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ABSTRACT

Conducted as part of a major effort to test and evaluate Job Performance Aids (JPA) and their integration with Navy personnel and training systems, this study systematically reviewed and organized existing JPA techniques, related research data, and various applicable principles and concepts. One hundred and one JPA systems and techniques were classified under the following five categories: (1) format/content, (2) display media, (3) applied training, (4) peripheral test/diagnostic, and (5) delivery systems. The following factors were identified as critical to the development of a JPA algorithm: personnel aptitude and experience; type and complexity of task; type and complexity of equipment; and the degree of proceduralization required. A conceptual model was developed for use by the JPA community in making cost trade-off analyses, writing JPA selection algorithms, and grouping theoretical trends. The study also examined a theoretical base for the use of memory in JPA's; previewed a theory for mixing JPA techniques, principles, and methodologies; and set goals for future JPA research and technology efforts. (Author/BM)

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JOB PERFORMANCE AIDS:
RESEARCH AND TECHNOLOGY STATE-OF-THE-ART

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes and compares the various Job Performance Aid techniques and identifies and categorizes factors important to selection, design, cost-performance trade-off, conduct of future research, and implementation of performance aiding technology. More than 100 surveyed JPA systems and techniques are classified under five categories: (1) format/content, (2) display media, (3) applied training, (4) peripheral test/diagnostic, and (5) delivery systems. Major factors are identified as critical to the

(19 con't)

JPA state-of-the-art
JPA organizing model
Maintenance concepts
Maintenance training

(20 con't)

development of a JPA algorithm, including personnel aptitude and experience, type and complexity of task, type and complexity of equipment, and degree of proceduralization required. A conceptual model is presented for use by the JPA community in cost trade-off analyses, in JPA selection algorithms, and in the grouping of theoretical trends. The report also presents a theoretical base for use of memory in JPA; previews a theory for mixing JPA techniques, principles, and methodologies; and outlines goals for future JPA research and technology efforts.

FOREWORD

This research and development was conducted in response to Navy Decision Coordinating Paper, Performance Aids Test and Evaluation (NDCP-Z0828-PN), under the sponsorship of the Director, Naval Education and Training (OP-99).

The overall objectives of the NDCP are to define the state-of-the-art in Job Performance Aids (JPA) technology, to develop a conceptual model for an integrated JPA-based personnel system including cost benefits and trade-off analysis, to test the JPA concept, and to quantify performance increments and cost benefits obtainable for various applications. The immediate effort described in this report relates to Task 1 of the NDCP: (1) the systematic review and organization of existing JPA techniques, related research data, and various applicable principles and concepts, and (2) the establishment of meaningful discourse within the JPA research, development, and operational communities. The final two sections of the report, on conceptual organization and new research directions, are directed to the JPA community at large. As such, comments are not only welcomed but solicited on the concepts and recommendations presented.

Appreciation is expressed to Dr. John Foley of the Air Force Human Resources Laboratory, Dr. Edgar Shriver of Kinton, Inc., Mr. Theodore Post of BioTechnology, Inc., and Mr. Tom Elliott of Applied Science Associates for their assistance in providing key documents that were useful in describing and organizing the existing JPA technology base. In addition, their concepts and those of others involved in performance aiding research, such as Mr. Reid Joyce of Applied Science Associates and Mr. John Klesch of the Army, were extremely valuable in arriving at those presented in this report.

J. J. CLARKIN
Commanding Officer

SUMMARY

Problem

Data collected over the past 20 years, primarily by the military services but also in the civilian sector, suggest that Job Performance Aid (JPA) technology offers major potential payoffs in personnel performance increments and cost avoidance throughout the personnel, training, and maintenance communities. Unfortunately, the lack of a well-formulated conceptual definition of JPAs has impeded the advancement and utilization of JPA technology in military personnel, maintenance, and training programs. This has created difficulties in retaining researchers and practitioners in the field, has discouraged the development of a solid theoretical basis for JPAs, and has contributed to underutilization of the technology. Moreover, an integrated approach to JPAs in personnel systems has never been taken.

Purpose

The Navy Personnel Research and Development Center is conducting a major effort concerning the test and evaluation of JPAs and their integration with Navy personnel and training systems. That effort, outlined in Navy Decision Coordinating Paper, Performance Aids Test and Evaluation (NDCP-Z0828-PN), has as its first task the detailed definition of current JPA technology. The objective of the present study, conducted as part of the larger task, was to systematically review and organize existing JPA techniques, related research data, and various applicable principles and concepts.

Approach

A literature review and conceptual analysis were conducted to assess and organize the state-of-the-art of JPA research and technology.

Results

In the present study, 101 JPA systems and techniques were classified under five categories: (1) format/content, (2) display media, (3) applied training, (4) peripheral test/diagnostic, and (5) delivery systems. Major factors that were identified as critical to the development of a JPA algorithm included (1) personnel aptitude and experience, (2) type and complexity of task, (3) type and complexity of equipment, and (4) the degree of proceduralization required. A conceptual model was developed for use by the JPA community in making cost trade-off analyses, writing JPA selection algorithms, and grouping theoretical trends. The study also examined a theoretical base for the use of memory in JPAs; previewed a theory for mixing JPA techniques, principles, and methodologies; and set goals for future JPA research and technology efforts.

Conclusions

1. Several format/content type JPA systems are sufficiently developed to be integrated with major military personnel and training systems with reasonable expectations of major payoffs in reduced personnel, training, and maintenance costs and in increased overall operational readiness.

2. Within format/content types, it appears that three--the FPJPA, the hybrid aid, and the deductive aid--would be sufficient to cover most operation/maintainer aiding needs throughout their Navy careers. However, the hybrid aid requires further refinement before full-scale demonstration or implementation.

3. Satisfactory aiding techniques exist for all nontroubleshooting operation and maintenance tasks and for the majority of troubleshooting tasks on most mechanical, electrical, and electromechanical syatema, but no aiding techniques were found that were satisfactory for complex digital electronic systems.

4. The greatest weakness in JPA systems technology is in the timely and accurate production, distribution, and update of JPAs.

5. The major aid development cost items to be considered when comparing one format/content type JPA with another are (a) the detail required for front-end analysis and (b) the amount of graphic or verbal enrichment necessary for increased intelligibility.

6. The greater the amount of proceduralization and enrichment, the greater the production, distribution, and storage costs becauae of increased aid size.

7. Microform and audiovisual systems either show no differences or are inferior to hard-copy print media in terms of their effects on user performance. For information aiding needs, most of the unique demands of the job environmen. (e.g., work space, wind, temperature) can be met with modified hard-copy print.

8. Devices that can increase the performance capability of the user beyond that possible with hard-copy print need further research and development.

9. The FPJPA appears unsatisfactory for aiding lower-aptitude personnel to perform troubleshooting tasks, but it can allow inexperienced peraonnel who meet normal aptitude requirements to perform such tasks with minimal training.

10. Existing JPA development and selection techniques have not provided sufficient organization of the technology to permit confident reaearch or implementation decisions.

11. Basic research is needed to answer questions about the behavioral foundation of aiding.

12. There is still a need to determine the effects of aiding on lowered aptitude levels and the motivation to use aiding systems.

13. Cost/performance criteria and basic cost data are needed to make valid comparisons of aids in trade-off models.

14. Research is needed to help determine what kind of process is required to produce and measure high-quality JPAs.

Recommendations

1. The methods and problems of integrated JPAs with training and job design should receive immediate attention in efforts directed toward algorithm development.

2. Problems of career advancement, skills retention, and other major personnel system factors should be investigated to determine the effects of progressively changing JPA systems.

3. Task-oriented training and job design should be developed to support or complement the aiding system.

4. Aiding as a personnel system technology should act on an equal footing with selection and training, but it should be the primary technique for meeting most job objectives for new or first-term enlistees.

5. Front-end analyses commonly conducted for integrated JPA and training requirements should be expanded to include job design requirements.

6. Selection of media other than hard-copy print should be based on system support requirements that improve the timeliness or accuracy of the aid rather than personnel performance-related criteria.

7. Development of new aiding devices (e.g., hand-held calculators, holographic displays), aids that change with personnel needs (e.g., hybrid aids), and aids that specifically address digital electronic systems are needed to fill gaps and to advance the state-of-the-art in aiding technology.

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INTRODUCTION

Problem

The Navy currently faces expanding personnel costs; decreasing force levels; declining entry-level skills; and degraded operational readiness with respect to personnel, systems, and equipment. Advances in personnel technology are therefore being combed for systems or techniques to enhance the performance of lesser-trained or lesser-skilled individuals, to reduce the attrition of personnel with Navy career potential, and to reduce personnel and training costs.

Data collected over the past 20 years, primarily by the military, suggest that job performance aiding technology offers major potential in personnel performance increments and cost avoidance. Unfortunately, the lack of a well-formulated, conceptual definition of job performance aids (JPAs) has impeded the advancement and utilization of JPA technology in military personnel, maintenance, and training programs. This has created difficulties in retaining researchers and practitioners in the field, has discouraged the development of a solid theoretical basis for JPAs, and has contributed to underutilization of the technology.

Recently, users have perceived their major problem to be that of selecting from among the hundreds of JPA candidates, and researchers have obligingly directed most of their efforts toward the development of JPA selection algorithms. Little progress has been made in this area, however, because a total integrated approach to JPAs in personnel systems has never been taken (Booher, 1977a). Thus, the first steps for the development of a JPA-relevant integrated personnel system are (1) the formulation of a conceptual definition of JPAs and (2) an analysis of the state-of-the-art in performance-aiding R&D.

Purpose

The Navy Personnel Research and Development Center is conducting a major effort concerning the test and evaluation of JPAs and their integration with Navy personnel and training systems. That effort, outlined in Navy Decision Coordinating Paper, Performance Aids Test and Evaluation (NDCP-Z0828-PN), has as its first task the detailed definition of current JPA technology. Specific objectives of that task are (1) to conduct a comprehensive survey of current JPA systems and techniques, (2) to investigate implications for equipment, environmental, personnel, and behavioral characteristics of job tasks, and (3) to develop schema that would aid in achieving optimal utilization of state-of-the-art JPA technology.

The purpose of the present study is to meet these objectives by systematically reviewing and organizing existing JPA systems and techniques; JPA research data; and related principles, methods, and concepts.

Background

In February 1977, NAVPERSRANDCEN sponsored a conference at which selected researchers and practitioners were asked to critically assess the current status of JPA technology (Booher, 1977a). A primary objective of that conference was to determine if JPA technology could be structured to stimulate meaningful discourse among those concerned with JPA research, development, and implementation. It became apparent that, while such a structure would be useful, there are a great many unique problems associated with JPA technology R&D. The conference's findings and the results of an analysis by NAVPERSRANDCEN provide the basis for the approach taken in this study.

JPA Definition

In the literature, the earliest definition of the JPA was expressed in terms of man-machine systems:

> A job aid is an item whose purpose is the support of performances by system personnel, which are necessary for overall system performance. It is developed as an alternative to training as a means of obtaining the necessary performances, and is therefore designed deliberately to complement training. The job aid is developed in response to a requirement which specifies the performances that must be supported and the conditions under which these performances must be obtained. It is an end product of a system development cycle which is delivered as part of an operational system. (Wulff & Berry, 1962, p. 279)

More recently, Smillie (Note 1) redefined the job aid more concisely as:

> Any contrivance which permits the human component of the system to perform some function which could not otherwise be accomplished without extensive training or complex information processing. (p. 1)

Most often, definitions use information storage and retrieval language. For example, Joyce (1975) said:

> 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 training--requirements imposed upon the performer. (p. 5)

Several definitions have emphasized proceduralization--typically meaning fully proceduralized job performance aids (FPJPAs), which are "Documents or devices that give precise step-by-step instruction for each task or otherwise present in a concise and consolidated manner all information relevant to the task" (Rowan, 1973, p. 1). This is primarily a behavior-guiding or "active" definition in that it states the direct purpose of the aid in terms of supporting the efficient performance of a predetermined set of behaviors.

Some researchers prefer to look also at the indirect or "passive" aspects of job aiding. Chalupsky and Kopf (1967), for example, addressed the informational content and instructional aspects of job aids and how they facilitate performance by relieving certain job demands. They categorized these as task modifying aids and cited as an example a table of square roots that performs the appropriate calculations for the user.

An interesting theoretical approach to defining the JPA was taken by Lewis and Cook (1969) in considering the JPA an undirectional communication device. In describing a "theory of telling," they pointed out that, since there is no feedback from the user, the design of a JPA must be responsive to a model of the user's abilities, limitations, and processing functions in attending, listening, and reading. They therefore inferred that pictorial and linguistic channels are primary means of telling and that algorithms in the form of question-and-answer flow charts or question lists are superior to prose for this purpose.

A rather unusual insight into the problem of defining JPAs is the recognition that it is not the media or format aspects of JPAs that affect performance aiding so much as it is the ability of the JPA to change the content of the information. Shriver and Hart (1975) concluded that much of the research on new JPA concepts deals with the software link between the hardware and maintenance personnel. They recognized that, traditionally, this software link has been the technical manual. Although media (e.g., microfiche, tape, file records) have been substituted in the link, it has been informational content, and not the medium of presentation, that has changed job performance. They stressed that the new concepts of importance are those concerned with changing the information that flows across the link.

Although aspects of all these definitions apply to JPAs, the following definition has been adopted for the purposes of the present research on performance enhancement: "A job performance aid is any device, manual, guide, or tool used on the job to facilitate performance or to avoid costs where learning from the aid is incidental." Such aids can vary from a simple metric conversion card to a complex troubleshooting logic network diagram used in electronic fault isolation. Other examples are a pilot's preflight checklist, a hand-held computer, or a job-guide manual.

The written (textual) aid could be a fully proceduralized, step-by-step guide requiring no user decision making; it could provide only an overall picture of available options in various problem situations with deductive guidelines as to various decision paths; or it could be a combination of the two, directed toward an intermediate level of performance aiding.

For the most part, a JPA is a means of extending human capability by providing a mechanism for storing information for later retrieval in connection with on-the-job performance. It also may serve as a short-term memory facilitator, since human memory often is not sufficiently reliable and because some tasks are performed too seldom for habit patterns to form. Consequently, an aid may reduce or eliminate training requirements by eliminating the need to learn and retain information concerning specific aspects of a job.

DESCRIPTION AND COMPARISON OF JPA TECHNIQUES

The glossary lists 101 JPA techniques that were surveyed in this study. Shriver and Hart (1975) reviewed many of them in the development of their "fundamental elements," noting that many can be sorted into relatively independent classes. Post, Price, and Diffley (1976) also classified various JPAs into basic types of format and content for use in a guide for selecting formats and media in maintenance information presentation. Considerable thought has been given to the problem, but no general agreement has been reached among JPA investigators on a classification system that would be most useful in describing and comparing various JPA techniques. This study, therefore, has sought to describe JPA technology in a global sense, considering aiding techniques not only individually but also in conjunction with other technologies and then breaking out the various classes of aids in a way that might help the decision-making activities of researchers, developers, and implementers.

The conference on job aids (Booher, 1977a) concluded that the JPA technology base can be organized into three fairly distinct categories: (1) technology associated directly with job-aiding systems, which includes format or content types, display media types, applied training systems, peripheral diagnostic systems, and delivery systems, (2) technology competing with job aids, which includes automatic test equipment, maintainability design, formal training, selection, and human engineering design, and (3) technology supporting job aids, which includes instructional system design, job design, maintenance simulation, test and evaluation technology, and performance testing. This chapter simply describes and compares JPA systems, devices, and techniques that exemplify the five subcategories of direct job-aiding systems. The glossary lists titles and acronyms commonly used to identify most of the JPAs.

Format/Content Types

Table 1 classifies 37 JPA techniques according to (1) basic format or content types (modified from Post, Price, & Diffley, 1976), (2) personnel qualification requirements for using each technique, (3) the type of hardware system for which each technique is designed, and (4) general demonstrated feasibility. Middleton, Guilliams, and Weber (1977) criticized the Special Case formats, pointing out that they can generally be subsumed under the major categories for troubleshooting and nontroubleshooting aids. With the exception of the Quick Fix procedure, the analyses performed for this task confirmed that finding. However, the Special Case categories are useful in that they suggest unique requirements (e.g., hazardous conditions, time, one-trial learning) that could be major considerations in some systems. Also available are specifications that deal independently with certain of the Special Case aids (i.e., maintenance requirement cards and maintenance dependency charts) and that give them a uniqueness for both performance and cost considerations that could be lost by attempting too broad a classification.

Table 1

Classification of Selected JPA Systems and Techniques

JPA Technique	Type Aid													Personnel Qualifications			Type System			Feasibility Factors		
	Troubleshooting				Non-TS			Special Case														
	FPJPA	Partially Proceduralized	Simple Logic Deductive	System Description	FPJPA	Partially Proceduralized	System Description	FPJPA (Complex Action)	Standard Operating Procedure	Periodic Action Aids	Time Critical, or Hazardous Conditions	One-trial Learning	Highly Complex Integrated System	Novice	Intermediate	Experienced	Electrical	Mechanical	Other	Concept	Field Usage	Experimental Data
AF/FPJPA	X				X			X	X	X		X		X	X	X	X	X	X	X		X
AAT		X	X												X	X	X			X		X
ADMIRE/MIRAID		X													X	X	X			X	X	
AMSAS					X									X	X	X	X	X	X	X		X
ATOMS		X	X	X											X		X			X	X	
AVIS			X	X											X	X	X			X		X
EPIC		X													X	X	X			X		X
BLOCK FORM	X													X	X	X	X			X		
British Algorithm			X														X			X	X	
CATA			X												X	X	X			X	X	
C-141 Aids	X	X			X									X	X	X	X	X	X	X	X	X
CMG			X										X			X	X			X	X	
CONSD			X										X			X	X			X	X	
DATOM			X	X	X	X					X				X	X	X			X		
FEFI/TAFI		X		X	X	X									X	X	X			X	X	X
FIST			X												X	X	X			X		
FLAPS					X					X							X			X	X	
FOMM/SIMM			X	X									X			X	X	X	X	X	X	X
FORECAST		X	X	X			X								X	X	X			X		X
GPAM					X									X	X	X		X		X		
GM Manual	X				X									X	X	X	X	X		X	X	
HEATHKIT					X									X			X			X	X	
JOBTRAIN		X	X	X										X	X	X	X			X	X	X
JPM/JTG	X				X				X	X		X		X	X	X	X	X	X	X	X	
LCI		X												X	X					X	X	
MADAR/GPS		X	X											X	X		X	X		X	X	
MAINTRAIN			X	X												X	X			X	X	
MDS		X	X	X												X	X	X	X	X	X	X
MDC			X										X		X	X	X			X	X	X
MEC						X	X			X					X		X	X	X	X	X	
MT Magazine							X							X			X	X	X	X	X	
OPTIMUM PIC/WORD	X				X						X			X	X	X	X	X	X	X		X
PIMO			X		X									X	X	X	X	X	X	X		X
PYRAGRAM			X	X											X	X	X			X		
Quick Fix											X				X	X	X			X		
SADIE		X													X	X	X	X		X		(X)*
TRACE			X	X											X	X	X			X	X	
Work Package		X	X	X		X	X		X	X			X		X	X	X	X	X	X	X	(X)*
XFL			X																	X		X

*Claimed but not published as of this writing.

The discussion of Post et al. (1976) on the Special Case aids appears adequate for describing the unique features of Troubleshooting, Nontroubleshooting, and Special Case JPAs. One aid type that they did not discuss but that is listed in Table 1 is that of highly complex integrated systems, such as CMG, CONSD, FOMM, SIMM (listed in the glossary with FOMM), MDC, and Work Package. The CMG and CONSD were designed only for experienced personnel, while the FOMM, MDC, and Work Package are aimed at both fully and lesser-experienced personnel. Of this set, only the SIMM and MDC are supported by published experimental results, and those results have not been overly favorable toward the JPA. In some cases, they have even been negative (Rowan, 1973; Shriver & Hart, 1975).

The FPJPA, exemplified by Figure 1 (Westinghouse, 1973), is unique among existing JPA format or content types. From the early Army studies until the present time, it has had the most consistently positive experimental results. Because of this, the FPJPA has been mistakenly regarded by some as being the only type of JPA. It forms the basis for the JTM/JTG format in the Army ITDT program and has been the preferred format of the Air Force in its attempts to implement job aids on the C-141 program; both services have prepared specifications for procuring both nontroubleshooting and troubleshooting FPJPAs. The Navy has not done so, but it does have the NAVAIR Work Package specifications and the NAVAIR/NAVSEA writer guidelines, which include many of the features of the FPJPA for nontroubleshooting operation and maintenance tasks. The Work Package concept, which is classified in Table 1 as a partially proceduralized aid, also provides for a troubleshooting decision logic tree.

Only the FPJPA types of JPAs (i.e., Air Force FPJPA, AMSAS, C-141 Aids, JOBTRAIN, OPTIMUM PIC/WORD, and PIMO) have demonstrated positive results with the novice technician (acceptable aptitude but inexperienced). Positive results have also been claimed for the Work Package concept on a demonstration with organization- and intermediate-level maintenance on the APQ-126 radar (Horn, Note 2), but the results have not been published. The positive results of the MDC (Krohn, Clayton, & Dunn, 1971) with inexperienced personnel were confounded by the lack of an experimental control, and therefore are not conclusive.

