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STRUCTURED HYPERMEDIA APPLICATION DEVELOPMENT MODEL (SHADM): A STRUCTURED MODEL FOR TECHNICAL DOCUMENTATION APPLICATION DESIGN

THESIS

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THESIS

Presented to the Faculty of the
School of Systems and Logistics
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Information Resource Management

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December 1991

Acknowledgements

I would like to thank the people who have helped me in the research, testing and preparation of this thesis. Their assistance was invaluable and provided me with the opportunity to not only increase my knowledge but to expand my personal horizons as well.

I am particularly indebted to my thesis advisor, Mr. Arthur Munguia, for his timely advice, guidance and knowledge when it was most needed. Additionally, special thanks go to the Commander of ASD/VF, Colonel Kadish, for giving me access to his organization and personnel.

I also wish to thank SMSgt S. McLoud, Mr. Al Stringer, Mr. Jack Willey, Capt Terry Ryan, Mr. Paul Hrosch, TSgt Dan Newton, Msgt Larry Stepney, SqnLdr Bob Muns and FltLt John Turner for taking the interest and time to test the prototype model for me.

Finally I am dedicating this project to my wife Lisa and children, Troy and Davina, for without their support and understanding none of this would have been possible.

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Abstract

This research was conducted to determine how a Royal Australian Air Force technical maintenance publication could be transformed into a task oriented hypermedia application and to develop a model that could be used for future similar transformations.

The model was developed following in-depth analysis of the existing USAF F-15E maintenance publication set and validation was conducted using a prototype developed in HyperWriter, a commercial hypermedia product.

The prototype model was based around the performance of three maintenance tasks on an aircraft sub-subsystem and incorporated online user access to the necessary support data for task completion. Publication managers, producers, and users were involved in prototype testing and results validated the model design with limited modification recommendations. Recommended changes were subsequently incorporated in the final model.

STRUCTURED HYPERMEDIA APPLICATION DEVELOPMENT MODEL (SHADM): A Structured Model for Technical Documentation Application Design

I. Introduction

Effective and efficient utilization of resources is arguably one of the most significant components of operational management. During periods of seemingly unlimited budgetary allocations there is a tendency to not always recognize this as an important function and tight cost management becomes indulgent. As finance is not considered a critical resource, managers may not be as rigorous or objective in their evaluation of project proposals and their predicted efficiency returns. This has resulted in acceptance of projects that are not essential and congruent with organizational goals. Given the absence of restrictive finance budgets the urgent need for better utilization of assets and constant improvement is relieved. External and internal environment scanning for performance and efficiency enhancing technologies is not performed.

Given the present financial environment and facing the potential for additional reductions in defence budgetary allocations, the Royal Australian Air Force (RAAF) must continue to focus on stringent cost control. The onus is on all levels of RAAF management, now more than ever, to ensure that only essential and cost effective practices are introduced and maintained to support operational capability.

One area that has significant potential for greater efficiencies in cost control is that of logistics support, particularly the management of publications. To support its operations, the RAAF presently produces and manages in excess of 17,000 technical and administrative publications at an annual cost of approximately AD$12 million. These are distributed on a national and international basis.

RAAF publications are Australian military handbooks that contain the rules, regulations, technical and administrative knowledge used by RAAF and Department of Defence·personnel in the daily operation of the RAAF. The publications are produced and distributed in semi-pliant plastic four post binders and the contents are printed on each side of A4 size paper. Each binder has an external identification card affixed to the front detailing the subject information contained in it.

Publications are divided into groups following their general area of specialization; the groups are:

a. Education and Training

b. Supply

c. Defence and Security

d. Administration

e. Medical

f. Technical

g. Air and Operations (23:1-2)

Each specialist area is further divided into sequentially numbered topics containing detailed information and instructions pertaining to that area.

RAAF administrative and regulatory publications derive their content from the:

a. Australian Minister for Defence, in the form of instructions and directives

b. Chief of the Air Staff, in the form of administrative directions governing the day to day operation of the RAAF

c. Australian Government Department of Finance Regulations

Technical and maintenance publications are sourced from:

a. Manufacturers of weapons platforms and supporting technical equipment, in the form of technical specifications and maintenance documents

b. Experienced in-house specialists

An integral element of the production cost of technical and maintenance publications is the development of in-house corporate knowledge and the training and development of experts to carry out this task. Presently there are in excess of 268 publication sponsors, or "experts", whose primary roles are the evaluation and conversion of acquired technical information into publication format.

The conversion of technical information takes on a number of forms; rewriting an acquired text in toto so that it relates to specifically RAAF configured equipment; disregarding acquired data and writing a publication from scratch based on experiential knowledge; transferring an acquired publication into an RAAF publication binder and making service unique changes through the insertion of additional pages (usually pink in color to allow for easier differentiation).

The end result of this approach to information acquisition and dissemination is a labor intensive system and an end product that is far from perfect. The user is faced with a large number of technical and maintenance publications that are presented in varying formats thus making information difficult and time consuming to find. Add to this the requirement for the user to incorporate a large and continuous volume of amendments and publication updates, to both technical and administrative publications, and a significant amount of expensive man-time is lost. Inefficiencies of this magnitude can no longer be tolerated in times of reduced manpower and funding.

Problem Statement

The field of technical publications is one where information acquisition, delivery and maintenance costs are relatively high and application of technology in information delivery systems is low. The book has been an efficient and well accepted delivery vehicle and studies in the field of artificial intelligence, particularly expert systems and hypertext, indicate that a suitable replacement for the book may have been found in Hypermedia applications (22:65) (26:63) (20:116) (17:91).

The objective of this study is to determine how an RAAF technical maintenance publication can be transformed into a task oriented Hypermedia application, and to develop a model that can be used for similar future transformations. This will allow the RAAF to reduce costs associated with technical maintenance publication:

a. acquisition

b. conversion

c. distribution

d. storage

e. updating

It will provide maintenance personnel with a standard publication format and layout as well as allow more efficient access to information. Resolution of the specific research problem will be determined by answering the following objective statements:

What is a RAAF technical maintenance publication?

What is Hypermedia?

What is a task oriented application?

How can a maintenance publication be transformed into a task oriented Hypermedia application?

What is an appropriate model structure for future use?

What criteria needs to be considered in the model design?

What general cost benefits can be realized from this application?

Scope

The objective of this research is to determine how an RAAF technical maintenance publication can be converted into a Hypermedia application. To design and test a Hypermedia model that will guide publication managers, or sponsors, in the transformation of manufacturers technical specifications and maintenance documentation into RAAF specific task oriented publications within a Hypermedia environment.

Technical maintenance documentation evaluation and Hypermedia model development will be based on USAF Job Guides prepared for the F-15E aircraft, due to the unavailability of RAAF technical publications. The highly structured nature of the job guides, their availability and the trend towards simplified text and graphics presentation make them ideal subjects for model construction. The differences between the two services are minimal in the area of technical maintenance, particularly as similar aircraft types are operated and technical publications are sourced from original equipment manufacturers (OEM), therefore the applicability of research findings and final model to the RAAF environment will be assured.

Resolution of research question 8 will be limited to identification of general cost areas and potential savings realized through elimination of redundant processes. The limitations imposed by the academic requirements of AFIT and the amount of time available for this study preclude more detailed cost/benefit analysis.

II. Literature Review

RAAF Technical Maintenance Publications Deficiencies

As indicated in the introduction, the present RAAF technical maintenance publication system is producing publications in a variety of formats. Inherent with this approach are inefficiencies in conversion, production and use. There is no consistency in conversion, not all publications are fully reworked into RAAF format and no formal guidelines exist to help the individual publication managers in identifying publications suitable for conversion, although there are extensive regulations detailing the actual acquisition and management process (23). The decision to convert is based on a heuristic process exercised by the relevant publication manager. This lack of consistency results in maintenance documentation in varying formats being placed in the unit workshops which place an added burden on the users requiring them to be familiar with each layout and indexing style.

Two investigations were conducted into the management of publication production in the RAAF. The first was in 1978, its goal being to evaluate the replacement of printed publication medium with microfiche (24:1). The second, in 1981, at the request of the Senior Administrative Staff Officer, Headquarters Support Command, was tasked to specifically study increasing expenses and reducing efficiency in publications production. While this study concentrated on the physical printing aspects of the production cycle (6) both reports referenced the problems outlined above. The recommendations of the 1978 report were to replace technical maintenance paper publications with microfiche as it was considered a superior medium that removed the excessive and convoluted production process and eliminated the requirement for field users to continually update publications. The 1981 report recommended replacement of deficient and redundant printing and production machinery. Of the two, only the 1981 recommendations were acted upon and despite the earlier findings, no further action has been taken to address this aspect of technical maintenance publication management.

Expert Systems

A good starting point for a definition and understanding of what an Expert System is is to define Artificial Intelligence, "The study of mental faculties through the use of computational models by attempting to duplicate (or simulate) the mental faculties and thought processes of an individual, as in speech and vision" (19:1); and an Expert System is "a computer based system that uses knowledge, facts, and reasoning techniques to solve problems that normally require the abilities of human experts" (19:14).

Expert Systems are designed to replace "experts" in decision making processes by acting as repositories of knowledge. Researchers are divided in opinion on the extent to which Artificial Intelligence and Expert Systems can be applied or are successful in replacing the human element in decision making, given that studies have revealed that they are suitable applications where the interest domains are very narrow or highly bounded (7:4-7). Given that a significant proportion of human decision making is unbounded (7:4-7) and involves the application of heuristics or intuitive knowledge, traditional researchers are skeptical regarding the level of application and see AI and expert systems in a supportive role similar to decision support systems (DSS) (13:333). Henderson examines both applications and appropriately and succinctly concludes that "DSS and expert systems technologies can offer opportunities to enable, and perhaps provide, a catalyst for major organizational transformations" (13:345). Introduction of these technologies in the RAAF publication system would result in the need for a significant review of the current publication management structure. The ramifications in relation to organizational transformation would extend far beyond the immediate publications environment and would force the review of manning and career structures for a number of officer and airman job streams as the need to employ people in the production and management spheres becomes redundant.

Hypermedia

To better understand Hypermedia and its role in on-line technical maintenance documentation a clear definition of what it is and where it fits into the overall hierarchy of data processing is essential. Although the terms Hypermedia and Hypertext are often used synonymously, Hypermedia was spawned from Hypertext; Hypermedia incorporates basic elements of Expert Systems, Hypertext and Artificial Intelligence technology (16:4).

In general terms, "Hypertext may be viewed as multidimensional text space constructed as associative links within and between documents" (12:45), or "a combination of natural language text with the computer's capacity for interactive branching, or dynamic display...of a nonlinear text... which cannot be printed conveniently on a conventional page" (10:17). Multidimensionalism is achieved through the use of "nodes",and "links" and is best represented graphically, see Figure 1. The nodes are the files or pages of text while the links are the joining points bet.een t e files. The links between the nodes provide the nonlinearity of Hypertext and can be compared to footnotes or bibliographic references (10:33) where the reader can access them and "pursue ideas suggested by one level of a document to another level or document" (12:45) without physically leaving the text under study. Put more succinctly, nodes can be described as single "concepts" or "ideas" while links are the relationships or "interdependencies" between them (10:37).

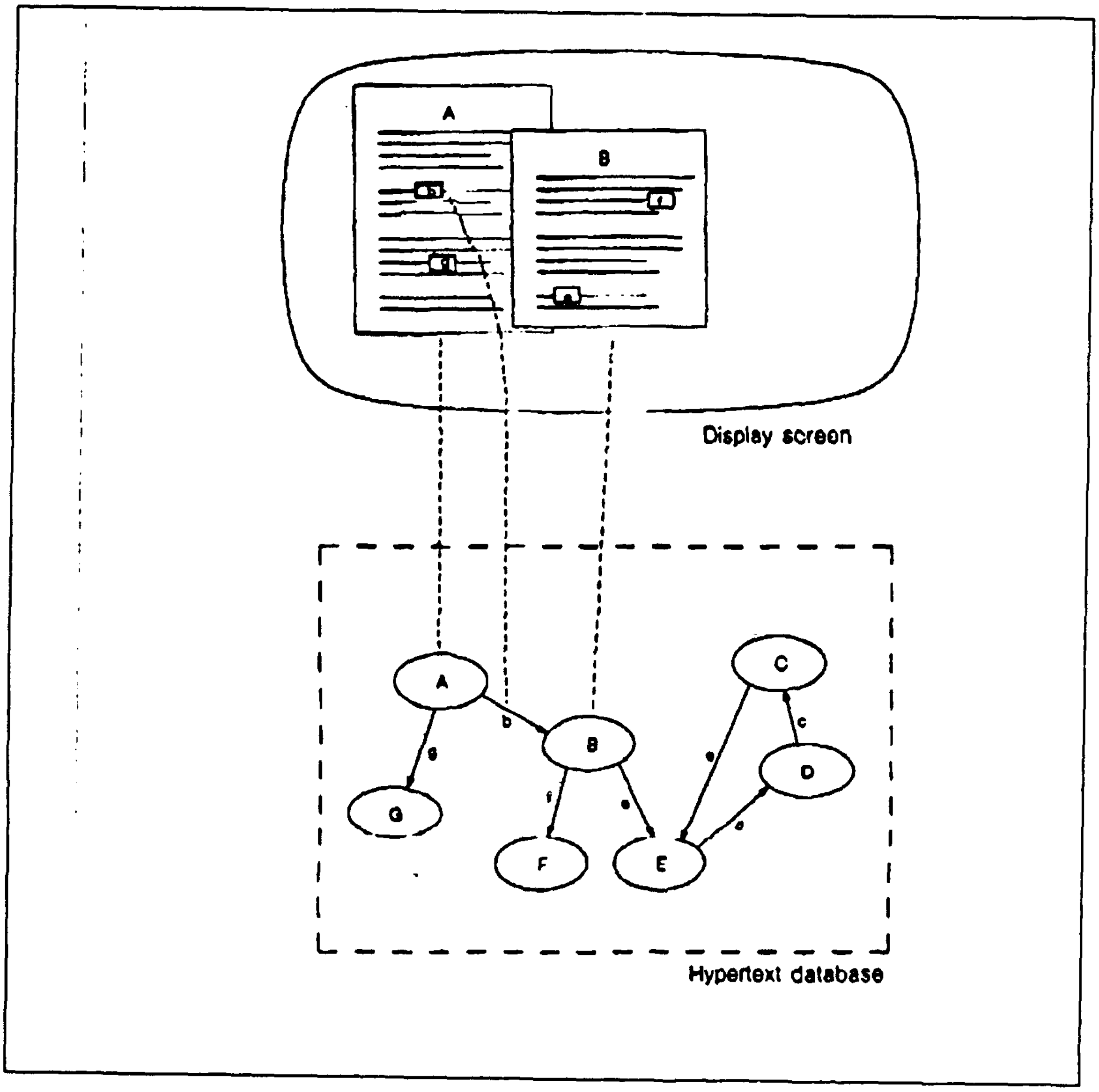

Figure 1: Hypertext Documents Showing Nodes and Links (10:18)

Hypermedia encompasses the power of Hypertext as an information database retrieval system (10:33) and combines it with additional information storage and presentation media such as graphics, audio, animation and video; in combination with heuristic based expert system applications, this produces an extremely powerful and flexible knowledge-based information storage and retrieval system. User query responses can therefore be presented in a number of ways dependent upon the type of query made and is described by Franklin as:

> A hypermedia computer system integrates media to facilitate the associative retrieval, manipulation, and storage of information. The associative links among pieces of information allow the computer to mimic human memory. Words, pictures, and sounds can be linked to represent an idea or to aid in problem solving. While hypermedia cannot fully represent realia, other media such as music, video, text and graphics are ideal. (12:44)

Application of Hypermedia

The particular area of interest for this study is in the field of "macro literary systems" (10:20). This is "the study of technologies to support large on-line libraries in which interdocument links are machine-supported"(10:20); in particular their applicability to a military environment supporting highly technical repair and maintenance operations specifically at the task achievement level. The ability of Hypertext systems to operate successfully in this environment was demonstrated by the application of the ZOG hypertext system on the USS Carl Vinson (5:2). Although ZOG was a prototype it was successfully used to support four applications:

> "1. On-line policy manual (Ship's Organisation and Regulation Manual)
>
> 2. Interactive task management system (for analyzing and tracking complex tasks)
>
> 3. On-line maintenance manual with interface to videodisc (for weapons elevators)
>
> 4. Interact to the Air Plan expert system" (5:2).

The lessons learned from the ZOG experiments were applied to a commercial version called KMS (Knowledge Management System) (5:2) further establishing the suitability of hypertext in military environments.

The military application of hypertext was developed further, although on a limited basis by Adam Levitt in his 1989 thesis (17) where he modelled a shipboard messaging system using hypertext. He concluded that, as a technology, hypertext offered exciting and promising alternatives to the current "paper" system (17:90), although he did identify the need to further address principles and design issues that are consistent with present military policies (17:91).

