Electronic Authoring and Delivery of Technical Information

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Abstract. Current developments in automating the processes to author technical information and deliver it using microcomputers are described in this article. The Department of Defense (DoD) has directed that the entire logistics support system (including technical information now contained in printed manuals) be computer-based for new major systems entering production during the 1990s. Addressed are issues relating to authoring efficiency, information access, user acceptance, and screen formats. The article also reviews several ongoing projects and discusses implications for making the transition from paper to computer-based technical manuals.

If current Department of Defense (DoD) policy is implemented as planned, within the next ten years most technical manuals used by the military service will be "paperless." Technical information, now mainly in paper form, will be presented on computers, with all the advantages and problems to be overcome that this technology entails.

While this article is primarily concerned with the automation of technical information, it should be noted that a computer logistic support system is envisioned as a comprehensive tool, integrating the automated processes to create, store, retrieve, use, and exchange weapons system procurement and support data.

Two major goals of this DoD program specifically relating to technical information are to:

1. accelerate the automation of contractor processes for generating logistic products such as technical manuals and training materials.
2. rapidly increase U.S. military capabilities to receive, distribute, and use technical information in digital form to improve weapons system maintenance and training.

Much development needs to occur in the next few years to accomplish these ambitious and worthwhile goals. This article describes some of the programs to date as well as problems, research, and management issues which must be addressed over the next several years.

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Problems with Traditional Technical Manuals

The volume and cost of technical manuals used by the U.S. military forces has grown exponentially in the past 40 years. Whereas a World War II fighter aircraft required just a few technical manuals, a current weapons system may require over 100 separate volumes (Nauta, 1985). This increase in technical data, typical of most major U.S. weapons systems, has burdened the user. It is commonly stated that it takes "six foot lockers to hold the technical manuals for the M1 tank." Maintenance technicians frequently need several manuals to perform troubleshooting and repair tasks. More often than not, checklists for a particu-

lar troubleshooting task have multiple references, sometimes contained in several volumes. As equipment is modified, technical information updates are slow to reach users in the field, and correcting technical manuals with update sheets is so awkward and time-consuming that it is frequently not done correctly. It is not surprising that technicians do not always consult the manuals when they should.

The documentation problem is compounded by a potential shortage of highly skilled technicians, and demographic figures offer little encouragement. The birth rate in the United States fell considerably about 18 years ago, which will soon result in an insufficient manpower pool for recruiting. Skilled technicians will be in short supply throughout the remainder of this century.

Another problem with traditional technical manuals is that they are composed mostly of text and contain a minimum of graphics. An exception is the U.S. Army's New Look manuals, which have been well accepted by their users but are expensive to produce.

This dual problem of difficult-to-use documentation and a lack of adequate numbers of skilled technicians results in maintenance errors of four types, according to Inaba (1985):

1. unnecessary removal of good parts,
2. failure to isolate reported problems,
3. damage to equipment, and
4. process errors which do not damage the equipment but take excessive time to correct.

Current Paperless Technical Manual Projects

All three U.S. military services are involved in projects to automate the authoring and display of technical information supporting weapons systems, such as technical manuals, job performance aids, computer-based technical training materials, and automated diagnostics. In addition, many major U.S. defense contractors are working on such projects. A brief listing of several projects follows. A more thorough description of several military programs may be found in Johnson and Smillie (1987).

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Naval Technical Information Presentation System (NTIPS)

NTIPS is a system consisting of a family of delivery devices and an authoring system which is being designed as an integral part of the Navy's logistic support system. Its goals are to:

1. present comprehensible, high-quality technical information to enlisted technicians for all types of maintenance and operation functions,
2. present training information to achieve, maintain, and advance technical competency in shore schools and aboard ship, and
3. communicate with centralized and administrative functions for the consolidation of reports and logistical actions.