The FPJPA, FOMM, and Work Package have all been fully developed for electrical, mechanical, and electromechanical systems, but the FOMM generally is not considered adequate for digital electronics or mechanical systems. As shown by Table 1, no single JPA system concept includes all levels of proceduralization. The only true attempt to combine two or more levels of proceduralization was the AAT, a NAVAIR hybrid aid for troubleshooting that provided two separate routes to successful fault isolation. This technique introduced special cues designed (1) to allow the technician to move from one route to the other and (2) to suggest why certain tests were being made. The latter feature was to encourage greater incidental learning of higher order troubleshooting skills.

CAMERA CHECKOUT

1. Observe oscilloscope screen and depress camera SHUTTER bar (7). Note that oscilloscope trace (2) moves across screen 4-1/2 to 5-1/2 divisions (3) before dropping to the lower level (1).

2. If repeat of test is necessary, depress RESET button (5) then depress SHUTTER bar (7).

   Does sweep drop between limits (3)?

   YES ↓ NO → Go to page 1-26.

3. Set camera SHUTTER SPEED knob (6) to 2.

4. Set oscilloscope TIME/CM knob (4) to .1 SEC. Depress oscilloscope RESET button (5). RESET button should light. If not, depress RESET button (5) again.

5. Observe oscilloscope screen very closely and depress camera SHUTTER bar (7). Note that oscilloscope trace (2) moves across screen 4-1/2 to 5-1/2 divisions (3) before dropping to the lower level (1).

6. If repeat of test is necessary, depress RESET button (5) then depress SHUTTER bar (7).

   Does sweep drop between limits (3)?

   YES → Proceed to next page.

   NO → Go to page 1-87.

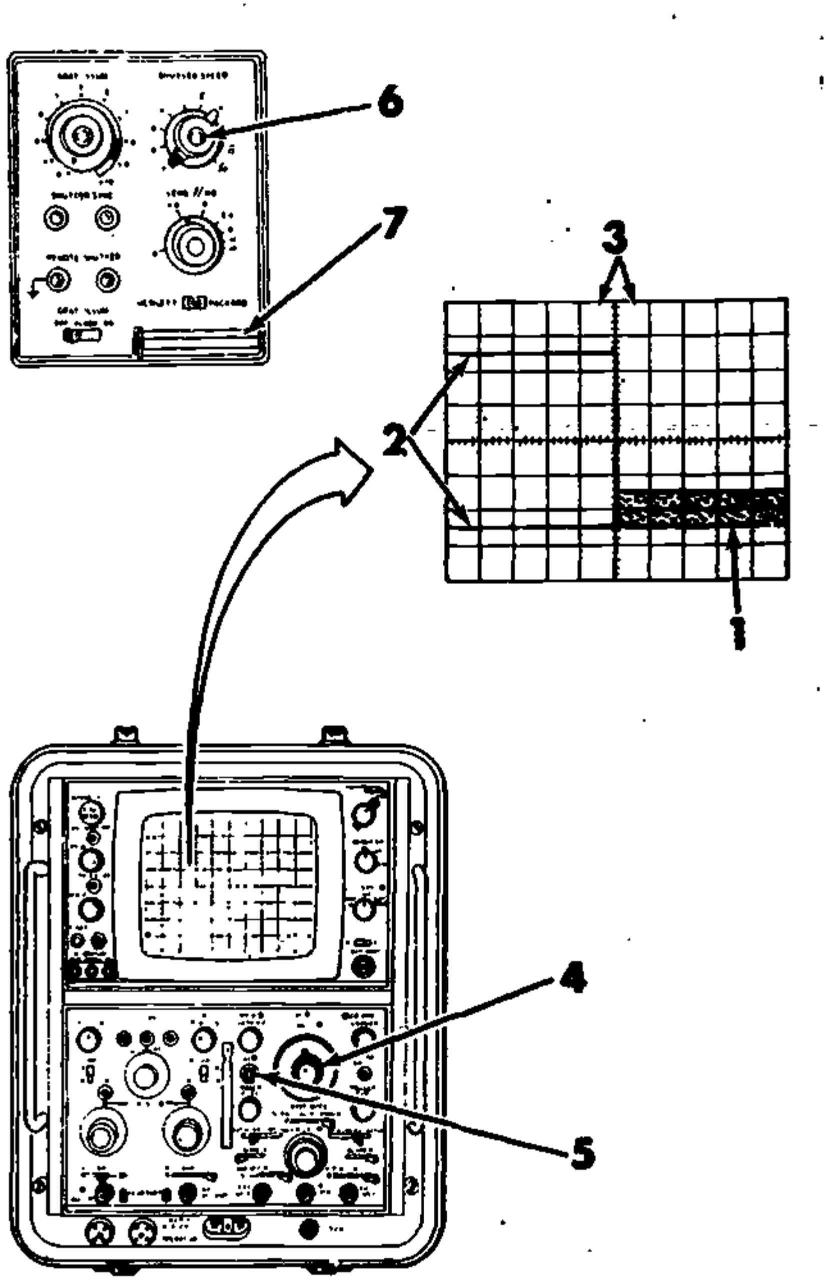

Figure 1. Example of FPJPA format/content.

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The FPJPA, exemplified by Figure 1 (Westinghouse, 1973), is unique among existing JPA format or content types. From the early Army studies until the present time, it has had the most consistently positive experimental results. Because of this, the FPJPA has been mistakenly regarded by some as being the <u>only</u> type of JPA. It forms the basis for the JTM/JTG format in the Army ITDT program and has been the preferred format of the Air Force in its attempts to implement job aids on the C-141 program; both services have prepared specifications for procuring both nontroubleshooting and troubleshooting FPJPAs. The Navy has not done so, but it does have the NAVAIR Work Package specifications and the NAVAIR/NAVSEA writer guidelines, which include many of the features of the FPJPA for nontroubleshooting operation and maintenance tasks. The Work Package concept, which is classified in Table 1 as a partially proceduralized aid, also provides for a troubleshooting decision logic tree.

Only the FPJPA types of JPAs (i.e., Air Force FPJPA, AMSAS, C-141 Aids, JOBTRAIN, OPTIMUM PIC/WORD, and PIMO) have demonstrated positive results with the novice technician (acceptable aptitude but inexperienced). Positive results have also been claimed for the Work Package concept on a demonstration with organization- and intermediate-level maintenance on the APQ-126 radar (Horn, Note 2), but the results have not been published. The positive results of the MDC (Krohn, Clayton, & Dunn, 1971) with inexperienced personnel were confounded by the lack of adequate experimental control, and therefore are not conclusive.

The FPJPA, FOMM, and Work Package have all been fully developed for electrical, mechanical, and electromechanical systems, but the FOMM generally is not considered adequate for digital electronics or mechanical systems. As shown by Table 1, no single JPA system concept includes all levels of proceduralization. The only true attempt to combine two or more levels of proceduralization was the AAT, a NAVAIR hybrid aid for troubleshooting that provided two separate routes to successful fault isolation. This technique introduced special cues designed (1) to allow the technician to move from one route to the other and (2) to suggest why certain tests were being made. The latter feature was to encourage greater incidental learning of higher order troubleshooting skills.

Several techniques (e.g., ATOMS, AVIS, FOMM, MAINTRAIN) are sufficiently flexible to be classified as both simple logic deductive and system description types. Some (e.g., JOBTRAIN, Work Package) even provide for three levels of troubleshooting flexibility, but none were found that mixed FPJPA formats with the other basic formats. This is probably due to two factors: First, FPJPA is a unique form of aiding that relies on a complete front-end analysis and fully illustrated procedures for each task being aided while making no assumption for deductive reasoning abilities or formal training. The other aid forms assume at least a midlevel technical background achieved through training or experience. The second factor is that, in both the Army and the Air Force, the FPJPA has been promoted as a substitute for the conventional technical order or technical manual, not as an adjunct or supplement to it. It was thought that no program manager would readily approve expenditures for two parallel aiding systems on the same equipment. It has now become evident that no existing aid can meet all the objectives of cost, performance, and manpower of a particular organization at the command level. There is not even an easy division where FPJPA, FOMM, or the Work Package can be used that will be consistent over time across major groups of programs. There are instances where all 13 aid forms may be necessary on a single system, while on others only one may be required.

Display Media Types

Table 2 classifies 47 selected JPA techniques according to the 7 basic media display types. The differences in types of display and special physical features are much easier to discern than are the format/content types, but it is probably in this area that the greatest confusion exists regarding the relative advantages and disadvantages of performance aiding. There is little evidence to support the contention that performance can be further improved beyond that obtainable with hard-copy print simply by the use of other types of display media. However, there are exceptions, some quite impressive, that will be pointed out in the following discussion.

Hard-copy Print Displays

In hard-copy print, the major physical feature of interest is size. Printed performance aids can vary from hand-held cards, checklists, and booklets to large wall charts or manuals with table size foldouts. For presenting operator and maintenance instructions, PIMO has short, step-by-step instructions and facing illustrations bound in a pocket-size booklet; the MDC and FLAP formats use oversize pages so that complete task information can be presented on a single page.

There are many other uses for hard-copy print JPAs than just operator and maintenance procedures, particularly in the smaller formats. For example, Chalupsky and Kopf (1967) described hard-copy devices used as aids in product inspection tasks, as management aids, as nomographs, and as conversion charts. Conversion charts in particular have been especially useful in patient care for such things as making conversions from the apothecary to the metric system. Hooprich and Steinemann (1965) found that a wallet-size electrical measurement chart raised measurement conversion performance of electronics technicians with little or no training to a level equal to that of experienced technicians.

Table 2

Display Media Types, Special Physical Features, and Feasibility Factors Applicable to Various JPA Systems and Techniques

JPA Technique	Display Media Type							Special Physical Features						Feasibility Factors			
	Hard-copy Print	Microform	Audio	Audiovisual (Static)	Audiovisual (Motion)	3-Dimensional	Interactive	Other Senses	Access/Indexing	Size/Shape	Color Features	Special Mounting	Embellishments	Concept	Device Built	Field Usage	Experimental Data
FPJPA	X								X	X				X	X	X	X
AMSAS	X								X	X				X	X	X	X
AVIS				X					X				X	X	X	X	X
C-A LOGICAL PROCESSES							X							X			
CMG										X				X	X		
Computer Aided Loop Diagram Representation						X								X			
Computer (Hand-held)							X		X					X	X	X	X
COST								X						X	X		
DATOM	X										X			X	X		
3-D DYNAMIC DISPLAY						X								X			
ELECTROCULAR					X							X		X	X	X	X
FASTI									X					X	X	X	
Filesearch System									X					X	X	X	
FLAPS	X									X				X	X		
FOMM, etc.	X								X	X					X	X	X
GPAM	X												X	X			
Holography						X								X			X
Implosion					X									X	X	X	X
Imagery Enhancement	X						X							X	X	X	
M3DD		X												X	X		
MAGNA CARD		X												X	X		
MAGNAVUE		X												X	X		
MAINTRAIN	X								X	X				X	X	X	X
MEMRI		X												X			
MIARS		X												X	X	X	X
MICROCARD		X												X			
MICROFICHE		X												X	X	X	X
MINICARD SYSTEM		X												X			
MINIDATA		X												X			
Miracode System		X												X			

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Table 2 (Continued)

JPA Technique	Display Media Type							Special Physical Features						Feasibility Factors			
	Hard-copy Print	Microform	Audio	Audiovisual (Static)	Audiovisual (Motion)	3-Dimensional	Interactive	Other Senses	Access/Indexing	Size/Shape	Color Features	Special Mounting	Embellishments	Concept	Device Built	Field Usage	Experimental Data
MDS	X													X	X	X	X
MDC	X								X	X				X	X	X	X
MMS	X						X							X	X		
MRC	X								X	X				X	X	X	
PIMO	X			X					X	X				X	X	X	X
PS Magazine	X												X	X	X	X	
Quick Fix	X		X											X	X		
RAPIDS	X	X							X					X	X		X
REPOM/MIRM			X	X			X							X	X		X
SADIE			X											X	X		
SHOCK ACTION	X													X	X	X	
TRACE									X					X	X	X	
Videofile					X									X			
Videosonic				X										X	X	X	X
WALNUT					X									X			
Work Package	X	X												X	X	X	X
WSMAC	X	X							X					X	X		X

There have been other physical features of interest in the print format--for example, tab size (Rees & Kama, 1959); tabular displays (Wright & Fox, 1972); and special page coatings to resist grease, dirt, and dampness--but design questions apart from size have more frequently concerned the desirability of embellishments. Usually, attempts to embellish a printed aid employ color or cartoons. If such changes (e.g., color coding for search aiding, organization improvement, or reduction in reading requirement) enhance comprehension, then they may be desirable, particularly with low-aptitude groups; but when used strictly for their attention-getting properties, they do not usually increase acceptance or improve performance. AVIS experimented with a female voice as an audio embellishment but, rather than improving performance, it proved to be a distraction and tended to reduce confidence in the message.

Audiovisual Displays

Audiovisual (A/V) devices have been expected to play a much larger role in performance aiding, but military studies specifically designed to compare such devices, such as Audiscan on the Air Force C-141 aircraft (Goff, Schlesinger, & Parlog, 1969) and AVIS on the NIKE missile system (U. S. Army Test and Evaluation Directorate, 1964), have shown performance aided by A/Vs to be poorer than performance aided by visuals alone.

The implementation of A/V devices for performance aiding has not met with much success in the civilian sector either. Chalupsky and Kopf (1967), in their survey of 12 firms, found that the installation of A/V devices increased rapidly about 1960 but by 1963, few remained in full-time service as on-line aids. Travers (1964) explained that an A/V device is most likely to be of value when the rate of information input is very slow, so that the user can switch from one mode to the other without becoming overloaded with information.

One particularly novel A/V device (ELECTROCULAR), developed by the Office of Naval Research in the early 1960s, was a lightweight, head-worn unit that contained a 35mm filmstrip and an audio tape carrying operation or maintenance instructions (Brown, 1964). The unit's optical system allowed the user to see both the instructions and the work environment. The advantage of this device was not that it increased comprehension, due to the combined sensory modality presentation, but rather that it allowed greater flexibility. The device was most useful in presenting maintenance instructions where there was insufficient space for larger displays or where the operator or maintainer needed to use both hands or to be mobile.

Audio or Visual Displays

Audio systems and visual displays (in addition to hard-copy print) have been more successful as separate aiding devices than have the combined A/V units.

Audio Systems. JPAs with programmed audio instructions on tape have been reported by Chalupsky and Kopf (1967) to be highly successful for cable harness or cable board wiring in the electronics industry; however, only one device of those surveyed (SADIE) was a purely audio JPA for a military application. This device consisted of a 10-lb. (4.53 kg.) specially designed, two-track magnetic tape player and a hand-held controller. One track contained a series of detailed troubleshooting instructions while the other track contained the troubleshooting sequence logic in digital form. A "yes" button advanced the tape to the next instruction; a "no" button, to another step in the sequence. Although impressive claims were made for the device, it is not known to be in use and no experimental results have been reported in the literature.

Perhaps the best use of the audio channel has been in real-time voice communication, ranging from a supervisor instructing a worker directly to the use of a voice link connecting one station to another. Examples of the latter are the McDonnell Douglas FEFI-TAFI and the Quick Fix procedures, in which the pilot or an in-flight maintenance crew member alerts a ground station to a maintenance need by means of a coded signal.

Visual Displays. Photos, picture guides, slides, CRTs, 3-D models, and plastic overlays already have been employed extensively as JPAs. For example, the implosion technique, which used slides, allowed the user to form perceptual blueprints of how mechanical parts fit together or how electrical networks connect, but it has only been applied to training. The SHOCK ACTION technique provided picture guides for tank crewmen to use as on-the-job performance aids. The MMS system employs a computerized CRT for displaying and manipulating the Maintenance Dependency Chart (MDC). TRACE uses a plastic overlay on circuit boards to show test points, current flow, and test data to simplify the testing of transitor radios. Overlays have also been used in production facilities for the assembly of printed circuit cards. In one case, the arrangement of component bins was integrated with overlays to eliminate assemblers' decisions in selecting or locating components to be attached to the printed card.

Microform Systems

Microform is often considered an information transfer medium that can be substituted for hard-copy print or A/V devices. Actually, however, the advantages of microform systems alone are not really competitive with such devices on the same aiding factors. While print and A/V devices are primarily directed toward aiding information comprehension, microform systems are designed primarily to ease information access. All such systems used as job aids are storage and retrieval devices that provide a more convenient means of accessing large information sources at the work site. Decisions to use microform systems for on-the-job aiding are based not on direct user requirements, but on such criteria as reduced storage requirements or reduced distribution and update costs.

No studies were found that directly compared microform display systems to both A/V and print displays for relative advantages in job-oriented training or job performance. However, a few experimental studies compared microform systems against the print mode on training success criteria. The most recent of these (Rizzo, 1977) compared the efficiency of microfiche versus traditional paper copy for training Navy personnel on the Basic Electricity and Electronics (BE&E) curriculum. That experiment measured (1) the time it took individuals in three aptitude groups to complete 14 individualized, self-paced modules and (2) errors on comprehensive examination tests. An important finding was that the lower aptitude group was adversely affected (more than 25% greater training time) by the microfiche medium. These results are similar to those of an earlier Air Force study (Grausnick & Kottenstette, 1971) that found no advantages with microfilm for any aptitude group and definite disadvantages for lower-aptitude personnel.

Novel Displays and Devices

While the results with audiovisual and microform systems have been disappointing, some nonpaper aiding devices appear to offer considerable advantages over static paper displays. Examples are (1) devices such as holography and three-dimensional models, and (2) interactive devices such as hand-held computers and slide rules. Frey (1976) found the holographic medium to be as good as or superior to line drawings and photographs on assembly, discrepancy identification, and information extraction tasks. The production of good quality holograms is still an art, however, and no attempt has been made to produce them for use in schools or in the field.

Interactive devices can almost be considered as a distinct class in aiding technology. These devices, which can include slide rules, hand-held computers, and interactive CRT displays, are much more dependent on the state-of-the-art in information handling than are other devices, which tend to present one-way, relatively fixed instructions. Chalupsky and Kopf (1967) classified these as task modifying aids because they allow the user to achieve a desired result without performing all of the steps that normally would be necessary. Such devices are contrasted with task supporting aids such as proceduralized instructions, which guide task performance but result in the same behaviors that would occur without an aid.

Recent work of interest in this area is that of Burkett and Kruse (Note 3) on card-programmable and chip-programmable pocket calculators. They claim to have discovered an incidental learning process they call "Thinking Process Transmutation." In this process, the user is guided incidentally into reorganizing his own thinking processes to fit the calculator's logical processes. Thus, the user seems to develop a new capability to organize thoughts, to define necessary steps, and to develop the most efficient procedures for problem solution. The potential of such applications seems enormous in equipment fault isolation or in operator analyses in command-and-control decision making, but only one study has been found that actually applies the concept to job aiding (Rigney & Towne, 1977).

One unique method, called the Concentrated Odor Sensing Technique (COST), uses the sense of smell. Developed by the Illinois Institute of Technology, the technique employs up to 128 different odors concentrated and encapsulated in tiny seeds designed to be melted by heat, cracked open by pressure, or dissolved by a liquid, thereby releasing the odor. As an aiding device, the capsules could be used on electrical circuits, motors, pumps, hydraulic lines, or bearings to indicate trouble areas.

Applied Training

Of the systems surveyed, several aid on-the-job performance through applied training techniques. The importance of discussing such systems here is that these techniques, to some degree, have been designed for implementation in conjunction with job aids. Training designed in this manner tends to be most compatible with job aiding and has many of the same goals, including (1) the reduction of total class and instructor time, (2) imparting only those skills necessary for performing a job, (3) an emphasis on proficiency rather than knowledge tests, and (4) greater "hands-on" experience.

The older Army systems (e.g., FORECAST, JOBTRAIN, MAINTRAIN) were specifically designed around a combination of training and job aids that would require less training time than conventional courses. Some of the Navy-developed maintenance training concepts (e.g., TASKTEACH, MITIPAC, ISD) seem to consider interactive CAI and maintenance simulation to be the heart of improvements in job performance, with prescriptive aids and technical documentation being incidental to the training process. Such techniques need to be placed on an equal footing with aiding to fully achieve the advantages of aiding technology.

JOBTRAIN's training objectives included "theory," but such instruction was introduced only as the student needed it to solve practical problems. In FORECAST, the cue-response or behavioral type of task analysis was introduced as the basis for both training and job aiding. In FORECAST and JOBTRAIN the emphasis on theory also became more systems or functionally oriented than in the past. The shift in orientation toward logical approaches to troubleshooting greatly reduced the need for knowledge of the fine points of electronics theory. Theoretically, this trade-off (preliminary analysis with documented logic versus knowledge training) could be pursued to its natural limit: all information in the book for use directly on the job and no information presented beforehand for instilling knowledge in the head. It has been recognized for some time, however, that certain information necessary for job performance is better assigned to the head than to the book (Chalupsky & Kopf, 1967; Chenzoff, 1973).