USAF Technical Maintenance Publications

The USAF Technical Maintenance Publications produced for the F-15E aircraft were published using the Maintenance Integrated Data Access System (MIDAS) developed by McDonnell Aircraft Company in response to the Technical Order (TO) specification requirement detailed in MIL-M-83495 (19). The revised publication structure provides the following documentation:

a. General Vehicle Manual (GV)

b. General System Manual (GS)

c. Job Guide (JG)

d. Fault Reporting Manual (FR)

e. Fault Isolation Manual (FI)

f. Schematic Diagram Manual (SD)

g. Wiring Data Manual (WD) (21:2-3)

General Vehicle Manual. The object of the GV is to provide "an aircraft description and maintenance orientation and is designed to give the technician a broad view..", of the aircraft vehicle and "..the maintenance manuals needed to support it" (21:3). This publication contains the following information:

a. General maintenance information

b. Description of the maintenance manual set

c. Short systems description

d. Details of time compliance technical orders

e. General maintenance procedures

f. Danger areas, precautions and precautionary procedures

g. Vehicle measurements

h. Information relevant to vehicle lifting, jacking, levelling and towing

i. Consolidated list of supplies, test equipment and special tools

j. Abbreviations and symbols used (4:1-1)

General System Manuals. The GS manuals address the major aircraft systems and provide information on the following areas:

a. System, subsystem and sub-subsystem descriptions

b. Principles of operation

c. List of supplies, test equipment and special tools

d. List of Line Replaceable Units (LRU's)

e. List of abbreviations and symbols (4:1-1)

Job Guides. JG's are the task oriented element of the publication system and provide the step by step detail required by the user to perform operations on vehicle sub and sub-subsystems. Specifically they address:

a. The functions of each LRU

b. The performance tasks associated with each LRU function including:

    1. Removal

    2. Installation

    3. Inspection

    4. Cleaning

    5. Operational Checkout

    6. Adjustment

    7. Calibration (4:1-1)

c. Maintenance practices and functions covering:

    1. Applicability

    2. Required conditions

    3. Recommended personnel to perform task

4. Support equipment required

5. Support data

6. Applicable load specifications

7. Supplies required

8. Personal safety equipment needed

9. Safety condition

10. Checklist requirements

Fault Reporting Manual. The Fault Reporting Manual provides the vehicle for aircrew and maintenance staff to develop "fault codes" (21:3) that identify aircraft malfunctions and eventually allow for identification of specific faulty LRU's. The publication has three significant components:

a. "Alphabetical index with precise statements of possible malfunctions for every major aircraft system and subsystem" (21:3).

b. "A built-in test (BIT) fault indications index keyed to the avionics status panel fault indicator numbers" (21:3).

c. "A pictorial index which is an illustrated view of the cockpit with all gages and indicators fully detailed" (21:4).

Fault Isolation Manuals. These manuals are used in conjunction with the Fault Reporting Manuals and are used after the specific fault codes have been identified during the post flight debriefing. They provide the technicians with a clear logic tree approach to the aircraft systems and all possible faults that can be experienced with each LRU. Using the codes and the "yes/no logic approach" (21:4) the technician is able to quickly locate and repair the reported fault.

Wiring Data Manuals. These publications provide diagrammatic format explanations of the aircrafts' electrical wiring layouts.

Schematics Diagram Manuals. The SD manuals provide "the schematic diagrams required for troubleshooting malfunctions" (4:1-4). They combine electrical and hydraulic schematics in one manual for non-complex systems, however, they are separated for the more complex units (4:14).

Technical Order Numbering. The TO numbering requirements and structure are detailed in MIL-M-83495 and are designed to enable the user to identify "which model aircraft the TO supports; whether the TO supports a sub or sub-subsystem; the volume number of the TO; and what type of information the TO provides" (4:1-5).

Cost Comparison

Present System. Under the present system of publication acquisition, development and production in the RAAF the following significant cost areas can be identified:

a. Acquisition - the cost of purchasing technical maintenance documentation and update service. If the publications are prepared by the OEM in user format then the cost of production will be included in the purchase price.

b. Evaluation and Conversion - this is where the publication sponsor or manager evaluates the documentation and converts it to RAAF specific terminology and maintenance procedures.

c. Production - the input, manipulation, formatting and production of paper hardcopy publications for distribution to users. This involves both Australian Government printing facilities as well as civilian printing contractors.

d. Storage and Distribution - identifying and physically distributing publications to user units.

e. Unit distribution and maintenance - includes the receipt, recording and distributing at user level of publications. This area also includes the cost of maintaining the documentation through periodical updates and amendments.

Hypermedia System. Under a Hypermedia technical maintenance documentation system the following major cost areas are identified:

a. Data acquisition - under the CALS Information Data Exchange System weapons platforms publication data will be able to be transferred electronically thus formatting can be conducted at either contractor or System Project Office (SPO) level. If the contractor completes this process, given that formatting was previously done for hardcopy, the cost of paper copy production would be negated. If the publication manager at the SPO is required to format the document then this would be the only production cost involved in the conversion.

b. Distribution - with the technical data in electronic format, distribution to end users can be accomplished through either existing computer communications networks or by transferring the data to magnetic or optical storage media and utilizing present mail channels for distribution. This would produce a significant cost reduction in carrying charges for hardcopy publications. Further, large stockpiles of surplus publication holdings held to meet future demands for replacement books due to normal and abnormal wear and tear attrition, representing a major sunk cost, would not be required.

c. Maintenance - as updating of publications would be conducted at the SPO prior to transmission to users, no costs would be incurred at unit level in maintaining publications. Additionally, publication integrity can then be assured as the potential for incorrect amendment by users is negated further reducing the cause of incidental on cost through incorrect maintenance procedures.

Conclusion

This chapter detailed the background to the problem under study, defined the research question and laid out the investigative questions that support the research problem. The scope of the application was also defined, acknowledging the limitations placed on the study by academic and time restrictions. Topical literature was reviewed relative to expert systems, hypertext and hypermedia. Finally, a generalized cost/benefit comparison was conducted between the current RAAF publication system and the Hypermedia system under research to identify potential cost savings.

III. Methodology

Literature

As a research methodology, prototyping has significant benefits for the researcher:

a. It provides a live working application

b. Enables the quick development of a working application

c. Provides for the testing of assumptions made by the analyst and user relative to system features

d. Allows for iterative development

e. Is cost effective (19:15)

Figure 2 details a flowchart of the basic steps in prototyping.

The basic concept behind prototyping is to quickly produce a working model of the system being prototyped, one that has the look and feel of the desired system, and for the developer to work with the user to refine the model to meet the user requirement (1:274).

Proposed System

In this study the following steps will be utilized in developing the technical maintenance documentation model:

a. Two current USAF technical maintenance publications for F15E aircraft maintenance tasks will be selected and analyzed to determine basic structure and data segmentation. In particular commonality in structure, task division and relationships between data segments will be identified to facilitate the development of a transformation model to convert

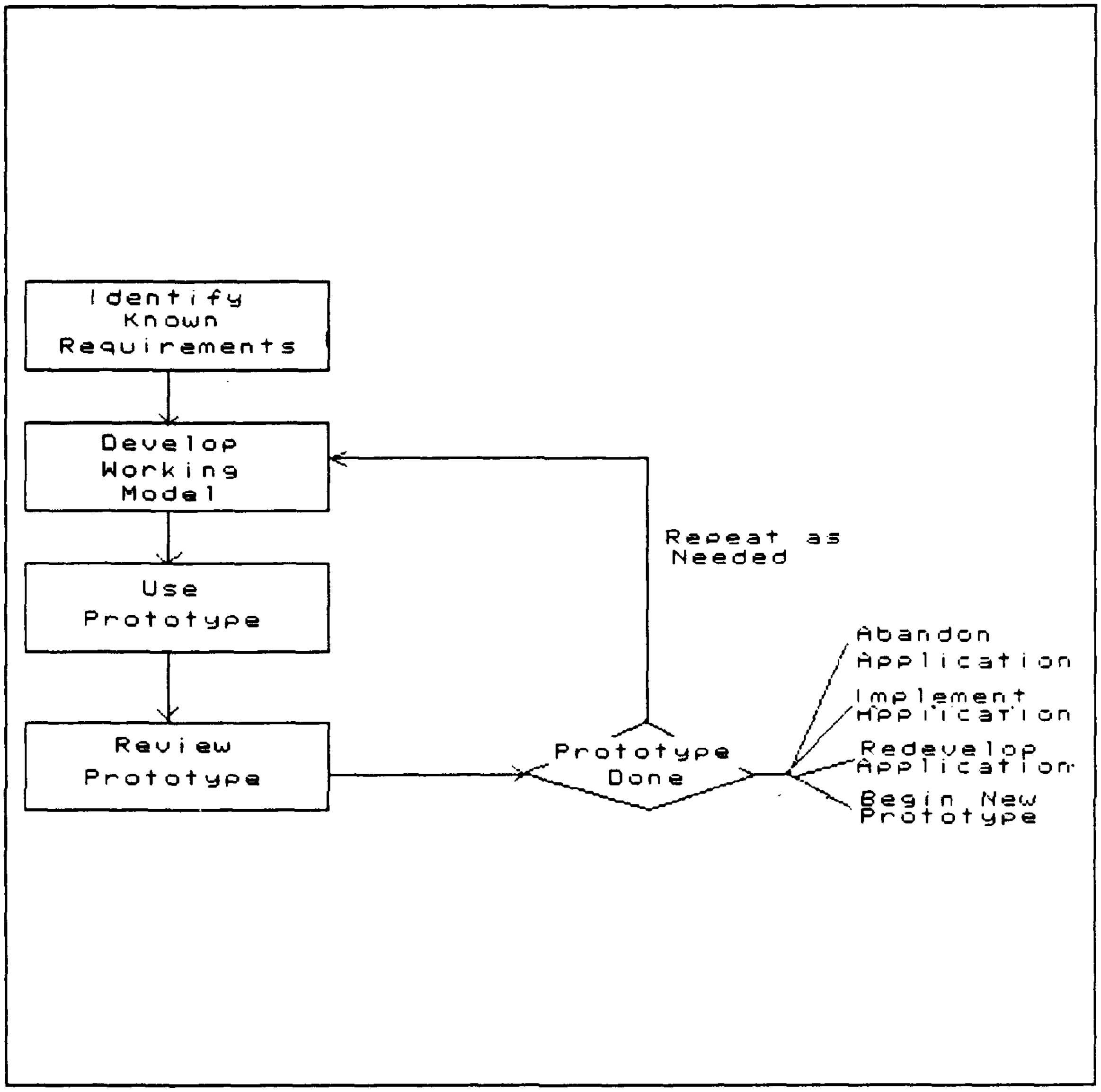

Figure 2: Steps in Prototype Development Method (25:221)

existing and future technical maintenance information to Hypermedia format.

b. A prototype model of a Job Guide structure will be developed using Hyperwriter development software. The prototype will be discussed and analyzed with USAF publication managers, engineers, senior aircraft technicians, an RAF engineer and an RAAF publication manager, to be selected from the F-15E, C-17 SPO's, AFIT and the RAF Liaison office. The prototype will be further developed as appropriate to meet the users' requirements.

c. In concert with the selected evaluation personnel, a specific job guide task will be selected for transformation to Hypermedia to test the appropriateness of the prototype model.

d. The Hypermedia model will be evaluated by the selected personnel through their testing of the model and success or failure will be judged by questionnaire responses.

Hypermedia Design Considerations

While the relevance and applicability of Hypermedia in the military environment has been determined, its suitability as a replacement for technical maintenance documentation and structure design considerations must be identified prior to any acceptance of application. As an absolute essential:

> Any electronic information delivery system must be able --at a very minimum-- to duplicate the capabilities provided by the combination of an experienced reader and a well-designed text. Anything less degrades the system: leaving, at best, an electronic page-turner; at worst, even less than the paper version. Furthermore, in order to; justify abandoning the conventional method and medium, an electronic system should offer improvements, such as increased flexibility, reduction in storage, and convenient document development and maintenance. (9:99)

Document Design Strategies

In Hypertext document structuring, information is broken into logical "chunks" and then joined by "links". While document structuring strategies range from the simplex to the complex, there is concurrence on the need to provide the user with an easily navigable document to avoid confusion and disorientation within the document while following information paths. Van Dyke Parunak offers a number of potential designs ranging from the hierarchical array to the highly complicated Hypertorus (28:46). Van Dyke Parunak provides a good insight into design strategies and document topologies yet makes no mention of the needs of the user and the users familiarity with the content of the document.

The topic of user interface and document design raises a number of questions on the non-linearity of specific design strategies. Present thinking on interaction interface designs present many strategies for coping with the problem of different naming or referencing styles between the user and the developer. The major approach used in document design is a writer directed movement through the hypertext document. This appears contrary to the concept of non-linear reading in that it removes the ability of the reader to branch when and where he feels relevant to his information needs or interest as the information presented is controlled by the developer. Also, for the user to successfully use this approach a common language or terminology is essential between the two. If this can be achieved the use of implicit links based on keywords supplied by the user as a "guess" (14:53) can minimize the possibility of the user becoming lost or disorientated within the document structure. Inherent in this approach is the problem of large overhead and confusion for the user through excessive numbers of successful "hits" on keyword/link finds. This slows the system down as the user is then required to assess each success for its relevance, also having a large number of successes also places greater data management overhead on the system with increased demand on memory and disk access.

A writer directed approach to information access generally implies the utilization of a hierarchical document design (14:52). As stated previously, the writer directed approach presupposes a number of things; firstly, that the writer knows what information is relevant to the reader and in what order he/she will want to access it; secondly, that this type of approach reverts the document to a quasi-linear format, losing the benefits attributable to the non-linearity of a true Hypertext document.

Information relevancy is a critical aspect of good Hypertext document design and in an unstructured information delivery system significant difficulty can be encountered in determining the right structure and order. A way of reducing this problematic aspect is to conduct rigorous analysis of users and user needs, in particular how and when the user requires or will query the system. Under these conditions it is not feasible to produce one document structure that meets all users requirements (14:48). One approach to overcoming this is to structure the document relative to the experience level of the user (14:49). A "novice" or beginner would require more information of an explanatory or background nature than would an "intermediate" or "expert" level user (14:49). Therefore, an alternate design strategy would take this into consideration and produce a document that would cater not only to the needs of the user but the users experience level.

The problems identified thus far in relation to Hypertext document structure lend significant support to the adoption of a task-oriented structure. This negates the requirement for the designer to pre-guess the user's information needs, particularly in a task that is highly structured and procedural as in aircraft maintenance publications. However, this does not remove the need for the background or explanatory information to be available to the user but affords the designer the opportunity to provide them as a choice option rather than as a rigid part of the pathway through the procedural elements of the document.

Human Aspects

In managing organizational change, particularly with the introduction of new technology, the human aspects must be considered among the priorities of change managers. Inappropriate approaches to this element can result in both overt and covert resistance to the systems being installed. This is just as true in a military environment as in a civilian one and was evidenced during the writer's involvement in the development of a computerized database system at RAAF Publications, Melbourne. There, personnel unfamiliar with the new technology, felt threatened and the introduction phase of the project was extremely difficult. These problems are supported by Bjorn-Andersen (8) who addresses the "human" factors in computer systems development and application focusing in particular on the propensity of systems developers to modify applications with "human weaknesses" to make them more acceptable to the end-user (8:386). Of significance is his development of the "Scandinavian Model" of system development which is heavily user oriented (8:389). The specific points raised by Bjorn-Andersen are supported by Hirschheim and Newman (15) who present a case study of an introduction of technological change (15:405). From the reports reviewed three common areas of significance relative to the development of this Hypermedia application are identified:

a. Ensure the system design is appropriate (15:400)

b. Allow the user to become involved in the system design (8:389)

c. Provide personnel with complete and comprehensive training (8:390)

Hirschheim and Newman conclude "The development and implementation of computer-based information systems is a type of major organizational change. Only those development strategies which view such change in terms of social and political processes are likely to prove satisfactory" (15:406).

System Design

As detailed in the objective of this study, the USAF Job Guide was used as the basis for the design of the Hypermedia development model because of its stylized structure allowing ease of conversion to hypertext nodes. This was not always the case. During the period 1962 to 1975, because of its complex structure and its inappropriate style for maintenance procedures, the format of the guide was modified from a "full size" structure to its present detailed step-by-step procedural presentation including explicit illustrations (26:5). This particular structure was validated during a 1975 survey by Air Force Human Resources Laboratory (AFHRL) conducted with maintenance technicians actively using the guides for day to day maintenance tasks (26:5).

Users of on-line data retrieval systems require a number of things from the system to ensure 'usability'; these include:

a. Simplicity of layout and information structure

b. Clarity of information

c. Understandability (27:320)

In addition a good program design should "provide backtracking, Boolean search capabilities, and other methods for easy navigation" (12:46). From a structural viewpoint these requirements are met by the current job guide structure, as validated by the 1975 AFHRL survey, combined with the introduction of simplified English and illustrations currently under way. Researchers concur that an analyst requires a common framework within which to develop his specific application (29:30). This is particularly so in an environment where many applications follow the same format structure.

While the structure of job guides lends itself to standardization, the actual *content* of the documents will not and in each case may require individual analysis. Figure 3 shows a model of this process, and while the structure half of the model has been taken care of by the adoption of the present structure, the content representation identifies clearly what the model under development will require from the publication producer, whether this be the OEM or the Service Publication Manager.

The supportive role of the other publications in the manual set is recognized and a detailed analysis was conducted to identify the information content, its structure and inter-relationships. The analysis is detailed at Appendix A.

