FUTURE PAST:

INTEGRATED PRESERVATION INFORMATION SYSTEMS

by

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in

ENVIRONMENTAL DESIGN AND PLANNING

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(ABSTRACT)

"And what we can see and imagine gives us faith for what surpasses the imagination." (Wells, 1902)

A rich cultural heritage can serve as a vehicle that enlivens all levels of educational development and promotes an interdisciplinary dialogue concerning preservation goals and objectives. A comprehensive, integrated information base is essential to sustaining the viability of this diverse cultural heritage and to promoting a national preservation agenda. The collective experiences and practices of local preservation efforts, when assembled into a readily accessible knowledge base, can effectively inform efforts to resolve preservation challenges nationwide.

As the ideal of historic preservation has come to accommodate a variety philosophical perspectives, so too must the efforts to adapt new technologies to the tasks of cultural resource management. The development of more effective mechanisms for informing the decision processes will encourage resource administrators to assume greater responsibility for the management of cultural resources. It will enable the preservation community to strengthen its social, economic, and political advocacy for the conservation and celebration of our delicate, yet durable, cultural roots. Through the outreach to public and private constituencies, and through the development of market applications for cost effective preservation products, technologies, and services, the positive socioeconomic benefits of sensible, sensitive cultural resource management will serve to institutionalize the perception of our cultural heritage as an integral part of a healthy, informed society.

The goal of this work is to demonstrate through developed prototypes and projected scenarios, alternatives for technology transfer, adaptation, and application that can facilitate better informed decisions about the management of an increasingly threatened cultural heritage. This body of information will contribute to the resolution of the most critical needs of the preservation process, and will enhance the ability of private, state, and federal agencies to meet their legal obligations in the management and protection of our cultural heritage. The work demonstrates that the whole of the preservation process can be enhanced by exploiting the opportunities inherent in emerging information management technologies.

Dedication

To Rebecca, whose quiet strength and loving heart will forever be an inspiration; Barrett, whose memory gives me purpose and strength in confronting challenges; Wright, with whom I revel in the joys of life; and Peg, who has given me the greatest gift, and for whom I care more than I can express.

Acknowledgements

Gratitude is extended to the colleagues, friends, and family that offered encouragement and counsel throughout this academic odyssey, often whether or not I solicited it, but invariably because I needed it. Insightful contributions have been made by many, but the individual members of my committee have brought to this effort an essential diversity of experience and knowledge, without which the final product could not have been realized. Thanks to: Joe Wang, for whom the communication of knowledge through dialogue and discourse is paramount; Bob Schubert and Dennis Jones for sharing their visions of the essential role of emerging electronic technologies in the architecture profession, and for their ability to penetrate the mystique that too often obscures the utility of computer tools; Hugh Miller for his perception of the critical need to articulate a new technological agenda for the preservation process, and for continuing to inspire my commitment to a conservation ethic; John Randolph for his belief in the possibilities, and his sincere interest in their realization. Thanks also to Mike Yamarik, whose professional expertise has been a source of revelation, and whose good nature and enthusiasm has frequently contributed to a balanced perspective. To each of these friends and colleagues, I express my deepest appreciation for the time and energy that they dedicated to this work.

Foreword

The Electronic Book

The integration of media resources represents the promise of a new paradigm for information processing and knowledge acquisition. Information exists in many formats and contexts, and this electronic "Information Age" in which we are participants is precipitating an information glut of staggering proportions. The rapid pace of technological change is outstripping society's ability to productively assimilate a remarkable variety of new tools that might favorably influence every aspect of our lives. A concerted effort is essential to affect the transfer and application of appropriate technologies that will facilitate information management tasks.

While the digital format represents an appropriate common denominator for the management of information (as virtually any data type can be translated into a digital environment), the superimposition of an ordering system is necessary to facilitate the extraction of knowledge from a large and diverse database. In order to become meaningful, information resources must be organized according to the hierarchical and network relationships that constitute the structural substance of the knowledge base. As a consequence of this structuring, the knowledge communities of the information ecology will become more accessible and comprehensible, and eminently more useful.

Hypertext systems are information management environments that make the superimposition of viable structural frameworks possible. As a test (and demonstration) of this information management paradigm, the hypertext application (IPIS-Hypertext) that is contained on the enclosed diskette serves as the primary vehicle for the presentation of the dissertation document. This interactive "electronic book" permits a high degree of user discretion in navigating the assembled information base, and it ensures the usefulness of the material as a reference resource to a broader audience than might otherwise be expected. Conceptually, this manifestation of an electronic document environment is a precursor to the ultimate ascendancy of a digital format over traditional printed media in the management and communication of data.

IPIS-Hypertext is intended to demonstrate the utility of hypertext as an interactive environment for information integration and management. This application enables system users with a broad variety of computer skills, professional interests, and preservation expertise to rapidly access, and hopefully assimilate, relevant information contained in the knowledge base. The IPIS-Hypertext environment allows knowledge base explorers to follow many paths through a wilderness of information resources in search of the content (single file nodes or complex, linked file paths) most appropriate to individual needs and interests. The primary basis for movement through the structure of the IPIS-Hypertext system are the associative links that mark information paths through the knowledge base.

The component parts of the knowledge base are called "information nodes". These modular idea entities are accessed through paths defined by associative links, represented by the enclosure of a filename in "< >" brackets (eg. <afile11>). Each associative link also includes a brief descriptive label (descriptor) that represents the idea content of the associated file. As the reader scans a particular file in the IPIS-Hypertext system, an understanding of the greater context of the knowledge

Figure 1. The IPIS-Hypertext Electronic Book: A 1.2Mbyte diskette for an IBM AT (or compatible) computer.

community (communities) of which an individual file may be but one small part can be acquired from the implied information content of the associatively linked nodes.

Upon inserting the enclosed 1.2 Mbyte diskette in the "A" drive of an IBM AT (or compatible) computer, the IPIS-Hypertext program is initiated by switching to the "A" drive (*A:*) and typing ***IPIS*** at the DOS prompt (*A:>*). After the primary IPIS-Hypertext network display appears on the computer screen, user directed interaction may begin. There are a variety of means which the reader can employ to move through the information base. These are described in the appropriate network screen (eg. "Interactive Utilities") and in the "Help" files. The most basic movement commands employ the Up and Down Arrow keys to position a highlight bar at the desired network topic or associative file link, and the Enter key or the Right Arrow key to activate the display of the topic screen or the linked file. Note that a text editor can be configured with this application when one is specified in the "Options" settings (ex. c:\path\program #).

Summary of IPIS-Hypertext navigational commands:

PgDn/PgUp Keys............ Control screen scroll

Up/Down Arrow Keys........ Highlight the associative links

Right Arrow Key........... Select a link path

Left Arrow Key............ Retreat along the current path

Press ***F1*** to activate a "Help" screen from anywhere in the program.

The system user should be aware that IPIS-Hypertext can:

Traverse links between ASCII files............ ***<filename>:*** ex. <afile11>

Traverse links leading to specified screens........ ***<filename screen>:*** ex. <gfile44 2>

Traverse links leading to specified lines........ ***<filename screen line>:*** ex. <gfile44 2 10>

Traverse links leading to specified text.......... ***<filename -text>:*** ex. <bfile22 -preservation>

Link an ASCII file with a [.PCX] graphics file ...... ***<filename.pcx>:*** ex. <hfig09.pcx>

Run a program application (.EXE, .COM, .BAT)..... ***<program.ext>:*** ex. <editor.bat>

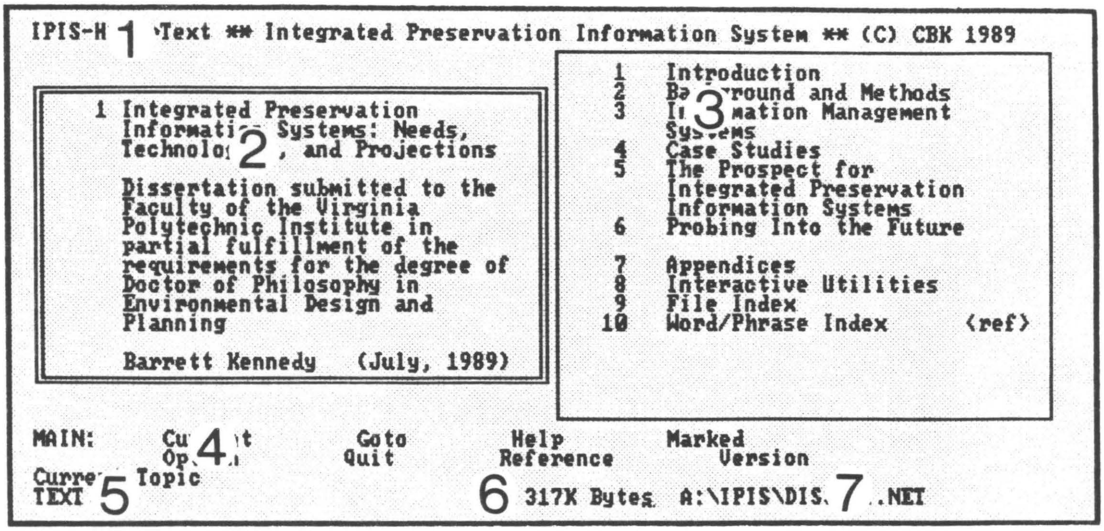

Figure 2. An IPIS-Hypertext Network Screen: (1) System Title; (2) Current Topic; (3) Subtopic List: use [Up/Down Arrow] to highlight and [Right Arrow] to select; (4) System Commands: use [Spacebar] to highlight and [Enter] to select; (5) Display Status: use [F2] to toggle "Text/Head" status; (6) System Memory (RAM); (7) Current Drive, Path, Filename.

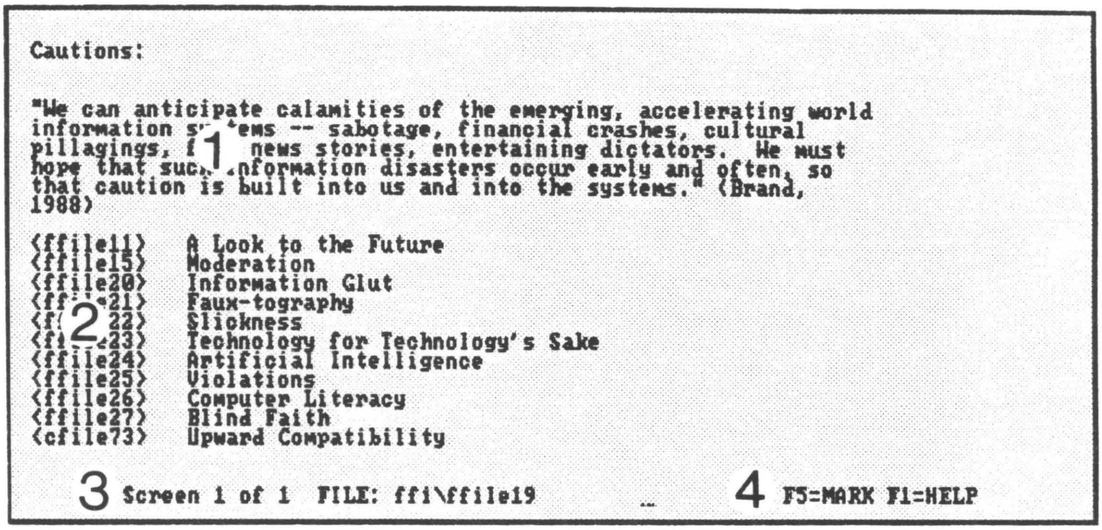

Figure 3. An IPIS-Hypertext Information Node (ASCII File): (1) ASCII Text; (2) Associative Links: use [Up/Down Arrow] to highlight and [Right Arrow] to select; (3) Current Screen, Path, Filename; (4) Press [F5] to "Mark" a file and [F1] to display a "Help" screen.

Recognition of the need to formulate new strategies for information management underscores the fundamental problems that exist with traditional print media. The Virginia Polytechnic Institute (VPI) Graduate School's recognition of the potential that this hypertext application represents as an alternative environment for dissertation documents acknowledges the importance of capitalizing on the capabilities of heretofore underutilized computer based systems. In order to meet the parameters set forth for microfilm reproduction, a printed dissertation document has also been produced as a supplement to the electronic version.

Some readers may be tempted to peruse (indeed, if tempted to engage in an exploration of these information management issues at all) the printed document as a familiar medium of information exchange. However, the author, wholeheartedly and without reservation, encourages the reader of this material to explore the electronic book rather than the traditional printed document. While the material in the electronic format can be reviewed in the same serial progression that the printed format offers, the user of the electronic book has far more powerful capabilities in accessing and extracting useful information contained in the body of the knowledge base.

Integrated Preservation Information Management

The greater context of this work encompasses a variety of concerns relevant to the design and planning professions, but the focal issues around which this project has been developed are the critical information management needs of the preservation community. As a means of structuring the discussion of needs, and the potential for resolving these needs through electronic technologies, the seven component activities of the preservation process offer an appropriate framework through which needs can be correlated with technological promise. These activities are neither rigidly serial nor content exclusive. Rather, the steps of the preservation process represent a broad range of interrelated tasks that are directed towards one central objective, the preservation and celebration of the cultural heritage.

In the examination of this focal preservation theme, an understanding of the following terminology is essential:

Cultural resources can be defined as "unique, nonrenewable resources subject to continual stress from human and natural agents" (U.S. Congress, 1986). The need to eliminate or limit the effects of such stress has resulted in the development of knowledge, skills, and techniques for managing cultural resources.

Cultural resource management (CRM) is the "process of preserving our cultural heritage (sites, structures, artifacts, records, landscapes) for the benefit of the American people through the application of management skills within the political process" (U.S. Congress, 1986).

The ***preservation process*** describes the seven component activities of sensitive, sensible cultural resource management. These components consist of resource identification, documentation, analysis, data management, conservation, protection, and education.

Preservation technology refers to the tools and techniques that enhance or facilitate the activities of the preservation process by improving the quality, quantity, and usefulness of cultural resource data. These preservation technologies can range from traditional, relatively simple techniques to highly sophisticated tools based on complex technologies.

Technology transfer is the term used to describe the resolution of challenges and problems encountered in one discipline through techniques and technologies developed in another discipline.

The Preservation Process at Work

This dissertation anticipates that by the year *2000*, the appropriate application of electronic technologies to the tasks of cultural resource management will enable the preservation process to unfold according to the following scenarios:

1. Resource Identification:

Predictive modeling and remote sensing techniques are used to identify a potentially significant site of prehistoric or historic cultural activity. The predictive computer models utilize artificial intelligence capabilities to define the criteria which indicate evidence of cultural activity or impact on the landscape. Powerful computer processors that employ superconductive components and superchips sort through the massive volumes of remotely sensed data (from space borne and aerial sources) in order to identify landscape anomalies that differentiate the evidence of human impact from naturally occurring features. The computer generated list of potential cultural sites is then corroborated through close range remote sensing techniques and field inspection.

2. Documentation:

Along with the use of multispectral, radar, and magnetic remote sensing devices, cultural sites are comprehensively documented using high resolution digital video recording equipment. The cultural landscape reflects man's activities and interactions with the natural environment. Whether buildings, roads, manipulations of the soil, or simple responses to the natural condition, the landscape marked by human activity is the most enduring monument to the presence of mankind. In addition to the documentation of the individual resource, the surrounding site and landscape are

Preservation Process	Ten Technologies									
	Superconductors	Super Chips	Artificial Intelligence	Hypermedia	User Interface	Storage	Connectivity	Animation and 3-D Graphics	Holography	Stereolithography
Identification	○	○	●				○			
Documentation		○		●		●		○		
Analysis			●		●		○	●	●	●
Data Management	○	○		●	●	●	○			
Conservation		○	●	●			●	●	●	○
Protection			○			○	●	●	●	○
Education	●	○		●	●	○	●	○	○	○

Figure 4. Impact of Technological Developments on the Preservation Process: The correlation between preservation activities and ten areas of technological development discussed in this document (● Direct Correlation; ○ Indirect Correlation).

videographically recorded to accurately portray the spatial relationships and environmental/cultural character of the larger context of the urban, industrial, or rural setting.

In this methodology, 3-D reference objects (reference stadia) are placed on or adjacent to the subject buildings (or ruins, etc.) in order to establish object scale. The video crew then works its way around the exterior of the structures, recording overall views and the larger context of the site. In addition, the crew videotapes detailed information about the material types, joints, evidence of physical condition and material performance, unique or significant design or construction features, and specific environmental information. Conditions permitting, interior views of the structure are similarly recorded in the context of spatial qualities, design intent, quality of craftsmanship, furnishings, etc. The completed video record represents a primary documentary source, and it is archivally secured in order to preserve record quality.

Selected frames of the video record are transferred to the computer environment using a frame grab board with digital signal capture capabilities. Digital audio recordings of environmental sounds, commentary, and oral histories are also transferred to the computer environment, parsed, and linked to appropriate graphic data fields. Additional sensory evidence that contributes to the characterization of the site and associated historic activities is also compiled and indexed to the resource record. Historic written and graphic materials are electronically scanned into the digital information base using systems with appropriate graphic capabilities (300-2000 dots per inch resolution; monochromatic with up to 256 gray shades; color with up to 32,000 colors). Hand written, typed, and typeset textual information is converted from graphic to ASCII format through an optical character recognition program.