Although convenient for JPA/training task assignments, the distinction of head versus book does not necessarily parallel that of training versus aiding. Contractors on the Army ITDT program are finding that many of the knowledges and skills needed to do productive work with available job aids can be acquired through the book (in an aiding format). One effort, for example, reduced the training requirement for tank maintenance tasks from 200 to 18 after finding that the majority of training tasks could be learned by simple proceduralized training aids that are indistinguishable from job aids. Many of the remaining skills seem to be learned incidentally while performing with job aids.

There appears to be less and less reason for the separation of training and aiding in the initial stages of enhancing job knowledges and skills. This is not to say that job aids can totally replace training. Teel and Chaney (Note 4), in one of the few experiments comparing training to aiding, showed that combining the two produced almost double the performance improvement of either method used alone. Furthermore, as Klesch (1977) pointed out with job-oriented training programs such as learner centered instruction (LCI) and job aiding programs such as PIMO, all of the problems of personnel careers (e.g., skills development, cross training, retention) must be considered if either is to be successful.

For example, neither applied training nor fully proceduralized job aids adequately address the long-term personnel problem of retaining and building a career force in any of the services. This then leads to the need to consider training and aiding as changing in relative usefulness over an individual's career.

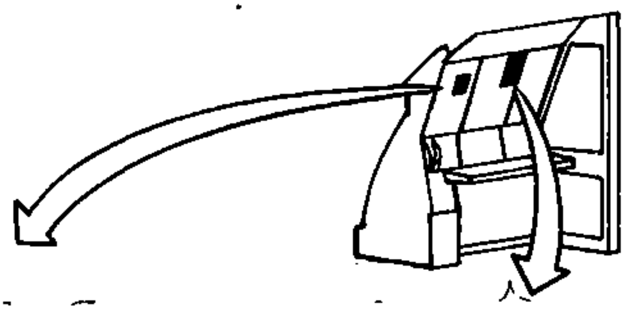
Peripheral Test/Diagnostic Systems

Some JPA systems combine automatic testing diagnostic features with further diagnostic and repair instructions for maintenance personnel to use in correcting malfunctions. Such systems usually cover electronic equipment and, to a lesser extent, hydraulic, pneumatic, and other flow systems. Three basic types of aiding systems can be classified under this category: (1) built-in, computer aided tests, (2) status displays, and (3) fault-probability displays.

The first type is more commonly known as ATE (automatic test equipment), but to be classified as a JPA, a system must be capable of (1) diagnosing the problem down to the level of repair and (2) providing the means for aiding the repair itself. Examples in the glossary are the Westinghouse ADMIRE/MIRAID and the Vought Aeronautics CATA, which have built-in equipment sensors that provide inputs directly to a computer for first-level diagnosis. The test equipment then provides follow-up instructions for the maintenance technician. Other systems, such as VAST and VATE, are even more automatic in that they use computerized fault isolation to indicate which unit needed to be replaced. In such systems an aid is most useful for operation and maintenance of the ATE or as a backup when the ATE is malfunctioning.

The second type, "status displays," either key lists of displays to troubleshooting instructions or include a decision logic table for completing the aiding function (Post et al., 1976). A decision logic table may be preferable where a large number of displays are present since it can provide patterns of display readings that more readily guide the technician to the trouble areas. A good example of this type of aiding system is the FEFI-TAFI system on DC-10 aircraft. The system controls and displays that normally are provided for commanding and monitoring the aircraft or the operation were found extremely useful in indicating system failures. Earlier studies by McDonnell Douglas had found that, typically (since several indicators and conditions sensed by the flight crew are associated with specific subsystems), malfunctions in different components produce relatively unique patterns of normal and abnormal indications that can be considered signatures of particular subsystem failures. Figure 2 (Burrows, Willets, & Miles, 1970) illustrates a typical flight engineer's fault isolation (FEFI) decision logic table of indicator patterns.

The final type of aiding system in this general category is that of probability-of-fault systems. Usually, these attempt to use historical data of system usage to improve reliability prediction. The aid allows a technician to go directly to a fault, based on major trouble symptoms and reliability prediction data.



ENGINE FIRE DETECT SYS

FIRE LT	ENG A LTS	ENG B LTS	APU A LT	APU B LT	LOOPS A & B TEST SWITCHES	FAULT CODE
APU FIRE (LT OFF)	LOOP A ENG LOOPS (LTS OFF)	LOOP B (LTS OFF)	LOOP A APU LOOPS (LT OFF)	LOOP B (LT OFF)	LOOPS A TEST, LOOPS B TEST (OFF POSITION)	NORMAL OPERATION
	LOOP A		LOOP A			26-12 A
		LOOP B		LOOP B		26-12 B
			LOOP A			26-12 C
				LOOP B		26-12 D
APU FIRE (LT ON)	LOOP A (LTS ON)	LOOP B (LTS ON)	LOOP A (LT ON)	LOOP B (LT ON)	TEST TEST (TEST POSITION)	NORMAL TEST
APU FIRE	LOOP A		LOOP A		TEST TEST	26-12 E
APU FIRE		LOOP B		LOOP B	TEST TEST	26-12 F
APU FIRE			LOOP A		TEST TEST	26-12 G
APU FIRE				LOOP B	TEST TEST	26-12 H
			LOOP A		TEST TEST	26-12 J
				LOOP B	TEST TEST	26-12 K
REPORT ANY FAULT SYSTEM OR PATTERN NOT SHOWN						26-12 XX

Figure 2. Typical FEFI decision logic table of indicator patterns.

Peripheral test/diagnostic systems are most useful where repairs need to be done rapidly, as on an aircraft carrier flight deck where a quick turnaround between landing and launching is needed. Of the systems sampled, those that have attempted to facilitate such rapid repairs are the Grumman Aircraft RAPIDS and the REPOM/MIRM system sponsored by the Naval Ordnance Laboratory. Although very helpful in rapid fault isolation, such systems have not been widely implemented because of the high cost of obtaining, maintaining, and analyzing the data necessary to continuously update the maintenance instructions.

Delivery Systems

Several types of systems that are classified as aiding systems are really process systems for developing and supporting the aid itself. Usually, such systems provide and update technical information to operators and maintainers and, as such, are outgrowths of the various technical manuals (also referred to as technical data, documentation, publications, and orders) systems for commercial and military applications. In this class of systems there are several stages in the process that could contribute greatly to the quality of the final aiding product. Many of the JPA systems identified in the glossary are subsystems of complete job aid delivery systems. TRUMP, for example, is concerned primarily with the rewrite and update of technical publications, while MIARS (listed in the glossary with TRUMP) is a microform system directed toward information storage, distribution, and retrieval.

The two systems of most interest in this discussion are the Navy NTIP system and the Army ITDT program. NTIP is concerned with each phase of the delivery process but places considerable emphasis on hardware systems for technical information production, handling, and display. The ITDT is primarily concerned with supporting both the publication and training needs of weapon systems and equipment, with heavy emphasis on a front-end analysis.

The NTIP has identified eight necessary stages in JPA delivery (Hughes, 1977a, 1977b)--user-data match requirements, data acquisition, content generation, content capture, content replication, distribution, update, and feedback--and has identified some research needs in each stage (Figure 3).

User-data Match Requirements

The user-data match stage, in specifying the appropriate aid formats, content, and media for any particular project, considers (1) personnel characteristics, (2) the results of the analysis of the equipment or system and task, and (3) environmental constraints. The primary media considered under this system are paper manuals, A/V devices, microform, and video disc devices. This stage is most similar to (but not as rigorous as) the Army's front-end analysis. It is probably at this stage that the various JPA selection algorithms should be used. Determining the level of detail required and the quality of the task analysis (front-end analysis) to be performed are the most critical decisions to be made at this stage.

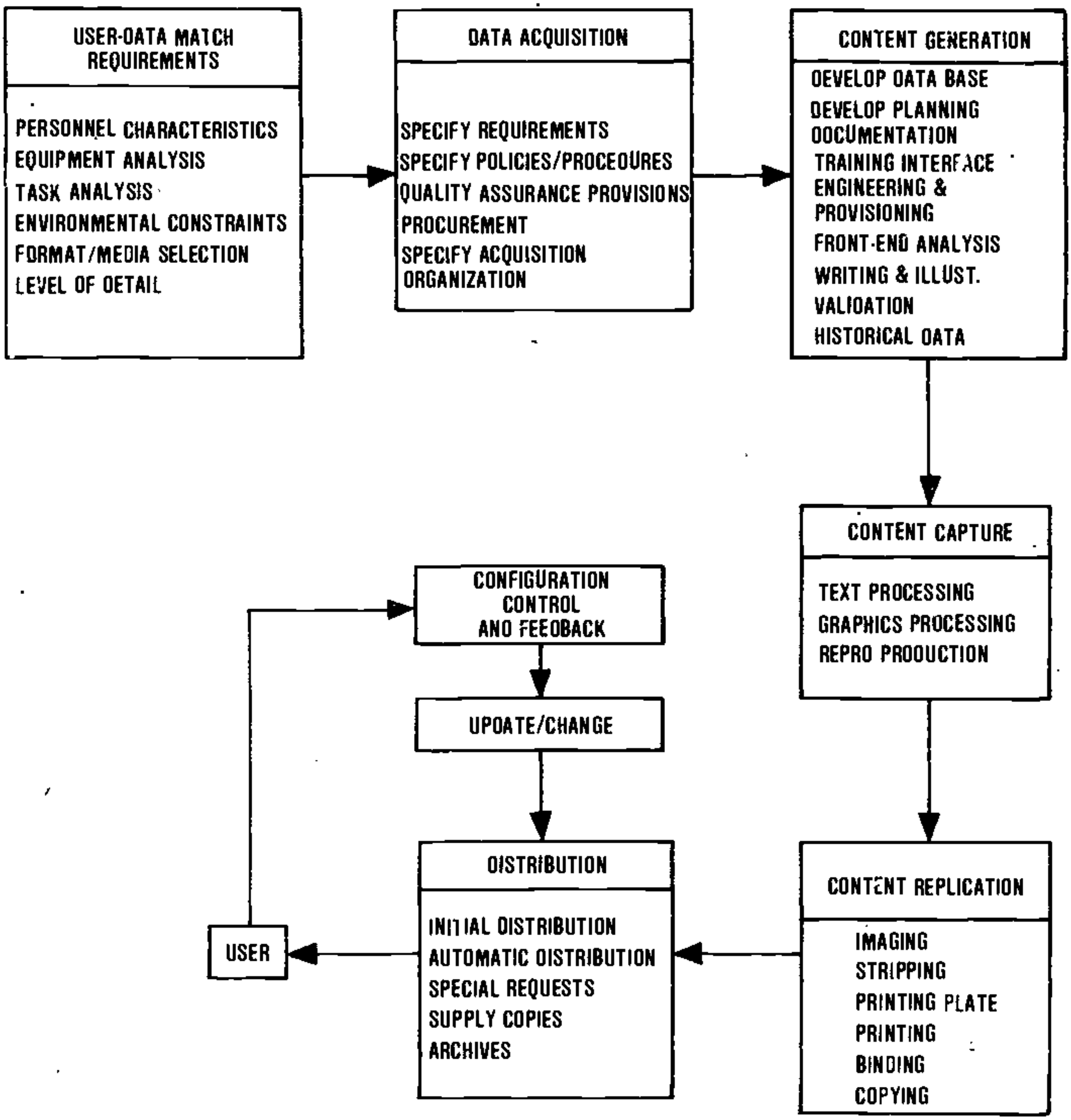


Figure 3. JPA delivery system stages.

Data Acquisition

Data acquisition includes the specifications, management policies and procedures, and data acquisition organizations involved in acquiring the JPA. In addition to specifying front-end analyses and media, attempts should be made to introduce quality assurance provisions to ensure that the delivered JPA is complete, accurate, comprehensible, and usable. The problem of accuracy, particularly with troubleshooting JPAs, appears to be the most difficult to solve and the least likely to be improved by increased rigidity in the specifications. Braid (1977) suggested that this problem can only be solved through more intelligent use of front-end analysis and feedback.

Content Generation

The content generation stage of the JPA process includes actually developing the content to be displayed with a JPA. Eight steps are involved: (1) developing or obtaining and accessing the engineering or manufacturing data base, (2) developing planning documents, (3) making interface assignments with training, (4) performing maintenance engineering, provisioning, and design engineering, (5) conducting the front-end analysis, (6) writing and illustrating the JPA, (7) validating the JPA, and (8) compiling program historical data. Regardless of the final user medium, the end product of the content generation stage will almost always be a draft JPA on paper.

Content Capture

The content capture function transforms the draft JPA into a form and format suitable for replication. It combines the functions of text processing (usually by typewriter), graphics processing (manually prepared or computer-assisted), and production, with the output being a reproducible copy in a predetermined medium. This entire function can be automated with state-of-the-art equipment. TRUMP is one of the most sophisticated military systems for this function. It uses optical character recognition (OCR) to scan printed pages, with graphic inputs processed in photographic form. The system can also receive alphanumerics, edit, and make data correction inputs through interactive terminals. Outputs can be either microform or reproducible copy.

Future systems are expected to store all information digitally. The methods for digital storage that have been considered include magnetic tape, magnetic disc, magnetic drum, optical, semiconductor, hologram, and video disc. The video disc and hologram appear to offer the most promise for mass storage techniques, but neither is currently suitable for application in JPA development systems.

Content Replication

Content replication involves printing and copying technology. While the technology for copying has made dramatic progress in the past years, printing technology as can be applied to JPAs has not changed appreciably for many years. The printing process includes several steps (i.e., imaging, stripping, making the printing plate, printing, and binding), but it is only in the binding process that automation is more fully developed for JPAs. It is unlikely that JPA printing technology for delivery systems will change much in the next few years because of the high capital investment in machines now being used and because JPAs are usually short-run but relatively large, especially when used as maintenance information aids.

Improvements in copying offer more possibilities to JPAs, particularly in the area of on-site, on-demand, quick-printout capability and in the reproduction of color originals. In addition to present-day microform copies, it is expected that technical information, including graphics, soon could be delivered in digital form at the work site, where it could then be replicated on CRT displays or produced as printed copy.

Distribution

The process of distributing JPAs for complex military weapon systems implies much more than a stockpile of aids that can be delivered to user activities. The distribution system must provide for (1) initial distribution to JPA users, (2) automatic distribution of future issues, changes, and corrections, and (3) special one-time requests. In military systems, configuration changes are common due to continued efforts to improve equipment operability and reliability. Also, equipment maintenance often turns out to be somewhat different than originally planned (e.g., planned dependence on automatic test equipment that becomes unreliable). JPAs require accuracy and must reflect the actual equipment being operated or maintained if they are to function properly. Assigning a configuration or identification number to the JPA for administrative control, and tracking the JPA with data management techniques throughout its life cycle, are the major means of ensuring such accuracy and fidelity. At present, no system exists outside of the technical manual or technical documentation fields with the means or responsibility for performing this critical function. The distribution process also must maintain (1) adequate supplies for rapid response to requests and (2) an archive for historical reference data and supply stock replenishment.

Feedback

The feedback link from the JPA users to the distribution and change systems is critical to JPA effectiveness. In fact, full utilization of this link may be the only way that troubleshooting JPAs (of the proceduralized variety) can be made to satisfactorily reflect the troubleshooting routines needed on any particular system or equipment. This is a particularly weak link in current technical manual systems--it is slow, user participation is low, and too little direct communication occurs between the user and the data manager. The situation is not likely to improve until the user is convinced that his efforts in detecting and reporting inaccuracies in the JPA are considered seriously and expeditiously.

Update

The update subsystem connects the configuration control and feedback system to the distribution process. It has content capture and content generation functions (as already discussed) for original materials, but also must consider methods for changing original material and for inserting new material. Inherent in the update process is a methodology for determining the effects of a change in one JPA upon other data and logistic elements. When a system is in production, there should be provisions for coordinating all logistic elements. The coordination among elements for out-of-production equipment tends to be under the control of Navy facilities and is less formalized, but the problems of configuration control are considerably reduced by the time an equipment reaches this stage. Here again, technical data systems have made bona fide attempts to control and manage this process, but it still is done less efficiently than would be required for a workable JPA system.

JPA ALGORITHM DEVELOPMENT FACTORS

In the development of a JPA algorithm, four general areas of JPA technology must be considered: (1) factors important in selecting the basic format or content type of JPA, (2) requirements for special (i.e., nonprint) media or special physical features of the JPA, (3) the relationships between the JPA, training, and job design, and (4) JPA test and evaluation technology.

JPA Selection Factors

In designing JPA systems to meet the personnel, training, and maintenance support requirements of a hardware system, the following variables are primary considerations in selecting the basic JPA system type:

1. Personnel aptitude.
2. Personnel job experience.
3. Type of task being aided.
4. Complexity of the task.
5. Complexity of the equipment.
6. Type of equipment.
7. Degree of proceduralization.

Various combinations of these variables have been investigated for the relative effects of one system over another on performance, training, or job design.

Personnel Aptitude

Rowan (1973) stated that the JPA and training literature is replete with studies indicating that lower-aptitude personnel can carry out nontroubleshooting maintenance tasks with minimal training using properly prepared job performance aids. Because of (1) decreasing aptitude levels among new enlistees and (2) a shrinking manpower pool at the high-aptitude levels, JPAs are being looked to as a way of better utilizing lower-aptitude personnel.

Overall, however, the results are not as convincing as Rowan has suggested. While numerous studies report the advantages of aiding <u>inexperienced</u> personnel, few directly address the problems of <u>lower-aptitude</u> personnel. Available data do tend to support Rowan's interpretation, but even the best studies base their conclusions on a finding of no statistical differences. Moreover, in studies that found no differences among aptitude levels, this finding was usually limited to nontroubleshooting tasks (Elliott, 1967; Hooprich & Steinemann, 1965). Elliott, for example, in comparing proceduralized job guide performance for 20 high school seniors--10 high aptitude (80-95 on the AQE Electronic Index) and 10 medium aptitude (50-65 on the AQE)--on troubleshooting and repair tasks, found that aptitude had no effect on errors in maintenance repairs or on the <u>time</u> required for troubleshooting. There was a statistically significant difference, however, in <u>errors</u> made on troubleshooting at both the system module and defective components levels; that is, high-aptitude performance was better than low-aptitude performance.

There have also been reports of successful nontroubleshooting performance by personnel considered to have lower aptitude levels, although the studies were not specifically designed to test the aptitude factors. Horn (1972), for example, found lower-aptitude mechanical ratings able to do electrical ratings' nontroubleshooting jobs with FPJPAs. Greater performance from lower-reading-ability personnel may also be inferred from the successful performance of maintenance tasks by non-English speaking Vietnamese on the American UH-1H helicopter.

Only one study has suggested that lower-aptitude personnel can also do troubleshooting accurately with the FPJPA: Theisen and Fishburne (in press), in a field-study demonstration with 41 Navy technicians whose selection test scores were below the cutoff for "A" school eligibility, concluded that the subjects were able to satisfactorily isolate and repair malfunctions in the AN-AQA-7 Sonar Signal Processing System with the use of the FPJPA. Unfortunately, the results of this study were greatly weakened by the lack of adequate control data.

The consensus of researchers in the field is that aptitude tradeoff has not been adequately studied. However, most are confident that, whatever the level of performance of the lower-aptitude personnel, increased training and the availability of JPAs can bring even very low-aptitude personnel (i.e., fifth-grade reading level or below) to acceptable performance levels in nontroubleshooting operator and maintenance tasks.

Job Experience

Unlike aptitude, the effects of experience are adequately considered in most JPA experimental research. Rowan (1973), in summarizing the literature, noted that all FPJPA experiments and field tests showed that inexperienced technicians performed better with aiding than with conventional documentation. This has been generally true for troubleshooting as well as nontroubleshooting tasks, although acceptable levels on complex troubleshooting tasks are more difficult to achieve and FPJPAs have failed completely in some instances (Klesch, 1977).

Some JPA techniques other than FPJPA have succeeded in raising the performance level of inexperienced technicians in troubleshooting; for example, the Augmented Action Tree (Horn, 1973), Logic Tree Troubleshooting Aids (Potter & Thomas, 1976), and the Work Package Concept (Horn, Note 2). All, however, have included some form of decision logic tree. One non-FPJPA technique that has received considerable attention is the MDC. Studies of the use of this technique by inexperienced personnel have yielded mixed results (Krohn, 1971; Horn, 1973).

Also, although all experience levels generally express more favorable attitudes toward proceduralized JPA techniques (Goff et al., 1969; Potter & Thomas, 1976), well-prepared conventional documentation in the hands of experienced personnel can result in better performance on some types of troubleshooting tasks (Potter & Thomas, 1976). Highly proceduralized techniques alone probably cannot support all of the troubleshooting demands of complex weapon systems (Klesch, 1977; Booher, 1977b).

Type of Task

For determining the major differential effects of aiding techniques, it is now clear that the type of maintenance task being aided can be classified as either troubleshooting or nontroubleshooting.

It has long been known that mechanics can become relatively skilled on nontroubleshooting tasks after 6 months of field experience, whereas troubleshooting skills continue to improve throughout their careers (Baldwin, Mater, Vineberg, & Whipple, 1957). With job aids, inexperienced and lower-aptitude personnel can be proficient on nontroubleshooting tasks almost immediately, essentially eliminating the first 6 months of warm-up. Considerably more time is required, even with job aids, to become proficient in troubleshooting skills, but proficiency can be achieved much earlier in the technician's career with aiding.