Two NTIPS field studies have recently been completed, one on an avionics subsystem of the F-14A aircraft and another on the SPA-25 radar repeater, which compare electronic delivery of technical information with printed manuals. Both experienced and inexperienced technicians did better using electronically delivered job aids and preferred their use (Fuller & Post, 1987).

Several other studies to develop comprehensible formats and language patterns for technical information have also been completed in support of NTIPS (e.g., Braby, Kincaid, Scott, & McDaniel, 1982; Kincaid, Aagard, O'Hara & Cottrell, 1981; Thomas, Braby, & Mears, in press).

Personal Electronic Aid for Maintenance (PEAM)

PEAM uses microcomputer technology and job-aid techniques to optimize the design and delivery of technical information. Field testing was conducted by the Army at Fort Knox, using maintenance tasks for the M1 tank (Schurman & Kincaid, in press), and by the Navy at San Diego, using troubleshooting tasks for the Seasparrow missile (Smillie & Nugent, in press). Results of both field tests indicate:

1. a high degree of user acceptance of the concept of electronically delivered technical information.
2. a substantial reduction in troubleshooting errors using PEAM as compared with paper technical manuals (about 3:1).
3. the need to further develop effective formats and techniques for organizing data bases of maintenance information to facilitate electronic delivery.

Electronic Maintenance Publication System (EMPS)

EMPS is a system combining a videodisc and microcomputer developed by the U.S. Army Missile Command (MICOM) at Redstone Arsenal. EMPS has been field tested at Fort Bliss, Texas, with a data base taken from over 1000 pages of technical manuals used to maintain the Patriot missile. The Production Management System

(PMS) developed by the Army Communicative Systems at Fort Eustis, Virginia, was used to produce the material. A test comparing technical information delivered using EMPs with printed manuals showed results similar to the PEAM field test: users accepted the concept of electronically delivered technical information and made far fewer maintenance errors.

EMPS is basically a prototype of the Electronic Information Delivery System (EIDS); both devices are designed to display information contained on videodisc under the control of a microcomputer. EIDS devices will be procured by the Army and other military services in large numbers, perhaps as many as 50,000. While EIDS is designed primarily as a training device, it almost certainly will also be used as a paperless technical manual.

Militarized Electronic Information Delivery System (MEIDS)

MEIDS is a portable electronic device which will largely replace the technical manuals that Army technicians use in the field. The configuration for the device is still being formulated, but it will be rugged, portable, and will use an expert system for indexing and accessing data stored in its data bases. The final design of MEIDS will benefit from the field tests of PEAM and EMPS. For example, the PEAM field test has contributed to the initial functional specifications for the MEIDS program.

Integrated Maintenance Information Systems (IMIS)

The Air Force Human Resources Laboratory is developing IMIS (Collins, 1985). The system will integrate computerized maintenance data bases with an automated technical data system, and will include diagnostic job aids to increase the ability of technicians to perform fault isolation. It will be an integrated approach to total weapons systems maintenance, linking technical data and information about training, diagnostics, management, and scheduling. The authoring software for IMIS, the Authoring and Presentation System (APS), has been developed in-house. One of the important characteristics of APS is that it incorporates a relational data base approach, allowing the creation of display frames from data bases rather than requiring the authoring and storage of a massive number of individual frames. A second part of the project is concerned with electronic delivery of technical information, primarily job performance aids (JPAs). A field test completed last year used a portable, commercially available Grid microcomputer and showed the same kind of favorable results as did the PEAM, NTIPS, and EMPS field tests.

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Design Considerations

The manner in which procedures are organized and presented to technicians, whether using paper or electronic devices, affects both learning time and subsequent job performance (Kincaid & Braby, 1987). While many questions still remain on how best to present procedural instructions electronically, progress is being achieved.

Booher (1975) proposed that pictures are effective in teaching location tasks, but that words must also be used to effectively teach complex procedures. Guidelines have recently been published for formatting procedural instructions (e.g., Braby, Hamel & Smode, 1982; Braby, Kincaid, Scott, & McDaniel, 1982). These formats have proved to be highly effective in training procedures and in preparing trainees to use expensive simulator training devices.