3. Analysis:

Close range application of remote sensing and predictive modeling techniques serve architectural concerns in evaluating the integrity of historic building structure and fabric. Digitized images of historic materials are examined through multispectral techniques to determine age, authenticity, structural character, and condition. A database of materials signatures (with an assigned gradient from healthy to failing for each of a range of historic and contemporary building materials) provides the AI engine with the criteria for comprehensively, but non-intrusively, assessing the condition of the historic structure or artifact.

Images of selected buildings and fragile artifacts are subjected to computerized dimensional analysis in order to generate accurate CADD drawings and 3-D graphic models of existing conditions. Views acquired from historic photographs are also dimensionally analyzed to enable the accurate computer generated modeling of the historic scene, and to graphically simulate the evolution of the site from the historic to contemporary context. The graphic representations (and simulations) will enhance the understanding of the character and quality of historic resources, as well as the impact of past, present, and future threats on the integrity and viability of each cultural resource.

4. Data Management:

The massive volumes of data that constitute the resource record are stored in a digital format on optical disks. Magneto-optical devices are used as a working medium for information processing and for supplements to the resource record. CD-ROM devices are used as an archival digital storage medium for the assembled information base.

To accommodate the graphic component of the resource record, compression algorithms reduce image file size by more than 99%, and dedicated image processing superchips with superconductive components permit the real time (1/30 sec.) decompression of high resolution color image files.

Similarly, compression algorithms process audio files for more efficient storage, and decompress them for serial transmission in real time on user demand.

The information generated by the activities of the preservation process is compiled in a hypermedia environment to facilitate integrated information management. The interactive environment provides rapid user access to the full range of data fields and data types that constitute the resource record. Network links to related records and other reference resources are constructed to facilitate information processing.

The user interface to the information base is predominantly via natural language processing. The user directs the processing of the information path and the synthesis of information nodes through voice commands. Audio and textual information stored in other languages is translated into English text or audio as required by the user. Text files can either be viewed and processed in an ASCII format, or processed as audio files.

5. Conservation:

Based on the analysis of the accumulated evidence, a determination of historic significance and integrity is established. Using computer generated 3-D graphic simulations and predictive modeling techniques, the projected implications of alternative conservation strategies and associated costs are visually depicted. The resource management decision process is facilitated by free space holographic representations of information regarding the historic, contemporary, and projected context of the historic site. The process of graphic evaluation of alternatives provides a fuller understanding of near and long term management consequences, and serves as a foundation for better informed decisions to ensure conservation of significant features, materials, qualities, and associations.

A global conservation knowledge network utilizing the Integrated Services Digital Network (ISDN) protocol provides a digital forum for the exchange of information regarding conservation strategies and techniques. Through the use of a collaborative software (groupware) environment, the network facilitates a global dialogue between conservation professionals as a means to share personal experiences and insight, as well as technical information derived from product application and research. The individual participant in the network can automate the extraction of information from the network by activating a programmable data filter that monitors the global knowledge base for information relevant to specifically defined issues and problems.

The integration of preservation information into a hypermedia environment facilitates the generation of conservation documents, from task specific work orders to comprehensive preservation directives. The hypermedia environment provides a foundation for the organization of a massive preservation knowledge base from which a user can extract text (specifications), graphics (working drawings and 3-D models), and material lists (product literature) appropriate to an individual project. The digital information is then utilized as a computer based "electronic working document" in a format (text, 2-D and 3-D graphics) that best meets the requirements of the application. Miniaturization of powerful electronic components (superchips) and the development of sophisticated graphics processing algorithms endow laptop computers with the requisite high resolution 3-D displays, immense optical storage capabilities, and real time animation and digital video capabilities to make them effective as portable work environments, and as vehicles for the dissemination and management of project documents. Cellular communications links permit the exchange of information between the field site and the office environment (the contractor, subcontractors, the project manager/designer, engineering services, materials suppliers, the client, etc.). Project information is updated regularly through the cellular link, facilitating the resolution of field problems, change orders, and scheduling conflicts. The hypermedia environment is also linked to the project document, so that the extraction of additional information from the knowledge base is possible. This also ensures that any modification of the electronic project document is recorded in the originating (archival) document in the hypermedia environment.

6. Protection:

Significant historic artifacts, writings, and graphic materials are accurately replicated as digital constructs in order to preserve their integrity while facilitating access to the information they contain or represent. The placement of the historic resource in an archivally stable environment ensures its continued protection. The digital construct (or clone) ensures the productive utilization of the resource for research, interpretation, and education activities. High capacity storage media (optical disks) are used to archive digital information resources. A StereoLithographic Apparatus produces 3-D replicas of historic artifacts, tools, and utensils. The ability to generate surrogate experiences through which contemporary individuals can interact with the component parts or the whole of an historic scene increases the understanding of conservation values and substantiates the socioeconomic foundation for cultural resource protection.

Culturally significant sites and structures are continually monitored for adverse impacts through electronic subsurface, surface, and remote sensory devices. These superchip devices have integral processing capabilities, and as a network, they constitute a comprehensive spatial data management system (SDMS). The individual programmable devices have specific predefined tasks (monitoring building movement, moisture content in building materials, the volume of visitor use, environmental quality, weather patterns, etc.). The whole of the site is a 3-D computer environment in free space that is linked to the monitoring component of a central resource management system. This centralized system also monitors the impact of forces, events, and policies that are external to the specific resource site. The accumulated body of information is continuously processed by an AI system that is programmed to recognize problems that threaten resource integrity, and to report policy, task, and scheduling recommendations.

As a function of the global conservation knowledge network, movable cultural resources are cataloged and monitored to mitigate the the theft and illegal sale of antiquities. The network can be queried for status reports on stolen or missing objects, and for information about known traffickers in the illegal antiquities trade.

7. Education:

An educational agenda for cultural literacy will be enhanced through the application of virtually all of the technologies discussed in this document. Fundamental to education processes is the nature of the user interface with the preservation knowledge base. Natural language processing capabilities will permit a virtual dialogue between the user and the machine environment, and between the various users of the network "machinery." The high degree of user discretion in defining paths through the information base, in marking and retracing paths, and in following paths defined by others establishes an appropriately interactive environment for learning. The sensory richness of the information base (audio, visual, olfactory, and tactile data) comprehensively represents the character of the constituent cultural resources. Representational techniques employing 3-D animation, stereoscopic video, and projected holography create a virtual reality from the resources of the information base, placing the system user into a simulated construct of the historic context.

The assembly of highly interactive and graphic presentation and working environments are the foundation for effective information dissemination. The miniaturization of electronic hardware components (superchips, superconductors, screen display, and storage media) and the development of powerful software modules and operating environments (compression algorithms, hypermedia systems, groupware) means that preservation information systems are highly portable, and can be utilized in environments and at times most suitable for learning. The ability to link remote information stations to a global network means that the whole of the knowledge base is always accessible to the individual user. These technologies facilitate the application of the open classroom concept for group instruction and for individual student users.

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Chapter One: Introduction

1.1. Preface:

The Congressional Office of Technology Assessment (OTA) in its report, "Technologies for Prehistoric and Historic Preservation" (U.S. Congress, 1986), asserts that the development of technologically advanced, cost-effective conservation tools and methods is essential to the preservation of our cultural heritage.

The objective of this research effort is to assess opportunities to adapt contemporary information technologies to the tasks of cultural resource management. This document presents an evaluation of the potential that a variety of emerging data acquisition and information management technologies might hold for the preservation process. Prototype preservation information systems were developed to test a representative range of available computer and videographic technologies, and to contribute to the formulation of a strategy for assimilating these technologies into the preservation process. Based on the technological evaluations and the prototype applications, projections were assembled to describe a future role for emerging electronic technologies in the preservation process.

1.2. Premise:

The preservation of our collective cultural heritage is important to all of us.

The preservation of culturally significant sites and structures represents a means of ensuring and reinforcing a continuity of cultural identity and expression. Preservation efforts typically reflect a spirit of community cooperation and commitment, and as a consequence, enhance the quality of life within the community. In addition to the less tangible value judgments that might be used to measure "quality of life", preservation activities can spawn tangible economic benefits by facilitating the growth of jobs, property values, and tax revenues. New sources of capital, such as tourism, can be created as a direct result of preservation efforts.

1.3. Threats:

In view of the substantial socioeconomic benefits, why are so many irreplaceable sites and resources in peril?

The degradation of the cultural resource heritage of the United States is the result of a wide range of forces. The simple, enduring processes of wind and water erosion have a significant adverse impact on the integrity of individual resources, and the cataclysmic effect of events such as hurricanes, tornadoes, flooding, and seismic shock can be devastating. Mankind exacerbates the impact of these natural forces of environmental attack by imposing additional threats to culturally significant resources. Threats of man induced resource degradation result not only from neglect and vandalism, but, additionally, from the well-intentioned but inappropriate preservation actions of uninformed administrators, designers, and tradesmen. As a consequence of these cumulative forces, the United States is rapidly losing the tangible, nonrenewable artifacts of its cultural heritage. This lamentable state of affairs is culturally unacceptable and in violation of the spirit (and often the letter) of the federal, state, and local legislation that protects our cultural heritage.

1.4. Preservation Context:

The quickened pace of societal change can adversely affect preservation efforts by forcing planning and design decisions without an adequate understanding of the larger cultural and environmental context of which an historic resource may be but a single part. It is essential to consider the greater context of the cultural resource, the 'toute ensemble' that characterizes the cultural 'ecosystem' and represents the collective significance and integrity of the cultural experience. The multidimensional context of place is especially difficult to record and demonstrate coherently, and yet a fundamental understanding of this scale is an essential task of the cultural resource manager. It is clear that the more comprehensive, coherent, and accessible the information base, the more effective the preservation specialist in making judgments about the historic resource.

Constraints imposed by the inadequate time or funding allowed to coherently examine and understand the implications of decision choices invariably exacerbate the already formidable challenges of cultural resource management. Although traditional techniques, when in the hands of adequately skilled professionals, have often proven successful as a basis for informed cultural resource management (CRM) decisions, the utilization of traditional tools and methods is often a costly, cumbersome process. With pressures on the integrity of individual resources mounting, the availability of fast, cost-effective methods for informed resource management decisions is essential.

1.5. Information Flow:

Addressing the threat of uninformed actions is necessarily a prerequisite to resolving the most persistent problems confronting the preservation agenda. Three fundamental deficiencies must be remedied in order to inform and enhance the preservation process.

- ***the lack of a cost effective method based on contemporary technologies to acquire the information that comprehensively describes the complex character of cultural resources in their environmental context.***

- ***the failure to gather the data generated by a plethora of preservation experiences and case studies into a rapidly accessible, fully integrated information base.***

- ***the lack of information processing tools that can manipulate the information base to simulate management or design proposals and in doing so, provide the foundation for better informed management decisions by the designers, engineers, and resource managers who prescribe preservation treatments and formulate resource management strategies.***

1.6. Hope:

A broad array of emerging technologies promises to revolutionize the tasks of cultural resource management. First and foremost, preservationists must assimilate the requisite technical skills that will enable them to develop electronic solutions to the dramatically expanding information management challenge. The fundamental key to successful cultural resource management is through enhanced access to a broad body of information relevant to the decision process.

Research that focuses on the development, adaptation, and application of appropriate information acquisition and management technologies can provide a means of redressing preservation deficiencies. Advances in computer and video technologies have made these electronic tools not only more sophisticated, but less expensive. As a consequence, these technologies hold significant promise for the development of cost effective tools to facilitate the tasks of preservation information acquisition and management.

Clearly, in order to take advantage of these opportunities, preservationists must begin to cultivate a better informed technological perspective. However, along with the ability to recognize and capitalize on technological opportunities, a fundamental understanding of resource management tasks and responsibilities is essential to appropriately and successfully adapt emerging information management technologies (and tools) to serve preservation needs.

In understanding the potential for resolving needs through advanced tools and techniques, the articulation of appropriate preservation applications can begin to drive the development of accessible, user friendly, cost effective tools and methodologies for preservation information integration, management, and dissemination. The preservation community must learn how to mold complex technologies into accessible, comprehensible tools and methodologies. The degree to which the end user finds the setup, operation, and maintenance of an information system comprehensible and useful, will determine the effectiveness of its application. Because of the intimidating character of many emerging technologies, application developers should be especially sensitive to the need to make complex operational parameters transparent to the user. The structure of an information management system designed to achieve broad, effective application must appear simple. A successful user interface must accommodate a variety of user skills and require a minimum of off-line support documentation.

1.7. Summary:

A rich cultural heritage can serve as a vehicle that enlivens all levels of educational development and promotes an interdisciplinary dialogue concerning preservation goals and objectives. A comprehensive, integrated information base is essential to sustaining the viability of this diverse cultural heritage and to promoting a national preservation agenda. The collective experiences and practices of local preservation efforts, when assembled into a readily accessible knowledge base, can effectively inform efforts to resolve preservation challenges nationwide.

As the ideal of historic preservation has come to accommodate a variety of philosophical perspectives, so too must the efforts to adapt new technologies to the tasks of cultural resource management. The development of more effective mechanisms for informing the decision processes will encourage resource administrators to assume greater responsibility for the management of cultural resources. It will enable the preservation community to strengthen its social, economic, and political advocacy for the conservation and celebration of our delicate, yet durable, cultural roots. Through the outreach to public and private constituencies, and through the development of market applications for cost effective preservation products, technologies, and services, the positive socioeconomic benefits of sensible, sensitive cultural resource management will serve to institutionalize the perception of our cultural heritage as an integral part of a healthy, informed society.

The goal of this work is to demonstrate through developed prototypes and projected scenarios, alternatives for technology transfer, adaptation, and application that can facilitate better informed decisions about the management of an increasingly threatened cultural heritage. This body of information will contribute to the resolution of the most critical needs of the preservation process, and will enhance the ability of private, state, and federal agencies to meet their legal obligations in the management and protection of our cultural heritage. The work demonstrates that the whole of the preservation process can be enhanced by exploiting the opportunities inherent in emerging information management technologies.

Chapter Two: Background and Methods

2.1. Context of Preservation Problems and Threats

"... the United States is losing important parts of its cultural heritage at an alarming rate" (U.S. Congress, 1986).

Whether willful or accidental, the destruction of an historic building means the loss of a nonrenewable and irreplaceable cultural resource.

Terminology:

Cultural resources can be defined as "unique, nonrenewable resources subject to continual stress from human and natural agents" (U.S. Congress, 1986). The need to eliminate or limit the effects of such stress has resulted in the development of knowledge, skills, and techniques for managing cultural resources.

Cultural resource management (CRM) is the "process of preserving our cultural heritage (sites, structures, artifacts, records, landscapes) for the benefit of the American people through the application of management skills within the political process" (U.S. Congress, 1986).

The ***preservation process*** describes the seven component activities of sensitive, sensible cultural resource management. These components consist of resource identification, documentation, analysis, data management, conservation, protection, and education.

Preservation technology refers to the tools and techniques that enhance or facilitate the activities of the preservation process by improving the quality, quantity, and usefulness of cultural resource data. These preservation technologies can range from traditional, relatively simple techniques to highly sophisticated tools based on complex technologies.

Technology transfer is the term used to describe the resolution of challenges and problems encountered in one discipline through techniques and technologies developed in another discipline.

Review:

Federal legislation in the form of the 1966 National Historic Preservation Act (NHPA) legally acknowledged the significant socioeconomic value of cultural resources by maintaining that:

> the preservation of this irreplaceable heritage is in the public interest so that its vital legacy of cultural educational, aesthetic, inspirational, economic, and energy benefits will be maintained and enriched for future generations of Americans (U.S. Congress, PL 89-665).

As a result of such legislative initiatives, preservation activities have come to represent a significant economic force in the United States, as demonstrated by the following points:

- In a four year period (1982-1985), historic preservation investments under the Tax Act of 1981 accounted for approximately $8 billion in rehabilitation investment, $6 billion in local salaries generated, $17.2 billion in local sales and general business generated, and 342,860 person years of employment (National Trust for Historic Preservation, 1986);

- Every $100,000 spent on historic preservation results in over $250,000 in retail sales and $74,000 in new earnings (Advisory Council on Historic Preservation, 1985);

- More than 50% of annual construction expenditures in the U.S. are for rehabilitation of existing structures (American Institute of Architects, 1986);

- As a result of the Tax Reform Act of 1986, historic preservation represents one of the few remaining areas for investment tax credits, an acknowledgment of the critical importance of historic preservation to the socioeconomic agenda in the U.S. (Stipe and Lee, 1987);

- It is estimated that up to $300 million is spent annually on archaeological activities alone by federal agencies, recipients of federal assistance, and regulated industries for compliance with Section 106 of the NHPA (Stipe and Lee, 1987).

In recognition of the changing needs of a maturing preservation movement, three major assessments of the achievements and failures of the preservation efforts of the past two decades have been published. The Advisory Council on Historic Preservation's annual report to Congress, ***Twenty Years of the National Historic Preservation Act*** (Advisory Council on Historic Preservation, 1986), details not only the accomplishments of the preservation community since the enactment of the NHPA in 1966, but also the contemporary challenges to the integrity of our cultural heritage. In 1986, at the direction of the U.S. Congress, the Office of Technology Assessment (OTA) investigated the deficiencies of contemporary cultural resource management practices. The resulting report, ***Technologies for Prehistoric and Historic Preservation*** (U.S. Congress, 1986), provides an account of the inadequacies of contemporary conservation tools and strategies in the face of increasingly complex cultural resource management issues. Similarly, ***The American Mosaic: Preserving a Nation's Heritage*** (Stipe and Lee, 1987), provides an alarming overview of the extensive technical needs and socioeconomic problems confronting the preservation community in the United States.