Proceduralized job aids are less expensive to develop for nontroubleshooting tasks than for troubleshooting tasks because the former require no functional analysis (Shriver & Hart, 1975) and are much easier to validate for accuracy (Johnson, 1977). According to Middleton et al. (1977), nontroubleshooting aids are also relatively easy to tailor to the degree of proceduralization needed to meet individual maintenance task requirements. The aiding of troubleshooting tasks, on the other hand, generally requires a functional analysis, can be difficult to validate for accuracy, and interacts considerably with variables such as technician experience, equipment complexity, and task complexity.

Complexity of Task and Equipment Factors

Studies have generally attempted to deal with the complexity of tasks and with the type and complexity of equipment by sampling across several difficulty levels and types rather than considering them to be major independent variables. Clear differences due to the these factors have not been evident. However, some general rules of thumb seem to have evolved during 20 years of JPA research. First, if the task is a nontroubleshooting task, then task complexity and the type and complexity of equipment have little bearing on the decision concerning the type of JPA. Second, some types of tasks, because of their special complexity (e.g., difficult alignment, adjustment tasks), might require additional training. Finally, if personnel of varied experience are to use the aid, then a dual-level presentation of procedures may be useful. Generally, however, these three factors do not create a great deal of difficulty once a JPA approach has been selected. The guidelines recommended by Middleton et al. (1977) appear quite useful as format selection criteria in accordance with varying task complexity on nontroubleshooting tasks.

If the task is a troubleshooting task, then task and equipment complexity, as well as the experience and training background of the personnel using the aid, help dictate which JPA is best. Short or excessive task length can greatly influence the decision to use either the FPJPA or a more deductive form of aiding. Other subfactors also contribute to complexity, such as (1) the subordination of equipment as determined by the top-down breakdown (Post, Price, & Diffley, 1976), and (2) the amount of special testing and unique requirements for deductive reasoning (Middleton et al., 1977).

FPJPA approaches are generslly good for electrical, mechanical, or electro-mechanical systems (Post & Brooks, 1970). The SIMM or FOMM format, on the other hand, is usually restricted to complex systems; it is generslly considered better for analog than digital electronics and not good at all for mechanical systems (Martin, 1975). However, no aiding systems were found that could be considered adequate for complex digital systems.

Mechanical systems tend to be aided best by highly pictorial formats; at least that is the inference drawn from the genersl acceptance of existing pictorial aids. Haggard and Shock (1962) long ago demonstrsted the effectiveness of visual aids for showing signs of malfunction and wear in equipment, and almost all mechanical maintenance personnel use the illustrated parts breakdown for performing maintenance and for ordering replacement parts. Several years ago the Navsl Ordnsnce Laborstory and the Army's Human Resources Research Organization (HumRRO), developed picture guides and manuals for operators and maintsiners of equipment such as tanks, guns, and mines. General Motors Corporation (1977) has developed a fault isolation and repair manual, done in a highly structured pictorial format, that already has sold more than 250,000 copies.

Proceduralization

In any model for JPA selection, probably the most critical factor regarding effects on performance, training, or job design is the degree of proceduralization. One of the earliest studies was reported by Atchley and Lehr (1964). Figures 4 and 5 (Atchley & Lehr, 1964) show the time and error performance advantages possible with proceduralized formats as compared to other types. Job aids that produced the performance improvements summarized by Rowan (1973) and Shriver and Hart (1975) have genersily relied heavily on proceduralization, as determined from the result of front-end analyses of equipment, operator, and maintenance task requirements.

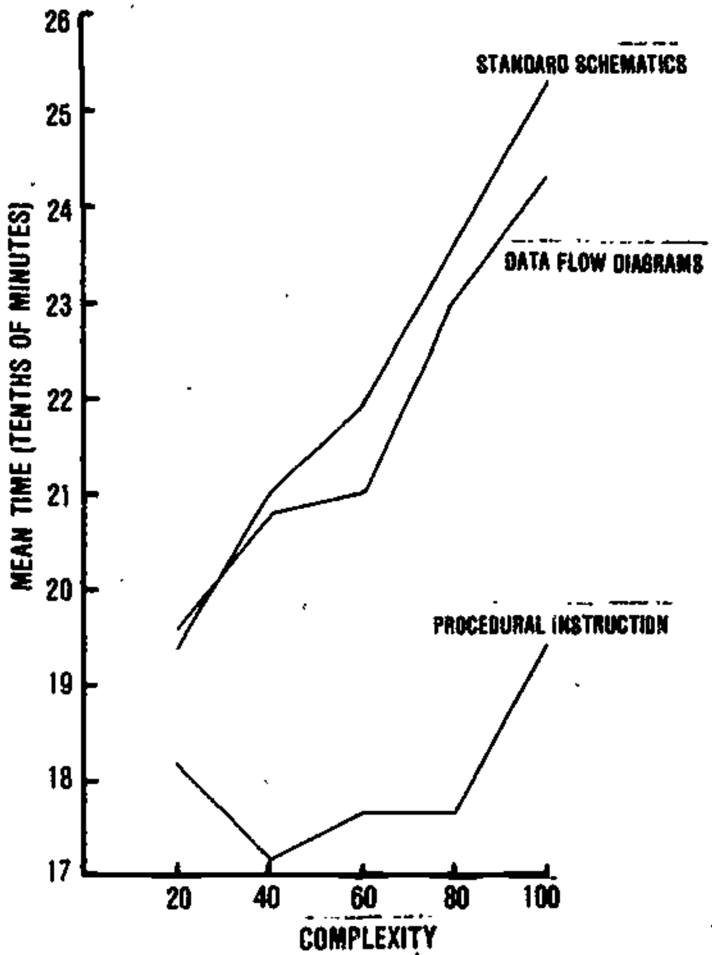


Figure 4. Troubleshooting performance speed of Air Force basic trainees with three JPA format components (Atchley & Lehr, 1964).

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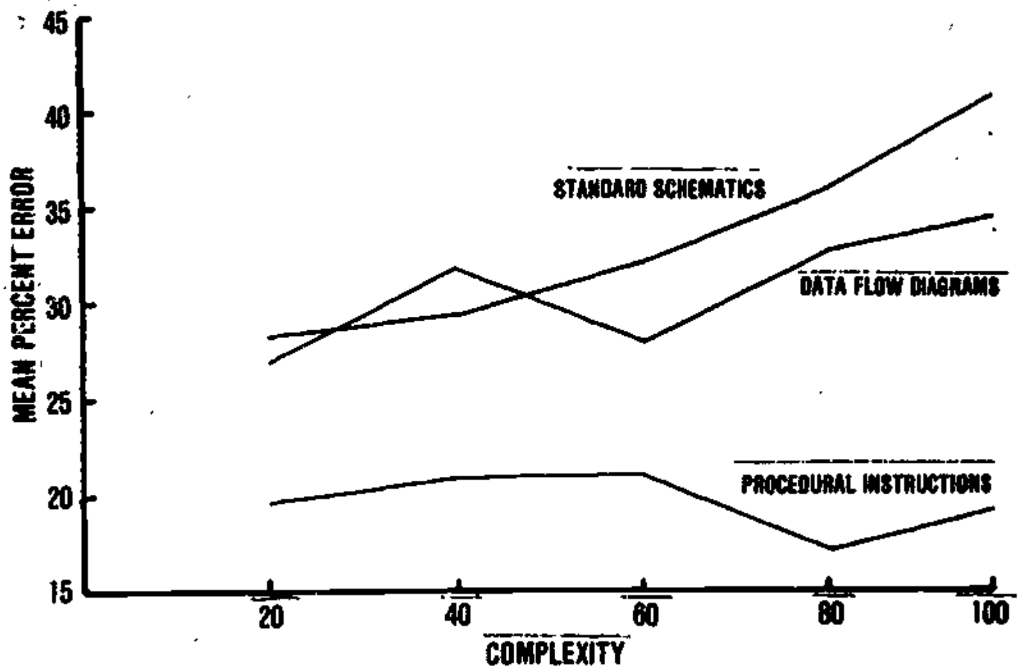

Figure 5. Troubleshooting performance accuracy of Air Force basic trainees with three JPA format components (Atchley & Lehr, 1964).

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Media and Design Factors

In selecting the media and physical design of performance aids, two major constraints must be considered: (1) that generally imposed by the hardware system itself, and (2) that set by the work or learning environment.

Hard-copy print is usually recommended because (1) it is the least expensive medium, (2) it is the easiest medium to use on the job, (3) performance studies have shown print to be equal to or as good as other media, and (4) the effect of JPAs on performance is content-dependent, not medium-dependent. There may be situations, however, where systems support requirements dictate the use of media other than hard-copy print; for example, there could be distribution, storage, or updating problems with the print format that adversely affect the aid's timeliness and accuracy. Regardless of the medium, any aid that has accurate, complete data is more essential to job performance than one without these qualities. There are also some situations where the task may not be presented feasibly with hard-copy print. For example, motion pictures could be used to describe complex alignments or adjustments; holography, to aid three-dimensional judgments; or hand-held computers, to facilitate assisting complex mathematical operations. In addition, costs may not always be on the side of hard-copy print; indeed, paper printing costs have risen exorbitantly in the past few years, making microform more and more appealing.

Post, Price, and Diffley (1976) said that three primary system support requirements influence media selection that is based on varying system design and operating conditions: (1) access to information, (2) recording medium, and (3) portrayal mode. The first, "access to information," is important because the task of locating information often consumes 20 percent of the maintenance technician's time. Important man-system interface considerations for access to the information depend on the availability of system status displays and automatic test equipment. Patterns of display readings and ATE readouts keyed to appropriate job aids can help minimize the initial search time. The second requirement, "recording medium," describes such things as system size, number of systems, distribution processes, and installations as constraints that may urge choices other than hard-copy print. Post et al. (1976) recommended that paper be used for information bases of up to 300 frames while the microform mode is more desirable beyond 1500 frames. The third requirement, "portrayal mode," is most critical in matching work place conditions to job aids utilization. They conclude that a single medium may not be equally suitable for all system aids or even for all aiding applications within a system.

Hughes (1977b) presented a detailed matrix of environmental constraints between and within systems that dictate the physical design of hard-copy print, microform, and audio or video. An ambitious attempt was made to recommend design choices to the extent of page size and typography. The environmental constraints noted are generally human engineering considerations and include work space, illumination, dirt, wind, moisture, temperature, noise, time, and hazards or safety restrictions. Table 3, a revision of the Hughes matrix, includes several additional techniques. For a discussion of the relative effectiveness of media characteristics developed around instructional research, see Guilliford (1973).

Table 3

Environmental Constraints for Job/Training Media

Medium and Characteristics	Work Space	Illumination	Dirt	Wind/ Moisture/ Temperature	Motion	Noise	Time	Hazard/Safety
	Environmental Constraints							
Hard-copy Print								
Page Size	X			X	X			
Typography		X			X			
Page Layout	X				X		X	X
Picture/Word Composition							X	
Color		X					X	
Page Material	X	X	X	X	X			X
Cover Material	X		X	X	X			X
Cover and Binding	X							
Graphics		X					X	
Microform								
Portable Viewer	X	X	X	X				
Hand-held Viewer	X	X	X	X	X			X
Printout Capability	X		X	X				
Roll Film Carrier	X		X					
Cartridge/Cassette	X							
Aperture Card								
Microfiche	X		X					
Frame Retrieval	X		X				X	
Shaded Screen	X	X						
Still Pictures		X	X					
Motion Pictures	X					X		
Television/Video	X	X				X		
3-D (Objects)	X	X				X		
3-D (Holography)	X	X						
Audio (Recording)						X		
Programmed Instruction								
Text	X	X						
CAI	X	X						
Demonstration	X	X				X		
Oral Presentation	X	X				X		
Hand-held Computers		X	X	X	X		X	
Imagery Enhancing Techniques		X			X		X	

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Considerable research in the education and training literature shows the advantages of various media in work environments intended to meet learning or performance objectives. A modification (Table 4) of Allen's (1967) illustration of the relationship of instructional media to learning objectives is considered the most useful classification matrix for such a comparison. Notice that no media type can be ranked "high" in meeting the objectives of learning factual information, performing skilled perceptual motor tasks, or developing desirable attitudes.

A final factor important to JPA design itself is the amount of effort expended on improving the aid's intelligibility (Shriver & Hart, 1975) or comprehensibility (Post & Price, 1974). This includes not only the readability of the written material but also the usability of graphics.

Integrated JPA/Training/Job Design

The importance of integrating the JPA, training, and job design cannot be overemphasized. The three have been considered trade-offs, depending on cost, performance, and manpower limitations in meeting overall weapon system/mission objectives. In the broadest sense, this is true. The availablity of a highly proceduralized JPA (i.e., an FPJPA) may eliminate the need for formal training and allow work centers to better design the workload around a complement of experienced and relatively inexperienced personnel, but the FPJPA would probably cost more than a deductive JPA. Less expensive deductive aids, on the other hand, require greater training and on-the-job experience and require work centers to operate primarily with highly skilled personnel.

However, this seems to be a gross oversimplification of the relationship among these three technologies. First, no one technology (i.e., JPA, training, or job design) is a direct substitute for the other. All three must be integrated for any weapon system. The savings suggested in the literature for military training (Shriver & Hart, 1975) as a result of the FPJPA cannot be realized simply by reducing training. The longer-term personnel career considerations and the FPJPA's inadequacy for complex troubleshooting tasks must also be taken into account (Klesch, 1977).

Second, the three technologies may have common cost areas. Much of the cost in developing a JPA is in the front-end analysis that, to a large extent, is fundamental to task-oriented training and job design. Job or task analyses designed to cover the requirements of all three technologies during weapon system design should be considerably less complex and costly than if each area conducted independent front-end analyses.

Further, it appears increasingly obvious that, after major manning decisions have been made, the selection of a JPA technology should be made prior to the selection of the other two technologies. Task-oriented training and work center organization can be more readily designed to support or take advantage of an aid than if the aid is designed to complement a style of training or work center organization. Also, an aid, once selected, is more similar to hardware in that it does not readily adapt to individual differences, whereas training and job design should by their very nature strive to support and take advantage of individual differences. The problems of trade-offs among the three disciplines is really one of systematically considering each of the technology areas at the appropriate stages of weapon system RDT&E.

Table 4

Relative Values of Various Media for Meeting Training/Performance Objectives

	Training Objectives				Performance Objectives		
Medium	Learning Factual Info	Learning Visual Identif.	Learning Principles, Concepts, Rules	Learning Procedures	Performing Skilled Perceptual-Motor Tasks	Developing Desirable Attitudes Opinions & Motivations	Performing Cognitive Problem-Solving Tasks
Hard-copy Print	Med	Low	Med	Med	Med	Med	Med
Microform	Med	Low	Low/Med	Med	Low	Low	Low
Still Pictures	Med	High	Med	Med	Low	Low	Low
Motion Pictures	Med	High	High	High	Med	Med	Low
Television/Video	Med	Med	High	Med	Low	Med	Med
3-D (Objects)	Low	High	Low	Low	Low	Low	Low
3-D (Holography)	Low	High	Low	Med	Low	Low	Low
Audio (Recording)	Med	Low	Low	Med	Low	Med	Low
Programmed Instruction							
Text	Med	Med	Med	High	Low	Med	Med
CAI	Med	Med	Med	High	Low	Med	High
Demonstration	Low	Med	Low	High	Low	Med	Low
Oral Presentation	Med	Low	Med	Med	Low	Med	Med
Hand-held Computers	Low	Low	Low	Med	Low	Low	High
Imagery-enhancing Techniques	Low	High	Med	High	Med	Low	Med

Note. Adapted from Allen (1967).

Training Interface with JPA

The earlier studies done for the Army by HumRRO (Shriver, 1960; Rogers & Thorne, 1965; Gebhard, 1970) provide the best data for integrated job aiding and training between the two extremes of FPJPA with minimal or no training and conventional technical manual aiding with extensive formal training. On the M-33 antiaircraft fire control system, for example, the Army found that electronics technicians using FORECAST aids could perform as well as conventionally trained technicians even though their training was reduced from 30 weeks to 12 weeks (Shriver, 1960). Similarly, Army radio relay/and carrier repair technicians using JOBTRAIN aids with a 50 percent reduction in training time were able to perform as well as conventionally trained technicians using conventional documentation (Gebhard, 1970).

A common question regarding the relationship of training and aiding asks what information is best presented via each technology. The literature provides numerous guidelines for assigning performance task coverage (Chalupsky & Kopf, 1967; Chenzoff, 1973; Lineberry, 1977). Information about the following types of tasks would best be presented via a training technology:

1. Tasks that are not very easy to learn on the job.

2. Tasks that are hard to communicate with words.

3. Tasks that need a great deal of practice for acceptable performance to be established.

4. Tasks that allow little room for error.

5. Tasks with serious consequences for errors.

6. Tasks with reasonable training costs.

7. Tasks that are performed frequently on the job.

8. Tasks for which the required speed or response rate does not permit referral to a manual.

9. Tasks performed by a large proportion of the individuals in a given specialty.

10. Tasks that can be performed with considerable freedom in individual style.

11. Tasks that are so new or undefined that the detailed steps of mastery are unknown.

12. Tasks wherein psychosocial factors are important.

An aiding technology would be the best method of presenting information about the following types of tasks:

1. Tasks that are usually performed in a fixed sequence.

2. Tasks that involve long or complex behavior sequences.

3. Tasks that are performed infrequently.

4. Tasks that involve readings and tolerances.

5. Tasks that can be rehearsed mentally before the need to perform them arises.

6. Tasks that are aided by illustrations.

7. Tasks that utilize reference information such as tables, graphs, flow charts, and schematics.

8. Tasks with branching step structures.

9. Tasks remaining stable over long periods of time.

10. Tasks for which established task sequences are critical.

11. Tasks for which the performance method is likely to change.

12. Tasks that must be treated with a very limited training budget.

As discussed in the previous section, a distinction is sometimes made between tasks that need to be memorized (head) and those that can be aided (book). Maintaining a separation between maintenance training and aiding tasks, when the aid is an FPJPA and the training is "hands-on experience," becomes extremely difficult. However, the difference between what is important to know without an aid and what is important to be able to do with an aid is still a good conceptual distinction.

Job Design Interface with JPA

Perhaps even more important than JPAs' effects on training are their effects on job design. Attempts to design a job or work center organization to take advantage of performance aiding have been few, although the potential manpower benefits are great.

Post and Brooks (1970) developed a mathematical model of the F-4J work center and applied it to the data collected under NAVAIR's AMSAS experimental study program. The findings demonstrated job guides' ability to aid performance on nontroubleshooting tasks for electrical, mechanical, and electromechanical equipments. In that study, 71 percent of the inexperienced technicians' time was spent observing and assisting experienced technicians, and the other 29 percent could not be assigned. If job guides were used, then 83 percent of inexperienced labor's time could be spent on maintenance. The provision of job aids, therefore, could result in major job design alternatives and flexibility for a work center. Post and Brooks' findings that a work center could expect a 52 percent increase in the availability of experienced technicians, a 25 percent decrease in maintenance queues, and a 75 percent decrease in failed maintenance actions, show that it would actually be feasible to increase operational readiness while reducing the number of maintenance personnel.

Horn (Note 2) demonstrated in field studies with FPJPA and Work Packages that a ratio of one experienced to four inexperienced technicians can perform all the maintenance actions of a work center.

JPA/Training/Job Design Interfaces

Several important factors must be considered in job design interfaces with JPA and training. The following factors have received the most attention: task organization, position definition, task modules or clusters, skill transfer areas, graded proficiency levels, span of supervison, teaming, spares philosophy, equipment test philosophy, and the use of ATE.

Skill transfer, for example, is always an important consideration in military operations. The ability to use personnel in operator or maintenance tasks for which they have not been formally trained is especially important in combat or other emergencies. Enlarging the scope of a job for career advancement or to balance workloads on a day-to-day basis is also more feasible if personnel can move readily from one job to another. Job aids' potential for facilitating such transfers has been demonstrated on several occasions. Rigney, Fromer, Langston, and Adams (1965a, 1965b) found that, with a fault locator aid (XFL), radio operators with little or no experience in electronics could readily solve radio problems. Horn (1972) also found that electronics and mechanical ratings could satisfactorily perform each other's jobs on a mobile electric power plant with the help of FPJPAs.

There has been some work to improve the methodology and provide guidance for determining an optimum JPA/training/job design interface. In the model proposed by Post, Price, and Diffley (1976) and Post (1977a) for selecting formats and media to present maintenance information, work center considerations such as span of supervision, personnel turnover, and maintenance demands (workload over time) were considered key decision criteria. It is unlikely, however, that data on those variables will be available early enough to make such sensitive selections on new system procurements. Here again, it appears that the decision for a particular type of job aid may be predetermined because of the personnel and training cost savings.

