable to the nonproductive time of personnel in training and the reduced productivity of personnel during their first 6 months on the job (assuming an average 15% reduction in productivity during the 6 months). These are the raw dollar figures.

Our next question is where cost can be reduced by changing the information transfer methodology available today. Studies over the past 20 years show reductions in training on the order of 50 to 90 percent. Increases in job productivity indicated in these studies have been as high as 50 and 60 percent. Many different conditions combine to produce this range of values (e.g., type of task trained, original length of training, etc.). But these are the ball park reductions that can be expected from new information transfer methods as projected from research studies over the past 20 years (Shriver & Hart, 1975). Savings on the order of one to two billion per year per service are implied by these reductions.

That sounds good for reductions. What are the increased costs? The increased costs are in producing the manuals that tell the maintenance personnel what to do on the job. The contracts for such new manuals in the Army MIL-M-632XX are running about as much as for old style manuals or somewhat more. The costs of JPA manuals in the Air Force are similarly 20 to 50 percent higher than conventional manuals. These increased costs represent no more than a million dollars per major system. This is a negligible amount for a new system when the reductions are so much greater. The cost of reworking all existing manuals is higher. It would not be prohibitive if the cost savings were ensured, but more data are needed to reduce risk.

The Study Conditions and State-of-the-Art Today

Reasons for Reduced Training and Increased Productivity

A recent study of 20 years of research identified five fundamental elements which account for the effectiveness of new concepts in manuals and training. They are:

1. Equipment Analysis. This is an indentured list of all parts in the system as entries in a matrix. The matrix has column headings referring to about ten kinds of maintenance. The matrix cell entries contain a code indicating the level or echelon of maintenance that provides the maintenance action. This is called the Task Identification Matrix (TIM) in Air Force Job Performance Aid (JPA) specifications, and the Maintenance Allocation Chart (MAC) in the Army. The Navy does not have a direct analogue, but the Maintenance Dependency Chart (MDC) for troubleshooting in SIMMS and FOMM specifications has certain similarities.

2. Functional Analysis. This is known by many terms: cause/effect analysis, failure mode analysis, logic trees, fault isolation charts, etc. There are similarities and differences among all the specific techniques, but they all have the following items in common: an analysis, a logical relating of part failures to indications of failure, and a guide for user maintenance actions on the basis of indications. They all apply to troubleshooting maintenance only and represent a way of codifying a process that was traditionally regarded as a problem-solving situation.

3. Task Analysis. This is describing in detail the steps to be taken in maintenance procedures when each step invariably follows another

to accomplish a task. It includes a description of the condition under which the tasks are performed and the needed tools. It is used for all nontroubleshooting tasks and the procedural aspects of troubleshooting tasks.

4. Behavioral Task Analysis. This is a refinement of Task Analysis in which the cues are specifically identified for the more detailed actions identified in the grosser task analysis. It includes use of graphics for showing cues.

5. Intelligibility Standards. This provides a process for making the graphic and written instructions intelligible to personnel with grade school reading ability. It includes a verb list of single syllable verbs (actions), which are allowed in instructions. It specifies how graphic cues take the place of nouns and how words relate to pictures. The sentence length is also restricted. It is a process for forcing intelligibility rather than for measuring intelligibility after a product is produced.

It was found that the increased effectiveness of personnel and the reductions in training time in 25 studies could be traced to one of these elements or some combination of them. It was also seen that all the techniques could be applied in each application; that is, they do not compete with each other. The exception is functional analysis. It has application only in troubleshooting situations. We might look at applications of these analytic techniques in each of the services for some illustrative examples.

The Army was first in 1956 with FORECAST. Research prior to that time was based on training only. FORECAST specifically dealt with manuals and training plus training devices and performance testing. The Army used the Maintenance Allocation Chart (MAC) at that time so the research never dealt with the first fundamental element. FORECAST dealt only with electronic troubleshooting. It used functional analysis, task analysis, and a rudimentary form of behavioral task analysis for its effects. It also used short words but not according to a prescribed list.

SIMMS with its Maintenance Dependency Chart (MDC) came next. It started in the Coast Guard and then was adopted by the Navy. The MDC used functional analysis and a form of equipment analysis for its effects. Words tended to be short, but special symbology was used to communicate logical relationships. In its original form, it was designed for electronic troubleshooting but was applied to mechanical systems as well.

PIMO followed very closely in the Air Force about 1960. It used behavioral task analysis and intelligibility standards for its effect. It was designed to show locations and appearances of mechanical system parts in graphic terms with short words and sentences. The prescribed word list was originated in this concept. PIMO was the first new concept to focus on mechanical maintenance. For troubleshooting tasks, the MDC was lifted from SIMM and used by PIMO. PIMO tests included a lot of opinion data from users. The key finding was that new users liked the information while experienced personnel disliked the detailed instruction.

The JPA concept is an amalgam of PIMO and fully proceduralized troubleshooting procedures. It used the fundamental elements of equipment analysis, functional analysis, task analysis, and intelligibility standards for its effects. The term JPA has become a generic one for all types of new concept manuals, as well as for the Air Force's new concept manual.

FOMM and Work Package are terms used in the Navy today. The basic analytic techniques and formats of FOMM are those of SIMM. The Army Job Performance Manual (JPM) and Job Performance Guide (JPG) are results of the study of all other concepts plus some Army TEC program elements for guiding on-the-job training.

The Army specification MIL-M-632XX approach specifically breaks the compartmentalizing of traditional training and technical documentation. The other concepts imply it but are not specific.

There are three other lines of development that should be discussed briefly at this point. The first two represent hardware approaches to a solution of the maintenance problem. The third is a paper solution to hardware training devices and hardware "hands-on" testing.

The first is concerned with the medium of transmission. Photographic and electronic means of recording and transmitting information are many. The machines for storing, accessing, displaying, and transmitting information are being "sold" very hard by large equipment manufacturers. There are no data that show an improvement in performance or reduction in training with the use of such media over that of the traditional paper manual. The arguments for it are made primarily on the grounds of reduced storage area, quick update, and the general attraction that new machines have for people in our culture. The arguments used in selling this equipment may be specious, but we are likely to see the introduction of such equipment anyway. There is nothing in the fundamental elements that cannot be transmitted by any medium.

The other entry of equipment producers is automated troubleshooting. The thesis for this equipment is that it can replace the human. The implication is that the human needs to be replaced because he can't do the job as well or costs more. Once we have accepted the troubleshooting situation as one that is <u>not</u> problem-solving but can be fully proceduralized, there is no reason that a machine can't be designed to sense faults--and even to take corrective action. But if a human being has to be present to take any actions or sense anything, it may be less expensive to let him do the whole job. The man/machine tradeoff has replaced the head/book tradeoff as a critical question.

Symbolic substitutes are a derivative of the graphics in JPAs. Research is being conducted in the Air Force and Army on symbolic substitutes for testing and for training. Graphics has been found to mediate transfer to job performance as well as real equipment for performance as well as real equipment for most tasks. Performance on symbolic substitutes correlates well with hands-on performance (Shriver & Foley, 1974; ARI, in press) and shows evidence of being more valid than hands-on, because observors of hands-on performance tend to become bored and inattentive while observing and scoring.

Impediments to Implementation

The twin impediments to implementation have been the institutional schools and the institutional specifications for technical documentation. These institutions represented the traditional philosophy of separate compartments for training and technical documentation. What success we have had is due to the crevices provided by R&D. The good work of individual scientists has produced effective materials, specifications, and tests that showed good results in operational terms, but all of this would have remained in a backwater if there had not been new factors at work in the military establishments. The new factors are increased personnel costs and a new philosphy for reducing personnel costs. The military establishment is ready to try out new approaches to training and technical documentation if a reasonable probability for reducing personnel costs exists. The R&D studies have been pulled together to show there is a common cause for their good effects. The effects have been costed out in global terms. There is more implementation. We are now ready to consider what the human resources R&D community must do to provide the basis for the next thrust.

We need an overall framework or point of view in order to go forward. In general, one might say that implementation came slowly because we did not start out with a large-scale point of view and build our options within that framework. We did small-scale studies that vied with each other for implementation. Times have changed; the framework has emerged from our individual efforts along with the outline of the large-scale cost factor for personnel.

The implementation of what has been accomplished in 20 years of research has created a new baseline for research that needs to be done. Research should not follow the structure that existed in the past or it will result in repetitions of what has been done--more refined perhaps but not adapted to answer the new questions that require answers.

New Directions for Information Transfer Documentation

The basis of JPA-type documentation is front-end analysis to make JPAs user-centered, plus processes for making the document intelligible for grade school reading capability. This type of analysis is what Instructional System Development (ISD) calls for but does not make explicit. ISD has had wholesale adoption. This has opened doors that were closed. ISD calls for decisions to be made by training analysts that previously were the perogative of the institutional instructor, but it provides no specification of techniques for making these decisions. The Army's Improved Technical Documentation and Training specification (ITDT MIL-M-632XX) recognizes the commonality of Technical Documentation and Training. The objective is to impart information that increases the capability of personnel to do tasks. The JPA represents training, criterion-referenced tests, and training devices just as much as it does technical documentation. Another important point about documented information is that it is not limited to an institutional site; it is moveable to the job site.

The difficulties of the past are past. The problem for the future is developing the potential of documentation for increasing user capabilities. Research must move quickly to fill the space which has been made available with the adoption of ISD. The research payoff for the next few years will be in:

1. Technical documentation as training simulators and tests to make OJT effective.

2. Technical documentation as a means to expand job duties each person can perform--first and successive enlistments.

3. How much to proceduralize troubleshooting for maximum job productivity.

4. Cost effectiveness studies in a simulation model that continually updates personnel capabilities versus machine and identifies what capabilities in personnel will produce the greatest cost effectiveness benefit.

Research is not needed on the old problem like which new concept is best or which format is best for which situation, or the head/book tradeoff, or making formats so experienced personnel like them. Those issues have been washed away with the opening of the flood gates. We must immediately get to work on the problems that have major importance.

Institutional training will be drastically reduced because it is high cost, relatively ineffective, and not in vogue. Training at the job site will be the dominant theme, and documentation makes OJT possible without turning the supervisor into an instructor. But the cost effectiveness of alternatives must be established in the next few years, and either the pendulum will return, or troubleshooting by machines will fill the gap. We have to understand the commonality of technical documentation, training, training devices, and criterion-referenced tests. They all spring from the same analytic roots. The roots are front-end analysis. The front-end analyses developed for new concepts in maintenance documentation represent the furthest advancement in the state-of-the-art and the best documented source of guidance for achieving reductions in personnel costs and increased system effectiveness. Training and technical manuals are no longer stand-alone processes. They work together in a process that includes training devices and performance testing as well.

The research personnel who focus on technical documentation must recognize what they have and where it fits. They have the most powerful analytic tools and the best means for delivering information to users on the job as required by the ISD process. They must quickly learn to perceive what new effects can be produced with these tools and delivery devices. For instance, one high-payoff effect is that personnel trained on the job produce useful products while learning a wider variety of job task performance. The individual can continue learning more and different tasks far beyond existing boundaries of job assignments based on old assumptions about training costs.

We must preapre to answer questions on the payoff of expanded job capabilities and the payoff of increased productivity. The question is no longer institutional training versus OJT. It is how the personnel subsystem will change as a result of increased individual capabilities developed on the job and what the payoffs are for these changes. The changes we want to promote are of overall system importance. They are highly visible, large payoffs.

Other research questions center on the mechanics of OJT. For example, should the new personnel be given job tasks as they come up in the maintenance situation or should they follow a prescribed series of tasks deemed appropriate for a new person on the job? Finally, the locus of the research should be recognized as the job site. In the Navy, the job site is often a floating platform--relatively inaccessible to research personnel. Therefore, the experiments have to be set up to run without the presence of a researcher. This may require some research on remote control of conditions.

What are the payoff situations today?

1. Getting useful work from the personnel without nonproductive school training. The payoff potential of this area is on the order ot $500 million dollars per year in each service.

2. Getting higher productivity from individuals on the job from the first day on. The payoff potential of this area is on the order of $1 billion dollars per year in each service.

3. Expansion of job duties and career development. The payoff potential of this area overlaps the previous two to some extent but probably represents an additional savings on the order of $1-1/2 billion dollars per year for each service, and a higher readiness state than the services have yet experienced.

4. Models of systems operations are needed:

a. To document increases in readiness brought about by new effects.

b. To prioritize research by "what if" studies.

c. To conduct man/machine tradeoffs.

d. To manage personnel operations (including imbalance of forces).

e. To codify personnel operations so they can be traded off against hardware developments in top-level discussions.

In doing this, we have to take a new view of training, training devices, manuals, OJT, job structure, career patterns, performance testing, and manning levels. We have to get in tune with operational and system design questions for structuring our research questions. The human resources community has marched in this direction before. We created Qualitative Quantitative Personnel Requirements Information (QQPRI) and human factors specialists in the process, but if we are honest with ourselves we will look around us and say that the hardware community still owns the battlefield. We lost, but we did gain an identity and experience by fighting the battle. Now let us use whatever wisdom and experience the "old heads" can bring to bear to structure the new research efforts. There are few "old heads," and they have cracked against each other enough that they are willing to opt for cooperation rather than conflict with each other. There is some funding. There is some new blood. There is enough difference in viewpoint to engage in several efforts at once that contribute to each other in a common frame of reference. The human resources research community must not squander its resources in fighting or in repeating the past.

It is with this background that I suggest some specifics in line with the general areas outlined above.

1. Project Area 1. A computer-based effectiveness model for tradeoff studies is needed to identify specifically how having personnel with certain kinds of technical information will effect the cost and readiness of the service. This is a "what if" model to define research alternatives, to establish research priorities, and to provide the detailed rationales and arguments for the use of personnel components and for the use of certain hardware components. It must be an iterative model, not a "one shot" model that comes up with personnel demands which the hardware must meet. In addition to all the personnel factors, it must model the hardware side as well as training, testing, career structure manuals, training devices, and other "human factors." Its output effectiveness must be in material readiness to do the job, not personnel errors or personnel tasks, skills, or knowledges. The overall results must be in terms of how ready the man/machine system is to do its job. On the personnel side, this will reduce to productivity and from that into tasks, skills, training, etc.

A cost model must be developed to go with the effectiveness model. The cost model must include both the personnel and hardware side in gross terms and trace the personnel side down into contributory factors of training, skill, tasks, etc.

2. Project Area 2. Development of methods for shaping personnel characteristics throughout a career. This includes getting the new personnel job-effective quickly, expanding their skills to increase their generality in successive enlistments, and determining how this ties back into life cycle costing of the cost-effectiveness, "what if" model. Career testing and promotion are included.

3. Project Area 3. An information transfer project with training and manuals and other media such as training devices. "Manuals" should be expanded to include other media. Training devices and manuals should be an integrated package: OJT, self-paced instruction learning from the JPA, school training for 2nd and 3rd termers, expansion into broader fields (e.g., from Radar A to all radars to all electronic equipment to administration and supply of all electronics). This is an area where the overall model can breakout those factors which enable personnel to do different things that the larger model indicates are cost effective.

