BOOKWORM

A TECHNOLOGY DEMONSTRATOR FOR THE STORAGE AND RETRIEVAL OF TECHNICAL INFORMATION IN SHIPS

BY

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ABSTRACT

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Introduction

In the spring of 1987 it became evident that digital Optical Storage Technology was reaching the stage of commercial viability, with the result

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Introduction

In the spring of 1987 it became evident that digital Optical Storage Technology was reaching the stage of commercial viability, with the result that manufacturers of computer systems were placing products on the commercial market aimed usually at large office filing systems and, to a lesser extent, technical and drawing offices holding large numbers of drawings and documents. The most common storage technologies demonstrated at that time were:

(*a*) *CD-ROM*. Essentially a 'read-only' information storage medium capable of digitally storing large quantities of text and graphics images using technology similar to that for producing CD audio discs. A single 4¾ inch CD-ROM can store up to 600 Megabytes of data equivalent to 275,000 A4 pages of non-indexed character text or 170,000 pages of indexed text or 11,000 pages of uncompressed raster images. Stored data can be retrieved, displayed and manipulated on a high resolution display. A laser printer is used for quality drawing reproduction. As CD mastering techniques are involved, initial production costs are quite high but thereafter copies can be cheap depending on quantity. Initially, CD-ROM seems particularly suitable for large information databases with wide distributions such as standards, technical indexes, administrative manuals, and some types of technical manual.

(*b*) *WORM (Write Once Read Many Times)*. WORM optical discs are a direct recording medium on which text and graphics can be recorded permanently using a variety of digital input devices including Optical Image Scanners and Optical Character Readers. By leaving spare capacity on the discs new material can be written to a fresh track location and the retrieval indexes amended to suit. Disc sizes of 5¼ inches, 12 inches and 14 inches are all commercially available. Typically a 5¼ inch disc might be quoted at 400 Megabytes (MB), a 12 inch disc at 2·6 Gegabytes and a 14 inch at 6·6 Gegabytes or 2·6 million pages of indexed A4 text. Re-writable optical disks are availiable, but for many applications the high integrity of a permanently recorded disk is considered to be a considerable advantage.

Other mass-storage optical technologies which may have an application in future include an optical card, the size of a credit card, holding about 2 Megabytes, and optical 'tape' which has a huge capacity (Terabytes) and is suitable for archival storage.

In the latter part of 1987 and continuing into 1988, VSEL Design Services Group in Bath were contracted by the Ministry of Defence to conduct a feasibility study into the use of optical disk technology at sea, prepare a user requirement, investigate the commercial market for potential suppliers, and ultimately prepare an outline design specification for a technology demonstrator system. The decision to construct a shore-based demonstrator was taken because it was felt that there was a need to increase awareness at all levels in both the MOD and the R.N. of the technology being considered, and to gain hands-on experience both in preparing material for the system and in actually using the equipment.

The design specification was submitted to a number of contractors who had expressed a strong interest in the project and already had systems in development that met many of the requirements. A competitive tender took place and this was won by a joint bid from Advent Systems Ltd. and Gould Computer Systems (now Encore Computer). Encore Computer will be familiar to many R.N. personnel as suppliers of the current OASIS System. The order was placed in February 1989; the system was commissioned in June 1989 and shown to over 700 R.N. MOD and Industry personnel at some 20 locations in the U.K. over a period of three months. Those attending were asked to complete a questionnaire after each presentation and the results have been analysed and presented in a report to MOD.

It was decided to opt for WORM as the storage medium for use at sea, for the following reasons:

(*a*) Each R.N. ship, even in the same class, has differences in equipment fit, and each equipment is likely to have a variety of build standards or variant definitions according to the ship. Thus, the number of replications of similar disks is small, mitigating against CD-ROM for cost reasons as the technical processes of producing a CD-ROM are similar to those for audio disks and require a master disk and a pressing plant. Ship-specific WORM disks can be economically created from a MOD master database ashore.

(*b*) Security problems are minimized as the WORM disks can be created in house on relatively low-cost equipment, rather than having to use contractors to produce the CD-ROMs externally.

(*c*) The technical material is subject to frequent updates and WORM allows the updated material to be added to the disk rather than having to use other forms of temporary storage or produce a new disk, as is the case for CD-ROM.

(*d*) There is a requirement to generate local files on the equipment which can be linked to the master documentation.

The Demonstrator System

Hardware

The demonstration system (FIGS. 1 and 2) used 550 MB 5·25 inch WORM disks which hold about 250 typical technical handbooks, including both text and illustrations, or about 2000 A0 size engineering drawings.