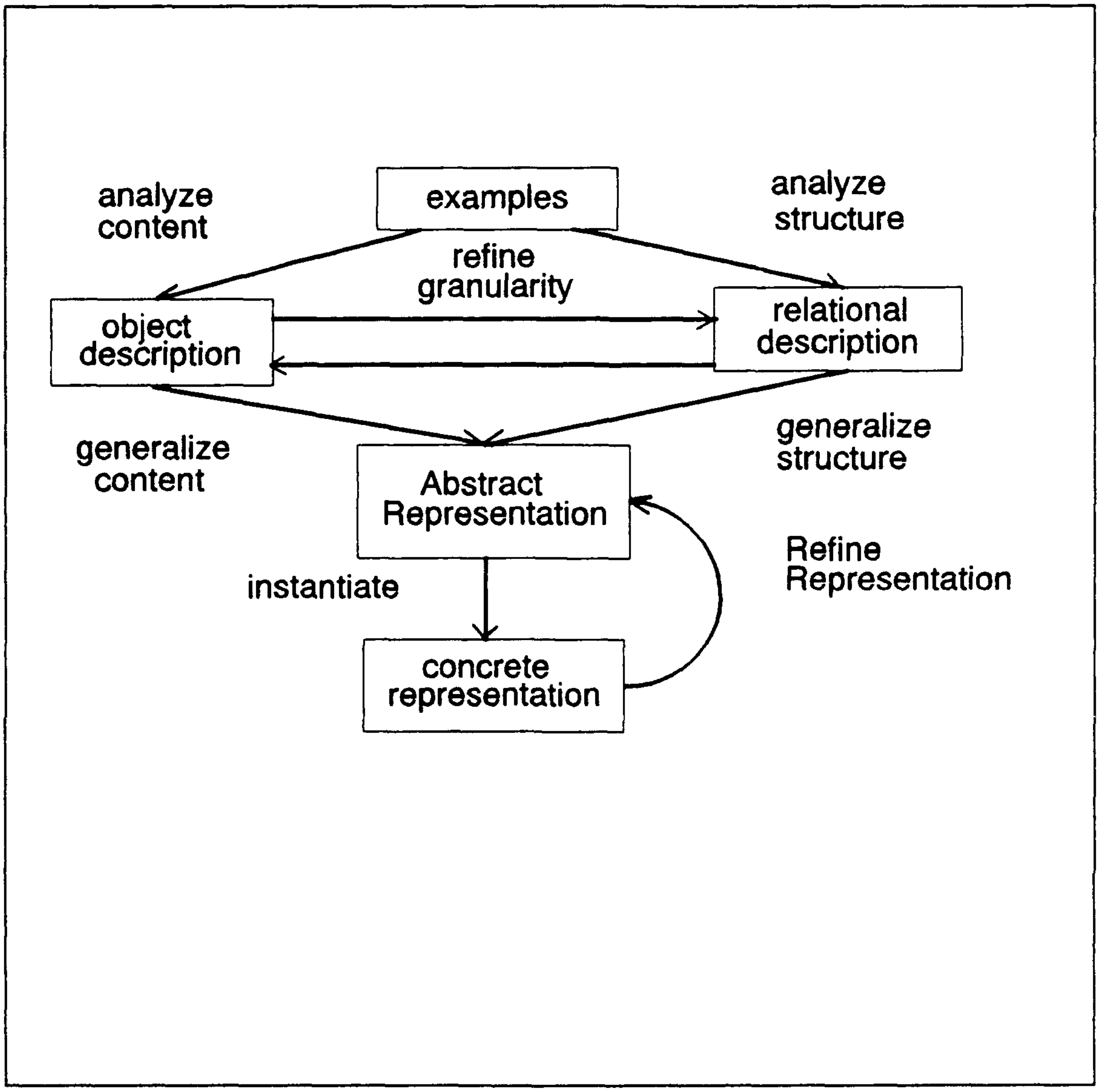

Figure 3: Model of the Representation Process (21:254)

Summary

This chapter identified current thinking and literature in relation to the prototyping methodology and detailed the proposed conduct of this research. Hypermedia design considerations were also discussed particularly in relation to system design and user interface aspects.

IV. Model Design

Introduction

The objective of this chapter is to develop and present the SHADM model to be used in converting technical maintenance documentation into hypermedia format.

The following areas are addressed:

a. Standards and formats

b. User interface sub-model

c. Data sub-model

d. Data relationship sub-model

Standards and Formats

This section describes the model standards and formats that should apply to a hypermedia application of technical maintenance documentation. A number of significant aspects impinging on successful model design were identified in the literature review conducted in Chapter 2. The object of the model design phase is to maximize the beneficial aspects of these elements giving cognizance to the other model elements to ensure that one is not maximized to the detriment of another. A fine line must be followed in design standards to obtain the optimum combination of:

a. User friendliness

b. Ease of model use

c. Use of hardware capabilities

d. Use of software capabilities

e. Model robustness

f. Compliance with existing information storage and transfer standards applicable within the military environment

In developing appropriate standards and formats the following areas are addressed:

a. Text

b. Graphics

c. Menus

Text. Text files used in a hypermedia application should conform to the following standards:

a. Storage. Text files used in technical maintenance publications must comply, as a minimum, with the CALS requirements detailed in MIL-STD-1840A. In particular, text should be stored in 7 bit ASCII format (11:11) and in separate files by vehicle system. This method of storage maximizes the use of both secondary and primary storage by not creating excessively large files that are difficult to maintain and address and not placing excessive demands on the CPU and primary storage through large numbers of I/O requests caused by significant numbers of small files. Where tables or large data screens contain logically segmentable data they should be broken into separate logical nodes and displayed in overlay windows. Their group heading should be returned in the initial window and provide the link anchor point. This serves a twofold purpose, first it avoids the user having to scroll through large screens of data to locate a specific element. Secondly, the individual nodes provide greater linking flexibility to other nodes because of their greater content specificity.

b. Presentation. Data should be displayed in an article metaphor presentation style (16:5) thus not limiting the display capability to individual 25 line screens. Article metaphor systems allow greater than 25 lines and provide the user with the capability to scroll in any direction through the information. Where text extends for greater than 30 lines in an overlay display box, to reduce the need for extensive scrolling, a link to a new display window should be used even through the text may be of an amplifying nature.

c. Color. Text presentation should be white characters on a black background. Cautions and Warnings text should be displayed as red characters on a white background to significantly differentiate them from normal text and to highlight the urgent nature of the information. Use of red should be limited solely to Warnings and Cautions, however, while other colors may be used sparingly to enhance presentation, consideration must be given to the visual quality and effect of their use to ensure overall presentation is not degraded.

Graphics. Graphics files used in a hypermedia application should conform to the following standards:

a. Storage. Compliance with CALS standards detailed in MIL-STD's 28000 and 28003 should be mandatory in all graphics transfer and storage. Common graphics should be stored once and reproduced as required in a background mode. This will reduce the high secondary storage memory costs associated with graphic images.

b. Presentation. All graphics should be presented as white lines on a black background. Using the background display method for common graphics detailed at sub-para a., different callouts appropriate to each task/function should be overlaid on the graphic to provide relationship link points and explanatory text. Color should be used in graphics where it is appropriate and enhances the ability of the image to transfer knowledge/information. However, as with color text representation, red is restricted solely to caution and warning messages and consideration must be given to the visual quality and effect. The use of additional color must not degrade the overall graphic presentation.

c. Icons. To simplify the presentation interface icons should be used to represent simple common repetitive tasks to be performed. Each icon should be stored once, used in background mode for display and be globally defined to enable the inexperienced user to ascertain an icon explanation by selecting it as a link.

d. Naming Standards. Graphic names should uniquely identify the task being described and either the common name or S/S/SN number of the LRU. It should be displayed as a window title in the format:

[TASK]-[LRU Common Name]/[LRU S/S/SN]

where use of titles is dependant upon the task/function being performed, e.g. the title of the nose landing gear installation function would be:

INSTALLATION - NOSE LANDING GEAR

At the task level of a specific LRU installation the title would be:

INSTALLATION - 32-20-10

This naming standard is applicable to both textual and graphical displays. It allows the user to directly address specific data windows dependent upon the information sought.

Menus. The SHADM model supports three menu strata, Primary, Secondary and Tertiary. These menu structures should comply with the following standards:

a. Primary Menus. Primary menus should allow the user to choose between graphic representation selection or direct addressing. Each selection should lead the user to a secondary menu which offers a function selection.

b. Direct Addressing. Direct addressing allows the user to specify precise data windows as destinations using window titles. The access mode should be interactive from a menu selection and should offer the user a range of titles to choose from.

c. Graphic Representation. Graphic representation should display a graphic image of the specific vehicle, at Primary menu, or system or LRU at the Secondary menu. The image should be divided into link areas or "hot-spots", for vehicle graphics this should be by system and for system or subsystem graphics by LRU. Selecting the desired system/LRU location activates the link and takes the user to the appropriate window.

d. Secondary Menus. Secondary menus should be in a textual format offering the user either graphical or direct addressing capability and should lead the user to either descriptive operational, and descriptive general information. Additionally, a textual selection should be offered to the user to perform a specific function.

e. <u>Menu Layouts.</u> Menus should comply with previously defined standards for textual and graphical representations. Where textual menus are the only content in a window they should be either centered vertically on the display screen or if a large number of options are available (i.e. greater than 25) they should be listed vertically down the left hand side of the window. Where menus are displayed with explanatory text or other amplifying data they should be displayed horizontally along the bottom or top of the screen. Horizontal menu selections should be non-scrolling and remain visible to the user during multi-screen scrolling operations. The user selection should be made by placing the cursor on a selection and pressing either the enter key or left pointing device (if used) button to activate the link. Each menu should contain an option to allow the user to exit or return to the previous menu level. Graphical representations should be centered on the display screen and provide sufficient textual explanation at the bottom of the display to guide the user in its use. The graphical representation should also have an option to allow the user to return to the previous menu level or exit. In all menus textual layouts and explanations should comply with defined standards and formats for screen layouts and be standard explanatory texts to facilitate user-friendliness.

f. <u>Tertiary Menus.</u> Tertiary menus are the task performance menus and should offer the user a graphical and textual selection interface to enable indication of the LRU to perform the task on. It should also provide the user with all Descriptive Operational, Procedural General and Descriptive General data for the selected task.

g. <u>Naming Standards.</u> Menu names should identify the type and level of the individual menu. At the primary menu names should identify the menu type and vehicle designation e.g.:

INITIAL MENU - F15E

The secondary menu name should identify the identify the selected system e.g.:

NOSE LANDING GEAR MENU

The tertiary menu name should identify the function/task and the system name or S/S/SN e.g.:

INSTALLATION - NOSE LANDING GEAR.

At any menu, the menu name should not only identify the function of that particular menu but should assist the user in determining location within the system. An additional benefit of standardized menu naming formats is that the user is more easily able to direct address access the menu by name rather than physically tracking through extra nodes to locate it.

User Interface Sub-Model

The user interface is one of the most important elements of any model design. While a high level of technical perfection may be achieved, the inability to transfer information to the intended audience in a meaningful and understandable manner signifies a failure to achieve the primary purpose of the application. The object of any information storage and retrieval system is to support the information needs of its users. Thus, it should be user responsive rather than system responsive.

While there is no one presentation method that is suitable or acceptable for all users, a strategy that maximizes its range of user satisfaction is optimal. There are three identified levels of user experience that need to be addressed: the inexperienced new user; the journeyman or intermediate experience user; the expert user.

In the military, experience levels can be equated with rank, thus, the inexperienced new user would equate to an enlisted technician having recently graduated from trade training school. The journeyman would have had a number of years experience and additional specialist training and achieved up to the rank of non-commissioned officer (NCO). The expert equates to a Senior NCO up to the rank of Master Sergeant (Warrant Officer in the Royal Australian Air Force) with significant experience on a range of vehicles.

Knowledge of experience levels of potential users helps to ensure that an appropriate user model interface is developed to properly support user requirements. The different experience levels outlined require that separate interfaces be modelled for each with the greatest assistance and rigidity given to the inexperienced user the greatest flexibility to the expert. While each experience level should have its own access method, users should not be locked permanently into one method and as their confidence and ability increases selection of the appropriate access method should be left to the user.

Another element impinging on design strategy is referencing technique. Individuals identify and label objects, thoughts and concepts based on prior knowledge, experience or socialization experiences. It is, therefore, possible for two individuals to reference the same object using different labels. Referencing is important in locating information as indexing strategies used are based on individually allocated labels. The problem of individual labelling anomalies is addressed in printed media through the use of "see" and "see also" cross-referencing techniques and the use of synonymous replicate entries in indexes.

Any indexing system developed must be flexible to allow users to obtain the desired information quickly and with a minimum of effort. The user should be able to access the task or any of the LRU specific supporting information using either a menu interface or a direct addressing method.

Inexperienced users should be provided with a hierarchical menu structure that will lead them to their desired information, reducing the potential for confusion and frustration in not being able to use the system as wished. The levels of experience and expertise previously discussed infer increased familiarity with terminology and labels commensurate with levels of experience. It therefore follows that the journeyman and expert user should be provided with an indexing and retrieval interface that recognizes this increased familiarity and allows direct specification of desired information. In either case the menu structure and direct addressing should be options available to all users with the individual choosing the desired method based on a self-assessment of needs and abilities.

The success of direct addressing is dependent upon a standardized naming convention for the individual data modules. A consistent strategy should allow the experienced user and journeyman to recognize information elements through the of: common names and S/S/SN's in the case of LRU's; names that reflect the nature of the task being performed; in the case of explanatory information, the type of explanation and S/S/SN; names for graphics that indicate the S/S/SN and type of graphic.

Data Sub-Model

Analysis of the current F15E technical maintenance publication set, Appendix A, has led to the categorization of five distinct data groups. These are:

a. Authoritative data

b. Descriptive General data

c. Procedural General data

d. Descriptive Operational data

e. Procedural Operational data

The SHADM model is structured around the performance of seven primitive tasks and the information contained in each data group has been segmented according to its relationship to each task and the vehicle and how it supports the performance of the task. The data sub-model so derived is detailed in Figure 4.

Authoritative Data. The Authoritative data group is comprised of two elements, implied authority and specified authority. Implied authority is vested in the publication set in that it implicitly grants authority for performance of the tasks and procedures contained in the manuals. Specified authority is contained in the Time Compliance Technical Orders which authorize specified actions with specified time frames.

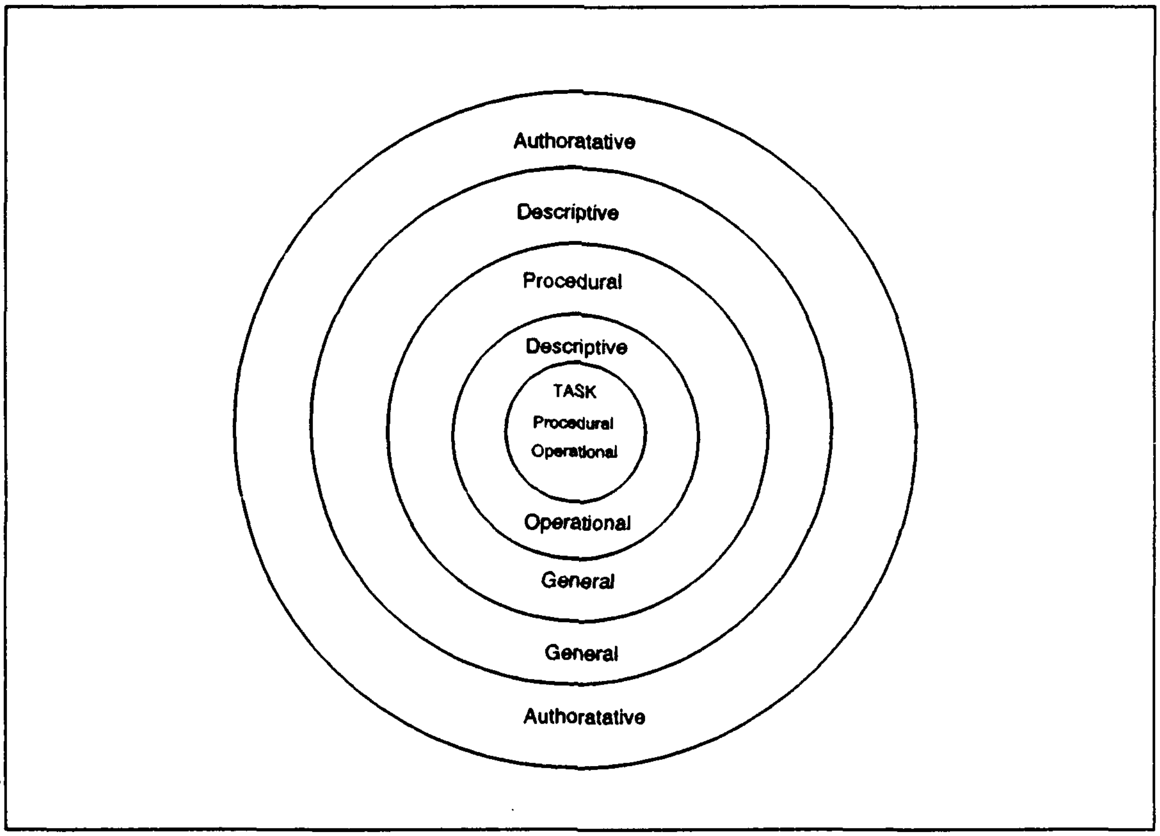

Figure 4: SHADM Data Sub-Model

specified time frames.

Descriptive General Data. Descriptive General data is made up of data elements that apply to all support aspects of technical maintenance and are not task performance specific. These include the following elements:

a. Symbols and abbreviations

b. General aircraft descriptions

c. Safety and protective devices

d. Emergency procedures

e. Placards and markings

f. Dimensions and Areas

application across the whole vehicle data set. They are displayed in either definitional text, verbose text or graphical format.

Procedural General Data. Procedural General data is made up of procedure or task specific information that relates to the performance of more than one task on systems/subsystems/LRU's. It is more specific than Descriptive General as it is procedural in its orientation and its key identifier is its data content support for multiple systems. Procedural General data includes the following elements:

a. General maintenance
b. Consumable materials
c. Support equipment
d. Jacking and lifting
e. Levelling
f. Aircraft towing
g. Parking and Mooring
h. Servicing

As these data components are of a general nature they are globally defined within the model for application across the entire vehicle procedural data set. They are displayed in either definitional text, verbose text or graphical format.