User Acceptance

One special requirement will be for displays that enhance the technicians' skills as well as guide them through the steps of an operation. Job performance aids must be built so that they serve as training materials. In a report on the status and future of maintenance job aids (Chenzoff & Joyce, 1985), this requirement was addressed in presenting research issues for JPA development:

> From a maintenance performance point of view, the sole purpose of an aid should be to wean the student away from needing the aid. . . . All further R&D in job aiding must be focused on facilitating skill development on-the-job. . . . Perhaps the most important factor that was ignored in the early JPA efforts was the needs of the maintenance workers themselves. The "technicians" felt degraded since they were only qualified to perform the simplest tasks. They felt they were being "led by the hand" through a series of steps that had no meaning for them.

It was also indicated that job performance aids have to be provided in a form that will enable technicians to understand what is happening within a system, what conditions need to be met for the system to operate properly, and what symptoms are produced when system components fail.

Effective Display Formats

In developing effective computer-based technical manuals, lessons learned through long experience in designing and using paper technical manuals should be utilized. However, electronic displays which are merely facsimiles of paper pages are likely to be rejected by technicians, and would underutilize the major capabilities of

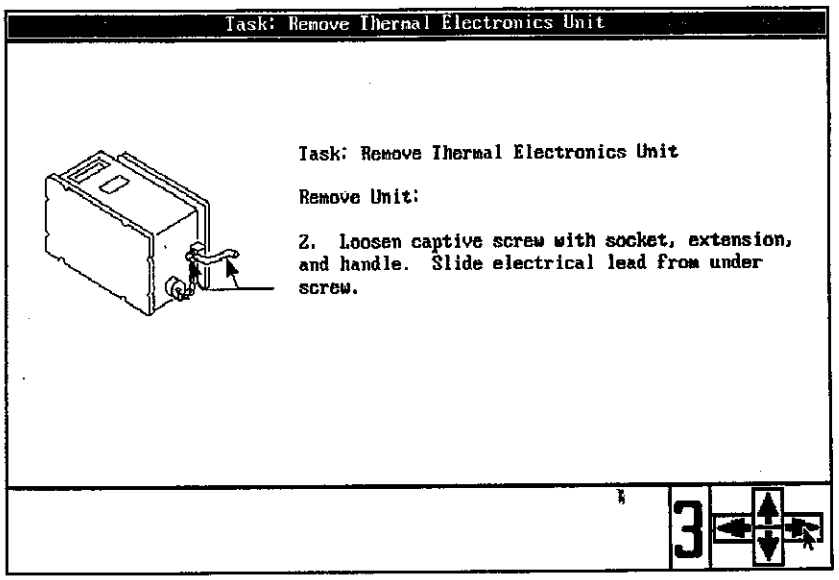
the computer. Unlike paper displays, computer displays can be dynamic, information can be manipulated by users, and indexing and accessing can be automatic. Computer displays can be made to automatically change as changes take place in the conditions of a problem. The displays can adapt to the skill level of the technician by presenting information at different levels of detail. Disadvantages of current computer displays are that they have much poorer resolution and are smaller than printed materials.

