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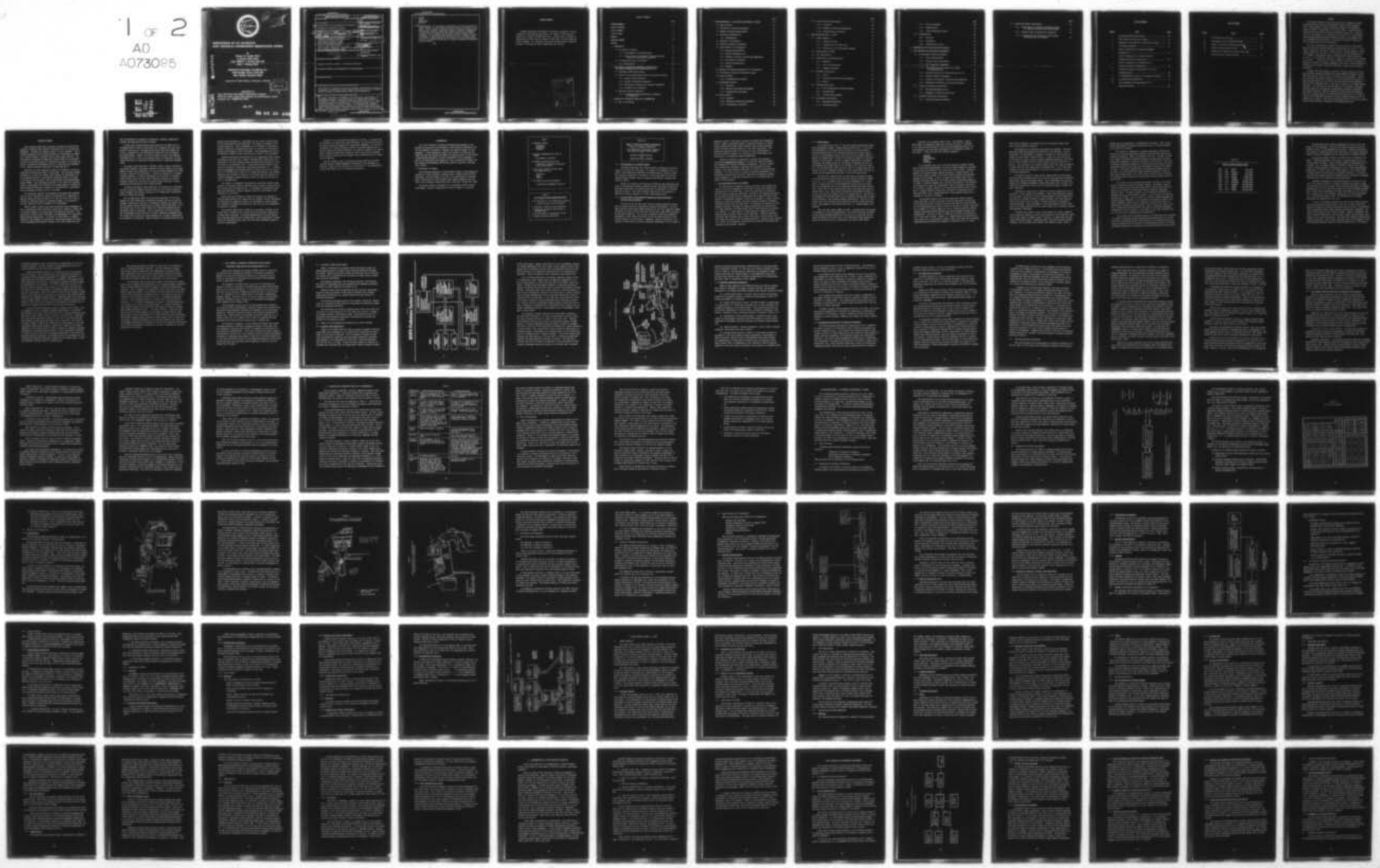

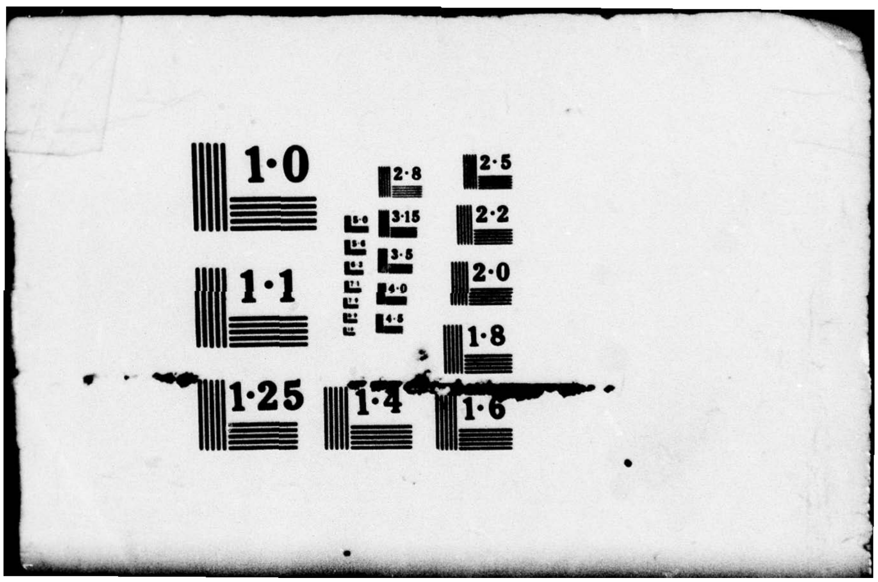
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IMPLICATIONS OF AN ALL-DIGITAL NAVY TECHNICAL INFORMATION PRESENTATION SYSTEM

by

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This report describes an assessment of the application, implications, and developments involved in the introduction of a single-medium computer-administered Technical Information presentation system into the U. S. Navy. It defines the nature and operation of a hypothetical system of this type through development of a system scenario. It identifies and considers implications of introducing such a system into the Navy from various viewpoints, including economic, strategic, naval missions, energy and personnel

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20. considerations. It also defines developments and procedural modifications necessary for introduction of such a system by the mide- to late 1980's. Such a system of optimized Technical Information preparation, distribution, delivery, change and updating is viewed as fundamental to the process of reversing current trends toward decreased combat readiness. An all-digital data approach can permit improved solutions to problems of lowered personnel productivity and of inherent human limitations in understanding and maintaining ever more complex systems, as well as an improved technology for Technical Information centralization and control.

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PREFACE

This report describes a short-term study effort intended to provide the Navy Technical Information Presentation Program (NTIPP) management with a system scenario in which an advanced technical data-automation system is adopted for Navy-wide use in the mid 1980's. Among alternative system choices for updating Technical Information preparation, distribution, use, and change, is the possibility of resorting to a system design involving distributed processing techniques and micro/mini-computer Technical Information delivery devices, with which the end user interacts directly without need of hard-copy material.

The report describes how a usability-oriented system of this general kind would function following Navy-wide implementation in the mid- to later 1980's. Based upon this short conceptual effort, and upon previous research contributions by the contractor, it is argued that such an approach is indeed feasible. The relevant computer technology and behavior principles are sufficiently advanced at this time to assure full feasibility of approach in the 1980's. Implementation of such an ambitious program for updating all aspects of Technical Information management could lead to combat-readiness and life-cycle-cost reduction advantages sufficient to make such an investment attractive.

No effort has been expended to duplicate the work involved in previous Navy Technical Information Presentation Program (NTIPP) preliminary system-definition efforts or other pieces of work associated with NTIPP. Instead, the contractor was tasked to establish a relatively broad-brush scenario, examine its implications to the Navy of 1985, and identify the developments that should be undertaken prior to that time in support of the NTIPP ultimate objective. The contractor was also directed not to reiterate or duplicate previous analyses of existing Navy organizations or missions performed by past NTIPP contractors. What was especially desired from this conceptual effort was a system scenario and associated projections that could provide a properly broad functional perspective of such an advanced system and its implications to the Navy. This task included identification of the more critical choices among alternative development and implementation paths.

EXECUTIVE SUMMARY

This conceptual study effort examines an advanced all-digital data approach to improving Navy Technical Information (TI) for the operation, maintenance, training, and logistics support of Fleet equipment. The increasing complexity of Navy hardware systems is outstripping the capability of naval personnel to maintain them in combat ready condition. The Navy Technical Information Presentation Program (NTIPP) was established to develop a Navy-wide system for integration and control of the many and diverse procedures and equipments used in TI acquisition and management so as to improve personnel productivity through improved TI.

Hard-copy TI is now reaching its limits as the medium of choice for supporting the information needs of technicians. Time and money expended in manual search time and no-defect parts removals are substantial, and the increasing fraction of less-skilled technicians tends to be unable to use some of the TI formats, such as Functionally Oriented Maintenance Manuals (FOMM). With increasing utilization of the newer fully proceduralized job performance aids (FPJPA's), even larger numbers of volumes and greater physical bulk must be supplied to, and searched by, technicians, with corresponding increases in cost to the Navy.

The alternative approach of developing an all-digital-data approach that can allow technicians to exploit the capabilities of computers for massive storage and rapid retrieval of TI, and can tailor the TI that is received to individual needs for information support, is postulated as the next significant major development in TI improvement.

NTIPP's mission includes exercising centralized systems management as well as operations control functions to guide the TI system as a whole, and for specific guidance of the major Navy TI acquisition activities. This mission will clearly involve development and implementation of large-scale data-automation capabilities. By the mid- to later-1980's, it appears feasible to add automated TI presentation using special-purpose TI presentation minicomputer/microcomputer systems to the other capabilities that will be developed for automated TI preparation, checking, transmission/transfer, and updating now planned by NTIPP.

In this study an NTIPP approach which adopts for the 1980's such an all-digital-data TI system for Navy-wide use is compared with other alternatives to hard-copy TI, including microform and video disk systems, and a case is presented for the technological superiority of an all-digital-data system design. However, the current status of some of the requisite technology has not at this time progressed beyond the laboratory, and must receive some level of field-study validation prior to large-scale implementation.

The present report describes a 1985 Navy, which is seen as incorporating further hardware technological advances in weapon systems, but as being manned by people whose capabilities are not particularly advanced over those of today's operators and technicians. A system of optimized TI, including training equipment, is viewed as fundamental to the process of reversing current trends toward decreased combat readiness resulting from lowered personnel productivity, and from the inherent human limitations in understanding and maintaining ever more complex systems.

A detailed all-digital system description is presented that identifies the major functional elements associated with the use of modern data-automation equipments and software techniques for TI preparation, distribution, delivery, change and updating.

For TI preparation, NTIPP can provide Navy contractors (1) with the software (or with specialized TI preparation systems) that can be used for automatic scanning and conversion of engineering drawings into digital data, (2) with graphic library software that can permit rapid construction of illustrations, and (3) with other software for translating engineering data into highly usable TI materials. With an interactive TI delivery system, the TI preparation system will have to include translation programming that can convert draft TI data into system dialogue that is highly understandable and acceptable to technicians. Special software to assure specification compliance can be developed as a replacement for the current military standards and specifications that leave much to be desired for guiding TI production contractors. Other programming can be developed for verifying TI usability during the TI-preparation process, in conjunction with hands-on testing (verification) by Navy technicians. This programming will improve the exercise of NTIPP's control functions with respect to TI procurement.

Technical Information distribution will be accomplished either through forwarding of hard copy (e.g., discs) or through direct digital data communications of TI from archival storage and distribution facilities to user activities at the ship/base level. A distribution network scheme is described to illustrate a storage and distribution strategy for TI. A complex data-base-management system design effort is viewed as one of the critical needs of the NTIPP effort, since the TI storage, distribution, and updating subsystems must interface in ways yet to be defined with the logistics information management systems in effect, several of which are now near the point of implementation.

With respect to automated TI presentation, alternative system configurations are evaluated, with the conclusion that prototype construction and field testing would be required soon. A minicomputer configuration using moderately-high-quality computer graphics, and with screen-content copy capabilities is advocated.

Recent pilot-study results on technician evaluation of proposed TI delivery-system features and capabilities are reviewed, and key requirements are identified for supportive research and development on aiding formats, cost analyses of automated TI preparation, and life cycle cost consequences of automated TI systems.

The principal implication to NTIPP of the decision to develop an all-digital-data TI system is one of being faced with some major analysis and planning tasks concerning: (1) phased implementation of the new digital-data technology approach and (2) maintaining a viable paper-based TI system during the transition period, which will take some considerable period of time for accomplishment.

Adoption of an all-digital-data system for TI would: (1) improve combat readiness, (2) improve unit self-sufficiency, (3) produce more accurate and timely readiness information for operational commanders, (4) reduce the requirements for formal schooling in favor of increased emphasis upon on-the-job training and aiding techniques, (5) improve TI feedback, (6) improve morale largely through earlier productive use of entry-level technicians, and (7) improve contractor-TI procurement office collaboration in TI production and updating.

Specific possible areas of cooperation between NTIPP and the Naval Aviation Logistics Command Management Information System (NALCOMIS) are discussed, along with the possible use of facilities of the Shipboard Non-tactical ADP (SNAP-2) type for shipboard applications.

1 INTRODUCTION

This report examines an advanced all-digital-data approach to improving the acquisition and maintenance of Navy Technical Information (TI) for the operation, maintenance, training, and logistics support of Fleet equipment. A brief appraisal is made of the current TI problem and how trends over the next decade will modify the existing nature of that problem. A single-medium automated TI system is postulated, and an assessment is made of the implications that adoption of such a system would present, and key research and development efforts that would be required to implement such a system.

1.1 The Current TI Problem

The increasing complexity of Navy hardware systems is outstripping the capability of naval personnel to maintain them in combat ready condition. Furthermore, observed trends do not point to an amelioration of this gap. Rather, indications are that as newer, more complex equipment joins the Fleet, and as personnel capabilities fail to keep pace, the gap will widen.

The present system of providing TI to technicians reflects serious shortcomings. These are summarized as follows in Tables I, II and III.

Table I

- **Technical content**
  - inaccurate
  - incomplete
  - illegible
- **Technical Information not what is needed**
  - not matched to user/job
- **Feedback procedures don't work**
  - complaints, inaccuracies reported, but no action taken
- **Fleet has to handle too many types of information; e.g.,**
  - microform
  - paper
  - digital
- **TI doesn't arrive with hardware**
  - configuration management defective

Table II

TI Problems From The SYSCOM's/PM's/CNM

- No consistency in TI acquisition procedure
  - everyone invents his own approach
- Deficiency reporting system inadequate
- Inadequate definition of/attention to training needs
- No sound basis for estimating TI costs
- Update procedures inefficient

Table III

Impact of Deficient Technical Information

Defective technical information
↓
Poor maintenance, operations, training, and logistics support effectiveness
↓
Reduced system availability
↓
Impaired material readiness

1.1.1 Establishment of the NTIPP Program

Providing technicians with optimal Technical Information has been of concern to the Navy for many years. In a letter of 14 November, 1973, the Chief of Naval Operations established the NTIPP program to develop a Navy-wide system for generation, distribution, control and update of TI accompanying hardware systems, used for operation, maintenance, training, and logistics support.

During its relatively brief existence, NTIPP has made significant progress in establishing baselines, defining problems, developing concepts and alternative approaches, and demonstrating that TI improvement can increase material readiness. This report analyzes implications of an approach to improved TI involving adoption of a fully computerized system.

1.1.2 Current Status of DOD Advanced Planning and System Definition Involving Data Automation

The Navy and the Air Force have both been making substantive investments in advanced Technical Information automation developments. The Automated Technical Order System (ATOS) program of the Air Force Logistics Command represents the main Air Force initiative in this area, while NTIPP represents the main Navy initiative. The Air Force developed an ATOS Data Automation Requirement in 1975, which was revised in 1976, but which has not yet been formally approved by the Air Staff. Meanwhile, computer technology is continuing to advance and the ATOS Data Automation Requirement is now in need of updating in order to take recent relevant developments into appropriate account. NTIPP is proceding, however, through development of a formal system definition and other studies oriented toward formal definitions of what the Navy's position should be in the 1980's and beyond. This design and planning activity is critical for proper organization of near-term efforts in support of a systematic path of development leading directly to building the desired capabilities.

NTIPP thus presents an opportunity to develop and implement a centralized integration and control of the many and diverse procedures and equipments for Technical Information management. The full capabilities of modern data automation technology can accordingly be better brought to bear upon personnel productivity in order to improve material readiness. It is clear that R & D aimed at achieving improvements in TI preparation processes must take place, exploiting contemporary computer-system capability, if personnel productivity is to be substantially enhanced by NTIPP products.

1.2 The Transitional Navy of the 1980's

To characterize an integrated system of procedures and equipments for control of Technical Information in the 1980's, we must first predict the characteristics of the 1985 Navy to which the system would be applicable, and the relevant background conditions, constraints, and changes anticipated. The following appraisal has been synthesized from a number of official and unofficial unclassified documents, referenced in Appendix A, headed: "Sources Serving as a Basis for Economic, Strategic, Mission, Personnel and Energy Projections Bearing upon the 1985 Navy." The appraisal was prepared by knowledgeable analysts, including Vice Admiral George Moore II, Supply Corps, U. S. Navy (Retired), the former Deputy Chief of Naval Material; and Captain W. Y. Howell, U. S. Navy (Retired), former Director, Programs and Plans Division under the Deputy Chief of Naval Operations. Numerous discussions with other naval officers, both on active duty and in retired status, were also taken into account in the following projections. Relevant public speeches at the level of the Secretary of Defense did not contradict the projections described in the relevant sections.

1.2.1 Naval Posture

In the next decade, the U. S. Navy will undergo evolutionary rather than revolutionary changes. Despite ongoing debates over: (1) the cost and vulnerability of the large aircraft carrier in a nuclear missile, satellite-tracking age; (2) the short-war/protracted war issue; and (3) the use of a few expensive nuclear task forces versus a greater number of smaller and cheaper ships, the Navy of the 1980's is likely to look quite similar to the 1978 Navy. It will be somewhat modernized as new sensor, evaluation, and weapons systems are introduced or improved, and will become somewhat more combat-ready as the problems of the 1970's are ironed out. As new construction joins the Fleet, some of the aging ships will be retired, but not in comparable numbers, so that overall Fleet size will increase from the present post World War II low of 459 combat ships.

The Fleet will comprise about the same types and classes of ships as in 1978 and will be built around aircraft carriers, whether the number is 10, 12, or 14, as compared with the current complement of 13. There will be continued need for limited amphibious warfare forces for brushfires or contingencies and for anti-submarine and anti-air missile protection. *There will be four nuclear-powered task forces which can operate* in distant waters (e.g., Indian Ocean) essentially unconstrained by fuel endurance, but which will normally employ oil-powered escorts. The Navy will be predominately petroleum powered, with concomitant restrictions of range, at-sea operations, and sea-going training opportunities. The role of submarine forces will increase both strategically (nuclear strike) and tactically: anti-submarine, anti-surface Fleet and, to a limited degree, anti-shipping.

Ship life will remain roughly 30 years, a lifetime which can possibly be extended to 45 years by modernization. The current Fleet and the ships in the present building program will be with us for a long time, and any decisions reached in the next year or two affecting the basic structure or nature of the Navy will not be reflected in the Fleet of the 1980's.