Guidelines for position (or job design) and documentation interface have also been developed for the Bell Laboratories (Price, Post, & Barker, 1973; Post, 1977b). These should be useful in the development of military systems to integrate JPAs, training, and job design for operation and maintenance tasks. The following is a list of job design factors that have been shown to be important to work productivity (Post, 1977b):

Factors	Design Guidelines
Process	
1. Sequence	Sequential tasks are good candidates to include in a job.
2. Dependencies	Dependent tasks, even though they might not be sequential, are good candidates to include in a job.
3. Functional Integrity	Tasks with a common objective are good candidates to include in a job.
4. Workload	The timing and duration of job tasks should be considered so as not to over- or underload the incumbents.
5. Difficulty	Task difficulty should be compatible with incumbents' performance capabilities and should be relatively homogeneous across the job.
Personnel	
6. Complete Work	Job tasks should result in a sense of completion or closure.
7. Autonomy	Job tasks should permit the incumbent to plan and control his own work.
8. Comprehension	Job tasks should be understood (both how and why) to promote performance reliability.
9. Challenge	Job tasks should be challenging, yet within the incumbent's capability.
10. Valued Abilities	Job tasks should require significant abilities (skills/knowledge).
11. Meaningfulness	The product of job tasks should be worthwhile and have a personalized nature (e.g., "my equipment").
12. Participation	An incumbent should be able to relate his tasks to the organization's goal or product.
13. Career Potential	Job tasks should provide direct or indirect opportunities to learn new and valued skills.

JPA Test and Evaluation Technology

Without a method for assessing a JPA's value relative to competing technologies and to other JPAs, there is no basis for knowing which JPA would serve best or whether or not a JPA should be used at all. Tools for making such an assessment generally can be classified as survey, experimental (laboratory), demonstration (field), and simulation.

Simulation

JPA technology has been tested and evaluated extensively with all four techniques. Losee et al. (1962) and Main (1974) are good examples of using the survey technique. Whether a survey employs a questionnaire, an interview, or some combination of the two, it can obtain a large amount of data relatively quickly and inexpensively. The survey can be used (1) to determine whether users would prefer a highly proceduralized format in pocket book form to a deductive format with all the information on one page, (2) to guide the choice between a printed page or microform frame display at the user site, or (3) to save the cost of printing expensive color-coded troubleshooting charts when other methods of coding would be just as effective.

The preferred method of collecting data for use in decision making at all levels is the controlled experiment, either in the laboratory or in the field. However, of all the JPA systems and techniques listed in the glossary, less than 25 percent have laboratory or field performance data to demonstrate their effectiveness. Most of these, as Rowan (1973) pointed out, simply compared the techniques against "traditional" documentation. Only a handful of studies have compared more than two techniques or have attempted to improve the conventional technique before testing. Studies that have attempted to improve the accuracy, completeness, compactness, and readability of the conventional technique include Post and Brooks (1970) on nontroubleshooting tasks and Elliott and Joyce (1968) on troubleshooting tasks. Studies that have compared more than two techniques include Atchley and Lehr (1964) on proceduralized instructions versus data flow versus schematics; Horn (1973), on Augmented Action Tree (AAT) versus MDC versus conventional Navy technical manual; Potter and Thomas (1976), on FPJPA versus Logic Tree versus Air Force Technical Order; Booher (1975), on six types of proceduralized instructions; and Frey (1976), on three types of pictorial media.

Because of the difficulty and expense of collecting data experimentally, computer simulation models are often considered as an alternative. A typical demonstration in the field may cost several hundred thousand dollars, the bulk of which goes for the preparation of JPA test materials. Even a controlled laboratory experiment that deals with a few tasks or subtasks may easily cost $50,000 to $100,000. However, the data used to validate simulation models, even in fields other than JPA, are often so unreliable that simulation is seldom applied.

The best applications of test and evaluation models have been system effectiveness estimates using simpler mathematical models. Post and Brooks' (1970) effort on manpower utilization is a good example. The only other study of this nature concerned the Air Force C-141A aircraft. The analyses reported in the PIMO final report (Serendipity, 1969) and by Braid (1975) indicate that simply reallocating time from OJT to maintenance would decrease the total time a one-term enlistee spends in training by 25 percent. Other predictions were that flight departure reliability could be improved by 50 to 65 percent; operational readiness time, by 38 to 40 percent; unscheduled maintenance manpower, by 30 to 39 percent; and spares demands, by 30 percent. If these results--assuming that the conservative estimates made by Rowan (1973), Shriver and Hart (1975), and Shriver (1977) are valid--could be fully applied to Navy personnel, training, and maintenance support associated with electronic systems, then the Navy could expect (1) decreases in first-enlistment training costs of 50 to 80 percent, or $900 million annually, (2) savings in spares of $75 million per year due to reductions in erroneous removal, and (3) a decrease in maintenance labor force of 15 percent, or $700 million annually.

Other payoffs are projected, but they have no quantitative basis for evaluation: (1) an increase in the affective use of lower-skilled personnel, (2) improved job involvement and satisfaction among first-term enlistees, and (3) an increase in retention rates for productive personnel.

One simulation technique for assessing and predicting the relative performance effectiveness of job performance aids was developed at North Carolina State University (Smillie, Edsall, Ayoub, & Muller, 1976). That approach combines features of predetermined time and motion systems (PTMS); a simulation modeling algorithm, Graphical Evaluation and Review Techniques (GERT); and the Systems Analysis of Integrated Networks of Tasks (SAINT).

Results of the simulation process should yield substantial information on JPAs' effects on performance time and errors. For instance, statistics can be obtained on the total performance time and the probability of successfully completing the task while using a specific JPA. In addition, simulation results can be used to identify the task step or steps that might be crucial to the success or failure of the task at hand. Based on these statistics and the cost data associated with JPA production and maintenance, a cost/benefit analysis can be performed to determine the best JPA-maintenance system or design--a design that could be expected to yield minimum performance time and errors at minimum cost.

Unfortunately, the model is not in a form that can be readily applied to specific JPAs, training, or job designs. It appears to be a rather complicated way of analyzing relatively simple task steps, and the model was never validated. Model development and validation were attempted on such simple tasks that time and error differences obtained in both the experiment and simulation were insignificant. Attempts to further reduce task steps into specific behavioral processes would not be meaningful on such easy operations. Furthermore, no attempt was made to address troubleshooting tasks, where it now appears that the greatest difficulty for JPA selection lies. At present, therefore, no usable mathematical model or simulation technique exists for assessing or predicting the effectiveness of job performance aids.

CONCEPTUAL ORGANIZATION OF JPA TECHNOLOGY

Development/Selection Methodology

The previous two sections of this report described the research and techniques that comprise the current JPA technology base. Unfortunately, the way JPA techniques have evolved and research has been conducted has not made the most efficient use of available resources. Also, most of the work was done without thought to fitting it into a larger conceptual framework that would later be useful to researchers, developers, and implementers.

The development or selection of JPA techniques has usually been done by one of five methods:

1. Trial and error. With this technique, which is the most common, an existing aid form (most often a technical manual for equipment operation or maintenance) is gradually changed over time to meet user demands. Research data are seldom collected. General user acceptance is considered the primary measure of success. Although this approach is generally quite inefficient, it has yielded some very good JPAs (e.g., the NAVAIR Work Package concept, the General Motors Diagnosis and Repair Manual).

2. Fiat. Although commonly applied in the military services to procure JPAs, this is the worst method. Under it, a system is built and implemented by decree. This method is largely to blame for the problems of the NAVAIR and NAVSEA microform systems.

3. Brochuremanship. Each of the 101 performance aids listed in the glossary has probably, at one time or another, been sold to a project manager simply on the basis of advertised advantages over the "conventional technique." This is known as brochuremanship.

4. Literature extrapolation. A few performance aids (e.g., the FPJPA type shown in Figure 1) have been developed by extrapolation from the literature. These incorporate such features as short sentences, short words, verb lists from readability research, and the limitation of seven callouts per page. This method provides a good quality system but may result in higher costs than necessary.

5. Algorithm. The technique stimulating the greatest interest recently has been that of building and selecting the optimum aid form, considering (a) the combined effects of several variables on user performance and (b) the cost factors. There have been a number of attempts to develop models or algorithms for this purpose, but no aid forms have actually been constructed using these techniques. Inherent in this approach is the assumption that selecting the optimum JPA depends on simultaneous consideration of major variables such as environment, personnel characteristics, and type of task, much as diagramed in Figure 6, a conceptual model for JPA technology utilization (Blanchard, 1977).

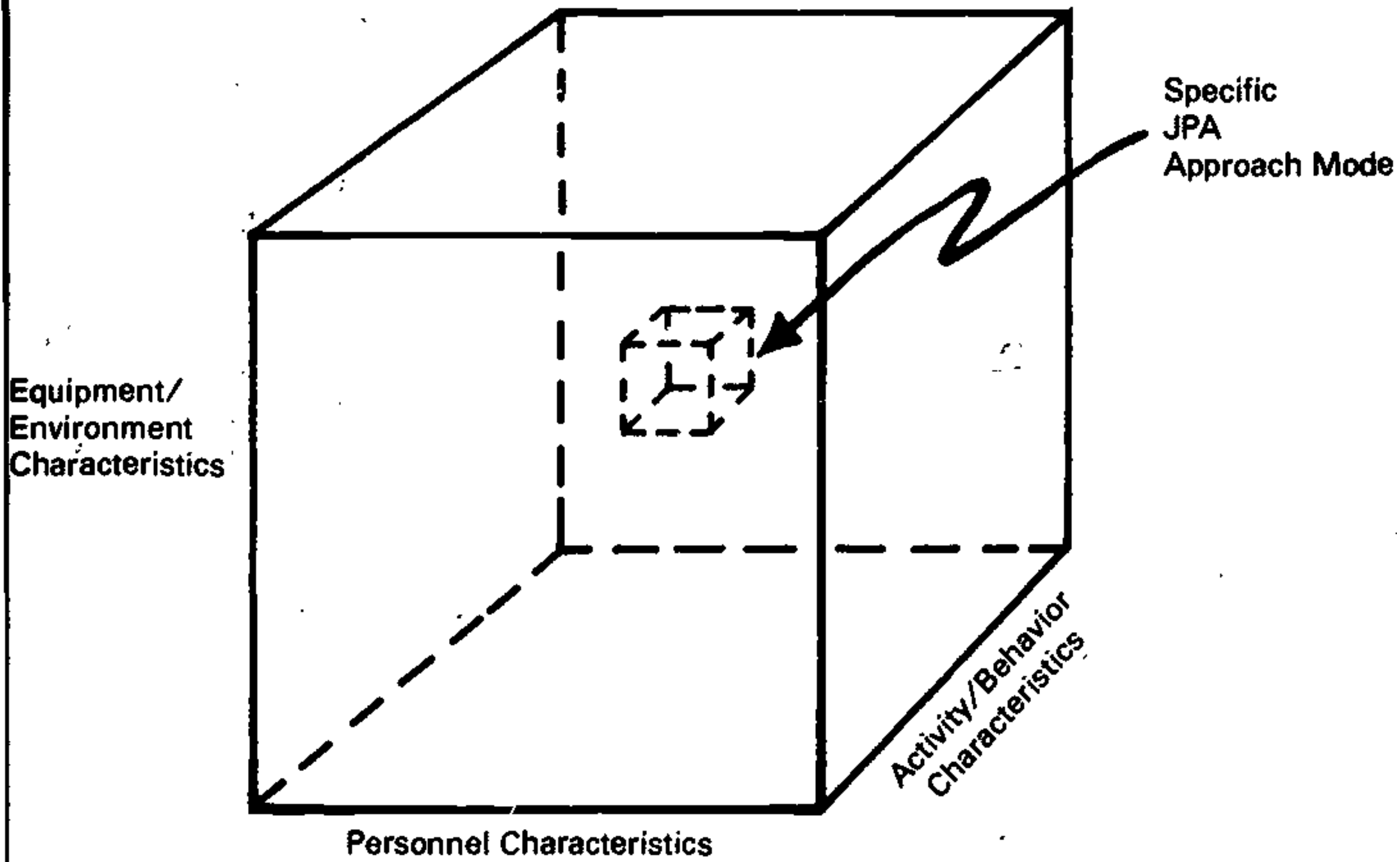

Figure 6. JPA selection variables.

None of the techniques, including the algorithm, has provided a satisfactory way of organizing JPA technology for research or implementation decisions. For that reason, an attempt was been made to formalize an organization of JPA technology that might be conceptually useful to those employed in either applying or advancing the current technology. Hopefully, the concept presented here will help organize the available technology for easier application decisions and for better determination of which future research should be emphasized.

Organizing the Model

A simple model for organizing JPA technology was found useful for reviewing the techniques listed in the glossary, for appraising the various algorithms recently developed in other military programs, and for identifying the known behavioral concepts applicable to JPA basic research. Briefly, as illustrated in Figure 7, this model consists of three major JPA technology levels, each of which has a number of distinguishing characteristics. The levels are (1) the JPA system level, (2) the performance aiding component level, and (3) the performance aiding element level. Depending on which level is addressed, there can be considerable variation in the performance aid structural form, research questions, application questions, and types of expertise involved.

Two important considerations become immediately obvious from this organization. First, Figure 6's three-dimensional arrangement of variables is useful only after one decides what level is being addressed. Applying variables directly to JPA systems, components, and elements alike without identifying what part of the larger system is being described simply adds to the existing confusion. Second, the organizing model provides a visual reminder of the major differences between the optimum paths for (1) the design of JPAs and (2) for the application of JPAs in personnel systems. The design building path should move from the element level to the system level, whereas the critical factors in JPA application diminish in importance as one moves from the system level to the element level. The structure of the three different levels is detailed in Table 5.

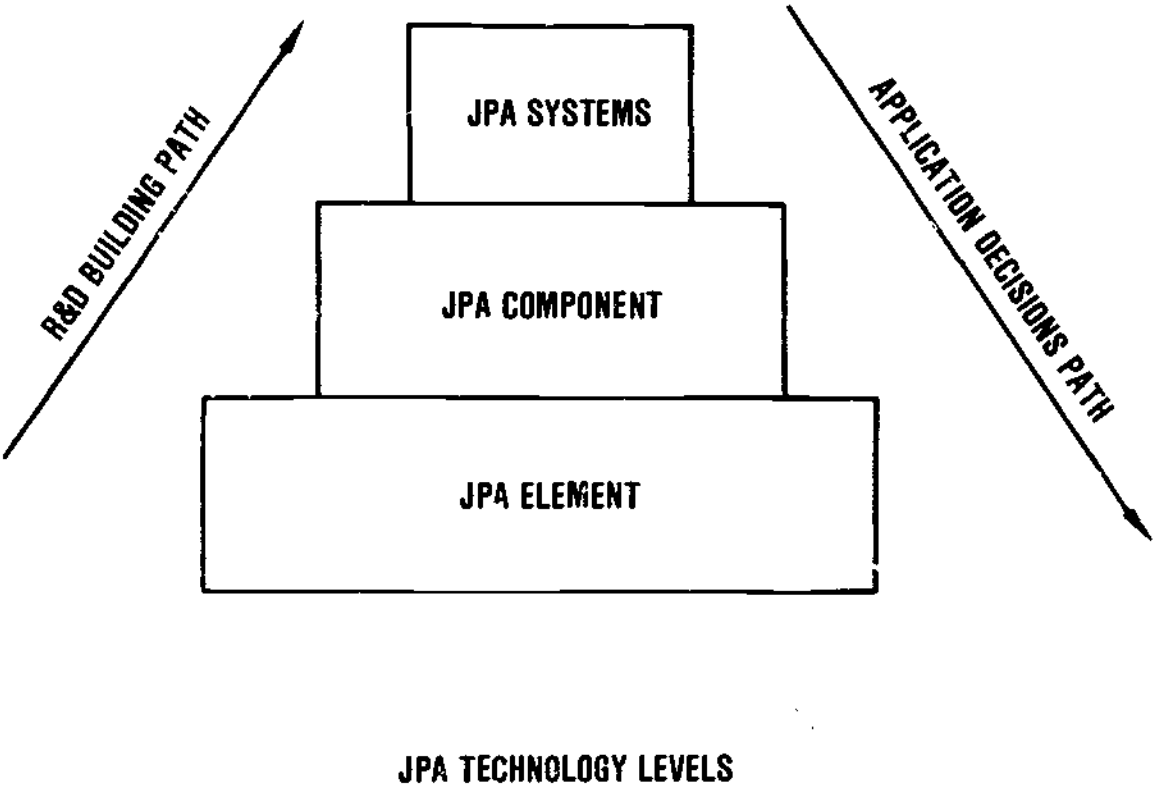

Figure 7. JPA technology levels.

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Table 5

JPA Organizing Concept

Information Categories	Technology Level		
	JPA System	JPA Component	JPA Element
Type Aids	FPJPA; FOMM; ITDT	MDC; pictogram; microform; audio	Callouts; lines; headings; sentences
Behaviors Aided	Jobs	Tasks	Subtasks
Application Questions	Task analysis? Special training? Manpower limitations?	Format interface? Content coverage? Storage/retrieval equipment?	Page size? Headings? Ratio of graphics to verbal?
Research Questions	JPA/training/job design? Personnel careers? Operational effectiveness?	Environmental variables? Single/multiple-channel communications?	Perceptual search? Readability?
Major Decision Makers	Organization management	Project/program managers	Research specialists
Major Implementation Vehicle	Company policy Instructions Specifications/standards	Specifications/standards sections Guidelines Trade expertise	Handbooks of principles Specialist advice

JPA Systems Level

A substantial body of literature describes two-way comparisons between new aiding concepts and conventional practice. Summaries (Rowan, 1973; Shriver & Hart, 1975) almost always show that aiding enhances on-the-job performance. Some job aids simply allow skilled people to do better, some allow unskilled people to do jobs they couldn't otherwise do, and some allow jobs to be done better or the same with fewer people. The selection of one of these types depends on factors that must be treated at fairly gross levels (e.g., troubleshooting tasks versus nontroubleshooting; low, intermediate, or high technician aptitude; high versus low equipment complexity). Data at this level are primarily useful for JPA systems decisions. An attempt is generally made to provide JPAs that cover all or large portions of several task groups required to support a particular hardware system or equipment. It therefore appears that the term "job" is most appropriate at this level. Implementation usually requires one specification for development, test, and evaluation, and another for associated training requirements. Good examples of JPA systems are the Air Force's Fully Proceduralized Job Performance Aid (FPJPA), the Army's Improved Technical Data and Training (ITDT), and the Navy's Functionally Oriented Maintenance Manual (FOMM).

JPA Component Level

The JPA system is generally comprised of several different types of presentation styles or formats, each designed to aid a different category of behavioral tasks (e.g., lubricate, remove, fault isolate, test). The FOMM, for example, contains tables, lists, functional blocks, matrices. written procedures, pictures, and schematics, each designed to aid different aspects of the maintenance tasks of any particular equipment. These performance aids, when used to present information, are in forms that tend to occupy the user's total field of view at any one time. Commonly described as pages, frames, or display events, such units exemplify the component level of JPA technology.

JPA Element Level

In many instances, the presentation component is used to aid a large number of different behavioral subtasks. Consider, for example, components such as an illustrated parts breakdown diagram or an electronic schematic. Specific behavioral subtasks (e.g., using callouts, searching for functional areas, following electron flow, reading voltages, reading wave forms) may be aided by different features of the same presentation component being used. Many times, features that show positive performance advantages by themselves interact negatively with positive performance features of other aiding techniques at this level. A good example of this is the attempt to put on one page a large number of callouts to a figure. There can be good performance advantages in eliminating references to other pages, but performance disadvantages will soon arise due to perceptual difficulties in isolating the correct callout. This level, the foundation for the component and system levels, is concerned with organizing information within a page, slide, film strip, etc. Investigation at this level most closely resembles conventional psychological experimental research in a controlled environment. This is also the level where the greatest amount of extrapolation from the experimental literature has been attempted. In new JPA development, caution should be exercised because laboratory data have seldom been collected on tasks that resemble the actual operator-maintainer task. (For example, results from research on perceptual recognition, reading speed, and reading comprehension are almost useless for application to the understandability of short, proceduralized instructions.) Furthermore, almost no data deal with the numerous interactions among the behavioral subtasks involved in using any performance aid presentation element.

Decision Making at the JPA Levels

Table 5 presents some examples to illustrate decision making at the three JPA technology levels. The different objectives and anticipated results depend greatly on which level is being addressed. In a long-term research program, the general direction in the development of a technique is from right to left in the table. In an implementation program, however, the criticality of the decisions in terms of cost/performance trade-offs and critical time for decision making is from left to right.

Application questions at the system level might be, "Are a task analysis or special training requirements necessary?" or "What manpower limitations should be considered?" At the component level, the questions revolve around formatting interface, content coverage, and requirements for special information storage and retrieval equipment. Research objectives vary from identifying trade-offs among major technology areas at the system level to determining principles of technical material readability at the presentation element level.

Perhaps one of the most useful applications of this concept is in identifying the decision makers who play major roles at the different levels. Top management decides when and where to use the overall JPA system, while personnel and training organizations decide which career paths can be made available with any particular aiding concept. However, top management should allow flexibility for the managers of specific programs to select the best combinations of schematics, illustrations, and special media to meet unique mission and environmental requirements. On the other hand, decisions already made at the system level and principles developed at the element level will limit the choices to be made at the component level. For example, if the system selection is FPJPA for personnel and training reasons, then the component choices are pretty well limited to illustrations, logic trees, and written procedures. Therefore, the program manager decision-making level that most JPA selection algorithms have been attempting to address may not have as critical a need for selection criteria as the other two levels.

JPA Organizing Concept Applications

There are at least three important application areas where the JPA organizing concept appears useful for grouping the theoretical and experimental literature: (1) cost trade-off analyses among performance aids, (2) JPA selection algorithms, and (3) theoretical trends in performance aiding.