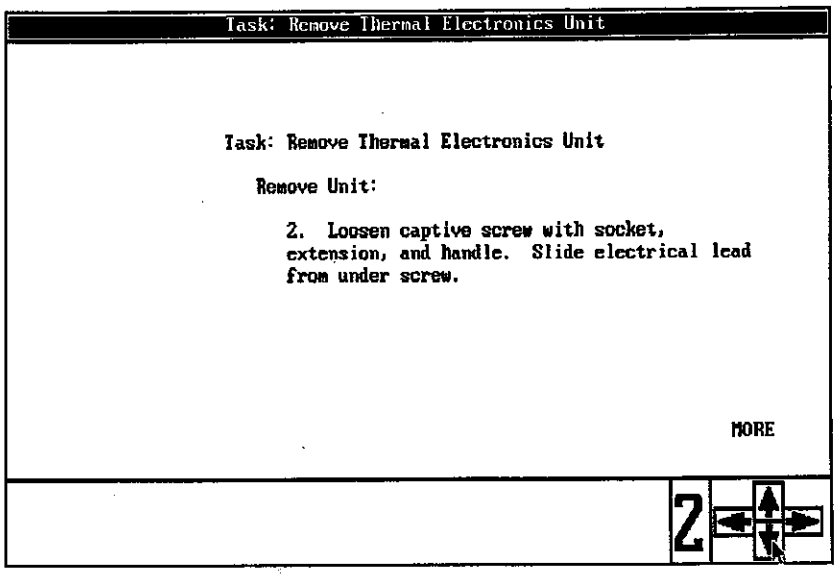
Designing displays and organizing information for computer presentation involve developing techniques that respond to contingencies and special requirements of the user and can be understood given the limitations of the presentation.

A number of issues related to the use of job aids, whether presented on paper or in electronic form, affect job satisfaction. Ideally, electronically presented job aids should have the following characteristics:

- The level of explanation can be adjusted, for example, information explaining the reasons for each action can be added.
- The level of detail in the job aid can be adjusted, so that the job aid can present full procedures illustrating each small action, partial procedures, or a short checklist without illustrations.
- The technician can retrieve from the system just the information that is required, and can obtain additional information about any particular part of a procedure.

These points are illustrated by computer display screens from an ongoing research project sponsored by the Army Research Institute. The screens depict a single step in a maintenance procedure, the removal of a component from the Thermal Imaging System of the M1 tank. The step is presented at three levels of difficulty: for the novice who relies on a step-by-step presentation including illustrations (Figure 1, top), for the experienced but not yet expert technician (Figure 1, middle), and for the expert (Figure 1, bottom), who only needs a checklist, not highly illustrated and complete instructions. Graphics and text are similar to that in the technical manual, but the organization of the material was altered significantly for computer presentation.





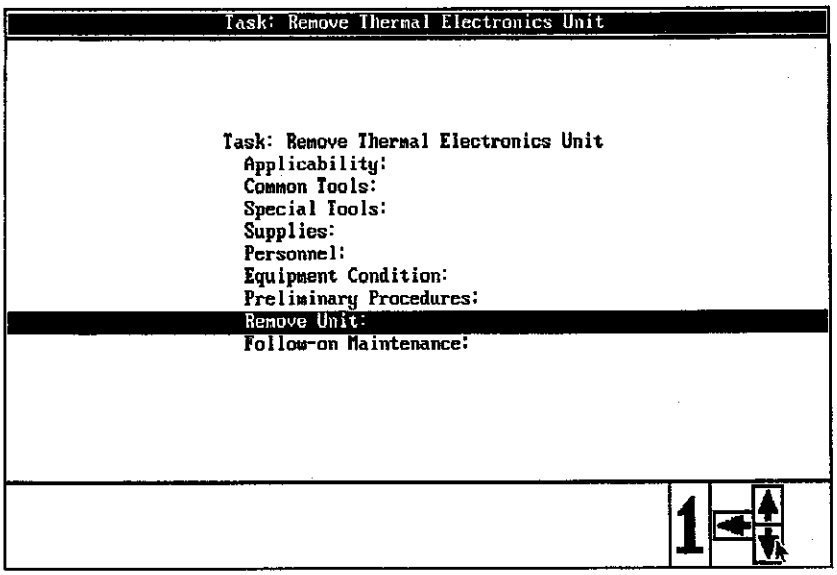


Figure 1. The same maintenance information presented to a novice (top), a somewhat experienced technician (middle), and an expert technician (bottom).

Figure 2 depicts how the information is loaded into a computer data base. Although space limitations do not permit us to fully describe the advantages of the authoring procedure, several points are worth noting. The equipment consists of a Zenith 248 computer, which is compatible with the IBM PC/AT computer and which the DoD has purchased in large numbers; a device for loading existing art into the database by a process of raster scanning; and associated peripheral equipment such as a laser printer. Total equipment and software costs are about $12,000.