4. Project Area 4. Personnel logistics. This area should concentrate on what equipment manufacturers are doing in automated troubleshooting equipment, spares provisioning, transportation of spares, storage of spares, costs of parts transportation, tactical operations, etc. It is a breakout from Project Area 1 and, like the other areas, feeds information back into the model of Area 1.

5. Project Area 5. Personnel System Architecture. The "front men" for the personnel subsystem in the system design and life cycle should be working in this area. It incorporates all that is developed from the other areas, but is different in that this group must also "go beyond" what is known. They have to give "best guesses" during concept development stages and then identify the studies needed to detail out the best guesses. These personnel include the most senior personnel available in the human resources research field. There will be Ad Hoc Teams, but a basic cadre is also needed. Staffing will include senior civil service and contractor personnel. Of all the areas, this is the most unusual because it goes beyond research into implementation. It uses all that is known, adds the best guesses to solve the new problem, and defines what studies are needed to iterate the research process. It will require a lot more thought than offered here. Project managers for particular personnel subsystems may be required. However, this area is the spearhead for implementation of research. Without it, the research may be filed in the "archives of arcane results." This spearhead also establishes the need for research. These personnel are engaged in the operational world, where research input goes in and research needs come back. It makes the human resources research community far more visible in the operational world than it has been heretofore, but it requires research personnel to "go beyond" their data. This has always been anathema to university-trained experimenters. The anathema hasn't stopped researchers from going beyond their data in the past. We have all done it many times, but we have done it from a very restricted frame of reference. Our research conditions have seldom matched the operational conditions they were supposed to predict, but that didn't stop us, and it didn't mean we were wrong. Basically, we have been right, and the world has come into congruence with us in large measure. Now, as we start out from this new baseline, we must create the operational conditions of the real-world research, then break out to apply it to major practical problems. Above all, we must make the jump from our new framework of conditions to the operational world with best guesses. The jump will be shorter than it was in the past, but this time we must say we will make the jump and build the platform to jump from.

IMPLEMENTATION OF THE JPA/JOB-ORIENTED TRAINING APPROACH TO MAINTENANCE: THE IMPACT ON PERSONNEL SYSTEMS

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Introduction

Innovations being made in the Department of Defense in the areas of technical training and technical manuals for maintenance can produce significant savings in the life cycle cost of weapons systems. These innovations can also produce negative side effects that, if not solved by technological or administrative changes, can seriously reduce their effectiveness. One such area of impact is the personnel system. Personnel specialists show considerable interest in the potential of these techniques for reducing aptitude requirements and thus expanding the manpower pool. They also are interested in facilitating the transfer of maintenance personnel between systems without extensive formal training. At the same time, they show concern for the impact these techniques will have on skill upgrading, recruitment, and retention. Although the Air Force has not conducted any in-depth studies of the impact of personnel policies of implementation of these techniques, a number of studies on Job-oriented Training and JPAs have been performed that can be used to deduce their effects, and likewise, to suggest some changes that will have to be made to present personnel policies in order to accommodate these techniques.

Job-oriented Training Studies

Three major studies on Job-oriented Training have been performed which have produced technicians who entered the Air Force maintenance environment. These studies were all designed to determine if a significant reduction in entry-level training is practical. The approach taken in each course development was to eliminate or reduce broad-based principles and concentrate on hands-on equipment training using essentially rote maintenance techniques. The students learn to perform specific job tasks by following carefully prepared step-by-step instructions. Although JPAs were not utilized in these efforts, it should be evident that a JPA/Job-oriented approach would be very similar. It would be expected that subsequent performance in the field would be improved if JPAs were available. This obvious difference does not negate the findings reported here, however, since the problems encountered involved variables other than routine task performance.

The Communications-Electronics Service Test

This study (DoD & USAF, 1970), which was begun in 1966, involved the application of two different concepts to reduce training: the job-oriented or "X" approach and a principles-only or "Y" approach. Both concepts were applied to two courses: an airborne electronic equipment repair course and a ground electronics repair course. The "C" conventional courses were 38 weeks and 42 weeks in length, respectively. Application of the concepts resulted in approximately a 40 percent reduction in course length for both the X and Y approaches. A total of 735 subjects participated (294 X graduates, 294 C graduates, and 147 Y graduates). Questionnaires,

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surveys, and supervisory appraisals were utilized to obtain data on the subjects' performance and problems throughout their initial 4-year tour. Although a number of criticisms could be made of the methodology employed in the study, the types of problems encountered are nonetheless valid and must be addressed in any future applications.

Performance.

1. Results. The X graduates demonstrated a performance capability equal to and sometimes greater than the C students during the first 10 weeks on the job. The Y graduates were less proficient, particularly in the use of test equipment and published maintenance procedures. Overall job performance ratings by supervisors at the first-year point indicated that the C and Y graduates were rated significantly higher than the X graduates. The X graduates were not as effective or flexible in adpating to new and unfamiliar maintenance demands. When confronted by unfamiliar equipment or unorthodox troubles, the X graduates frequently needed extensive assistance. While the Y students encountered similar problems, they appeared to profit more readily from experience and further training. The X graduates were given fundamentals training during this period but encountered difficulty absorbing and applying this training. At the conclusion of the 4-year tour, the supervisors rated the overall job performance of all graduates about equal. On specific job performance factors, however, supervisors consistently rated a higher percentage of the X graduates unsatisfactory than either the Y or C graduates.

2. Conclusions. Specific job task training results in immediate task proficiency but the transfer of these skills to other tasks, particularly in unorthodox situations, cannot be assumed. Supervisors (conventionally trained) did not perceive the X graduates to be the equivalent of the C graduates but believed the Y graduates were closer to the C graduates.

3. Implications. Job Performance Aids will have to be available for all systems that X-type graduates are assigned to repair. Training and/or expert assistance will be required to handle special problems. Mixture of conventionally trained personnel with X graduates in the same grade level will probably result in better ratings being awarded to the former group.

Training.

1. Results. At the 1-year and 2-1/2-year points, nearly 50 percent of the X graduates felt that their initial training was inadequate compared to only 7 percent of the C graduates. While 41 percent of the Y graduates indicated inadequacy of training at the 1-year point, this later dropped to 29 percent. All graduates felt that they were able to attain satisfactory proficiency in their normal job routines within a reasonable period of OJT. Over 50 percent of the X and Y graduates rated their initial training as inadequate for preparing them for their career development course (CDC) program. However, supervisors rated all graduates approximately equal in "speed of completing CDC" and "overall performance as CDC students." Over 50 percent

of the X graduates rated their training as inadequate in preparing for the Speciality Knowledge Test (SKT), compared to 37 percent of the Y graduates and 6 percent of the C graduates. At the 1-year point, 69 percent of the X graduates had passed the five skill level SKT compared to 75 percent and 83 percent for the Y and C graduates respectively. C graduates attained the five skill level an average of 3 weeks sooner than the X or Y graduates. A substantial amount of additional fundamentals training was provided to the X graduates in preparing them for upgrading to the five level compared to the Y and C graduates.

2. Conclusions. Substantial additional training was required to prepare X graduates for skill upgrading. Initial training was felt to be inadequate for both CDC progression and SKTs.

3. Implications. Careful study of task requirements at the five skill level need to be made to ensure that proper training and/or JPAs are provided. In the above system, it appeared that there were many tasks that the X graduates could not perform without considerable additional training. It is unlikely that such an approach will be cost effective, even though initial training has been reduced. In order for X training to be viable, the field requirements for the graduates would have to be carefully controlled or changed. Examples of changing field task requirements would be: restricting troubleshooting to black box replacement, providing better troubleshooting aids to enable the technician to troubleshoot to subassembly or module level, or providing automatic test equipment. The present personnel system operated against the X approach in that the graduates were assumed to have all of the knowledges of the conventional graduate. It also was assumed that these knowledges were, in fact, required to perform the tasks. Future efforts should examine this notion more carefully. The career development courses and speciality knowledge tests would also require substantial revision. In effect, new specialities would have to be created. Such a speciality need not be restricted to the repair of one equipment so long as JPAs and the same field requirements are available.

Other.

1. Results. At the conclusion of their initial tour, 87 percent of the X and Y graduates had been promoted to E-4 compared to 92 percent of the C graduates. The attitude and morale of the X and Y graduates were judged to be favorable even though they had judged their training to be unsatisfactory. Supervisors indicated a general acceptance of the graduates but remained highly critical of the X and Y training concepts. Job assignments and utilization of experimental graduates were restricted, particularly in the airborne specialty. Supervisors stated that they were forced to restrict the duties of these graduates to the flightline because of their inability to perform the more complex tasks. There was considerable doubt that the experimental graduates would have achieved an acceptable level of job proficiency if there had not been qualified electronic technicians, supervisors, and trainers to provide detailed assistance. After 3 years of service, approximately the same percentage of all three types of graduates indicated their intention to reenlist (11%).

2. Conclusions. Neither promotion nor reenlistment rate appeared to be seriously affected by the initial type of training received. However, job assignments and utilization appear to have been severely restricted. Supervisors had been and remained critical of the experimental courses. Despite promotion actions and ratings of overall satisfactory performance, the experimental graduates were considered to be less capable than the conventionally trained graduates.

3. Implications. If no further training is provided, airmen are not likely to pass their SKT and hence will not get promoted. In this study, they were promoted but presumably only because of further intensive training that was provided in their field. As noted earlier, this approach is probably not cost effective. The restricted work assignments given to the X graduates implies that jobs may have to be restructured to accommodate the utilization of these personnel. The restriction may also have been made on the basis of bias on the part of the supervisor. While that may be true, it is not likely to be overcome so long as conventionally trained graduates are mixed with the experimentally trained graduates in a given speciality. The reenlistment rate for all groups indicates that this personnel problem must be addressed in any solutions that are fomulated. Offering career resident training at the 3-year point may have provided an incentive for more of the X and Y graduates to reenlist.

The Learner-Centered Instruction (LCI) Study

In this study (Pieper, Sweezey, & Valverde, 1970), a Job-oriented Training approach (called Learner-Centered Instruction) was used for the F-11A Weapons Control Systems Mechanic Course. The conventional course was 24 weeks in length: 10 weeks of electronic fundamentals and 14 weeks of principles-centered instruction on equipment sets. The LCI course was 14 weeks in length. This was a reduction of close to 60 percent of the original course. Eighty airmen trainees received the LCI course; 40 had the required high electronics aptitudes and 40 had medium electronics aptitudes and would not normally be utilized in this specialty. The subjects were matched with 40 airmen who received the regular course training. Special tests were constructed to measure the graduates' performance ability and knowledge at both the end of training and after 5 months on the job. Supervisory ratings and student ratings were also obtained. Anecdotal, but nevertheless important, events occurring after the evaluation are reported here because of their relevance to the topic of this paper. The program was conducted from 1968 to 1969.

Performance.

1. Results. The high-aptitude LCI graduates were superior to the C graduates at both the end-of-course test and after 5 months on the job using job sample tests as the criterion measure. The medium aptitude LCI graduates were very similar in performance capability to the C graduates. The C graduates performed better than the LCI graduates on a "Practical Test" that is normally administered at the end of the C course. Special performance-oriented ratings obtained from supervisors at the 5-month period indicated no consistent differences among the three groups in ability to perform the job.

2. Conclusions. The results again indicate that teaching specific task performance results in superior task performance, especially when measured by job sample tests. Since the LCI graduates did not fare as well on the "Practical Tests" though, the doubt remains as to whether the specific training is readily transferred to other tasks. This type of training appears to permit the utilization of medium aptitude personnel to perform such tasks. Supervisory ratings indicate that these skills are retained on the job.

3. Implications. If specialities can be designed that are restricted to the kinds of tasks measured by the job sample tests, it will be quite feasible to expand the manpower pool by the utilization of medium aptitude personnel.

Training.

1. Results. The C students were superior to the LCI graduates in performance on a specially designed knowledge test (similar to the Speciality Knowledge Test used for promotion and skill upgrading) at both the end-of-course and 5-month intervals. Students indicated a general satisfaction with the training at the end of the course; however, no measurement of satisfaction was made at the 5-month interval.

2. Conclusions. It is unfortunate that no measurements of student satisfaction were taken at the 5-month point since the speciality test results indicate that they would have a difficult time passing the Speciality Knowledge Test without considerable additional training in theory. The C course was obviously designed to provide this knowledge.

3. Implications. Unless a new speciality is created along with new Career Development Courses and Speciality Knowledge Tests, considerable further special training for LCI graduates will be required. Normal OJT and career development courses are not likely to be sufficient to provide the knowledge of fundamentals expected in this speciality.

Other.

1. Results. The following anecdotal comments are not documented in the study reported above but are important events that occurred after the original study was concluded. Field personnel reported that LCI graduates performed satisfactorily at the three skill level but that performance had been below average at the five skill level, presumably because of a lack of knowledge and basic fundamentals. LCI graduates were reported as feeling in an inferior position to their contemporaries. The work load on supervisors and OJT trainers was greatly increased. Time required to upgrade the LCI personnel to the five skill level was about 4 months longer than normal.

2. Conclusions. Problems in morale, additional training workloads, delays in upgrading and promotions, and a negative attitude toward reenlistment are all likely to have resulted from the present personnel system. Since five skill level performance tests were not utilized as they were at the three skill level, it is not certain as to whether or not actual performance deficiencies surfaced. The LCI graduates' inability to readily

use existing CDC materials and pass the SKT tests may have been considered as the performance deficiencies. If the LCI graduates were never permitted to perform five skill level tasks because the supervisors felt they were not qualified (on the basis of the CDC and SKT square filling personnel exercise), then this should not be taken as an indication of a performance deficiency.

3. Implications. Future efforts must deal with this dilemma head-on. The problem of possible bias must be dealt with directly by permitting new concept trainees to perform all of the tasks required. Personnel policies of the square filling variety that govern skill upgrading (and hence permit the technician to perform the task) should be restricted to actual performance tests so that the supervisor can be assured that the technician indeed can perform the task assigned.

Project Hasty Chief

This project began in 1976 and involved the application of Instructional Systems Development procedures to an aircraft maintenance specialty. The conventional course is 12 weeks in length and contains broad-based principles training as well as some practical training. It is designed to prepare technicians to maintain a variety of aircraft. The technicians are then assigned to a Field Training Detachment (FTD) school for specific training on the aircraft to which they are assigned. This FTD course is usually 4 weeks in length and contains principles training for the specific aircraft. The Hasty Chief initial training is 4 weeks in length and includes a general aircraft introduction, safety instruction, supply, and maintenance data reporting procedures. The technician is then assigned to a FTD for 4 weeks of hands-on training on the specific aircraft. Half of each day is spent in the classroom and the remaining half is spent on the flightline performing the tasks presented in the classroom. Thus, although total training time has been reduced by 50 percent, the graduates should be more proficient in specific task performance. A total of 96 students have been entered into this training.