FIG. 1—THE BOOKWORM DEMONSTRATOR SYSTEM

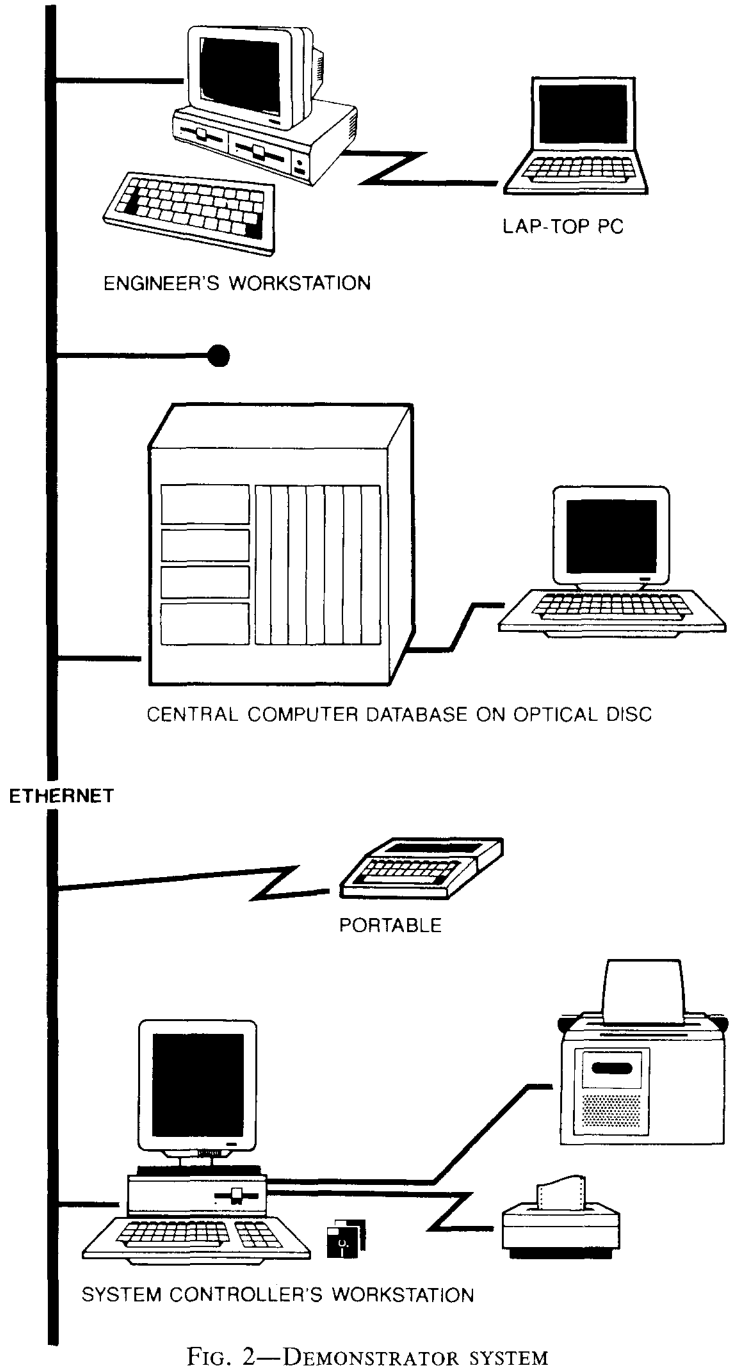


FIG. 2—DEMONSTRATOR SYSTEM

The main workstation was a Sun 3/60 Unix high resolution colour graphics workstation. Connected to this was a Cambridge Computers Z88 hand-held text only portable and, for the early demonstrations, the A4 laser printer. For later demonstrations the laser printer was connected to the parallel printer port on the Gould file server to improve print times. The Sun had 8 MB of main memory and 141 MB on hard disk to manipulate images once retrieved from the optical disk.

The second workstation consisted of an Olivetti M200 PC, of the type being fitted as part of the OASIS system. Connected to this was an A4 scanner. The Olivetti had 1 MB of main memory and a 20 MB hard disk and therefore its handling of images, especially graphics, was slower and restricted when compared with the Sun, although still effective.

A Toshiba T1600 lap-top, capable of taking text and images from either of the fixed workstations via floppy disk, was used as a stand-alone terminal and ran off either mains or rechargeable battery. The Toshiba had 1 MB of main memory, a 1·4 MB diskette and a 20 MB hard disk. It could also store and manipulate images effectively.

The Disk Drive and File Server comprised a single 5·25 inch WORM optical disk residing in a Gould PN6000RD processed unit. This was connected via a Thin Ethernet Local Area Network (LAN) to two fixed workstations.