While these publications appropriately celebrate the significant political and economic successes achieved by the preservation movement over the past two decades, they are a sobering assessment of the substantial challenges that continue to frustrate effective cultural resource management. In substance, these three major reports are in essential agreement that these challenges are most pronounced in the fields of education, data acquisition and management, and information dissemination. Accordingly, these reports propose that new strategies are required to overcome these persistent challenges, strategies that capitalize on the sophisticated tools and techniques made available to the preservation professions through the mechanism of technology transfer.

Threats:

The people who make decisions that impact the welfare and integrity of cultural resources encounter a wide variety of threats to the resource for which they have assumed a moral or legal obligation to protect. These threats can result from environmental attack, vandalism, or simple neglect. For example, threats from cataclysmic natural forces and hazards, such as flood, seismic, wind, storm, or fire, can imminently jeopardize resource integrity. A cumbersome information flow can deter decisive mitigation action and result in the loss of significant cultural resources to these variable and unpredictable environmental forces.

Less obvious, but equally catastrophic threats result from the implementation of well-intentioned but inappropriate maintenance or preservation techniques by uninformed professionals and tradesmen. This underscores the fact that the fate of our cultural heritage rests with the decision makers, whether they are formulating administrative policy at the highest management levels or wielding the hammers and saws that literally impact the historic fabric. Decision makers are constantly asked to make judgments about resource protection priorities, strategies, techniques, materials, and compromises, all too often with inadequate, inaccurate, or misunderstood information on which to base their decisions.

Needs:

Primary among the challenges to the effective management of cultural resources are the following:

- efficient access to technical and nontechnical information that will facilitate the decision making processes that affect the integrity and viability of the individual artifact and the collective cultural heritage;

- education of professional preservation practitioners in the availability and skillful utilization of contemporary technologies and techniques that represent appropriate, cost-effective tools for sensible cultural resource management;

- effective networking of preservation management and research interests, so that practical decision making experiences of the preservation movement can be fully shared across the local, regional, national, and international spectrum;

- application of "technology transfer" to develop sophisticated decision making tools, methodologies, and standards that employ contemporary technologies to serve cultural resource management needs;

- education of public constituencies in the value of our cultural heritage in order to promote cultural literacy and expand public support for protecting the integrity of this nation's cultural heritage.

Meeting Needs (Current):

There have been efforts in recent years to address technological issues in the conservation of historic architectural resources. The Technical Preservation Services Division of the National Park Service has published a series of "Preservation Briefs" that present information on the techniques, tools, and materials that constitute appropriate responses to particular preservation problems. The National Trust for Historic Preservation and the Association of Preservation Technology are similarly concerned with promoting appropriate solutions to conservation problems, and with the dissemination of information relating to the activities of the preservation process. However, as the natural and manmade environments are confronted with increasing economic development pressures, the need for understanding the complex interaction between cultural resources and societal needs will demand better access to preservation information. Knowledge of efficient conservation technologies and of appropriate, cost effective techniques will have a significant impact on the adaptability of our cities, towns, and rural landscapes to the social and economic development challenges of the future.

Current Inadequacies:

The burden of inefficient information management continues unabated, exacerbated by the dramatically expanding collection of administrative records, artifacts, and research products of all manner and variety. According to the U.S. National Park Service, the NPS has over 10 million museum objects, including furnishings, paintings, flags, notes, botanical specimens, basketry and crafts, and archaeological artifacts. Over 90% of these museum objects have not yet been properly cataloged (National Park Service, 1986). This means that these objects are virtually inaccessible to research, interpretation, or administrative activities.

Additionally, the Cultural Resources Management Bibliography (CRBIB) lists the titles of over 7000 reports about history, architecture, archaeology, and collections within the NPS. Much of this information is one of a kind, and although these reports are on microfiche, access to them is cumbersome and time consuming. For such information resources to contribute to decision processes, a more effective reference and retrieval mechanism is absolutely essential.

It is at the point where each resource management decision is made that the need for accurate, reliable information on which to base those decisions is most critical. The challenge facing those charged with the management of cultural resources is not only the fundamental need to understand the causes and effects of resource degradation, but additionally, the access to appropriate skills, knowledge, and technologies that can be used to redress these threats. Improvement in the flow of information is essential for the design of systems that effectively preserve the integrity of the resource in the face of environmental attack (both from natural and social forces).

Meeting Needs (Future):

In acknowledging the contributions that preservation has made to economic development and revitalization, it is important to understand the significant challenges that continue to confront the preservation community.

- The NPS estimated in 1985 that no more than 9% of the U.S. land mass had been intensively inspected to identify historic standing structures, and approximately 3% had been surveyed for archaeological sites (Advisory Council on Historic Preservation, 1986).

- More historic areas than natural areas are under the management of the National Park Service, and in the face of federal deficit reduction measures, it is vital for the NPS to have rapid access to the information resources essential to cost effective and responsible management (Stipe and Lee, 1987).

- It is estimated that approximately 60,000 projects are reviewed each year under Section 106 of NHPA (Advisory Council on Historic Preservation, 1986). With increased inventory and survey activity, existing archival and curatorial methods are often unable to accommodate the influx of archaeological and architectural artifacts and resource materials.

- As many as 95% of the buildings that will exist by the year 2000 have already been built, and the increased activity in rehabilitation has created an unfilled demand for tradesmen skilled in preservation practices (American Institute of Architects, 1986).

- With more than 2000 community preservation ordinances in place in 1986 (vs fewer than 24 in 1966), and a concomitant rise in the number of state and federal government regulations concerning preservation, activities that affect preservation issues have acquired broader legal implications and are being scrutinized ever more carefully (Stipe and Lee, 1987).

In the context of the needs and deficiencies of the preservation process that have been identified, consider the following prerequisites for effective resource management (Loeks, 1985):

1. Knowledge Base: define the characteristics and behavior of the resource to be managed, as well as the dynamics of the external forces that are acting on the resource in ways which either enhance or diminish its utility.

2. Information Retrieval: disseminate the knowledge in a manner which will influence public perception and will to act, and thereby build constituencies of support for creating the institutional capacity required for integrated management efforts.

The assembly, integration, synthesis, and dissemination of the information essential to coherently and sensitively managing our natural and cultural heritage is the chosen obligation of preservation professionals. Contemporary information management technologies can facilitate the interdisciplinary dialogue necessary for cooperative efforts in resource protection, planning, and management. By their active leadership and initiative, professionals can use these same information management tools to inform and include the public in the decision process. This act of consultation and inclusion, can gradually instill in the public (restore in the public) the will to take action to protect and defend its cultural heritage.

The ultimate key to successful CRM is the selection and application of appropriate preservation technologies throughout the preservation process. William Penn Mott, Jr., former Director of the National Park Service, has asserted that these preservation efforts will not only ensure the stability and continuity of the knowledge base of contemporary society, but will help us "understand the fundamental relationships of men to each other and of men living in communities to their environment as a whole" (National Park Service Position Paper, 2/10/86).

2.2. Focus Areas for Mitigating Threats to Preservation

(Education; Resource Planning and Management; Design and Construction)

2.2.1. Education

Education Objectives:

- *Promote the exchange of information relating to preservation needs.*
- *Increase the awareness of technological tools and opportunities.*
- *Enhance the understanding of cultural resource values.*
- *Broaden the public and professional foundation of the preservation decision processes.*
- *Facilitate access to technologically sophisticated preservation products and services.*

Preservation Education:

Cultural resources can be tools for learning the basic skills of language and literacy, and can be effective vehicles for developing conceptual thought processes. Cultural literacy itself is critical to comprehending the context of contemporary local, national, and international issues. Cultural literacy can provide the necessary foundation for an informed electorate, and as a consequence, a more vital and participatory democracy capable of guarding against the misuse and abuse of information technologies.

Professional Education:

The training of individuals with the special technological expertise or skills is urgently required to mitigate the adverse effects of extraordinary cultural resource management problems. Knowledge about appropriate preservation practices and cost effective techniques will serve to improve the quality of preservation work and lower real CRM costs by reducing preservation inefficiency.

The preservation movement must develop effective methods for training professional practitioners who are generally uninformed about contemporary preservation practices and technologies. The sensible management of our cultural heritage demands the services of an exceptionally well informed group of professional consultants and contractors to ensure the integrity of cultural objects, structures, and sites.

Crafts Education:

An educational need repeatedly mentioned in the OTA report was for the training of skilled restoration craftsmen (U.S. Congress, 1986). The preservation profession is experiencing a shortage of skilled workers, and successful historic preservation requires carpenters, metal workers, masons, and others with special knowledge and sensitivity in using preservation techniques. Increased sensitivity to historic crafts traditions can also contribute to the quality of contemporary construction projects, as the celebration of a traditional work ethic based on the accomplishment and accountability of the individual can make construction workers more cognizant of the implications of their actions. Additionally, a demonstrated increase in workforce skills can increase investment appeal and enhance efforts to promote sustainable economic development.

Public Education:

Effective public education and interpretation programs can play an important role in the preservation of prehistoric and historic resources. While many people are not aware of the significant socioeconomic implications of preservation, many more do not realize the range of threats that are facing our cultural heritage (National Council for Preservation Education, 1987). A more informed public will be less prone to the deliberate or unintentional abuse of cultural artifacts. Additionally, an enlightened public preservation constituency will be more responsive to the senseless loss and mismanagement of cultural resources, and as a consequence, will make public officials more accountable for their resource management responsibilities. An informed electorate that demonstrates it cares about its cultural heritage will increase the responsiveness of government and economic development forces to cultural resource management concerns. Active public participation in the decision processes that affect cultural resources can expedite the development of protective covenants or zoning ordinances, adaptive use rather than demolition, and the allocation of public and private sector funds essential to effective preservation and management.

Elementary Education:

The introduction of preservation issues into the classroom can provide an effective vehicle for learning basic language skills and cultural history. Efforts to promote preservation in the schools will also serve to introduce students to advanced technological tools that can be adapted to serve preservation needs. Preservation information management exercises using computers can give students a meaningful context for assimilating computer skills. In this way, cultural resource issues can serve as a basis for developing fundamental knowledge skills, and foster the assimilation of contemporary technological tools. As a consequence of such bipartite initiatives, both cultural and technical literacy will be enhanced.

2.2.2. Resource Management and Planning

As interest in historic preservation has grown, cultural resource management issues have assumed a higher profile in the socioeconomic agenda. An increase in the volume of preservation planning activities has produced a growing body of case study material that can contribute to the quality and effectiveness of cultural resource management. Unfortunately, limited, cumbersome access to the knowledge developed through these preservation planning experiences is a severe impediment to assimilating this knowledge across broader CRM decision processes.

The application of contemporary technologies such as geographical information systems (GIS) can greatly enhance the data manipulation process necessary to the formulation of resource protection and management guidelines. However, planners and administrators need a more effective means of integrating the immense database that these tools produce into the whole of the preservation information base.

Rapid access to relevant information concerning existing archaeological and architectural resources is fundamental to the shaping of successful cultural resource management strategies for both the rural and urban environment. Efficient information acquisition, processing, and retrieval has significant implications for preservation policy delineation, project feasibility analysis, and maintenance management. Through an information paradigm that integrates text, image, numeric, and audio data, preservation planners can focus on information synthesis and decision simulations rather than data gathering.

2.2.3. Design and Construction

Accurately documenting and assessing the condition of historic resources in order to develop and prescribe appropriate protection, preservation, and maintenance strategies is an essential component of the preservation process. A careful, thorough documentation and diagnostic process is a key to understanding symptoms of decay and system failure. It is the facility of preservation practitioners with information gathering and analysis tools that ultimately determines the welfare of the resource. Preservation is also hampered by an inadequate information flow in the exchange of professional experiences and expertise concerning these diagnostic processes and the manner in which they shape decisions regarding the rehabilitation of structures and the repair of historic (and often archaic) materials.

Unfortunately, current examination and inspection techniques depend predominantly on the skills of the individual professional. As the implications of preservation issues become more complex, even the most effective decision maker seriously inhibits the diagnostic process with a sole reliance on personal experience and intuition. While personal insight, supported by traditional techniques and tools, can continue to play an important role in the diagnostic process, the increasing sophistication of cultural resource management concerns demands the skillful formulation of new analytical strategies.

2.3. Technology Transfer

The processes of preservation have largely failed to capitalize on the opportunities inherent in the application of emerging technologies to the cultural resource management effort. The Congressional Office of Technology Assessment (OTA) in its report, ***Technologies for Prehistoric and Historic Preservation*** (U.S. Congress, 1986), asserted that the development of technologically advanced, cost effective conservation tools and methods is essential to the preservation of our cultural heritage. Accordingly, new strategies are required to form a basis for identifying and selecting these sophisticated tools and techniques from the ranks of emerging technologies. A concerted effort to broaden the professional base of CRM through interdisciplinary dialogue and collaboration can result in successful implementation of this technology transfer concept.

One area of significant potential for resolving the need for more sophisticated information management tools is the computer assisted data storage and retrieval technologies. Past archaeological and historical studies have developed a substantial body of data about the nation's past. Unfortunately, this data is largely unusable or inaccessible because of cumbersome and inadequate record keeping techniques. Efforts directed towards computer technology transfer, adapting integrated and cost effective computer hardware and software systems to resolve logistical data management problems and facilitate information accessibility, will have immediate and substantial benefits for the preservation community.

Computerized databases can contain a variety of information fields relating to the individual cultural resource, groups of resources, and resource management techniques and expertise. Such databases can provide preservation administrators with timely, relevant information on which to base resource management decisions. The application of computer technologies to the information management needs of CRM can provide a framework for developing and studying resource conservation strategies. It can provide a basis for dialogue and information exchange between professional disciplines brought together by particular preservation problems. The broader context of the conservation issue may be more fully comprehended when all of the information relevant to the decision process can be accessed and manipulated as part of an integrated system. The capacity of computer technologies to analyze and manipulate diverse data sources is the essential key to accommodating the requirements of interactive information management systems for cultural resource management. A system using these technologies can give regulatory bodies, design and planning professionals, developers, the public, and other participants in CRM decision processes a means of better understanding the increasingly complex issues constraining the effective management of cultural resources.

The fundamental challenge relating to database management systems for preservation applications is that of collecting, organizing, and disseminating information relating not only to the character of individual cultural resources, but also to the techniques, technologies, and policies that are the basis for preservation management decisions. While dependable tools for information management and manipulation are required to facilitate informed decision making processes, the OTA Report emphasized the vital importance of effective archival storage (U.S. Congress, 1986). The quality and stability of the archival record is a critical prerequisite for the development of an effective integrated preservation information system (IPIS).

Information storage has been revolutionized by the development of reliable analog and digital optical disk technologies. The utilization of these high density storage technologies can place the information necessary to shape better informed cultural resource management strategies at the rapid disposal of decision makers. These storage systems can also facilitate the widespread dissemination of relevant technical and nontechnical information to public or private interests, and to the preservation craftsmen and architects who must make specific management decisions about the very fabric of the cultural resource. Effective information dissemination enhances the decision environment and contributes to long term CRM cost effectiveness.

2.4. Summary

This research initiative examines the potential for bringing contemporary technologies to bear on preservation problems. A corollary objective is to articulate an information paradigm that will encourage broader application of effective cultural resource management strategies and tools, making the vehicle of technology transfer a two-way path between historic, contemporary, and projected needs. Based on this fundamental strategy, it is hoped that the work will contribute to:

(Education) A more informed public: a higher level of cultural literacy through cultural education and resource interpretation programs; the development of educational materials that can serve as vehicles for assimilating academic and vocational skills at all levels of the education process; the protection of the cultural resources themselves through increased understanding and respect;

(Planning and Resource Management) Better preservation tools: appropriate, cost-effective solutions to particular cultural resource management problems and needs; a more participatory planning and management decision process;

(Design and Construction 1) Better informed decisions: a framework for an accessible, integrated information management system describing the preservation techniques, tools, and experiences that facilitate decision processes and enhance the management of cultural resources;

(Design and Construction 2) A better informed professional community: an agenda for professional training that enhances the tradesman ethic of individual achievement and responsibility by improving and broadening worker skills, and informs professional practitioners about appropriate preservation practices and technologies.

The access to and manipulation of information relating to historic resources is fundamental to the shaping of successful cultural resource management strategies. The increasingly complex issues that must be addressed in contemporary cultural resource management efforts require a fresh perspective regarding the acquisition, storage, and retrieval of information. Emerging remote sensing and computer technologies can resolve the inherent complexity of integrating and productively managing information relevant to the significance, spatial qualities, and cultural value of historic resources.

The methodologies explored over the course of this research effort have the capacity to not only document historic resources, but additionally to analyze, manipulate, and disseminate the documentary material in support of a broad range of preservation management issues. Applications of emerging technologies for resource documentation and design processes have only recently begun to influence preservation. Opportunities for further exploration of the issues raised in this research are extensive, and concerted efforts to transfer and adapt appropriate emerging technologies to the activities of the preservation process can have a significant impact on the preservation profession as a whole.

Information relating to preservation needs can be assembled through research efforts, case studies, and technology transfer initiatives. This information must then be readily accessible to those charged with making CRM decisions. Computer based systems capable of multitasking and the manipulation and combination of data layers can be adapted to create powerful preservation data acquisition and retrieval systems. These systems will be capable of accommodating an extensive information base and a variety of data types. Similarly, information storage systems using optical disk technologies can be readily adapted to CRM needs. The skillful utilization of these technologies will place the information necessary to shape cost effective cultural resource management strategies at the rapid disposal of decision makers.