Cost Trade-off Analyses

One of the first applications that can be made with the JPA organizing concept is in grouping the theoretical and experimental literature for cost trade-off analysis. At the systems levels, decision makers should look for data that support major trade-offs among technologies as well as among aiding systems. The data on the FPJPA system strongly indicate that little or no preassignment training is required if the highly proceduralized aid form can be used. Less proceduralized systems, such as the Army's FORECAST (Shriver & Trexler, 1965) and JOBTRAIN (Gebhard, 1970), show a 50 percent reduction in training with joint aiding and training development. One field researcher (Horn, Note 2) obtained data that suggest that major job design alternatives are possible with proceduralized aids. Horn's results showed that if the organization permits, one skilled technician can keep four inexperienced technicians busy through the use of job aids. One of the few comparisons that included more than one JPA system alternative was recently completed by Potter and Thomas (1976). Table 6 shows that LTTA, which is not as fully proceduralized as the FPTA but is considerably cheaper, shows performance advantages over conventional techniques very similar to the advantages of the FPTA. A cost/performance trade-off analysis from these data could easily lead to an organizational decision in favor of the LTTA over the FPTA as the optimum aiding system.

Table 6

Comparison of Three JPA Troubleshooting Systems for Performance Accuracy, Parts Consumption, and Speed

System	Accuracy[a]	Parts Consumption[b]	Speed[c]
FPTA	95.4	.72	30.8
LTTA	89.4	1.05	34.8
TO	60.6	2.67	59.9

Note. From Potter and Thomas (1976).

[a]Mean proportion of problems solved.

[b]Mean number of parts used incorrectly.

[c]Mean time in minutes.

There are few good studies that give data on component-level comparisons. One notable exception is Atchley and Lehr (1964). Their data, shown previously in Figures 4 and 5, fit well at the component level because comparisons are made of several distinct presentation components and varying levels of complexity. These show clearly the advantages of proceduralized instruction over data flow diagrams and standard schematics. Unfortunately, this technique is also the most expensive of the three.

Table 7 summarizes a comparison of picture/word combination formats (Booher, 1975) that might fit best at the element level. Several subtasks were measured for performance time and errors in looking for the optimum organization of pictures and words within a component (in this case, a proceduralized instruction). The data clearly indicate that Format IV, the pictorial/related word format (see Figure 8 for an example), is optimum for both performance measures; however, it may not be the most cost-effective (Booher, 1975). Formats III and IV (the pictorial formats) are about equal in price, at least double the cost of Formats I and II (the verbal formats). Format III, the completely pictorial format, can be eliminated on performance factors, leaving I, II, and IV. Surprisingly, Format I (with no pictures) may be adequate if time is not a major consideration, whereas Format II (Figure 9, from Booher, 1972), the one most like the best FPJPA and PIMO formats, would not come out particularly well in a trade-off analysis because there are few instances in which it is desirable to sacrifice accuracy for speed.

Table 7

Speed and Accuracy of Navy Maintenance Personnel Completing a Series of Behavioral Subtasks Using Proceduralized Instructions with Varying Picture/Word Combinations

Format		Speed (in minutes)	Accuracy (% Errors)
I.	Printed Words	45.9	25
II.	Printed Words/Related Pictorial	38.8	32
III.	Pictorial	31.2	34
IV.	Pictorial/Related Words	30.7	24

<u>Note</u>. From Booher (1975).

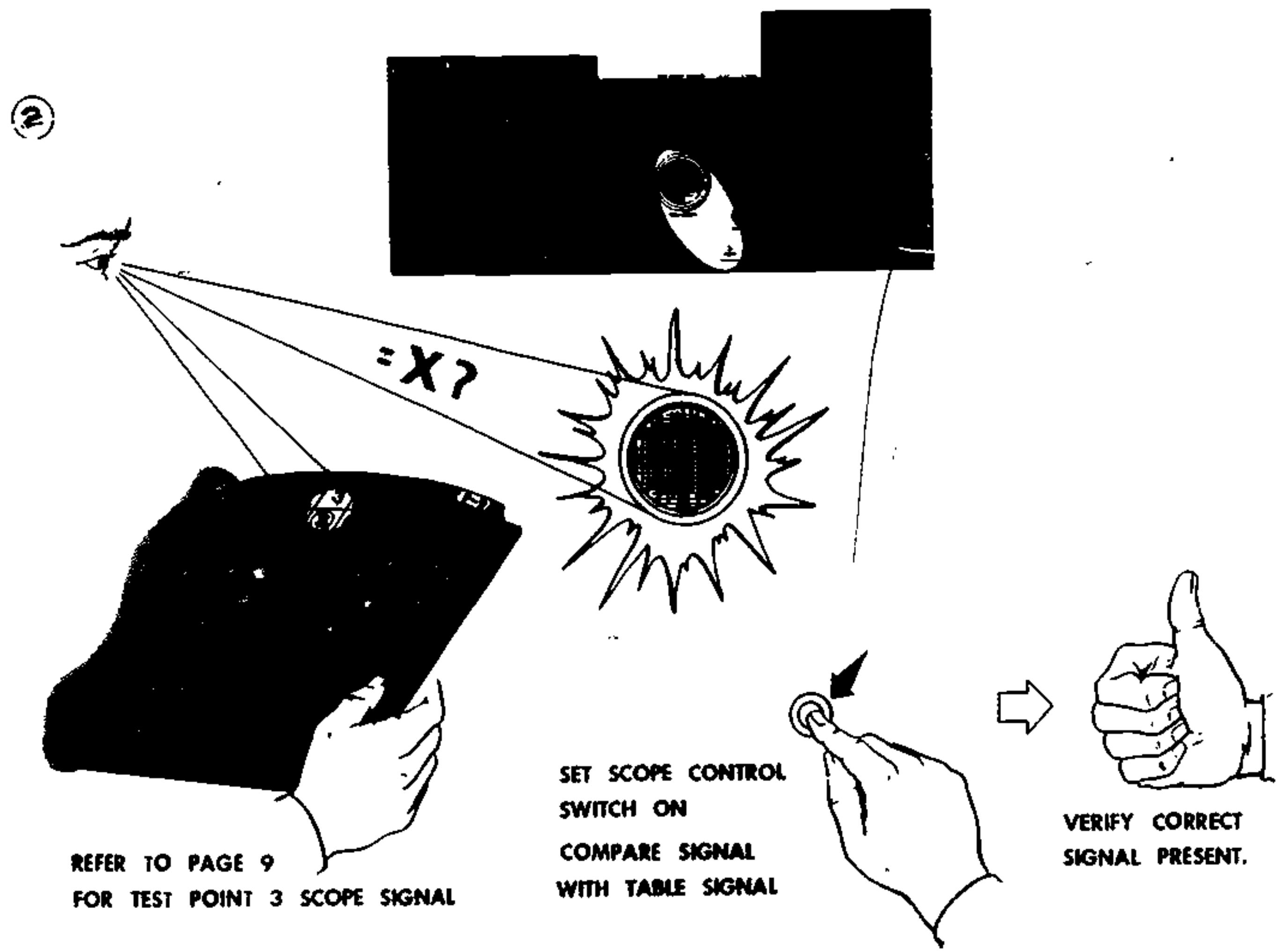

Figure 8. Highly pictorial, related printed words format for fully proceduralized instructions.

Refer to table I . . page 9 for SCOPE SIGNAL wave-shape and values for test point 3. Set SCOPE CONTROL push button switch to ON and compare table signal characteristics with SCOPE SIGNAL. Release SCOPE CONTROL switch to OFF and verify if correct signal is present.

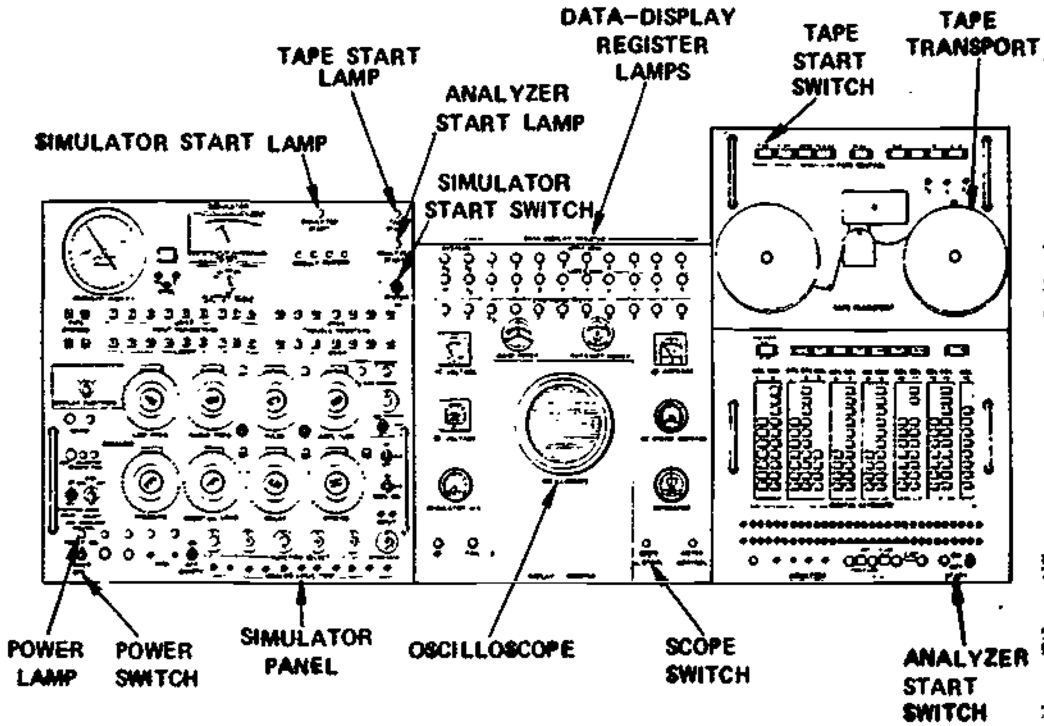

Figure 9. Highly printed words, related pictorial format for fully proceduralized instructions.

JPA Selection Algorithms

Another application for the JPA organizing concept is in organizing the various algorithms or models for selecting and designing optimum performance aids. In doing so, it appears that the model of Post (1977a) on formats and media and that of Shriver and Hart (1975) on fundamental elements are system-level concepts, while the user-data match model developed recently by the Navy Technical Information Presentation Program (NTIPP) (Hughes, 1977b) is directed specifically to the component level. A selection and organizing model being developed by Bell Laboratories (Dever, Note 5) may fit best at the element level.

In selecting and designing optimum performance aids there are several problems that seem unique to each level and that should be emphasized in their respective algorithms. At the system level, for example, the fundamental elements that make up front-end analysis are extremely important. Shriver and Hart (1975) pointed out that in designing an FPJPA it is not enough to do the engineering analysis or even the human factors task analysis. If troubleshooting is involved, then a functional analysis is required as well; and if the JPA is to be used by inexperienced personnel, then a behavioral task analysis is also required. Table 8 illustrates the different levels of front-end analysis that are involved, depending on the particular format and content selected at the system level. But even these analyses are inadequate for an integrated JPA/training/job design system. In the JPA conference at NAVPERSRANDCEN (Booher, 1977a), it was noted that tradeoff analyses among the various disciplines supporting weapon system operation and maintenance must also be conducted as early as possible in the system development. These analyses should then be reiterated throughout the system life cycle. The earlier and the more completely that cost/performance analyses are done, the more likely it is that maximum benefits will accrue from each of the three major disciplines.

General rules of information presentation are best applied at the JPA system level. Post and Price (1974), in applying their organization principles to maintenance task technical information manuals, recommended that designers should also attempt (1) to develop a maintenance manual on a hierarchy of maintainable units, (2) to include a repair cycle overview that gives a diagrammatic representation of the succession of maintenance actions, (3) to consolidate all information concerning a single maintainable unit into a single package, and (4) to standardize the content, format, and sequence of information within a package.

An algorithm for selecting optimum job aids at the component level is considerably different. Often, the designer will have an opportunity at the presentation component level to choose from several competing formats for conveying the information relevant to certain tasks. The choice could be within the print medium (i.e., table, chart. prose, or pictorial), or it might be among audio or audiovisual media. Decisions at this level vary with weapon systems and tend to be best made by the program manager, preferably with the assistance of presentation principles guidelines. Aids at this level tend to be structured into composite wholes capable of being presented within the user's field of view. Several attempts have been made to classify the various presentation components (Curran, Note 6; Powers, Dickerson, & Nugent. 1977; Hughes, 1977b).

Table 8

JPA Format/Content Cost Factors

Format & Content	Equipment Complexity	Equipment Type	Equipment Analysis	Functional Analysis	Task Analysis	Behavioral Task Analysis	Intelligibility/ Comprehensibility	Printing/ Distribution
FPJPA (Troubleshooting)	X	X	X	X	X	X	X	X
Partially Proceduralized (TS)	X	X	X	X	X		X	X
Simple Logic Deductive (TS)	X	X	X	X			X	X
System Description (TS)	X	X	X				X	X
FPJPA (Nontroubleshooting)	X	X	X		X	X	X	X
Partially Proceduralized (N-TS)	X	X	X		X		X	X
Systems Description (N-TS)	X	X	X				X	X
FPJPA (Complex Action)	X	X	X	X(TS)	X	X	X	X
Standardized Operating Procedures	X	X	X		X	X	X	X
Periodic Action Aids	X	X	X		X	X	X	X
Time Critical/ Hazardous Aids	X	X	X		X	X	X	X
One Trial Learning Aids	X	X	X		X	X	X	X
Highly Complex/ Integrated Systems	X	X	X	X	X		X	X

The question of which JPA (e.g., table, chart, schematic) is optimum for presenting fault isolation information can also be asked best at the component level. However, existing data are generally scarce and inadequate for making simple comparisons of JPA presentation components. Any decision about what is the best presentation component for any particular task and for any particular personnel attribute must be extrapolated from other data or "expert judgments." Hughes (1977b), for example, in developing extremely elaborate matrices of task actions versus "presentation components" for several Navy ratings, was unable to cite a single "ideal" presentation component for any specific task based upon data from controlled experiments. Specifications and guidelines for component selection for a particular task are also generally unavailable at this level.

As of this writing, the Bell Laboratories study (Dever, Note 5) was not available for review. According to Dever's description, however, Bell's structured programming technique appears to be useful as an algorithm at the element level. It has been observed that many of the "comprehensibility" problems facing the designer of computer programs are similar to those of job aid designers. Consequently, much of what is already known about writing computer programs can be applied to proceduralized job aids.

Theoretical Trends

The JPA organizing concept may also help to group the theoretical trends most applicable to performance aiding. It seems that the literature on motivation theory as applied to work and work situations--theories of job enrichment, job enlargement, and vertical and horizontal loading--are most applicable at the system level. Collins (1977) suggested that the experiential learning model and the action research method, with its foundation in Lewinian theory, can be suggestive of new developments in performance aid technology. These newer concepts, as well as older ones such as those of Miller, Galanter, and Pribram (1960), show how people develop hierarchical plans and strategies in organizing and executing their activities, and can best be applied to the integration of JPA systems into the larger organization. For example, the theory of Miller et al. suggests that people, while welcoming the organization of information they must filter to plan their own activities, object to being tightly regimented in planning, organizing, and executing their own behaviors. In proceduralized troubleshooting this objection to rigidity might be expected to increase from the novice technician who welcomes the procedure (because there is no other way he could do the job) to the experienced troubleshooter who might take serious exception to a particular procedure (because of the increased demands or because it does not allow for his greater knowledge of possible system faults). This points out the necessity for future JPA systems to be sufficiently flexible to change in response to personnel career progression.

At the component level, the theoretical and experimental base seem to be rooted most firmly in information communication theory. The work done in education and training on audiovisual channels of communication is applicable, particularly when organized under Hartman's (1961) model for multiple- and single-channel communication. Hartman said that, since the advent of motion pictures and television, researchers in communication have tended to define channels according to the kind of information presented. In multiple-channel communication, the different channels may present redundant information, related information, unrelated information, or contradictory information. In JPA design, multiple channels are desired only if the information in the two channels can be presented in redundant or related fashion, and with a high degree of confidence in low interference between channels.

In single-channel presentations, performance on tasks aided by visual formats has been found to be superior or equivalent to tasks utilizing audio formats (Elliott, 1966; Severin, 1967; Goff et al., 1969). Written formats are more accurate than pictorial (Dwyer, 1968; Booher, 1975) but pictorial formats take less time to use (Dwyer, 1968; Dickey & Schneider, 1971; Booher, 1975). The usefulness of pictorial information in facilitating perfo mance in concrete operational tasks appears to be relatively independent of personnel attributes. In one experiment with Navy maintenance personnel from 10 job skill categories, the best performance was achieved when the pictorial channel was used as the primary channel of a multiple-channel format (Booher, 1975). Similarly, studies with college students, both hearing (Dwy 1968, 1972) and hearing-impaired (Reynolds & Rosen, 1973), have shown advantages in the comprehension of individuslized narrative presentations with the use of highly pictorial formats.

Lewis and Cook (1969), in their theory of telling (which em hasizes one-way communication between the user and the performance aid), could be useful to investigators at both the component and element levels. In their words, "A theory of telling might be equivalently described as a theory of clear communication. Ideally, it would specify the conditions under which information could be communicated, in one direction only, without ambiguity. It would spotlight the difficulties that frustrate the unambiguous transfer of information, and it would serve as a reminder that problems of communication are problems of unclear communication."

Chapanis (1965), in addressing the problem of following simple instructions, pointed out how few data are available for decisions that might be made in designing instructions. At that time he was able to find only one experimental study that addressed the problem of the understandability of the information being presented. A clearly formulated theory of telling that concentrates on understandability might be most beneficial for guiding further JPA research.

One of the most perplexing research problems at the presentation component and element levels is that of controlling content. It is very difficult to ensure that content does not change when formats are varied. In fact, much of the research in multiple-channel comparisons has been deficient in this area. Many examples can be found in the literature where one type of audiovisual display was compared with another, but the results were valueless because totally different information was presented in each display.

At the JPA element level, experimenters and practitioners have come to realize that there are serious limitations in extrapolating from the large experimental data base on perception, memory, learning, retention, motivation, readability, and so forth to the composite wholes (presentation components) that are dictated by realistic operation and maintenance tasks. Since the data were seldom collected on tasks resembling operator or maintainer tasks, extrapolations require considerable faith that the job task being presented in a JPA component can be adequately defined by a summation of behavioral subtasks.

Several researchers (Newman, 1957; Folley, 1961) attempted to identify potential JPA techniques through a taxonomy of behavioral subtasks, but this does not appear to be a particularly fruitful approach. The listing of each subtask becomes an extremely complex way of defining the various behaviors involved in job performance. Also, the data linking the various behavioral subtasks to specific job aid formats are extremely limited, and the complex interactions of behavioral subtasks for any realistic tasks are undefined. Studies that have succeeded in finding optimum forms for realistic tasks (Dwyer, 1968, 1969; Booher, 1975) have varied format across wide dimensions while maintaining fairly gross categories of behavioral tasks. Furthermore, even if these problems could be overcome, the final JPA format designed to optimize each behavioral subtask would probably be rejected either as being too voluminous or too densely compacted, depending on the degree of proceduralization required from earlier decisions at the JPA system level.

An optimum format size for guiding operator maintainer actions can usually be assumed to lie somewhere near the totally verbal print or the completely schematic. Any deviation from these two extremes will generally require greater space and be relatively more difficult to prepare, thereby increasing the size of the format and cost. Decisions to carry optimization to the level of the behavioral subtasks must be approached cautiously, therefore, with these factors in mind.

Perhaps a totally new theoretical approach is needed at the element level. Concepts in memory would seem to be fundamental to an understanding of optimum ways to organize information at this level. Smillie (Note 1), in a recent doctoral dissertation on performance aiding, used memory concepts such as encoding specificity, cue-dependent forgetting, episodic memory, and depth of processing to explain past research findings; but concepts in memory (along with theories of perception and reading) have yet to be used satisfactorily in formulating and testing hypotheses for performance aid research.

NEW DIRECTIONS IN PERFORMANCE AIDING RESEARCH

Use of Memory in JPAs

The theoretical discussion of JPAs by Frase (1976) and Smillie (Note 1) may be beneficial for researchers and JPA designers at the presentation component or element levels. Frase described a model of the information processing skills involved in reading, with an emphasis on memory in reading performance. Smillie suggested that theoretical developments in memory be used for hypothesis formulation and testing of JPAs. Furthermore, Smillie concluded that the most important concepts contributing to a theoretical base for understanding JPA performance differences in print and pictorial channels are (1) pictorial superiority, (2) encoding specificity/cue-dependent forgetting, (3) episodic memory, and (4) depth of processing.

There is considerable agreement among researchers that pictorial stimuli are processed faster and remembered better than their verbal equivalents. Numerous explanations have been made to account for this fact. In stimulus-response terms, Klatsky (1975) concluded that processing is faster for pictorial stimuli because the process of forming symbolic representations from verbal inputs is bypassed. Other explanations for the relative superiority of the pictorial channel are (1) that the array search time is reduced (Pavio & Begg, 1974; Mandler & Johnson, 1976), (2) pictorial material may be encoded both aurally and visually (Pellegrino, Siegel, & Dhawan, 1975, 1976), and (3) the sensory code for pictures seems to be more differentiating and less susceptible to interference from successive items (Nelson, Reed, & Walling, 1976). This does not mean, however, that pictorial JPAs will necessarily be comprehended better than verbal JPAs. There are other aspects of the storage and retrieval process that have to be considered before any such generalizations can be drawn.