Software

The demonstrations used Advent software combined with other commercially available retrieval software to illustrate three techniques of information retrieval. These were:

(*a*) *Indexed Database.* This is the simplest of the techniques to implement and probably the cheapest. It involves creating electronic images of pages by passing them through a scanner and then filing these images in a database under a suitably designed index. It can be regarded as a form of electronic microfilm but the user can select information very rapidly from a relational database using a series of menus and a keyboard, mouse, or other pointing device. Images can then be zoomed, panned or windowed with other images, and printed on a laser printer which produces sharp black and white prints. The software used in this part of the demonstration was:

- Advent Superpeep (for all scanned images and photographs).
- Advent Designer 40 (for the CAD drawing).

(*b*) *Free Text Retrieval.* For this technique to be implemented, the text for the documentation must be obtained in a character-encoded form such as ASC11. This may be obtained direct from a word processor or publishing system, or by converting hard copy using Optical Character Recognition (OCR) software. With the text in this format, the software indexes all words (except 'and', 'the', 'is' and other defined stop words) and then responds to user enquiries on particular words or phrases by presenting a list of sections of the document that are relevant, any of which may be selected for display. A graphical interface allows diagrams to be called in and manipulated, print-outs of text, diagrams or screen to be obtained, and downloading to portable computers. The interface is controlled by use of the mouse and as well as displaying selected images, the user can page through the text section by section. The software used in this part of the demonstration was:

- Advent EDIS, incorporating Information Librarian.
- Advent Superpeep.

(*c*) *Hypertext.* For this technique to be implemented, it is again necessary to obtain the text of the documentation in character-encoded form. 'Buttons' (links to other parts of the document or related documents) can then be implemented and can also run other software, allowing diagrams to be displayed and manipulated and scratch pads to be created for user notes. The user may then rapidly access information, without using the keyboard, along controlled routes. A similar graphical interface to Free Text Retrieval is used. 'Buttons' are used in particular to provide links from contents lists, cross-references, and key subjects in the text to information held elsewhere in the document. This mirrors the way many users find information at present in a conventional handbook. The software used in this part of the demonstration was:

- Guide.
- Advent Superpeep.
- Vi Unix Editor.

The Demonstrations

The demonstrations used current R.N. documentation, including BRs obtained in hardcopy and a variety of electronic forms, from main frame publishing systems and word processors. The project team inserted the necessary structuring information for the retrieval software. The demonstration material also included A0 engineering drawings, a CAD file, a map, and monochrome and colour photographs.

The demonstrations lasted about one and a half hours and began with a brief introduction to the project, optical storage and the demonstration system. Users were shown:

(*a*) how to solve a particular maintenance problem using free text retrieval to locate relevant text and diagrams;

(*b*) how to down load selected material to the portable computers;

(*c*) how to print selected material.

(*d*) how hypertext could be used to obtain the same information without use of the keyboard and how it could give access to additional features including cross-referenced material, notepad facility and other applications such as the stores system;

(*e*) how to scan, index and retrieve information at sea;

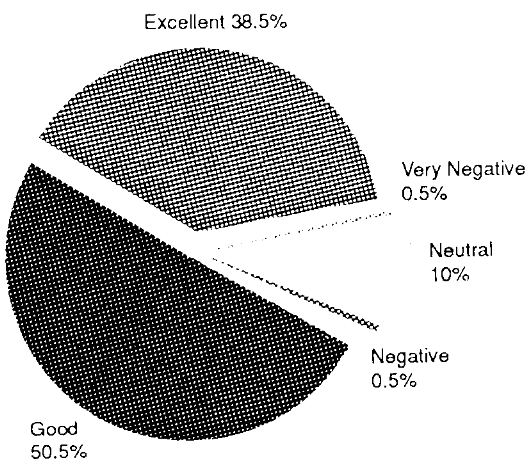
(*f*) how the amendment process is simplified and automated for the information user.

A typical demonstration programme included a number of exercises carried out by a team member (a former Chief MEM, Royal Navy) who was familiar with R.N. documentation but not with the use of computers.

The presentations were followed by a lively question and answer session. Members of the audience were invited to try the system and to complete a questionnaire, giving their overall views and specific comments on hardware, software, management and use.