While destruction by natural forces or intentional demolition by man are significant threats to the integrity of our cultural heritage, the uninformed action of the well-intentioned preservationist represents the most tragic degradation of historic resources. A well-informed community of preservationists is fundamentally the most cost effective way to achieve resource protection objectives, and efficient information acquisition, processing, and retrieval are the linchpins of sound preservation practices.

Chapter Three: Information Management Systems

3.0. Information Introduction

Premise:

The value of information is derived from its organization (Larson, 1988).

Effective information management has significant implications for preservation policy delineation, project feasibility analysis, design, construction, and maintenance management. The increasingly complex issues that must be addressed in contemporary cultural resource management efforts require new solutions to data acquisition, management, and storage needs. The CRM processes have not yet capitalized on the remarkable information processing capabilities that existing computer technologies provide. There is a considerable variety of proven, "off the shelf" technologies which are underutilized, and they languish particularly for want of CRM applications. Unfortunately, both the novelty and mystique that surrounds modern technologies often obscures efforts to develop practical, cost effective applications.

Developments in a variety of automated data processing technologies suggest that significant opportunities for preservation information applications do, in fact, exist. Computer systems have acquired sophisticated capabilities for managing complex tasks involving multiple media types and peripheral data sources. At the same time, these systems have become considerably less expensive. The technologies have also witnessed a trend towards miniaturization, suggesting the potential for developing electronic tools as highly portable information systems with capabilities that were inconceivable only a few years ago. It is essential for the preservation community to develop an understanding of these emerging technologies in order to recognize and exploit opportunities to develop appropriate information management tools.

Information Systems:

An information system is "a set or arrangement of things so related or connected as to form a unity or organic whole; a set of facts, principles, rules, etc. classified or arranged in a regular, orderly form so as to show a logical plan linking the various parts" (McKechnie, 1978).

Component processes in an information system might include the specification, collection, transmission, and processing of data, and the display, dissemination, and use of information derived from such data. Specification is input; information use is output; material resources are the hardware and software utilized in the system processes; human resources are the users interacting with the information system. The information system necessarily exists as a subsystem of a larger real-world system. The larger system constitutes the global environment of the information system.

Information Hierarchy:

What is data? Data is information without an underlying structure of associative relationships. Many computer processes convert information into data. Data is the lowest form of information, and generally refers to any set of measurements, facts, or figures, regardless of whether or not they have been acquired with a certain purpose in mind. Data becomes information after it has been retrieved and processed for a particular purpose.

What is information? Information is an ordering of data fields. It is an aggregate of facts so organized that it can subsequently be selectively tailored or structured in response to a particular context so as to become knowledge. Information is meaningful data, whereas data as such has no intrinsic meaning or significance.

What is knowledge? Knowledge is information with structured relationships. It is information that clarifies or shifts a perspective, resulting in an understanding, awareness, or concept of how components fit together. Most computing applications serve to automatically and rapidly process data, rather than extend thought processes and broaden the knowledge base. The paradox of the Information Age is that while society is drowning in data, proportionately little knowledge is being realized.

What is wisdom? Wisdom implies a useful application of knowledge (Larson, 1988).

Information Structure:

While knowledge is information with structure, the value of the knowledge base depends not only on the fact that the information contained therein is structured, but also on the appropriateness of the organization for a particular task or application. Information without clearly articulated structural relationships requires critical interpretation in order for the user to comprehend and assemble the associative relationships. However, with a knowledge base containing minimal information and a complete structure, it is possible to discover or re-create the missing components of the knowledge community if the structure is known. In fact, it is the essential structure of information that characterizes effective communication of knowledge, and makes comprehension possible through an understanding of the inherent relationships that exist (or are established) between the component parts of the information base.

The use of a hierarchical structure within the information base is an effective ordering strategy that facilitates the communication of knowledge. According to Neil Larson of MaxThink, Inc. (a software development company), the structure of information hierarchies are most effective when:

(1) Subtopics are complete (representing a comprehensive elaboration on the parent topic);

(2) Subtopics are parallel (representing a shared or common theme in reference to the parent topic);

(3) Subtopics are predictably and logically ordered;

(4) Subtopics for each parent topic are limited in number so as not to overwhelm the user (Larson, 1988).

Criteria for an Information System:

According to Larson, the success of the Industrial Age can be fundamentally characterized by the effective organization of repetitive sequences (Larson, 1989). Because many electronic technologies have embodied the mechanization of repetitive, sequential data management processes which seldom lead to new knowledge, it can be argued that word processors, spreadsheets, and DBMS programs are products of an Electronic Industrial Age.

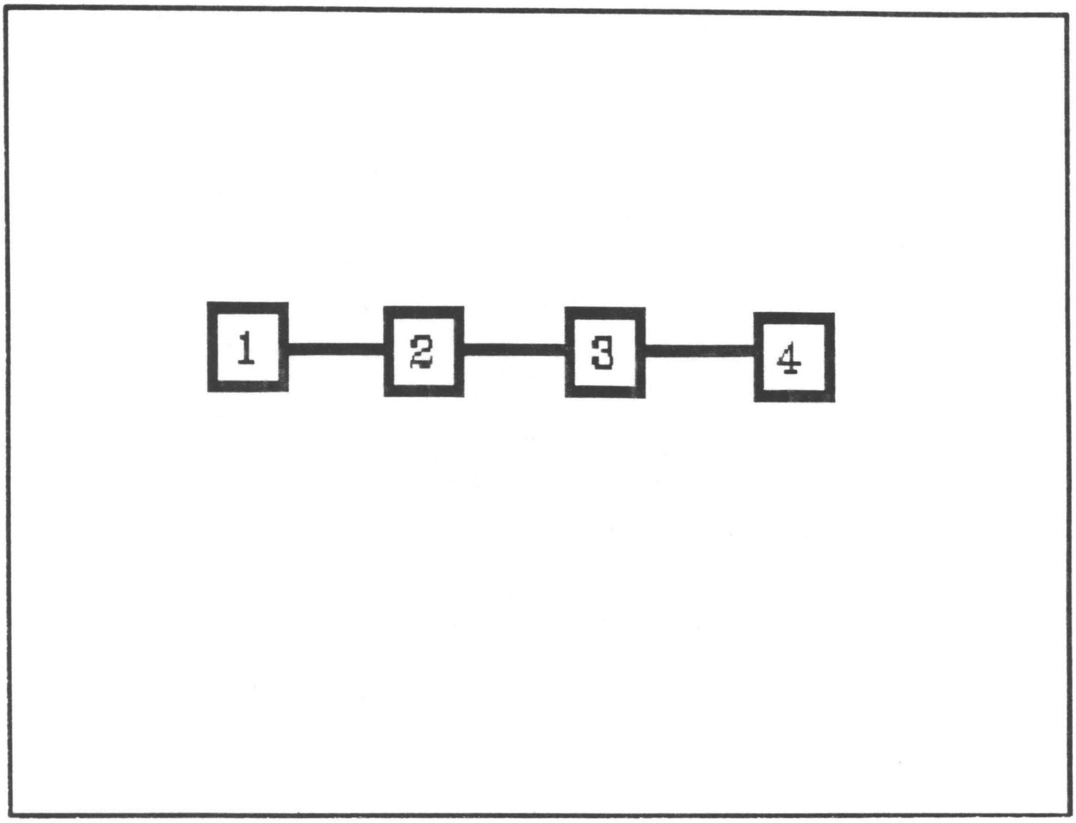


Figure 5. A Serial or Sequential Information Structure

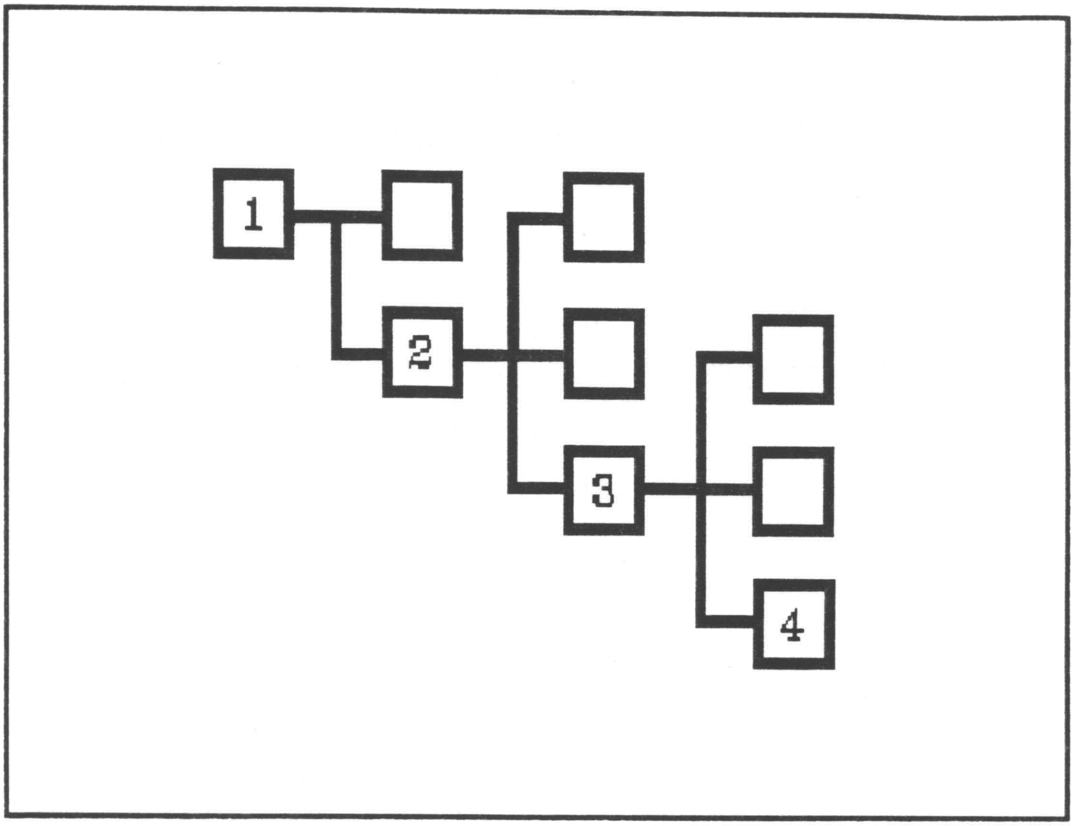


Figure 6. A Hierarchical Information Structure

The telecommunications and computer revolution that has characterized the Electronic Industrial Age has created an overabundance of information. The Electronic Industrial Age must now be succeeded by an Information Age that focuses on the extraction of knowledge from an ever expanding global information base. The assertion that knowledge is information with structure is the conceptual linchpin for the development of associative relationships that give relevance and context to information fields and nodes. The key to the effectiveness of the Information Age is to be found in this associative interrelationship between information resources within a knowledge base, and in the relationship between the knowledge base and the information requirements of the decision processes.

Software systems based on the principles of associative information structures (such as hypertext) encourage the information linking and integration that is essential to knowledge processing. The value of such systems is derived from the hierarchical and network structure of information relationships. If the value of information lies in how it is organized, then systems that effectively communicate this organization of relationships can represent powerful sources of knowledge.

Since contemporary documentation activities and tools have the capacity to collect enormous amounts of data, it is essential to devise a strategy for coherently organizing what is otherwise a disparate and widely fragmented information base. The effectiveness of a preservation information system is embodied in a structure that will facilitate the rapid access to a CRM knowledge base, and thereby enhance decision processes by providing researchers, planners, and managers with appropriate, meaningful data which has relevance to the context of preservation needs. It was on the basis of this fundamental premise that the information systems presented in this research were reviewed.

Problems in Information Science:

While the prospect of adapting contemporary computer technologies to the preservation process as a means of facilitating information processing and enhancing decision processes may be alluring, a major problem remains. Many emerging computer and imaging technologies do not conform to existing design and engineering standards. In fact, the technologies are developing so rapidly that few standards have been defined. Along with the rapid rate of change in the development of these technologies, the absence of standards means that it is difficult to assess the risk of investing the necessary time and money to procure and integrate the technology into the preservation process. There is little assurance that the initial investment will be upwardly compatible with the next generation of computer graphics tools and information management systems. However, there are sophisticated CADD systems, modeling tools, and hypertext systems that do conform to widely acknowledged (***de facto***) standards. Many of these systems have become available relatively low cost. If these demonstrate the capacity to immediately enhance and clarify not only presentation, but design and decision processes, then the investment would seem cost effective, whatever the risk of eventual technical obsolescence.

3.1. Software

The effective utilization of vast new galaxies of information has made a new information management paradigm absolutely essential. Consider the implications of the following statements:

> "The amount of paper behind a battleship weighs more than the ship." (Larson, 1988)

> "In the commercial aircraft industry, the standard rule of thumb is -- when the weight of the paper equals the estimated weight of the plane, it will fly." (Larson, 1988)

Although these statements are rather tongue-in-cheek, they accurately express the dilemma faced by contemporary society. Professionals of all disciplines are becoming overwhelmed by the ever increasing amount of information available to them. When the volume of information is more than the human brain can process effectively, the result is not the faster decision making that was predicted, but instead, a delay in or even abdication of the implementation of the decision process. This paradox might be called "negative information - that is, information that reduces rather than increases one's knowledge" (Weiner and Brown, 1989). The superimposition of a coherent data structure can put information resources into useful contextual perspectives. The application of several contemporary software programming concepts has demonstrated promise in providing ordering systems that facilitate the extraction of knowledge from information resources and, as a consequence, enhance decision processes.

3.1.1. Database Management Systems (DBMS)

A database organizes information in a system of records and fields. The records represent the primary level of data classification, reflecting the general taxonomy or theme of the database. For instance, a resource database for a national park might contain records which comprehensively describe each individual park building or structure. Each building record is comprised of numerous data fields which contain specific information concerning the particular traits or qualities that are relevant in characterizing the individual structures. The database fields describe a variety of site or building components and materials, knowledge of which is essential to the management of the resource. In a DBMS, the records and fields are manipulated through a query process that seeks specific information from the database by defining particular parameters for data retrieval (Robie, 1988). The database is searched according to the specified qualifiers, and only that information which matches those conditions is retrieved from the data records.

A relational database stores all information in tables, and a user can manage data by direct manipulation of these tables without reference to other constructs. Any piece of information in a relational database can be accessed directly by referring to the table number, key value, and column name. The structure of a DBMS also permits the manipulation and merging of data fields according to predefined operations. Basic relational operators (select, project, and join) each produce a new table by combining one or more tables on the basis of shared data fields. These operations include "joins", "nested-loops joins", and "sort-merge joins". "Joins" are simply a way of merging two tables. A "nested-loops join" compares every row in one table to every row in another, and combines the qualifying rows. A "sort-merge join" sorts each table on the columns that will be compared, then scans the tables and joins the qualifying rows (Robie, 1988). While operations such as these can provide a skillful user with tools that permit the creative comparison and combination of data fields, they have limited capabilities in accessing and manipulating idea entities. As a result, a DBMS structure does not represent the best strategy for an integrated information system that contains widely fragmented and diverse idea resources.

An electronic preservation information application based on a DBMS structure has been developed by the National Park Service, and this system was evaluated as part of this project. This system uses an "off the shelf" software program called dBASE III Plus (Ashton-Tate, Inc.). The application is described in Section 4.1.

3.1.2. Authoring Systems

Authoring systems based on macro language libraries facilitate the development of tailored information management applications. These application authoring programs use a resident macro language to permit the assembly of a variety of data management structures (including DBMS types, as well as hierarchical and network systems). A system developer can configure sets of macro routines as modular components to create the necessary data management structure suitable to the character of the information base and the data manipulation demands of the specific application.

A macro is a recorded sequence of commands or keyboard equivalents that can be invoked by a single command (key stroke or pointer action). Macro commands can be structured to access, activate, and control any of the functions of the computer keyboard, and can perform other predefined program or function calls. When a macro is executed, the application program performs the computer processing actions that are recorded in the macro statement. Macros are specific to the individual application program, with each authored application having a unique set of macros associated with it. As the engine that drives the interaction between application users and the information base, macro statements can be tailored to perform various application specific operations, such as menu selections, operation specifications, or data input. The implementation of these predefined macro statements can activate the execution a user specified operation without further operator intervention.

Macro commands generally provide an extensive range of programming functions, including looping, branching, and other subroutines. Because macro commands can be utilized in a variety of task specific applications, the level of complexity, sophistication, and perhaps most importantly, the effectiveness of the macro functions is dependent on the application requirements and the abilities of the system developer.

A macro command language is the heart of the application development capabilities of the CRISTAL System described in Section 4.2.5 and in Appendix A. In CRISTAL, the application developer uses macros to create the program structure necessary to accommodate specific information management needs. CRISTAL macro statements can initiate an automated sequence of actions or program functions, such as incremental movement through a block of worksheet cells to facilitate data entry or to validate data type. Macro statements can prompt the application user for passwords or data input, and can retrieve program data from inactive files stored in disk memory. CRISTAL macro routines can also activate the display of images, graphs, or worksheets in an integrated information retrieval system or an interactive instructional program.

An application developer with a good understanding of the CRISTAL macro language can assemble appropriately tailored programs for a user base possessing varied levels of computer and professional skills. These application users would only require operational knowledge of the specific application interface, and could become skillful system operators without possessing any understanding of the CRISTAL program itself. As the application developer becomes more familiar with the structure, utility, and application of the CRISTAL macro command set, complex command sequences and routines can be used to assemble the comprehensive structure for a tailored program application.