1. Results. No specific job task performance tests were used to compare the performance of Hasty Chief graduates with conventional graduates. At this time, only end-of-course interview results and preliminary field ratings are available. Hasty Chief graduates performed the specific tasks as well as conventional graduates. Using commands have indicated acceptance of the graduates to date, although they expressed some reservation about the large amount of equipment required to support the job-oriented training. At the present time, there are no plans to revise either the Career Development Course or the Speciality Knowledge Test. Results of these events concerning skill upgrading and future performance will have to be obtained before definitive conclusions can be made.

2. Implications. Many of the mechanical tasks of this speciality are straightforward, such as servicing, towing, and inspecting, and may be particularly suitable to the hands-on training approach. Nevertheless, the future performance and skill progression of the Hasty Chief graduates will be of prime importance to the successful implementation of this concept. The refusal of the personnel people to modify or eliminate the SKT may cause problems similar to those encountered by the X graduates and LCI

graduates. Failure or delay in receiving skill upgrading will then be met by a frustrating attempt to provide fundamentals training in the field. Current plans are to provide advanced resident training to those technicians who commit to a career beyond the first enlistment. While this approach sounds good in theory, the potential problems that could arise in the meanwhile could negate the whole purpose of the exercise--namely, to obtain more productive time out of the first-term airmen. In addition, if the SKTs prove to be a stumbling block to skill level upgrading and promotion, morale and, hence, retention problems may be so damaging that the additional training inducement will lose its effect.

Job Performance Aid Studies

Three efforts will be briefly summarized here: a demonstration of the JPA/Job-oriented Training concept, a controlled experimental test, and a JPA field impact study. While none of these studies addressed personnel system problems directly, they are reported here to provide insight and possible hypotheses that will be useful in planning future efforts.

Demonstration of a JPA/Job-oriented Approach

This study (Mullen & Joyce, 1974) involved the development of JPAs and Job-oriented Training for a complex electronic system. Eight high aptitude and eight medium aptitude graduates of basic training were used as subjects. No training in electronic fundamentals was provided. Subjects were taught soldering, test equipment use, equipment geography and nomenclature, and use of JPAs. JPAs were provided that would permit the technicians to perform both flightline and shop tasks. At the end of the course, a demonstration/quasi-evaluation was made during which the students were presented a variety of tasks to perform. The students were then reassigned to conventional technical schools in a variety of specialties. The course took about 4 weeks, compared to the normal 35-week course.

1. Results. Both groups were able to successfully complete the course that utilized proficiency tests as a criterion for course completion. High aptitude personnel were superior to medium aptitude personnel. Results of the demonstration tests were disappointing. High aptitude personnel again were superior to medium aptitude personnel; both groups, however, made errors. Skills taught in the course were performed satisfactorily. Using the JPAs to perform troubleshooting tasks, both groups could not find the majority of problems without assistance. Under controlled experimental conditions, it is safe to say they would have failed. While part of the performance problem could be directly attributable to the stressful nature of the observed demonstration, the most readily identified problems were in the JPAs themselves. The JPAs had a number of technical errors but, more importantly, apparently could not adequately convey the information in a manner in which the specially trained technicians could use it effectively.

2. Conclusions. The Job-oriented Training portion of this study indicated that fundamentals training was not required to obtain certain types of task performance. The graduates were unable, however, to circumvent

problems presented when the JPAs were inadequate. Medium aptitude personnel had a more difficult time than did the high aptitude personnel.

3. Implications. This approach to maintenance will be entirely dependent upon the ability to produce good JPAs. If the graduates are restricted to only some of the tasks and the other tasks are not changed, two specialties will be required. As shown earlier, such a solution is undesirable. Efficient utilization of medium aptitude personnel will be dependent on more training.

Evaluation of Three Types of Troubleshooting Aids

In this study (Potter & Thomas, 1976), two types of proceduralized troubleshooting aids and conventional manuals were experimentally compared for a complex electronic system. Eighteen apprentice technicians and 18 experienced technicians performed actual on-equipment troubleshooting problems for both organizational and intermediate levels of maintenance. Eighteen new technical school graduates performed the same problems but only with two types of proceduralized data. Previous studies had indicated that these new graduates cannot perform troubleshooting tasks with conventional manuals. In addition, eight experienced electronic technicians from a different specialty were tested. Job-oriented skills training similar to that used in the demonstration study by the basic trainees was provided to all of the new graduates. This training was only 2 days in length and concentrated on primary test equipment use and JPA use. This training was also administered to the apprentice and experienced technicians on an as-needed basis as determined by proficiency pretests.

1. Results. Proceduralized troubleshooting aids were superior for all groups for the shop level troubleshooting tasks in terms of time, spare parts consumed, and ability to find the problem. The new graduates performed better with the more detailed fully proceduralized troubleshooting aid than with the less detailed logic tree proceduralized aids. Of particular interest is the finding that the new graduates performed shop level tasks as well as the most experienced technicians. The eight technicians who were transitioned from another specialty were virtually unable to perform shop level tasks with the conventional manuals and yet performed as well as the experienced technicians when they used proceduralized data.

2. Conclusions. Good JPAs and Job-oriented Training can support both inexperienced and experienced personnel. They can also be effective in shortening the transition period for personnel who are moved to different systems.

3. Implications. Personnel system flexibility can be increased if proper JPAs can be developed. Availability of the JPAs will increase the effective manpower available without further addition of personnel; i.e., better utilization will be obtained from personnel by decreasing the necessary OJT period.

JPA Utilization Study

An attempt was made to determine the impact of JPAs on the effectiveness of maintenance for the recently implemented C-141 JPAs. Four bases were examined, two where the JPAs had been introduced and two where the conventional manuals were still in use. Sample observations and interviews were made at the bases and maintenance data collection records were examined for all bases for both the previous periods (pre-JPA) and past periods.

1. Results. No significant differences were detected from the data collection records for any of the comparisons made (i.e., non-JPA base vs. JPA base and pre-JPA base vs. post-JPA base, etc.). This was believed due to a number of factors. First, all of the bases were heavily manned with experienced personnel during these periods. The general observation was made that these personnel used neither the conventional manuals nor the JPAs. Finally, it was concluded that the data collection records available are too insensitive to the types of changes that could be expected.

2. Implications. Careful planning must be made in future operational tests of JPA and Job-oriented Training Systems to ensure that valid measures can be obtained.

Conclusions and Recommendations

The present personnel system has had a direct impact on the successful implementation of these new techniques in the following areas: skill level advancement that is geared to conventional training, assignments that are related to the award of a higher skill level, and promotions that are tied to both skill level advancement and passing of a Speciality Knowledge Test. Research data indicates that at least some of the performance problems experienced by these graduates can be overcome by providing better JPAs. Personnel system changes that must be made generally involve changing the emphasis from knowledge to performance as the criteria for skill level advancement and promotion.

Even if personnel system changes can be made, the problem of possible bias of the supervisors must be overcome. It was suggested earlier that, in future efforts, care must be taken to ensure that trainees are permitted to perform all of the tasks required even though they cannot pass the SKT. On the other hand, the judgment of experienced technicians and supervisors should not be treated lightly, since they perform or supervise others performing these tasks. They would and have argued that a basic understanding of the system contributes to work performance by enabling the technician to actually "solve" problems rather than fix problems by rote maintenance techniques. The new concept approach is much more dependent on many support conditions being idealized while the conventional approach provides sufficient knowledge to enable the technician to circumvent these problems. If this is true, then the use of the Job-oriented Training/JPA approach should be very restricted in application rather than be applied across the entire maintenance spectrum.

These are, of course, assumptions and should be subjected to experimental test. One approach would be to carefully observe many (several thousand) maintenance actions to determine the true incidence rate of unorthodox problems. These need not be restricted to strictly defined troubleshooting problems but should address all tasks. Simple remove and replace tasks can quickly become a problem when replacement parts do not match the JPA illustrations.

The above problem relates to a more basic issue--namely, does the existence of JPAs eliminate the need for knowledge of the system? Field results thus far have indicated that this assumption may be erroneous. While we can surmise that learning by doing would be effective for equipment such as automobiles, this does not appear to be the case for electronics. Two areas of research are suggested. The first is to reexamine our approach to task analysis. Assumptions that have been made should be evaluated for possible impact on the validity of our approach. Examples of such assumptions are: (1) that proper tools, test equipment, and trained personnel will always be available, (2) that technical data will be available to the level required (maintenance concepts frequently change as a matter of necessity), (3) that adequate shop support and supervisory support will be available, and (4) that adequate time will be available to accomplish the mission. The second area of research is to determine if learning takes place under the new concept and to develop procedures (if necessary) to allow it to take place. The work reported by Shriver and Trexler (1966)for the Coast Guard and by Post and Price (1973) for the Navy on hybrid aids should be used as starting points in the electronics area. Mechanical systems should be studied as well.

Finally, a common argument presented is that the more experienced second enlistment technician can be used to solve these unorthodox problems and that principles training should be deferred until this time so that it can be used as an inducement to reenlist. Anecdotal evidence indicates, however, that most of the maintenance performed today is, in fact, performed by first-term enlistees. A personnel study should be made by survey and monitoring of data collection records to determine the actual jobs and percentage of work that is now being performed by first-term personnel.

STATUS OF JPA TECHNOLOGY:
ANALYSIS AND CONCLUSIONS

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Introduction

One of the major objectives of the JPA symposium was to assess the state-of-the-art in JPA technology to determine if it could be structured in some way that would stimulate meaningful discourse within JPA research, development, and implementation communities. It was anticipated that those areas that were well defined might be highlighted for near-term demonstration in Navy personnel and training systems while those areas not so well defined might be assigned relative priorities for research. This objective was well met by the papers presented and the discussion that followed each topic. This was no easy task, however, because of many of the misconceptions surrounding JPAs and--as was discovered in the first morning's meeting--there is no generally accepted definition of job performance aid, even among those who have done considerable research and development in the field.

JPA Technology Base

The paper presented by Dr. Collins, "Some Perspectives on the Job Performance Aids Technology Base," outlined a generally broad concept of JPA for consideration. His description of major conceptual and methodological developments in such areas as motivation theory, job structure, and learning stimulated discussion well beyond the textual, highly proceduralized type of job aid.

JPA Definition

Conceptually, the panel agreed that job performance aids can cover any information presentation format and media, any sensory or physical unburdening tool or activity, and, possibly, the whole area of organizational job design for matching personnel to the job. There is the basic requirement that the JPA is actually used at or near the job itself. In the past, however, and this is where our strong data base lies, we have considered JPAs primarily within the area of information transfer. Reid Joyce's definition appeared quite adequate, therefore, for discussion during the rest of the symposium. He stated that the defining characteristic of a performance aid is the capacity to store information for later retrieval in connection with the performance of a job. The aid facilitates performance by reducing the memory and possibly the training requirements imposed upon the performer.

JPA Classification

It appears that a broad classification of types of technologies that form the JPA technology base can now begin to take shape. The technology base can be broken into three fairly distinct classes: (1) technology associated directly with job aiding systems, (2) technology competing with job aids, and (3) technology that supports job aids. The major subclasses that can be formed under the direct job aiding systems area are (1) format/content type of which the fully proceduralized JPA is one basic type, (2) media (e.g., book, microform, CAI), and (3) job aid delivery system, which has conventionally been the technical data system for textual maintenance information.

Competing and Supporting Technologies

Those areas that should be considered potential tradeoffs with the JPA (e.g., automatic test equipment, human engineering maintainability design, and perhaps job design) can be listed under competing technologies. Supporting technologies are those that act to ensure a workable interface between a particular type of JPA and personnel and training systems. They could include maintenance simulation, instructional system design, job design, and test and evaluation technology.

The classification of a technology as competing or supporting is not always distinct. It depends a great deal on what decisions have already been made and what stages of system development are being addressed. Areas of technological support that could also form part of the technology base and for which a great deal of literature is available are in instructional system design for optimum training strategies and in job satisfaction and job design. The work that has been done in these areas should now be reexamined in the context of supporting the utilization of JPAs. An important technology suggested by Mr. Klesch for tradeoff evaluation with the JPA in the competitive technologies is automatic test equipment. Early in the system concept development, tradeoff studies may also be useful among human engineering design, automatic test equipment, job design, training, and JPA.

Technical Information Transfer Systems

If the existing technology base is probed more deeply within this framework, it is found that the information being stored and transferred is usually technical information and, in particular, technical information to be used by equipment maintenance personnel--and most of the data within that is for electronics equipment. Here the technology base is strong for two types of aids, which can be generally summarized under the "directive" and the "deductive" type aiding systems. Mr. Post has described at least 12 basic format/content types that can be built upon a combination of the directive and deductive aids. Within any basic type "format/content," Dr. Shriver has formulated five fundamental elements that, to the degree they are used, will define the quality of the aid and, correspondingly, perhaps the relative cost of the aid.

Media of Presentation

The panel's consensus on the usefulness of specific media was that media consideration should always be secondary to the format/content decision for a JPA. Specific environmental uses of audio cassettes, CAI, head devices, minicomputers, and holography have been described in the literature and form part of the technology base. Although certain environmental considerations like tight quarters, poor illumination, or flight-deck operation might warrant specific media for presentation of the information, the medium chosen for demonstration can show payoffs in a paper format as well as any other.

Test and Evaluation Methodology

Dr. Collins also points out that test and evaluation methodology itself forms part of the technology base. Part of that methodology is measuring those things that relate to life-cycle payoff. Here COL Grossel emphasizes the concept of "Product Improvement" for evaluating payoffs. It is important as a measure because it not only is useful on new systems that have good tradeoff opportunities, but on existing systems as well. Performance errors, the traditional measure of psychologists, are not particularly useful on large-scale test and evaluation projects for, as Dr. Shriver noted, "errors don't translate into money (or) . . . productivity."

Adequacy of JPA Technology Base

The panel recognized that the positive assessments of JPA experimental evaluations made by Rowen (1973), Shriver (1975), and King (1975) must be qualified with the knowledge that all of those tests were short-term and did not consider the full implications of long-term applications. For the most part, the answer must be no to Dr. Collins' question, "Does the technology base adequately address the integration of the range of psychological factors in the individual, job, and the environment?" A final comment regarding the adequacy of the JPA technology base was the consensus that, although a number of demonstrations have been done over the past, the basic and exploratory research support has been quite weak. In Mr. Post's words:

> We have had no underlying technology base development. In the 50's what was being done about JPAs that we can draw upon? Hardly anything. In the 60's what was done? Most of the inputs for the whole program came from the Air Force PIMO Program.

It is for that reason that the present NAVPERSRANDCEN project has some good but quite limited JPA candidates for integration within the personnel and training communities. 6.1 and 6.2 R&D efforts should probably by initiated now to fill gaps in the technology base and to explore the feasibility of some truly new concepts for JPAs.