System Performance

The demonstration system performed well in terms of the functionality provided to users, it was adequate in terms of response times, and the majority of the system components proved reliable in spite of the packing, transportation, re-assembly and use at a new site every few days over an intensive three month period. A fully engineered system for the Navy would of course have to comply with the usual environmental standards although



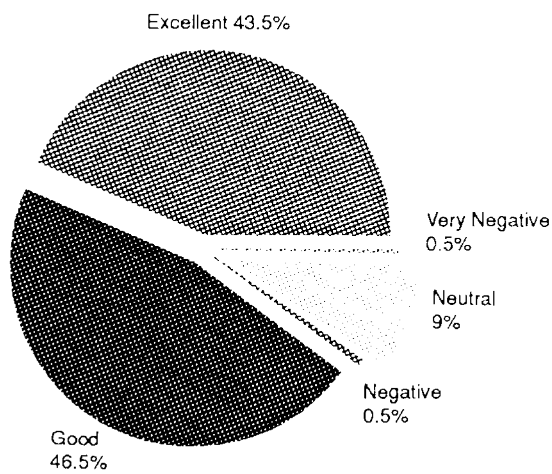


FIG. 3—BOOKWORM REACTION
LEFT: OVERALL REACTION (SAMPLE FIELD 541)
RIGHT: R.N. REACTION (SAMPLE FIELD 299)

it might well use commercial equipment. Typical response times to user enquiries are shown in TABLE 1. Audiences agreed that these response times were adequate but it should be noted that seconds spent waiting in front of a VDU can seem more frustrating to the user than minutes spent moving to another location to obtain information. However, faster processors developed since the demonstration system was procured means that many of the times could be dramatically reduced.

TABLE I—*Select and display times*

Time to select and display specific manual from menu on primary workstation:	
free text	8 seconds
hypertext	13 seconds
Time to type simple free text enquiry and display relevant text	12 seconds
(this is a repeated operation)	
Time to select equivalent section using hypertext.	10 seconds
(this is a repeated operation)	
Time to select, decompress and display A4 diagram from B.R.	12 seconds
Time to zoom in and re-display portion of A4 diagram	8 seconds
Time to select and print page of A4 text (300 dpi)	24 seconds
Time to select and print A4 diagram (300 dpi)	2 minutes 5 seconds
Time to select and print screen dump (300 dpi)	58 seconds
Time to select and display A0 drawing (300 dpi)	30 seconds
Time to select and display A4 monochrome photograph (300 dpi)	14 seconds
Time to display high resolution colour photograph	16 seconds

Reactions of Users

At the end of each session the audience was asked to complete a questionnaire. A summary of the responses follows, based on the 544 questionnaires analysed by VSEL.

First Impressions

FIG. 3 shows how potential users classified their immediate reactions to the demonstrations. The classifications were as follows:

- Excellent—should proceed as fast as possible.
- Good—should proceed, subject to normal disciplines and timescales.
- Neutral—might be worthwhile but would like more time and information to consider.
- Negative—don't think it will be worthwhile but might be convinced in the future.
- Very negative—consider it a waste of time.

481 (89%) of all users (naval and civilian) chose Excellent or Good as their categories which reflects the need of the user in the fleet, the dissatisfaction with current arrangements and a recognition of the potential of such systems.

58 (10%) reserved judgement, although in some cases the reason given for this was they were not regular users of technical documentation. Four (less than 1%) expressed any kind of negative reaction. If the analysis is restricted to serving naval personnel (a sample size of 299) then the proportions are almost identical to the overall sample, but with a higher proportion, 130 (43.5%) of Excellent reactions expressed.