Descriptive Operational Data. Descriptive Operational data relates to the performance of specific tasks on individual systems, subsystems or LRU's. This data type is unique to each unit and as such is not able to be globally defined, rather, it must be locally defined. The data type includes:

a. System functional description

b. Special maintenance requirements

c. Principles of operation

Descriptive Operational data is presented in the textual verbose mode only.

Procedural Operational Data. Procedural Operational data is the task specific information used in the performance of the seven primitive tasks on systems, subsystems and LRU's. It is that information that is unique to both task and system and as such is not suitable for global definition. It is displayed in either definitional text, verbose text or graphical format.

Data Relationship Sub-Model

The data relationship sub-model examines the various data elements in the current technical maintenance publication system and defines the relationships between these elements. These relationships become the hypermedia links. The SHADM model utilizes the following linking strategies:

a. links to text

b. links to graphics

The textual links result in the following display formats:

a. text expansion - where the existing text is expanded through the insertion of additional text.

This additional text is removed from the display when the link is selected again.

b. new window text - where the text window displayed is replaced by a new text window.

c. text sub-window - where a smaller window opens within the current display window to provide amplifying or explanatory text.

The data relationship sub-model will be developed in two stages: firstly, the elements that are Descriptive General and Descriptive Operational and support the vehicle and its systems rather than the individual tasks will be examined; secondly, the Procedural Operational and Procedural General segments will be developed.

Analysis of the current publication set, Appendix A, has revealed that all data available in the manuals supports the performance of seven (7) primitive tasks. These are:

a. Removal

b. Installation

c. Inspection

d. Cleaning

e. Rigging and Operational Checkout

f. Adjustment

g. Calibration (4:1-1)

In their current format these tasks form a complex set of relationships which exist within each level and between each level of the publication set as well as in the performance of the different functions on the various systems, and subsystems strata. This complication and subsequent necessity for the user to be completely familiar with the publication set is a function of the media and not the data or the task. As previously identified, the data supports the performance of seven primitive tasks on the vehicle and its components thus, it is suited to a task oriented structure. This is not possible with the present manual system as the volume of relationship cross-references would be difficult, if not impossible to elucidate, and would result in an incomprehensible document. This data interaction complexity has been addressed to some extent through the use of the three tiered publication system currently in place.

The Job Guide details functions to be performed on system, subsystem and sub-subsystem LRU's (21:8). McDonnell Douglas define three specific elements to the operations described in the JG set:

a. step - "a single and separate maintenance action" (21:8).

b. task - "a series of steps leading to the accomplishment of one of the procedures" (21:8).

c. function - "is composed of one or more tasks" (21:8).

Conceptually, these definitions are represented in Figure 5.

Each of the tasks defined for a function represent one of the seven primitive tasks identified earlier. As can be seen from the diagram, each step, task and function (not

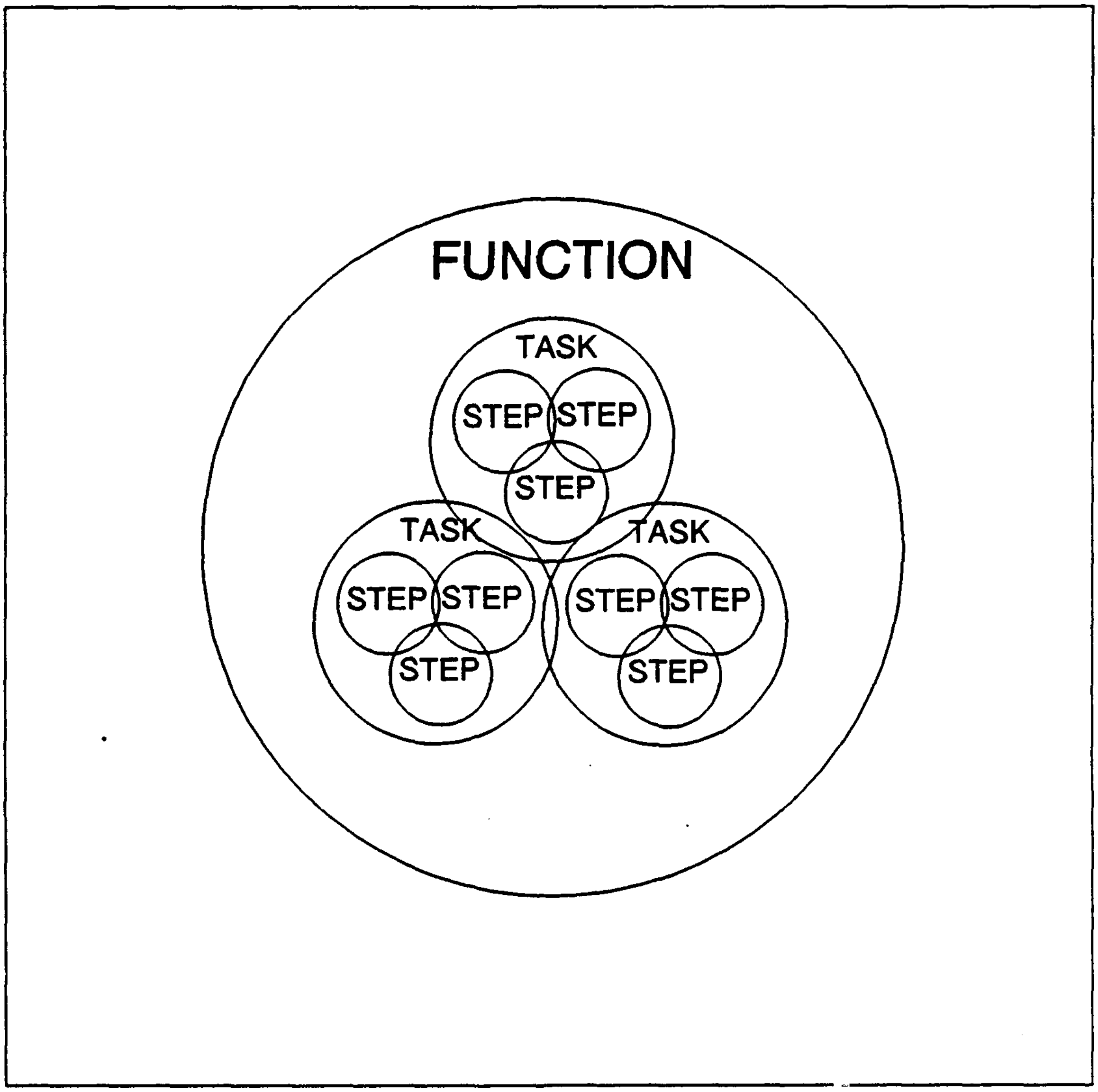

Figure 5: Operational Elements

Each of the tasks defined for a function represent one of the seven primitive tasks identified earlier. As can be seen from the diagram, each step, task and function (not shown) are not mutually exclusive but share common information relationships. Although the relationships identified through analysis are significantly more complex procedural elements. Dissecting the structure to the procedural element level would create a model or representation of such complexity that it would be unusable.

In its present structure the task orientation of the publication set is based on the performance of the primitive maintenance procedures on each LRU. Thus, the publication set at the JG level potentially has seven times the total number of vehicle LRU instantiations. Transferring this structure to electronic format as it is would not be feasible due to the large demand it would place on both primary and secondary data storage resources. Additionally, updating and deleting data would be difficult and time consuming due to the potentially large number of replications.

Identifying the primitive tasks, installation, removal, etc, as the tasks for orientation, rather than a specific LRU installation or LRU removal, allows the segmenting of common global procedures from the LRU specific ones. Graphically this is shown in Figure 6. Thus the relationships are on the basis of common to uncommon, where common data relates to more than one LRU while uncommon is single LRU specific in nature. This will result in a significantly smaller physical data base. Data maintenance will be enhanced as changes would affect either common data (task) or specific data (LRU) each contained in separate files or nodes.

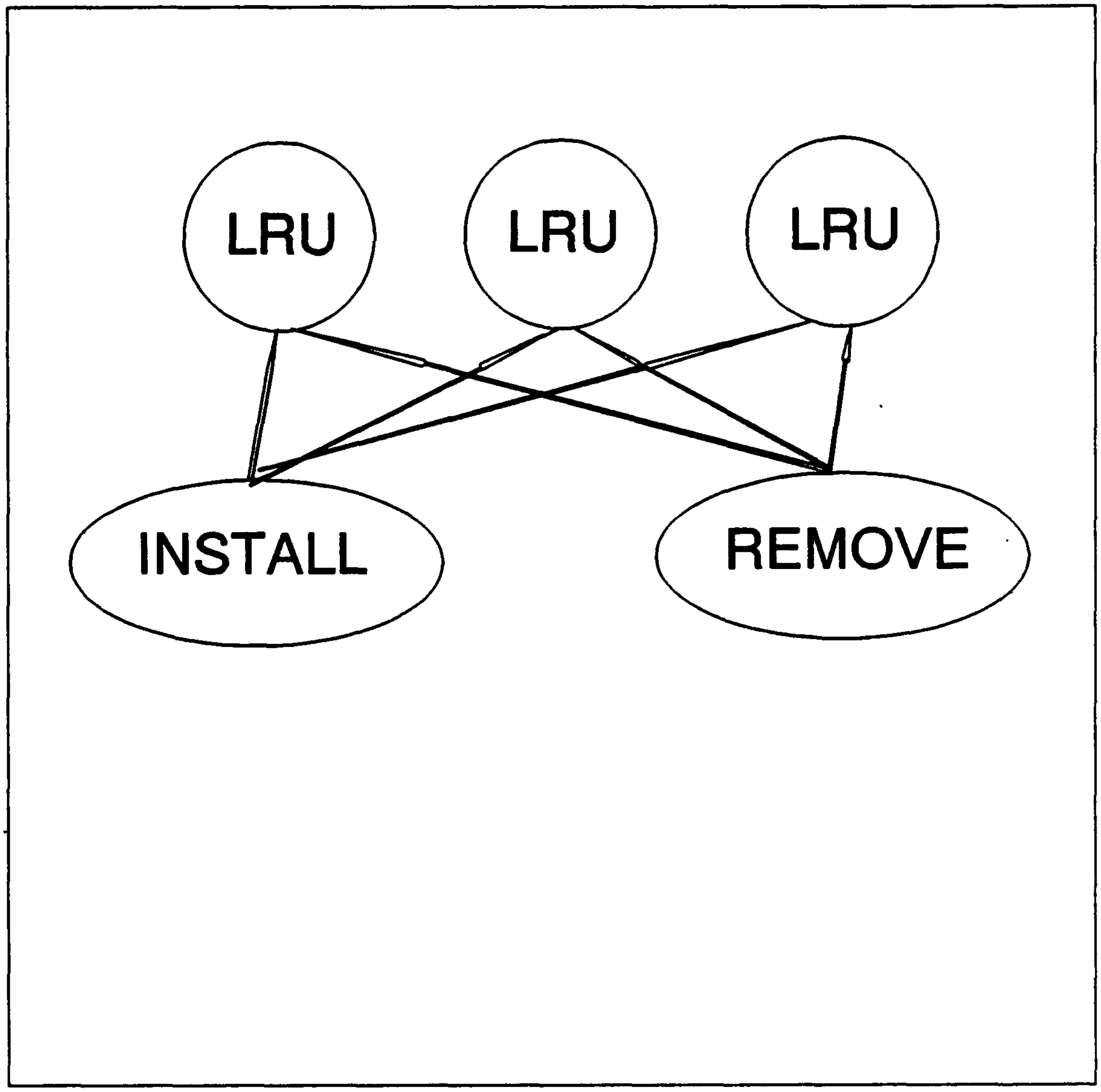

Figure 6: Primitive Task Orientation

will be enhanced as changes would affect either common data (task) or specific data (LRU) each contained in separate files or nodes.

Removing common data from the LRU nodes will allow for global definition strategies and multiple node links to be used thus further reducing overall document size. Global definition is where data elements and their definitions or link from multiple files that contain references to data or require amplification by the target data stored in that node. This element of the model is considered essential for robustness as it will significantly limit the potential for deletion and update anomalies during data modification as commonly referenced data are located in single files.

Descriptive General data supports the task performance by providing technical information that is not specific to an individual function or task on a system, subsystem or LRU but refers generally to the overall vehicle, system, subsystem, or LRU.

The general descriptive nature of this data type produces relationships with other elements of the data set in a supportive role. This data has three formats and each should have a linking strategy that recognizes both its role and format. The formats are:

a. Descriptive verbose

b. Definitional

c. Graphical

Descriptive Verbose. Descriptive verbose data provides information to the user in a textual format and can range in size from one line to any number of paragraphs. This type of data requires a separate window and the linking strategy is to use a link to text in a new window.

Definitional. This data type usually comprises one or two lines and provides explanatory information about a word, phrase or graphic element. Due to its amplifying nature its link type should be a text link within the same window but using either:

a. a technique that physically expands the selected text by placing the definition data adjacent to the current data.

b. displaying the data in another location in the display window.

Returning from the link should remove the definitional text and leave the display screen as it was prior to the link selection.

Graphical. Graphical data requires a separate display window to ensure there is no data loss due to physical size reduction. The link should be a graphics link to a new window, thus totally replacing the data in the window where the link was selected with the chosen graphic.

Procedural General and Procedural Operational data are those data elements that specifically support the performance of the seven primitive tasks, previously defined, on the system, subsystem or LRU.

Procedural General data perform the same supportive function as the Descriptive General data although possessing a more specific nature. Rather than providing global data definition, the procedural data directly relates to the performance of tasks on the vehicle elements. It has the same formats and relationships as the Descriptive General data and as such uses the same linking strategies.

Procedural Operational data are data elements that are task performance specific. They have the same formats and relationships as the Descriptive General data although their display requirements differ. The graphical elements provide visual prompts to the user in task completion while the descriptive verbose provide a textual description of the task steps.

The linking strategies used with Procedural Operational data differ from the other data elements in that the user requires the graphical data to be constantly displayed for referential purposes concurrently with textual explanation of steps and definitions. To avoid conflict between both formats the model displays them simultaneously, when required, but in a manner that eliminates interference between the two. The SHADM model displays the graphical data as the main display with callouts to the procedural steps, numbered in task completion sequence. Links between the procedural step numbers are text links to a boxed display at the top of the display page. Text scrolling is required within the link display where the text size is larger than the display box to avoid the central graphic being overwritten by text. This linking and display strategy ensures that the user is able to visually access both information formats simultaneously.

Definition displays resulting from global linkages to descriptive support data utilize the linkage mode detailed for definitional descriptive general data.

Summary

In Chapter IV the SHADM model was developed based on the consensus direction provided by the findings of the literature review conducted in Chapter II and the detailed analysis of the F-15E Technical Maintenance manual set in Chapter III. Four major areas of significance were addressed in the design phase:

a. Standards and formats - these detailed how data should be presented to the user

b. User interface sub-model - which provided alternate methods of using the system based on user experience levels

c. Data sub-model - defined the logical structuring and segmenting of the overall data set

d. Data relationship sub-model - which provided the style of the links to be created between the logical data segments based on content relationships to the task orientation of the model

V. Findings and Analysis

The objective of this chapter is to detail the SHADM model prototype development and testing procedures undertaken, and examine the test results. To achieve this, the following areas will be examined:

a. Prototype development

b. Software selection

c. Model testing

d. Test results

Prototype Development

Preparation of the prototype system was completed using the following commercial software packages:

a. HyperWriter - hypermedia application

b. Omnipage Professional - optical character recognition application

c. Microsoft Paintbrush - graphics display and manipulation application

d. Chinon Deskscan 2000 - scanning hardware and software

The prototype design rigidly followed the standards and constructs detailed in Chapter IV, with the exception of the graphics display and storage formats. Graphics were scanned as raster images in accordance with MIL-STD-1840A, however, they were converted to .PCX format for storage and display purposes. Additionally, a HyperWriter generated graphics forms, .MGR, was also used in one file application. This divergence from model requirements for conformance with MIL-STD specifications resulted from software rather than model limitations and is not considered to have effected the validity of final testing results.

The second divergence from standards was in the presentation style of graphics and text at the task level. Two methods were offered to the users for evaluation, the first being graphic to text format. This method displayed the illustration and had embedded links on the relevant graphic elements relative to the required procedural steps. Selecting these links resulted in the required step text being displayed in a window in the top right hand corner of the screen. The effect of this approach was that both text and graphic information were visible simultaneously thus allowing the user to read the text while retaining visual reference to the part being worked on.

The second option offered was a text to graphic approach whereby the user entered a full text screen detailing individual procedural steps in full. Each step was linked to its relevant illustration. Link activation resulted in the text screen being replaced with the full page graphic screen containing the illustration. Additional textual support was not provided nor were there further external links. Reference to the procedural text required deactivation of the link.

The prototype took approximately 60 hours to complete and was structured around the Nose Landing Gear (NLG) system of the F-15E aircraft. Approximately 50% of the General Vehicle Manual was converted to hypertext and linked using the model relationship criteria. All NLG specific information from the General Service Manual was converted, with the exception of graphics. The maintenance procedure selected for display was:

NLG UPPER JURY LINK REMOVAL, INSTALLATION, AND OPERATIONAL CHECKOUT

The prototype included all procedural support data, maintenance steps and graphical representations. The final package was comprised of one ASCII text file, 22 .PCX format graphics files and one HyperWriter generated .MGR format graphics file.

Software Selection

HyperWriter was selected as the software for use in the prototype modeling, however, this should not be seen as a recommendation for the use of this package over any other. Time limitations imposed by academic requirements denied the ability to rigorously and extensively evaluate all commercially available hypermedia packages.