Therefore, we can examine today's Fleet - and problems - without grave danger of fundamental change over the next few years. In addition to the long lead-time involved in ship planning/funding/construction, certain premises in the following areas underlie the assessment provided by this report. These fall into the following categories:

economic
strategic
naval missions
energy
personnel

In the economic area, even if the Navy retains its present funding lead in the Defense Establishment, and even if Defense budgets are increased over and above the inflation factor, money will still be tight. Competing demands in the Federal budget, ongoing resistance to higher budgets, and the overall economic climate of the nation militate against any substantial upswing in Navy funding. In fact, the Navy will encounter difficulty in obtaining the funds embodied in the current planned shipbuilding program of 111 ships. Therefore, emphasis will be placed upon phasing of new shipbuilding, holding costs down, and refurbishing, rather than massive replacement. In the event of a major conflict in the next decade, whether a short all-out war or a longer brush-fire limited war, the Navy will essentially have to fight with what it has. Another World War II-type massive buildup and replacement of the Fleet is unlikely.

The strategic picture over the next decade will change in degree rather than kind. We will still need to control and protect the sea lanes to our major allies and to be able to project sea power onto land littorals, but the responsibility will have to be met in the face of a Soviet fleet which will outnumber us in ships roughly two to one. Advanced satellite tracking systems, long-range accurate missiles, and nuclear weaponry increase ship vulnerability. In short, we will no longer have virtually uncontested control of the world's oceans. Indeed, U. S. resources must be concentrated in vital areas; e.g., the sea lanes to Europe, while other areas like the Eastern Mediterranean would probably be untenable in wartime for the U. S. Fleet.

These factors highlight the absolute need for both improved combat readiness and quick-reaction capability.

New dimensions to traditional requirements are emerging. The United States has become decreasingly self-sufficient in raw materials. Even in "peacetime", the requirement to maintain our channels to vital overseas resources may well require a Naval presence. In overt war, the Fleet would be faced with the need to protect, against formidable opposition, the 10,000-mile sea lane to Middle East oil and the shipping lanes for other key resources. The protection of our overseas supply routes will require dispersal of some escort and other combat ships on detached duty. It is crucial that readiness and also self-maintenance of such units be optimized if they are to perform independently.

The greater variety of tasks and the longer required at-sea periods implied by these considerations dictate that the Fleet must have an efficient and reliable logistics and supply system. These requirements place growing emphasis on information-management systems which permit rapid, accurate, and secure data transmissions and access, with increased recourse to newer computer technology.

Basically, the Navy will be required to do more through better use of resources - fiscal, material and personnel - rather than through any substantial increases. The need to rely on a limited number of ships requires that each ship be in optimal condition of combat readiness, with less down-time, less out-of-service time for repair, and fewer inoperative or marginally effective systems. Better performance of existing systems and proper readiness of new systems joining the Fleet require better use of available training and maintenance technology.

The Navy cannot afford to have a high fraction of a ship's communications, propulsion, weapons, or other vital systems in a down condition, awaiting the next tender or overhaul period. The mix of 1) aging ships with age-related maintenance needs, 2) modernized ships with newly installed complex equipment, and 3) new ships with advanced (and complex) systems, places a premium on proper maintenance, troubleshooting, and repair. This, in turn, places heavy demands on personnel productivity and on the systems backing up the technical personnel.

The increase in complexity of shipboard maintenance operations described will place extremely heavy burdens on crews who must use hard-copy Technical Information. Table IV illustrates this point. By 1962, the number of pages of Technical Information required for supporting an aircraft system had increased by a factor of ten beyond a 1953 aircraft. This trend in Technical Information complexity is continuing and has already obviously progressed beyond the point that hard-copy manuals represent the TI medium of choice. It has been estimated that a technician now spends around 30 per cent of his time searching through Technical Information to find the data that he needs (Rogers, 1977). This search function could be allocated to a computer system and give the Navy back most of this time for more productive uses.

For critical at-sea shipboard applications, the Navy is now modernizing its shipboard nontactical computer systems. The AN/UYK-7 computer series is being replaced with more modern ADP and the increased capacities that will be necessary for improving logistics information management (Roberts, 1978). The SNAP-2 program is now establishing requirements for shipboard ADP that will probably be similar to those required for shipboard applications of NTIPS. Also, the Naval Air Logistics Command Management Information System (NALCOMIS) is now developing an integrated logistics information management system that could implement nontactical ADP aspects of automated job performance aiding systems. Thus, the specific computer hardware, communications network design, and logistics information management framework that will be operative in the 1980's are now being formulated and are not now far from installation and implementation.

The current trend of decreased support in foreign bases may be expected to continue, reflecting growing nationalism and depolarization of the world. This factor necessitates greater self-sufficiency of deployed Fleets and implies an important need for recourse to new-technology solutions of Technical Information acquisition and distribution problems involving non-tactical data.

Table IV

Typical Technical Manual Growth

1939	J-F	GOOSE	525 pages
1942	F-6F	HELLCAT	950 pages
1946	F-8F	BEARCAT	1,180 pages
1950	F-9F	COUGAR	1,880 pages
1953	S-2	TRACKER	12,500 pages
1962	A-6A	INTRUDER	150,000 pages
1969	F-4	PHANTOM	225,000 pages
1978	F-14	TOMCAT	380,000 pages
1978	F-18	HORNET	400,000 pages

The world-wide energy situation emphasizes the need to use at-sea periods to full advantage. The Fleet will continue, during the next two decades at least, to be predominantly non-nuclear. Petroleum availability will continue to constrain at-sea time, which will not be fully exploitable because of material breakdowns and the inoperability of hardware systems.

The present personnel "crunch" in the Navy will not diminish in the 1980's. Spiralling personnel costs dictate a continued need to rely on reduced numbers of people. Labor-intensive manning is undergoing critical scrutiny; e.g., the minimum numbers of personnel required on the ship's bridge if bridge equipment is redesigned; the use of fewer supernumeraries aboard ship. In short, there will be fewer people to do the work, underscoring the need for technicians to be optimally effective. To this end, they must have improved Technical Information and TI presentation techniques beyond the best of the improved job aiding techniques.

Personnel stringencies are being experienced in the face of a currently poor personnel posture. Presently, motivation and esprit de corps are relatively low, and the supply of fully trained technicians is inadequate. Desertions are at an all-time high; around 42% of first-enlistment personnel fail to finish their enlistments; and while reenlistment is up to 19% overall, it remains low in key technical ratings that are already undermanned (U. S. News and World Report, 1978). The implications for technical maintenance and training needs are clear.

In part, the personnel situation also reflects two "vicious circles." The first involves the current nature of sea duty, in which long at-sea periods are followed by gruelling maintenance periods in port. As motivation falls, maintenance worsens, needs increase, and work load intensifies. The second circle pertains to key critical ratings. Because of inadequate numbers of trained technicians in these ratings, present personnel must be overworked to try to meet the workload. They then leave the Navy, further exacerbating the shortage. Both of these conditions point to the necessity to provide maintenance-aiding information-support systems which can both shorten and simplify maintenance jobs and permit their accomplishment by less fully trained technicians. In turn, a sense of accomplishment will lead to increased motivation and the cycle can be reversed.

The Navy inevitably reflects U. S. society and this is particularly true of its people. The "volunteer force" has accentuated increasing use of incentives and decreasing the prevalence of "negative incentives"; e.g., unduly harsh and long working conditions, frustrations, and inadequate Technical Information to do the work. Accordingly, personnel costs are climbing, but performance is not improving. It could be argued that the Navy is affected by overall changes in the work ethic in our society; that the drive for shorter hours, more perquisites, and improved working conditions carries over into the Services. Much of the glamor of Navy life has lessened; foreign travel is now available on a wide scale in our society; and civilian working conditions and compensations have improved. Competing against the attractions of the civilian economy, the Navy is encountering a manpower supply which will shrink by 15% by 1985, as the relatively low birthrates of the 1960's are reflected in a limited "new work pool" in the 18-year-old age group.

Nor can the Navy realistically expect an upswing in the caliber, level of knowledge on entry, or inherent technical capabilities of its recruits. The products of our schools and society will not be radically different in the basic ability than current recruits. Even the old cliche that a "depression will solve the Navy personnel problem" is true only to the extent that bad times simplify recruiting and may permit better selectivity. Bad times are not likely thereby to improve the capabilities of new personnel to cope with increasingly sophisticated hardware. Rather than a change in the inherent capability of new recruits, what is likely to emerge is a demand for improved communication of knowledge within the Navy, so that less-skilled technicians can benefit from the collected and systematized knowledge of more senior and equipment-familiar technicians. This demand implies the requirement for computer-mediated Technical Information systems for more complex types of technical maintenance functions such as troubleshooting.

The increased prevalence of women in the Navy will very probably extend to technical maintenance functions. The still relatively untapped pool of women offers a prime source for augmenting the technician ranks. Women technicians, however, may require more initial training in prerequisite skills than men for some years to come because of the cultural stereotypes and role identifications still persisting in the United States.

It would appear that the Navy should react to these factors by making greater use of computer-aided technology in its training programs, particularly those providing Technical Information support to technical and maintenance personnel. Thus in summary, we are expecting a Navy in the mid-to-late 1980's which is basically similar to the 1978 Navy, with the Fleet built around aircraft carrier task groups and submarine forces. The task of protecting sea channels of vital overseas resources; e.g., oil, is becoming increasingly difficult. This transitional Navy of the 1980's will have developed the techniques for exploiting the advantages of computer technology particularly to the extent that Technical Information Support is automated according to user-oriented designs and interfaced with new logistics information management systems now being developed. The 1970's have been a high-technology period, and with further engineering development of advanced-design ships and systems, technical maintenance will be faced with even greater challenges. User-oriented computer-based training and aiding systems that can replace the in-the-head skills and knowledge of the technical expertise that has become increasingly unavailable can be expected to develop into important cornerstones in the orderly and practical transition to the as-yet undefined but very different Navy of the 1990's.

2. NAVY TECHNICAL INFORMATION PRESENTATION SYSTEM CONCEPT: FUNCTIONAL CENTRALIZATION AND STANDARDIZATION OF TI

This section describes the mission of NTIPP, which is a functional centralization and standardization modality for Technical Information. Emphasis is placed upon outlining the impact of an all-digital data approach to its mission, as contrasted with centralization and standardization of paper-based TI control.

The origination of NTIPP arose from the need for developing contemporary solutions to problems of providing Fleet personnel with accurate, usable, and up-to-date information. It was determined that two major problems exist in the Technical Information now being provided to fleet personnel: (1) unusability of the standard kinds of information (engineering drawings, reports, and data), and (2) the lack of practical and definitive Technical Information writers' guides and TI development and management guides (Hughes Aircraft Company, 1978).

The preliminary system concept included upgrading Navy technology for producing Technical Information in hard-copy (manual and microform) form, using modern data-automation techniques and equipment for text and graphic production. Many Navy contractors already store Technical Information in digital form. NTIPP was seen as developing a Navy-wide capability for accepting contractors' TI in digital form, as well as accepting internally generated TI and converting this hard-copy data to digital form.

The decision to progress to a more advanced all-digital data system, including automation of Technical Information delivery, would impact upon the fundamental techniques used by NTIPP to accomplish its functional centralization and standardization. This section outlines how these techniques would generally contrast with a less advanced concept of using data-automation techniques for enhancing effectiveness of hard-copy TI materials preparation. It also deals with NTIPP functions in the system and operations control areas and outlines how these functions would be impacted by recourse to an all-digital data TI system.

2.1 Preliminary NTIPP System Concept

Figure 1 illustrates a preliminary system description concept concerning improving Navy TI through a Naval Technical Information Presentation System. NTIPS would exercise systems and operations control functions at a central level to guide both the TI system, as a whole and the acquisition activities individually.

The Technical Information (TI) definition subsystem would specify the precise TI requirements for each acquisition and implement procurement procedures to ensure timeliness and quality of TI.

Technical content would be generated by Navy contractor engineering activities under the guidance of Navy quality assurance (QA) personnel working under NTIPS direction, using new ground rules and improved TI-preparation guidelines.

The Replication subsystem would accept equipment contractors' digital output for processing through production, mastering, and replication stages, using data-automation facilities.

The Distribution and Delivery subsystem would control the initial distribution of TI, and delivery of TI to the final user, as well as storage for resupply purposes, and archival storage. This subsystem would also incorporate data-automation technology for maintaining the archives and automation of distribution control.

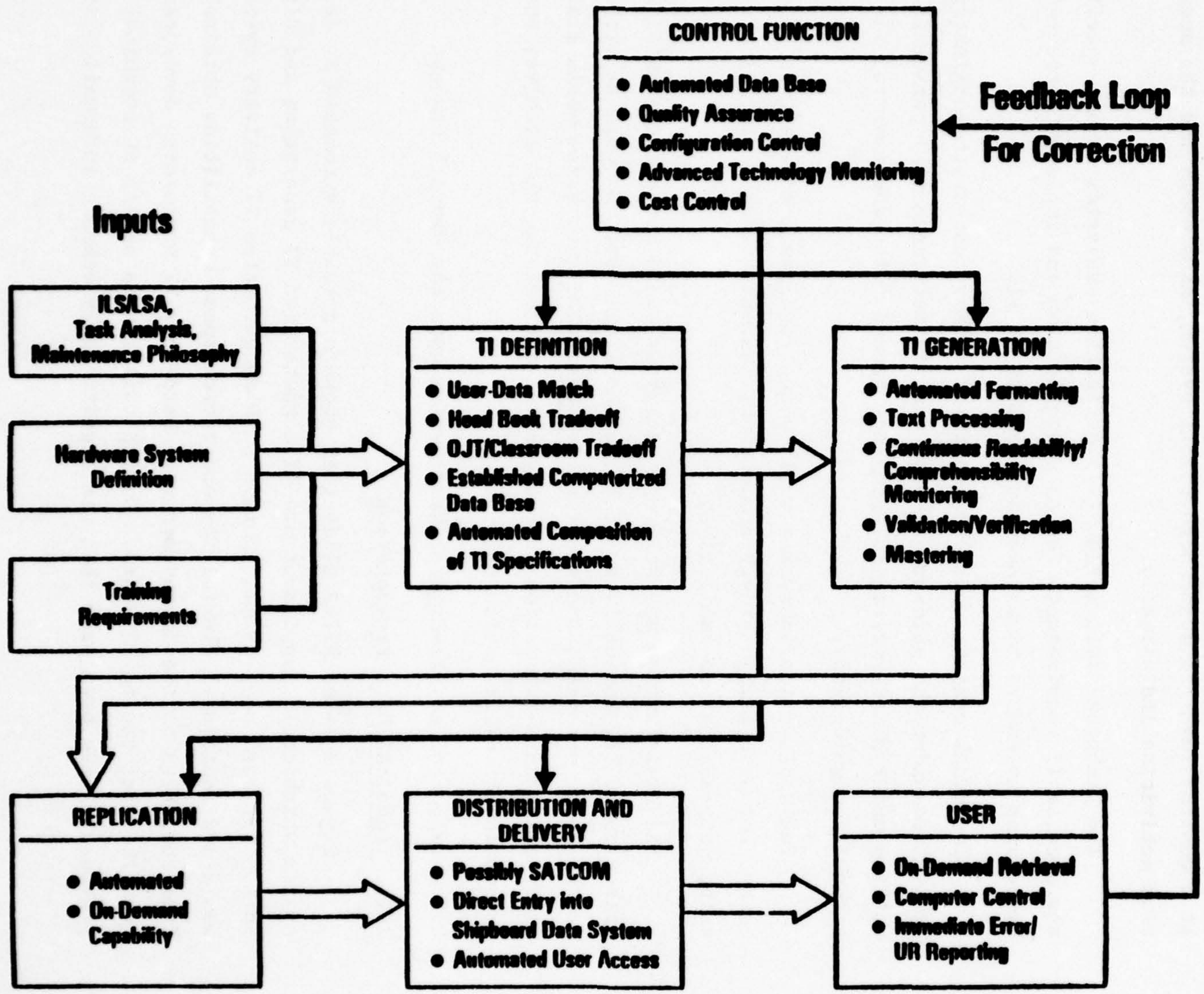
2.2 Impact of an All-Digital-Data System upon the Overall Concept

2.2.1 Technical Data Presentation

Figure 2 is an NTIPP slide that shows a possible automated TI delivery system which could supplement use of computerized TI generation and distribution for hard copy or microform. Such an automated TI delivery system would add additional flexibility and search-speed capabilities obtainable from computers to the improvements in hard-copy TI processing developed over the last ten to 15 years. During this time a number of technical improvements have been made that can significantly enhance information support

FIGURE 1

NTIPS Preliminary System Concept



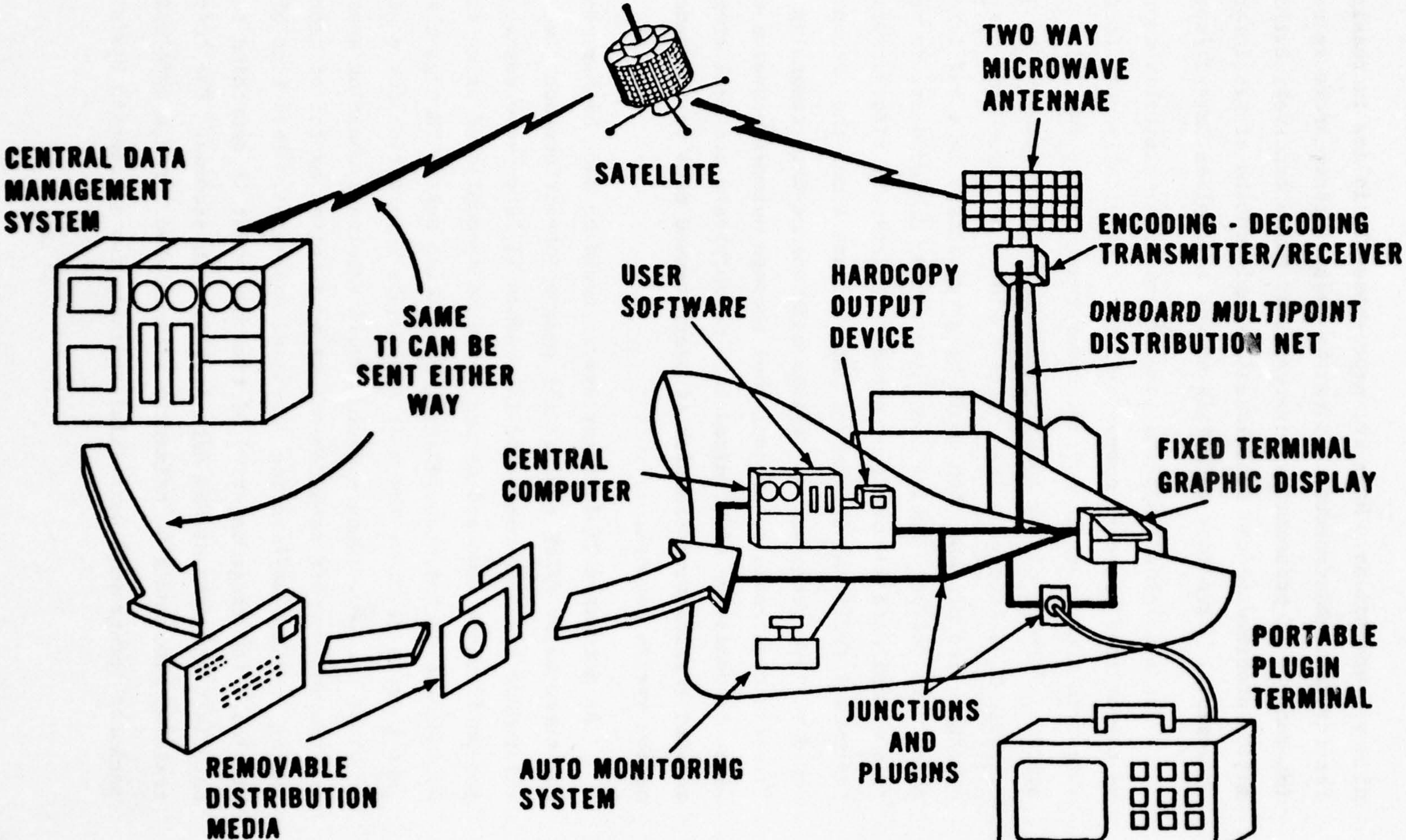
of Navy technicians. However, paper-based TI is now increasingly limiting the further enhancements that can be made; further progress requires fully interactive TI presentation systems that can effectively tailor the information provided to the technician's specification of his information requirements. Hard-copy materials cannot accomplish this objective well.