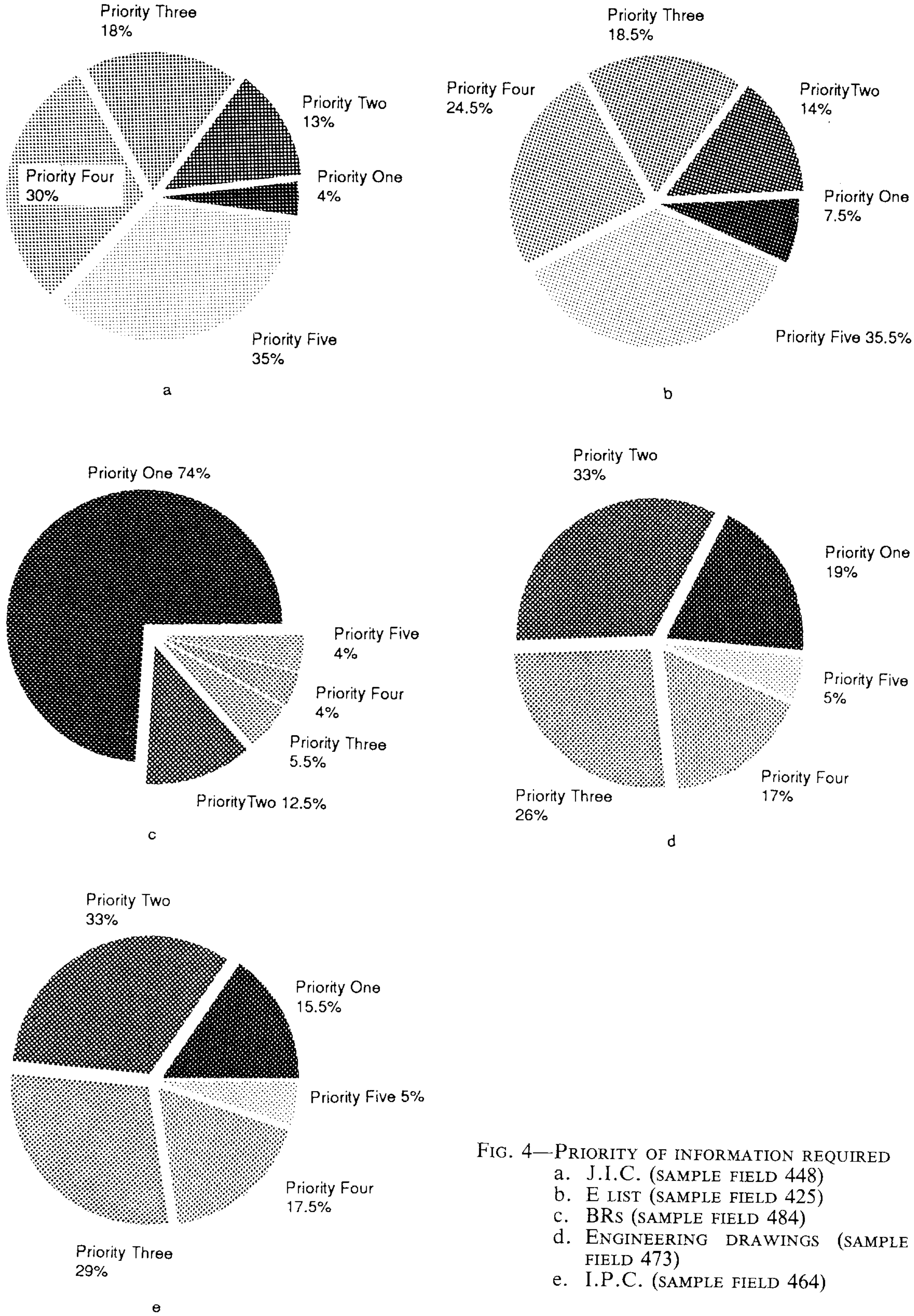


FIG. 4—PRIORITY OF INFORMATION REQUIRED
a. J.I.C. (SAMPLE FIELD 448)
b. E LIST (SAMPLE FIELD 425)
c. BRs (SAMPLE FIELD 484)
d. ENGINEERING DRAWINGS (SAMPLE FIELD 473)
e. I.P.C. (SAMPLE FIELD 464)

Priorities

Users were asked to allocate priorities to five types of information that could be put on a Bookworm system:

- BRs (handbooks)
- Engineering Drawings
- Illustrated Parts Catalogues (IPCs)
- Job Information Cards (JICs)
- Equipment Lists (E-Lists).

The answers to this question are shown graphically in FIG. 4. The clear favourite was BRs, with Engineering Drawings and IPCs running each other a close second. Overall, 'E' Lists were slightly less popular then JICs, but as 'E' Lists relate only to WE equipment, it is clear that WE personnel gave them a higher priority than JICs. Not everyone felt able to categorize each type of information and those who did based their judgement on the priorities of their current job. An analysis using just the R.N. personnel reflected the same order of priorities.

A second part of the question asked people to list other types of information that they would like to see on a Bookworm system. In all some 80 further applications were identified ranging across the whole field of R.N. paperwork.

TABLE II—*Perceived benefits of Bookworm, compared with present-day practice (per cent.)*

	Very Important	*Quite Important*	*Marginal Benefit*	*Not Important*	*Disadvantage*
Faster Access	39 (37)	47 (48)	13 (13)	1 (2)	0 (0)
Easier Access	63 (68)	30 (26)	5 (6)	1 (0)	1 (0)
More Information	43 (45)	46 (44)	10 (11)	0·5 (0)	0·5 (0)
Higher Quality	66 (67)	27 (27)	6 (5)	1 (1)	0 (0)
Greater Selectivity	28 (28)	55 (56)	16 (15)	1 (1)	0 (0)
Local Updating	36 (37)	41 (44)	20 (18)	1 (0·5)	2 (0·5)
Feedback Link	33 (32)	42 (42)	22 (23)	2 (3)	1 (0)
Weight Saving	23 (16)	35 (34)	28 (36)	13 (14)	1 (0)
Space Saving	38 (33)	34 (35)	21 (26)	6 (5)	1 (1)

Note: Figures in brackets are for R.N. personnel only.
Sample size: Overall 544; R.N. 299.