The current version of HyperWriter does not meet the requirements of MIL-STD's in that it is unable to handle the storage, retrieval and presentation of either Computer Graphic Metafile (CGM) or Initial Graphics Exchange

Specification (IGES) graphic formats. Given this limitation it did meet the selection requirement parameters of:

a. Ease of use
b. User friendly
c. Fast response times
d. Easy development environment
e. Uncomplicated document navigation capability
f. Ability to concurrently display graphics and text
g. Boolean search capability

Two other commercial hypertext packages were subjected to limited evaluation, limited by the capabilities of the demonstration packages provided by the manufacturers, rather than the depth of evaluation. The products were:

a. Knowledgepro from Knowledge Garden Inc
b. Guide by Owl International

Knowledgepro was not considered suitable due to the slow speed with which it activated links and its screen refresh, despite being tested on an 80386/25Mhz computer. Additionally, it possessed a complex programming language and was oriented towards Expert Systems development rather than Hypermedia.

Owl was also found to be unsuited to the technical maintenance documentation model. Despite having a well developed graphics display and handling capability, it did not provide the required hypermedia support, was difficult to program in and its navigational capabilities were limited.

Model Testing

Model prototype testing was conducted at Wright Patterson AFB utilizing personnel from the F-15E Systems Project Office, C-17 Systems Project Office, International Logistics Office and the Air Force Institute of Technology (AFIT). The objectives of the testing were to establish the validity of the proposed technical maintenance publication model through specific field examination of the following areas:

a. User interface - how user friendly and easy the system is to understand and use.

b. Display standards - are the screen formats/layouts appropriate for the information content being presented and is the model logically structured.

c. Usability - how robust is the model when placed in a working environment and subjected to non-developer use.

Testing was conducted unsupervised with each participant being provided with minimal instruction on the system use. Instructions were verbal and were limited to: starting the package; the concept of links; how to activate and deactivate links; explanation of the two graphic display formats; how to exit the package. Instruction was deliberately restricted as a further validation test of the user friendliness and ease of model use.

User feedback was obtained using a questionnaire which addressed the specific areas of interest. A copy of the questionnaire is at Appendix B.

Test Results

Testing of the SHADM model prototype was conducted over a two week period and of the nine participants selected for the evaluation, eight returned completed questionnaires at the end of the testing period. These responses were consolidated and the results are detailed at Appendix C.

Analysis of the results was conducted in two parts, a general overview analysis of each general area tested and a detailed question by question analysis is provided at Appendix D.

Scoring Evaluations. Scoring of the evaluation test was done using a 10 point scale with users indicating their level of agreement with the listed statements. A rating of 10 indicated strong agreement while a rating of 0 indicated a strong disagreement. These scores were evaluated on the basis of:

a. 0 - totally unacceptable

b. 1-4 - unacceptable

c. 5 - acceptable

d. 6-7 - good

e. 8-9 - very good

f. 10 - excellent

User-Interface. Questions 1 to 5 addressed aspects of the model relative to the user-interface. The objective was to determine how friendly the system was to the user and how much it assisted the user to operate the system effectively. Overall, this segment received an average score of 8.37 from a range of 7.625 to 9. This indicates a very good user-interface. Individual comments addressed the need for supporting user documentation and there were a number of complimentary comments that provided no additional model developmental support.

Display Standards. Model display standards were addressed by questions 6 to 16 and covered the areas of text and menu displays, and graphic presentations. Overall users rated the display standards as good with an average score of 7.74. This lower score was qualified with pertinent comments regarding the colors to use on graphical displays, black on white; the need to display menu buttons in a standard length for uniformity; a preference for both text to graphic and graphic to text displays with both elements displayed simultaneously; the need for the user to reference multiple screens for schematic and wiring data fault finding; improvement in graphics display quality; provision of proper user documentation to support on-line access. The comments offered indicated that additional support of the system was required in the form of training and user documentation. This particular aspect is not considered an element of the SHADM model per se, rather an implementation strategy.

General. Questions 17 to 20 addressed general issues relative to the acceptability and usability of the model in a working environment. The average score of 7.34 rates this as good and the additional comments raised issues of concern, although not all related to the model design. In particular, failure of the tested system to meet military specifications resulted in some significantly lower scores, however this issue has already been addressed in the model design standards and further discussion is not warranted. Hardware suitability and availability was another issue that concerned the users and although this does not warrant consideration in this study, it is certainly an issue that demands attention prior to any implementation decisions.

Model Modifications

The model testing resulted in a number of recommendations from the users for improvement of the model. These were:

a. Standardization of menu button sizes

b. Provision of both text to graphic and graphic to text for Procedural Operational data and illustration displays

c. Use of markers for quick multiple window cross-referencing

Each of these recommendations will be incorporated in the SHADM model.

Summary

This chapter addressed the development of the SHADM prototype model, identified the software and hardware used to create the prototype, examined the software selection criteria and justified final presentation software selection. Model testing was conducted using personnel with a diverse range of backgrounds including military aircraft technicians, military engineers both domestic and foreign, and civilian contractor publication specialists. Overall the test results rated the SHADM model as being good and three modification recommendations received from the evaluation panel will be incorporated in the model.

VI. Conclusions and Recommendations

This chapter details the writers' conclusions regarding the objective of this research, as defined in Chapter I, and recommendations for future development of the SHADM model.

Publications

Determination of how an RAAF technical maintenance publication could be converted to a Hypermedia application and to design and test a Hypermedia model was the stated objective of this research. In approaching this task definitions of RAAF technical maintenance publications and Hypermedia applications were presented.

Detailed analysis of the existing F-15E maintenance publication set revealed a tiered structure based around the performance of functions on specific LRU's. This was identified as a function of the delivery media, books, rather than the logical structure of the data content. Content was determined to be task-oriented, however, modification was required in the underlying structure from a task LRU specific to task specific orientation.

A data structure was extracted from the existing data set revolving around three data types which supported the required task-orientation for Hypermedia compatibility. These data types were further stratified into five distinct groups which supported each task. These groups were:

a. Authoritative

b. Descriptive General

c. Procedural General

d. Descriptive Operational

e. Procedural Operational

Natural relationships between the data groups and the individual tasks provided the basis of a linking strategy. In this format the existing publication set was readily transitioned into a robust Hypermedia application.

Model

Model creation on the basis of the publication data set analysis centered around meeting the criteria identified in the literature review relative to user-interaction. This was achieved through extensive use of graphical representations and a tiered menuing strategy. Three levels of user were identified, new, intermediate, and expert, and a strategy developed for each based on their experience and anticipated vehicle familiarity. There is a temptation for developers to over-emphasize the graphical presentations, resulting in cluttered displays. In this respect the HyperWriter software imposed no limitations and a disciplined approach to presentation design was essential.

Segmentation of existing data was rapidly achieved by applying the model criteria to each section. The most difficult and time consuming element was converting the text into electronic format. The quality of existing publications, relative to font and typeface size, made it difficult to effectively utilize the OCR software acquired for the purpose, however, it significantly reduced the required effort. Given the capabilities of electronic data transfer required under CALS, this is not seen as a major problem in future conversion or in the development of new applications. The ease of data conversion using the model validates its inherent logic and structure, and supports the conclusion that it is an appropriate model on which to base Hypermedia design of technical maintenance publications.

This conclusion was further validated by the results and recommendations of the prototype evaluators who rated the model in three areas; user-friendliness which addressed the presentation formats and layouts; data structures which examined the data segmentation, logical flow and linking strategies implemented; general applicability in working environment use and publications management. Cosmetic change recommendations were made but overall the users declared the model as being good and easy to use.

Cost Benefits

Without doubt one of the most significant justifications for implementing new systems is a reduction in expenditure over the existing system. This is even more so given the present economic climate relative to military spending. Use of the SHADM model and electronic management of technical maintenance publications data will result in both financial and manpower savings in overall production, distribution, maintenance, and storage.

Production savings will be realized through replacement of the current paper based hard copy publication set with electronically prepared and stored technical data. The present system requires the preparation, proof reading, printing and collation of the paper manuals. Under an electronic Hypermedia system these processes would become redundant as the technical data would be prepared and transmitted to the user electronically.

Publication maintenance becomes significantly easier in an electronic environment as the need to provide manpower and time to physically incorporate publication amendments and updates is negated. Technicians could be released for primary task performance rather than publication maintenance. Additionally, the costs associated with bulk handling and postage of publication and amendment distributions would be reduced to an insignificant amount, sufficient to cover the expenses associated with either floppy disk, tape cartridge or compact disc distribution, depending upon the media transfer strategy adopted.

Further cost savings would be realized through removal of the need to bulk store excess publication and amendment copies for future use. The master copies would be stored electronically thus releasing expensive warehouse capacity and personnel for reallocation.

General

This research project has resulted in the development of a robust, user-friendly technical maintenance publication model. This has been achieved in the model design through the use of standardized formats and presentation style, multiple data accessing techniques that recognize different levels of user experience, the use of uncluttered screen presentations, and the structuring of the data presentation to a task orientation format.

The analysis conducted on existing publications and Hypermedia applications shows that these manuals are suited to conversion to Hypermedia. The information content has distinct and identifiable logical links based on data types which support the completion of seven distinct primitive tasks. Data replications, both textual and graphical, that exist as a result of the existing presentation format can be easily removed to streamline data storage and presentation. The model developed was prototyped and tested by experienced specialist users who validated it indicating that technical maintenance publications can be successfully converted to a Hypermedia application using the SHADM model.

Existing RAAF technical maintenance publications, are similar to USAF publications in that weapons systems and delivery vehicles used by both services come from the same sources, and similar aircraft are employed by both air forces. While some publication conversions are made to a unique RAAF format, in most instances the manuals are utilized in their original format with only RAAF unique amendments being incorporated through additional page insertions. This similarity and the validation of the SHADM prototype clearly indicates that these publications can be successfully converted using the SHADM model. However, conversion of all publication sets will not result in savings and careful analysis of cost benefit against vehicle life cycle and conversion costs will be essential prior to implementation.

Recommendations

The RAAF has been managing its technical maintenance publications in paper media since its inception in 1921. While production methods have changed and developed over the years, the basic information delivery method has not. Technology in hardware and software, and user knowledge and experience has now reached a stage where it can adequately support the new devel mental step in information management, electro anagement. The SHADM model developed through t research is considered a suitable basis on which to begin the transition.

The SHADM model has been validated through prototype testing and the objective of this research, how an RAAF technical maintenance publication can be transformed into a task-oriented Hypermedia application, and to develop a model that can be used for future transformations, has been achieved. The prototype developed was a limited application of the model, limited by restrictions addressed elsewhere in this paper, and while this does not detract from the efficacy of the underlying design and structure, it does demand further extensive and rigorous testing prior to adoption. The critical nature of the application, aircraft maintenance, demands that a full working application be developed and tested under operational conditions before any implementation decision be made. This testing should address the issues of model reliability, accuracy and robustness and provide a test bed for evaluation of delivery strategies, hardware systems, and user acceptance.

Extensive evaluation of available Hypermedia packages should be conducted to ensure selection of the optimal application to meet model, existing CALS specifications, and end user requirements.

Future Directions

Future research directions should be focused on maximizing the utility of the elements contained in Hypermedia packages. The integration of these components should result in significant synergistic benefits.

Lateral development, utilizing the flexibility of Hypermedia applications, into expert system for fault isolation and diagnosis should be the subject of further research. This extension should also be applied to the integration of supply systems allowing technicians to identify defective parts in the procedural phase of the task completion and interrogate the supply database for spares availability and to lodge order requests without the need for paperwork.

Training is another aspect of this development that offers significant potential benefits. Yet another element of Hypermedia, the ability to incorporate video segments, would allow the development of interactive training packages that would provide the ability for trainees to engage in self-paced education. This particular application could also be incorporated in the maintenance publication model to provide procedural refresher video sequences for tasks that are not commonly performed or require the performance of complex procedures.

Appendix A: Publication Structural Overview

The present Technical Order (TO) set is hierarchical in structure with three distinct levels of publications. At each level of the hierarchy the information provided changes in both detail and style. At level I (GV) general descriptions of the overall vehicle and systems are given as well as lists of abbreviations, symbols, mathematical signs used (3:1). The GV also provides warnings and safety guidelines for the handling of hazardous materials, identifies potential vehicle hazards and describes maintenance procedures in general terms (3:1).

Level II publications provide more specific detailed information based on individual vehicle systems. System theory and principles of operation are explained and lists of consumable and support equipment are provided. This level also has simplified schematic diagrams for both electrical and hydraulic systems (3:1).

Job Guides are located at Level III and provide detailed step by step procedural information to guide the user through the various maintenance and repair procedures associated with the vehicle. These procedures are presented in a "function, task, step sequence for each LRU of a system or subsystem" (3:1). The terms function, task and step are defined as:

a. Function - a series of one or more tasks (21:8)

b. Task - a series of one or more steps that lead to the completion of a procedure (21:8)

c. Step - a "single or separate maintenance action" (21:8)

The three publication levels are detailed in Figure 7.

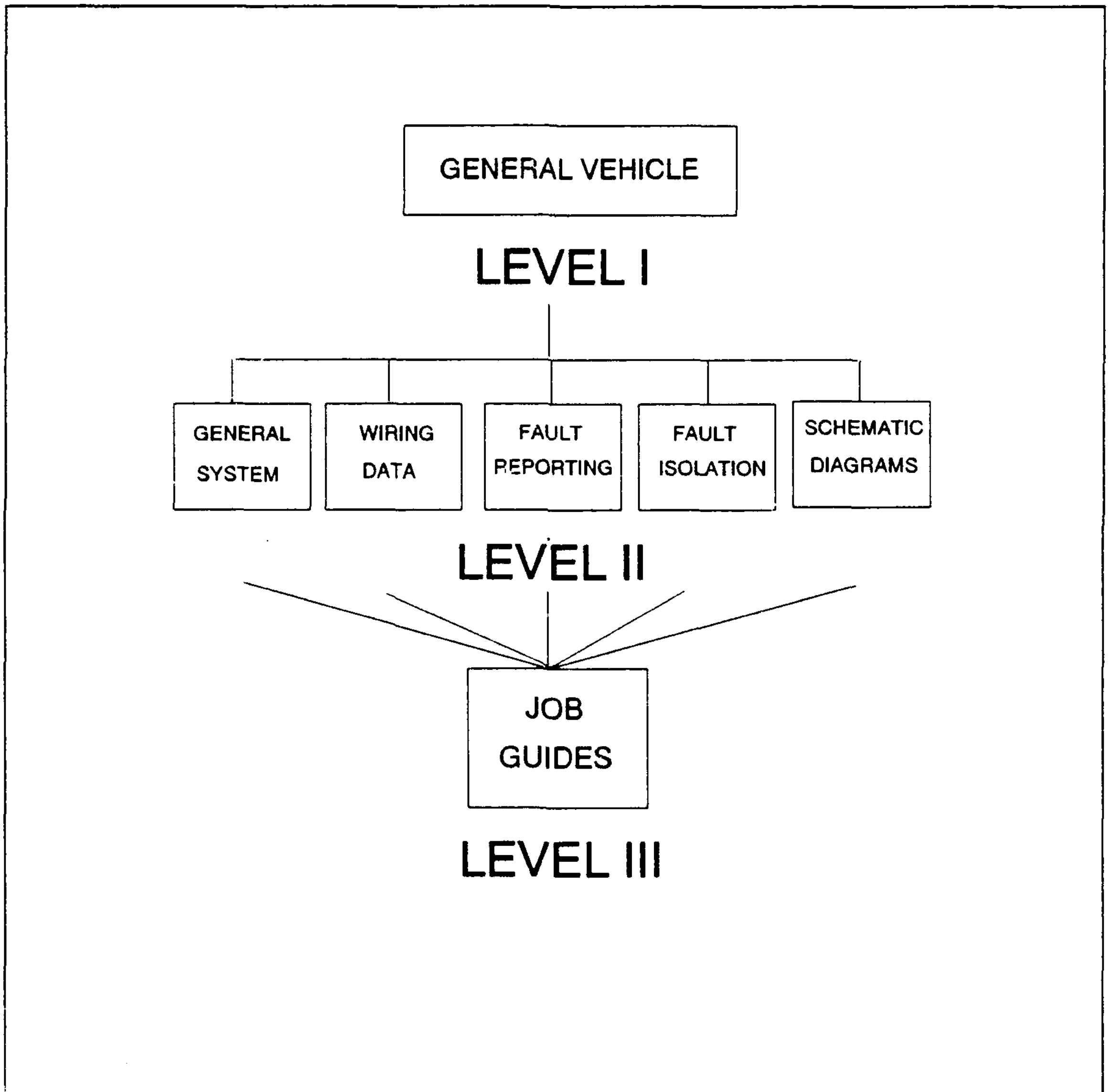

Figure 7: Technical Order Publication Hierarchy

Analysis of the type of information at each hierarchical level revealed that there are three distinct information groups. These are:

a. Authorative - gives formal authority for the performance of the tasks, specified in the publication set, on the vehicle.

b. Descriptive - describes the operation and function of the various elements of the vehicle, equipment and tools to be used and the physical location of the systems, sub-systems and LRU's on the vehicle.

c. Procedural - provides step by step instructions on the performance of the specified task.

The type of information provided differs at each level with the following groupings identified:

a. LEVEL I - Authorative/Descriptive/Procedural

b. LEVEL II - Descriptive/Procedural

c. LEVEL III - Procedural/Descriptive

This is represented graphically in Figure 8.

Publication Numbering System

Publication numbering system compliance requirements are detailed in MIL-M-83495 and require all manufacturers to comply with this standard. This standard establishes three different numbering systems which result in all publications for a specific vehicle being linked together (21:7).