For a shipboard application, for example, digitally stored TI could be transmitted by radio communications or physically transferred to the ship from an archives at a level lower than that of the NTIPS central subsystem. Through either intelligent terminals or stand-alone mini/microcomputer TI-delivery devices, data could be accessed from shipboard archival storage. Technicians then could be given access to a sufficient amount of data, with delivery-device searching of the stored data, to permit presentation of tailored information suited to relatively idiosyncratic levels of individual skill and knowledge. At the same time, the presentation device could relieve personnel of various maintenance-data reporting procedures. This function could be accomplished through automatic system collection of data, transmission of acquired data to shipboard archival storage, and subsequent transmission/transfer of preprocessed data up the management information system network.

An automated TI delivery system could be made highly responsive to the three major NTIPS goals: (1) reduce job-performance time and errors; (2) reduce training time; and (3) reduce TI life-cycle costs. Reducing job-performance time and errors would be accomplished primarily through design of a system accommodating technician search through the automated data bank to retrieve the most applicable information for a given maintenance or other problem. Such a search would involve technician specification of information-support requirements as an integral aspect of user-system interaction (a dialogue/function keyboard approach). This kind of design could eliminate the large majority of time now spent in searching through bulky materials and make needed data available in seconds. The reduction of training time would be primarily accomplished through developing training packages (programmed materials) suitable for increasing basic technician

Figure 2

TOTAL SYSTEM FOR ELECTRONIC DISPLAY



skills and through allocating greater responsibilities to the system (book) in the "head-book" tradeoff. TI life-cycle costs would be reduced in various ways as a result of incorporating the experience and knowledge of highly skilled technicians into system guidance of less-experienced system users. No-defect parts removals could be reduced through making TI troubleshooting and repair easier to comprehend and more complete.

2.2.2 Technical Information Preparation

Among the most important of the NTIPS functions are those of assuring that Technical Information is properly defined, specified, and purchased. Tentatively it is proposed that NTIPS accomplish this function through four means:

(1) User-Data Match Module - Provide a means by which user-optimized presentation techniques relating to technician characteristics, tasks, and working environment, are identified.

(2) Modular Specification Concept - Provide the means to custom-tailor a TI specification to a particular procurement and to reduce redundancy and extraneous information in the specification. Such specifications would contain precise requirements for the TI content, presentation techniques, readability, vocabulary, access, publishing processes, and quality control of TI.

(3) Standardized TI Procurement Approach - Acquisition would be performed by system managers operating under NTIPS guidance to provide uniform customized TI procurement services coordinated with hardware system acquisition.

(4) Quality Assurance - Oversee development of the TI itself, insuring validation, verification and timely delivery.

An all-digital-data approach to NTIPS (1) could permit precision in matching TI to the user primarily through establishing TI requirements in terms of multiple, parallel levels of informational specificity (tracks) for communicating to individuals of different skill and experience levels. These "tracks" could be supplemented by the insertion of back-up reference materials to that they could be retrieved at those points in a procedure where they would be particularly relevant (information pools). Large amounts of back-up information could be stored in immediately available form, but not presented unless needed and called for.

An all-digital data approach would emphasize the use of data-preparation programs that would guide users and, in effect, enforce compliance with requirements for content, presentation techniques, readability, vocabulary, access, and quality control established by the modular specifications. Standard software and even use of complete minicomputer-based TI preparation systems could be called out for use under the contract as standard procedures. Such programming would reduce the problems of TI production monitoring and control of contractors' TI products.

The all-digital data approach would still require a standardized TI procurement approach in which Fleet needs for specified TI formats could be satisfied in a timely manner. Such standardization would require that development of specialists in the technical areas associated with TI and digital data TI systems operations.

In summary automatic data-processing facilities, data bases, and special applications programs would be required for supervising or overseeing development of TI requirements, delivery, scheduling, proposal and contract preparation, quality assurance, budgeting and funding, and contract administration.

2.2.3 Distribution and Delivery of Technical Information

The NTIP Distribution and Delivery subsystem must build a capability to control an amount of TI equivalent to some 12,000 new procurements and 20,000 TI updates per year. An all-digital data system can greatly reduce storage facilities for paper materials and also provide for rapid updating of digital data-base information, with high-speed digital data-transmission facilities. The central archive maintained by NTIPS would be supplemented with intermediate- and lower-level archives that could help to handle the TI distribution load. These facilities would also be used for processing and transmitting feedback data from the fleets upstream through the network to the NTIPS control function. The use of intermediate archives would also contribute improved protection of the TI data base.

2.2.4 The NTIPP Control Subsystem

The NTIPS subsystem for control establishes system policies and objectives at a centralized level, and provides operations support to acquisition activities. The first set of functions include: (1) system/product improvement engineering, (2) research and development, and (3) cost analysis/forecasting.

Whether the NTIPS places ultimate reliance upon hard-copy, microform, or all-digital-data TI-preparation systems, some substantial amount of system-product improvement engineering will be required, primarily in the ar ; of interactive software, data-base design, communications-network design, and analytical programming.

For either all-digital-data base system or a more conventional system cost analysis/forecasting functions will permit the Navy to obtain greatly improved baselines on procurement costs for new TI and for changes in TI. None of the agencies of the Department of Defense are now able to substantiate typical TI procurement costs well, largely because of the lack of such a centralization as has been planned for NTIPS.

The management information system (MIS) required at the Control function level to support an all-digital-data system offers a possibility of building-in better feedback from the fleets than might be obtainable with a hard-copy oriented TI system approach, because of capabilities for substituting automatic collection of maintenance feedback data for normally prepared reports. System data-logging capabilities can offer capabilities for establishing performance and training standards, based upon hands-on maintenance in on-the-job settings. Certain kinds of logistics information can also be obtained with an all-digital-data system. The total MIS impact of an all-digital-data approach cannot be projected until decisions are made with respect to the NTIPS relationship to logistics-management information-consolidation programs now being planned.

The NTIPS Control function will also promulgate detailed operating procedures for the NTIPP activities. An all-digital-data system approach would very likely emphasize standardization via development of interactive programming to support accomplishment of practices and procedures. The remaining NTIPS operations management functions (configuration accounting, feedback/update, and cost monitor/evaluation) provide centralized TI configuration, the feedback network, the out-of-production TI-update capability, and the cost-monitoring and evaluation system.

In summary, the all-digital-data approach could permit extensions of the usability of Navy TI (1) through allocating more favorable headbook tradeoffs; (2) through providing more complete, but easily retrievable data; (3) through providing improved TI guidance for troubleshooting; and (4) through providing special programmed materials for training purposes. The development of support programming for TI preparation could help to force compliance with the NTIPS TI-standardization mission and also provide more useful guidance on TI preparation to Navy contractors. The process of procuring TI and the work of TI engineers could be simplified through development of an appropriate data-base management system compatible with contractor-owned or government-furnished ADP equipment. Distribution of digitized TI through a distribution network involving several levels of TI processing and storage would reduce physical TI storage requirements and permit more rapid transmission of TI to TI users. Change orders could be more rapidly and more economically accomplished through interactive-programming approaches to TI modification. The all-digital-data approach would also permit better monitoring and evaluation of TI costs, both in general and with respect to specific TI procurements. Feedback from the fleets could also be facilitated through substitution of automatic reporting procedures for manually prepared reporting procedures.

2.3 Hard-Copy Technical Information

This section deals with the improvements in Technical Information that have been made in recent years and the remaining limitations that the paper-and-print medium continues to impose upon TI usability to technicians.

Foley (1978) has recently prepared an analysis of the impact of advanced maintenance data and task-oriented training systems of the Department of Defense. He pointed out that life cycle costs of military hardware systems are already high and are continuing to rise, particularly because of such factors as high maintenance-personnel costs, high cost of spare parts, and the prevalence of no-defect part removals. The primary solution Foley identified was that of increasing on-the-job utilization of first-enlistment personnel, as well as increasing the efficiency with which all maintenance tasks are performed. Hence, those technologies which are effective for improving maintenance efficiency and offer potential for reducing entry-training requirements are essential if life cycle costs are to be substantially reduced.

It has been clearly established that traditional maintenance manuals are surpassed by various of the more newly developed job performance aiding techniques. Fully proceduralized job performance aids (FPJPA's) have been studied in comparison with traditional maintenance manuals, using highly trained as well as inexperienced technicians. For nontroubleshooting tasks, FPJPA's are superior to the enriched logic-tree troubleshooting aids, which in turn are more effective (for experienced technicians) than the traditional manuals. The deductive aiding approaches represented by the Air Force Symbolic Integrated Maintenance Manuals (SIMM) or the newer Navy Functionally Oriented Maintenance Manuals (FOMM) are more effective (for experienced technicians) than traditional maintenance manuals. The deductive aids (FOMM/SIMM), however, are usable only by highly trained and experienced personnel, for whom they were designed. Less-skilled technicians do not have the background of knowledge and skills assumed of the user by FOMM/SIMM and are, therefore, less able to benefit from these types of Technical Information (Foley, 1978).

Despite the current enthusiasm and the data on hand supporting adoption of the fully proceduralized job performance aids, some problems will remain to be solved until such aids are transferred to an automated medium.

One of these problems being observed in the Army's Integrated Technical Documentation and Training Program (ITDT - now called Skill Performance Aids, SPA, program) is that less skilled technicians can accomplish non-troubleshooting tasks with proceduralized job performance aids, but at a considerable cost of time. Problems also exist in the determination of step size in the step-by-step instructions, which are sometimes too large for a less-skilled technician to follow and sometimes too small or detailed.

Troubleshooting remains the primary challenge as an assignment to less experienced technicians, and typically has to be reserved for more experienced and highly trained personnel. It is essential to solve this particular problem if the Navy is to obtain needed life cycle cost reductions and material-readiness improvements. Logic-tree troubleshooting aids can be enriched for use by less-skilled personnel, but they also require levels of in-the-head knowledge that the less-skilled technicians do not often possess.

Foley's major point in his review article was that, considering the transitory nature of maintenance personnel, as well as their limited training, logic would dictate that maximum utilization be made of the "book" when making the head/book trade off.

Foley's review was limited to hard-copy aiding and task-oriented training. It did not review or discuss automated job performance aiding systems, for which the current data are quite scant.

Recourse to data-automation technology, however, could quite likely provide an effective approach to implementing Foley's recommendation to increase emphasis upon the book in the head/book trade-off. This subject and supportive data will be briefly discussed subsequently in this report.

From Foley's and our own reviews of the relevant literature on R & D directed toward Technical Information improvement, it is clear that the newer proceduralized aiding techniques should be implemented on a much wider scale than in the past, as the Army's Training and Doctrine Command is now doing. However, it is also clear that the FPJPA approach is no panacea and that it still presents limitations with respect to providing the levels of information support that less-skilled technicians need both in non-troubleshooting and troubleshooting tasks. Behavioral Technology Consultants has, in fact, been undertaking studies of enhancing the usability of both FPJPAs and deductive aids through adding the flexibility of automation to the innovations previously identified, in order to improve usability of the FPJPA's (Frazier, Huang, and Roth, 1978). Preliminary results on technician evaluation of these further enhancements have been encouraging.

2.3.1 The Argument Supporting Recourse to Automated TI Presentation

While all three services are actively working on data-automation techniques for computer-assisted generation of hard-copy Technical Information, some uncertainty continues to exist regarding the feasibility of choosing an alternative, or mix of alternatives, to continuing reliance upon hard-copy Technical Information for use by technicians. Three major alternatives to hard-copy Technical Information delivery are: video disk, microfiche, and computer information delivery systems.

Based upon the present BTC study of the last alternative over the last several years for the Air Force, it has been possible to develop a case supporting the introduction and increasing reliance upon automated Technical Information delivery systems similar to NTIPP's earlier formulations. The remainder of this section describes this case in detail, and then provides an analysis of the alternative medium choices and medium mixes.

Reallocation of the TI search function. An interactive automated TI presentation system can permit the technician to specify his information needs and can task the system to find and present the needed data. This feature can save time and reduce frustration.

Motivation enhancement. An interactive automated system can be designed specifically to make system use positively reinforcing, so that technical data will be better used. Interaction with a system follows the laws of operant behavior (Frazier, 1969), and the involved reinforcement parameters can be treated in ways that can reinforce system use.

Graphic enhancements. Computer graphic techniques can provide more abundant illustrations, choices among alternative graphics, animated graphics, graphic simplification, and graphic enlargement for viewing graphic materials at distances.

Information tailoring. Using dialogue-based information-retrieval techniques, it is possible for technicians to construct the pattern of information support provided by the system to suit their individual experience and skill levels.

Ease of communication. The use of function keys to communicate with an automated system can effectively eliminate the need for training technicians in system operation. Technicians also do not have to have typing or programming skills for this kind of communication.

Capability for data collection. An automated system can be constructed with the capacity for automatic data collection of information on technician proficiency for training purposes, and of 3-M types of data.

Administration of enriched troubleshooting-tree guidance. The experience of highly trained and experienced technicians can be preserved and converted into automated logical troubleshooting trees and these provide less-skilled and less-experienced technicians with the experience of others.

Ease of integration into an overall logistics information management system. Digitally coded Technical Information can be transmitted, changed, duplicated, and stored easily through the use of communication networks and automatic data-processing equipment.

It is clear that the potential advantages to be derived from recourse to automated Technical Information delivery systems cannot be achieved with simple transliteration of hard-copy manuals. In order to solve important Technical Information usability problems, an interactive system design is absolutely required to implement the enhancements needed in Technical Information usability that are possible with an automated Technical Information delivery system.

Technician evaluation of Technical Information enhancements. The Frazier, Huang, and Roth (1978) study provided an opportunity to empirically assess technician reactions to a system capable of presenting information enhancements of the kinds described above. Interviews and questionnaires were administered to 16 veteran technicians, from Army, Navy, and Air Force maintenance backgrounds. Skill ratings ranged across a wide spectrum, from strikers to first-class maintenance technicians and beyond. A hands-on test of actual troubleshooting proficiency with system assistance was delivered to eight of the technicians, who came in pairs to the system simulation laboratory used for the study.

All eight of these technicians performing the troubleshooting task were able to locate an experimentally-introduced fault in a printed circuit board of the C-141 navigational computer which was used as a testbed.

Technicians provided very helpful design inputs with respect to graphic presentation formats. For the FPJPA evaluations, the single most useful feature was rated by most technicians as the use of multiple, selectable, and changeable levels of informational specificity (tracks), with provision of back-up reference information in the form of information "pools" that could be retrieved when and where needed, but which were not presented unless needed. The provision of selectable graphics information concurrent with textual dialogue was also rated as the single most useful feature of the automated FPJPA data by other technicians. For the deductive-aid materials (integration of FOMM-type aids), the single most useful feature was identified as system guidance for troubleshooting based upon the experience of technicians familiar with the equipment.

One very interesting observation had to do with the type of deductive aids that technicians selected for use in troubleshooting. Almost invariably, technicians retrieved system guidance for a troubleshooting sequence, in conjunction with printed circuit board-locator diagrams, in preference to the use of blocked schematics, electrical diagrams, or functional descriptions. Experienced technicians were not observably different in this respect from inexperienced technicians. This choice was described in terms of a preference for taking advantage of the experience of knowledgeable persons in preference to hardware information, which provides no special cues for use in fault detection.

Technicians rated system operation in terms generally ranging from favorable to highly favorable, and generally as enjoyable and efficient. The use of computer graphics was considered helpful and useful by all but three technicians. Being able to work at one's preferred level of technical detail was rated as easily possible by eleven; as possible with some effort by two, and as not possible by two. Almost every technician rated the use of function-key communications as covering everything he wanted to communicate to the system.

These results must be considered preliminary in nature, but represent the only source of data available on such a system design at this time. It is anticipated, however, that technician acceptance of such an interactive Technical Information presentation system will be satisfactory upon introduction to Navy operations. While CRT-graphics terminal presentation of graphics information required some modularization (subpictures) of complex graphics materials, the capabilities for retrieval of selectable graphics and for graphics enlargements were rated highly.

Thus, the only data obtained to date on a truly user-oriented automated Technical Information system support the use of an automated medium. Comparisons with the alternative-medium choices are presented in the next section.

It can be noted that the usability enhancements pointed to by the technicians studied represent extensions and modifications of the better features of the improved hard-copy aids applied in conjunction with exploiting the capabilities of computers for doing what computers do best; i.e., rapid search and retrieval of selectable information, and storing and presenting massive amounts of data.

3. EVALUATION OF ALTERNATIVE MEDIA FOR TI PRESENTATION

BTC was tasked to undertake a specific comparison between the all-digital-data alternative to hard-copy technical data presentation and alternative choices. Among the alternative choices was that of a mix of different media, as opposed to total dependence upon one medium of choice.

The results of the task are summarized in Table V. Video disk and microfilm are evaluated in this table against all-digital system approaches, with respect to significant evaluation criteria.

The microfiche/microfilm alternative has already been rather heavily promoted and tried, with clearly less-than-desired results. The most obvious advantage of microform lies in the fact that less physical space is consumed in storage of these materials. It is interesting to note that for use in hybrid systems such as PLATO, which employs computer-controlled alpha-numeric displays and microfilm or filmstrip photographs of graphic materials, current emphasis is being placed upon getting away from microfilm. The use of 35-mm. film strips is now preferred in support of higher quality graphic materials. The Navy has encountered problems in using microfilm, and the microfiche/microfilm presentation of Technical Information as a primary modality is considered unsatisfactory by some naval commanders and Navy logistics officials.