Optimum Job Performance Aid

A problem facing any program manager of a new weapon system is the selection of the best JPA technique for his particular system, considering specific operational constraints, manning skills and levels, and availability of funds. In the past within the technical manual system, for example, he has had the choice of almost 100 acronyms to select from (SIMM, FOMM, MDC, FPJPA, MIARS, etc.), but little idea of relative advantages or disadvantages of each. It would be highly desirable, therefore, for the PM to have a guide or an algorithm for selecting job aid techniques that are optimum for his specific requirements.

Directive and Deductive JPAs

Mr. Post's paper, "Selection of Formats and Media for Presenting Maintenance Information," showed an intriguing approach being considered by the NTIPP for matching systems to presentation techniques. Inherent in the methodology, of course, is the hypothesis that job aid utilization levels will be much higher than the utilization typically shown by the conventional technical manual (less than 5% of the total maintenance time).

The approach proposed by Post takes advantage of the available technology base where it is strongest (i.e., maintenance technical data presentation) and makes use of desirable/undesirable aiding characteristics that tend to be classifiable under either "directive" or "deductive" types of format/content. Examples of the directive aid are the FPJPA or the maintenance action procedures in a technical manual. Examples of the deductive aid may be MDCs, functional flow diagrams, or electrical schematics. It is possible, therefore, with the framework set forth in the JPA technology base, to catalog all of the job aiding systems with acronyms into a much smaller, more meaningful number of basic aiding systems.

Fully Proceduralized JPA

As discussion progressed on this topic, another piece of the technology base became more evident. It seems that whenever the task of being aided, whether operator or maintenance, can be classified as nontroubleshooting, the fully proceduralized aid improves performance, no matter whether the person being aided is experienced or inexperienced. For the nontroubleshooting conditions, then, the selection problem reduces to a cost tradeoff on how much of the FPJPA can be afforded. Here, Shriver's fundamental elements, which in the nontroubleshooting case reduce to four, can be used to assess how much quality the PM will be willing to pay for in return for training and personnel cost savings.

The selection model proposed by Mr. Post would be most useful in troubleshooting situations, but it is in the troubleshooting areas that the tradeoff data for showing relative superiority for one aid over the other are weakest. A fully proceduralized troubleshooting format does not appear feasible for all troubleshooting cases, even if it could be afforded. For long checkout chains, Joyce and Shriver stated that it is an inherently inefficient (i.e., time consuming) procedure and, like automatic test equipment, will not be totally reliable if faults occur that were not considered originally.

Performance Data for Selection Criteria

The panel was in agreement that the ability of a PM to select one troubleshooting aid over another or, better, yet, to design an optimum aid to meet his system and operational constraints, manning levels, personnel skills and costs would be highly desirable. But, as Post emphasized, from his past discussion with program managers, "They are not going out on a limb, they want concrete data and relatively good assurances." This was reiterated by Dr. Blanchard who felt that the only way to make the system work is to bring the decision maker some kind of established set of payoff expectancies. It became apparent throughout this discussion that sufficient performance data for selecting one troubleshooting technique over another for developing a useful program manager's guide does not exist at this time and probably should be addressed as a relatively high priority of the NTIPP.

JPA Costs

Equally important, however, if not more so, is the problem of relative costs of aids. Dependable data on the costs of JPAs are almost nonexistent. There was virtually no agreement among the panel members on this matter. Estimates of the FPJPA compared to conventional technical manuals ranged from little difference to five to ten times greater. As one member pointed out, there is really no basis for comparing one format versus another if content and quality are not quantified. For example, a conventional TM could cost more if all the technical data information other than maintenance action information is included in the cost. On the other hand, if a detailed level of analysis is required for the FPJPA and this is compared against gross maintenance procedures in TMs where the writer assumed the reader to be highly experienced or trained in maintenance procedures, the FPJPA would cost considerably more.

Dynamic Aiding Characteristics

Whatever the aid selected, it is also important, as Post suggests, to consider the dynamic features of the aid, not only as to its ability to be revised by user feedback or to conform with system changes, but also to progress with advances in the personnel career ladder. Some of the work already done on a hybrid aid by NAVAIR (combination of directive and deductive, with overlapping information so the maintainer could gradually progress from a highly directive aid early in his career to a highly deductive aid later in this career) would find application within this selection model and possibly further reduce the requirement to choose between one or the other.

JPA Integration Model

Dr. Collins likened the JPA selection problem to that of the human factors engineering integration project in the conceptual design process. There you may be dealing with data and principles that provide guidelines for making decisions about whether it's going to be a man in the system or a piece of hardware in the system. With respect to the JPA, this brings up the question of where in the process JPAs ought to be considered and what decisions should be considered at each stage. The selection model should be sophisticated enough to at least tell what the tradeoffs are with training or manning skill levels. If some of the performance data and cost data gaps can be filled, perhaps a model like the one started by NAVAIR with N. C. State (Ayoub, Smillie, Edsall, & Muller, 1976) could be used for addressing the relative advantages and disadvantages of one aid versus another, or JPA versus training. It became quite clear by this point, however, that the problem of JPA utilization in training and personnel design is going to be much greater than selecting the optimum aid from a host of candidates.

JPA Delivery System

One of the most fundamental assumptions of using job performance aids to reduce training requirements or to accomplish a job with lower skill personnel is dependability of the aid. It must be accurate and available at the time the job is being performed. To the degree it is not, additional training or backup personnel must be made available. When the JPA is to display operator or maintenance information, the available engineering data base is the starting point for its development. From this, both on-the-job information (operator and maintainer) and training information can be developed and placed into textual formats or special media for presentation.

Independence of Training and Technical Data Systems

In the past, the technical manual people have been the main users of on-the-job operator and maintenance information, but have assumed the personnel using the technical manual will have had considerable training before using the manual. The training people, on the other hand, may use the same engineering data base to develop learning materials aimed primarily at improving those knowledges and skills that can be retained in memory. The result of these two almost independent systems is a type of redundancy that tends to take care of a great deal of uncertainty that exists in the operational world. The adverse effects of inaccurate and unavailable technical data is offset (and, to a great extent, disguised) by the availability of highly trained personnel. Conversely, the availability of a good maintenance manual in the hands of an experienced maintenance technician can offset (and similarly disguise) the effects of inadequately trained personnel.

The fact that the two systems are independent (at least in the Navy) was expressed most succinctly by Post, "Articulation between the training process, the process by which training materials are developed, and the process by which JPAs or technical manuals are developed does not exist." In short, training people and technical manual people do not speak and do not attempt to speak the same language.

There are three major problems with the operation of two relatively independent systems in this way: (1) There is no assurance that either system is working sufficiently well to compensate for weaknesses in the other--thus allowing tremendous operational deficiencies, (2) in the best of systems, the dual support systems approach is extremely costly, and (3) the masking effects of one system on the other make it almost impossible to pinpoint major faults so that intelligent decisions can be made on where to cut costs and where to improve efficiency.

Future JPA Delivery System Alternatives

The move toward the JPA to cut costs in training and personnel has to change the way of procuring and producing technical data for the two redundant systems. Assuming a methodology for selecting an optimum aid can be developed for predicting payoff expectancies relative to training and manning, the next problem to be solved becomes essentially a policy decision by top Navy management. This question centers around what delivery system will be used to produce, distribute, and update JPAs. Conference participants suggested three alternatives: (1) modify the existing technical data system to include training requirements, such as being attempted by the NTIPP program, (2) create a whole new system for delivery and update--possibly within the training command, and (3) combine training and technical data into one system, following the example being set by the Army in their ITDT program. The first of these is probably the best short-term goal for the Navy, but the third suggestion, to combine the two major areas of training and technical data so that both are speaking the same, albeit a new language, appears to be the more advanced, most efficient long-term solution.

Integrated Training and Technical Data

If the provincialism of Navy training and Navy technical data systems could be overcome, tremendous savings in data and training costs could become a possibility. As Dr. Shriver suggests:

> The pattern should be to stop talking about such things as, this is training, this is documentation, and this is training aids, but that it is all one thing . . . the old assumption was that training is supposed to describe *the equipment . . . Bring the two together* and the individual will figure out what to do: A new approach is to analyze the whole thing . . . figure out what he is supposed to do, and tell him.

When one hears the arguments for technical data being the prime mover (e.g., Mr. Johnson's emphasis on needs for configuration control and close association to engineering drawings) versus that of training (e.g., Mr. Post's comments on user feedback and Dr. Shriver's statements about training command assurance of validation), it becomes even more evident that both have something to offer but need to be addressing a common goal.

Technology Limitations in JPA Accuracy

Mr. Johnson brought up points in his paper, "Problems in Procuring, Producing, and Evaluating JPAs," that, for the most part, probably will not go away completely with any delivery process. There seems to be a limit to how much accuracy can be incorporated into JPAs. His information on the two major sources of error (i.e., human limitations in predicting all possible faults for all systems and equipment and errors due to hardware revisions) illustrates why it is not reasonable to expect error-free documentation in complex systems. This knowledge, coupled with the first-hand experiences of almost everyone at the conference of never having had totally error-free JPAs to work with, makes it only too clear that there is a technological limitation to how much accuracy is obtainable with JPAs. This confirms earlier suspicions that JPAs cannot (at least in the troubleshooting areas) totally eliminate the need for training of skills greater than those that can be imparted totally by the JPA itself. The panel was also sure, however, that the level of quality could be made quite high, provided maximum efforts are made toward tight enforcement, use of professional writers, and a training validation.

User Acceptance

Whenever a new piece of equipment, a new system, or a new way of doing business is introduced, it must first gain user acceptance before its value can be realized. The paper by Reid Joyce, "User Problems in JPA Utilization," provided an excellent status report on the general nonacceptance of JPAs even though almost every experimental evaluation has shown that technicians, both experienced and inexperienced, make fewer errors on the job when using a JPA. He emphasized that much, if not most, of the problem lies in the fact that there are a large number of users, in addition to the person doing the job, who are affected by JPAs being introduced into the system. These include the technicians' peers and supervisors, nonmaintenance users of the documentation system, and all those connected with hardware and logistics problems at the program manager level.

"Real" and "Imaginary" User Acceptance Problems

For the purpose of organizing the technology base, it is useful to treat the two types of user acceptance problems separately. One type is what may be considered "real" problems with user acceptance because they have to do with acceptance or rejection of the aid itself by the field user himself because of his initial or acquired attitude toward how the aid effects his actual performance on the job. The other type may be considered to be "imaginary" with respect to those kinds of things that may be inherent in the aid, but that nevertheless can override acceptance of the aid. These are problems of general acceptance by the operational and support systems already in existence. The "imaginary" problems, of course, must be dealt with for successful long-term demonstration or eventual implementation, but they should not be confused with the inherent advantages or limitations of the job-aiding technology itself.

The first set of problems, those which contribute directly to aid acceptance, include things like the actual limitations of the JPA (e.g., inaccuracies, insufficient level of detail, or too much detail) but they also include a lot of attitudinal characteristics of the technician. For example, as Joyce warns, if the JPA is introduced as something to help "dummies" or something to make the job "simpler" rather than "easier," it will be rejected. Also, no matter how good the aid is, it must compete, as Post suggests, with other styles of operation: "In the eyes of the user, is the JPA better, worse, or the same as getting advice from peers, working it out according to their own ingenuity, or admitting to their supervisor they don't know and ask for advice?"

JPAs' Contribution to Job Satisfaction

The data available support the concept of JPAs as a means of enhancing job satisfaction that should provide a strong motivation for user acceptance. For example, there are sufficient learning concepts to infer that job satisfaction/motivation can improve through satisfactory on-job performance. Dr. Collins states in this paper: "Learning, change, and growth are best facilitated by an integrated process involving immediate experience, validation of that experience, modification of this behavior, and the choice of new experiences." Also attitude information that has been collected, much of it by panel members themselves (e.g., Post, Shriver, & Joyce) has indicated a strong preference for JPAs over conventional materials. Even the personnel, reported in Klesch's paper, could be assumed to have had high morale and good attitudes toward the JPA initially.

Adequacy of User Acceptance Technology Base

Although the first set of problems is substantial, the technology base seems to be on firmer ground there than with the second set. The conference participants were confident that many of the direct user problems had been addressed in the past and could be solved with what we now have available. The second set of problems, gaining acceptance of all the indirect users, is the challenge which remains to be solved by the JPA community.

JPA/Training Interface

Dr. Shriver's paper, "New Directions for Information Transfer Research in Maintenance Jobs," reiterates the basis for the NAVPERSRANDCEN project. There appear to be major potential payoffs on the order of 100 to 1 in personnel and training maintenance costs with the utilization of JPAs even if the JPAs cost 20 percent to 50 percent more to procure than conventional technical maintenance action materials. He notes that studies over the past 20 years show reductions in training on the order of 50 percent to 90 percent with corresponding increases in job productivity as high as 50 percent and 60 percent. These gains cannot be realized, however, by the simple introduction of the JPA into the current maintenance and training system.

Adequacy of Interface Technology

The questions raised by Merle Malehorn in his paper "Impact of Job Performance Aids in Personnel and Training" (In Rowan, 1975) on career patterns for personnel, cross-training, backup training, on-the-job training, generalized skills, and measures of proficiency are still valid. The JPA/training interface becomes very critical to the actual achievement of any of the potential JPA gains. As already discussed, the technology base for JPA development is excellent for nontroubleshooting tasks for operators and maintainers and offers several strong contenders for troubleshooting tasks. Also, the research base, in education and training on instructional system design, appears quite strong for determining optimum strategies in achieving basic learning objectives. The place where the technology base is weak is at the interface of these two technologies. It would probably be helpful at this point to consider some of the concepts and assumptions offered by JPA specialists for dealing with the questions raised by Mr. Malehorn.

Common Task Analysis

One of the most fundamental assumptions of JPA proponents is that a common task analysis be conducted for both training and JPA development. Four of Shriver's fundamental elements deal with the different levels of analysis required for both training and performance aids. One of the earliest decisions would be for the analyst to determine which items should go into the book (JPA) and which into the head (training). The questionable area, here again, is in troubleshooting. As Mr. Johnson pointed out, there is no standard or optimum means of developing troubleshooting. There is a paragraph in FPJPA specifications that says, "find an experienced technician to do the troubleshooting."

There are some assumptions here for training. One of these is that the primary strategy (in electrical, electronic, electromechanical, and hydraulic maintenance) to be learned is signal tracking. The way to optimize this is thought to be through emphasis on understanding functional relationships of major components at a block diagram level for specific systems as opposed to learning general circuit theory or fluid flow dynamics. An interface question to be answered however, for any specific system, is how much of this could also go into a JPA rather than in a classroom.

Career Patterns

A new concept is beginning to take place in an attempt to help integrated JPAs and training handle career patterns. Post suggests we stop talking about experienced and inexperienced personnel and recognize that there are gradations of experience. The job aids and the training in combination must not only get productive labor at the lowest level but also has to prepare the technician for progression to the next plateau of his career. To the degree this is attempted through the aid rather than formal training, the hybrid aid concept developed by NAVAIR about 4 years ago should be considered a plausible candidate.