Benefits

The third question asked for a series of nine possible benefits of the system to be arranged according to their importance. A complete breakdown of the answers to this question is shown in TABLE II. Most felt that a Bookworm system would offer benefits in all nine areas with 'Higher Quality of Information' and 'Easier Access to Information' seen as the most important benefits, ahead of 'More Information Available' and 'Faster Access to Information'. The least important factor was perceived to be 'Weight Saving' while some rated the ability to update information locally a disadvantage.

An analysis of just the R.N. personnel revealed a similar order but with 'Easier Access' just ahead of 'Higher Quality Information' in importance, and the 'Local Updating Facility' rating fourth rather than sixth in the overall analysis.

Problems

Another question asked people to list 11 potential problems in introducing and using the system, according to their perceived seriousness. The breakdown of answers is shown in TABLE III. The overall and R.N. answers agreed on most issues and the problem that was ranked most serious was 'Running A Mixed System', that is the problems associated with having to produce material in hard copy, fiche and electronic form for different vessels. However, modern electronic publishing systems have the capability to output the same material in different forms and formats and this will considerably ease the problems.

Most recognized the problems of information conversion and restructuring which, purely in terms of scale, can seem daunting. Again, we believe that developing publications technology will minimize the problems here.

A point of particular note, in view of the overall reactions, was the number of those who rated 'Convincing Users' a serious problem. This can be explained by their awareness of the R.N. maintainers' reactions to, and lack of confidence in microform and early IT systems. Communication involving the user in the design process, and training, are the keys to overcoming difficulties in this area.

In summary, the points users raised were not major technical problems but concerned matters of organization and implementation. Security, reliability, and information management all ranked highly and the remainder of this article will address some of these issues.

TABLE III—*Perceived problems with Bookworm (per cent.)*

	Serious Problem	*Problem*	*Minor Problem*	*Not a Problem*
Conversion of BRs	17 (15)	54 (52)	23 (26)	6 (7)
Conversion of Drawings	16 (10)	51 (52)	26 (31)	7 (7)
Restructuring Material	18 (18)	53 (50)	24 (27)	5 (5)
Convincing Users	24 (27)	36 (34)	28 (26)	12 (13)
Training Users	12 (17)	30 (29)	46 (43)	12 (11)
Preparing New Material	4 (3)	33 (32)	41 (44)	22 (21)
Running a Mixed System	30 (32)	44 (41)	21 (20)	5 (7)
Integration	14 (16)	55 (56)	20 (18)	11 (10)
Hardware Aspects	19 (21)	33 (30)	28 (30)	20 (19)
Software Aspects	11 (12)	33 (25)	29 (36)	27 (27)

Note: Figures in brackets are for R.N. personnel only.
Sample size: Overall 544; R.N. 299.

Access Points

The provision of sufficient access points around the ships, and the resilience required to meet the high availability needs was also a matter of concern—again possibly arising from the problems with microform. This has led to the proposed system architecture of a distributed database with file servers and terminals connected by a dual redundant network. Terminals would range from a few large screen primary workstations to many secondary X-terminals and PCs for more routine access. It is not economically feasible to fit a workstation in every required location but it is feasible, particularly when refitting or building a new vessel, to route a network to every likely compartment and provide a termination point. It is envisaged that a series of portable terminals with fly leads could be carried to locations where no fixed workstations are fitted and connected to the network through these termination points. The data base may then be interrogated for the information required. Some of the portable devices could also incorporate WORM drives so that, in the event of catastrophic system failure, information can still be accessed. The development of a suitable portable terminal is seen as one of the key factors in achieving widespread acceptance of this system and high availability.

Integrity and Security

Integrity and security were also mentioned as factors. They are, however, problems that the Navy have had to address for all their IT systems and are something of a problem with the present hard copy and microfiche systems. The majority of the technical information is not highly classified (probably no more than 15%) and simple access controls and normal physical control procedures should ensure the integrity of the system. More highly classified information is unlikely to be available over the network and the disks containing such information could be physically controlled in the same way as CBs. Rigid access controls using passwords and logging could provide some of the security requirements and the network itself could be fibre-optic for both security and electromagnetic reasons.

All these are matters for system design, but do not pose insuperable technical problems and should not inhibit progress on a system for the bulk of unclassified and restricted material. The aggregation of large quantities of unclassified and restricted information may still require the disks to be physically protected using procedures already in force.

TABLE IV—*Conversion times for demonstration material (seconds)*

Document	*Source Conversion*	*Information Structuring*	
		Free Text	*Hypertext*
BR—Echo Sounder	10	12	24
BR—Trim, Bilge & Ballast	7	7	15
BR—Sting Ray Torpedo	3	—	8

Information Management

Systems using retrieval software such as free text or hypertext require intelligent digital encoding in order to insert the necessary 'Tags' and create indexes. Material which is already digitally encoded, e.g. from word processor or CAD systems, can be readily interpreted and the necessary conversion and structuring performed by the author. Actual times of conversion for the material used on the demonstrator are given in TABLE IV. Where material is not available in digital form then it either has to be raster scanned, giving an electronic image of the page which can then be indexed as an entry, or alternatively it must be passed through an OCR scanner which converts the text to an ASCII file of alphanumeric characters. OCR scanners are not yet perfect and require human intervention in the form of visual editing for high accuracy.