Video-disk systems are usually claimed by supporters of this technology to offer the advantages of high graphic capacity and graphics quality. It is now clear that if they are to be made flexible enough to suit the criteria of usability cited above, in Section 2.2.2, then a computer and a magnetic-disk storage with associated software are required. These additional requirements make video-disk systems no different from all-digital systems except for the need for additional electromechanical hardware; i.e., video disks, and viewing devices. While the lower cost of reproducing video-disk materials from earlier recordings is claimed as an advantage of the approach, the costs of changing data in any way can be expensive. Digital data bases can be modified quite easily with appropriate programming and then transmitted

Table V

Capabilities	Video Disks and Microfilm	All Digital Systems
Physical Handling	Hardly any protection from dust, scratch, and fingerprints. Problems aggravated by dirty and greasy hands.	Disks and drives are hermetically sealed. Technicians need to touch only the keyboard.
Need of Multiple Copies	If, say, 3 technicians have to perform the same task independently, 3 copies of the same TI must be available.	Only one copy is necessary at local TI library. A technician just selects and loads his system with the TI he needs.
Data Compression	A frame occupies the same amount of space no matter how much information it carries.	Data may be compressed to save storage. There is no wasted space.
Access to Needed Information	Without computer control, search can be time-consuming, straining and frustrating. Although it can be computer controlled, the access time is typically more than 5 seconds, about 100 times that of magnetic disk storage.	Access time is in the range of 25-80 milliseconds. Only needed information is shown on screen.
Modification	Cannot be changed or modified.	A file in disk storage can be retrieved, modified or changed, and deleted.
Recording	Cannot record at end-user level.	Can collect and record data for audit of performance, supplies, etc.
Software Innovation	Not programmable, thus no different from paper-based job aiding except for physical size of TI.	Software flexibility and innovations are possible and actually in existence which can make job performance aiding much more effective and efficient. Relevant data may be collected during performance of a task to identify a technician's weakness area and to make sure he completes his task correctly and thoroughly.
Zoom	No zooming capability.	Can zoom.
Classified Data	Mechanical video disks and microfilm offer little safeguard in handling and transmitting of classified data. With optical disks, video may be encoded so that specific combinations of tracks must be read simultaneously in order to view the classified data.	Data security measures can be implemented easily.

from central archival storage via satellite or high-speed digital data links to any desired location. Especially noteworthy is the fact that both microform and video-disk systems are player systems that do not record, store, or transmit information up-line from user locations. In effect, microfilm and video disk technologies present the same essential inflexibility as hard-copy Technical Information. In order to achieve any useful flexibility, video-disk systems would require interfacing with computers. The addition of video disk storage to a computer system for purposes of adding graphic-presentation capacities to a basic alphanumeric-presentation system also adds additional mechanical and optical hardware, which may not tolerate adverse physical environments well.

3.1 Mix of Alternatives

Several alternatives to an absolute single-medium for Technical Information can be identified. It should be recognized that the Navy cannot switch from hard-copy Technical Information to any other medium overnight. A modular implementation approach for NTIPS is implied, and it should be recognized that the all-digital data TI medium still lies in the category of an "advanced system" which has not yet been subjected to rigorous field evaluation. Support of an all-digital data approach appears to be growing in the Navy as relevant research and orientations of naval officials bring the feasibility, relevance, and practicability of the approach into clearer perspective. However, for some years to come, and probably well into the latter 1980's, some kind of mix of alternative TI presentation media will be necessary.

If data-automation techniques are used for preparation of hard-copy TI, it is possible to develop microfiche/microfilm as a by-product of the TI production process. The development of computer-controlled video-disk systems that can approach the flexibility of computer technology is much more complex and would require substantial investments in special-purpose hardware and software development, along with field test and evaluation of user acceptance and performance-enhancement.

Since microform does not represent a substantive usability-enhancement measure, the only useful application that would appear reasonable to maintain would be the use of microfilm for back-up archival storage of technical data. This utilization can be easily and inexpensively accomplished at some central location in the logistics establishment, regardless of whether the main source of Technical Information to be provided to the technicians is based on video-disk, hard-copy, or digital data presentation. However, under appropriate storage conditions, magnetic storage does not degrade much over time, so microfiche storage may really be unnecessary.

The alternative of interfacing a minicomputer system with a video-disk system is now receiving evaluation at the Army's Training and Doctrine Command (TRADOC). The results of this analysis are not yet available. This possibility would appear to be the most attractive alternative to the fully digital-data approach emphasized by this report. The expectation by the evaluation staff at TRADOC has been informally reported to be that the system flexibility will be less satisfactory than the fully digital-data approach, although specific interest exists in adding voice tracks in conjunction with graphics and text.

The alternative of a continuing dependence upon hard-copy Technical Data, using modern minicomputer- and computer-controlled photocomposers, is receiving substantial emphasis in the Air Force Logistics Command.

This approach offers potential for reducing backlogs in TI production and change orders. However, care must be taken to insure that hard-copy production actually incorporates the usability improvements already contributed by TI-improvement research programs, and that such a system does not become a dead-end development. This plan does not thus far provide for improving performance of other aspects of the TI system, such as digital-data delivery of technical data to users.

Issues involved in making selections among alternative all-digital-data TI delivery systems are discussed in a subsequent section.

Given that no radically new or unexpected developments in the video-disk area occur, the results of the present study support the following recommendations. The NTIPS Development effort should:

1. Place emphasis upon developing an all-digital-data delivery system for textual and graphics information, to be phased into subsequent operations in an incremental and modularized way.

2. Develop specialized computer-assisted TI-preparation systems and digital-storage and -reproduction facilities for archival storage and distribution of Technical Information.

3. Consider use of hard-copy illustrations in conjunction with automated presentation of alphanumeric data, as an interim measure, during early implementation of the data-automation system.

4. Actively monitor the Army's feasibility studies and any subsequent system-development studies of video disk.

5. Incorporate a hard-copy printout feature for retrieving disposable printouts of screen information.

4 SYSTEM DESCRIPTION: AN ADVANCED SINGLE-MEDIUM TI SYSTEM

The following discussion describes a system in the latter 1980's, in which the entire body of Technical Information (TI) is maintained in computer storage for on-demand retrieval and use by naval personnel. The system design is an interactive, dialogue-driven design, for user utilization on an ad hoc basis. It supports operation and maintenance, troubleshooting and repair, and training and supply/maintenance/repair management and reporting.

The implementation of this Navy-wide system will offer, for the first time, a full integration of the maintenance manual, operational software for logistics/supply management, and automatic test equipment/ built-in test equipment. This implementation will be fully user-oriented, with high levels of conformity to usability standards from initial generation of TI through TI presentation. Emphasis will be placed upon maximizing on-the-job performance productivity in maintaining naval material in combat-ready condition through increased emphasis upon TI presentation-system guidance of the technician. TI usability enhancement will be made a continuing element of routine work, so that the increasingly complex systems of the 1980's can be maintained by a relatively small, young, male and female work force, without elaborate training.

4.1 Basic Functions

A computer-based Technical Information system fulfills three functions:

- Preparation of Technical Information
- Distribution and Delivery of Technical Information
- Use of Technical Information

These functions will be discussed in the following sections.

4.2 Utilization of Technical Information

The nature of TI content to be used by means of an information-delivery system is the controlling factor governing the structure of TI, and therefore, its preparation. For this reason, the process of using TI that meets usability standards is discussed prior to discussions of TI preparation or TI distribution and updating.

The characteristics of the system used for delivery of TI to users should be determined early in the overall system-design process. The process of TI creation and the form in which TI can be presented are dependent upon the specific characteristics of the delivery device and associated software.

Utilization by the end-user (technician) of computerized Technical Information for job aiding in performance of maintenance tasks involves a vertical interaction or dialogue between a human and the presentation system. In undertaking a specific maintenance or troubleshooting/repair work assignment, the technician loads up his delivery device from the local shipboard archive according to a work-order retrieval code provided through supervisory channels. If he is using a non-portable system, this loading is accomplished by appropriate terminal keying at an output point of the shipboard digital communications system. If a portable device is used, the device is plugged into the shipboard digital communications network or directly into an archival output terminal. In either of these possibilities, the local archival computer recognizes the presence of the online delivery device and initiates a brief dialogue to identify the purpose of the transmission. The technician replies with natural-language dialogue functions, specifying whether data are being requested from archival storage or whether data are being presented for archival storage. In the former case, this interaction process results in loading a data "package," containing all the TI needed for performance of the work assignment, including all the primary and secondary information available in the presentation formats that the technician might wish to use.

After the local archival system has selected the data package and loaded the package downline to the delivery device, the delivery device may then be disconnected or unplugged from access to the local archival system.

At the same time, a print-out may be prepared by the archival system at the appropriate supply station, so that the equipment and supplies needed for the job can be made available when needed. Parts utilization can be identified for logistics data acquisition at this time.

Upon arrival at the work site, the technician initiates a process of interaction that provides primary information such as set-up procedures, cautions, warnings, and special notes, initial tests, step-by-step procedures, follow-on tasks, etc. Back-up reference information is retrieved on an ad lib basis at appropriate points of the procedure, so that the technician can construct or tailor the information provided to satisfy the information needs associated with his existing level of skill and experience.

During the interaction process, the delivery device maintains a data log of the information presented and requested by the technician, as well as time data regarding how long the user takes to complete specific work functions. The system also recognizes and logs additional information for logistics/supply and other purposes.

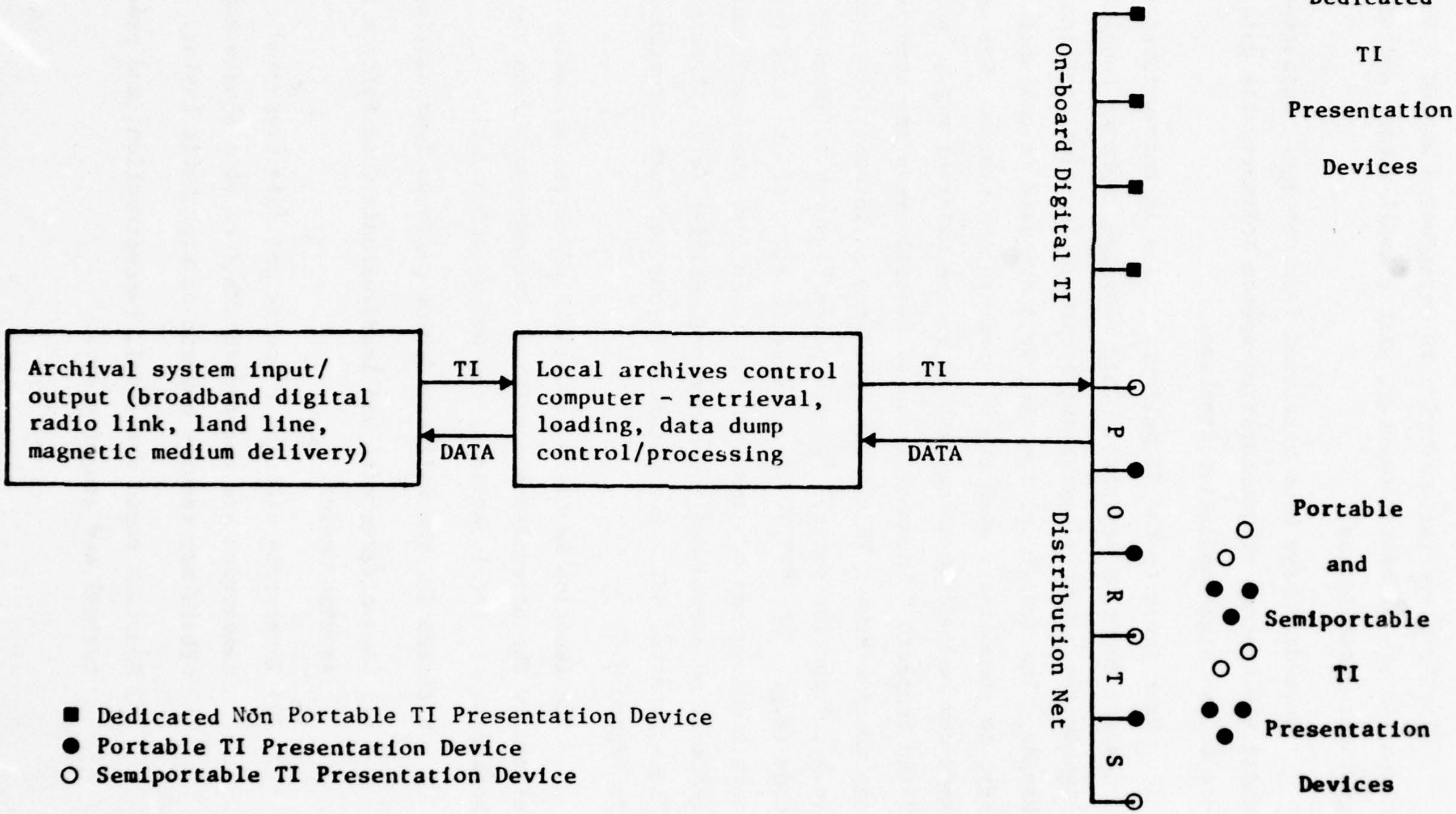
When the work has been completed, the delivery device is reconnected to the local archives for dumping the delivery device's collected data into the archives for processing and analysis. After the data dump, the delivery device is again disconnected from the digital data communications or from the archival storage device. Such a system is illustrated schematically in Figure 3.

4.3 Hardware and Software Requirements

The central processor unit (CPU) is a general-purpose processor that has been interfaced to a medium-capacity mass memory. This mass-storage device will probably be a disk system that can accept data from local archives for delivery to the TI presentation or delivery device. TI can reside in archival storage after being transmitted through a high-speed digital-data network or after being physically transported in the form of magnetic-disk storage to the shipboard or land-based site.

FIGURE 3

Shipboard Or Land Station TI Distribution System:
Receipt/Transmission, Archiving and Presentation of TI



The TI-presentation device is constructed around a small, special-purpose mini- or micro-computer, with a small memory and with high-quality graphics capabilities.

Once data have been retrieved from storage, reconstructed, and formatted under the control of presentation-system software, the data are displayed on one or two high-resolution displays.

User input to the TI delivery device is accomplished through the use of a special function keyboard. This function keyboard consists of a small, lightweight assembly containing around 30 function keys and a standard numeric keypad. The individual function keys are used in conjunction with numeric keys to communicate with the TI presentation system. One group of function keys can be used to accomplish an entire message; e.g., "Suggest next step," "Step complete." Another group of function keys are used in conjunction with the numeric keys. This group specifies an information request of some type (e.g., "Describe parts," "Locate parts.") which is identified by a numeric code (e.g., "1", "3".) The message consists of at least two key presses for this second group of communicative functions, the specification of type of information needed and the numeric identifier (e.g., "Describe parts, 3," "Locate parts, 4"). One possible layout for such a function is illustrated in Figure 4.

The function keyboard can be cabled to the presentation device, to eliminate the necessity for walking back and forth from the equipment being worked on to the location of the presentation device.

Software for the delivery device performs four distinct functions:

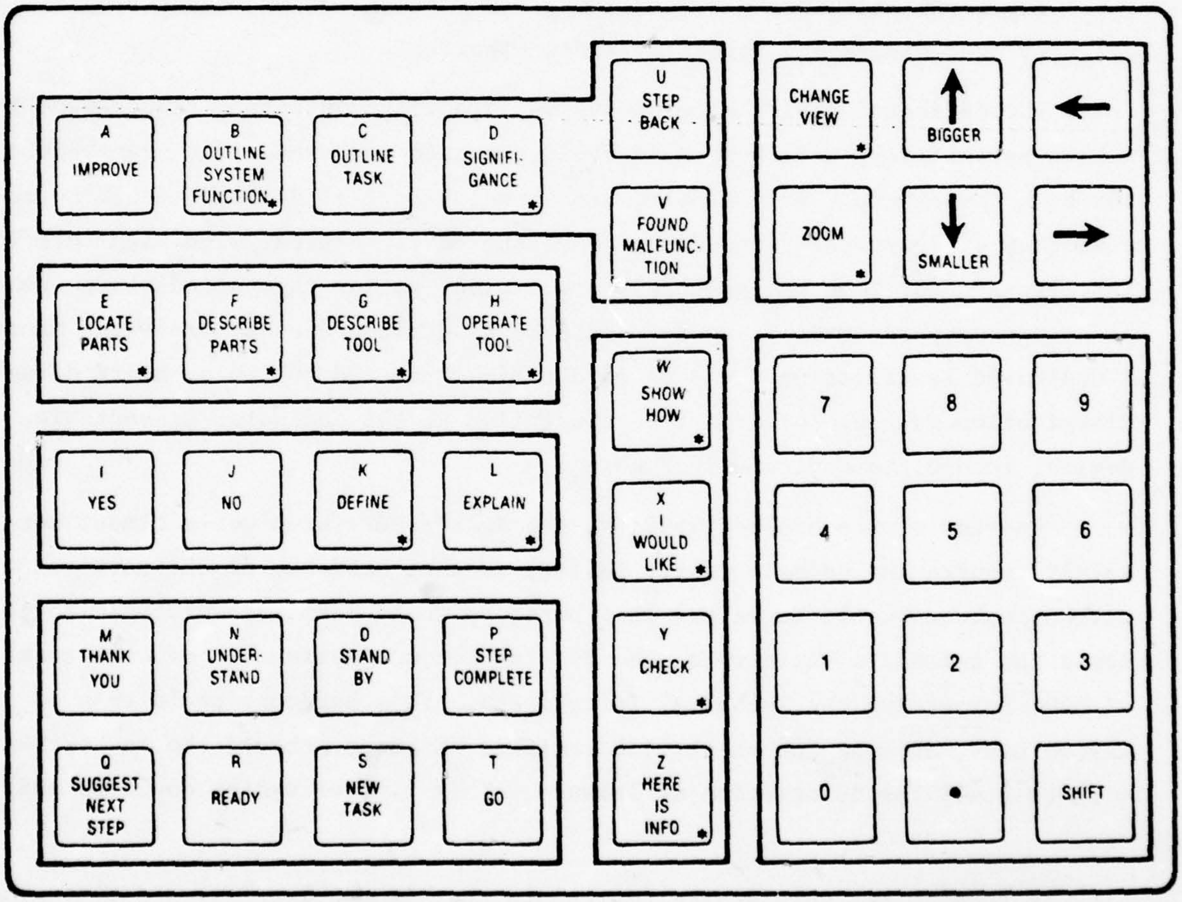
(1) Communicates with and loads/unloads data to/from the local archival storage device.

(2) Interprets dialogue requests and data presented. Some dialogue categories are entered in the form of a single key-stroke, while others may require numeric or alphabetic keying.

(3) Provides rapid retrieval, reconstruction, and presentation of textual and graphics data.

FIGURE 4

The Function Keyboard



(4) Collects feedback data. This can be accomplished through simply maintaining an information and time log in system memory, specifying which information has been presented, and retaining various time data associated with rate of progress through the given maintenance procedure. These accumulated data are then subjected to analytical programs for interpretation at archival levels, so as to extract needed information.

4.4 Options and Considerations

4.4.1 Configurations

Three potential hardware-configuration options for implementation of TI delivery are: dedicated, portable, and semiportable.