One of the oldest assumptions of the JPA community was set forth by Dr. Shriver; that is, to put the first-term enlistees to work immediately, and, with the JPA, some productive work can be achieved while he is learning higher skills on the job. If the technician signs up for another tour, he can then be given formal theory training. This person with both theory training and several years of on-job experience can become part of the backup used to solve the difficult troubleshooting problems that, for one reason or another, were not covered adequately by the job aid. A special path for the high aptitude first-tour enlistee should also be available in such a system.

Generalized Skills

Another important aspect of career patterns through integrated training and job aiding to be considered is the development of generalized skills. Here again, it is primarily troubleshooting where this is a concern. A good maintenance technician should be able to carry more than basic skills learned on one type of equipment to other similar types. Because of many of the problems discussed on the limitations in the technology for delivering a totally reliable JPA and the realistic view that operational conditions seldom if ever meet the "idealized" planned conditions, career maintenance personnel must learn to solve problems as well as to fix them by rote. The hybrid aid concept may be useful here too for achieving generalizable cognitive skills when used in conjunction with on-job training. As Joyce states in his paper, "The ultimate solution will probably include JPAs used by inexpensively-trained, early enlistment people, and more conventional aids used by more experienced people who have received supplemental training along the way or at the beginning of their next enlistment." Job design technology would need to be used to match a large, less complex workload for the large number of JPA users and a smaller, but critical, backup workload for the conventional aid user.

Measure of Proficiency

Finally, with respect to the new JPA/training interface, and personnel career patterns, it is absolutely essential that measures of proficiency be designed around actual job performance skills rather than conventional knowledge tasks as basic criteria for skill level advancement, job assignment, and promotion.

Effects on Personnel System

It was with the presentation of John Klesch's paper that the full magnitude of the problem of implementing a new technology like the JPA came clearly into focus. Even though the job aid technology base is sound, the optimum aiding technique is selected, the delivery system is providing an accurate and timely JPA, and the field user has accepted and is using the JPA, the JPA is doomed to failure if long-term personnel effects are not considered. Again those questions raised by Merle Malehorn at the conference on "Improved Information Aids for Technicians" in 1975 are those to be answered. In summary, they include personnel considerations like job structures, assignment structures and processes, processes for personnel classification, advancement procedures, and recruiting and retention.

Test Subject Careers

No JPA experimental demonstration has really attempted to deal with long-term personnel effects in the past, but they must be primary considerations in any future research. In fact, with the knowledge of the damaging long-term effects on the personnel trained with JPAs reported in Klesch's paper, it would be irresponsible, if not raising legal liability, to do further JPA experimentation without providing satisfactory career paths for test subjects. It is useful here, as with the User Acceptance Technology discussion, to separate those things that may adversely effect the technician's career because of inherent limitations in the JPA concept itself from those that are almost entirely related to "the way of doing business."

Personnel System Cooperation

Assuming the training interface, the assignments, and criteria for proficiency are fully considered through an integrated approach from the available technology base in JPA, training, and job design, most of the questions raised in the personnel system can be classified as system implementation problems. And the results of the NAVPERSRANDCEN demonstration will, of course, be needed to justify any major changes in the personnel system. Until the NAVPERSRANDCEN demonstration is completed, however, it will not be known whether JPAs can positively influence personnel careers and upgrade skills. It is known that JPAs simply introduced into existing logistics support systems without corresponding system changes will have a negative effect on personnel careers. In order to conduct a demonstration, therefore, special case procedures for the test subjects must be developed and approved at the BUPERS level for classification, assignment, and advancement. In addition, at the field level, the confounding effects of peer rejection and supervisor bias must be rigorously controlled.

Recruitment and Retention

Recruitment and retention aspects of this personnel system are different. They raise special considerations that relate more directly to concepts of the JPA itself. For example, Klesch brings up the possibility that many first-term enlistees are already performing useful productive labor. His impression is that, in the Air Force, many of the first-term airmen are indeed performing a great deal of maintenance. If that is happening, it certainly is not being done on any systematic basis. But, to the degree that special groups can be identified that do make good use of new enlistees, they may provide clues for job design and might provide useful information for the concept that increased productivity can lead to greater job satisfaction and, consequently, increased retention. A problem mentioned in the recruitment area with respect to JPA is also critical. There could be fewer first-term enlistees, if the incentive "Navy training" provided in the past is removed. Surveys should probably be conducted in the near term to determine how much "truth" there is to these two JPA personnel system effects.

Implications for JPA Demonstration and Implementation

Many specific recommendations for JPA research and development are given in the papers and in the selected verbatim comments in the appendix. They all have implications, either for the current NAVPERSRANDCEN test and evaluation project or for the long-term implementation of JPA technology into Navy weapon logistics support systems. Some of the recommendations appear most directly applicable to the NAVPERSRANDCEN project goals; others appear outside the scope of the immediate project, but relate to it indirectly if the payoffs anticipated in the demonstration project are ever to be realized in the operational world.

Long-term Demonstration Recommendations

A general conclusion can be drawn that directly influences the scope and direction of the NAVPERSRANDCEN advanced development performance aids project. The panel concurred that the JPA concepts and approaches in the available technology base are sufficiently broad and flexible to show major payoffs only within maintenance areas using technical information presentation for troubleshooting and nontroubleshooting tasks. The data are strong here and should be pursued with a longitudinal demonstration (1-5 years) for effects on training and personnel. The demonstration should show the ability to influence costs across the system life cycle and to positively influence personnel careers and upgrade skills.

The test cases selected for demonstration should probably agree wherever possible with those suggested by Klesch. He suggests a complex task electronics system, a not-so-complex electronic system, a mechanical system, and a system that integrates a mechanical system with a complex digital electronics system. For at least some of the test cases chosen, nontroubleshooting tasks should be covered. These could cover both operator and maintainer tasks equally well. The type of format/content JPA for nontroubleshooting should be the FPJPA.

Each test bed chosen should probably address troubleshooting tasks. The selection methodology being developed on the NTIPP program should be helpful to NAVPERSRANDCEN in the program manager's guidelines to be developed. However, experimental performance data and cost data for comparing one concept versus another for use in a payoff model will be required before it can be used reliably by a program manager. The troubleshooting format/content should probably be a combination of "directive" and "deductive" aiding selected from techniques known in FPJPA, FOMM, work package concept, and logic tree block diagrams. The NAVAIR hybrid aid or similar concept should be reviewed for applicability to each troubleshooting test case.

Methodological Study Recommendations

Cost-effective use of training and training systems in conjunction with JPA is a most critical factor. A near-term study should address how much "deductive" troubleshooting should be left to the JPA and how much should be part of a job-based training package. Methodological problems that should have highest priority include (1) methods of integrating job-based training with JPA technology, (2) a study of the implications of JPA technology for job design on personnel careers and job satisfaction, and (3) the development of a JPA-based personnel system concept.

The personnel system concept would define a limited model integrated across training, personnel, and job design with the objective of achieving full utilization of JPA technology wherein an operator or maintainer could be given work assignments early in his career. The concept should also provide a system by which career-oriented personnel could seek preparation and experience for advancement. Such factors as career patterns, channels of advancement, proficiency assessment, motivation and morale, career-oriented training, and accelerated OJT would need to be considered. The personnel system concept would provide a step toward the broader problem, that of integrating the JPA/training/job design tradeoffs into the total weapon system and logistics support research and development stages.

JPA Technology Implementation Recommendations

The conference participants agreed that a total model should start by laying out the communication interfaces with training, manning, technical documentation, and the other logistics support areas. Ideally, at each decision stage in the conceptualization, design, and development of each major weapon system, the PM could exercise decisions with quantitative criteria and reliable tradeoff methodology among the human resources and the other logistic support areas. The Human Factors Engineering Integration Project of NSRCD, Annapolis, should be reviewed for applicability to the larger problem since it addresses problems that may parallel those of the JPA technology implementation. The recent work of Essex Corporation (Collins, 1977) for NAVPERSRANDCEN on assessing strategies for mapping the processes and defining the communications networks that interface personnel R&D end products would also be useful as a starting point for implementation of JPA technology.

COL Grossel's points on product improvement measures for new and existing system development, operational readiness, and availability to help war-time surge capability, and the need to increase standardization wherever possible, reflects the larger picture that JPA technology must address as well to ensure eventual implementation.

Implementation Research

In conclusion, there was little doubt in the minds of the conference participants that the status of JPA technology is at the point where major benefits can be achieved if the technology is implemented. It is in the implementation area, however, where the R&D technology is weakest not only for job aids but also for all other human resources products. A conference that started with the question, "Is JPA technology sufficiently developed for implementation?", ended with the conclusion that research is most needed on implementation itself. This was most succinctly summarized by Dr. Shriver:

> We, the human resources research community, are in an implementation area we are not prepared to deal with. We have a technology base but not enough people who have the technology to get implementation accomplished correctly. The problem is research in implementation itself.

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APPENDIX

CONFERENCE DISCUSSION

SESSION 1--Wednesday morning, February 23, 1977

The selected discussion comments below followed Dr. Collin's paper "Some Persepctives on the Job Performance Aids Technology Base."

Mr. Klesch: In the 1930s, work centered on the job simplification concept. Then there was work on actual tasks in the 40s and later, in the 50s, we started moving on to research areas for such things as motivation, work fulfillment, self-enrichment, and job satisfaction. But it seems to me that with the Air Force application of what we call JPAs today we are still back with the job simplification concept.

Dr. Shriver: Some experimenters have done task simplification when they made JPAs, others haven't, but there is a payoff. You can get an effect whether you make your task analysis to simplify the job or just to describe it more accurately. There are several effects that different experimenters have gotten. They have used different analytic techniques but any of the techniques work. I think there are four or five. If you put them all together you get a bigger effect. Sometimes the simplification has been there, sometimes it hasn't.

Mr. Klesch: There is a question here regarding the net impact on the individual. That is, is he happier, more satisfied being able to accomplish a task that he may not have been able to accomplish before JPA; or, has he been reduced to a lower status by following a book technique so that in fact there isn't job satisfaction?

Dr. Shriver: My experience has been that most people are interested in doing well. Doing a job well is the only intrinsic kind of motivation there is in the military service. Most everything else is expensive--promotion, money, etc.--but doing well at a job is what most people really need.

Dr. Booher: What about peer recognition?

Dr. Shriver: I think that that is a function of how the technicians happen to grow up. I went to school for a year when I was in the Navy. That's how long the training was for electronic technicians during the war. If that's the way you did it, that's what the senior people did; and unless everybody else has done that then you don't really know. It seems to me there is a present opportunity to break that very neatly with the supervised on-the-job instruction. It isn't just reducing the amount of time in school which is degrading. The portable JPA has made it possible to deliver the instructional content on the job without the supervisor turning himself into an instructor.

Mr. Post: You are taking an instantaneous snap shot of the situation. The person without the job guide who goes out and is unable to perform is now able to perform with the job guide. That's great. Now we have a productive member of the group and everything is fine. Jack Collins' comment in his paper about Maslow's Hierarchy needs, that's only fine for a certain period of time. Then he has to go to the next plateau. I don't think job aids and conventional JPA style provide or accommodate for that next plateau. The work that Hal and I did a couple of years ago tried to combine some different aid forms so that we had a series of plateaus. Mastery of the first plateau automatically provided entry into the second level plateau. We have to support the gent's career progression.

Dr. Collins: There is a human goals program which has a lot of intervention strategies and it has broad-base approaches, not only to the quality of life but also performance. I was also thinking in terms of whatever progress we have made in the job performance area of trying to become more definitive about what accounts for so much of the variance that we haven't been able to deal with historically. In trying to look at some dimensions in job performance in some broader context than a skill level kind, I think there is knowledge available which (if only from the job design literature) deals with some of these other dimensions.

Mr. Post: In question No. 3 you talked about the inclusion of group requirements.

Dr. Collins: One of the things that prompted me to suggest that, in addition to what appears in the literature generally, is the recent action of the defense science board. The board published a rather strong report on the need for improvements in training, including especially team training. I think there is a lot of interest at the moment in this area of team training and implicit is team performance. What have we done in the context of the historical developments of JPAs to support teams as distinct from individuals?

Mr. Post: The hands-on aspects are obviously personal and individual but I think that it has to be a group effort. You've got to get the most from your entire work force whether they are inexperienced or experienced. In that sense I think they're a team but you are not performing in a coordinated two-man type fashion.

Dr. Shriver: Technically it is not a team sport. Not that whenever there is a group of people you don't attend to those aspects with JPAs.

Dr. Collins: Are you saying maintenance is not a team function at the behavioral level?

Dr. Booher: What about the type of situation where a man is down in a submarine somewhere and is trying to repair something in a tight, dark environment? How about the use of audio communication where someone else reads the manual or guide while the other man does the work?

Dr. Shriver: I think that that is a trivial case where one person is a repeater. It could have been done with an audio cassette. It is not interaction; it's just a channel of communication. I mean team in terms of where you have to do this while I push up on that, the tradition of group dynamics. Four people on the corner of a box and each one must keep it level so that the ball in the center doesn't roll out of its position. Joint interaction among them all. I don't see that in maintenance JPAs definitely are changing our old notions on how things should be compartmentalized. My feeling is that JPA makes everybody equal to go out and do the job with no training. Follow the instructions and do the job. If its a calibration job, you just follow the instructions. Therefore, everybody's job duties expand greatly.

Dr. Booher: I am very concerned that we may not have an adequate data base to do a demonstration on much other than tech data kinds of things. It seems to me that JPAs have always been defined (the way we use them) as information aids. Are we thinking of a JPA in terms of anything other than information aids? The other main thing I have heard addressed today is job design. There seems to me to be other categories like tools which aid physical areas. Another category which may be considered a job aid is the automatic test equipment.

Dr. Blanchard: There may be many other kinds of aids. There could be psychomotor aids also. There could be visual information aids in the case of a situation where you facilitate an alignment, calibration, etc.

Mr. Johnson: When you finally decide that you are going to need a particular type of JPA, many other decisions have already been made which restrict the choice of the JPA maker. Specifically, take a new system, critical design reviews have already been held, and at this point in time the decision has been made to the degree of built-in test. The decision has been made that certain kinds of test equipment are going to be used. A decision has been made as to the kind of tasks that have to be performed in terms of the hardware that you've designed. Very little is left for the JPA technologist to contribute and say we are going to do this or not do this. I would like to suggest that we may want to concentrate on what JPA technology is going to assist.

Dr. Blanchard: The reason we are here is precisely because of that problem. We don't have a solid technology that has been organized in the framework that the design process can use. If we had something like that then we have a chance of affecting this process. We have to get this technology in the R&D institutions. When people design weapons systems, they'll have a means for considering tradeoffs within personnel training, maintenance, and the use of JPA technology. We don't have that tool now. We can't hold it out or we can't introduce it. We can't interject ourselves into that process because we don't have anything to sell. That is recognized.