The programming language which produced these computer screens is called SMALLTALK. It is inexpensive, easy to modify, and is excellent at handling graphics. Our implementation of SMALLTALK provides for automatic cross-referencing, including graphics. Individual screens are created from separate components. For example, the screen shown at the top of Figure 1 was created from the line drawing, the text, and the arrows. It takes less than a second for it to appear on the screen. Individual screens are created "on the fly" from separate files so that the same graphic or string of text need only be stored once and can be used many times in different combinations.

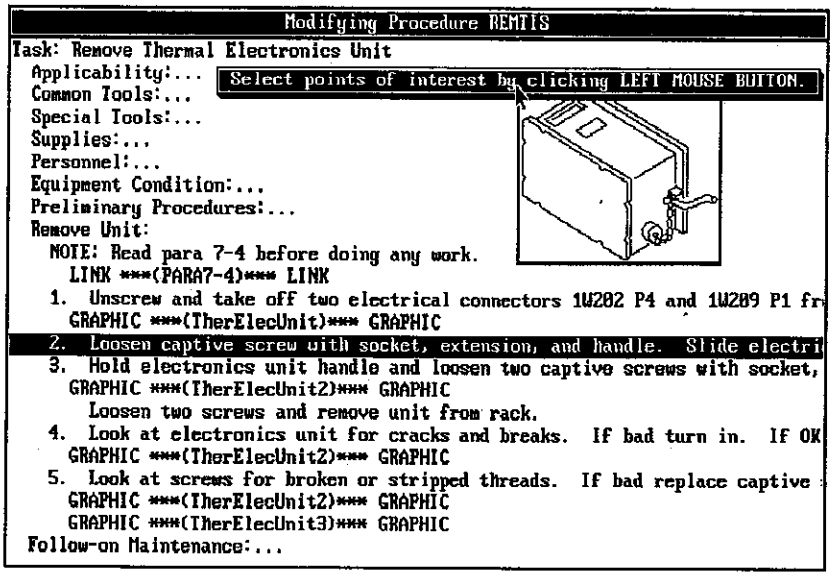


Figure 2. Screen demonstrating authoring of the three screens in Figure 1.

Cost of Production

The high cost of producing printed job performance aids that include full procedures and illustrations, such as Army New Look manuals, has kept them from being widely used. The high cost of these materials is due to an increase in the number of pages required to support a given task and the more extensive use of expensive graphics.

There is the general expectation that computer-based job aids will be less expensive than paper job performance aids. However, computer-based job performance aids could prove to be even more costly if they are produced in the traditional way, frame by frame. Each electronic frame contains less information than an equivalent paper page, so a substantial increase in effort would be required to produce electronic frames in the place of paper pages. One estimate is that it will require 15 to 20 times more electronic frames than paper pages to present a given task in a job aid.

To be economical, an authoring system should be built on relational data bases from which individual frames can be constructed, and should use compaction techniques to minimize digital storage requirements. Both the PEAM and IMIS authoring systems have incorporated these concepts to varying degrees. For example, the authoring system for PEAM incorporates a number of features to compact both the storage of text and graphics. The authoring system for IMIS makes extensive use of elements of information retrieved from a relational data base to build a frame "on the fly," which reduces the need to store large numbers of individual frames. The project illustrated in the figures that accompany this article also includes a relational data base and builds frames "on the fly."

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Conclusions

A major technical challenge, as articulated in this article, is to produce and demonstrate practical and useful authoring and delivery techniques for electronic technical information. To be most effective, efforts should: (1) build on previous and ongoing research and development initiatives, many of which were described here, (2) incorporate computer hardware and software developments from the com-

mercial sector, and (3) attend to issues of user acceptance. The development of display formats and techniques for organizing large amounts of information should be given high priority in future research.

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