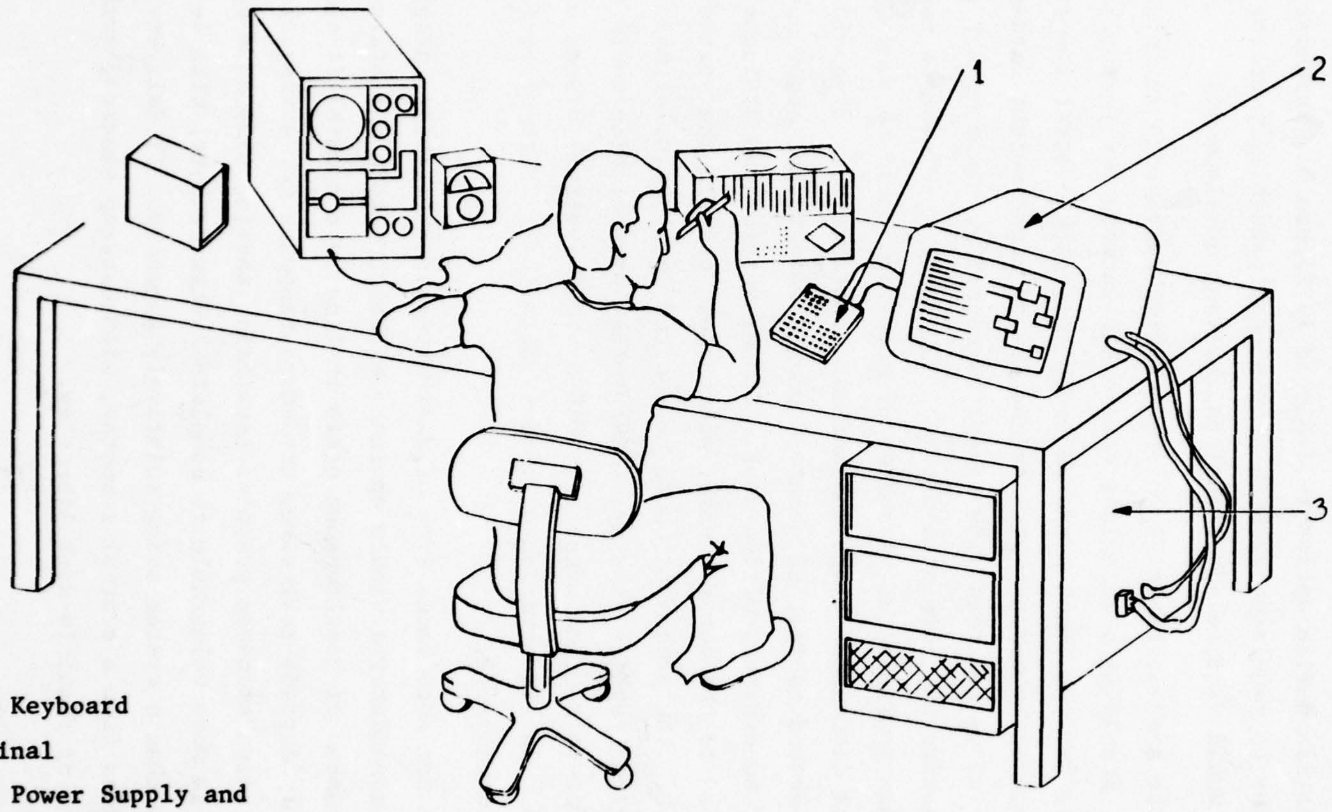
The dedicated-device alternative would not incorporate a requirement for device portability, and thus could avoid the need for expensive, lightweight, low-bulk components. For example, high-resolution flat displays could be replaced by a high-resolution cathode ray tube (CRT) terminal with high interval intelligence for text and graphics data. Disk, rather than solid-state (bubble or charge-coupled device) memory, could be used for presentation-device memory. A dedicated installation would be hard-cable connected to the on-board data-distribution system. An artist's conception of the dedicated presentation device, in use, is depicted in Figure 5.

In view of its non-portability, the dedicated system would almost certainly require including a copier device, so that hardcopy of CRT-terminal screen contents could be made. This hardcopy would permit the technician to leave the immediate vicinity of the display for accomplishment of work tasks, without forgetting the Technical Information. This hardcopy could then be thrown away, or kept for on-the-job training purposes, should the technician wish to study the information at leisure. This kind of system could be built now.

A totally portable device represents the highest level of sophistication. This device would be about the size of a small suitcase, weighing on the order of 20 kilograms. Flat-panel displays and solid-state mass storage of very

Figure 5

Artist's Conception of a
Dedicated Hardware Configuration



1. Function Keyboard
2. CRT Terminal
3. Computer Power Supply and Direct Access Storage

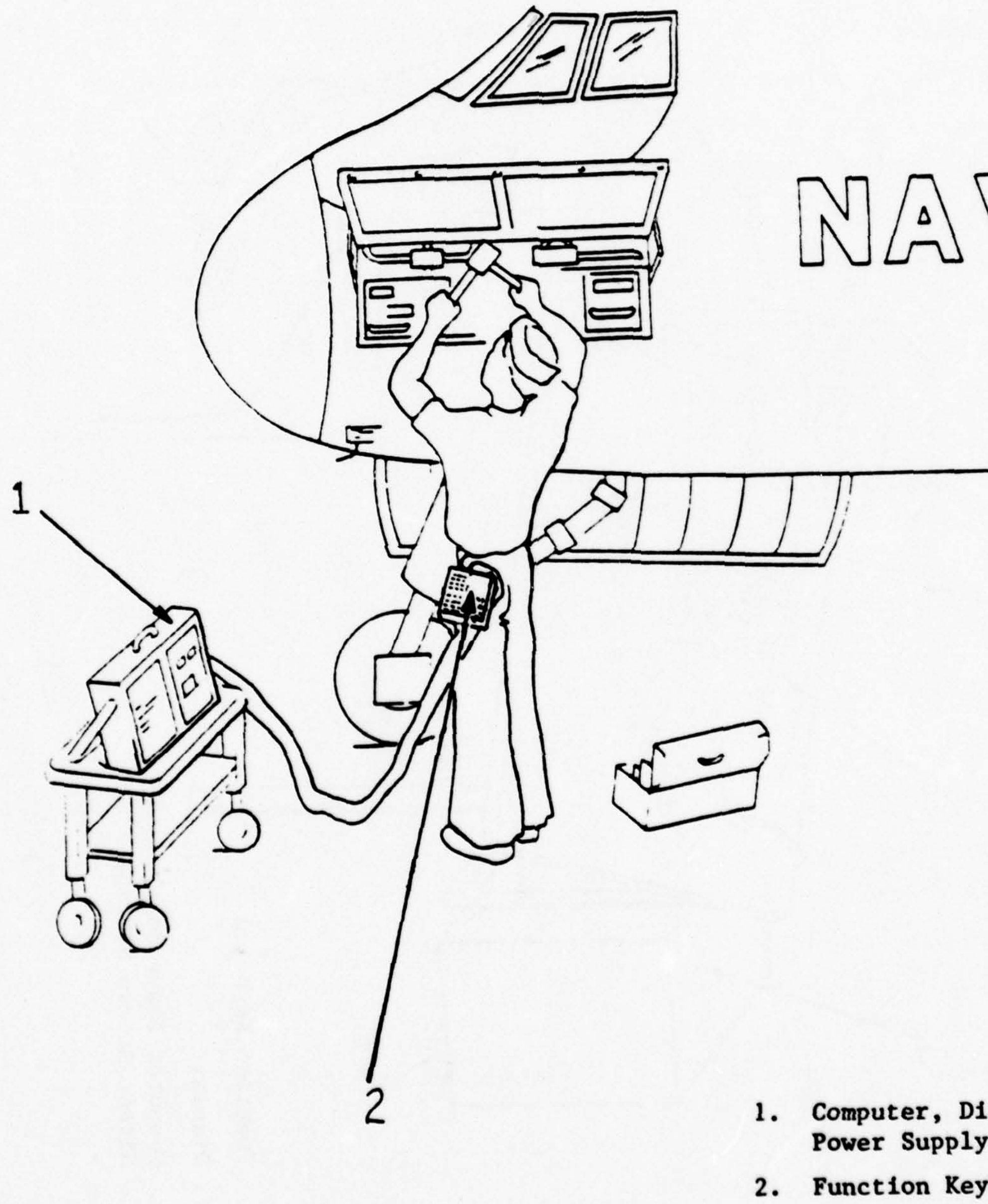
high density could be used to meet mass and size constraints imposed by the need for portability and the requirement for use in confined work spaces, such as a jet aircraft's cockpit. An artist's conception of this presentation device option is depicted in Figure 6. Hardcopy printouts would not be required, because of the easy portability of the system. This system would require additional engineering development.

The semi-portable TI delivery device represents an intermediate approach, providing a technical compromise between the portable and non-portable devices. Such a system could incorporate several options. Current technology already permits the use of light-weight hard-disk storage systems of up to around 100 megabytes capacity, minicomputer processors, and graphics CRT-terminals with all the basic requirements needed to support this application. A system of this kind could be hand-carried by use of quick disconnect plugs and modular construction. It could be mounted in a roll-around cabinet of about 80 pounds weight, and about one-eighth the size of an ordinary office desk. The display(s) and dialogue panel would be cabled to the central unit, which would contain the system power-supply and disk. The processor would be mounted in the display module. For high-resolution graphics display, CRT-terminal presentation would be superior. For lower-resolution graphics, 1040 by 1040 (points) plasma displays could be used. An illustration of a semi-portable TI delivery configuration is given in Figure 7.

A non-autonomous type of delivery device (standard graphics terminal) is not considered a viable option. Although within the state-of-the art, a large number of simultaneous users on-line to a central TI computer would seriously degrade real-time, on-demand response for users. In addition, a system using standard graphics terminals, sharing time on a central TI computer, is more vulnerable to complete system failure, with less emergency back-up than a system using relatively autonomous TI delivery devices which are loaded from a central computer, with back-up storage, such as digital casettes or flexible-disk libraries.

FIGURE 6

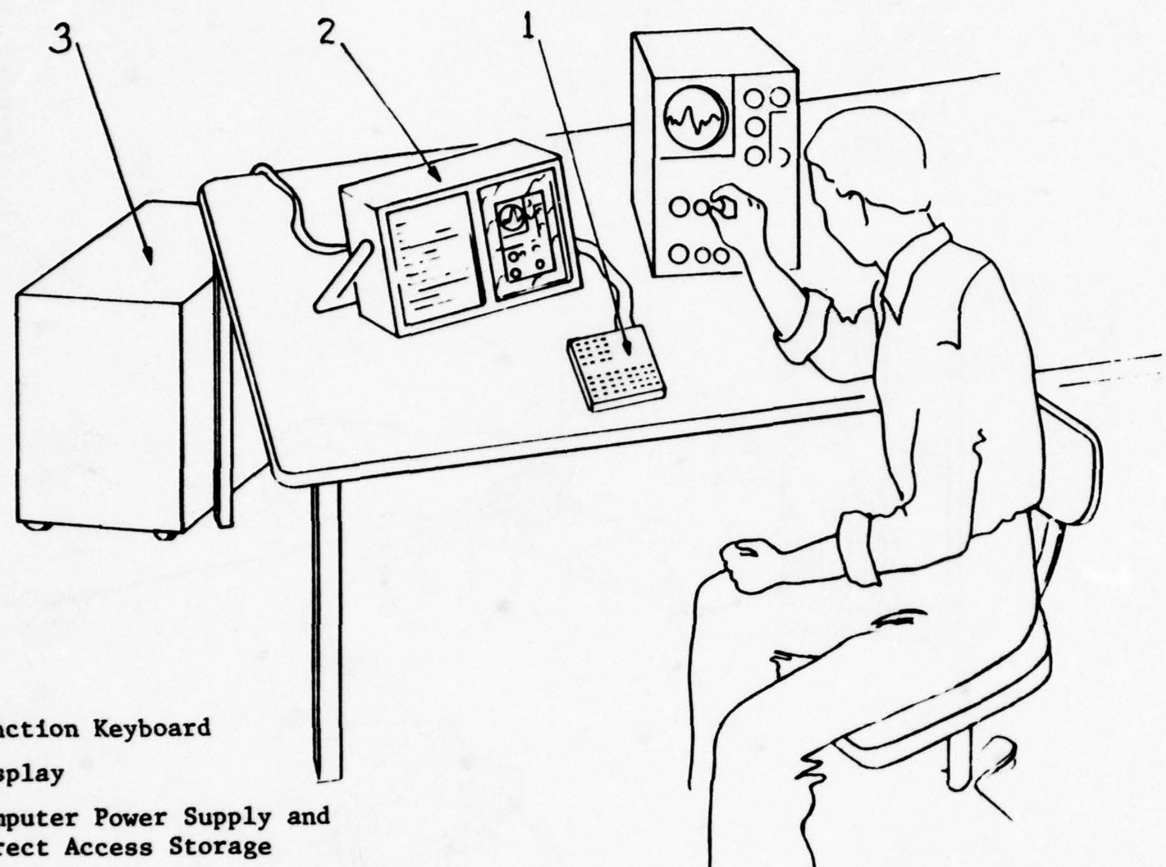
Artist's Conception of a Fully Portable
TI Presentation Device Configuration



1. Computer, Display and Power Supply
2. Function Keyboard

Figure 7

Artist's Conception of a Semiportable TI Presentation Device Configuration



1. Function Keyboard
2. Display
3. Computer Power Supply and Direct Access Storage

The final alternative delivery device considered is a semi-portable design that does not offer graphics capabilities. Instead of employing a heavy CRT-terminal, it would be possible to incorporate low-cost plasma panels that can provide high quality alphanumeric information and to substitute a hard-copy "picture book" or manual of technical illustrations to substitute for the computer graphics. Dialogue with the system would provide the technician with page and illustration numbers for relatively rapid retrieval of graphics data.

4.5 Evaluation of Alternatives

The choice among alternatives depends largely upon three considerations:

How important is system portability?,
How important is graphics resolution?
How important is graphics flexibility?

There are certainly various training and shipboard applications, as well as depot-maintenance applications for which portability is not a crucial factor.

Graphics flexibility may not be *essential* to improve the usability of TI substantially beyond the present levels, but future enhancements of TI usability will depend in important ways upon available graphics flexibility. This is particularly the case in enhancement of the deductive aids, where less experienced technicians may need extensive graphics support.

If high graphics resolution is required, which is the case particularly in line drawings, flat-panel (plasma) technology becomes a less desirable preference. The apparent limits of resolution for plasma displays are 100 points per inch (10,000 points per square inch). This resolution is marginal for complex line drawings. CRT-terminal displays can present much better resolution than this.

In designing an automated TI delivery system for the 1980's recourse to display technology that is not now available at a component prototype level would appear unwise. It is therefore suggested that strong consideration be given to initial emphasis on one of the semi-portable alternatives, with throw-away hardcopy-printing capabilities, as the primary hardware system. High-quality computer graphic features should, however, be retained in any prototype system design that is seriously contemplated. These features include conic, circle and linear vectorgraphic capabilities.

It is also recommended that developments in the area of high-quality flat-panel display technology and solid-state mass-memory technology be monitored closely, for incorporation into Technical Information delivery systems if and when these technologies become commercially available and reasonable in cost.

4.6 Technical Information Preparation

The computer-based preparation of TI requires a fast, streamlined, method of converting original engineering and hardware data into usable TI. Analysis, specification, data capture and integration, and checking and verification will be accomplished by computer manipulation of digital data bases. Pertinent TI specifications and standards will be integrated into interactive TI preparation-system software, so that system assistance is provided to Technical Information preparers in meeting Navy requirements. Automated nonconformance test routines will also be run for detection of unacceptable TI prior to Navy inspection of contractors' data, or internally-generated data.

The preparation system will be flexible in application, suitable either for internal use or for contractor use.

It should be stressed that preparation of TI using modern data-automation technology is a replacement for, rather than an addition to, the present system used by the Navy. The same writers who now prepare TI can continue to prepare TI, but instead of writing paper-based technical manuals, they will be writing the TI in a form dictated by the computerized system's interactive software. This requirement for non-programmer end users will require some careful attention to development of specialized aiding techniques for TI preparation by non-programmers.

4.7 Steps Involved in TI Preparation

There are six major steps involved in TI preparation:

analysis and formatting;
physical preparation of the TI in computer form;
assurance of quality and accuracy;
verification of usability;
approval and replicating; and
updating.

These activities generate a considerable requirement for maintaining records essential to the TI-preparation process. Through planning and programming of functional allocations, a computer can be used to help maintain these records in easily accessible formats and also help to aid in TI production and in the assurance of quality and usability of the information generated. This process is outlined in Figure 8 for a fully automated system.

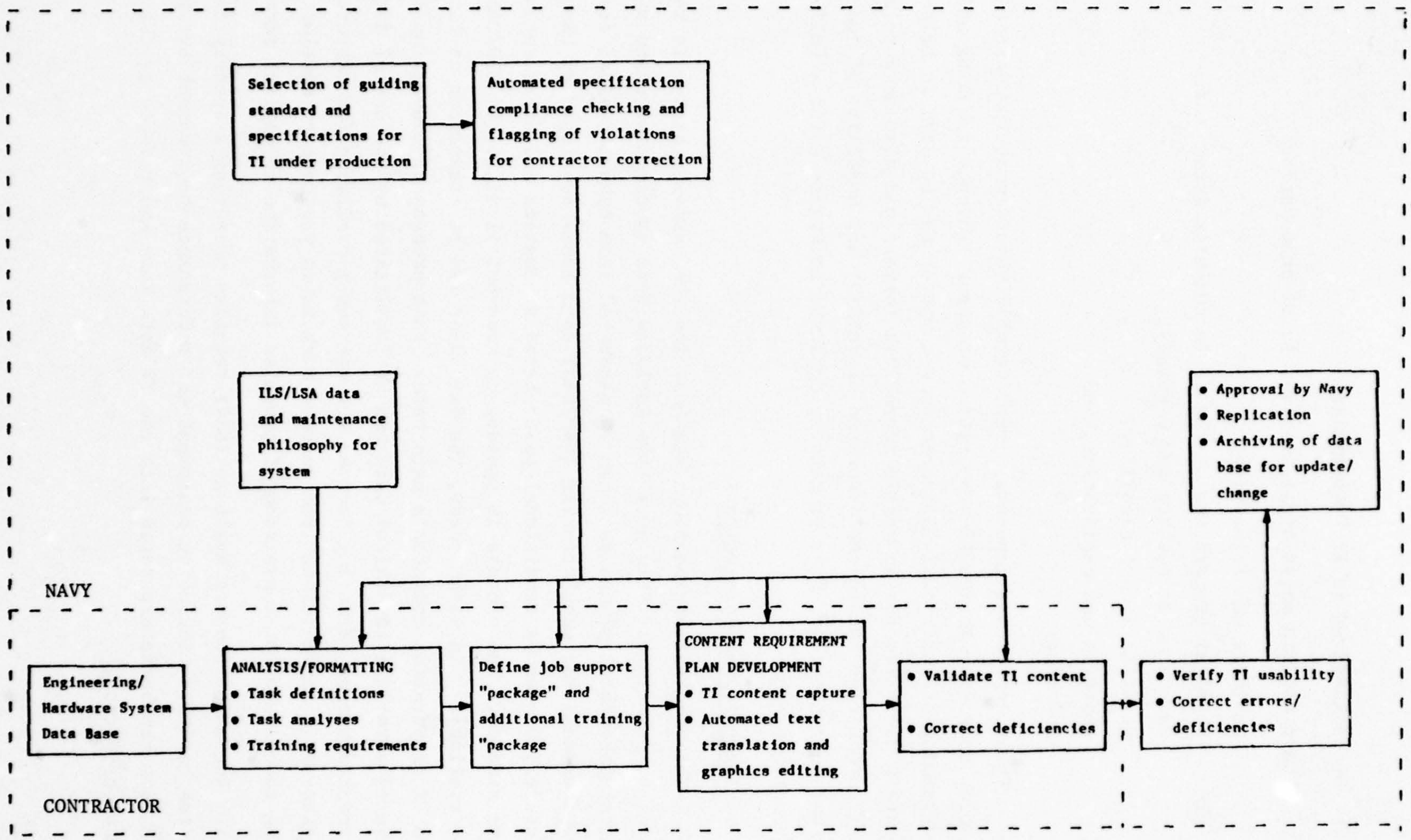
4.7.1 Analysis and Formatting

The original engineering data base for the hardware system is the major point of departure. This data base includes both system-design and system-performance data. These data can be generated from computer-aided design/computer-assisted manufacturing (CAD/CAM) data bases developed by the manufacturer, or can be traditional paper-based schematics and other engineering data records. The process is speeded up somewhat if digitized CAD/CAM data are available. In either case, the data base can be translated on-line into the TI preparation computer's data base. This process of conversion from printed materials to digital data can be facilitated by the use of digital scanner devices. Scanning devices are currently available for capture of alphanumeric information, and current work is in progress to develop scanning techniques for conversion of graphics information to digital records.