These number systems are the Technical Order number, system/Subsystem/Subject Number (S/S/SN) and the Fault

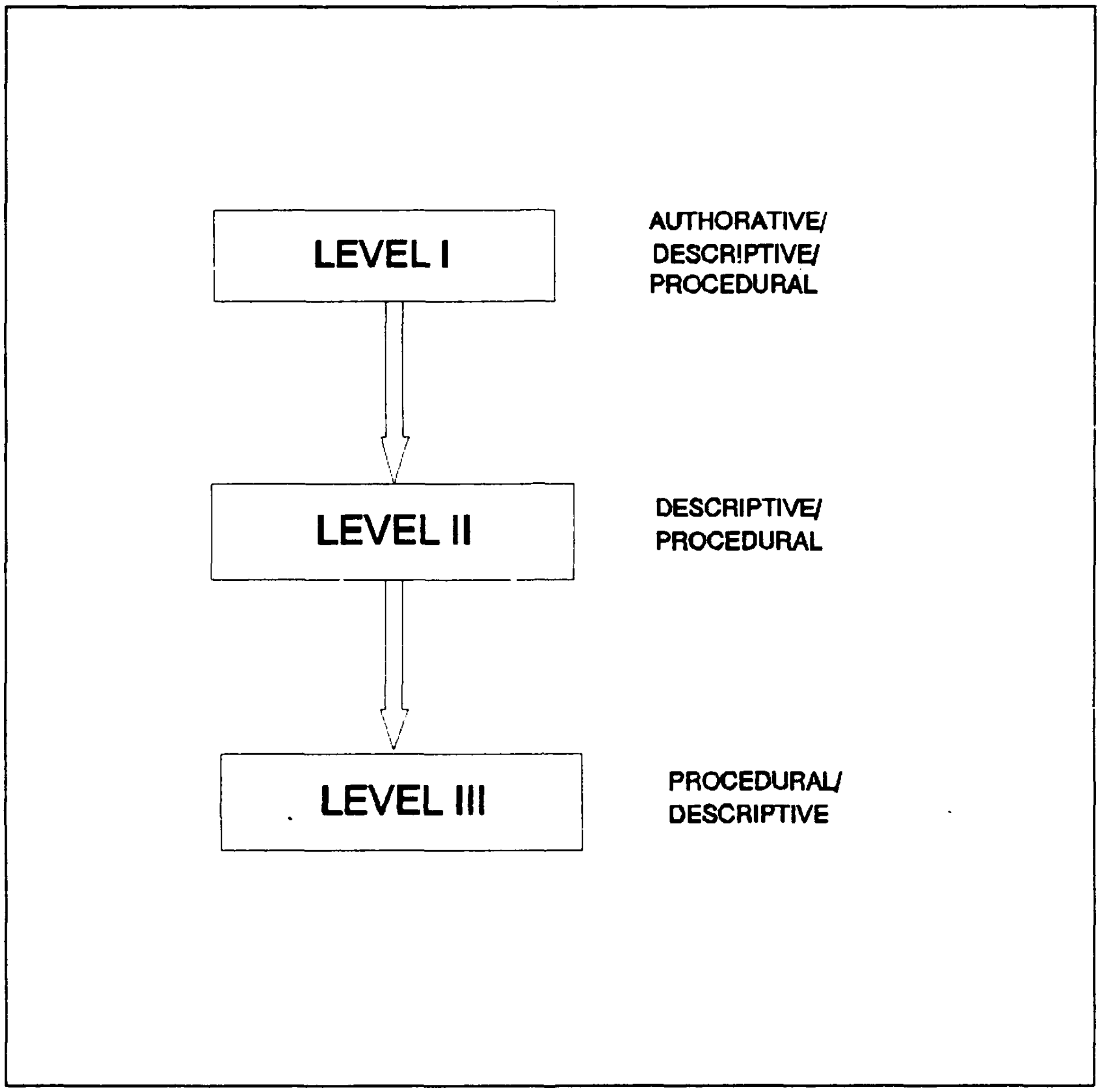

Figure 8: Publication Content Stratification

Reporting/Fault Indicator (FRI/FI) numbers. These systems are graphically illustrated in Figure 9.

Under this numbering method each system and subsystem is given a unique number which when combined provide the required indexing reference throughout the publication set. Thus any user can easily locate needed information from any publication for a specific system or subsystem by knowing

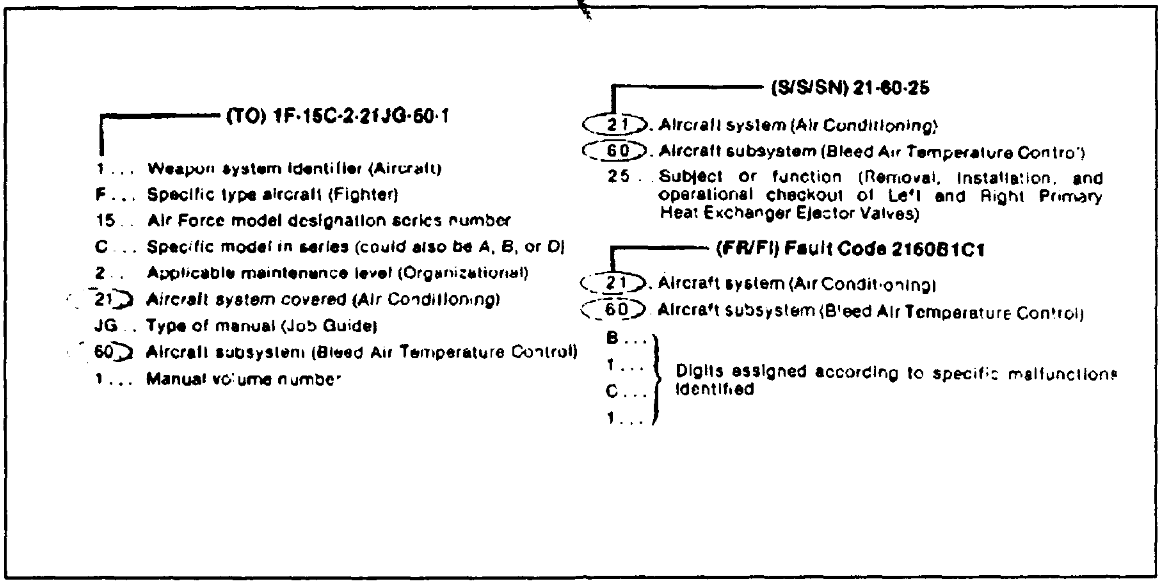

Figure 9: Publication Numbering System (19:7)

only its S/S/SN number (21:7).

This approach works well within the current top-down system/subsystem publication structure as the amount of referential information contained in the manuals could not feasibly be held in one publication due to the sheer volume and the complex indexing that would be required to support information location.

General Service Manual

The manual analyzed for this segment of the research was the TO 1F-15E-2-32GS-00-1, Landing Gear System USAF Series F-15E Aircraft. This publication contains technical maintenance instructions for the F15E aircraft at the system, subsystem and sub-subsystem level. The subsystem under analysis is the Nose Landing Gear (NLG).

The GS manual contains the following sections that relate specifically to the NLG subsystem:

a. Section 20 - Nose Landing Gear and Doors

    1. System Functional Description

        i. Description

        ii. Principles of Operation

    2. Special Maintenance Requirements

    3. Nose Landing Gear Pertinent Data

    4. Consumable Materials List

    5. Supplies (consumable)

    6. Support Equipment List

    7. Test Equipment

    8. Special Tools

In addition, the following sections also contain elements pertinent to the NLG subsystem:

a. Section 30 - Extension and Retraction

b. Section 50 - Steering

c. Section 60 - Position and Warning

The NLG references in the GS manual were concept mapped to highlight relationships, content and presentation format. The higher level concept map is detailed at Figure 10 and the lower level is shown at Figure 11. Examination of the map reveals that the content meets the previous assessment of Descriptive/Procedural, however presentation is in one of three formats:

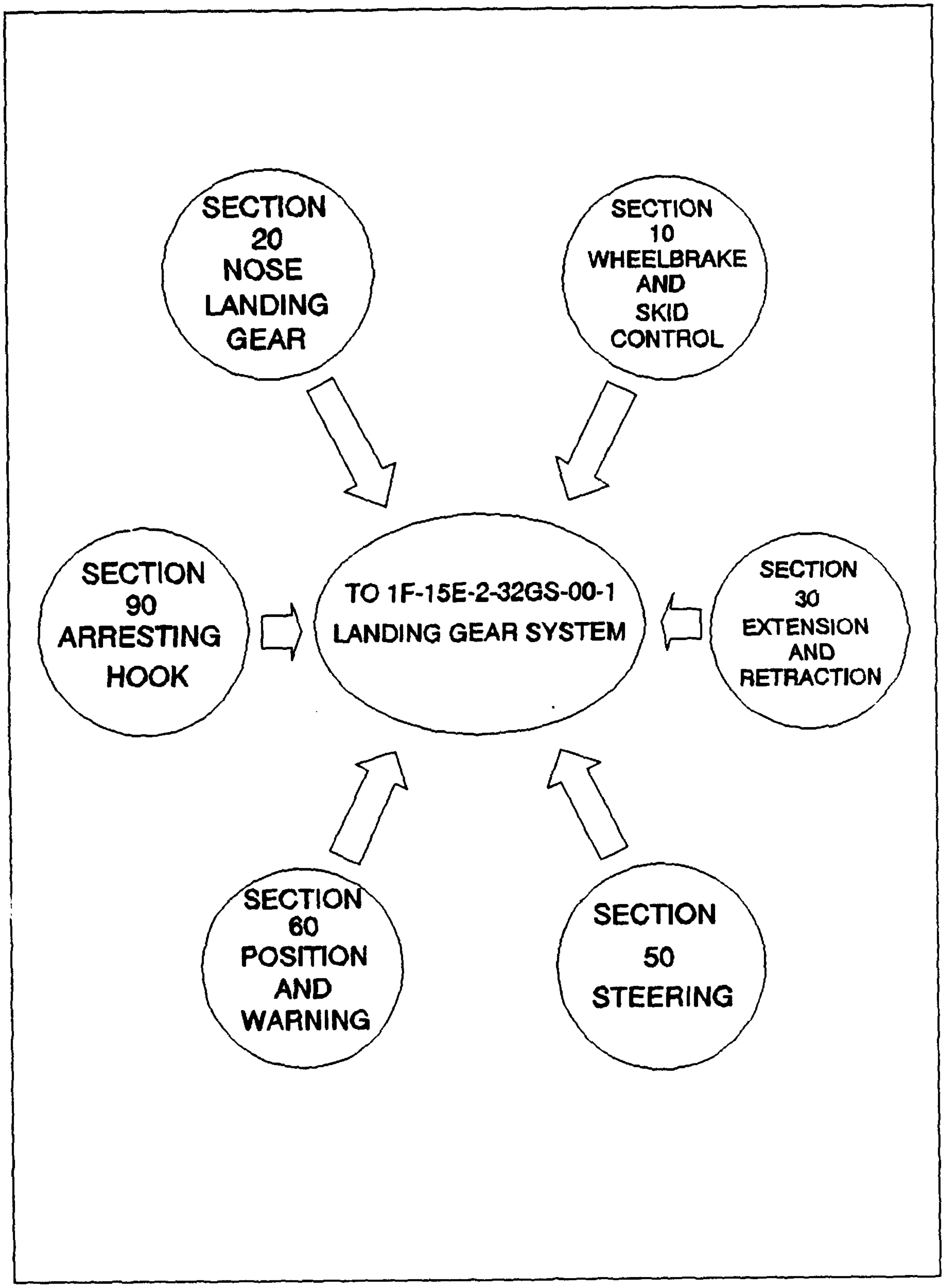

Figure 10: NLG GS Manual Data References - Level 0

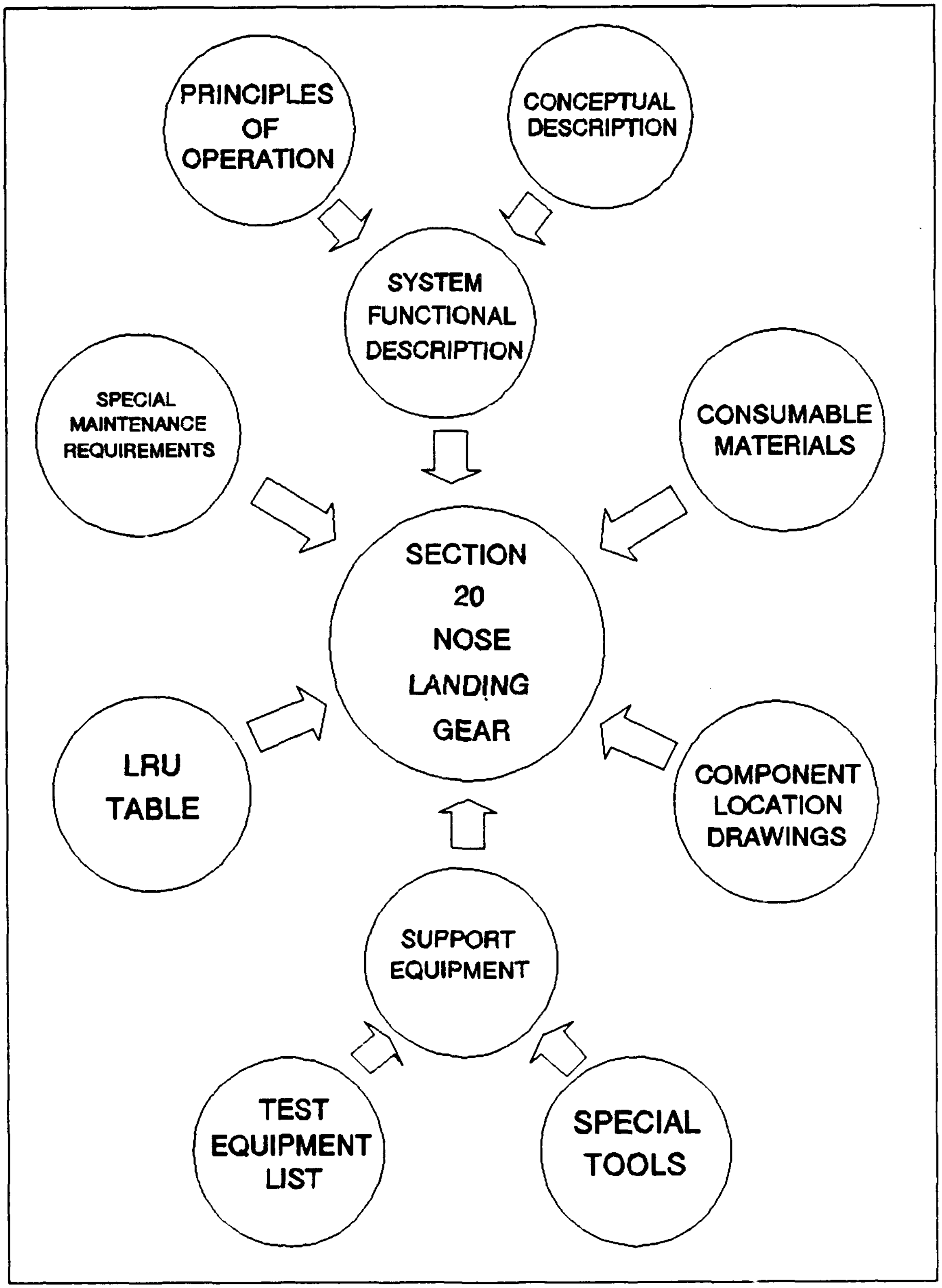

Figure 11: NLG GS Manual Data References - Level 1

a. Graphical - drawings and diagrams

b. Conceptual - written descriptions

c. Tabular - data is present in column format

GS Manual Analysis

Conceptual. At this publication level the conceptual information presentation is in the written verbose form and provides the user with a technical explanation of the system and its general theory of operation. There is little attempt made to link the conceptual data presentation to either the graphical or tabular representations. Use of technical abbreviations is made consistent with definitions of LRU's, systems and subsystems provided in this and other publications, however, there are no direct references made to either the tabular or graphical data. The user must resort to the graphical in order to identify physical location of a part on the vehicle and then cross reference this to the supporting tabular data for explanatory information. At this level, the conceptual data presentations are task supportive in that they provide descriptive data not directly involved in task performance.

Tabular. The tabular data is presented in columnar format and meets two distinct roles:

a. Provide descriptive data on a specific LRU or subsystem identified either by physical location on the vehicle or in alphabetical order by its common name. Columns provide sufficient information to enable the user to move to other publications as desired.

b. Provide supportive data relative to ancillary equipment and supplies that support the LRU's and proposed maintenance actions. This data is provided in alphabetical order and describes uses and applications as well as manufacturers part numbers.

Information acquired at sub-para a. is by either identifying a specific subsystem or LRU on the physical representation of the vehicle or looking up in the table by a known common name. On the other hand, data provided at sub-para b. is generally knowledge required to support the performance of a specific maintenance task, thus the user must access this prior to commencing the task. Repetitions of table entries were identified between tables in different sections, in particular the Consumable, Test Equipment and Special Tools tables.