Dr. Collins: Stay within the realm of maintenance and try to define within at least those parameters what kinds of technology are available.

Dr. Booher: I think the one big important area is job design. To really make the job aid work we have to consider other characteristics of designing the job for the individual. We really have not built the whole literature of what's going on in job design into our technology base.

Mr. Post: Let me digress for a moment to Rowan's report. Somebody else seems to think that it was relatively negative, but I think it was relatively honest. As I recall, I think he reviewed some 14 or 15 field experiments that evaluated information aids of one type or another. I think more than half were positively assessed by Rowan, maybe as many as two-thirds. He made comments about the experimental design and the rationale of the test with regard to some others. I think of it as a positive appraisal.

Dr. Blanchard: I think we are finding it difficult to carry out experimental controls in the traditional sense. Experimental design in the applied situations is a difficult process. There are many variables that have to be controlled.

Mr. Post: In terms of some of the JPA technology, I think we are pretty well along and ready to apply. I think some particular sectors of that technology might have some holes, but it would be useful to get it out into the field. I think the answer is both yes and no. Yes, for some purposes and no for others; and, in which case, we have to go into some R&D phases. I think that's one of the things that the Navy has not till recent months done very well. We have had no underlying technology base development. In the 50s, what was being done about JPAs that we can now draw upon? Hardly anything. In the 60s, what was done? Most of the inputs for this whole program came with the Air Force PIMO Program. I think we need both. We have to get some portions of technology out into the field and draw the benefits from it. We have to continue to develop the technology at the same time.

Mr. Johnson: The technical manual publications system as it's entrenched today is not really ready to accept JPAs.

Dr. Collins: Is there any special kind of test and evaluation technology unique or applicable to JPA evaluation?

COL Grossel: The change is to really try and get the program managers to take more of the life cycle cost approach in developing systems. They are not going to be on watch when the system is operational, but there is definitely a very strong drive to force the program manager to include life cycle costs in the design of the system. There is a new instruction that came out (5000.2) on acquisition of systems. There is a requirement in there at the DSARC 1, 2, and 3 level to have a one-page logistics annex.

Mr. Johnson: The JPA tool includes something that is already going on that we should make ourselves aware of--the maintenance engineering analysis. Then, getting to your second point, how do we use the tool? I suggest that the way to make this thing work is to get the results of our analyses included and made a part of the engineering production drawings. For example, right now every engineering production drawing that goes off to that shop includes one line for a schematic diagram. It strikes me that we could have another line that says JPA technology procedure number such and such for each separate procedure that was developed for that black box. You could make it follow the design process that we enter and it becomes part of the engineering production drawing. Once that is done, then you've got a self-healing kind of thing because the inspector who is testing the equipment will insist that that line of that drawing be performed.

Dr. Blanchard: I think that we've got to get in even earlier than that. We talked about tradeoff analysis early in system design conception where you are looking at various alternative ways of performing certain functions. I think we have to be in there because that's where you are looking at personnel variables and training variables. Once you get into the maintenance engineering analysis you have a fairly fixed system concept. That may be a bit late. I'd like to shoot for something a little earlier.

Dr. Shriver: The pattern I see over the years is to stop talking about such things separately, such as this is training, this is documentation, and this is training aids. It is all one thing. Allocating to those old categories sounds funny to me at this point. It seems to me all categories are being merged into one thing. The old assumption was that training is supposed to provide the individual with certain knowledges. The book is supposed to describe the equipment. Then you bring the two together and the individual figures out what to do. A new approach is to analyze the whole thing and figure out what he is supposed to do and tell him.

Mr. Joyce: When there is a substantial string of things that a guy has to do, it doesn't lend itself very well to his following an aid in the time-limited situation. While the steps that he performs may be correct, there are many situations where he is going to have to learn to do that thing prior to the time he comes to it in the job aid.

Dr. Shriver: All tasks can be proceduralized. I don't know if it is the most efficient.

Dr. Blanchard: It seems we are not looking down the road far enough in terms of what happens to this guy. We may have some problems down there. We have looked at certain variables and our optimization models say if we can do these kinds of things, we can achieve this kind of payoff and it looks pretty good. However, if we stretch this down the road three years and look at channels of advancement and what the personnel structure might look like, it begins to get shaky. There are other kinds of problems that have to be considered in terms of how we use JPA technology.

Dr. Shriver: You can put concepts in a book for him to memorize and carry around in his head, that is, block diagrams and things like that which are not fully proceduralized. Instead of an instructor saying it, the book becomes the communication device.

Dr. Shriver: You can deal with paper and that is real world. Technical documentation the world knows about. The effects that have been documented are there because of types of analysis, not whether it's displayed on a CRT, or a piece of film, or on a piece of paper. CAI gets into tough programming. Also, paper is the cheapest way to do it.

Dr. Collins: I would just like to make one comment in terms of the task analysis side of the development of JPAs. I would suggest that we seriously consider as an option a behavioral requirements approach as distinct from behavioral descriptive approach. In the behavioral requirements approach, of course, the emphasis is on acceptable levels of standards of performance and it consists of both a skill and a training dimension. It also seems clear under the broader question that maintenance is probably the demonstration area that we would want to pursue.

Dr. Shriver: Just to pick up what Jack said on the last point, maintenance certainly seems to be just the area to stick to; don't broaden it. There is plenty of payoff there. We know what we're doing. Stick to what you know. I think the technology base is strong enough there. People all over the country are doing these things now. The analysis results can be put in a book easily enough but when you get to the technology of putting it in some other form than in a book, e.g., CAI, etc., I think it is getting risky.

COL Grossel: I am still not adequately satisfied in my own mind that we have tackled the definition of JPA, although a lot of things have been discussed. I think that there are really two main areas where we can apply the technology today. I think I agree with what Ed said that book technology seems to be sort of defined and there seem to be some concepts which people can be sold on the idea of applying even without further data. Further data, of course, will help the speed and depth of implementation. I think the biggest thing right now is what you might call product improvement--implementation on existing systems. If you go product improvement, you don't have all these tradeoffs of ATE vs. job aids vs. other support test equipment. I think you definitely take a different approach although your technology base may have a lot of common elements in it. If you go design of new equipment, you bring up all the things that Frank was mentioning in the LSA analysis and the MEA analysis. An awful lot of things have to be considered, and one of the big things in that area that I see is a need to get a better handle on the tradeoff decisions. I think too many trades in human resources are made in heads of one or a group of engineers, and they are undocumented. They use their experience and say okay this is the way we are going to go. We are going to use ATE to do such and such without bringing those decision points to the surface. What grounds were considered, what were the objectives, what were the constraints, and then what were the decisions made? Without all that being documented adequately, I don't think we can ever make an improvement. We have got to make them visible. We have to have a path that we can trace back and also get historical purposes of this system. What approach did they use, and were they successful or unsuccessful? With respect to both new equipment and product improvement, I think we have got to define what we see as the purpose of the job aid. Is it just for operators and maintainers? In addition, is it to provide some sort of training, probably on the job? Don't eliminate training, but put a new man out there who can train on the job and develop some of this knowledge in the head. We can take lesser initial training; but, in addition to the operating and maintaining, we have got upgraded skills to consider. Getting into the hierarchy of needs, possibly through this training, you can upgrade his skill levels, upgrade his self-image, upgrade his actual contribution to the mission. If that's the purpose, well maybe some of the simplified proceduralized approaches aren't the best or at least the only answer. There would be other things that can help him upgrade his skills. I think that anything you can give to someone and have it essentially done by "a monkey" doesn't really do much to upgrade the skills of that person. I think we have also got to consider readiness and availability and operational needs. We have got to look at training vs. wartime in the face of surge. Right now, let's face it, we are in a training situation. We are training for defense or whatever you want to call it. Shouldn't we really convince these people to try out some new concepts right now when we're really not at war? We are certainly not going to get any of these things when we are at war, because then we're there to shoot guns or drop bombs or ward off the enemy and so on. Maybe some of these new approaches can also help us in the surge. If they can, in fact, in a real environment take a new person with minimal training and bring him up to skill quickly and provide for on-the-job training, provide some support to the mission, provide for upgrading of skills and still retain attention to the personnel aspects of it, we increase the surge capability of our forces.

Mr. Post: I think in the interest of a solid demonstration for the program we ought to define JPA tools as the things we know most about which comes in two forms. One is the proceduralized form which tells the user what to do and how to do it. The other form I've been calling "deductive," and it leaves the user to go on his own inferences as to what to do. I think that we should restrict ourselves to these two basic aid forms, and the thing we need to do in the program is to devise a methodology that tells us when and how to use either or both or combinations of these two basic forms. I think we should do

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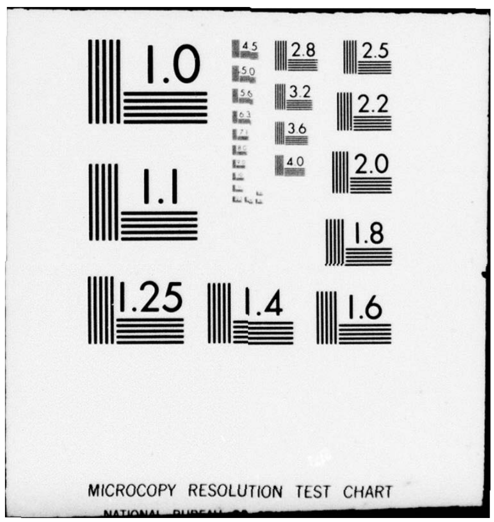
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what we know most about and the thing that our "audience," whoever that is, is predisposed to accept. I think that is maintenance. Rather than branch out into a new application, let's stick with the firm definition or demonstration of what we know in a field that most people know about.

Mr. Joyce: I agree just about entirely with what Ted said. The areas in which most of us in the room are most familiar are construction and use of those two kinds of aids. I think we really do have a technology for building both. I think we can look backwards from those concepts to how we could interact with people who are in a position to design the jobs and come up with more optimal job designs that include the use of aids. I think that the techniques that we have right now for building either of the kinds of aids we have talked about can deal with any kind of mix of job designs. We tend to let ourselves be driven by the way the job presently is designed, and we build the aids to reflect the job as it is which may not be optimum. We get in trouble that way. We wind up with our own interface problem because we have been driven by an existing job design. I agree that the demonstration that comes out of this project is going to have to consider a mix of these kinds of aids for no other reason than to deal with the problem of building career structures for people that they are willing to tolerate. We have by virtue of the structure of some of our experiments led the world to believe that we've got some kind of peculiar ideas about what our aids are supposed to do. We have left in our wake some bad feelings because we failed to try to explain to people after we left what they are supposed to do.

Mr. Johnson: First I'd like to say that we should stick in the field of maintenance because I think we know most about that. I'd like to say that we should go ahead and use the existing technology which is the proceduralized aids. If we are going to really be effective in a demonstration, we have got to look at the maintenance system as such and identify what kind of aid we are talking about. Obviously, we cannot say that a JPA is going to do everything that the existing technical data does now, so we should find out how the JPA complements and uses information that is already available in the technical manual system. If we don't do this systems maintenance aid design, we are still looking at a little tiny tree in the big woods. I do believe that if we are going to really demonstrate that we have a technology base, we have got to first identify through some kind of maintenance engineering analysis where the JPA fits in the maintenance system; and than go ahead and produce the JPAs for those areas that are most applicable and profitable.

Mr. Klesch: I think your demonstration should attempt to convince others and ourselves of the ability of the JPAs to indeed make an impact on life-cycle costs. In that regard I think the technology base for development exists. Technology for proper assessment of other impacts does not exist and has not been utilized. I think one of the other areas that we should also be interested in is the payoffs in the long-term on personnel, for example, the psychological effects. So far we have only experimentally demonstrated how we want the man to use the JPA and how we want him to learn. The question is, how, in fact, will this occur in the real world? We may be off base. I think you'll have wasted a lot of good money to take one type for a month or 2-month demonstration. I don't think that's going to yield any payoff that will help us. We need to have something more in-depth. Believe it or not, when we are talking about the impact on personnel, we are talking about 1 to 5 years.

SESSION 2--Wednesday afternoon, February 23, 1977

The selected discussion comments below followed the paper of Mr. Post on "Methodology for Selecting Optimum JPA Techniques."

Dr. Booher: One question about your model, Ted. Are we to assume that this is the kind of thing that the program manager would have available? Some of these items we would have available, but I wonder about the things like span of supervision. At the decision stage he may assume he's going to have a narrow span of supervision but in real life it turns out differently. Another comment is, perhaps one of the objectives of the program manager would be to increase the skill level or utilization of his people, rather than having it an established fact that he always has low-skilled people. He may feel that an aid would allow him to use lower-skilled people.

Mr. Post: Diagnostic technique would be a difficult thing for him to predict at the early stages of system design. I guess we've got to give the program manager some sort of generalized model that will allow him to run through these kinds of considerations. Whether it's a set of guidelines that we try to develop to reduce these considerations, I don't know at the moment. I've talked to a couple of program managers, and I guess the feeling is that they are not going to go out on a limb for some fly-by-night idea. You've got to give them some concrete data and relatively good assurances. There are too many other safer options open to them. I don't have any answer to that particular question, but this is an important issue.

Dr. Collins: Ted, about that slide on conditions versus impacts, do you have some data with regard to the assumption of the relationship between those conditions and impact areas? Did you generate some data at some points?

Mr. Post: In some cases, yes, I do have some data, but in a lot of cases I do not. It's hopefully a rationale that was presented to support the association. The business about subordination, for example, is really based on the amount of information that the aid would have to contain--the more information, the more complicated. This is supported to some extent in the literature. In the example about cleanliness dealing with the medium you use to present information, it is just something simple like a laminated page or a cleanable viewer. There is not much there you would have to go to research literature to support. Take work space, for example. There has been some work done on cramped work space and suitability of head-mounted devices. Maybe for about one-half to two-thirds of the conditions, I could point to the literature and say that's where I got my idea. The other third I might have to say I made it up.

Dr. Collins: Is there any differential weighting here with regard to how these are used or combined? It's not going to be made on a single condition by the program manager. Do you have some data that's going to relate to how those will be weighted and combined? Do you plan to get any?

Mr. Post: The plan to get it is probably the better description. For example, I don't know what the relative contribution would be between hardware complexity factors and supervision purposes. I'd like to go out and establish that experimentally.

Dr. Blanchard: We are looking for some way of quantifying the performance levels that are delivered under various combinations of factors. I have those divided up into environment, activities, and personnel characteristics. How sensitive is the task of media selection? Are we going to come up with a directive or deductive approach to specify what the aid would look like? The question is just how sensitive is that process to variations in those factors. Also, I don't like the use of labels, FOMM, SIMM, etc. In many cases, it covers up important properties for which we want to account. Ultimately we should tie into your conditions matrix and be able to model payoff. We can start with ordinal property data and hope some day to improve it. Starting with ordinal data, we can give the decision maker some idea of what his payoffs might be. The weights might be gross, but at least they can give him direction.