Logistics Support Analysis (LSA) requires preparing a description of system hardware, including equipment and maintenance-requirement breakdowns. LSA data can be incorporated into the TI data base and related to the hardware definition.

FIGURE 8

Processes and Flows in
Preparation of TI In An Automated System



Once these point-of-departure data are filed in digital storage, that portion of the LSA begins which will ultimately permit updating of originally established TI requirements. The first step is to perform analyses specifying which operational and maintenance procedures require TI support, and which TI presentation formats would be most appropriate for the technicians' uses. Physical construction and energy flow-path information from the LSA are required to make these determinations. The maintenance philosophy to be used for the hardware system is also considered at this point in the process. Then, the initial TI support plan is developed and added to the data base, preparatory to later refinement.

After the operational and maintenance task requirements have been defined, task analyses are performed for each task or task group to determine how they may best be performed, and associated task descriptions are prepared. Requirements are developed for each task, in terms of conditions, equipment and supplies, and personnel. These data are then filed in digital storage.

Once operational and maintenance requirements have been identified, the training requirements for various tasks and task groups are established through a head-book tradeoff and included in the data base.

Individual TI support needs are next defined in terms of detailed content requirements for job-training support packages. A package is defined as all the information needed (or potentially needed) for TI support of a specified work assignment or training assignment. Each of these packages will be designed to include the back-up information likely to be needed by users of any level of skill, experience, or sophistication.

4.7.2 Physical Preparation of TI

Following development of the data items described above, the actual preparation of the TI data packages for use by technicians/trainees begins. This process requires preparation of an overall data-structure plan for TI presentation according to the format to be used. The data are constructed as individual frames, as the unit to be used for presentation on the display.

The data structure plan is followed, frame by frame, until the preliminary package has been completed. Any frame may include textual or graphics information, or both, but must also include structure information showing its relationships to the other frames of the package, in order to permit retrieval through the use of function keying. This structural information is entered along with frame contents for each frame.

An editing process is then undertaken, converting the textual language used into language that is known to be preferred and natural to the specific technicians that will use the TI. For this purpose, a computer thesaurus of technician terminology and phraseology is used to convert the preliminary package language into the preferred language. The revised text will subsequently be verified for acceptability to proctors, or cooperating representative members of the end-user population, during the usability verification process.

Graphics data are also edited, but in a different way. In order to conserve digital storage space, graphics originally entered as vector data and identified by files will be reduced and stored in system memory in the form of structural transformations of basic graphic components. These graphic primitives (components) are then combined using the transformation information into the actual graphic illustrations presented to users by the TI delivery system's software. This particular approach to data compression is in current use on some large computer systems.

4.7.3 Assurance of Quality, Accuracy, and Completeness

The next stage of the TI preparation process is to validate the prepared TI for technical accuracy, adherence to guiding specifications, and completeness of the back-up pool information. This stage is accomplished through a hands-on assessment using technicians to evaluate the data on the basis of using system guidance to accomplish prescribed tasks. Based upon observation of technician performance and technician consultation, the necessary revisions and additions are identified, and entered into storage.

4.7.4 Verification of Usability

Verification of the TI is accomplished through having members of the user population use the TI packages in hands-on performance of operation/maintenance tasks. Technicians of various levels of skill and experience must be included for assuring usability across the necessary range of technician skills and experience levels. Delivery-system data collection and associated analytic software are used to pinpoint problem areas involving inadequacy of or errors in the data. Then, corrections are made to the data as indicated.

4.7.5 Approval and Replication

The TI is then submitted for approval, along with a justification for acceptance on the basis of the usability verification data. Following acceptance by the procuring activity, the stored data are replicated and stored on the medium/media of choice, ready to be transmitted to users from archival storage facilities.

4.7.6 Updating

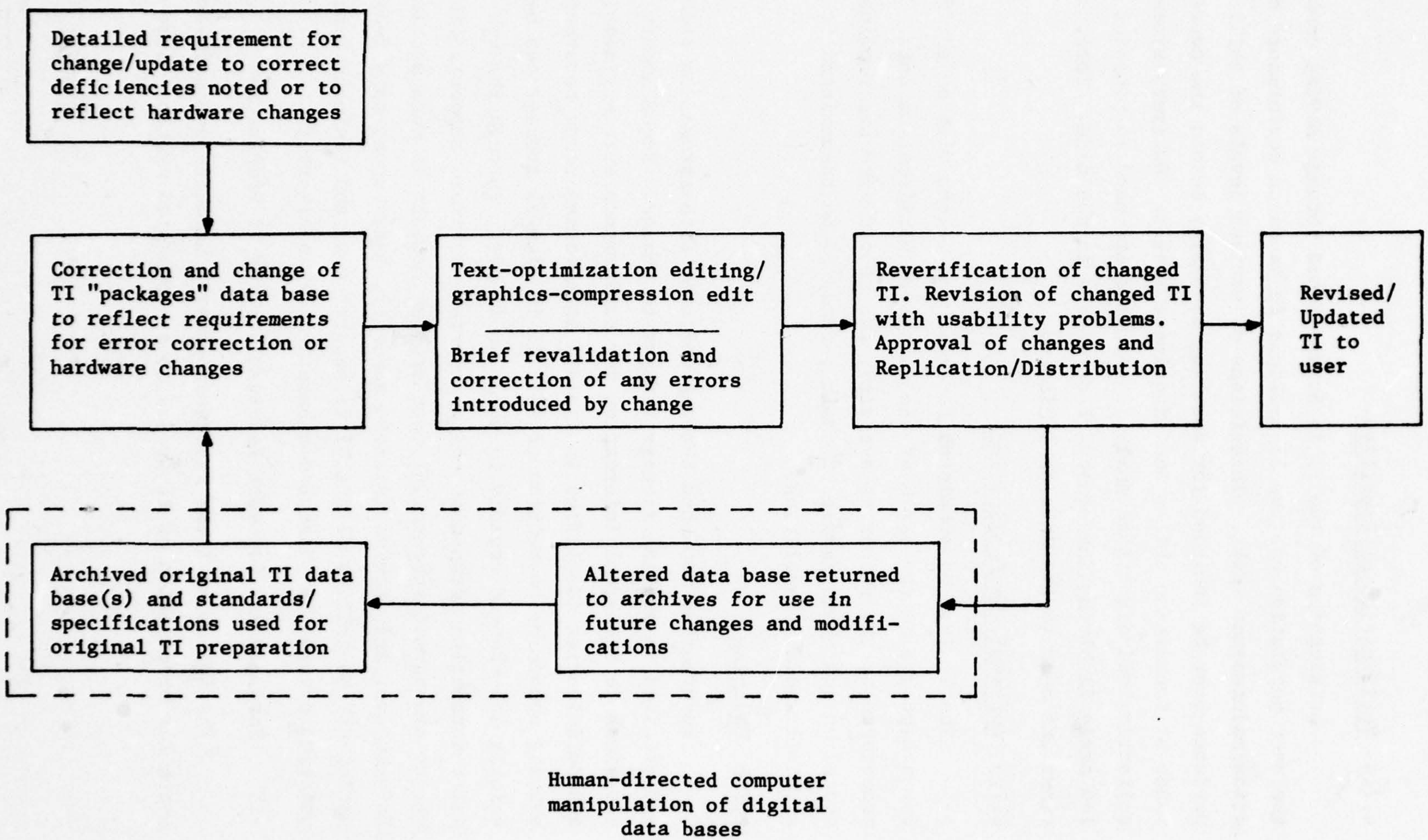
Information produced through computer data-automation techniques and archived in digital storage is easy to change. Requirements for modifications in Technical Information for conformance with engineering changes and deficiencies identified in fielded information occur constantly, requiring update or correction of TI. TI in digital storage can be accessed quickly and changed rapidly in whole or in part, through the use of computer automation techniques and appropriate software support. This capability can permit substantial cost savings, result in more usable Technical Information, and provide improved accuracy, based upon rapid feedback evaluation of the ability of the TI to support work and training functions. The updating process is presented schematically in Figure 9.

4.8 Hardware and Software Requirements for TI Preparation

The following items represent general hardware and software requirements for preparation of TI by use of an automated system. Some details of

FIGURE 9

TI Change/Update Process In An Automated TI System



these requirements are discussed in the Considerations and Options section (4.10.1) below.

Requirements include:

A flexible, general-purpose computer for processing and data-handling control and data-base management

Multiple work stations for textual, tabular, and graphics entry of data (which will become TI), and for planning data for TI production.

Large amounts of on- and off-line mass storage to maintain TI planning, preparation, and production data

Replication facilities for prepared TI. May be magnetic-medium duplicators

Control software to assist in defining, preparing, capturing, checking, formatting, and replicating TI

Off-line storage of retrievable archives for update and change to TI already prepared.

4.9 The Technical Information Distribution System

Distribution of TI through the system will be accomplished at three general levels, with communications between them: (1) SYSCOM, (2) Type Command/Fleet Service Force level, and (3) Local archival level, with NTIPS management of the central archives (an NTIPS control function).

At the SYSCOM level, intermediate archives can be made available for storing TI and for selected distribution to lower-level archives (TYCOMS, Service Force Command levels; Tenders, Repair Facilities/Bases).

At the Type Command/Fleet Service Force level, TI is managed and distributed to the local archives (ships, bases, etc.).

At the lowest level, local archives load TI into the individual delivery devices used by technicians and maintain necessary information concerning the individual systems assigned to the ship, base, or squadron.

4.10 Central Archives

Central archives accept TI from TI-preparation sites for categorizing, storing, grouping, and transmission/transfer to lower archival levels.

A general-purpose computer system with large amounts of on- and off-line mass storage is required for this function, together with digital data-replication facilities. Data-base-management-system software, with ability to perform configuration control of TI will also be needed.

4.10.1 Considerations and Options

Several central archival systems may be desirable at Systems Command levels (NAVSEA, NAVAIR, etc.), since different TI is likely to be required for supporting different Commands' hardware systems, and for security protection of the overall TI data base. Communication between high-level archives may be used when the same TI is to be used by different Systems Commands.

TI-preparation data bases might not need to be maintained in central archives. If updating is accomplished in-house, a central location at each key command involved would be efficient. On the other hand, if changes/updates are to be performed by contractors, retention of the production data bases at contractors' facilities could be considered as an alternative to SYSCOM archiving of the TI data base.

An alternative plan would be to distribute TI from a single major system central archive to end-user activities at the ship or station level; i.e.; to eliminate intermediate archives. This central system archive could provide distribution services directly to all local archives.

The NTIPS control function might be more easily exercised using such a single major-system central archive for distribution to the ship level, and some cost advantages might accrue from this greater centralization. However, a more distributed processing approach has several significant potential advantages:

1. Decreased Vulnerability: The use of multiple archives can provide a measure of protection against sabotage or attack. If one archive is

knocked out, other archives can transmit the same TI to TI users. Also, configuration data can be cross-filed, so that various network data-transmission schemes can be made available.

2. Decreased Criticality of Downtime: With a distributed system, system failure in a particular unit is less significant, since other systems up or down the distribution network can absorb the workload temporarily.

3. Configuration Control Efficiency: Configuration control of data can be more efficient if there are successive levels for distributing workload, where many updates, changes, and new TI have to be processed.

4. Overall System Response Efficiency: A distributed system can provide more rapid overall system response in distribution of TI and TI updates.

4.11 Intermediate Archives

4.11.1 Functions

Intermediate archives can further group TI for distribution to end-user site archives. There can be one or more intermediate archival levels, depending upon the structure of the organization at which these archives are established. For example, the first intermediate level under the SYSCOM level could be a Type Commander (e.g., COMNAVSURFPAC, COMNAVAIRLANT) or SERVLANT or SERVPAC, with overall cognizance of repair and material supply. Secondary levels could be Fleet bases or echelons (e.g., COMFAIRMED, Service Force Sixth Fleet), particularly for time-critical key systems.

Transmission of TI to user-level archives and acceptance of summarized data from user archives for transmission to higher levels would represent intermediate analysis functions.

4.11.2 Hardware and Software Requirements

A general-purpose computer with moderately large amounts of on- and off-line storage will be required. Digital replication facilities intermediate between those of central archives and local archives will be required.

A small data-base management system is needed for TI configuration and formatting and for scheduling and transmitting data to the next archival level.

4.11.3 <u>Considerations and Options</u>

Intermediate archiving will serve relay functions for TI distribution. For analysis of data acquired by the systems at the user level, some minor software development will be necessary, in order to synthesize, log, and analyze logistics data.

The main question for this level of the distribution system is how much of the various types of logistics data provided upstream from the ship and base levels is to be included for transmission and analysis. The answer would depend upon the degree to which the TI system is to be merged with logistics information management systems operative at the time, a system characteristic which cannot be estimated at this time.

4.12 Local Archives

4.12.1 <u>Functions</u>

The local archives would function as follows:

Accept TI packages from the distribution subsystem and store them in user-accessible on-line storage.

Select and load delivery devices with the TI required by technicians.

Accept, format, and decode raw data from individual user TI-presentation devices.

Transmit user data to higher level archives.

Maintain preventive maintenance schedules; maintain records on maintenance histories of major systems, and prepare readiness reports for local uses.

Accept and log automated feedback reports in standard format.

4.12.2 Hardware and Software Requirements

A general-purpose computer, which may be the same as that used for all shipboard or base logistics data reporting, will be required. An interface to a radio link for high-speed on-line digital transmission will be required. Requirements will exist for a small-scale data-base management system to control selection and loading of TI and treatment of logistics data for transmission and local analyses. The computer will need the ability to summarize and correlate system-collected data and summarize data for retransmission.

The on-board distribution network will consist of communication lines and interfaces through which TI delivery devices are to be attached to the local archival system. For large local installations, microprocessor controllers may be needed at interface points, as message concentrators or multiplexers. This would allow polling of interface points or selective activation and deactivation of portions of the system.

4.12.3 Considerations and Options

Consideration should be given to using existing nontactical ADP systems onboard ship or at shore stations. This plan is feasible, since the only additions to an existing computer system would be interfaces to an encoder/decoder with broadband digital data capability, and the controlling hardware and interface software for loading and accepting data from TI delivery devices.

4.13 Inter-Archival Communications

4.13.1 Functions

To provide a means of sending and receiving digital data between archival levels to distribute TI and organize and summarize TI-system-collected data.

4.13.2 Hardware and Software Requirements

If high-speed broadband communication links are necessary, encoding/decoding hardware will be necessary to prepare data for transmission and to prepare for storage at end sites. This hardware must be interfaced both with the computers and the transceiver equipment, and controlled by system software. Satellite on-line transmission of data is feasible for more urgently-needed kinds of data.

If a high-speed radio link is not required, high- or low-speed land-line communications or off-line batch-data delivery can be used. Voice-grade lines may be used for low-speed data, but conditioned lines would be necessary for high data rates.

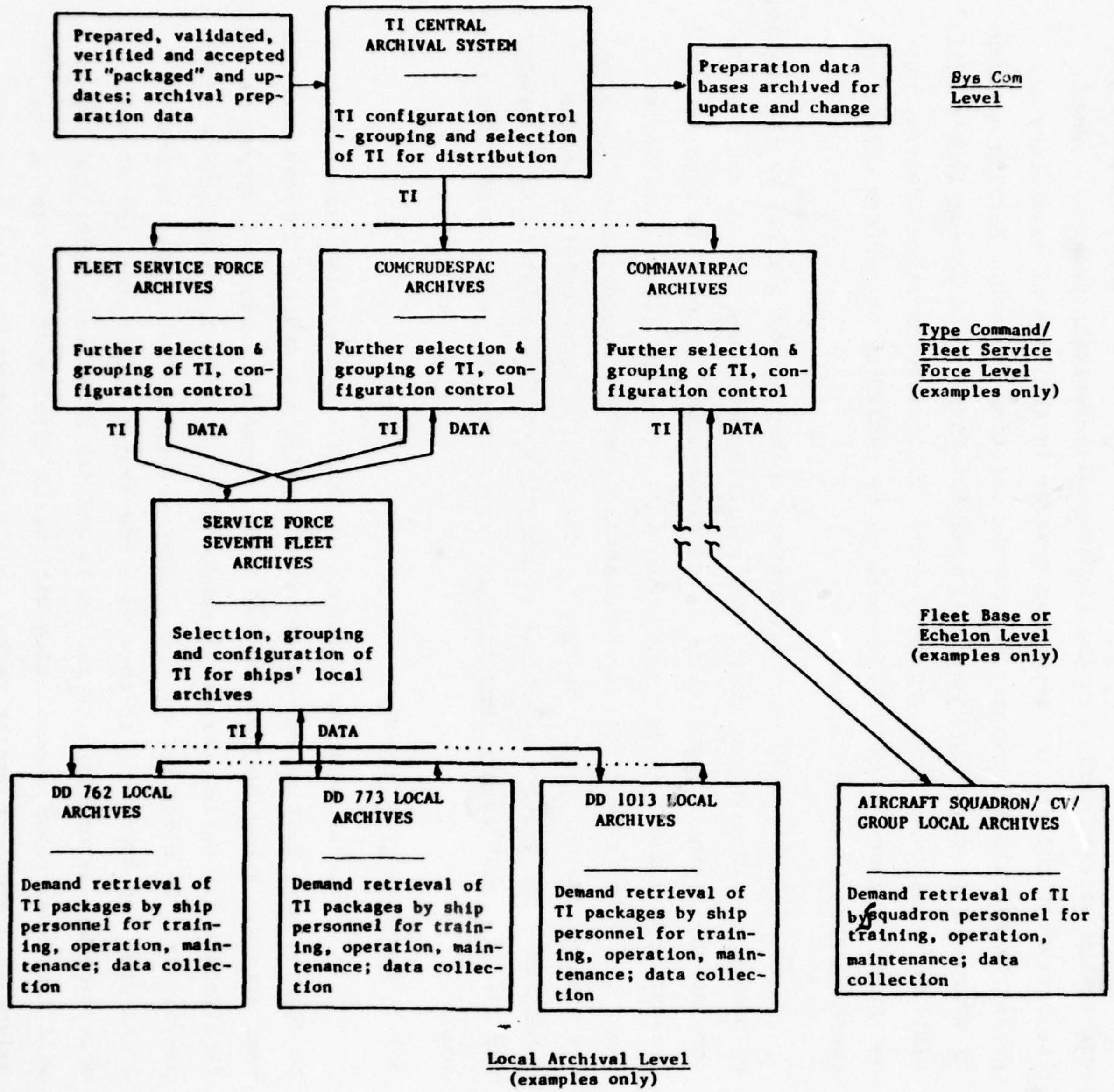
4.13.3 Considerations and Options

TI data may be transferred between archives by physical delivery; e.g., by mail or hand delivery of disks, especially if delivery or update time is not critical. Once a ship has deployed, little configuration change in TI will probably be necessary. This offers the potential for delivering data on disk or tape to the ship in base or during at-sea replenishing periods. If critical TI is needed on board, replicated data could be transferred by a broadband digital link, or preferably, on a non-volatile magnetic medium from another ship in company.