Tulving (1974) and Tulving and Thomson (1973) discussed the perceptual encoding and forgetting aspects of storing information for later retrieval. They noted that the retrieval process depends on retrieval cues that are most precise in accessing previously stored information. The availability of retrieval cues in memory depend upon (1) how well during encoding the performer perceives the cues necessary for later response, and (2) how resistant the relevant cues are to forgetting. JPAs designed to take advantage of this memory process would strive to provide cues in the presentation format that (1) are most likely to be perceived as relevant for encoding as aids for later information retrieval, and (2) are most likely to trigger retrieval cues at the time of performance. Smillie implied that specific verbal cues, rather than pictorial, would lead to greatest performance accuracy under this concept.

Episodic memory and depth of processing concepts may also be important to JPA design if information inputs are truly stored as unique traces (e.g., phonemic, semantic, imaginal) and if the memory traces are stored as specific episodes. Smillie interpreted this to mean that each instruction in a proceduralized JPA should be designed to provide individuals with unique episodes; that is, to avoid miscuing and interference, each instruction step should be as distinct as possible from the rest of the instruction. The depth of processing of each unique trace tends to be a function of the amount of time and the level of analysis undergone while attending presentation formats.

It is generally easier for a designer of procedural instructions to provide unique episodes and deeper encodings of information with verbal formats. These developments in memory, when looked at in a performance aiding context, may help to explain why both pictorial and verbal information must be used in varying combinations to maximize performance advantages.

Towards a Theory of JPA Format Mix

The theoretical discussions of memory and cognition and of multiple- and single-channel perceptual modes have been useful in interpreting unexpected findings in JPA research, but they have not been particularly useful in predicting optimum format design or in formulating JPA research hypotheses for experimental verification. For example, the cue summation and stimulus generation concepts used by Hartman (1961) and other audiovisual researchers to resolve discrepancies in findings regarding the learning efficiency of test materials does not explain the results of JPA picture-word studies.

What seems to be most needed at all JPA conceptual levels--system, component, and element--is a theory for mixing JPA techniques, principles, and methodologies. For example, it is now thought that the optimum technique at the system level may be to combine elements of both the FPJPA and the more conventional deductive aids into a hybrid aid (Post, 1977a; Klesch, 1977). It is also interesting to note that "pure" presentation formats (i.e., prose, tables, pictures, and schematics) are seldom used alone to present information for realistic tasks. Printed prose or proceduralized instructions usually refer to tables and illustrations for completing the information; even schematics will have some additional non-schematic information such as verbal cues or wave forms. In general, the knowledge that performance can be improved by combining print, pictorial, and audio channels is not nearly so valuable to JPA design as knowing what information to put in each channel and how to structure each channel to be compatible with the other.

Recent experiments on novel information transfer techniques for aiding location, comparison, and symptom recognition tasks (Booher, 1975), three-dimensional performance tasks (Frey, 1976), and long-term retention (Sitterley, 1974) suggest that major improvements in JPAs resulting from changes in the structure of the format itself (as opposed to content change) are most likely to be found in designs that primarily address the human visual memory system. However, the verbal channel must usually be kept available in a supporting role because of the ambiguity present in most techniques that attempt to convey performance information through visual memory. Also, the visual mode is generally considered inferior to the verbal in conveying abstract concepts, but even this does not appear true for all people. Split-brain research indicates that a high level of abstract reasoning can be carried on in the visual memory centers (Diam[illegible]d & Beaumont, 1974).

A start toward a theory of JPA format mixing may now be possible for the presentation component and element levels. Although a complete theory is beyond the scope of this task, the experimental findings of JPA investigators are beginning to suggest a theory for JPA mix. Booher (1975) obtained the surprising results that the print channel alone was superior in performance accuracy to formats that most closely resemble the FPJPA, and that the FPJPA format was generally inferior in both performance time and accuracy to multiple-channel, highly pictorial formats. As Booher explained it:

> The findings of relatively poor accuracy and time performance with high-print multiple-channel formats suggest that the formats which most closely resemble conventional proceduralized instructions are not structured sufficiently well to take advantage of the distinct pictorial and verbal internal processes available for selecting, translating, and organizing information. (pp. 275-276)

These findings now appear to be more universally applicable than was thought at that time. The same relative performance was also attained with hearing-impaired college students (Booher & Reynolds, in press). The findings here are even more surprising (i.e., the relative superiority of print format in performance accuracy over pictorial aid FPJPA formats) because hearing impairment usually seriously degrades reading ability.

A different model than that proposed by Hartman (1961) or Smillie (Note 1) appears necessary to explain these unexpected results. It should first be recognized, as suggested by Haber (1970), that there are two different processing paths--pictorial and verbal--through the stages of selecting, translating, and organizing information presented visually. These paths can operate either independently or together, depending upon the information presented and the individual's approach to information comprehension. Applying this to JPA comprehension, it can be assumed that the pictorial path translates directly from pictorial inputs to the selection of a range of possible perceptual-motor routines for use in completing the task that organizes the routines in a time-sharing manner. The verbal path, however, translates from verbal inputs in a more step-by-step manner, tending to select routines in series. It is important to note that the human organism is capable of using both together in an optimum fashion but is forced to use one or the other initially depending on what type of format is presented.

Before these experiments, the manner in which people are most predisposed to use the two systems for comprehending mixed formats was not known. However, these results strongly suggest that people understand instructions best when the pictorial mode is used to aid in selecting and organizing a range of perceptual motor actions and when verbal material is available to confirm specific actions within the range.

Another way of looking at efficiency in processing information through mixed formats is with the analogy of a two-stage filtering system: a first-stage, wide-band filter and a second-stage, narrow-band filter. The pictorial channel would be best for the wide-band activity, quickly reading the memory routines most likely to be applicable to the situation at hand, while the verbal channel, acting as the narrow-band filter, would be most useful in selecting the most accurate response routine available within the range obtained by the first filtering action.

This concept may have applicability beyond the proceduralized instruction. A recent study (Curran & Mecherikoff, 1978) of Navy maintenance personnel performing location and identification tasks using technical manual illustrations suggested that the concept may also apply to deductive, nonproceduralized aids. The study investigated the optimum arrangement and design of callouts consisting either of numbers, nomenclature, or nomenclature and numbers combined to aid in locating and identifying mechanical parts on cross-sectional illustrations. In discussions before the data collection, an attempt was made to predict the optimum callout arrangement and mix of pictorial and verbal channels. It was reasoned that a wide-band filtering action would first be required to get the user to the correct area of the illustration. This could best be done with callout numbers and an arrow (a highly pictorial-channel technique). Often, however, it is not obvious, simply from viewing the illustration, exactly what the part is. A name (verbal channel) would be best to perform such identifications. In deciding then on an optimum format for callouts to aid in both locating and identifying parts, the theory suggests that the designer (1) use both callout numbers and arrows (pictorial) and names (verbal), and (2) arrange the numbers sequentially to be prominently displayed alone, with each name nearest its own callout number and arrow.

Curran and Mecherikoff found that nomenclature and number callouts arranged as described above resulted in the best performance for identification tasks without degrading performance on location tasks. Some very useful future research efforts, suggested by these studies, could have both theoretical and practical merit. A particularly interesting research area would be the optimum mix of verbal and pictorial information for schematics, functional block diagrams, and wiring diagrams used in maintenance troubleshooting tasks. Here again, the problem is not so much when to use a particular visual aid or even how to arrange the lines and blocks on a page. What the JPA designer needs to know is what kind of verbal information would best aid troubleshooting and where should it be placed in the chosen JPA formats.

Priorities for Future JPA Research and Technology

In R&D efforts at the system level, the greatest potential payoffs are seen in the efforts recommended at the JPA conference (Booher, 1977) and categorized as (1) JPA technology application, (2) methodological studies, and (3) future R&D. The current project plans to address the first two categories, including the R&D necessary for a long-term test and cost/benefit evaluation of performance aids in large personnel and training systems. Two of the papers presented at that conference (Collins, 1977; Shriver, 1977), provided specific recommendations for future JPA R&D at the system level that the current project does not address directly: (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 JPA, and (2) develop a scientific and technical approach for identifying, developing, testing, and evaluating principles and methodology applicable to the implementation of advanced technology into Navy weapon and logistics support systems.

Research should be conducted at the systems level, therefore, with JPA system technology remaining relatively fixed while the effects on training, the personnel system, and job design variables are studied. In general, the most applicable methodology for implementing an integrated JPA/training/job design paradigm should be that of an integrated personnel system, capable of self-design, test, evaluation, and change in response to advances in technology. Unfortunately, an integrated personnel system implementation methodology does not currently exist, and efforts along these lines may need to look to a project such as the job aids T&E for the data necessary for its own development.

More specifically, research on work, motivation, learning, and issues of aiding versus other technological means for improving performance are especially important system considerations in successful JPA implementation. The methods and problems of integrating JPAs with training and job design should receive immediate attention, particularly with efforts in algorithm development. Also, problems of career advancement, skills retention, and other major personnel system factors have not really been investigated for the effects of progressively changing JPA systems (e.g., FPJPA to hybrid to deductive). The optimum points in the personnel career paths for the introduction of higher level JPAs should probably be another major factor to consider in future algorithms and integrated personnel system trade-off models.

In addition, there is still a need to determine the effects of aiding on lowered aptitude levels and to study the motivation to use aiding systems. Studies at the other two JPA conceptual levels may give some information about the ability of different aids to allow lower-aptitude personnel to perform better or to provide greater job satisfaction through on-the-job performance, but whether performance aids are to be used more than 5 percent of the time (as is generally reported for maintenance instructions) or whether lower-aptitude personnel can handle other aspects of the job that have not been aided are systems research problems.

At the JPA component level, work on new aiding devices, basic comparison performance data, and further work on aids that change with personnel needs (e.g., hybrid aids) is still warranted. Most needed at this level are criteria for making valid comparisons that consider both cost and performance data. The biggest problem here is obtaining valid data on what it costs to develop a JPA.

The research problems at the JPA element level are greatly in need of basic research. A whole new approach may be required to solidify the foundation of performance aiding. The readability of technical instructions, for example, needs something more than standards of short words and short sentences drawn from the reading research for education. Performance data on the comprehensibility of technical instructions indicate that information transfer processing for decision making is on the order of 5 to 25 words per minute, whereas reading studies operate more on the order of 100 to 1000 words per minute.

Finally, a problem that has yet to be addressed and that cuts across all three JPA levels is that of determining what kind of process is needed to produce and measure high-quality aids. If performance aids cannot be made extremely accurate at a reasonable cost, then the attempts to solve systems problems in motivation and productivity with lower skill and experience levels are not going to be very satisfactory. Similarly, holograms with false images or picture-word formats with erroneous illustrations and verbal descriptions are of little value to the user.

Perhaps what is needed most, whether for improving performance aids, finding management techniques to raise quality, or compensating for inadequate quality, are early warning systems with methods of predicting errors in the aid development process.

CONCLUSIONS

Several JPA systems, classified as format/content types, are sufficiently developed to be integrated with major military personnel and training systems with reasonable expectations of major payoffs in reduced personnel, training, and maintenance costs and in increased overall operational readiness. These basic types of JPAs vary primarily in accordance with the amount of proceduralization required, which in turn is directly proportional to the amount of front-end analysis employed. The major cost items for comparing one format/content JPA with another are the amount of detail required for front-end analysis and the amount of required graphic or verbal enrichment. The greater the amount of proceduralization and enrichment, the larger the size of the aid.

Three format/content types--the FPJPA, the hybrid aid, and the deductive aid--seem sufficient to cover the aiding needs of most operators and maintainers throughout their Navy careers. With the exception of quality assurance, which is considered a delivery system problem, the FPJPA and the deductive aid (NAVAIR Work Package or NAVSEA SIMM/FOMM) are fully developed systems. The hybrid aid is still in conceptual form, and probably needs further refinement before full-scale demonstration or implementation. This is particularly true for complex digital electronic systems where no satisfactory aiding techniques were found.

Three other major types--display media, applied training, and peripheral diagnostic--are secondary means of improving performance through aiding. Systems that could be classified into these groups often had a format/content aspect that accounted for the increases in performance.

The greatest weakness in JPA systems technology now lies in the systems for producing, distributing, and updating accurate JPAs. The only delivery systems presently available for providing format/content JPAs are improved technical publication systems. The Navy Technical Information Presentation System (NTIPS) now under development should greatly strengthen this branch of the technology.

Unique demands of the job environment (e.g., work space, wind, temperature) often create special physical design requirements for the job aid. In most instances, however, specially developed devices (e.g., audiovisual or microform) offer few advantages and several disadvantages to the user. Most information aiding needs obtainable within the state-of-the-art can usually be met with hard-copy print modified to fit environmental constraints. Devices that can inherently increase the capability of the user beyond that possible with hard-copy print (e.g., three-dimensional devices, interactive computer-aided devices) need further research to determine whether or not aiding technology can be advanced along these lines.

Much of the recent JPA research by the Army, Navy, and Air Force has been directed toward the development of algorithms or models to be used in selecting the optimum JPA. Several factors are important in the selection of the appropriate aid form. In most instances, the application of these factors to an algorithm for the selection of optimum performance aids is not complicated. The FPJPA, for all its promotion as a solution to the problem of decreased enlistment skills, does not appear satisfactory for aiding lower-aptitude personnel to do troubleshooting. However, inexperienced personnel who meet the usual aptitude levels can do troubleshooting with the aid of an FPJPA after minimal training. Also, the FPJPA will not satisfactorily cover all troubleshooting and maintenance actions, particularly those in complex electronic systems (both digital and analog). Such maintenance tasks (perhaps 25% of the maintenance workload) require additional training and less proceduralized aids.

Once a set of aids for a particular weapon system or a particular rating has been selected, the preferred medium and other physical characteristics must be determined. Too often, such decisions are made first and other decisions must be made as compromises. Although there are exceptions, the general rule is to provide a hard-copy print medium wherever possible.

Aiding technology stands on an equal footing with training, but the need to use lower-aptitude personnel and to cope with the high costs of training makes aiding a much more attractive technique for meeting most job objectives with first-term enlistees. Under current conditions in the military, it is more reasonable to save training investments for those who are most likely to make the military a career and to emphasize aiding at the beginning of enlistments. Job design is different; it both leads and follows the selection of the JPA. In leading, it helps determine the actual need for aiding and how to plan which people in a work force should be aided, trained, or both. It follows by being applied in the work centers themselves. If particular JPAs are available, then the work center can plan its workload accordingly.

A conceptual organization of JPA technology has long been needed, as is evident from the piecemeal approaches to research and the turnover of experts in the field. Basic research is obviously needed to answer questions about the behavioral foundations of aiding. There is still a need to determine the effects of aiding on lowered aptitude levels and the motivation to use aiding. Cost/performance criteria and basic cost data are needed to make valid comparisons of aids in trade-off models. Finally, research is needed to determine what kind of process is required to provide and measure high quality JPAs.

After 20 years of development, performance aiding is now clearly a sought-after technology with clear directions for improvement. But it is not unusual for organizational inertia to limit promising advances before they can demonstrate their full potential. It remains to be seen if the military's personnel organizations can adjust to the impact that will accompany the introduction of such a sweeping technology as that offered by Job Performance Aids.

RECOMMENDATIONS

1. The methods and problems of integrating JPAs with training and job design should receive immediate attention in efforts directed toward algorithm development.

2. Problems of career advancement, skills retention, and other major personnel system factors should be investigated to determine the effects of progressively changing JPA systems.

3. Task-oriented training and job design should be developed to support or complement the aiding system.

4. Aiding as a personnel system technology should act on an equal footing with selection and training, but it should be the primary technique for meeting most job objectives for new or first-term enlistees.

5. Front-end analyses commonly conducted for integrated JPA and training requirements should be expanded to include job design requirements.

6. Selection of media other than hard-copy print should be based on system support requirements that improve the timeliness or accuracy of the aid rather than personnel performance-related criteria.

7. Development of new aiding devices (e.g., hand-held calculators, holographic displays), aids that change with personnel needs (e.g., hybrid aids), and aids that specifically address digital electronic systems are needed to fill gaps and to advance the state-of-the-art in aiding technology.

REFERENCES

Allen, W. H. Media stimulus and types of learning. Audio-visual Instruction, 1967, 12, 27-31.

Atchley, W. R., & Lehr, D. J. Troubleshooting performance as a function of presentation technique and equipment characteristics. Human Factors, 1964, June, 257-263.

Baldwin, R. D., Mager, R. F., Vineberg, R., & Whipple, J. E. The AAFCS M-33 Mechanical Proficiency Test: Part I, Comparison of the mechanics with and without field experience. Part II, Development and cross-validation (HumRRO Tech. Rep. 38). Alexandria, VA: May 1957. (AD-A0133 219)

Blanchard, R. E. Performance aids test and evaluation. Proceedings from the review on maintenance training and performance aids. OASD(I&R) WR/ODDR&E (E&LS) Carderock, MD: Navy Ship Research and Development Center, February 1977.

Booher, H. R. Research technique for evaluating information presentation methods. NSIA-DoD Proceedings: Equipment Manuals Symposium. Equipment Manuals for the New Decade. Y, 1-20, October 1972, National Security Industry Association, Washington, D. C.

Booher, H. R. Relative comprehensibility of pictorial information and printed words in proceduralized instructions. Human Factors, 1975, 17(3), 266-277.

Booher, H. R. (Ed.). Proceedings of the invitational conference on status of job performance aid technology (NPRDC Tech. Rep. 77-33). San Diego: Navy Personnel Research and Development Center, May 1977. (AD-A040 540) (a)

Booher, H. R. (Ed.) Status of JPA technology: Analysis and conclusions. Proceedings of the invitational conference on status of job performance aid technology (NPRDC Tech. Rep. 77-33). San Diego: Navy Personnel Research and Development Center, May 1977. (AD-A040 540) (b)

Booher, H. R., & Reynolds, H. N. Relative comprehensibility of pictorial and verbal instructional materials by hearing-impaired college students. Washington, D. C.: Gallaulet College, in press.

Braid, M. T. A new technique for presenting technical data. Proceedings: Invitational conference on improved information aids for technicians. Washington, D. C.: Society for Applied Learning Technology and the Logistics Management Institute, May 1975.

Braid, M. T. Design cost considerations in utilization of job performance aids. Proceedings of job performance aids technology workshop. San Francisco: Human Factors Society Annual Meeting, October 1977.

Brown, H. T., Jr. Evaluation of a head-worn audiovisual aid. Port Washington, NY: Office of Naval Research, Psychological Sciences Division, Engineering Psychology Branch, November 1964. (AD-A0461 613)

Burrows, A. A., Willets, C. A., & Miles, W. L. Human factors test and evaluation as tools for developing aircraft fault isolation aids based on pattern of cockpit indicators. San Diego: Douglas Paper 5864, 3rd Annual Tri-Service Human Factors Test and Evaluation Conference (TESCON 111), December 1970.

Chalupsky, A. B., & Kopf, T. J. Job performance aids and their impact on manpower utilization (WDL-TR3276). Palo Alto, CA: Philco-Ford Corporation, May 1967.

Chapanis, A. Words, words, words. Human Factors, 1965, 7, 1-17.

Chenzoff, A. P. Aeronautical requirement. Integrated development of training/performance aid requirements for naval air maintenance personnel. Valencia, PA: Applied Science Associates, August 1973.

Collins, J. J. Some perspectives on the job performance aids technology base. Symposium proceedings: Invitational conference on status of job performance aid technology (NPRDC Tech. Rep. 77-33). San Diego: Navy Personnel Research and Development Center, May 1977. (AD-A040 540)

Curran, T. E., & Mecherikoff, M. Quantification of technical manual graphics comprehensibility (NPRDC Tech. Note 78-2). San Diego: Navy Personnel Research and Development Center, January 1978.

Diamond, S. J., & Beaumont, J. G. (Eds.). Hemisphere function in the human brain. New York: Wiley, 1974.

Dickey, G. L., & Schneider, M. H. Multichannel communication of an industrial task. International Journal of Production Research, 1971, 9, 487-499.

Dwyer, F. M. Effect of varying amount of realistic detail in visual illustrations designed to complement programmed instruction. Perceptual and Motor Skills, 1968, 27, 351-354.

Dwyer, F. M. An analysis of instructional effectiveness of visual illustration presented via television. Journal of Psychology, 1969, 72(1), 61-64.

Dwyer, F. M. A guide for improving visual instruction. University Park Pennsylvania: Pennsylvania State University, 1972.