The majority of MOD contractors use electronic systems for the preparation of text and drawings but as yet there are no agreed standards for the transfer of this information to MOD in digital form. International standards for digital exchange do exist but do not yet guarantee efficient error-proof exchange and there is some presssure for MOD to adopt the U.S. Department of Defense CALS (Computer Aquisition and Logistic Support) standards in future procurement which is some way towards achieving this aim. This is

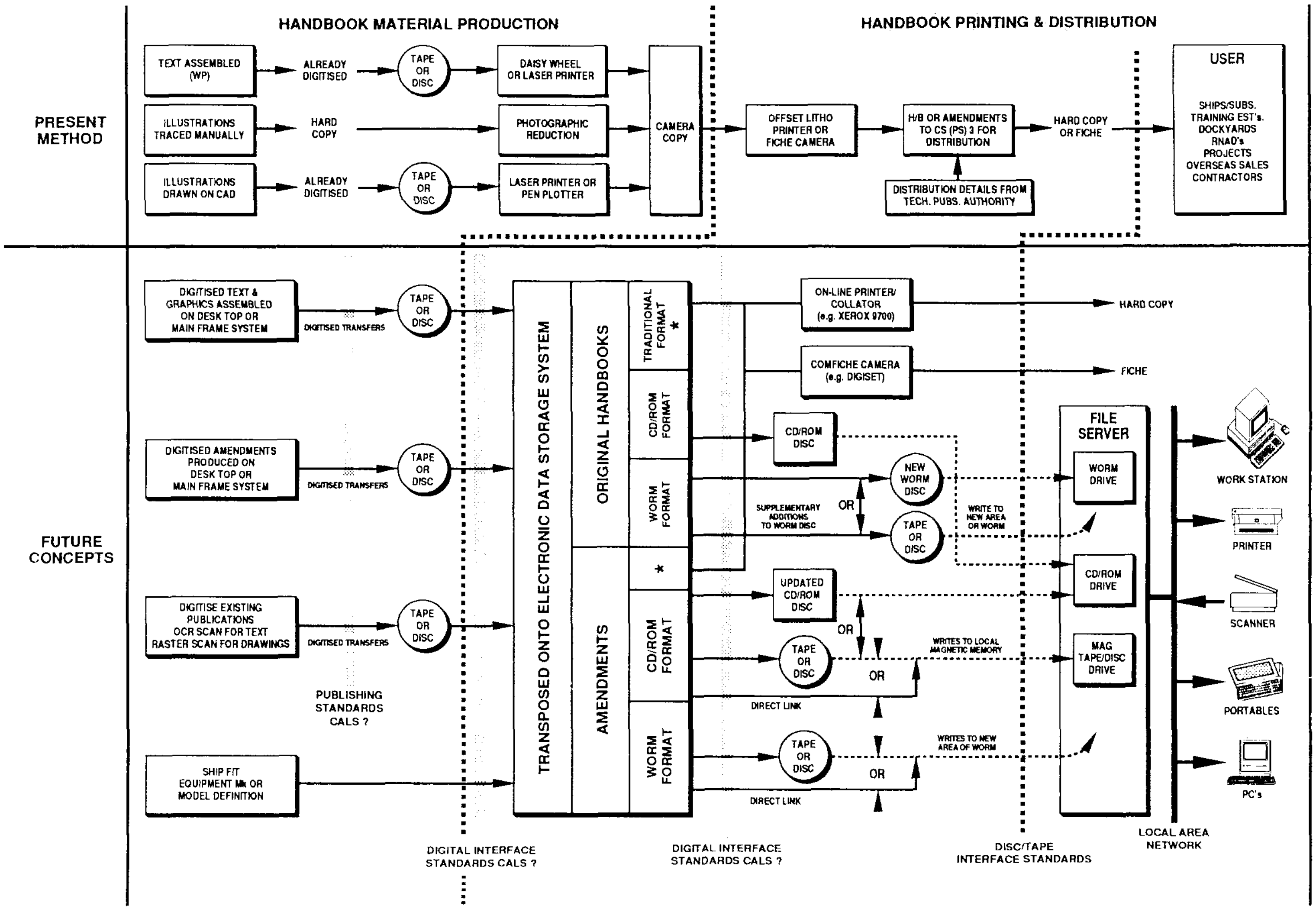


FIG. 5—PRESENT AND POSSIBLE FUTURE HANDBOOK PRODUCTION SYSTEMS

still being debated, although most are convinced that better standards will simplify the situation and therefore reduce costs in the longer term. A system such as Bookworm must adapt to the situation that currently exists, and part of the demonstrator programme was to show how effectively material of various types and format standards could be economically loaded into the system. A conceptual view of a possible future electronic publishing system is given in FIG. 5. An advantage of such a publishing system is the close control which the central database affords in the updating and supply of information to the user. The ability to tailor information to the fit and build standard of the actual equipment fitted and to automatically issue amendments as changes of fit are made should give confidence to the user and avoid the problem of outdated information being used in error.

An important feature of any future system will be the ability to scan in and index 35 mm aperture cards automatically and to create indexes using the existing punch card formats. Such systems exist but their effectiveness in dealing with a wide variety of material of varying quality has yet to be tested.

Bookworm has concentrated on current presentation methods and information structure and any system fitted in the immediate future would clearly have to do the same, as the task of restructuring the entire documentation database is unlikely to be attempted for some time and may not even be possible with the current state of technology.

As Bookworm is basically a computer system with a very high storage capacity, it could support many other more effective ways of presenting information than is possible with a paper-based system. A few possibilities are:

Common Source Database

With a common source database, the concept of BRs, Engineering Drawings, IPCs and other separate streams of documentation disappears and the user is encouraged to think in terms of an integrated information package for a particular system or equipment. Within this package, a user may start at any convenient point, say a diagram or photograph of an equipment, highlight a particular component and, from a menu, be able to access information about the component. This could be an exploded diagram, a parts list, a functional description or maintenance information. A properly designed database, with all elements and links defined, would avoid duplication, and simplify a maintainer's task in finding the appropriate information. The information elements need not be just text or graphics, but can be any of those described in the following paragraphs. The database approach also lends itself to future expert system incorporation, where the system assists the maintainer in diagnosing faults based on past experience.

Sound