Mr. Post: Let's tailor the aid to the depot situation. Let's tailor the aid to the work center. Or let's tailor the aid to the bows of the ship or the automatic boiler control system. Let's not use one technique and hope that it works equally well in all those circumstances because those circumstances differ.

Dr. Collins: If you look at an analogy in human factors engineering where you are trying to make an impact at the conceptual stages, you are dealing principally with data and principles of human engineering, and habitability applied against some classes of problems that are perceived to exist within this new system. The level of generality of the class of problem becomes important in trying to relate it to some principles and guidelines for making decisions about whether it's going to be a man in the system or piece of hardware in the system. If one were trying to think of the DSARC process, you would have to think in terms of a handbook which has some principles for selection. One of the things this points out is the decision making process in the whole DSARC process relates to where job performance aids ought to be considered, what kinds of information are important, etc. That is an area where nothing has been done to identify what those decisions are and where in the process they should occur.

Dr. Blanchard: There is an interesting point here concerning the perennial struggle of the human factors engineer for acceptance and consideration in the design process. I think we are proposing to do one thing that the human factors community has failed to do; that is, to bring the decision maker some kind of established set of payoff expectancies. To get attention, we have to be persuasive. In order to be persuasive, we have to bring the decision maker some kind of formalized model that has a data base so he can see what his payoff expectancies are.

Dr. Collins: That's one of the objectives that the human factors engineering integration project is to produce. Produce the handbook which will deliver to the engineer information to tell him what the payoff is if he goes with these techniques or these kinds of decisions in human factors engineering.

Dr. Booher: There is another question I want to raise under this topic. It is related to cost variables. We feel we don't have a lot of cost data or a way of getting at cost data to make this tradeoff even after we've gone through the algorithm for the other reasons, showing its payoff for operational readiness, personnel turnover, etc.

Dr. Shriver: All I recall seeing on cost was the cost to produce the manuals not the payoff in personnel time. They are probably different by a magnitude of ten. If you get even a tenth of the savings on the personnel effectiveness side, it's worth doing. The analysis time is the expense. Whatever format you put it up in is relatively unimportant in cost.

Mr. Post: The only indicator I have seen is the Air Force work, and it seems that they are indicating an order of magnitude cost difference between conventional materials and fully proceduralized JPAs.

Mr. Johnson: We produced MDCs for the F4J and they cost the government a little over $1000 a page. Don't forget they were generally two-and-a-half folds, 11 x 17--tremendously compact information. To support your $2900 figure, which is the top figure you have, Ted, these MDCs we produced were produced from existing technical manuals and technical manual data (which is not the point you made). Conceivably by the time you went through the first cut, the various iterations, the manuscript, validation, and vertification, you could very well be up to $3000 a page. The question is, are you producing them from engineering drawings, data, specs, etc., or are you producing them from existing technical manuals? Most JPAs have been produced from existing technical manuals.

Dr. Shriver: It depends on how you look at data. As I look at it, it's about the same cost; and it will come out about the same in the long run after people get used to it. That was also true on all the tank turrets that they produced new ITDT JPAs for. It is about the same ball park. To a large extent, you don't go to engineering information to create the JPAs, you go to behavioral performances.

Dr. Shriver: The training people have gotten to the program managers. Validation is what training people want. They want to see that people can actually perform and get products. The training command assures that the program manager pays attention to validation. It is required on the charts, but they are the ones that are watching to see that it gets done. It seems that it is up to us to change industry. Three months after we completed the ITDT specification for JPAs, it was out on the street for procurement of five major systems. There were eight or ten companies in the country who were ready to go. Management does miracles when it has to for business.

Mr. Johnson: Whole empires within DoD have their own security blanket to worry about. We in industry have to stay alive. We are going to go with our leaders. Management in industry will get it straightened out. They can do it. But the Government has got to ask for it.

Dr. Collins: The quality assurance points are not dependent upon the hardware availability. That's not part of the technology interface required to conduct it.

Mr. Post: It seems, Frank, what you're really saying is that there are so many problems regarding quality assurance, validation, verification, etc., that, in fact, we are transferring a lot of responsibility to the user in the field. If that is the case, then we ought to concentrate on firing up on the feedback loop.

Dr. Blanchard: We need to have some way of interacting with the information in the tech data base. That is going to influence how we go about building JPAs, or how we go about trading off with training. This whole process is based on a temporal framework with the data coming out of the engineering development process.

SESSION 3--Thursday morning, February 24, 1977

The selected discussion comments below followed the papers given by Mr. Johnson, "Problems in Procuring, Producing, and Evaluating JPAs" and Mr. Joyce, "User Problems in JPA Utilization."

Dr. Collins: How accurate can we really expect to be in JPA? Have we promised too much accuracy? That is a technological issue that seems to be critical to dealing with the problem, the fact that a step has been left out or not left out. I think it's even more fundamental than that and that is the implementation of these processes is going to vary organizationally, individually, environmentally, and on a lot of other dimensions. I think the technical question is can you cover all of those? I suspect that's the real technical limitation. Realistically, you may only be able to deal with the training interface in this program.

Mr. Joyce: One of the reasons we were having a problem is because the decision was made for that system to take the proceduralized troubleshooting all the way down. There was essentially nothing very well planned in the way of other backup tech data and other more conventionally trained and oriented people to do the system maintenance. We were having to validate procedures that went so far down that we were being interfered with by hardware problems. If we had chosen to cut the proceduralized troubleshooting at a higher level and just stop, we would have been much better off. By a higher level, I would say to the board rather than to the components on a board.

Mr. Johnson: It comes back to your point of where do the errors come from? There are two kinds of errors. First the errors in the procedures may have been developed because the problem was very difficult. To develop accurate procedures you have to have very good engineering writers to be able to do all the logic and be able to do all the combinations and permutations of possible troubles and faults. That is the one area, the other one relates entirely to the hardware. Errors creep in because of hardware revisions. If I have a good set of drawings in a good operating environment in terms of producing the equipment, the plant that uses those drawings is going to produce that equipment to these drawings. If I then do my technical manuals, fully proceduralized JPAs included, to these drawings and follow whatever changes are made to those drawings with revisions in my manuals, then I'm going to reduce that kind of an error. The only error I will have left of any consequence is the error that my troubleshooting procedures are not good.

Dr. Booher: I think that's a good point about limitations of people that can do this. We have this problem in every field.

Dr. Collins: That's part of the technology base to me. We have a capability to design, develop, test, and evaluate people limitations.

Dr. Booher: Getting good people to do the troubleshooting is difficult and apparently there is still a lot of art to it. You may know who the best man is, and he may be selected for some of the work. Then you have all the rest of the men that have to do something, and they are just not going to give you the best product every time.

Dr. Booher: From what Ed said and from what we know, even if the JPA we select should cost more, the PM should select it over some traditional approach because of the total system life-cycle savings. But, if it gets down to the point where someone has to make a decision to pay more for something than he would have expected, he is going to be very reluctant to make that decision. However, if right at that time you can show them the savings in the other data areas, the decision becomes much easier. You can almost make the decision based on performance parameters and system needs and not even have to consider the training and personnel savings. That is all extra. There is an awful lot of slop just in the data area itself which, if better cost data were available, would greatly ease the decision making of the program manager.

Mr. Joyce: Even if we spend a good bundle at the front end on procedural troubleshooting for the first enlistment guys, we won't be spending huge training bucks on them. You can recover the cost of your whole JPA production effort in the first couple of years by avoiding the cost of training these people. Even if we still have that same kind of training, we apply it on a much smaller scale to a smaller group of people downstream, we're still avoiding those costs.

Mr. Klesch: The situation in the Air Force is that, in many of our maintenance squadrons, the first-term airman is indeed performing a great deal of maintenance. He is not just a black box swapper. He is indeed performing a great deal of maintenance. I think we need to dispell some of our own myths here about who does maintenance.

Mr. Post: If you go to a workshop or some work center in a maintenance situation, and you watch the supervisor in the way he handles his people, one of the ways he gets productive labor from the inexperienced portion of his work force is to chuck the job.

Mr. Klesch: If you have to operate with only ten people, suddenly JPAs take on a tremendous importance. That is the only way they are going to survive. If you give them 20 men to do it, they can handle it without job aids.

Mr. Post: One of the things we don't do in trying to assess the utility of job aids is to compare them with other styles of operation. I think that the technicians, even at the lowest experience level, are not really dummies; and they have a great deal of ingenuity. They can figure out how to do certain things. In the eyes of the user, is the JPA better, worse, or the same as getting advice from his peers, sitting together and working it out according to their own ingenuity. or admitting to their supervisor they don't know and ask for advice? There are several alternative ways of getting the job done. JPAs have to compete with these several alternative ways. So far it doesn't seem to be competing very well.

Dr. Collins: Task analysis is faced with three kinds of options: (1) you can go out and sample the operational environment based on descriptive information and you can then report on what goes on in terms of structure; (2) you can form some theoretical point of view, look at these tasks, and then superimpose some principles on them and structure them along some "optimum" position; and (3) you can listen to what the management people who operate the system say the position ought to be. It seems that JPA developers have to decide where they are going to fit into those kinds of options.

Mr. Klesch: I think production control and acceptance are all tied together. Based on my experience, I think we do not have as much acceptance as we would like because of the fact that we haven't produced solutions to real problems that users have. This is not a categorical statement though; it is qualified. One qualification is, for example, on nontroubleshooting tasks. I think we have convinced users that we can give them much clearer data, easier to understand. We've conducted actual usability studies and asked people to compare this to the tech manual and there is no question about it. We have not made the same kinds of inroads on troubleshooting. I'm not sure that the total troubleshooting state-of-the-art is in fact here. I would suggest that any study you do, consider at least the possibility of sticking with modern equipment, but look at equipment that results in complex tasks and other equipment. Although it may be complex, the tasks, in fact, are not that difficult. Both of those areas appear to me to be primarily in the electronics area. I think you should also look into a mechanical system. I would look at three test cases. I would look at a complex task electronic system, a not-so-complex task electronic system, and a mechanical system. If you're rich, also look at a system that involves an integration of mechanical and electrical systems that uses "high-powered" electronics. I would suggest that you analyze and test proceduralized troubleshooting vs. deductive troubleshooting for those kinds of systems. At least analyze it to see whether we have evidence that we can produce troubleshooting formats for them. Regardless of the complexity of the equipment, if the equipment tasks are manageable and task breakouts are limited, fully proceduralized aids can work. As the number of things that can go wrong goes up, fully proceduralized troubleshooting aids are not a viable solution.

Mr. Johnson: I'd like to comment on Reid's discussion on the acceptance of JPAs, not so much at the user level but at the program manager's level. I think that that is the area we are going to have to concentrate on if we are going to realize the potential of JPAs. The tool that appears to be most available is the concept that Ted is working on which could be built into a program manager's guide. This program manager's guide should identify what is required for a system in terms of time (year one, year two, etc.) and identify some costs in each year. As you progress through your program and get more experience on what kind of data you need and the kind of maintenance manuals, the PM can go ahead and selectively commit himself to buy one thing and then in year three you can take a better look and buy another. In this way we've accomplished several things. First, you have given him a tool that he can actually use to cost out his program and you can show him that you can reduce total program costs. You don't want to commit all your dollars at one time. If you do, towards the end of the program, you will find that a lot of dollars you committed earlier were just wasted because the material was bought too soon. The program manager is taking a very big chance by buying too early in the game.

Mr. Joyce: Ted presently has a lot of information to put into the program manager's guide; but, to use Jack's refinement of the idea, I think we as the research community really do have to start postulating some bigger pictures of the system. Run numbers and concepts through to establish that they are economically feasible so we will have something to sell to the program managers. I don't really care whether that is driving the system or just providing enough input so the system would be willing to change for itself. I think we do have to have the whole personnel system view before we are going to be in a position to have something that is really saleable. Our arguments over the years have been the use of fully proceduralized kinds of things. The use of fully proceduralized aids has the potential for substantial saving in training. Our experiments have been snapshots that demonstrated that we can produce aids, some of them that work, some of them that don't work so well. People usually can perform with the aids pretty well. I don't feel confident that we have something saleable, but I haven't spent very much time trying to conceptualize it for myself.

Mr. Post: I guess I'd like to make two points. One about the production of technical data, whether its fully proceduralized or whether it's the deductive type or some other type. I guess I feel that one of the biggest problems in the production process has to do with the accuracy and timeliness of delivery and I wish I had a solution to it. I think we need an entirely new notion of validation and verification. I think we might look to the NTIPP program and the work that Hughes is doing and hope that they come up with some good notions as to how to improve the process. I think maybe we ought to give some thought to a complete change. In the automotive industry, for example, if the factories seem unable to get cars out in good shape, they transfer some of the responsibility to the dealerships. Maybe something like that might take place in the production and use process. We might transfer some of the responsibility for verifying aids to the technicians who use them. After all, that is happening now. They are the people that identify all the errors and omissions. But we ought to give them the wherewithall to do that. We ought to slick up the feedback process a great deal more than it is right now. That gives me an entree to the second thought which is acceptability by the user and if in fact we can get him to be a cooperating and productive part of the accuracy improvement program. It is going to be his aid a great deal more than our aid. Also, we have to stop looking at the using community as solely inexperienced or experienced. We, in fact, have gradations of experience and we ought to have aids that meet the needs of all of these people out in the field. I think they have to be progressive and the aid at the lowest level not only has to get productive labor but it has to transition the gent to the next plateau. The notion that Hal Booher had about a family of aids is a very viable and needed concept.

COL Grossel: I want to believe and I keep hearing from other places in addition to here that the so-called JPA technology base is here and ready to be implemented. There are still a lot of things that have to be worked out. For example, you're talking about implementation. What are you going to implement? In order to implement something you have to have a spec. You need a data item description. I hear a lot of talk about the need for task analysis and other products. Some products called for in the past may or may not be necessary. I don't think there is any agreement as to what products, what single specs, what standards, what data item should be put on contract. It's nice to have a lot of people promoting different concepts which may have the same underlying requirements but until we can get agreement on some small number of specs and other standards to support underlying processes I don't see the system as really being there for implementation. I'm not saying we don't need the guides for program managers; we do need them! It's even more basic than that. Ed's work for the Army looked across the commodities, and essentially all these commodities could use essentially the same spec. At my level I'm looking for some attempt to get more tech manual and spec standards established. This is an important fact for evaluations also because you can go ahead and evaluate technology. When you do that, you are evaluating a spec, and the necessary things that go with that spec. But the Army may not buy it or the Air Force. I think to make real progress in this area we have got to get the services together and get more agreement. It's not industry's fault. I think it's the Department of Defense's fault. I think it's even the services' fault because they have their own interests and they have their own operating environments and so on. DoD hasn't clamped down hard enough on standardization.