The ability to provide "data links" allows CRISTAL to integrate various types of information into a common reference database. Different data types can be linked together by implementing a unique set of macro commands. These macros include operations for loading or saving a spreadsheet, image, or text file, sorting and querying a range of cells to form a database, and a menu subroutine to provide users with selection lists to facilitate access to information. Links between data files are created by coordinating the execution of a macro sequence that activates these files when specified conditions are met.

An example of a data link system is the CRISTAL resource database that was created for the National Park Service (NPS). This Mt. Rainier National Park (MORA) prototype consists of images and associated text information describing the park's historic building resources. The prototype CRISTAL System is described in Section 4.2.

3.1.3. Hypertext

Introduction:

Hypertext (hyper: "over" and text: "the body of words") is a term that was first proposed by software developer Theodor Nelson in the early 1960's to indicate an information management paradigm based on nonsequential access to a body of knowledge (Nelson, 1967). Ted Nelson is continuing his development of hypertext systems with Xanadu, an expandable publishing environment for interconnecting a multitude of users and a variety of media resources. Nelson's interactive super network is ultimately intended to "bring all published text, sound, and film into every home in the world." (Miller, 1989).

A hypertext system allows users to explore an information base in terms of their particular interests, needs, and degree of prior knowledge or comprehension. The ability to access information nonsequentially means that the user can construct a unique path through the body of information according to a perception of the relevancy of information patterns, associations, and perspectives in satisfying the objectives of the search. Hypertext products mimic the brain's ability to use reference links to quickly and intuitively store and retrieve information. At its most basic level, a hypertext system is a database management system that connects screens of information (idea nodes) by using referential links. A sophisticated hypertext system establishes an integrated information environment for professional collaboration, communication, and the acquisition of knowledge (Fiderio, 1988).

The concept of a hypertext type system was first proposed by Vannevar Bush, national science adviser to President Franklin Roosevelt. Bush realized that as a result of the technological and socioeconomic changes wrought by World War II, the world was on the threshold of an information revolution of staggering proportions. Bush recognized that the rapidly increasing volume of information was compounding the complexities of decision processes. He perceived that to productively harness information resources, it would be essential to develop an integrated and comprehensively indexed storage and retrieval system that could effectively manage this information explosion.

In 1945, Bush articulated his proposal for a multimedia system (Memex) that would permit information search, retrieval, and processing within an environment consisting of disparate media resources. As indicated in his seminal article, "As We May Think", humans think most effectively by recognizing associations and patterns. Bush postulated that the development of an effective multimedia system would require a new technological paradigm based on the structure of human memory. He conceived the Memex machine as a device "in which an individual stores his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility." Memex was to be an "enlarged supplement to memory" which, like the human mind, would operate through an associative structure: "... with one item in its grasp, it snaps instantly to the next that is suggested by the association of thoughts in accordance with some intricate web of trails carried by the cells of the brain." While Bush recognized that a mechanized system might not equal the speed and flexibility with which the human mind followed an associative trail, he proposed that it was technologically possible to "beat the mind decisively in regard to the permanence and clarity of the items resurrected from storage" (Bush, 1945).

As the technology of computer processing and its attendant activities of data input, storage, and output have evolved, so too has the practical viability of Vannevar Bush's initial concept for an integrated information system. The contemporary manifestation of Bush's idea is a "hypermedia" system which frees knowledge (information with structure) from the constraints of purely sequential or hierarchical relationships. In a sense, hypermedia is a DBMS that not only indexes information as a relational database might, but also connects nodes of network information using associative links. However, hypertext systems represent a radical departure from relational databases by virtue of the indexing of information by idea content rather than by words, and by a retrieval mechanism that facilitates access to information resources regardless of the user's level of understanding.

Hypertext systems consist of information cells called "nodes". These nodes are linked by hierarchical and non-hierarchical structures. The structural cross linking of information nodes permits non-hierarchical browsing (or discretionary navigation) through information fields. The fundamental attributes that differentiate hypertext from DBMS result from this capacity for constructing multiple layers of associative relationships between information nodes. In fact, the National Aeronautical and Space Administration (NASA) has explored the potential for using a hypertext system to index the massive information base that will support the design, construction, and maintenance of the anticipated U.S. space station. NASA has concluded that relational databases are inappropriate for the information management requirements of the space station project, and that a hypertext strategy will provide a more effective structure for the massive and highly complex knowledge base (Neil Larson: oral communication on 2/12/89).

The demonstration of a prototype "Memex" system by Doug Englebart of Stanford Research Institute in 1968 was the catalyst that prompted much of the contemporary development of the hypertext concept. Significant developmental research was initiated at Xerox PARC, Carnegie-Mellon University, Brown University, University of North Carolina (Chapel Hill), Tektronix Corp., and Symbolics Corp. (Smith and Weiss, 1988). The systems development activity has accelerated dramatically in the past 5 years, as the significant advancement of computer hardware technology (particularly with regard to processor chips and storage systems) has made the implementation of a viable hypertext system finally possible not only on main frame processors, but on microcomputers as well. A number of these hypermedia systems are currently available as programming shells which can be tailored to meet the particular structural demands of specific information management applications. The Memex concept of Vannevar Bush has finally reached the desktop, and it holds promise for resolving the paradox of the information revolution.

Characteristics of Hypertext Systems:

According to most hypertext developers, there are 4 basic types of hypertext systems: problem resolution, on-line browsing, library or literary exchange, and multipurpose. Whatever the particular application, a typical hypertext system consists of text editor, graphics editor, database, and

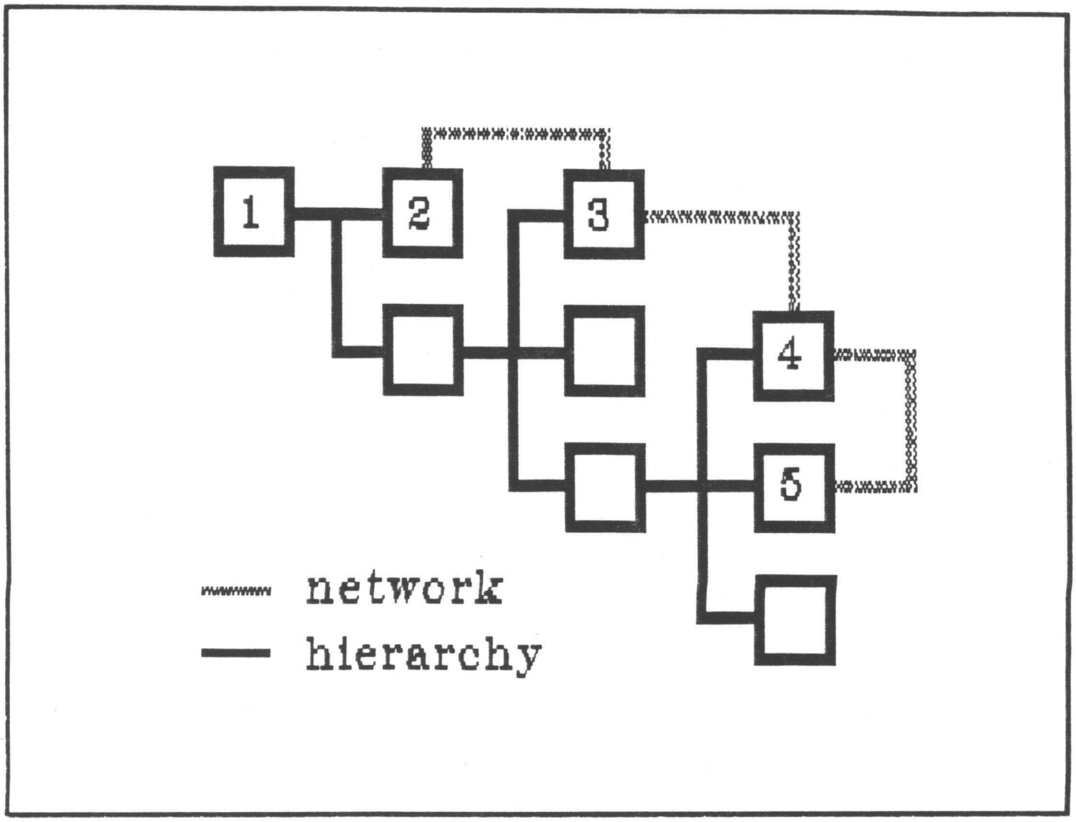


Figure 7. A Hierarchical Structure with Network Links

browsing tool for 3-D viewing. Many systems use the "Standard General Markup Language" (SGML) that lets hypertext systems create links across various applications. Most text editors can read links created with SGML (Frisse, 1988).

In constructing an application, a developer must parse information into small, discrete units (nodes) which consist of a single concept or idea. Nodes should be both semantically and syntactically discrete, representing a single idea or thematic statement. These idea units, or nodes, which are usually displayable on one screen, can be classified as either "untyped" or "typed". Untyped nodes are idea units that have no label or descriptor to identify the information they contain. Typed nodes are labeled as a means of classifying the nodal information and defining particular nodal applications. Associative links establish nodal relationships and connect individual ideas to related points, sources, ancillary information, and annotations. As with the nodes, the links themselves can be assigned "type". The origin of an associative link is a point called "link reference". This "point" is a character, token, or icon that identifies a link in a document. A link destination consists of a node or region of text (or graphics, etc.), and is called a "link referent" (Fiderio, 1988). Links provide the primary means of discretionary navigation through the network and hierarchical structure of a hypertext system.

The ability of the user to browse through information nodes is a fundamental attribute of hypertext. However, in large hypertext systems a user can quickly lose a sense of context and orientation if additional navigational aids are not present. A "graphical browser" is a structural diagram of nodal networks, and it graphically communicates the user's position in the information base. The information "path" is either a user defined or a default route through an information network. A "filter" suppresses detail and allows quick scanning of network information and associative relationships to facilitate user orientation within the knowledge base (Fiderio, 1988).

In spite of its many attributes in providing an effective information management strategy, "hypertext is an immature technology with many limitations yet to be resolved. Perhaps the most difficult part of creating a hypertext system is not building the user interface, but creating sound underlying data models that can be maintained" (Fiderio, 1988). The hypertext developer should be wary of maintenance problems such as weak links and uncontrolled links, which result in "spaghetti code". The system structure must be coherent and logical to facilitate user interactivity and minimize the danger of disorientation, so that system users can effectively retain control over the definition of information paths.

Hypertext Application:

According to Neil Larson of MaxThink Inc. (Kensington, CA), good hypertext systems are characterized by three principles. These principles reflect the inherent capabilities of the hypertext programming shell as well as the structural design capabilities of the application developer. Larson's three principles of good hypertext are:

(1) Information is organized by idea content.

(2) Desired information is obtained with a minimum of keystrokes.

(3) Each use of the system confirms or expands the user's understanding of the information resources and the knowledge (relationships between information nodes) in the system (Larson, 1988).

Accordingly, Larson believes that the success of an effective hypertext system depends on its fulfillment of these principles. The final measure of successful system development, the degree to which a hypertext application increases the user's knowledge through an acquired or reaffirmed understanding of associative relationships between idea nodes, is the key to the transformation of knowledge into wisdom.

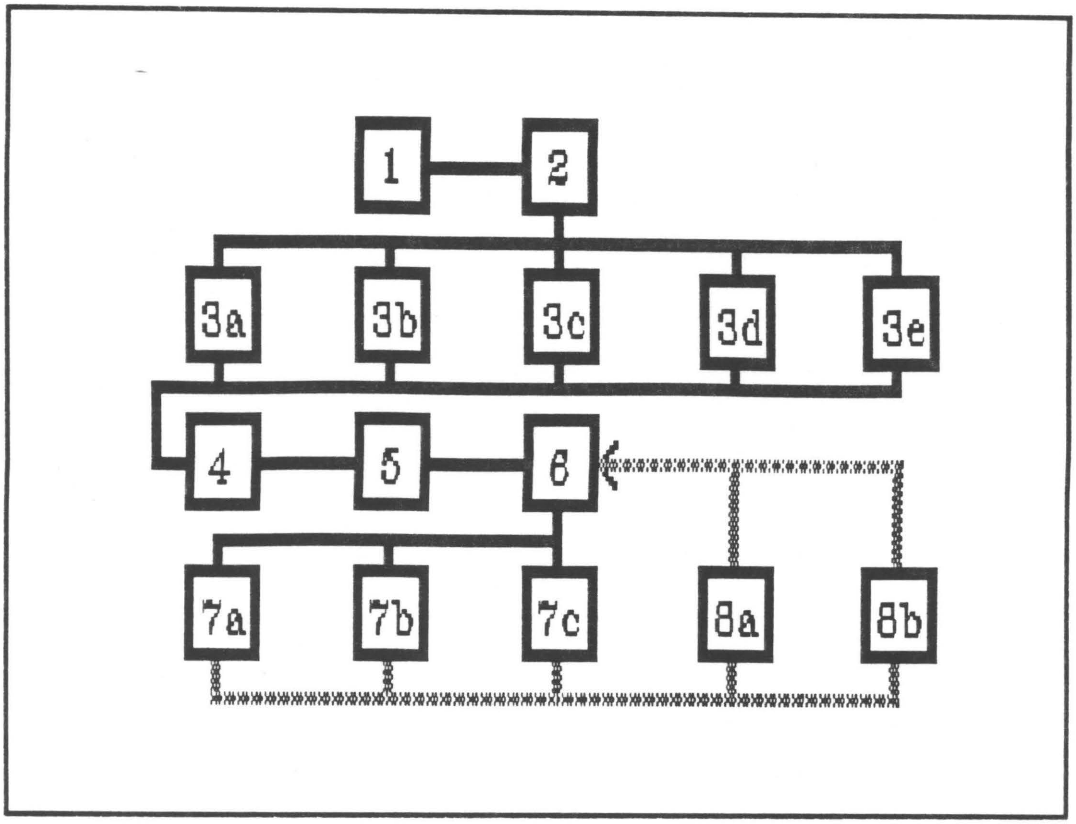


Figure 8. The Assembly of a Hypertext Information Base: (1) Develop a documentation plan; (2) Design a structural framework; (3) Assemble resource records: (a) video, (b) audio, (c) photographs, (d) drawings, (e) text; (4) Convert resource records to digital data format; (5) Design the hierarchical structure for the database; (6) Parse data into discrete information nodes (idea units); (7) Implement the structural links within the database: (a) create associative links between individual nodes according to hierarchical relationships, (b) create associative links between individual nodes according to network relationships, (c) create an index of ideas to establish the taxonomy of the information base; (8) Interact with the information base through the hypertext structure to extract specific information related to current task, and to superimpose additional layers of structural relationships on the information base: (a) user defined marked paths, annotation nodes, and information modifications or supplements provide the basis for creating new associative links between existing nodes in current network, (b) new associative links establish structural relationships with other information networks and broaden the content of the knowledge base as a whole.

Beginning users of a body of knowledge have no understanding of the subject, language, or classification schemes peculiar to the knowledge base. A hypertext system can be structured with an abridged, sequential format as a means of effectively introducing a neophyte user to unfamiliar information. This introductory overview can present the scope and limits of the knowledge base, the structural classifications of knowledge in the system (the system taxonomy), and the mechanism for the effective operation of the system itself. The command language and syntax of a hypertext system are most effective if they are coherent and easy to assimilate. A new user of a hypertext system should be quickly capable of retrieving useful information from the knowledge base.

The information retrieval process in a hypertext system is analogous to using a road map to navigate through the countryside to arrive at a destination location. It is a process that encourages trial and error, and the exploration of alternative trails. A traveler can discover a variety of paths that lead successfully from start to destination. Depending on the context of the particular journey, one path might prove to be most appropriate. Such is the concept behind hypertext systems. The system user selects the associative links that seem most appropriate to the context of the current decision environment. Different link choices lead to different paths which can be explored for information relevant to the current task. As the trail of relevant nodes becomes better defined, the user can leave "blazes" which mark the trail for reuse, or for other users to follow. After the information path is fully defined, the user applies the acquired knowledge to the decision process. Repeated system use establishes greater familiarity with nodal landmarks, confirming knowledge acquisition and enhancing user interaction with the whole of the information base.

Repeated use also enables users to become familiar with the structure of the hypertext system and the significance of the variable paths through the knowledge base. As suggested in the introduction to information management (Section 3.0), the path choices presented to the user at each information node should be perceived as parallel (representing a shared or common theme in reference to the parent topic) and complete (representing a comprehensive elaboration on the parent topic). The exploration of the system according to various navigational criteria can enhance the user's understanding of the knowledge base as a whole. Additionally, by comprehending the implications of the associative link structure, the user can gain an understanding of the general knowledge base without literally navigating every path in the system. In other words, if structure is coherent and comprehensible, users can begin to understand the context of information areas that can be accessed with the selection of paths defined by alternative nodal relationships.

There are component parts of the information base called knowledge communities which represent thematic information clusters. Information retrieval is most efficient when the interactive process begins in what the user believes is the most relevant knowledge community. By gaining an understanding of the relationships between component parts of the knowledge base, the user can discover associative links that expedite access to particular knowledge communities.

*As a user becomes increasingly familiar with a particular subject area, indexes of the subject lan-*guage can facilitate the retrieval of information by permitting the rapid location of relevant knowledge communities or specific information nodes. These indexes of knowledge communities, information nodes, key words, and text phrases are essential components of effective hypertext systems. The ability to access information nodes directly from the index list environment reflects the successful assimilation of the language of the knowledge area, and "systems that provide access to information nodes (knowledge communities) directly from the language index can reinforce this assimilation process, and enhance system interaction for all levels of user expertise" (Larson, 1989).