Sound can be utilized in a number of ways. Its simplest use is an audible alarm to draw the user's attention to such things as Warnings and Cautions. It could be made interactive, by requiring a response from the user before further information can be viewed. A more complex use is to be able to output information directly in an audible form or to store comments. Software to interpret the written word is being developed by various companies, and this would allow downloaded information to be played back to the user through headphones, making it suitable for use in confined or hazardous areas.

Colour

Although colour was utilized for the demonstrations, this was in a very limited way. Apart from its use in drawings, it can also be applied to text.

Windows containing maintenance information could be coloured differently from those containing functional descriptions. Amendments could be picked out in particular colours and important text, such as warnings, contrasted.

Photographs

Monochrome and colour photographs could be used more extensively. These are easy to prepare compared with line drawings, and can be scanned into the system, as some of the demonstration material was. Scanning at 300 dpi produced a usable photograph on the screen, but scanning at higher resolution, although it took up more storage space, produced a picture that was easier on the eye. Editors could be used to add labels to photographs quite simply and these could act as hypertext links to further information.

Animation

The workstations used in the Bookworm demonstrations are capable of displaying animation, which could be stored on the optical disk. This could be used to show fluid flow through pipes or current flow around circuits, and could be made interactive, allowing the user to open and close valves or switches. This would be particularly useful in training applications.

Video

This is similar to the animation described above, but applications to date have mainly been confined to Laser disks (analogue representation) and CD (digital representation). There is no reason why WORM could not be used, and this would allow users to view maintenance operations before, or as, they perform them. Again, its major use would probably be as a training aid.

3-D Graphics

Modern CAD/CAM systems hold three-dimensional representations of components, allowing them to be viewed from any position. If this was available to the maintainer, he would be able to view areas of equipment that were hidden from him, and undertake tasks more confidently.

Conclusion

In summary, Bookworm can be seen as the first step along a road which could radically change the way we procure and use information both ashore and afloat and, while we must sensibly address the solutions to today's problems and to gain immediate benefit from the investment involved using existing information structures, the standards and systems that are evolved should take account of the possible future developments in the information management field.

Approval has been given to conduct a set of sea trials using 'Bookworm' type systems to replace microform in a number of surface ships and a submarine. Work is in hand to plan, cost and define the equipment requirements for these trials which it is hoped will start in late 1991. It is firmly believed that a comprehensive trial is necessary to ensure full and active user participation and input to the design of a future shipborne system. Studies will also take place in parallel on the requirements of the shore infra-structure needed to support such a system at sea.

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The authors wish to acknowledge the efforts and advice of the many officers in the Royal Navy, MOD and Industry who have contributed to the success of this project.