Figure 10 presents an example of an archival distribution net for TI data distribution.

FIGURE 10

An Archival Distribution Net (organizations cited for example only)



5 IMPLICATIONS FOR THE U. S. NAVY

5.1 Combat Readiness

The present material and combat readiness of the Navy is less than satisfactory and will not improve over the next decade unless programs are undertaken soon to deal with the fundamental underlying problems. One limitation of the present readiness posture is the lack of capability of people in service to maintain and repair existing systems. Barring a change of approach, it can only be assumed that the Navy of the latter 1980's will similarly, but to an even greater degree, be limited in effectiveness, not by innate hardware capability so much as by inability to perform effective system maintenance and repair.

The effectiveness of newer systems technology is limited by the ability of people to maintain and repair the resulting hardware, and we can readily foresee the limits of applicability of paper-based TI for this purpose. Present improvements in approaches based on hard-copy TI are leveling off. Thus, the primary implication of adopting a fully computer-based TI system for maintenance and repair of Navy systems is the improvement of system readiness - the greater assurance of material which realistically is ready for use in combat rather than inoperative or operating at marginal effectiveness.

5.1.1 Personnel Posture

In 1978, the personnel posture of the U. S. Navy also leaves much to be desired and, barring unforeseen events, will not greatly improve over the next decade. A key implication for a new approach to material upkeep is the requirement for better personnel productivity and the improved morale accompanying it. As units become more combat ready, as Navy people become less frustrated and more able to cope with new system technology, and as available manpower is provided better tools and job aids, unit pride and esprit will increase. Such capabilities will break circles of overworking the undermanned group of senior technicians and operators (a practice which contributes to their low re-enlistment rate), and under-utilizing first-enlistees and thereby contributing to their frustration. Navy pilots must have fully operational aircraft and maintenance costs must not attain such high levels that flying opportunities are seriously curtailed, if pilots are to be retained. All of these trends are already well-established and must be dealt with before they get much worse.

5.1.2 Transition to the 1990's Navy

There is little question that the Navy of the 1990's will be technologically advanced beyond the present Navy, but one which must still be maintained and manned by people whose innate capabilities are not particularly advanced over those of today's operators and technicians. It is in the next ten years that the support technology must be developed, tested, and incrementally introduced which will enable people to operate and maintain this future Navy. A system of optimized TI, including training equipment, is fundamental to this process.

5.1.3 Redirection of TI Improvement Programs

Movement toward a fully computerized TI system will require substantial program funding as well as technical support from Navy R & D facilities such as the Naval Training Equipment Center and the Naval Personnel Research and Development Center. Since Navy RDT&E and appropriate laboratory resources are limited, it follows that a substantial fraction of research and laboratory effort must be directed to support the transition to computerized TI. At the same time, the system will necessitate a much closer continuing TI relationship with equipment contractors than now exists.

5.2 Implications for NTIPP

The principal implications for NTIPP of a decision to move to computerized TI involve allocation of resources and facilities development. NTIPP will be faced with major analysis and planning tasks in: (1) phasing implementation of the new digital-data technology approach and (2) maintaining viable paper-based TI during the transition, which is likely to take some years for accomplishment. The other aspect of resource allocation and facility development pertains to the degree to which NTIPP objectives are merged to a fruitful degree with other current Navy planning and implementation efforts dedicated to improving logistics information management. In all likelihood, the same shipboard hardware and some of the same software can be shared for support of these closely related objectives.

5.3 Cost Implications

The cost of a fully computerized TI system will be expensive. Most of this cost will be in the area of computerized data preparation, which will be somewhat more expensive than the paper-based TI it replaces. The FPJPA versions of TI cost as much as three times conventional manual preparation costs. However, it must be understood that increased procurement costs involved in improved TI are balanced in other areas of the TI life cycle cost by reductions in cost and improvement of system performance. Delivery costs through the archival systems should be no more, and possibly less, than those now experienced for preparing hard-copy materials.

Changes to TI for updates, corrections, and modifications will be possible with a computerized system at a fraction of the effort and costs involved in changing hard-copy TI. This will be a major cost saving.

In general, cost-effectiveness analyses cannot be performed quantitatively before a Fleet test and evaluation of such a computer-based system is carried out. However, outweighing somewhat heavier costs in computerized TI preparation will be savings in delivery costs, updating costs, costs of technician search time, no-defect parts removal costs, parts inventory costs, and above all, costs of training technicians and operators, and equipment readiness.

The unit price of the technician's presentation device should lie in the range of $20,000 to $30,000 in production quantities. The local archival computer facilities will probably cost several hundreds of thousands.

5.4 Implications for Naval Operations

5.4.1 Readiness

The prime implication of adoption of a system of the type described for command, control, and operations is improved combat readiness of material and collaterally, of personnel. Maintenance and repair will be faster and better. Better maintenance and troubleshooting will lead to fewer breakdowns, less equipment downtime, fewer unscheduled tender or base repair periods for ships with breakdowns of essential systems (emergency availabilities) and in general, greater availability of combat systems.

5.4.2 Unit Self-Sufficiency

With fleet units better able to maintain and repair their on-board systems, there will be a looser "umbilical cord" to higher echelon/base repair capability. Task groups and units will be more self-sufficient, and better enabled to undertake the independent and far-ranging operations projected to be necessary in the 1980's.

5.4.3 Command Information

Commanders will be presented with more accurate readiness information and better management data as to equipment status, "time to repair," and critical parts needed. Operational commanders will profit by (1) a simplified parts/supplies re-supply procedure and (2) improved data to present to fleet-readiness assistance offices when assistance is needed from these offices.

5.5 Personnel Implications

5.5.1 Policy

Enhancement of TI usability resulting from greater recourse to automated aiding and training techniques will enable effective implementation of current suggestions from various quarters for emphasizing on-the-job training (OJT) to a greater degree and for depending less on in-the-head experience and knowledge. This implication suggests that reduction of training costs and improved personnel utilization may be achieved. Training time in formal schools will be reduced and technicians/operators can progress more rapidly in the task complexity of the jobs to which they can be usefully assigned.

Equipment operators, such as pilots, will be given more opportunities for practice, since equipment MTOF should be lengthened and since more equipment will be in a ready condition.

5.5.2 Personnel Allocations and Assignments

Greater usage of first enlistees, together with other personnel trends, will help to overcome the shortage of technicians in the fleet.

Use of computerized TI will enable entry-level technicians to be assigned to the Fleet after shorter Class A school training, and possibly directly to the Fleet for on-the-job training as strikers. Thus, there will be a decrease in the billet requirements for instructors and trainees. There will be a significant requirement, however, for use of trained technicians and instructors in TI data preparation, test, and validation; and this requirement will probably soak up the training instructor billets freed from the school commands.

It is anticipated that rating structures may undergo some adjustment. Particularly if the Navy moves toward school consolidation to teach basic technical knowledge common to rating categories, there may be some consolidation of certain ratings. On the other hand, it is possible that a new rating(s) will be established to deal with TI preparation, with TI delivery, and with associated equipment operation.

The data-retrieval and feedback capability of a technician's TI delivery device would permit analysis of the time it takes individual technicians to perform given tasks. Thus, objective measures of technician proficiency would be available to supplement supervisors' subjective evaluations. It is most likely, however, that such feedback data will be mainly used by training activities and TI-preparation facilities for training and aiding improvement purposes. Normative maintenance and repair data can be developed from feedback information, permitting more precise determination of technician quantitative and qualitative (rate level) manning requirements. In addition, such data will disclose equipment maintainability and repairability factors for more efficient estimations of life cycle cost.

5.5.3 <u>Morale</u>

The earlier productive use of entry-level technicians and the opportunities for increased availability of Navy equipment to operators will decrease job frustration and promote job satisfaction. Improved material readiness will also lead to an upsurge in unit pride and esprit. These developments should be reflected in improved re-enlistment, further upgrading the numerical and qualitative capability of the technician corps, overcoming shortages, eliminating overwork, and further improving morale.

As availability of shipboard equipment increases, a decrease will occur in the maintenance and repair work accumulated for in-port periods, permitting an easing of the workloads that now make shore duty less attractive.

The requirement for senior petty officers to perform low-level work will be eased by enhanced job-aiding techniques for lower-level rates. Senior rates can then work on more complex tasks, suitable to their expertise, and supervisors will have more time for supervision.

5.6 Training Implications

5.6.1 <u>Use of Computerized Training Packages</u>

The transition to computerized Technical Information and job aiding will have substantial implications for training. Whether they are at shore schools or serving as shipboard strikers, entry-level technicians must absorb requisite knowledge, including basic theory, nomenclature, and conceptual relationships. This learning inevitably will entail considerable amounts of individual study. In such study, system-simulation techniques and hands-on practice of learning tasks can offer valuable and effective means for increasing learning effectiveness.

Training packages similar to computer job performance aiding modules can be tailored to the vocabulary and natural dialogue of the trainee and can make extensive use of graphics and simplified animation, a development which will be highly acceptable to a generation which is less reading-oriented than earlier groups.

5.6.2 Training Time

The tradeoff toward more system (book) knowledge and less in-the-head knowledge will result in shorter formal school time and a reorganization of training objectives. Remedial and basic-skill training packages can be prepared for those individuals in need, and self-paced learning techniques can be more effectively implemented. The current deficiencies in female understanding of mechanical relationships and lack of experience in mechanical matters can be remedied where necessary with these remediation and basic-skill training packages.

5.6.3 Instructor Requirements

One implication of the transition to computer-based training is the effect on numerical requirements for instructors and their training, use, and attitudes. Numerical requirements will decrease somewhat, as there will be less instructor time and fewer instructors in the classroom. However, instructors will need to spend a considerable portion of their time in (1) evaluating student performance, group and individual, (2) determining requirements for further training packages or refinements needed to overcome demonstrated teaching gaps, and (3) designing and producing computer training packages or evaluating packages supplied by centralized production units (e.g., schools, service school commands, training commands).

The first training in the use of computerized training packages and package preparation will be directed to the instructors themselves. Initially, there may be some uncertainty concerning allocating functions, which are ordinarily reserved to instructors, to an automated system. However, as instructors become familiar with the process of package development and associated rationale and research results, acceptance should be readily elicited.

With computerized job-performance-aiding systems, emphasis on "A" and "B" schools will decrease, while the number and use of "C" schools will increase. "C"-school instruction in specific equipment(s) would prepare students to use the automated TI available in forthcoming ship and base assignments and to make the transition from school to the Fleet smoother for personnel.

5.7 Procurement and Logistics

5.7.1 Maintenance Philosophy

The major shift that will be required in maintenance philosophy is that procurement of TI is not procurement of systems engineering data only, but rather of an instructional system for supporting the needs of maintenance personnel. TI procurement personnel must recognize that relatively inexperienced technicians will have to receive more usable data and that means must be developed for objective assessment of TI effectiveness prior to acceptance of a contractor's TI products.

A further shift in orientation will be an emphasis upon the importance of routine incorporation of feedback concerning TI deficiencies into scheduling change orders for digitally stored data.

In these respects, NTIP can provide important education and control functions, since it can help procurement offices exert more control and Quality Assurance with respect to buying TI.

5.7.2 Contractor Factors

Equipment manufacturers will be able to produce more uniformly useful TI, because the NTIPP effort will lead to development of the support programming that makes usable TI simpler and more efficiently produced. Contractors will be able to follow this program, rather than be required to interpret incomplete and often unclear specifications and standards that can be superceded in part and that can conflict with one another.

Equipment manufacturers will also profit from improved feedback concerning the quality of the products they deliver to the Navy and become better informed with respect to the need for engineering re-design to extend the functional life of their equipment.

Especially important will be the ability to continue to increase the sophistication of new equipment and still be assured that further increments in new-equipment complexity will not result in impossible-to-maintain equipment. Various equipment manufacturers already report management concern over (1) increasing the complexity of their products any further than present complexity levels and (2) the increasing degree to which factory representatives and technicians must be routinely used for servicing and repairing company-produced equipment. Complements of civilian technicians as routine participants in naval operations, as a necessity for maintaining equipment availability, will be increasingly required if equipment continues to become more sophisticated and the quality of TI support to naval personnel does not improve substantially. This practice is extremely costly.

Equipment-procurement specifications will increasingly be able to base quantitative requirements for reliability, maintainability, and repairability factors on analyses derived from feedback data on parts breakdowns, parts usage, and maintenance/repair task time requirements occurring in actual operational environments.

5.7.3 Parts and Supplies

The new system with its automatic feedback features will aid in the supply process. With better data on part and supply usage, it will become easier to have the parts and supplies actually on hand when they are needed, and to avoid shortages or gross overages.

No-defect parts replacements will decrease as the system better aids the technician in pinpointing the actual trouble and specific parts failures.

Other NTIPP contributions to logistics information-management will depend in value upon the nature of the interface developed between NTIPP activities and cooperating logistics information-management organizations and activities. In this respect, NTIPP can be potentially quite useful if it develops an interactive type of job-performance-aiding software that can be used to support man-machine interaction in enhancing accomplishment of complex maintenance data-reporting functions.

5.7.4 Communications

The system will use broad-band digital communications in addition to land-line and hard-copy TI supply. This plan creates added requirements for communications transceivers and antennae, and an increased appeal for integration of NTIPP requirements with those associated with logistics information-management functions. Although hard-copy delivery or land-line communicatives should suffice for routine Fleet needs, the volume of radio digital communication could be considerable. Undue pressures on circuit availability and transmission time may be minimized by compression of data for transmission ("squirt" technique).

Radio communications, of course, present obvious vulnerabilities in wartime, and although modern satellite tracking to some degree diminishes the importance of electronic emission control, there will still be occasions where radio transmission is unavailable. However, it is likely that only critical equipment breakdowns not covered by onboard archives and spares will require radio communication.

5.7.5 Other Technological Issues

A number of technological issues in system development and design must be addressed, and their alternatives and effects evaluated as part of the system-definition process. One of the most salient of these is the design and allocation of TI presentation (delivery) systems. Should the systems be portable, dedicated, semiportable, or a mixture of the three configurations? What are realistic requirements for the critical-element testing necessary to discriminate between real problems and unfounded concerns? What are the actual requirements and needed operating parameters of the devices? How well can computer-assisted TI-preparation procedures guarantee highly usable data without extensive hands-on testing by Navy technicians?

Achieving an optimal Navy-contractor interface in Technical Information preparation, using the new technology, is an especially important issue. This issue includes the question of contractor-maintained TI-preparation data bases and Navy provision of representative enlisted technicians for use in usability verification at contractors facilities. Also included in the Navy-contractor interface issue is the possibility of providing to contractors either TI-preparation software or entire TI preparation systems as Government-furnished equipment.

It will be clearly necessary at an early date to establish NTIPP or NTIPP-supported RTD&E facilities for system-development research purposes. The system-definition process can only progress to a certain level of specification without such laboratory capabilities for study of emerging methodologies and analyses of their potential technical and cost-effectiveness payoffs.

5.8 Implementation

5.8.1 Direction

It is in the hard choices and costs of actual implementation that the most difficult issues lie. The proposed system is within the technological state-of-the-art and will work. Preliminary data to this effect have already been obtained by the present contractor. Phased implementation of the proposed system, on a Navy-wide basis will be costly, although cost-effective relative to the present baseline costs in the wider material-readiness perspective, and will take substantial time. The concurrent existence of two Navy systems (one automated and one hard-copy), even on a temporary basis, could be clumsy. The overriding issue, however, is whether the Navy can affort not to adopt this new-technology approach. It is the only approach capable of offering real two-way communication between technician/operator and the TI delivery system. This interactive, information-tailoring approach appears to represent the most potentially successful way to guarantee that Navy TI is specifically responsive to individual technician/operator needs for information support. Our analysis indicates that the hard-copy medium began to be unresponsive to information support needs even before 1962. It took around 10 years before vigorous efforts were launched at a tri-service level to produce more usable TI. It is now known that with continuing increases in Navy system complexity, the best of the job-aiding techniques need further enhancement, and this can be realistically implemented only with interactive systems.

Balanced against these considerations is the fact that the Navy, like the rest of the Department of Defense, has become highly dependent on paper-and-print, and that any system of the kind generally proposed in this system scenario will represent a significant departure that will perturb organizational machinery and generate resistances. A strong commitment must be obtained at the highest levels of the Navy and the Department of Defense, since support technology (improved TI systems) must compete with other claimants for a finite and limited Navy budget. For example, in explaining President Carter's veto of the military appropriation bill, Secretary of Defense Harold Brown pointed out that when Congress included a nuclear aircraft carrier, without a commensurate increase in the Navy budget, the result was a decrease of almost half a billion dollars in funds for readiness, for repairing existing ships, for allowing ships more steaming time so that they are in a higher state of readiness, for Army ammunition, and so on. The tri-service costs involved were estimated by the Secretary at two billion dollars, an amount that would cut a great deal out of combat capability (Brown, August 20, 1978).

5.8.2 Constraints

Institution of fundamental changes to a large complex organization like the U. S. Navy, such as have been proposed by this system scenario, would require radical alterations across the board. Such actions would be inadvisable without first testing the system involved in the shipboard/air squadron environment. After such testing and verification, it is further advisable to introduce such a new system incrementally and to extend it in steps across-the-board, taking problems, potential improvements, and modifications of approach into careful account as they are discovered.

The technology that appears to be needed is still in the research laboratory, with several years before definitive field-test and evaluation results can be obtained and analyzed. It is also often the case that system-wide innovations of any kind are difficult to implement quickly. Existing researchers in military technical-data improvement are few. Senior personnel with Navy training-equipment capabilities are also few. If NTIPP is to make progress rapidly in pursuing this avenue of development, it must find the means for enlisting and building the talents of highly specialized professionals, especially TI engineers. For this reason alone, an incremental implementation plan would be required.