The highest level of understanding information is characterized by what Neil Larson terms "theological" expertise (Neil Larson: oral communication on 12/7/88). This level of expertise acknowledges the ability of an expert to cite the sources of relevant knowledge, the equivalent of citing the chapter and verse of Biblical quotations. However, the objective of the hypertext strategy is not to commit the information base to rote memory. Instead, hypertext systems are intended to emulate the associative relationships that constitute the knowledge networks in the human brain, providing efficient access to relevant information paths that can be navigated according to the par-

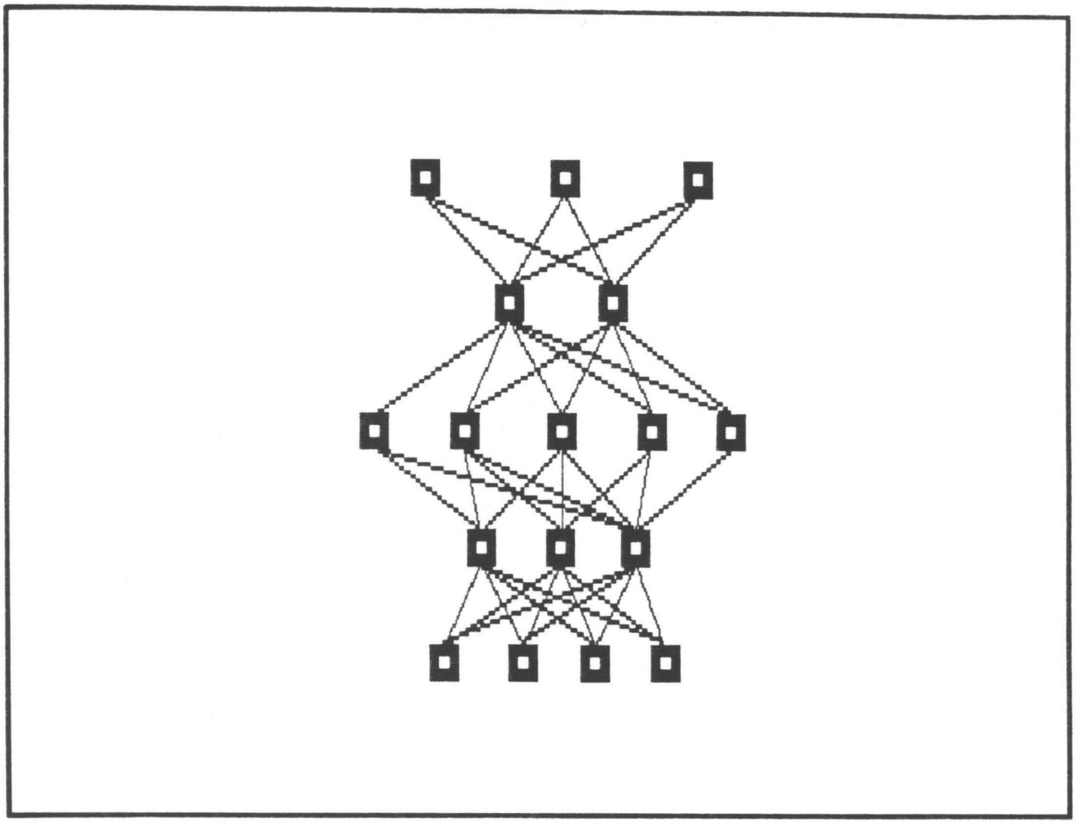


Figure 9. Associatively Linked Nodes in an Information Base

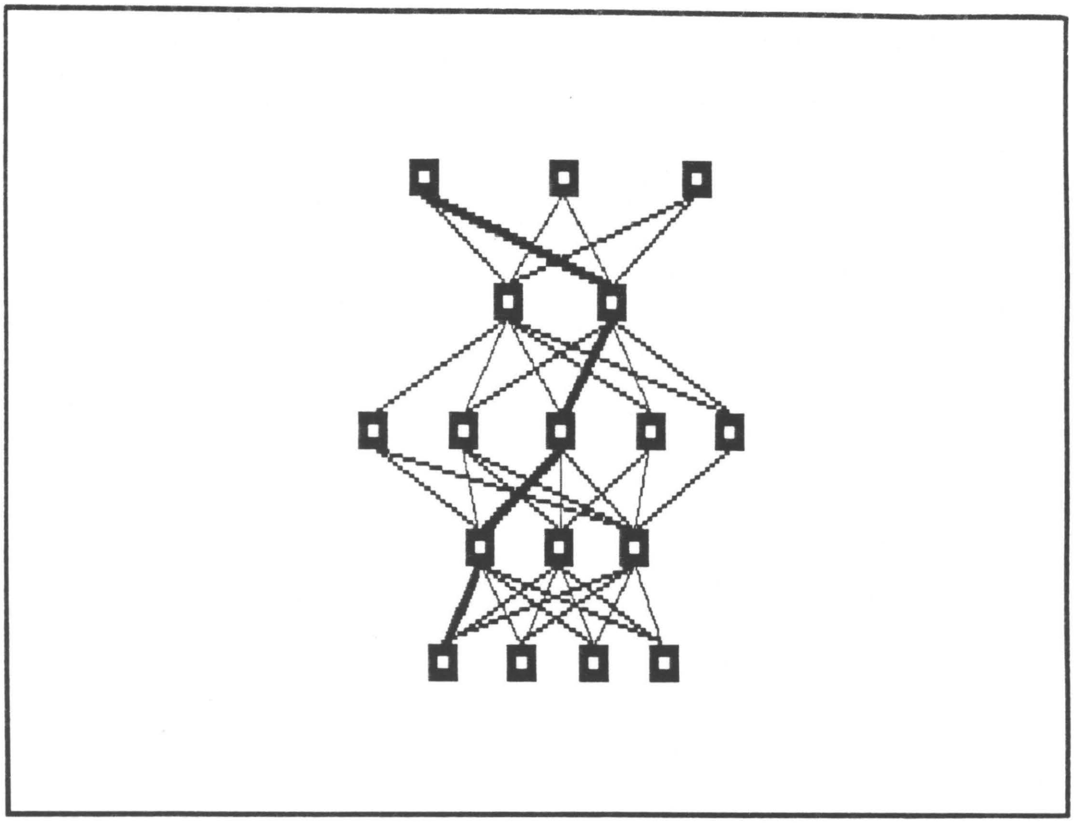


Figure 10. A User Defined Path Through an Information Base

ticular context of user needs. Knowing a subject area well enough to recall the file, node, and line location of desired information may facilitate the retrieval of information, but it does not represent a substitute for the knowledge processing and synthesis essential to the decision process. As a consequence of the essential interactivity between the user and the information network, and the context sensitivity of the information retrieval process, hypertext systems can radically change the value and usefulness of the information that constitutes the knowledge base.

Hypertext Applications Notes:

1. IPIS-Hypertext:

The IPIS-Hypertext System was assembled as a test of the potential of the hypertext concept for preservation applications. The intent was to not only respond to the programmatic demands that guided the assembly of the HSPD, but to expand on its capabilities by implementing intuitive and discretionary navigation in an associative reference structure. The product was a prototype application that put preservation information into an accessible, integrated environment which would allow the system user to focus on evaluation and synthesis of information rather than the gathering of information.

2. Project Jefferson:

The objective of Project Jefferson was to create a research and writing tool for freshmen English classes at USC that would put information resources into an accessible, integrated environment which would allow a researcher (system user) to focus on evaluation and synthesis of information rather than on seeking and gathering information. The researchers found that although the present is often characterized as an "Information Age" where independent, individualized learning is possible through electronic access to a vast information network, little evidence exists that this is happening. The project culminated in the installation of a prototype system built around a Hypercard (Apple Computer Corp.) shell. The hypertext prototype has been made available to other university teaching environments for adaptation and evaluation (Chignell and Lacy, 1988).

3. Issue Based Information System (IBIS):

The researchers developed a hypertext shell called the "Issue Based Information System" (IBIS). This effort represented an attempt to create an environment that would be suitable for interdisciplinary collaboration. The assembly of the IBIS system was based on the principle that the design process for complex problem resolution is fundamentally an interdisciplinary dialogue among participants who hold a particular interest (stake) in the issues under consideration. These "stakeholders" use the IBIS environment to exchange information, share perspectives, and pool their expertise in addressing design issues and resolving strategic differences (Begeman and Conklin, 1988).

3.2. Hardware

3.2.1. Data Acquisition

Video:

High end consumer grade video devices, including video cameras, camcorders, and video cassette recorders (VCR), represent convenient, low-cost alternatives for providing image data to the computer environment. These devices operate according to television standards, supplying analog image data that conforms to either RS-170 (Black/White) or NTSC (Color) signal standards. A single image in these formats consists of two separate fields of lines, odd and even numbered, which interlace to form the displayed image. In the interlaced video signal, horizontal synchronization pulses control the orientation of video lines, and vertical synchronization pulses control the alignment of video fields. The fields are displayed at a rate of 60 per second. Consequently, complete images are displayed at a rate of 30 frames per second. This rate of 30 image frames per second is referred to as "real-time" video, and is the standard rate for recording and displaying action video sequences.

Some video devices provide nonstandard video signals which are not compatible with the RS-170 or the NTSC formats. These devices (CAT scanners, scanning electron microscopes, and slow scan cameras) are most often used in medical or scientific applications which have unique image acquisition requirements. In order to incorporate these devices into an image management system, frame grab cards must be capable of variable synchronization settings (Molinari, 1989).

Super-VHS is the technological successor to the VHS format. The S-VHS format has digital freeze frame capabilities, higher resolution than VHS (400+ vs. 240 lines), 4 audio channels vs. 2 for VHS, high fidelity audio as a standard feature, better video and audio signal/noise ratio, improved contrast with detail, and wider Y/C separation for dot interference elimination. Since the cost of S-VHS and VHS recorder, editing, and camcorder systems of comparable features are virtually the same, these advantages of S-VHS come at the expense of only a slightly higher cost for recording tapes. If S-VHS begins to penetrate the consumer market and production of S-VHS tapes expands, these costs are also likely to fall.

For documentation efforts, video cameras are proving to be of considerable utility in capturing the multidimensional character of the individual resource as well as the larger context of the site. Video is lightweight and easily transportable, and the quality and completeness of a video recording can be immediately confirmed in the field. Video sequences also capture the environmental sounds at the site, and the images can be supplemented with verbal commentary either during or after the video documentation. The video record is inexpensive, and the two hour length (SP mode) of a 1/2″ videotape provides ample opportunity to comprehensively record the resource in context. Oral histories, images of field notes and sketches, historic photographs, and other documentary evidence can be placed on tape as part of the video record.

Individual images from the video tape can be digitized, processed on the computer, combined with other images or graphic information to simulate historic conditions or design proposals, and then printed, output to a film recorder, or recorded once again on videotape. These output recordings can be supplemented with additional descriptive or explanatory information to complete the resource record.

Video can effectively portray a sense of scale and continuity of the total landscape that conventional photography cannot convey as vividly or accurately. The video medium is especially appropriate for describing a context where motion is an essential factor (human activities, environmental forces, etc.). Research studies have examined the extent that videotape presentation of landscapes provoke responses which replicate responses by observers of the actual landscape. Experiments with video surrogates suggest that if the video image includes most of the textural and color variation present in the actual scene, respondents will react similarly to the scene and the video surrogate (Smith, 1985). This means that visual completeness and perceived resolution and color are important attributes for successful video surrogates. Since it is the function of the video system to reproduce the original scenes as faithfully as possible in terms of resolution, geometry, photometry, and color, it can be effective in enhancing the communication between designers/planners and the public constituency. Public perceptions of site values and design intentions can be clarified with the skillful production of video presentations (Chenoweth, 1984). Since video has become a familiar medium of popular communication and VCR's are becoming as ubiquitous as television itself, video technology is positioned to play a significant role in the information acquisition and dissemination activities of the preservation process.

Digital Cameras:

Digital single frame cameras are gradually making their appearance on the professional and consumer market. Sony Corporation and Canon both have models that use a small (2 inch) erasable magnetic disk that can accommodate a maximum of 50 images. The cameras can be connected to a standard television set for image display. While digital cameras were not available for use in this project, the product literature suggests that they could play a significant role in an image acquisition system.

Frame Grabbers:

An essential component of an image acquisition system that utilizes analog video sources is an analog/digital converter. This hardware device superimposes a grid (256x256, 512x512, etc.) over each image frame, and translates each grid unit of the image frame into binary values called pixels (picture elements) according to the brightness value of each unit. The pixels represent a digital format, enabling the transformed image to be manipulated in a computer environment. Pixels may be square or rectangular, with their shape corresponding to the ratio of the horizontal dimension to the vertical dimension (aspect ratio) of the image. The spatial resolution of a digitized image is expressed as the ratio of lines to pixels per line (horizontal rows x vertical columns).

The digitization process must be synchronized with the speed of the analog video (30 frames per second) for the system to capture images in real-time. The frame grab board must also have a resident memory capacity that can accommodate one or more frames of digitized video. The memory requirements for a frame grab system can be extensive, with image file size depending on factors of image resolution, number of gray levels, and color capabilities.

The AT&T Targa 16 and the Willow Peripherals Publishers VGA provided the frame grab capability for this project. The Targa 16 has sophisticated color capabilities, with a capture resolution of 512 by 480 pixels and 32,768 displayable colors (from a palette of 16 million). Because the large color spectrum of the Targa 16 cannot be displayed on a digital PC monitor, the Targa must reconvert image output into an analog RGB (red-green-blue) format for display on an analog monitor. The Publishers VGA is a B/W system that captures images at a resolution of 320 by 200 pixels with 64 gray levels, and 640 by 400 pixels with 256 gray levels in an enhanced version. The integration of a frame grab component into an image acquisition and management system is discussed in Section 4.2, where a description of the CRISTAL System prototype is presented.

Scanners:

Hand held scanners show promise as inexpensive and portable data acquisition devices. Desk top scanners have similar capabilities as the hand held models, with the obvious exception that they can scan larger areas of copy. Desk top scanners are not subject to the variables of the hand manipulated device, but they are not as portable nor do they allow the same application flexibility as hand scanners.

A scanned document database consists of bit mapped digital images of the source documents. In many applications, an image of a source document stored in a graphic file format and retrieved through a reference index may fulfill data acquisition and storage requirements. Graphic files and component elements can be processed using a raster type graphic editors such as TIPS or PC Paintbrush. Graphic elements can also be converted by software to a vector format that is compatible with computer aided design (CADD) systems.

The DFI Handy Scanner 3000, a hand held device that scans at 100/200/300/400 dots per inch (dpi), was used in this project. The system operates with the IBM PC-AT, PS/2 Models 25/30, and compatible computers operating under MS-DOS 2.0 (or later). The scan width is 4.13 inches, with scan length varying from 20.84 to 5.66 inches according to dpi setting (100-400) and available system memory (384-640K RAM). The scanner has three halftone patterns, a black/white setting, and contrast control. Scanned images are recorded with thirty-two apparent shades of gray. The yellow-green scan light gives the device good sensitivity to reddish tones which are often lost in one color (red) scanners. The scanner comes with graphics processing software for manipulating and editing images, and for merging text with scanned graphics. Scanned files can be saved in a variety of graphics file formats (Diamond Flower Industries, 1989).

If stored as a graphic format, the text information contained in the document is not recognized as such by the computer and cannot be indexed or processed as a text file by the system user. To directly index and process text data in a document, it must be converted into ASCII format by an OCR (Optical Character Recognition) software program.

Optical character recognition (OCR) software transcribes scanned text into machine readable ASCII files has become increasingly more sophisticated and accurate (and considerably less expensive). The variety of recognizable fonts and formats has broadened, and a good system will typically accept 200 dpi scans of typeset, monospaced, dot matrix and proportional fonts, and ligatures within a range of 6-20 point fonts. The software comes with libraries of predefined fonts, and can often be trained to recognize additional fonts. Advanced recognition capabilities allow some OCR software to accept formatting commands such as italics and underlines. Hand scanners with less than full page scanning capabilities require software that joins split page scans into full page ASCII files.

The OCR software used in this project was CARETS/BY HAND DELUXE (Version 2.0) by Pattern Analytics, Inc. (Raleigh, NC). CARETS requires MS-DOS 3.0 (or later), 640K of DOS partition memory (RAM), and a hard disk. An 80287 math coprocessor will facilitate font training operations. According to the CARETS *User's Guide*, CARETS "incorporates a statistical pattern matching method that enables it to measure how well scanned letters conform in shape to known templates" (Pattern Analytics, 1989). The program can read tight letter spacing where adjacent characters overlap and sometimes touch, and can transcribe dot matrix printer output.