Graphical. Graphical data presentations are illustrations of the various systems, subsystems, sub-subsystems and LRU's that provide the user with a visual reference. There are four levels of graphics at the GS manual level:

a. Level 1 - detailed diagrams. This graphic provides the user with a detailed illustrations supported by numbered call-outs referenced to the tabular system Component Location List. This is

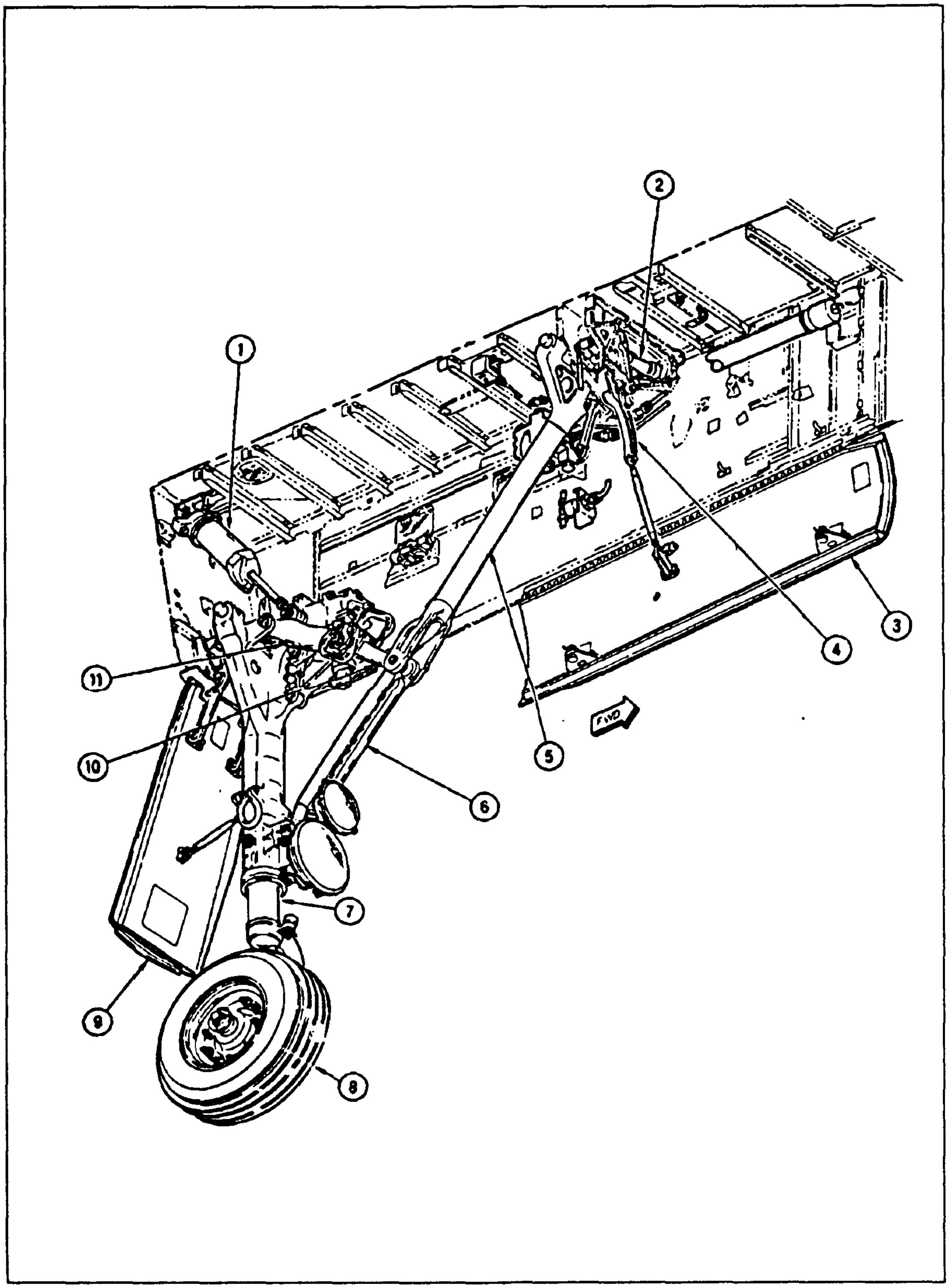

Figure 12: Level 1 Graphic - Nose Landing Gear
(3:20-3)

illustrated in Figure 12.

b. Level 2 - Vehicle location diagrams. These illustrations are simplified graphics that identify the specific location of the subsystem/sub-subsystem/LRU. They are supported by call-outs to detailed diagrams which in turn have call-outs to the aforementioned Locations Listing. This is illustrated in Figure 13.

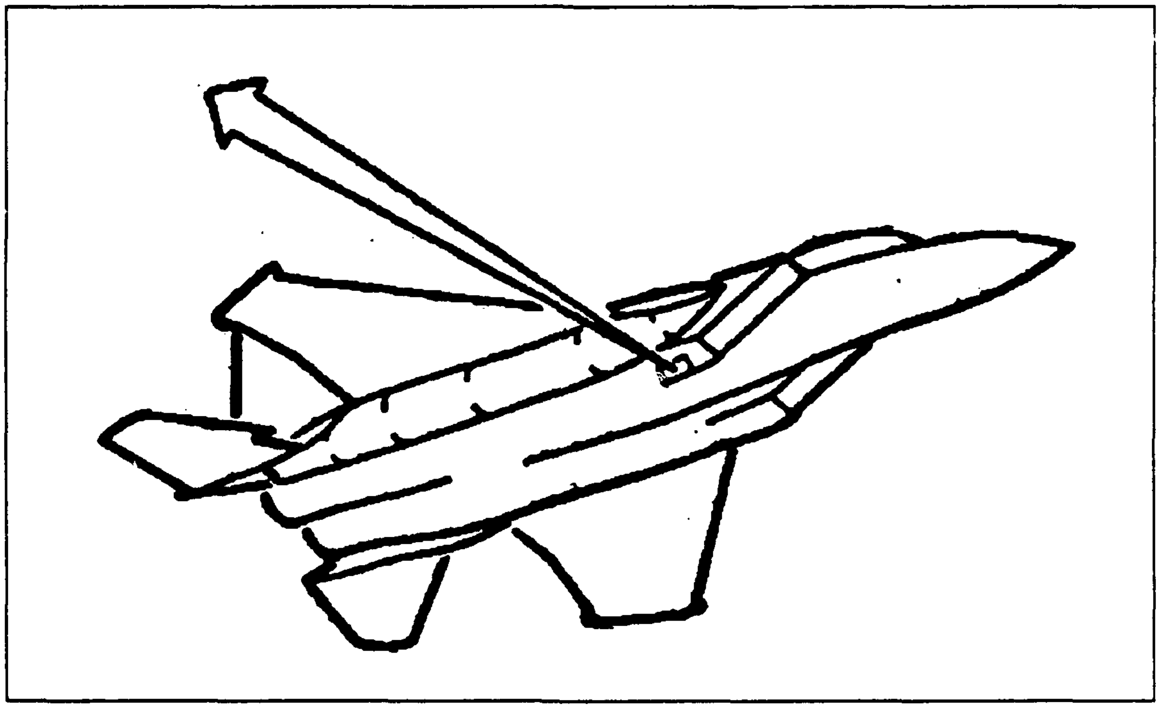

Figure 13: Level 2 Graphic - Vehicle Location Diagram (3:30-15)

c. Level 3 - Schematic diagrams. These provide both electric and hydraulic schematics for the subsystem/sub-subsystem/LRU. At this publication level they are generalized, however, the major components are referenced to the Parts Location Listing. This is illustrated in Figure 14.

d. Level 4 - special tool illustrations. These diagrams are self explanatory providing illustrations of special tools required for task performance. See Figure 15.

Level 2 illustrations also describe component and vehicle referential views from the front, back, left side, right side, top and bottom. Level 2 diagrams are repeated throughout the publication and maintain size and, depending on the view, aspect. In relation to task performance the graphical representations at the GS manual level fulfill a part identification and location reference role.

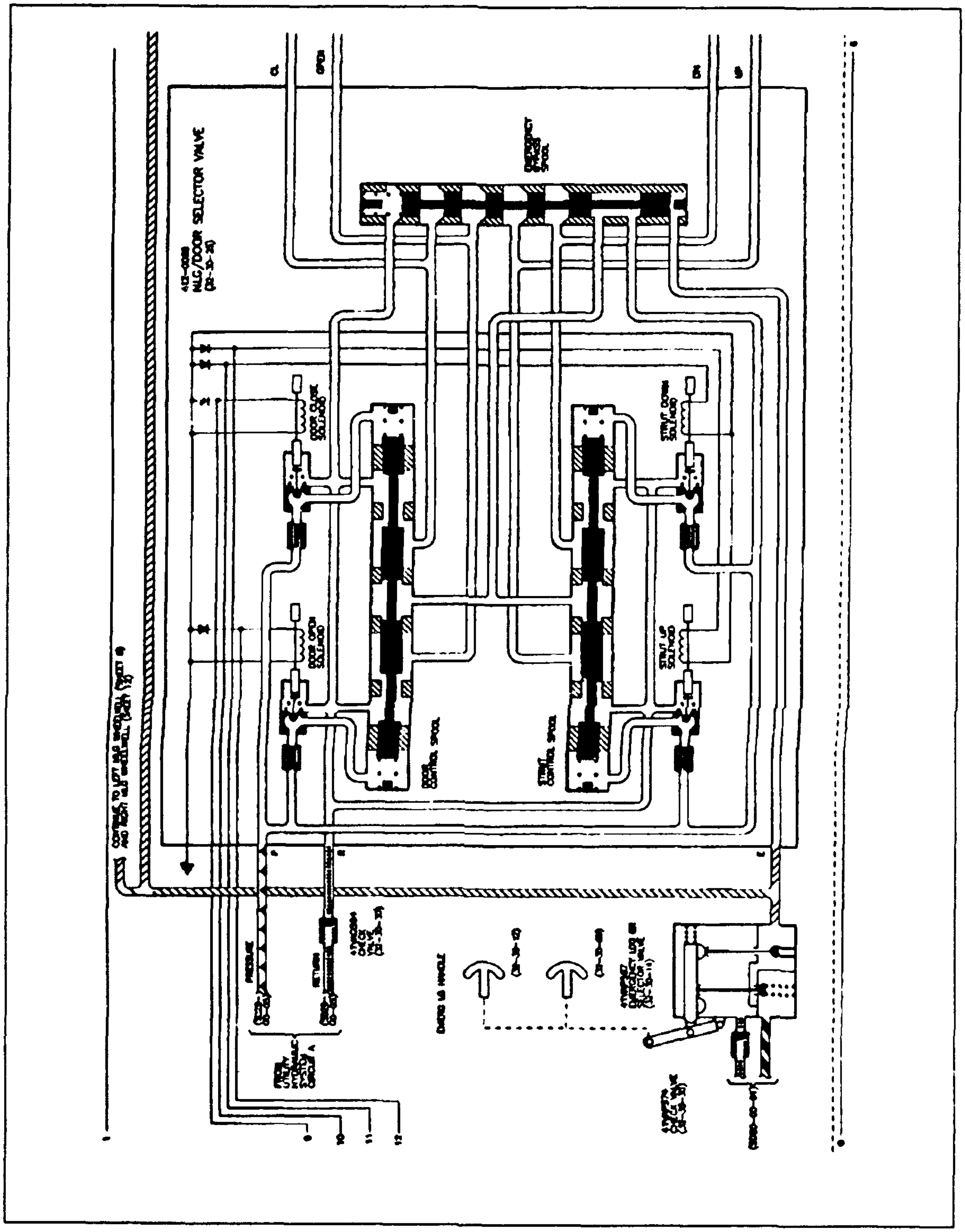

Figure 14: Level 3 Graphic - Schematic Diagram (3:30-18)

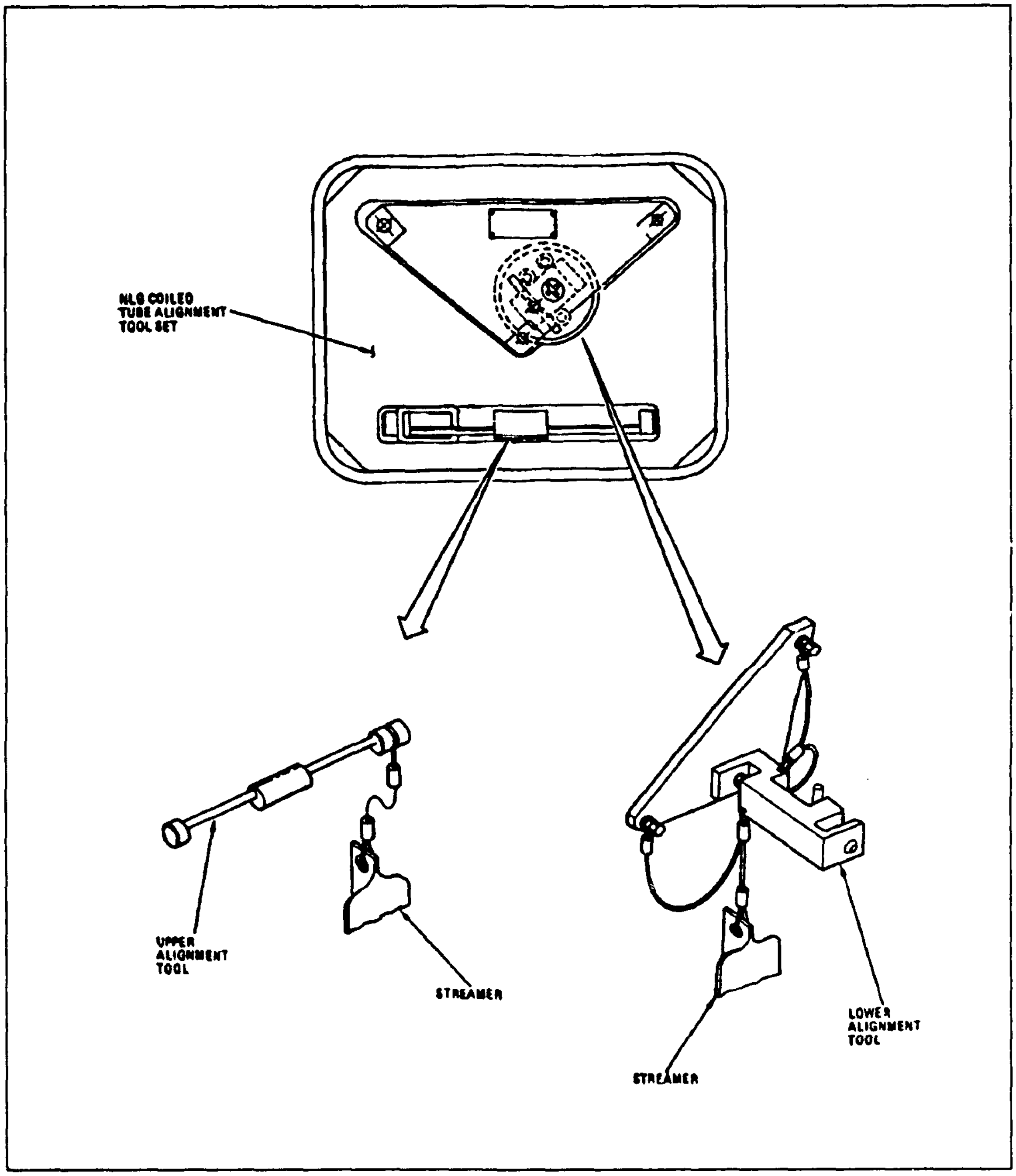

Figure 15: Level 4 Graphic - Special Tools Illustration
(3:30-30)

Appendix B: Model Evaluation Questionnaire

SHADM MODEL EVALUATION QUESTIONNAIRE

After using the SHADM model program please indicate on the scales your feelings about the following statements. Where you score a statement below 5 please provide supporting comments for your score.

User Interface

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

1. The program is easy to start.

Comments:

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

2. The use of the program is not difficult to understand.

Comments:

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

3. Navigating within the system is easy.

Comments:

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

4. The direct addressing capability made it easier for the experienced person to use the system.

Comments:

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

5. Overall the program is user friendly.

Comments:

Display Standards

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

6. The textual presentation is easy to read.

Comments:

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

7. The menus are laid out logically and are easy to read.

Comments:

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

8. The graphic to text format of the task procedure step presentation is best.

Comments:

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

9. The text to graphic format of the task procedure step presentation is best.

Comments:

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

10. The use of different windowing techniques makes the information easier to use.

Comments:

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

11. The data is segmented into logical groups.

Comments:

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

12. The structure of the information is good and facilitates easy use.

Comments:

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

13. The graphic menu choice will make it easier for new users to use.

Comments:

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

14. Navigating through the information is made easier by its structure and layout.

Comments:

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

15. The links between the various information nodes are logical.

Comments:

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

16. The links are correctly made and facilitate easy use of the system.

Comments:

General

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

17. The package meets the needs of the user.

Comments:

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

18. I would use this system in a workshop environment.

Comments:

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

19. I would use this system in a Systems Project Office to manage publications.

Comments:

STRONGLY DISAGREE										STRONGLY AGREE
0	1	2	3	4	5	6	7	8	9	10

20. The system will be accepted by the technician end user.

Comments:

Please feel free to address any specific strengths or weaknesses you observe in the package but were not addressed specifically by the questionnaire. Use the space below or attach additional sheets as required.

Comments:

Appendix C: Questionnaire Responses

The SHADM model was prototyped using the HyperWriter hypermedia software package. The prototype was validated by eight personnel in unsupervised testing. The following is a compilation of their assessments and recommendations.

Question 1: The program is easy to start.

Scores: 6(2), 7(2), 9(2), 10(2).

Comments:

1. Warrants 10 if you turn computer on and it automatically takes you to user login and password.
2. With users guide available for knowledge of executable commands.
3. A more dedicated interface would obviously be used in a real application.

Question 2: The use of the program is not difficult to understand.

Scores: 5(1), 6(2), 8(1), 9(4).

Comments:

1. Program is almost self explanatory.
2. At least as far as the user interface makes the program easy to use.
3. After very little experimentation easy to understand.
4. Some of the concepts would need to be taught to anyone not computer orientated.

Question 3: Navigating within the system is easy.

Scores: 6(1), 8(3), 9(3), 10(1).