As validation of approach proceeds and a decision is made to implement the general approach proposed in this report, it will be necessary to solicit cooperation of selected schools, ships, and aircraft squadrons. This cooperation can provide the data needed before approval of any widespread implementation can be expected, and can provide research and training sites for the manpower needed for subsequent implementation actions.

5.8.3 Other Implementation Issues

The need for several fundamental decisions concerning implementation will arise shortly after any decision to pursue the line of development under the current study. One of these is the question of whether to develop computerized TI for out-of-production equipment as well as for new equipment. Another fundamental issue has to do with emphasis upon aircraft or ships. Which should receive more initial emphasis in implementing the system? A third fundamental decision will involve the previously mentioned issue of interfacing with the new shipboard non-tactical ADP that is already near the point of final specification, and with advanced planners concerning integration of Navy logistics-information management systems.

6. IMPLEMENTATION OF NTIPP-DEVELOPED TECHNOLOGY

This section deals with the implementation of NTIPP developed products with respect to improvement of Navy-wide logistics information management.

There are numerous Navy information systems for management of logistics and supply data. However, despite the efforts of Integrated Logistics System (ILS) managers, the Systems Commands, and the Fleets, material readiness is not improving and in many areas is decreasing. NTIPP is not the only ongoing effort to improve logistics and supply information management. The Naval Aviation Logistics Command Information System (NALCOMIS) and the Shipboard Nontactical Automatic Data-Processing (SNAP) system program are two major current efforts being made to modernize management information in the Navy. How and when NTIPP will interface with these two programs is, as has been noted, not yet clear. However, for shipboard applications, it can be anticipated that NTIPP products will be used by both of these programs. One possible outcome is that NALCOMIS will expand its mission to include dissemination of maintenance and on-the-job training data as an extension of its current mission. Such an extension would very probably be implemented using the ADP systems developed from SNAP-I and SNAP-2. SNAP-I involves upgrading the nontactical ADP facilities on ships that have older existing nontactical ADP systems. SNAP-2 will outfit additional ships with nontactical ADP systems.

NTIPS, SNAP, and NALCOMIS are complementary, since NTIPS will be formulated primarily to improve information support downline to technical personnel and SNAP and NALCOMIS are emphasizing improving information support upline to Navy management. A total logistics management-information system would integrate both of these functions into a single communicative and management instrumentality for effective implementation of NTIPP-developed technology. In fact, a coordination among the program managers of these different programs should be established in anticipation of implementing NTIPP products in a 1980's time frame.

The NTIP Program can potentially support the collection of logistics and supply data transmitted upstream to Navy management in several ways, through building-in automatic recording and through formatting the following types of data:

a. Purpose of work task -- inspection, special removal of components, modifications, alterations, Technical Directive compliances, routine servicing, other scheduled maintenance, repair/troubleshooting.

b. Reason for problem -- breakdown, sub-marginal performance, intermittent outage.

c. Parts and supplies consumption.

d. Level and quantification of technician performance -- for personnel allocation assessments, training requirement analyses, and TI improvement.

e. Nature of faults corrected -- which components required repair/replacement, with implications for inventory, reliability-centered maintenance standards, need for equipment modifications, and individual system maintenance histories.

Current complexities and maintenance/supply loads are such that adequate and thorough analysis of manually prepared reports has become impractical. Manually prepared reports have never been prepared with the reliability and accuracy desired. They must also be translated into machine-readable formats for transmission upline or for computer-aided analysis at management levels. This problem has led to a proliferation of localized self-help systems employing various kinds of hardware and software, with heavy procurement, maintenance training, and management costs. The automation of source-data entry will alleviate this situation by reducing manual paperwork, eliminating the need for manual translation into machine-readable formats, and through simplifying the reporting requirements placed upon technicians.

Some logistics- and supply-information needs of management can be made a routine part of the maintenance function. For other types of logistics and supply-information acquisition, the use of automated job-performance-aiding procedures also offers promise as an aid to maintenance and supply administration. FPJPA techniques, for example, could also be used to provide a source of interactive support for preparation of reporting data and for logging the data, preparatory for subsequent upline transmission.

Through developing job-performance-aiding techniques for non-technician system users involved in logistics- and supply-reporting activities, NTIPP could provide information support to main supply/finance functions using shipboard automated data processing systems. Other examples of reporting activities which could be supported by NTIPP products include the End Use of Stock Points (SUADPS-EU, SUADPS-SP) Systems, Improved Repairable Asset Management (IRAM), Uniform Inventory Control Point (UICP), etc.

In summary, based upon the relevance of NTIPP plans and activities to complementary Navy logistics- and supply-information management systems, development of coordination and information-sharing resources at some appropriate level is recommended. There is a good possibility that NTIPP can support these programs through providing for automatic system collection of some types of source data, and through developing formats for system-assisted preparation of other types of logistics and supply data.

7 NTIPP RESEARCH AND DEVELOPMENT REQUIREMENTS

This section identifies key research and development efforts that should be undertaken to optimize NTIPP capabilities for improving Navy Technical Information, given the choice of pursuing an all-digital-data approach to TI.

7.1 TI Preparation System Developments

The most challenging problems associated with the all-digital-data approach involve developing the system(s) used for preparation of Technical Information and TI procurement control. Figure 11 identifies key development area functions for this subsystem of NTIPS.

7.1.1 Laser Scanning System

The system hardware development that would now appear to be most important for NTIPP development is a laser scanning system for graphics composition. A system of this kind converts line drawings to digital vector information and stores the vector information in a computer. While digital scanners are now available from various commercial sources for alphanumeric scanning, a suitable device for scanning graphic illustrations and converting them into digital data has not yet appeared on the market.

One relevant development effort to produce such a graphics scanner is in current progress at Aberdeen Proving Grounds, which has funded a contractor effort through the U. S. Army Armament Research and Development Command. A very recent inquiry as to the status of this development effort was made to the technical monitor. The report indicated that this effort appears to be promising with respect to potential success, although it will be some time before full feasibility of the design approach can be assessed.

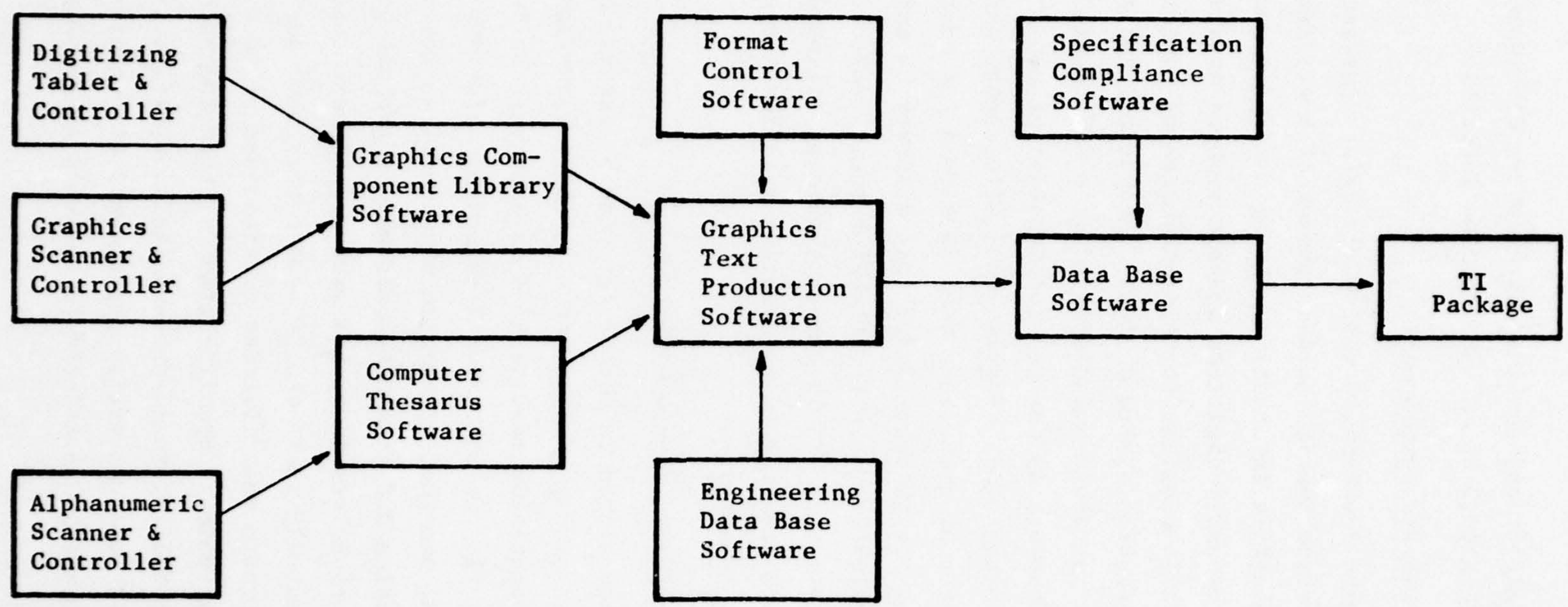
Until such a scanner becomes available, it will remain necessary to use digitizing tablets and controllers for conversion of graphics data to digital information.

In view of cost- and time-reduction advantages of such a scanning device in preparing TI, it is recommended that the Navy monitor the Aberdeen

FIGURE 11

Key Development Area Requirements for

TI Preparation System



Proving Grounds effort and consider alternative development strategies should the Aberdeen development prove to be infertile.

7.1.2 Graphics Library Development

One software development that would offer substantial time and cost savings in TI preparation is the development of a graphics library for composition of graphics information. Using a scanner such as described above, or using manually digitized graphic symbols previously stored in system memory, it is possible to take advantage of contemporary approaches to interactive graphics system design. The basic graphic symbols stored in memory can be retrieved and displayed on a CRT-terminal screen, scaled, positioned and combined as desired for creation of new graphics materials, such as complex schematics, diagrams, and illustrated parts breakdowns. A variety of computer programs have been developed for such interactive graphics systems. It is recommended that a survey be made of alternative interactive graphics programs to establish their respective suitabilities for NTIPP TI preparation. This survey should be followed with a software development effort concerned with creating a tailored system for interactive graphics preparation.

7.1.3 Data-Compression Programming

Information stored in vector form can be further compressed in order to reduce digital storage requirements. Such a reduction could be important for storing a potentially massive TI data base such as is represented by the entirety of Navy TI. Of the several potential solutions to this problem of data compression, one that appears to have merit is that of storing transformations (defining and attach transforms) of graphic primitives (symbols) along with the primitives in system memory. Through this approach, symbols that appear repeatedly in TI can be stored only once and the transformations can be used to create the different combinations of these symbols that are involved in TI graphics. Specific study of this approach would appear to be warranted in the NTIPP formal system-definition effort. This approach is in current use in some university departments of computer science, but appears to be currently restricted to use with large computer installations.

7.1.4 Analytic/Preparatory Software for Storage of Engineering Data

The content and structure of the engineering data base which will be transformed into Navy TI must be logged, stored, and retrieved in accordance with programs that are used for TI generation. Software must be developed to provide the capability for accepting hardware information and task-analysis data and store this information in easily retrievable and usable forms. This software should also provide capabilities for computer indexes of hardware information on subsystems/assemblies, so that when changes are made to systems, updates can be more easily made. It is much easier to change TI when the system can identify every instance where reference is made to components. Under this condition, changes can be made automatically when designated components are changed in the course of system modification.

7.1.5 Automated Generation of Data Structures for TI

The organization of engineering-data content to be used in constructing TI could be simplified by development of interactive TI-preparation software. Software-support programs of this kind could be developed so that the preparation system could provide the TI preparer with a task structure he can use for translating the engineering data into draft aiding/training packages. Such support software would represent one major subsystem of the TI preparation software.

7.1.6 Thesarus Software Development

With an interactive system, it is necessary to develop system dialogue that is acceptable and understandable by system users. One potentially satisfactory solution to this problem is development of a computer thesarus that can convert statements entered by a TI preparer into language that technicians understand and prefer. Such an approach would involve some minor special-purpose software development, as well as field studies of technician-technician discourse in appropriate maintenance environments. The thesarus of words and phrases could be developed from sociolinguistics analysis of technician discourse. The software then developed could create the TI by substituting preferred terms and phraseology for the corresponding language created by the technical writer or engineer.

7.1.7 Software for Assurance of Specification Compliance

One potential requirement for accomplishing NTIPP's control and standardization functions could be the development of software techniques for assurance of specification compliance; i.e. for QA. This would be the case whether NTIPP decided to pursue a total digital-data approach or some other approach involving the use of data-automation techniques for producing TI in other forms, such as hard-copy manuals.

Software can be developed, for example, that does not permit sentence length to exceed a given number of words, or that does not permit graphics complexity to exceed a given number of vectors. Accuracy verification is also possible to automate through software that can permit automatic comparisons of terms or other events with corresponding engineering data. Discrepancies and errors could be more easily detected and corrected in this way. Specific study should establish design requirements for such specification-compliance-assurance software.

7.1.8 Simulation and Usability-Verification Software

The present scenario implicates the need for increased efforts to verify TI usability prior to Navy acceptance of contractor-prepared TI. In order to accomplish the hands-on testing needed for usability verification, simulation and usability-verification software are required. This software would be similar to the software used for TI presentation, although the system-acquired data logging and analysis would probably differ in some respects.

For training and training-analysis purposes, some additional software development would also be required. For training, system use would primarily involve identifying individual areas of strength and pinpointing individual areas of weakness in initial technician knowledge and skills. Also, system-acquired data could be used for establishing quantitative performance standards, to be used for providing normative baselines against which training proficiency could be estimated.

7.2 Technical-Information Distribution

A network for TI distribution needs to be developed. A study should be conducted to determine optimal network topology and information flow in terms of reliability, speed, and cost-effectiveness. Interfacing with logistics information management systems should be considered.

7.2.1 Data-Base Management System

The storage and distribution functions must be implemented through development of a data-base management system for central processing purposes, with smaller data-base management subsystems required for lower level archives in the distribution network. If some consolidation is planned between NTIPP-developed TI and associated logistics information management systems, an integration study on overall data-base management-system design is clearly required. One important consideration of such a study would be that of configuration control. For proper automated configuration control of TI, information requirements for specified TI must be known and tracked in the case of changes in or transfers of equipment. This task would represent a major record-keeping job, and might best be down-loaded to the best degree possible to the intermediate-level archives. Configuration control would involve an important interface point with the operative logistics-information management systems, such as the current Uniform Inventory Control Point data system for material management.

7.2.2 Management of System-Acquired Data

The other major software development requirement for distribution and storage of TI is the data-management system for collection, analysis, and distribution of data required to evaluate TI, obtained from analysis of system-collected data. A management system would be necessary to provide for summarization, interpretation, and routing of such information for appropriate data users.

7.3 Technical Information Presentation

A near-term study is required for constructing a prototype of the TI presentation system that can accomplish most of the functions desired of

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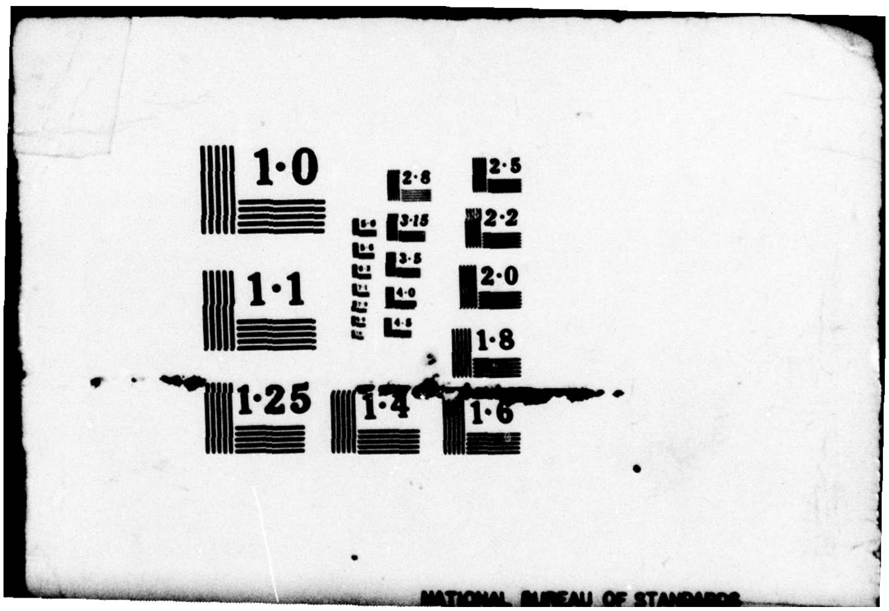
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the production product in order to conduct a design evaluation. This prototype system could be used in laboratory and field settings to generate data needed in the detailed system design and to assess the efficacy of such an approach.

7.3.1 Delivery-Software Development

Three types of programs will be required for TI delivery: (1) programming to control the user-system interaction and the presentation control of stored data; (2) the data compression/reconstruction software (if used) and (3) the data collection and analysis software used for system data acquisition.

7.4 Supporting Research Requirements

Development of automated TI systems represents a new technology and can be expected, like any new technology, to require continuing programs of supportive research and development for some years to come. NTIPP would be well-advised to develop dedicated system-simulation laboratory facilities, so that ongoing supportive R & D can be undertaken and so that sound scientific and technological foundations for this technology can be established. The second NTIPP capability that appears to be important would be the establishment of capacities for the critical-element testing referenced in earlier descriptions of the NTIPP program concept. Field-study R & D opportunities will permit bridging the gap between the current laboatory level of automated aiding systems and Navy implementation of automated TI.

The present contractor's recent work in this area indicates some specific areas of supportive research that should receive formal investigation through system simulation and field test and evaluation studies. These areas are discussed below:

7.4.1 Formal Study of Automated Format Effectiveness for Deductive and Directive Aiding Formats

Ways have been identified in which data-automation capabilities can enhance TI usability to technicians and operators. Using these laboratory-level formulations as hypotheses, field study should validate the significance of these prospective TI enhancements, comparing maintenance-task performance with automated aiding techniques against paper-based TI, for a variety of maintenance tasks.

7.4.2 Relative Costs of Automated TI Preparation

Precise estimates of the relative costs of preparing TI with automated TI preparation systems cannot be provided at this time. What is needed for this cost-analysis purpose is a working automated TI preparation system that can be used for generating TI and for comparing specific costs against comparable costs incurred through traditional TI preparation approaches. This study could not be undertaken, however, until NTIPP has developed at least a prototype system for automated TI preparation.

7.4.3 Projection of Life Cycle Cost (LCC) Savings Associated with TI Automation

The documentation of LCC savings resulting from TI automation is another important area of supportive study, but it, too, cannot be undertaken in any definitive way until some years downstream in the NTIP Program. Such an effort might best be structured as follows: (1) develop a system for which total TI automation is used for maintenance and on-the-job training purposes, and (2) then perform a longitudinal study of system life cycle costs, compared against similar systems maintained by hard-copy TI. It is anticipated that studies of this kind can become routine after the NTIPP program receives full implementation.

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