3.2.2. Data Manipulation

Interactive Video:

Interactive video is a design concept for user controlled information access within a linear or non-linear system structure. The concept is particularly appropriate for nonlinear and random access applications. The objective of interactive video is to tailor the speed and order of information presentation to suit the individual user. The user assumes an active role in the information retrieval process, defining the desired path through the information base. This technique has been used primarily for predefined (programmed) instructional and information dissemination applications. As a learning environment, the computer and videodisc system is infinitely patient, allowing the programming of limitless remediation loops and user controlled drill and practice routines. The videodisc medium provides an opportunity to integrate text, sound, still graphic image frames, and real time motion segments to simulate a meaningful learning environment. A wide range of user interface alternatives are possible, including keyboard, audio, video, pointing devices, and touch sensitive screens. Systems are relatively transportable, meaning that a user can interact with a "portable classroom" at an appropriate training site free from traditional educational constraints. Interactive video is a particularly effective instructional strategy where visual demonstration of technique is required, and where on the job training would otherwise entail excessive costs, special expertise, equipment down time, or high risk activities. Preservation applications might include instructional programs containing simulations of preservation activities requiring sensitive handwork, special craft techniques or tool use, and diagnostic interpretation from sensory evidence.

In many ways, the design intentions of good hypertext and interactive video systems are similar. These intentions address the need to create a user friendly environment that has a coherent, comprehensible structure, maximizes user control and discretion in information retrieval, encourages browsing, and permits effective interaction with users of varied skills and experiences.

The effectiveness of interactive video as an instructional methodology has been hotly debated, and its introduction provoked a Luddite reaction among the ranks of educators. However, research indicates that well conceived applications have yielded positive results. In a study that evaluated interactive video applications for military, higher education, elementary education, junior high, high school, industry, and social services, thirty-nine instances using statistical tests to assess effectiveness concluded that in 61% of the instances there was a favorable finding for use of the interactive video technique; twenty-three instances evaluated without statistical tests indicated a 96% favorable finding for interactive video (Bosco, 1986). In another study, the Annenburg ICPB Project, four major conclusions for the development of interactive video instruction programs were drawn from an attempt to develop interactive disks to simulate laboratory experiences in college physics, chemistry, and biology. These conclusions recognized the need to:

1) develop interactive video environments around features from other instructional methods and materials that are known to be effective;

2) make the structure of the disk obvious;

3) provide the maximum amount of user control;

4) use feedback messages to reinforce performance, and provide diagnostic messages to correct errors (Bosco, 1986).

While these studies indicate positive results in the use of interactive video instructional systems, there is no conclusive evidence that the technique it is significantly better than other forms of instruction based on the same four principles. As with virtually all technological developments, the key issue in the successful use of interactive video is in the appropriate design and application of a system to meet well defined instructional objectives. Interactive video does offer advantages over conventional instruction in particular applications, but needs and goals must be clearly articulated (Bosco, 1986).

3.2.3. Data Storage

> "If it were really a memory you could say it had perfect recall, but you can't personally teach it a thing" (Brand, 1988).

The issues of archival stability and technological obsolescence are critical to the design of a computer based information management system. Although seldom addressed outright, concerns for archival stability, data accessibility, and technological obsolescence will undoubtedly become more prominent as the concept of integrated information systems (hypermedia) is employed in an expanding body of applications with extensive storage requirements.

Format:

Hard copy (ie. printed text and photographs on stable, archival paper) represents a low technology, common denominator as a storage medium that ensures data accessibility and relative longevity (barring any cataclysm that destroys or damages the archive itself... flood, fire, insect infestation, climatic degradation, etc.). This is the reason why archival photographic films are appealing for long term information storage. Using principles of basic chemistry, high quality photographic prints can be made from the film resource. The information contained on the film can be subsequently transferred to a digital environment (via high resolution scanning) where it can be manipulated by "state of the art" image processing technologies for administrative, research, or design purposes.

Memex, the desk manager system proposed by the grandfather of the "hypermedia" concept of information integration, Vannevar Bush, was to be based on microfilm (which had been developed and perfected for espionage work during WWII). In a contemporary application, access to microfilm data could be facilitated by a juke box type system containing indexes of film cards. These cards would be retrieved and scanned on pin registered mounts, and then processed and displayed in a computer based digital environment. Information contained on rolls of microfilm could be similarly accessed. The addressing of information "fields" or "records" on the microfilm could be structured according to a matrix coordinate system, or simply by frame sequence on the rolls of microfilm.

However, in view of the immense storage needs of truly sophisticated information management systems, the logistics of physically managing and manipulating microfilm, microfiche, or related photographic media would be cumbersome and woefully inadequate. Perhaps film media will continue to have application as an archival medium, but it is unlikely that it will be appropriate as a primary storage medium in an integrated information system.

A more conceptually sophisticated common denominator for information storage that combines attributes of traditional systems and contemporary technologies would be a numeric data structure capable of reducing data (images, text, whole computer programs, etc.) to a fractal equation. The concise formula that describes the data structure could then be stored on archivally stable film or disks. Ted Nelson is conducting research in this area with the development of the Xanadu System (see Section 6.2.4).

In addition to the debate over appropriate data format and structure, there is no industry consensus on the design of archivally stable storage media. With each corporate pronouncement of technical advancement, storage devices continue to shift from "industry standard" to "industry standard". In fact, there are virtually no standards in terms of the structure and design of the physical medium, the data format, and compression routines. In regard to storage media, recent departures from the ubiquitous 5.25" disks (360K and 1.2K) and high density fixed disks (10 to 80 Mbyte hard drives) have involved 3.5" disks (720K and 1.44K), tape drives, WORM, CD-ROM, laser disks, magneto-optical disks, and fixed drives of ever higher capacity. Additional developments have included the "smart card" optical film technology as an appropriate medium for data portability and stability, and continuing initiatives relating to the miniaturization of storage hardware. With each storage medium, there are a number of competing physical configurations and data structure formats. This means that many data storage cartridges or disks are not transportable from the devices of one manufacturer to those of another.

Optical Disk Technologies:

Aside from their ability to accommodate massive volumes of data (200 to 1000 megabytes), the non-erasable disk technologies offer a distinct advantage to preservation applications. These storage technologies can facilitate access to historic documents that would otherwise be too valuable or fragile to permit even limited dissemination or handling. As a result, these historic materials can play vital roles in the cultural resource management decision processes without risk to their integrity.

A number of the optical disk technologies seem to promise archival durability and data stability along with rapid access time and economy of data structure. However, the technologies are so new and progressing so quickly that there are no application track records to corroborate the accelerated wear testing done under laboratory controls. These tests simulate a variety of conditions expected to be encountered in normal use, as well as conditions resulting from cataclysmic events and extreme environmental forces. As a measure of the durability and stability of the physical storage medium and the stored data, the veracity of these tests is critical to the integrity of archival data. As a consequence, the decision to make the significant financial investment required to implement these technologies as part of an integrated information system should be carefully considered.

CD-ROM:

The use of "Compact Disk-Read Only Memory" (CD-ROM) for information storage represents a significant opportunity in the development of archival storage devices. Microcomputer based CD-ROM storage systems with removable cartridges that can accommodate approximately 600 megabytes (Mbytes) of digital data are currently available. To put this storage capacity into a more familiar perspective, these CD-ROM disks can accommodate a text content of about 240,000 printed pages, or the contents of 1700 standard (360K) floppy disks.

Storage capacity is not the only attribute of the CD-ROM technology. An important requirement of information systems is that the stored data fields be rapidly and randomly accessible. Not only does CD-ROM meet these prerequisites, but the retrieval of information can be supported by a number of "off the shelf" database management systems (DBMS) and/or full text searching systems.

Another important attribute of CD-ROM for archival management is the fact that it is a "read-only" medium. This makes it appropriate for historical databases that represent an accumulation of unchanging, culturally significant materials. However, since CD-ROM is a read-only medium, production of a "master" disk is required. In order to ensure an accurate replication of the data that is to be encoded on the CD-ROM, this mastering process is necessarily an expensive, tedious process. Once the master disk is created, copies of the disk can be produced rapidly and cheaply, meaning that the technology is particularly appropriate for the dissemination of massive, identical volumes of digital information to a broad user audience.

In terms of current hardware and software costs, the fully configured CD-ROM based information systems are relatively inexpensive (under $5000.00). However, in addition to basic hardware costs, a substantial investment is required to assemble the archival data and produce the master CD-ROM disk.

WORM:

The characteristics of the "Write Once-Read Many" (WORM) technologies are similar to those of CD-ROM. WORM devices are optically based with a storage capacity from 200 to more than 1000 megabytes. The WORM disk is a plastic encapsulated, metallic finished, polycarbonate disk contained in a removable cartridge. The disk is designed to be written on by the end user with a laser device that etches digital data into pits on surface of the disk. The data field, once written to disk, is an unalterable, permanent archive. New data can be written to the disk until either file limits are reached or storage volume is consumed. Since data cannot be overwritten, a data audit trail, or backup archive, is always present to preserve the progression of project or program development. The anticipated design life of the disks is 10 years, as opposed to 3 years for magnetic media, and the data is not susceptible to magnetic fields (Kalstrom, 1988).

Analog Storage (Videodisc):

A videodisc is an analog medium that holds up to 54000 single video frames on each side of a 12 inch disk. Each video frame is randomly accessible and can be viewed as a still frame. If the frames are shown at a continuous playing speed of 30 frames/sec, one half hour of real time video is possible per side. As with the CD-ROM technology, standard videodisc productions must be preprogrammed, and the production of a "master" disk is required. However, there are nonstandard videodisc systems which offer analog "write once-read many" capabilities that are similar in concept to the digital WORM technologies.

A videodisc has two channels of audio tracks to permit the production of stereo sound as an accompaniment to the video display or as a separate audio record. Alternatively, each track can be programmed individually to permit single track audio programs in two languages. A videodisc system can also be developed with the capability for still frame audio programming. This capability enables an audio segment to be played while a single image frame is displayed on the screen. This is accomplished by special hardware that has the capability to retrieve approximately 10 seconds of audio information from each video frame (see Section 3.2.4).

As with the CD-ROM medium, the standard videodisc format is a read-only medium, and production of a "master" disk is required. Similarly, ensuring an accurate replication of the data to be encoded on the videodisc is an expensive, tedious process. However, copies of the master disk can be produced rapidly and cheaply, making the videodisc an appropriate medium for the distribution of image libraries to a broad user audience. The current hardware and software costs for a fully configured videodisc based system are relatively inexpensive (under $5000.00). However, for tailored applications, a significant cost is incurred in assembly of archival data and the production of the master videodisc.

3.2.4. Data Output

Output:

The output of information from a system must respond to the context of the information need. An integrated information system must have the ability to generate output in a format appropriate to information type, and that output should be able to replicate the quality and appearance of the original information source to the degree required by the system user.

Film recorders:

Film recorders are instruments designed to write digital data directly to photographic paper or film. In most contemporary systems, the film is mounted on a cylindrical drum which spins rapidly during the printing operation. The beam of light that prints the data to the photo sensitive surface varies its intensity in proportion to the image brightness. As the drum spins, the light slowly moves the length of the image. This process is repeated line by line until the entire image is exposed. For color images, the exposure is made in three parts, one each for red, green, and blue (the primary colors of the RGB separation). Film negatives, positives (slides), and photographic prints can all be produced by the current generation of film recorder devices. Image resolutions ranging from 200 to 3000 lines per inch are attainable with contemporary systems.

Printers:

Digital data can be produced on paper using virtually any one of the various types of printer devices, including dot matrix, ink jet, thermal, and laser printers. The production of color prints implies a substantial investment in order to achieve the quality of resolution attainable in relatively low cost black and white systems. The least expensive color technology is the thermal type, though the end product, while having the aesthetic appeal of a pointillist painting, may be of limited utility if high image resolution and accurate edge definition is required. As in other computer related fields, color printing technologies are advancing rapidly. The quality of color output will continue to improve dramatically even as the cost of the technology drops.

Video:

Image data files can be recorded from the digital environment onto videotape by connecting a VCR to the output port on a frame grab board located in the computer. The digital image is translated into an analog image as it is transmitted through the analog/digital (A/D) converter resident on the frame grab board. The analog videotape image can then be displayed using a VCR with a standard television set. The image can also be displayed in its analog form directly from the frame grab board to a television set or an RGB analog monitor. Image quality is higher when displayed on the RGB monitor rather than as an NTSC composite signal on a standard television.

Audio:

An emerging technology that has recently demonstrated commercial viability is that of synthetic audio generation. Speech synthesizer devices have the capability to convert ASCII text files to synthetic speech. These systems are memory intensive, requiring up to 10-25K of memory per second of speech. Though the technology is becoming more sophisticated, the limited inflection of the current commercial systems produces poor sound quality.

There are ROM based synthetic speech systems that have a limited vocabulary of several hundred words and require no memory overhead. These systems possess instant response capabilities without requiring any delay for file conversion. The programmable ROM environment enables the system operator to record predefined messages and to modify speech patterns.

There is also technology capable of storing compressed audio on a single frame of a videodisc. The system, which accommodates up to 10 seconds of audio per frame, requires that an audio decoder device be installed in the computer. As much as 40 seconds of audio can be stored in a memory buffer for playback during the display of a still image frame from the videodisc. The system is capable of accommodating a total of 100 hours of sound with 1800 images at a display rate of 20 seconds per image.

The current limitations of each these audio technologies make a hybrid system an appropriate strategy for a large information management application with audio capabilities. A standard videodisc soundtrack would be the most cost effective audio strategy for real time (30 frames per second) motion segments. Depending on the system design parameters, digitized sound stored on a dedicated hard disk would be suitable for audio segments subject to change, while ROM based synthetic audio would accommodate repetitive or generic requirements.

3.3. Summary

An integrated preservation information system can be effectively assembled from the data acquisition, storage, and dissemination capabilities of computer and imaging technologies. Through the combination of appropriate data acquisition tools, optical storage technologies (CD ROM, WORM, Videodisc), and output systems, preservation professionals can create vast databases that integrate a variety of culturally relevant image resources, significant written and spoken words, and real time motion sequences of historical value.

The problematic issues for any system with immense information retrieval and processing needs are those of data storage structure and archival stability. In addressing the former issue, many innovative strategies are being pursued as possible solutions to multimedia requirements. As an example of efforts to this end, Ted Nelson of Project Xanadu is proposing a data structure for mass information storage that represents a radical departure from conventional approaches (Nelson, 1988). In addressing the latter, the reliable accessibility of stored data must be ensured for the expected life cycle of the system. Stable, durable materials are being sought as an appropriate medium for digital data.

It is important to note that the ultimate archival system may be one that ensures the inviolability of data by paradoxically becoming technologically obsolete... an inviolate archival system by virtue of its inaccessibility. Consider the futuristic vision of information storage in the work of H.G. Wells. Wells proposed that the history of Earth's civilization might be recorded on an archive of talking disks. The disks were to be activated by spinning them as one would spin a coin. As the disks spun, an audio message would be broadcast (there was no mention of any difference in effect between clockwise and counterclockwise spin) (Wells, 1895). As long as the species of man retained the necessary suppleness of wrist and the coordination to apply the force required to initiate the spin of the disk, the information would remain accessible with a minimum of technological support (ie. a relatively smooth, horizontal surface on which the disk could spin). Of course, the presentation of information was sequential, and the message length would be a factor of the expected duration of spin. Obviously, these limitations would constrain the efficacy of an interactive information system.

The rate of technological innovation and change is accelerating, and the system designer or assembler must be cautious of specifying hardware or software components that might rapidly lead to system obsolescence. Every effort must be made to avoid the pitfalls of technological dead-ends. The design objective must be one of upward compatibility in regard to the fundamental data structure and operating system environment. Examples of technologies that were highly touted and failed for a variety of reasons litter the trail of the information revolution. Significant failures include the CP/M operating system (by virtue of the popularity of the standard setting IBM PC and its MS-DOS operating system), and the RCA videodisc system (with a stylus signal reader that was ill conceived and technologically archaic from its initial inception).

Design strategies must be devised that permit the adaptation of new hardware components without major system revisions. While it is difficult to foresee the changes that will undoubtedly occur in existing technologies, or to anticipate fully the new technologies that might significantly enhance the utility of information integration and processing systems, there already are general operational (***de facto***) standards that can serve as a platform for the development of contemporary applications. The adherence to technological standards with large followings will ensure the continued viability of a carefully conceived system. Upward compatability can be expected for such basics as the MS-DOS and Unix operating systems, and for programming languages with a large user base such as "Pascal" and "C".

It can be expected that the rapid pace of change will continue, especially in the realm of hardware development. System designers must endeavor to assemble hardware and software configurations so that this dynamic technological environment is not viewed as a constraint to application development, but instead as an opportunity for future system enhancement and expansion.

Chapter Four: Systems Reviews

4.0. Reviews: Introduction

Premise:

It is the ability to categorize and classify ideas in ways that accommodate the various needs of the user group(s) that characterizes successful information processing systems.

The relative effectiveness of three types of information management systems for preservation applications was examined over the course of the research effort. The objective of this portion of the project is to evaluate the appropriateness of a current information management strategy for preservation applications, and to formulate and assess alternative strategies by drawing from contemporary software and hardware resources that had not yet been adequately explored. The Historic Structures Preservation Database (HSPD) System that has been developed by the National Park Service served as the research vehicle for the former concern, and the CRISTAL System software environment and the MaxThink Hypertext System for the latter. The discussion of these respective systems describes the operating environment, the design objectives, and the assembly of each. The attributes and limitations of the systems are evaluated according to the stated objectives of each system, as well as in the context of the technologies available to the investigator. It should be noted that the pursuit of effective information management is the fundamental issue guiding this research endeavor, and that the elucidation of potential strategies for enhancing the preservation decision processes is the ultimate goal. Unfortunately, hardware constraints (cost and availability of equipment) meant that the optimum configuration of neither the CRISTAL nor the MaxThink System was possible, but each holds exceptional promise for enhanced utility and performance with a more sophisticated hardware environment.