Elliott, T. K. A comparison of three methods for presenting procedural troublshooting information (AMRL-TR-66-191). Ohio: Wright-Patterson Air Force Base, Aerospace Medical Research Laboratories, December 1966. (AD-A0629 992)

Elliott, T. K. The effect of electronic aptitude on performance of proceduralized troubleshooting tasks (AMRL-TR-67-154). Ohio: Wright-Patterson Air Force Base, Aerospace Medical Research Laboratories, November 1967. (AD-A0604 889)

Elliott, T. K., & Joyce, R. P. An experimental comparison of procedural and conventional electronic troubleshooting (AFHRL-TR-68-1). Ohio: Wright-Patterson Air Force Base, Human Resources Laboratory, November 1968. (AD-A0681 510)

Folley, J. D. A preliminary procedure for systematically designing performance aids (ASD-TR-61-550). Ohio: Wright-Patterson Air Force Base, October 1961. (AD-A0270 868)

Frase, L. T. Reading performances and document design. Proceedings Vol. III, Second annual job information presentation conference, Rowan and Genovese (Eds.). Washington, D. C.: Society for Applied Learning Technology, July 1976.

Frey, A. Holography: Applications in training and technical documentation, Final report. Washington, D. C.: Naval Air Systems Command, July 1976.

Gebhard, R. M. Development of a training program and job aids for maintenance of electronic communication equipment (HumRRO-TR-70-19). Alexandria, VA: Human Resources Research Organization, December 1970.

General Motors Corporation. Diagnosis and repair manual. Southfield, MI: GMDR Manual Headquarters, January 1977.

Goff, J., Schlesinger, R., & Parlog, J. Project PIMO final report. Vol. II. PIMO test summary (TR-315-69-14(u), Vol. 2, SAMSO, TR-69-155, Vol. 2). Chatsworth, CA: Serendipity, Inc., May 1969. (AD-A0852 102)

Grausnick, R. R., & Kottenstette, J. P. A performance evaluation: Microfiche versus hardcopy (AFHRL-TR-71-42). Texas: Brooks Air Force Base, Air Force Human Resources Laboratory, May 1971.

Gulliford, N. L. Current research on the relative effectiveness of selected media characteristics. Pittsburg, PA: Westinghouse Electric Corporation, October 1973.

Haber, R. N. How we remember what we see. Scientific American, 1970, 222, 104-115.

Haggard, D. F., & Shock, R. G. The effectiveness of visual demonstrations of signs of malfunction and wear in equipment (HumRRO Research Memo). Alexandria, VA: Human Resources Research Organization, June 1962. (AD-A0489 892)

Hartman, R. F. Single and multiple channel communication. A review of research and a proposed model. AV Communication Review, 1961, 9, 235-262.

Hooprich, E. A., & Steinemann, J. H. An investigation of the utility of a conversion chart as a job aid for electronics technicians (Tech. Bulletin STB 66-13). San Diego: U. S. Naval Personnel Research Activity, November 1965. (AD-A0624 608)

Horn, L. Job performance aids test. Washington, D. C.: Washington Navy Yard, Naval Weapons Engineering Support Activity, November 1972.

Horn, L. Optimum troubleshooting aids study (Report No. 25-73). Washington, D. C.: Washington Navy Yard, Naval Weapons Engineering Support Activity, June 1973.

Hughes Aircraft Company, Ground Systems Group, Task 1 Report. Preliminary NTIP system concept and alternative configurations. Bethesda, MD: David W. Taylor Naval Ship Research and Development Center, March 1977. (a)

Hughes Aircraft Company, Ground Systems Group, Task 3 Report. Preliminary NTIP system concept and alternative configurations. Bethesda, MD: David W. Taylor Naval Ship Research and Development Center, April 1977. (b)

Johnson, F. Problems in procuring, producing, and evaluating JPAs. Proceedings of the invitational conference on status of job performance aid technology (NPRDC Tech. Rep. 77-33). San Diego: Navy Personnel Research and Development Center, May 1977. (AD-A040 540)

Joyce, R. P. Performance aids and technical training: Complementary information sources. New concepts in maintenance trainers and performance aids (TR-IH-255). Orlando, FL: Naval Training Equipment Center, October 1975.

Klatzky, R. L. Human memory: Structures and processes. San Francisco: W. H. Freeman and Co., 1975.

Klesch, J. J. Implementation of the JPA/job oriented training approach to maintenance: The impact on personnel systems. Proceedings of the invitational conference on status of job performance aid technology (NPRDC Tech. Rep. 77-33). San Diego: Navy Personnel Research and Development Center, May 1977.

Krohn, C. A., Clayton, C. A., & Dunn, J. W. Evaluation of SIMMS for AN/SRC-20 radio set (Report No. RTI-SU-603-1). Research Triangle Park, NC: Research Triangle Institute, November 1971.

Lewis, B. N., & Cook, J. A. Toward a theory of telling. International Journal of Man-Machine Studies, 1969, 1, 129-176.

Lineberry, C. S. When to develop aids for on-the-job use and when to provide instruction. Proceedings of the invitational conference on status of job performance aid technology (NPRDC Tech. Rep. 77-33). San Diego: Navy Personnel Research and Development Center, May 1977. (AD-A040 540)

Losee, J. E., Allen, R. H., Stroud, J. W., & ver Hulst, J. A study of the Air Force maintenance technical data system (AMRL-TDR-62-85). Ohio: Wright-Patterson Air Force Base, Aerospace Medical Division, August 1962.

Main, R. E. Advancing the application of job performance aids within the Navy: II. Mailout surveys of machinery repairmen and commissary ratings (NPRDC Tech. Rep. 75-14). San Diego: Navy Personnel Research and Development Center, September 1974. (AD-A001 688)

Mandler, J. M., & Johnson, N. S. Some of the thousand words a picture is worth. Journal of Experimental Psychology: Human Learning and Memory, 1976, 2, 529-540.

Martin, A. C. Relative merits of SIMM/FOMM and JPA/JGM. Proceedings: Invitational conference on improved information aids for technicians. Washington, D. C.: Society for Applied Learning Technology and the Logistics Management Institute, May 1975.

Middleton, W., Guilliams, J., & Weber, P. Technical evaluation of a guide for selecting formats and media for presenting maintenance information. Bethesda, MD: David W. Taylor Naval Ship Research and Development Center, April 1977.

Miller, G. A., Galanter, E., & Pribram, K. H. Plans and the structure of behavior. New York: Holt, Rinehart, and Winston, 1960.

Nelson, D. L., Reed, V. S., & Walling, J. R. Pictorial superiority effect. Journal of Experimental Psychology: Human Learning and Memory, 1976, 2, 523-528.

Newman, S. E. On identifying effective handbook techniques (ML-TM-57-26). Colorado: Lowry Air Force Base, Air Force Personnel and Training Research Center, December 1957.

Pavio, A., & Begg, I. Pictures and words in visual search. Memory and Cognition, 1974, 3, 515-521.

Pellegrino, J. W., Siegel, A. W., & Dhawan, M. Short-term retention of pictures and words: Evidence for dual coding systems. Journal of Experimental Psychology: Human Learning and Memory, 1975, 104, 95-102.

Pellegrino, J. W., Siegel, A. W., & Dhawan, M. Differential distraction effects in short-term and long-term retention of pictures and words. Journal of Experimental Psychology: Human Learning and Memory, 1976, 2, 541-547.

Post, T. J. Selection of formats and media for presenting maintenance information. Proceedings of the invitational conference on status of job performance aids technology (NPRDC Tech. Rep. 77-33). San Diego: Navy Personnel Research and Development Center, May 1977. (AD-A040 540)

Post, T. J. Job design, performance aids, and training. Proceedings of job performance aids technology workshop. San Francisco: Human Factors Society annual meeting, October 1977. (b)

Post, T. J., & Brooks, F. A. Advanced manpower concepts for sea-based aviation systems (AMSAS). Washington, D. C.: Naval Air Systems Command, December 1970.

Post, T. J., & Price, H. E. Requirements and critiera for improving reading comprehension of technical manuals. Falls Church, VA: BioTechnology, Inc., November 1974.

Post, T. J., Price, H. E., & Diffley, G. A guide for selecting formats and media for presenting maintenance information. Falls Church, VA: BioTechnology, Inc., April 1976.

Potter, N. R., & Thomas, D. L. Evaluation of three types of technical data for troubleshooting: Results and project summary (AFHRL TR-76-74(I)). Dayton, OH: Systems Research Laboratory, September 1976.

Powers, T. E. Generic cognitive behaviors in technical job tasks. Proceedings from the review on maintenance training and performance aids. OASD(I&R` WR ODDR&E(E&LS). Carderock, MD: Naval Ship Research and Developme Center, February 1977.

Powers, T. E., Dickerson, L., & Nugent, J. D. Selecting presentation modes according to personnel characteristics and the nature of job tasks, Part III: Presentation models. Bethesda, MD: David W. Taylor Research and Development Center, May 1977.

Price, H. E., Post, T. J., & Barker, W. A. A guide for position design and documentation. Hemdel, NJ: Bell Laboratories, 1973.

Rees, D. W., & Kama, W. N. Size of tabs: A factor in handling of guides and checklists (WADC-TR-59-154). Ohio: Wright-Patterson Air Force Base, Wright Air Development Center, March 1959. (AD-A0213 595)

Reynolds, H. N., & Rosen, R. F. The effectiveness of textbook, individualized, and pictorial instructional formats for hearing-impaired college students. Washington, D. C.: Gallaudet College, Annual meeting of the American Educational Research Association, 1973.

Rigney, J. W., Fromer, R., Langston, E. T., & Adams, H. C. Evaluation of an experimental fault location device. I. Fault location by radio operators (Tech. Rep. 43). Los Angeles: University of Southern California, Department of Psychology, August 1965. (a)

Rigney, J. W., Fromer, R., Langston, E. T., & Adams, H. C. Evaluation of an experimental fault location device. II. Fault location and isolation by experienced electronics technicians (Tech. Rep. 44). Los Angeles: University of Southern California, Department of Psychology, August 1965. (b)

Rigney. J. W., & Towne, D. M. Some concepts, devices, and procedures for improving technical training and on-the-job performance of maintenance. Los Angeles, CA: University of Southern California, Behavioral Technology Laboratories, August 1977.

Rizzo, W. A. Evaluation of microfiche as an instructional medium in a technical training environment (TAEG Report No. 48). Orlando, FL: Training Analysis and Evaluation Group, July 1977.

Rogers, J. P., & Thorne, H. W. The development and evaluation of an improved electronics troubleshooting manual (Tech. Rep. 65-1). Alexandria, VA. Human Resources Research Organization, March 1965. (AD-A0614 616)

Rowan, T. C. Improving DOD maintenance through etter performance aids. Arlington, VA: Information Concepts, Inc., March 1973. (AD-A0758 713)

Serendipity, Inc. Project PIMO Field Report, PIMO Final Report Summary (TR-69-155, Vol. I). Space and Missile System Organization, AFSC, May 1969. (AD-A0852 101)

Severin, W. J. The effectiveness of relevant pictures in multiple channel communications. AV Communications Review, 1967, 15, 386-401.

Shriver, E. L. Determining training requirements for electronic system maintenance: Development and test of a new method of skill and knowledge analysis (HumRRO Rep. 63). Alexandria, VA: Human Resources Research Organization, June 1960. (AD-A0239 416)

Shriver, E. L. New directions for information transfer research in maintenance aids. Proceedings of the invitational conference on status of job performance aid technology (NPRDC Tech. Rep. 77-33). San Diego: Navy Personnel Research and Development Center, May 1977. (AD-A040 540)

Shriver, E. L., & Hart, F. L. Study and proposal for the improvement of military technical information transfer methods. Alexandria, VA: Kinton, Inc., December 1975. (AD-A023 409)

Shriver, E. L., & Trexler, R. C. Application and test of the FORECAST concept of electronics maintenance on Navy LORAN equipment (HumRRO Report 65-3). Alexandria, VA: Human Resources Research Organization, May 1965. (AD-A0616 753)

Sitterley, T. E. Degradation of learned skills: Static practice effectiveness for visual approach and landing skills retention (Rep. D180-17876-1). Seattle, WA: Boeing Aircraft Company, May 1974.

Smillie, R. J., Edsall, J. C., Ayoub, M. A., & Muller, W. Assessment and evaluation of job performance aids: A simulation approach. Part II--Main report (Tech. Rep.). Raleigh, NC: North Carolina State University, 1976.

Theisen, C. J., & Fishburne, R. P. Assessment of a training program in support of the fully proceduralized job performance aid. Warminster, PA: Naval Air Development Center, in press.

Travers, R. M. W. (Ed.). Research and theory related to audiovisual information transmission. University of Utah, Bureau of Educational Research, July 1964.

Tulving, E. Cue dependent forgetting. American Scientist, 1974, 62, 74-82.

Tulving, E., & Thomson, D. M. Encoding specificity and retrieval processing in episodic memory. Psychological Review, 1973, 80, 352-373.

U. S. Army Test and Evaluation Directorate. Final report of test of Audio-visual Information System (A-VIS) (NIKE X Report No. 65-2). White Sands Missile Range, NM: September 1964. (AD-A0608 308)

Westinghouse Electric Corporation. Fully proceduralized troubleshooting aid. JPA-SC-FPTA Oscilloscope Camera HP-197A. Cockeysville, MD: Electronic Systems Support Division, June 1973.

Wright, P., & Fox, K. Explicit and implict tabulation formats. Ergonomics, 15(2), 1972, 175-187.

Wulff, J. J., & Berry, P. C. Aids to job performance. In R. M. Gagne (Ed.), Psychological principles in system development. New York: Holt, Rinehart, and Winston, 1962.

REFERENCE NOTES

1. Smillie, R. J. The assessment and evaluation of job performance aid formats using computer simulation (Doctoral Dissertation). Raleigh, NC: North Carolina State University, 1977.

2. Horn, L. Personal communication on AN-APQ-126 radar test. Washington, D. C.: Washington Navy Yard, Navy Weapons Engineering Support Activity, June 1977.

3. Burkett, H. A., & Kruse, H. Investigation of card programmable and chip programmable pocket calculators and calculator systems for use at Naval Postgraduate School and in the naval establishment (Master Thesis). Monterey, CA: Naval Postgraduate School, June 1977.

4. Teel, K. S., & Chaney, F. B. Improving inspector performance through training and visual aids. Paper presented to the 74th Annual Convention of the American Psychological Association, September 1966.

5. Dever, J. J. Personal communication on structured programming applied to JPA Personnel Subsystems Department, Bell Laboratories, Piscataway, NJ, August 1977.

6. Curran, T. E. Technical manual graphic comprehensibility classification scheme and graphics catalog (Letter Report). San Diego: Navy Personnel Research and Development Center, October 1976.

GLOSSARY

JPA SYSTEMS AND TECHNIQUES

Acronym or Popular Name	Full Title (if different)	Source
AAT	Augmented Action Tree	BioTechnology, Inc.
ADMIRE/MIRAID	Automatic Diagnostic Maintenance Information	Westinghouse Electric Corporation
ADPEP	Automated Data Preparation Evaluation Program	McDonnell-Douglas Aircraft Company
AGCS	Alden Graphic Communication System	Alden, Inc.
AMSAS	Advanced Manpower Concepts for Sea-Based Aviation Systems	Naval Air Systems Command
ATOMS	Automated Technical Order Maintenance Sequence	Boeing Aircraft Company
ATS	Administrative Terminal System	
AVIS	Audiovisual Information System	Letterkenny Army Depot
BFIC/BIFAC	Binary Fault Isolation Chart	Westinghouse Electric Corporation
BLOCK FORM		Air Force Human Resources Laboratory
BRITISH ALGORITHM		British Air Force
C-A LOGICAL PROCESSES		(Various sources)
CATA	Computer-Aided Trouble Analysis	Vought Aeronautics
CMG	Condensed Maintenance Guides	Hughes Aircraft
Computer-aided Loop Diagram Representations		Technical Communications

Acronym or Popular Name	Full Title (if different)	Source
Computer Graphics and Visual Module System		William A. Fetter
Calculator (hand-held)	Personal Programmable Calculators	Texas Instruments or Hewlett Packard
CONSD	Condensed Servicing Data	General Electric Company
CONTEX		VITRO Laboratories
COST	Concentrated Odor Sensing Technique	Illinois Institute of Technology
DACOM	Data Communicator	Letterkenny Army Depot
DATOM	Data Aids to Training Operation and Maintenance	General Electric Company
DSA	Diagnostic Sonic Analyzer	Curtiss-Wright Corporation
DIMATE	Depot Installed Maintenance Test Equipment	RCA
3-D Dynamic Display		(various sources)
ELECTROCULAR	Electronic Ocular	Hughes (Brown, H. T.)
FASTI	Fast Access to System Technical Information	National Security Industry Association
FEFI/TAFI	Flight Engineers Fault Isolation/Turn Around Fault Isolation	McDonnell-Douglas Aircraft
Filesearch System		
FIST	Fault Isolation by Semi-Automatic Techniques	U. S. Navy
FLAPS	Functional Layout and Presentation System	Hughes Aircraft Company

Acronym or Popular Name	Full Title (if different)	Source
FOMM/SIMMS/IM/IMP/ IMC/BAMAGAT	Functionally Oriented Maintenance Manuals Symbolic Integrated Maintenance Manuals/ Integrated Maintenance Package/Integrated Maintenance Concept/Block-a-Matic, a-Gram, a-Text	Naval Sea Systems Command
FORECAST		Human Resources Research Organization
FPJPA	Fully Proceduralized Job Performance Aid	Air Force Human Resources Research Laboratory
GM	Diagnosis and repair manual	General Motors Corporation
GPAM	Graphically Proceduralized Aids for Maintenance	Publication Engineers
HAWK Radar Mechanic System Collection Manual		Human Resources Research Organization
Hayden Fault Indicator		A. W. Hayden Company
Holography		Randomline, Inc.
Hybrid Maintenance Aid		Naval Air Systems Command
Imagery Enhancing Technique		Imagetics, Inc.
Implosion		Hoehn and Lumsdaine
Information Retrieval and Display Systems		(various sources)
ITDT	Integrated Technical Data and Training	DARCOM
JOBTRAIN		Human Resources Research Organization
JPA Assessment Algorithm		Naval Air Systems Command/ North Carolina State
JTG/JTM	Job Task Guide/Job Task Manual	DARCOM

Acronym or Popular Name	Full Title (if different)	Source
KINTEL		NSIA
LCI	Learner-Centered Instruction	AFHRL
LGCP	Lexical-Graphical Composer-Printer	
LTS-1/LTS-2	Lincoln Training System	Lincoln Lab MIT
M3DD	Microfilmed Maintenance Manual Data Dissemination	3-M Company
MADAR/GPS	Malfunction Detection, Analysis and Recording System and Its Ground Processing System	Lockheed-Georgia Company
MAGNACARD		NSIA
MAGNAVUE		Magnavox
MAINTRAIN	Maintenance and Training in Complex Systems	Human Resources Research Organization
MDC	Maintenance Dependency Chart	Naval Sea Systems Command
MDS	Safeguard Maintenance Data System	Western Electric
MEDIA		Bell Labs
MEMRI	Maintenance Engineering Management and Repair Information	Republic Aviation Company
Micro-Vue		Republic Aviation Company
MIM	Multi-Image Microfilming	Technical Operations, Inc.
Minicard System		
MINIDATA		Martin Marietta Corporation
Miracode System		
MITIPAC		Navy
MMS	Maintenance Management System	
MRC	Maintenance Requirements Card	Navy

Acronym or Popular Name	Full Title (if different)	Source
MT Magazine	Maintenance Tips	Navy
NAMES	Navy Aircraft Maintenance Evaluation System	Naval Air Systems Command
NEOSTYLIZED MANUALS		Army
NTIPS/NTMS	Navy Technical Information Presentation System	Navy Ship Research and Development Center
Optimum Picture/ Word Format		Naval Air Systems Command
PIMO	Presentation of Information for Maintenance and Operations	Serendipity, Inc.
Procedures Flow Chart		
PROFILE CARDS		Philco Corporation
PS Magazine		Army
Pulsed Light Projection		Letterkenny Army Depot
PYRAGRAM	Pyramid Diagrams	Hughes
Quick Fix		McDonnell-Douglas Aircraft Company
RAPIDS	Rapid Automated Problem Identification Data Systems	Grumman Aircraft Company
REPOM/MIRM	Reliability Prediction Oriented Maintenance/Maintenance Instructions Recorded Magnetically	Naval Ordnance Laboratory
RESTORE	Rapid Evaluation System to Repair Equipment	Martin Marietta
SADIE	Smiths Aural Diagnostic Inspection Equipment	British European Airways
SHOCK ACTION		Human Resources Research Organization

Acronym or Popular Name	Full Title (if different)	Source
SPARES Test Capability Report		General Dynamics
TASKTEACH		J. W. Rigney/R. Fromer
TOPP	Task Oriented Plant Practices	Bell Laboratories
Team Training		(various sources)
TEAMS		Northrup
TRACE	Transitor Radio Automatic Circuit Evaluator	Philco Corporation
TROUBLE LOCATORS		U. S. Air Force
TRUMP/MIARS	Technical Review and Update of Manuals and Publications/Maintenance Information Automated Retrieval System	Naval Air Systems Command
TSP		Lincoln Lab MIT
VAt	Versatile Avionics Systems Test	Naval Air Systems Command
Videofile System		
VIDEOSONIC SYSTEM		Hughes
WALNUT		Letterkenny Army Depot
WORK PACKAGE CONCEPT		Naval Air Systems Command
WSMAC	Weapon System Maintenance Action Center	McDonnell-Douglas Aircraft
XFL	Experimental Fault Locator	J. W. Rigney

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