Dr. Shriver: We, the human resources research community, are in an implementation area we are not prepared to deal with. We have a technological base but not enough people who have the technology to get implementation accomplished correctly. As Jack says, that is all part of the base, whether we've got it or not is the question. The result, though, is many errors in implementation or products; and, as Reid says, we need to get a bigger implementation picture for JPA products or we'll wind up at road blocks like we can't pass promotion tests, no growth on the job, etc. We don't have the technical manpower to handle what's happening. We need to get bigger and I think this is a new rock and hard place for us which even research funding doesn't adequately recognize. It is research on implementation itself in its funny new kind of place. The bridge from research to implementation isn't there. Research funds are now being cut off on the grounds that we already know that JPAs work, and we don't need any more research to demonstrate that. It's true that we don't need more research in the old structured mold. We desperately need research on a larger context that has been opened up by partial implementation. I think this is an immediate, desperate need. We have not built up the logic and sales compaign to explain the new rock and hard place problems to the controllers and research funders. Our old pitches are for different purposes and Joyce was talking about them. They have merely led to the new problems. We are just gathering the pieces of a new pitch and we're beginning to put it together here. Funds may dry up before we can get the pitch and an audience together. I think Roger Grossel's presence here is very important. He's at the money priority control spickets and he's hearing the beginnings of a new strategy being put together in this meeting. I sincerely hope that we can refocus the research community on the next generation of problems.

Dr. Collins: One area that interests me is the test and evaluation area which relates to demonstration and implementation. I am only aware of one computerized approach that has been developed by NAVAIR which was reported at the sixth IEA meeting last year for the assessment of JPAs, and I think that is part of the technology base. That was the work that was done at North Carolina State for NAVAIR. There may be other capabilities but that is the only one of which I am aware. We all know that there is supposed to be cut-off scores for people to go to schools, to get into occupations, and you can design JPAs around that cut-off score. In the real world, if you look at the distribution of mental levels, you'll find a rather wide dispersion, and whether or not the JPAs are adequate to handle that dispersion as compared to the label he may have of an MOS or an NEC is a very legitimate question with regard to utilization and implementation. I'd like to make one other modest suggestion. I just finished a report for NAVPERSRANDCEN in the area of technology applications. It included a review of the literature and development of a set of guidelines for technology application where I look at 24 specific end products of the center and the fleet support area. I looked at the defining characteristics of those end products and what were the communication networks associated with planning development and implementation. Follow-on work to that will be a definitive network analysis in the training area. Perhaps there is a requirement here to have some kind of mapping of the process or planning development and implementation that relates to this kind of set of interfaces, organizational and other dimensions.

Mr. Post: I think that's a strong point, in my view anyhow. The idea to look at a larger portion of the R&D implementation sequence started with Merle Malehorn. I think some of the points he made in his paper of 2 years ago are still very valid. We have to go ahead and look at those kinds of things.

Mr. Joyce: We need to come up with a better validation/verification process and also answer the problems of delivering to the user. The project that I did involved 15,000 pages of fully proceduralized troubleshooting. We got the average amount validated (10-15%) before all of the systems, including some that were still being assembled in the factory, were delivered to the user. At last report the North Vietnamese were still trying to verify them.

SESSION 4--Thursday afternoon, February 24, 1977

The selected discussion comments below followed the papers of Dr. Shriver, "New Direction for Information Transfer Research in Maintenance Jobs," and Mr. Klesch, "Implementation of the JPA/Job-oriented Training Approach to Maintenance: The Impact on Personnel Systems."

Dr. Shriver: You have to go ahead and make the personnel reduction. The studies show that increased performance is there. That's got to be translated into reduced personnel. The other payoff is reduction of training time. That's nonproductive time. You can use OJT where he is working on the job while turning out some products on the job.

Dr. Collins: What about preserving the life of the equipment? I'm saying that a man who does an effective maintenance job perhaps could save an airplane.

Mr. Post: Better operation or better maintenance of a smaller buy of expensive hardware is a possibility. We are dealing with the front end now.

COL Grossel: That is something the operational commanders will never buy. They will buy, "reduce my personnel if you can give me more airplanes."

Mr. Post: I get nervous, Ed, when you give the big global figures that we have a quarter of a million in this or that area (for savings in personnel reduction). I have looked down a list of data items and one of the things listed there was the amount of boiler technician's time spent on scheduled maintenance. It was about 2 percent of his time, but we are not going to eliminate that man.

Dr. Booher: I would like to go back to some of the questions we have been sliding over. I get the impression that there are only two alternatives being offered so far in this training area. Either we cut it (training) out entirely and have it (training) supported by a book with the supervisor there to aid and assist, but he won't be an instructor; or, we have the conventional type training system.

Dr. Collins: I was interested in what kinds of troubleshooting strategies were preferred and being designed into the fully proceduralized aids.

Mr. Johnson: I go back to the various specifications that tell you how to get fully proceduralized troubleshooting. It's a big thick book. There's one paragraph in there that says find youself an experienced technician and let him do the actual troubleshooting.

Dr. Shriver: He is taught an overview of the thing, at the block diagram level. Why he would stop going down the (decision) chain and switch to another (branch) will probably be a function of the next check that he has to make. If this one is going to take him half an hour to set up, he might as well skip that one, go over here and make a 2-minute check, remembering that it still may be down there (the first branch).

Mr. Johnson: There is no standard means of developing troubleshooting. One of the better techniques that is very costly is maintenance dependency charts. With a good maintenance dependency chart, you know what your inputs are, you know what your dependencies are, you know what your test specifications are, and you know what your output should be.

Dr. Collins: I was interested in this concept of the naive man who is given the information to go and do diagnostic troubleshooting. How generalizable are the skills he was learning or using with this JPA to other classes of similar problems? How equipment specific do they have to be?

Dr. Shriver: He learns the test equipment, how to open the latches, how to cheat the interlocks, and another system may have some similarities. He learns all the junk stuff, which is very useful to him since it frees his head for other things.

Dr. Blanchard: Jack, are you getting at the Bayesian strategies, the cognitive processes in troubleshooting that people like Joe Rigney tried to model?

Dr. Collins: That's part of it. I was trying to get a better understanding of what was being designed into these capabilities for several reasons, one being user acceptance, also generalizability. There are a variety of other kinds of criteria that one might want to think about. My impression is that we are talking about signal tracking. Signal tracking is the primary strategy being designed here. There was also a suggestion that once you do that, through some kind of engineering analysis, the people developing these (analyses) hopefully have some optimum strategy that is more efficient than other strategies.

Mr. Klesch: When you don't know what is wrong, the situation looks different. What used to be a puppy dog, when I fail it or when I take a circuit board or card out, becomes a tiger in the real world. When they bring one in off the line, we all stand around, and now we are going to put our magic book to work. I'm not sure if my legs are going to be lowered or what. We took that same procedure over to Lockheed and their equipment was running a little bit differently. The power supply varied a little bit and our tolerances for the windows were much too narrow. It was only because a qualified technician was there that we found the fault. A dummy using this JPA would go off the track. But the technician knew that the window should have been wider. He proceeded down and found the fault. He demonstrated to us that there are a lot of available cues (not in the book) used by the conventionally trained man.

COL Grossel: Problems can be overcome by providing better JPAs. When are our JPAs good enough to implement and when do we go out on the limb to become operational? Are you in the Air Force ready to put your case on the line and say there is our specification, here are the standards and DIDs and CDRLs? Put that in the contract and that will give you a good JPA?

Mr. Klesch: Say we have a new HF radio. To JPA or not to JPA, that is the question. I think we can do that. But if he comes to me with an F106 firecontrol system, I don't think I can do JPAs on that system. I don't think anybody can.

Dr. Collins: Are you saying it's the technology of JPAs that's making you reluctant or the absence of a good technical base about the system or the hardware?

Dr. Shriver: The JPA for troubleshooting is inherently inefficient.

Mr. Post: Troubleshooting JPAs are based on the checkout procedure and it may not be right.

Mr. Klesch: On a missile cooling unit, no matter even if you took the least efficient approach, there are only X number of things to check. Inefficiency doesn't matter.

Dr. Collins: Are there any guidelines that you can see, John, that would help to define the upper limits if there are any upper limits? Are there classes of equipments that come to mind?

Mr. Klesch: You almost need to do a hierarchical equipment inventory of what you've got. I don't know how to answer the problem of do we only go so far or what happens when we get into a strange problem. If you have it in that same specialty, man X comes in and is only allowed to troubleshoot down so far. If you think man Y is going to be the higher cat within that same specialty, I think you're asking for trouble. There almost has to be two guys. Can we train a medium aptitude guy to train second enlistments a higher electronics? The data indicate in the past that you can't.

Mr. Johnson: Every system is a combination of various components and not a mass of electronics just shoved in. We don't manufacture things that way anymore. Nobody does.

Dr. Shriver: Every system can be analyzed into parts.

Mr. Johnson: Yes, otherwise you couldn't design it. You couldn't even check it in the shop. At Westinghouse 10 years ago they brought in a new numerical control wiring machine. It was a marvel to behold. They just threw wires in there all over the place and if it worked, it worked. But if it didn't work, you could forget about it. Nobody could fix it. They had to do away with it finally because of maintainability requirements.

Dr. Collins: Are you saying, Frank, that there are no systems for which a fully proceduralized JPA could be developed for electronics?

Mr. Johnson: If you are time bound, you may not have time to go through many of these steps.

Mr. Klesch: I would like to see an automatic test equipment vs. manual approach examined thoroughly. Where does that tradeoff occur?

Mr. Post: I think that is an excellent point and it's something that I describe as, if you have a buck to get the kind of performance needed out of the technician you have to work with, how do you spend that buck? Do you spend it 60¢ on training and 20¢ on JPA? Or is there a different balance? I don't know a scintilla of evidence to support any such analyses.

Mr. Post: I think this business of considering the tech manual or the JPA or MDC or whatever it is as being developed only when it comes time to deliver the equipment is just untenable. I think it's a dynamic process that goes throughout development of the system. It has to be updated, corrected, refined, and modified with heavy inputs from the user. I get the idea that the articulation between the training process, the process by which training materials are developed, and the process by which JPAs or tech manuals are developed does not exist. There is no articulation between them. I don't think the tech manual people talk the training language and I think the reverse is true also. When we modify the training program and complement it with JPAs in the field, it seems like we are coming from two different arenas.

Dr. Collins: One of the most basic principles in all training is that you design training as much as possible around the previous learning and learning style of the individual to fit that kind of interface.

SESSION 5--Friday morning, February 25, 1977

The following comments are selected concluding remarks.

Dr. Blanchard: We need to incorporate the JPA with some form of training support so that the individual can't just be confronted with the JPA at some point and left to fend for himself. What ideas do we have, what experiences have we had concerning the need and the manner in which training packages have been incorporated with the introduction of JPAs?

Mr. Klesch: There are three ways that you can address this training situation. The first one is that, given some X amount of training you now create JPA, or (second) given you have a JPA, you now make some training. It now seems that (the third way) doing them together, makes the most sense.

Mr. Post: Concerning the interaction of JPA and the training the ultimate user will receive, I'd like to broaden that concept a little bit and talk about the process by which JPAs are selected and developed. JPA development should interact more fully with the rest of the personnel and training subsystem. Job design is a key aspect of the entire personnel subsystem. I'm asking for a full disclosure, interactive kind of process. We ought to bring in the personnel turnover that we're expecting. From the personnel turnover aspect, we can say we are anticipating certain things. In response to this, we in the JPA business are going to counter with this approach. It's not just training and JPAs. It's more than that. With respect to the maintenance workload, arriving at the same time is a consideration. I think that has major implications for organizational structure and job design as well as JPAs.

Dr. Collins: It would be useful to distinguish the general problems associated with the introduction of JPAs from the problems of running a demonstration project. One of the dangers in any new program of this kind is to be too ambitious. If you're going to conduct a series of demonstrations or experiments under this program, it seems you have essentially three objectives. One is to demonstrate the utility or the value of some technology that is available. The second one is to solve the specific operational problems in the process. Thirdly, is to impact on the system in some general way whether it is the personnel system or the training system or both. One of the things that needs to be considered is how much of this general goal of interaction can you really try to encompass within the NAVPERSRANDCEN project. I agree that it is important to think about the impact on the personnel system. You may find that tackling the interaction process between JPAs and training is all you can hope to do.

Mr. Johnson: I'd like to suggest that the area of engineering drawings plays an important part in bringing together the package. If JPA technology is going to offer anything, it has to tie in training, tie in basic job-oriented tasks, and give the maintainer the tools he needs to perform his actual maintenance. A way of implementing a new program is to tie it in to the release of engineering drawings, to the engineering production process.

That is the very beginning of all training, all maintenance, and we never really address that particular facet of it in my experience. We should investigate the possibility (during the early acquisition/design process by the contractor) of identifying in the work breakdown structure exactly what is required in the way of maintenance training for each assembly as it is released for engineering production drawing to the shop for manufacturing. If you do this, you gain a tremendous number of advantages. The biggest advantage is manageable chunks of work. Another powerful tool is I can schedule it in the same way that engineering design groups schedule right out of the drafting room into the shop and released for manufacture. I can schedule my training requirements, maintenance analysis, and JPA production. This is a specific way of doing the things that we're talking about.

Dr. Collins: People will argue if you want to go from a theory-based training program to one that's highly job structured. Do that analysis on the old system first and add your changes. Systems don't change that much. I think people tend to go to an analysis of the old hardware and then introduce the new changes into that, and go to drawings and do an analysis.

Dr. Shriver: JPA is a code word to refer to a procedure. JPA is also generic but you don't use it generically because when you use it generically there are lots of new concepts that have conceptual material in them. FORECAST is the one that has the most of it, i.e., concepts put on paper. JPA has been used as a code word to refer to a click, click, click procedure, and not in the generic sense. One way of dealing with concepts is to lay it out in block diagram form so you can see everything. Work breakdown structure can be thought of as slicing the whole thing down into pieces. It is the same process for a block diagram, slice it up into pieces. Conceptually people can understand how all those pieces are put together. There is a dependency between them. They can learn that. The old timers, who understand a system, break it up in their heads so they understand it functionally and then they understand the schematics.

Dr. Booher: Could we give them a much shortened course, say ten percent of what is normally given? Give them some basic skills training, and along with this, some ability to read functional flow blocks, and be able to utilize written material in much shorter training session?

Dr. Shriver: Yes, if you are talking troubleshooting, which is only half the world.

COL Grossel: One of the words Hall used was common use test equipment. One of the things that this ITDT specification breaks out is common task in a separate job performance guide. Common tasks could include common use test equipment.

Mr. Post: I think it would be useful to have a glossary to try to at least identify some of these things.

Dr. Blanchard: Our goals are: (1) we have to demonstrate a technology; (2) we have to try to make some hay by solving an operational problem; and (3) at the same time we have to assess JPA impact on the larger system, i.e., the personnel and training you are trying to integrate into the system, and the development process. With those three general things in mind, considering our resources, we have an optimization problem.

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