Comments:

1. Pull down windows are great.

	2. Mouse application very good.
Question 4:	The direct addressing capability made it easier for the experienced person to use the system.
Scores:	8(1), 9(6), Not answered (1).
Comments:	1. Warnings, Cautions should always be present.
Question 5:	Overall the program is user friendly.
Scores:	7(1), 8(1), 9(3), 10(3).
Comments:	1. Very friendly.
	2. For the technician to use as a T.O. (publication), may not be if you mean use of Hypermedia to program publication into format.
Question 6:	The textual presentation is easy to read.
Scores:	4(1), 5(1), 7(1), 9(4), 10(1).
Comments:	1. Blue background was a problem, I know you are looking at this also, some numbers and letters were difficult to read (blue background again).
	2. Black text on blue background difficult for this reviewer, some displays were black text with art on white background - better.
Question 7:	The menus are laid out logically and are easy to read.
Scores:	8(3), 9(5).

Comments: 1. Being familiar with 83495 Mil spec may have biased my perspective.

2. I would block out the menu 'buttons' to the same length to make it tidier.

Question 8: The graphic to text format of the task procedure step presentation is best.

Scores: 2(1), 5(2), 7(1), 8(1), 9(1), 10(1), Did not answer (1).

Comments: 1. Easier to use text to graphics. Having both on screen would be beneficial.

2. It would be more simplistic if it were a split screen.

3. Both text-graphics and graphics to text are appropriate; in certain circumstances one is better to use than the other and vice versa.

Question 9: The text to graphic format of the task procedure step presentation is best.

Scores: 2(1), 5(2), 6(1), 7(1), 9(1), Did not answer (2).

Comments: Same as for Question 8.

1. I like the idea of being able to see what's going to happen. A picture is worth a 1000 words. The best thing that could happen is having the text listed next to the drawing and maybe even a video option.

	2. Text and graphics should be on screen together without text covering text.
Question 10:	The use of different windowing techniques makes the information easier to use.
Scores:	7(2), 8(3), 9(3).
Comments:	1. Windows keep all pertinent information at the technicians fingertips.
	2. However, as you have done in some cases, wherever there is a reference to a figure or procedure, use a window to view this figure, procedure. Not all links have been included time constraints probably prevented you from including this feature in all cases where required.
Question 11:	The data is segmented into logical groups.
Scores:	6(1), 7(2), 8(3), 9(2).
Comments:	1. The data available was segmented logically.
	2. Only lack of user experience prevents my scoring higher.
Question 12:	The structure of the information is good and facilitates easy use.
Scores:	6(1), 7(3), 9(4).
Comments:	1. Again, what was available was excellent.
	2. But watch for occasions where multiple screens are desired, may have troops

producing hard copies to work in concert with display info.

Question 13: The graphic menu choice will make it easier for new users to use.

Scores: 7(1), 8(2), 9(3), 10(2).

Comments: 1. Quality of graphics needs to be enhanced. Once this is accomplished the graphic menu should ease the utility of SHADM.

2. This application OK but several other tasks not with the 32-20-xx series are in N-W-W e.g. ASP Panel R&I 31-50-10. Window needed for all items in NWW that can be accessed via graphics menu.

Question 14: Navigating through the *information* is made easier by its structure and layout.

Scores: 6(2), 7(2), 8(1), 9(3).

Comments: 1. Information should be able to move about the screen.

2. Understanding the <green> <blue> are links. (Users guide).

3. Yes, but 'easier' than what? Technicians are very used to hard copy.

Question 15: The links between the various information nodes are logical.

Scores: 7(1), 8(4), 9(2), 10(1).

Comments: 1. What was available was logical.

2. Once again, I suspect a higher score is deserved but more experience is needed.

Question 16: The links are correctly made and facilitate easy use of the system.

Scores: 6(1), 7(1), 8(4), 9(1), 10(1).

Comments: 1. My limited knowledge of the aircraft system was a disadvantage, however I didn't see any obvious links that were incorrect.

Question 17: The package meets the needs of the user.

Scores: 3(1), 5(1), 7(3), 8(1), 9(1), 10(1).

Comments: 1. This package needs to be MIL-SPEC'd.

2. Good for in-shop use. Now it needs to be able to be used on the flight-line.

3. For in shop use with this configuration hardware. Flight-line use may need hand held unit.

4. Subject to possibility of requiring simultaneous access to > 1 page at a time, such as for circuit diagrams in fault finding rather than scheduled maint. functions. Also, might need package for fault finding needs.

5. Must be tested by a true user to answer this I suspect so.

Question 18: I would use this system in a workshop environment.

Scores: 5(1), 6(1), 7(1), 9(3), 10(2).

Comments: 1. If MIL-SPEC'd.

2. Excellent for workshop.

3. Subject to comment 3 at question 17 and comment 2 question 12.

Question 19: I would use this system in a Systems Project Office to manage publications.

Scores: 0(1), 4(1), 7(1), 8(1), 9(1), 10(3).

Comments: 1. There wouldn't be a practical use in a SPO since we use partial manuals, 35%, 70%.

2. Only in digital data format. That the only way changes to the data could be made and sent to the user.

3. Providing amendments, including drawing changes, could be readily incorporated.

4. Keeping publications current with engineering data not function of SPO, contractor responsibility. Management of publications program SPO responsibility. don't see application to aid in administrative management of full publications program.

Question 20: The system will be accepted by the technician end user.

Scores: 2(1), 5(1), 6(1), 7(1), 8(1), 9(2), 10(1).

Comments: 1. The hardware needs to be ruggedized and environmentally tested.

2. This should be an acceptable system for the flight-line supervisor and mechanic.

Being familiar with computer operation would enhance my evaluation of this system. An hand held device for flight-line use, rugged enough would be accepted in the flight-line.

3. There will be a great deal of user resistance and the outcome will depend on the practicality and reliability of the associated hardware.

General Comments

1. Good System. Easy to use and very easy to move through. Great for inshop use. Need to develop a way for flight-line use without paper.

2. How much growth memory is there available.

3. How are checklists handled.

4. Any warranty or time change recognition in database.

5. Warnings, Cautions need to be called out in text, before procedure is performed.

6. When more than one page of text is presented on the screen, especially numerous pages, adjust the software so that one can go from page to page rather than forwarding one line at a time.

7. How do I know which LRU is what Installation/Removal/Rigging. Put link to LRU window.

8. Nothing of big importance but I prefer the listings to go down the columns in sequence rather than across columns.

9. Like the screen selections at the bottom rather than top so I don't have the listings block the selections.

10. USAF MIL SPEC MIL-M-83495 and MIL-M-38784 require warnings/cautions to precede steps that they apply to.

11. There are 106,000 pages of text and art in the F-15E JG set. How much storage space is required on computer to handle these units/pages.

12. The more information that is stored in computers, what is the effect on system speed.

13. As we have discussed, I feel the key to it all will be lie in the practicality of the hardware needed to run the system. It must be reliable and user friendly.

14. The potential for the monitoring and management of resources is enormous, and may even outweigh the more obvious benefits associated with document maintenance.

15. Considerably more work is required to answer your queries about the real use of the system and the logical layout of the structure to meet user needs. The likes of you and I in an office environment can never anticipate the true needs. However, I think it is a path we must go down and a trial of the system in the real world (possible after some simulation exercises) would be very worthwhile.

16. Biggest problem I see is how to include circuit diagrams and other schematic diagrams required for fault diagnosis of electrical and electronic sub-systems. A corollary of this is that technicians might be included to produce hard copies of these pages so that he may access > 1 page simultaneously. Unfortunately, such pages are not

subject to amendment and may therefore contribute to maintenance errors if relied upon.

17. Also, in some steps, such as the steps required to install LRU 32-20-18, some of the steps in the 30-steps process were not included. As I do not know the particular procedure, I don't know if you left them out because the book did, or you didn't have time to include them. Whatever the reason, omission of procedural steps left me wondering about those steps I haven't undertaken, and also inspired some doubt as to whether or not I was using the package correctly.

18. Overall, very impressed with product. I see further applications for Systems Engineers in staff positions. Also, this type of tool should be made available as part of the system deliverable (at least, if not this system exactly, then some system following the broad principles).

Appendix D: Prototype Test Question Analysis

This Appendix provides question by question analysis of the Prototype testing results.

Question 1 Ease of starting the model was rated as very good with an average score of 8 from a range of 6 to 10. Individual comments were addressed to peripheral issues, which, while not directly pertinent to the underlying model design, are considered relevant to overall package presentation and ultimate user acceptance.

Question 2 Program understanding was assessed as good with an average score of 7.625 from a range of 5 to 9. Comments were in the most part complimentary of the system although one user addressed the issue of computer literacy of end users and the need to provide adequate user documentation. The need for appropriate and timely training, and documentation in the form of a User Guide is seen as an implementation strategy.

Question 3 Navigation within hypertext documents is considered a significant problem area. Due to the non-linear layout and proliferation of nodes and links, it is very easy for users to become lost or disoriented. This aspect of the model was rated as very good with an average score of 8.375 and a range of 6 to 10. Amplifying comments were limited to complimentary statements about individual navigation aids provided in the model and developed no significant issues worthy of further consideration.

Question 4 The model offered the user two menuing options, firstly a graphic selection where the desired system was selected from an aircraft illustration. This option was provided for the inexperienced user and took the user through a number of menu levels to the desired function. Direct addressing was the second option provided and this was directed at the experienced user, allowing a menu choice that led directly to the desired function, bypassing the other menu layers. The evaluation panel rated this aspect of the model as very good with an average score of 8.85 and a score range of 8 to 9. This indicated that the high rating assessment was shared by all users. One user did not provide a response to this statement. Only one comment was received on this aspect of the model and that was complimentary, offering nothing to model enhancement.

Question 5 In overall user friendliness the users rated the model as very good giving it an average score of 9 and a range of 7 to 10. Amplifying comments were complimentary and added nothing to further model development.

Question 6 Readability of textual presentation rated an average score of 7.75 from a range of 4 to 10. This wide range of evaluations was supported by comments indicating dissatisfaction with the graphics display colors, black illustration on blue background. This unfortunately resulted from a conflict between the color palette of the graphics package and the display palette of HyperWriter, a matter that has been addressed to NTERGAID. Users indicated that the preferred display colors for graphics are black illustrations on white backgrounds, as specified in the SHADM model.

<u>Question 7</u> Menu structure and layout received both favorable comment and a very good rating with an average score of 8.625. Individual comments related to the sizing of link buttons on menus, expressing a preference for a standard size to create display uniformity. This is acknowledged and will be included in the model.

<u>Question 8</u> With an average score of 6.57 the graphic to text display format was only rated by the users as good. Opinions regarding this format were widely varied, indicated in the score range of 2 to 10. One user did not respond to this question. Qualifying comments indicate that the preference is to have both the text and the graphic on the screen simultaneously and in such a manner that neither encroaches on the other Additionally, users indicated that both graphics formats may be appropriate depending upon the circumstances. One option is to provide both formats within the model, although this would incur additional programming, memory and data storage overhead, however, this would appear a negligible consideration when the improved user assessed utility and friendliness is taken into account.

<u>Question 9</u> The graphic presentation option of text to graphic was less well liked by the users than the text to graphic display. The average score was 5.67 which rated it

as acceptable. The score range was from 2 to 9 with two users not providing responses. The individual comments were of a similar nature to those provided for question 8 and analysis is unchanged.

Question 10 Users appear satisfied with the use of different windowing techniques and this is reflected in the high average score of 8.125, a rating of very good. No additional meaningful input was provided through supporting comments.

Question 11 Logical segmentation of data was classified as good with a users average score of 7.75 and score range of 6 to 9. Supporting comments justifying this low rating were not provided.

Question 12 Question 12 examined the structure of the data provided. Users only rated the structure as good with an average score of 7.875, while overall scores ranged from 6 to 9. Concern was expressed that while the data was structured well, there may be a necessity for users to view multiple screens, and, without a way of moving quickly between them, users may be induced to provide hardcopy to meet a perceived system deficiency. The result of this would be that these hard copies are retained for future use and because the paper copies would not be updated by publication amendment action, the user would be relying on outdated data. This is an extremely serious problem which can be solved by including a facility in the model that is available from the HyperWriter software. HyperWriter provides a facility for the user to implement place markers which enable the system to remember specific window locations. This would allow the user to quickly move between windows using short keystroke combinations (16:30). The requirement for this capability will be written into the model specifications based on this recommendation.

Question 13 This question addressed the graphical menu provided for new users. Participants rated it as very good with an average score of 8.75 from a range of 7 to 10. Individual comments addressed the quality of graphics used and the need to introduce an additional menu layer after the initial aircraft display. This is to ensure that all subsystems and sub-subsystems can be displayed and made available for user selection. This is a valid comment and can be implemented using the existing three tiered menu structure already existing in the model.

Question 14 Question 14 sought assessment of the navigation capabilities of the system with particular emphasis on ease of movement through the document. Individual scores were evenly spread over the range 6 to 9 and the overall average was 7.625 which rated the navigation aspects as only being good. Individual comments addressed movement through data page at a time, a facility that is already available on the tested system but not identified in the initial briefing. This aspect leads into the second comment on the need for a users guide. This need is recognized and in a field application of this model a users guide and training course should be provided to end users. One user commented on the end users predilection for the current hardcopy system, a comment that was further developed by the user at question 20. This comment was examined in greater detail in the analysis of question 20.

<u>Question 15</u> Logical link evaluation was the subject of question 15 and the users rated this aspect as very good with an average score of 8.375 from a range of 7 to 10. Comments provided were of a confirmatory nature and added nothing to further model development.

<u>Question 16</u> Question 16 addressed the correctness of the links and how easy they made the system to use. The range of scores was wide from 6 to 10 and the average score of 8 gave the linking strategy a rating of very good. Only one amplifying comment was offered which questioned an individual users ability to properly evaluate this aspect of the model design due to lack of aircraft data knowledge. This is considered a valid comment, however, it offered nothing in the way of further model development.

<u>Question 17</u> This question was designed to determine how well the package met the users needs. With an average score of 7, this aspect only rated as good. Examination of individual responses indicated that the severest criticism came from a technician publication manager who expressed concern over the failure of the tested system to meet MIL-Specifications. In its current presentation style he rated it as unacceptable. Given the requirement in the model

specifications for compliance with MIL-Specifications, no further action will be taken on this recommendation. Other comments addressed the ability of the package to perform in the flight-line environment and particularly highlighted hardware capabilities and requirements. This area is beyond the scope of this study however it is an important consideration for future studies and will be discussed in the recommendations section. Other comments identified the perceived need for users to be able to access more than one page at a time during diagnostic procedures requiring use of wiring diagram or hydraulic schematics that involve multiple displays. This issue was previously discussed at question 12 with the implementation of marker strategies.

Question 18 Question 18 sought to determine how useful the users perceived the system would be in a workshop environment. Overall, users gave this aspect of the model a very good rating with an average score of 8.125 from a range of 5 to 10. Individual comments were related to the packages' non-compliance with military documentation specifications, this user rating it as a 5 in present format. This issue was previously discussed at question 17.

Question 19 This question was designed to follow on from question 18 to identify the environments in which the users perceived the model as being usable. Use in a Systems Project Office was rated as good with an average score of 7.25 from a range of 0 to 10. Amplifying comments indicated that SPO's are not normally involved in the day to day preparation and use of publications. The high rating is explained by users not involved in or knowledgeable about the function and role of the SPO in publications management interpreting it as the central publications manager responsible for producing and updating documentation prior to distribution to units. This hypothesis is supported by the high scores allocated by the foreign engineers. Thus, while the average score rates this function as good indications are it is biased and therefore not acceptable.

Question 20 The final question in the test addressed whether the user believed that the model would be accepted by the technician end user. While this called for the offer of an opinion it was designed to call on the users experience within his professional field, exposure to the package and knowledge of the existing system. Non USAF testers and non F-15E SPO personnel were expected to draw on knowledge of their own maintenance publication system and its use. Overall this aspect of the test was rated as good with an average score of 7. However, the range of scores was from 2 to 10 indicating a wide disparity in opinions. Individual comments mainly revolved around providing the requisite hardware that would meet the end users needs to deliver information and be capable of surviving the rugged working environment. The one score of 2 was given by a foreign engineer who believed that there would be significant user resistance to the system, dependent on the "practicality and reliability of the associated hardware".

While this aspect is acknowledged as a potential problem area it is not considered of relevance to this specific test. Future research, however, should address this aspect prior to any implementation.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE

3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE

STRUCTURED HYPERMEDIA APPLICATION DEVELOPMENT MODEL (SHADM): A STRUCTURED MODEL FOR TECHNICAL DOCUMENTATION APPLICATION DESIGN

5. FUNDING NUMBERS

6. AUTHOR(S)

PETER W. CASSELL, Flight Lieutenant, RAAF

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

AIR FORCE INSTITUE OF TECHNOLOGY, WPAFB OH 45433-6583

8. PERFORMING ORGANIZATION REPORT NUMBER

AFIT/GIR/LSY/91D-3

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This research was conducted to determine how a Royal Australian Air Force technical maintenance publication could be transformed into a task oriented hypermedia application and to develop a model that could be used for future similar transformations.
The model was developed following in-depth analysis of the existing USAF F-15E maintenance publication set and validation was conducted using a prototype developed in HyperWriter, a commercial hypermedia product.
The prototype model was based around the performance of three maintenance tasks on an aircraft sub-subsystem and incorporated online user access to the necessary support data for task completion. Publication managers, producers, and users were involved in prototype testing and results validated the model design with limited modification recommendations. Recommended changes were subsequently incorporated in the final model.

14. SUBJECT TERMS

Hypermedia, Hypertext, Technical Publications, Publications, Maintenance Manuals, Expert Systems.

15. NUMBER OF PAGES

125

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

AFIT Control Number AFIT/GIR/LSY/91D-3

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