The system applications were examined and evaluated according to the following criteria:

- ***Configuration:*** What are the components, and how sophisticated are the hardware requirements?
- ***Description:*** What are the performance parameters that can serve as a basis for evaluation in the context of preservation needs and technological opportunities?
- ***Operation:*** What can the system do, and how effective is it at integrating various media resources? Are there built-in computer processing capabilities and/or the capability to call supplemental external (stand alone) programs? What is the nature of the user interface?
- ***Assembly Process:*** Are there authoring capabilities for tailoring applications? How user friendly are these capabilities?
- ***Attributes and Limitations:*** Can the information base grow (annotation, modification, system maintenance)? How is storage handled (technological obsolescence, archival stability)? Does the system permit browsing, nonsequential navigation (linear and/or nonlinear)? Is there a defined vocabulary (key words, synonyms)? Are key words or ideas (data fields, idea nodes, indexing, data lists) manually or automatically linked? Is there clarity of structure and is it conveyed to user (hierarchical, associative, relational), and can the user mark or trace paths (does the user leave a trail)?
- ***Summary:*** How appropriate does the strategy seem for preservation applications?

4.1. Historic Structures Preservation Database

4.1.1. Introduction

During the past ten years, the Historic Architecture Division of the National Park Service (NPS) has viewed with increasing concern the growing complexity of information management as it relates to preservation activities of all kinds. As a consequence, the NPS has initiated the development of a computerized information base called the Historic Structures Preservation Database (HSPD). The HSPD is designed to serve as a data resource capable of supporting activities relating to "historic and prehistoric structures preservation technology and procedures" (Battle, 1988).

4.1.2. Hardware and Software Requirements

The HSPD is an ASCII text based DBMS that was constructed using "dBASE III PLUS", a popular "off the shelf" software package that was developed by Ashton-Tate, Inc. (Torrance, CA). The system is designed to operate on a microcomputer running under the "MS-DOS" system. The HSPD program application is compiled in Clipper (Nantucket Corp.), which enables it to operate on a microcomputer without a resident version of the dBASE software. However, as a consequence of the use of this program structure, the application user is unable to annotate or implement any other modifications to the database structure in the compiled Clipper version of the HSPD.

The minimum configuration for operating the system requires DOS version 2.0 (or newer), 512K of RAM (random access memory), and two 360K disk drives. Although the system will operate without one, a hard disk drive is recommended to facilitate practical use of the system. For this research, the HSPD was installed on an IBM-AT compatible (DOS 3.1) with 1024K of RAM, a 20meg hard disk, and two (1.2meg and 360K) disk drives.

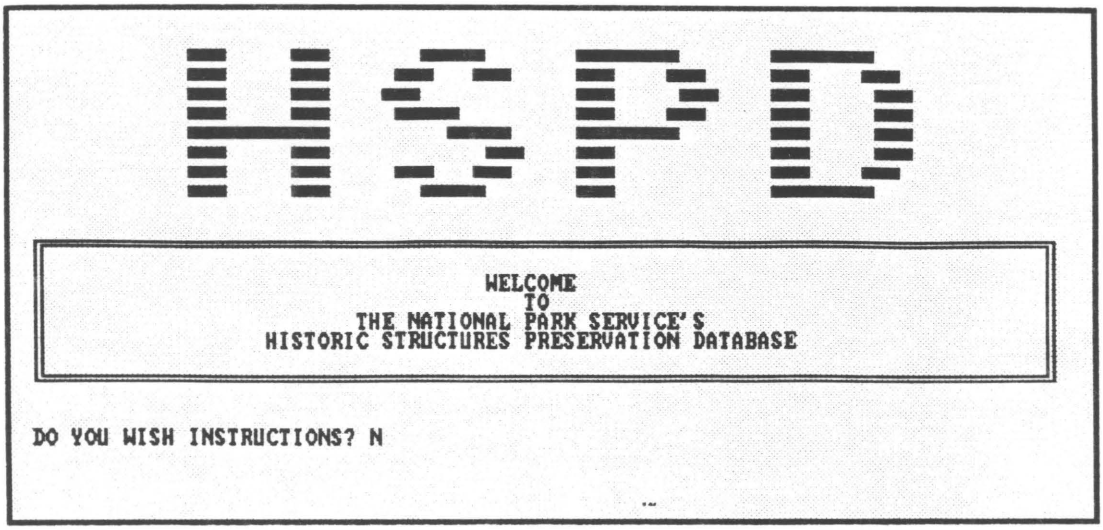


Figure 11. The Initial HSPD Screen

4.1.3. Objectives

The primary objective of the HSPD information management project was to develop "a database by conservators for conservators" (Battle, 1988). In addition to this conceptual foundation, the primary design parameters for the HSPD required that as a database system, it be based on the current NPS DBMS standard, "dBASE III PLUS", that it be flexible enough to relate to other NPS databases, and that it be easy to use. In addition, the HSPD system developer expressed the hope that the HSPD could be a "smart" system capable of growth through continuing user contributions of expertise and case study information (Battle, 1988).

4.1.4. Description

The HSPD was developed in response to the continuing need to effectively "provide preservation maintenance information about the historic and prehistoric structures in the parks to the staffs of those parks" (Battle, 1988). The initial attempts to resolve this need resulted in cultural resource management guidelines for preparing Historic Structure Preservation Guides (HSPG) that were set forth in a park service policy called "NPS-28". According to the primary developer of both "NPS-28" and the HSPD, the HSPG guidelines have several major deficiencies. They recommend the use of a Construction Specifications Institute (CSI) format that has not worked well in practice, and the lack of written information about the maintenance of prehistoric and historic structures necessitates extensive research has made the production of HSPG's expensive and time consuming (David Battle: oral communication on 12/5/88). In addition, with the advent of new materials and technologies, and unanticipated legal or environmental constraints, written documents such as HSPG's that cannot be easily updated are quickly rendered obsolete.

To resolve the inadequacies of the "NPS-28" guidelines, the National Park Service decided to establish a computerized database that could be maintained with the latest construction specifications, maintenance techniques, and materials technology developments. After an initial attempt at a computerized information system proved to be inadequate (though it did succeed in assembling a significant volume of preservation pseudo-specifications), work was begun on the development of the HSPD (Randall Biallis: oral communication on 11/30/88).

As a consequence of design parameters that were shaped by NPS personnel familiar with preservation information needs, the HSPD is organized as a hierarchical structure consisting of preservation information types, categories, and activities. The highest level of the hierarchy delineates seven "partitions" of preservation information resources: assessment, maintenance, conservation, construction, products, reference, and bibliographical data. Each information partition consists of a separate database. In turn, each of the seven databases contains subsets of "categories" of information. Since no two databases contain identical categories, the user can specify a particular category of information in his query and expect to retrieve the desired data from the single corresponding database. Each category may describe particular preservation "activities" as part of the database, and the retrieval of these must also be specified in the user query.

The premise in developing "a database by conservators for conservators" (Battle, 1988) was that an appropriate, effective system would best result from the contributions and interactions of the user community (the cultural resource management and maintenance professionals that the system is to serve). This underscored the importance of making a prototype of the system available to the end users as quickly as possible in order to facilitate design and programmatic review by them. In response to the objective of quickly assembling a working prototype, the application developer selected an "off the shelf" database management program (dBASE III PLUS) which had already been designated as an NPS DBMS software standard. The rapid prototyping was also intended to encourage the contribution to the system of relevant data derived from the professional experiences of the individual users. It was hoped that this strategy would quickly bring a larger and more varied body of knowledge to the system than might otherwise be realized (David Battle: oral communication on 12/5/88).

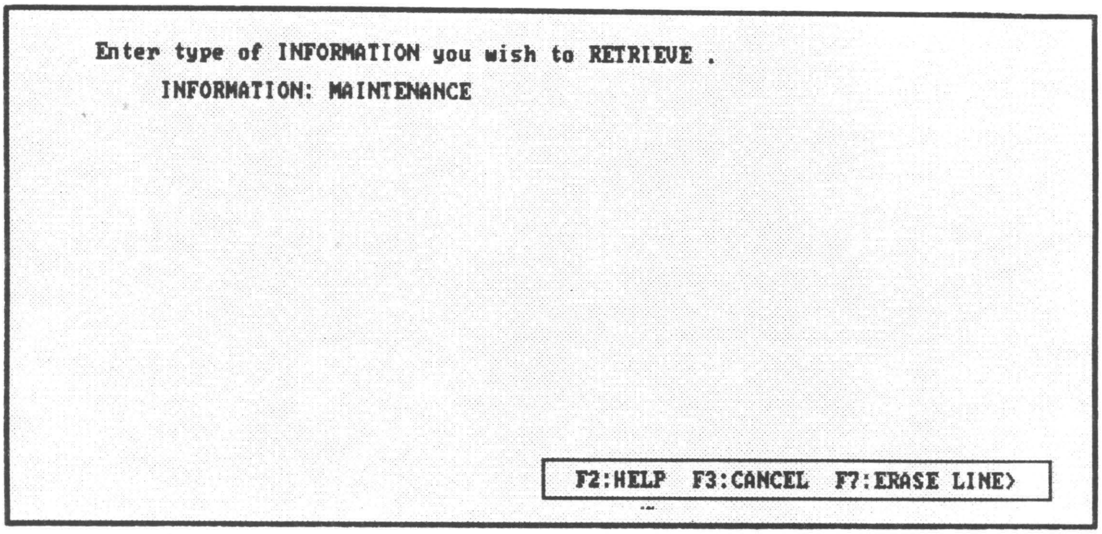


Figure 12. The Specification of an Information Type (HSPD)

```
Enter type of INFORMATION you wish to RETRIEVE .
     INFORMATION: MAINTENANCE

Enter at least one of the following items to indicate what you wish to
     MAINTAIN:

     ELEMENT:      ROOF
     UNIT:         SHINGLES
     MATERIAL:     WOOD
     TYPE:

     PROBLEM:

RETRIEVE RELATED INFORMATION?     Y
RETRIEVE BIBLIOGRAPHY?            N

ANY CORRECTIONS? Y
                                   F2:HELP  F3:CANCEL  F7:ERASE LINE>
```

Figure 13. The Detailed Retrieval Specifications Screen (HSPD)

Since the HSPD databases are hierarchical in organization, the user can retrieve more detailed information with a more particular (qualified) query. If the user desires, information that does not exactly match but is related to the query parameters can also be retrieved from the databases. The query process instructs the user to enter data specifiers that establish the context of the information query. These specifiers are element, unit, material, type, and problem. Only one specifier needs to be entered to begin a search of the database, but the more parameters specified, the greater the detail and context sensitivity of the information retrieved. In addition to the five specifier fields, the user can choose to retrieve data "related" to the specified search parameters. To retrieve detailed information about a particular topic, the query itself must be as detailed as possible. General query parameters yield only the most generic levels of information. As an alternative to a well defined query, the HSPD does allow the user to specify "ALL" as a search parameter. This all inclusive specifier will yield information about the query topic from every category in each database (except the reference database).

If mistakes are made in specifying query parameters, the user can respond "Yes" to a final prompt of "Any Corrections?" before the search begins. The user is then returned to top of the specifier screen. The program does not give the user the ability to move backwards on the specifier screen, so corrections tend to be rather cumbersome. When returning to the specifier screen, whatever search parameters were last entered remain on the screen as the default specifiers.

The HSPD has context sensitive "Help" which can be called during the process of entering query parameters by pressing the [F2] function key. A screen will appear that presents an explanation of the current operation and examples of allowable user input. After reviewing the Help screen(s), the user is returned to the current operation to continue the execution of the program.

Search results are presented sequentially to the user. On the last screen of the search results, the program informs the user about "related information that the computer cannot automatically include as part of the data set... requested" (Battle, 1988). Additional information pertaining to

REPAIR : WOOD SHINGLES

Remove damaged shingle by splitting into smaller pieces with a chisel until free of nails, then sliding a hacksaw blade under the overlapping shingle and cutting off nails.
Cut a replacement shingle to fit, allowing a 1/4-inch gap on each side.
For siding, or steeply pitched roofs, the following method of application is recommended: Fit replacement shingle into place. Secure by toenailing through shingle at the butt line of the lapping shingle, so that the head is sheltered by the butt. Cover the nail head with clear silicone sealer. Use one or two nails, depending upon shingle width. Do not place nails closer to edge than 3/4 inch.
For moderately pitched roofs, the "hidden nail" method is recommended: Nail one or more strips, depending upon width, of 20 oz. copper, 1-inch wide, into the area to be covered by the replacement shingle and about 1 inch above the butt line. Use copper roofing nails. Insert replacement shingle. Bend copper strips around butt to form tabs. Trim tabs about 3/8 inch above butt, and make sure that they fit tightly against the exposed surface so that sliding ice, snow or wind will not loosen them.
Press any key to continue...

F3:CANCEL

Figure 14. A Retrieved Information Field (HSPD)

```
HELP : INFORMATION TYPES                                              1

     There are seven types of information that can be retrieved.  Each
     is contained in a separate database.  The seven types are:

     REFERENCE          ASSESSMENT        MAINTENANCE       CONSERVATION
     CONSTRUCTION       PRODUCTS          BIBLIOGRAPHY

     You may obtain any one of the above types of information by
     entering any one of the above words into the information box, or
     you can obtain all of the above types of information by entering
     the word "ALL".

     Each of the above types contains several categories of infor-
     mation.  Entering one of the above words will give you infor-
     mation from all categories, but you can limit your search to
     specific categories if you wish.

WOULD YOU LIKE MORE INFORMATION?
```

Figure 15. An HSPD Help Screen

ASTM standards, National Park Service policies, federal specifications, and other relevant references is also displayed if available. A bibliographical database is also intended to become part of the system, with annotations and abstracts to be included according to availability. In the final step of the HSPD data retrieval process, the user can send the complete set of retrieved data to a printer after the screens have been reviewed.

According to the system developer, revisions to the HSPD are projected to occur "two to three times a year" (Battle, 1988). Under this process of system maintenance and expansion, comments and proposed revisions or additions submitted by the user group will be evaluated by the "Keeper of the HSPD." It is intended that the Keeper alone shall decide what information will be included in the database and which submissions will be entered into the system, as "there are sometimes conflicting data and varying opinions to be considered, and in such cases, someone must make a final decision" (Battle, 1988). This strategy is intended to ensure centralized control over information content and quality by limiting the ability of users to affect system modifications.

4.1.5. Assembly

The dBASE application examined in this portion of the research was assembled by David Battle of the National Park Service. As mentioned previously, the parameters for the HSPD required that as a database system, it be based on the current NPS DBMS standard, "dBASE III PLUS." Since the actual design and assembly of the HSPD preceded this research effort, the description of the assembly process will not be discussed in this document. Numerous books and articles have been published on dBASE (and dBASE compatible) DBMS applications which cover the developmental processes in detail, and interested readers should refer to those for elaboration on the assembly of DBMS systems of this type.

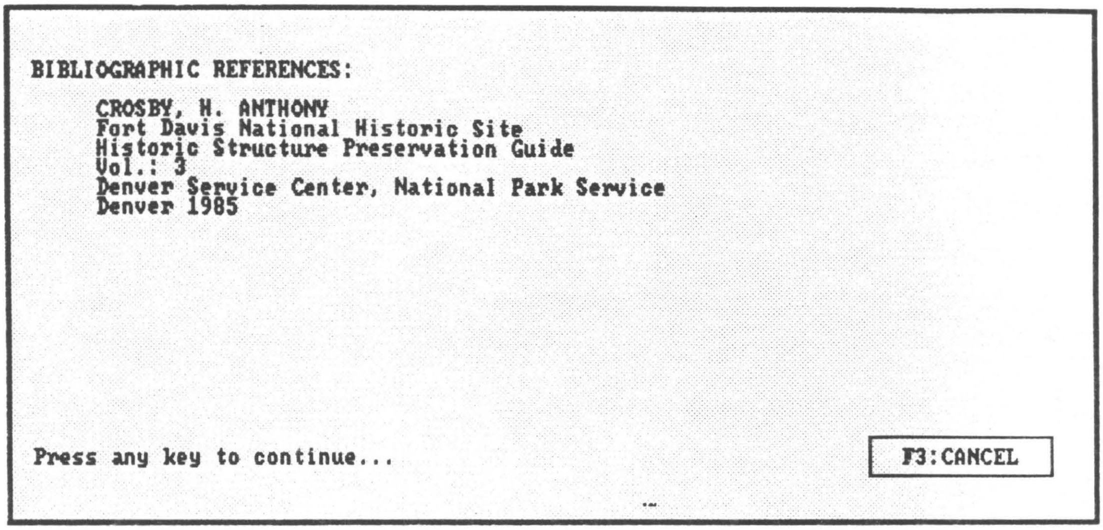
```
See Also:   INFORMATION: MAINTENANCE
            ELEMENT: ROOF
            UNITS: SPECIFIC UNITS
            MATERIALS: GENERAL, SPECIFIC MATERIALS





Press any key to continue...                          F3:CANCEL
```

Figure 16. A Related Reference Screen (HSPD)



BIBLIOGRAPHIC REFERENCES:

CROSBY, H. ANTHONY
Fort Davis National Historic Site
Historic Structure Preservation Guide
Vol.: 3
Denver Service Center, National Park Service
Denver 1985

Press any key to continue...

F3:CANCEL

Figure 17. A Bibliographic Reference Screen (HSPD)

4.1.6. Attributes

- The dBASE III PLUS software is a popular DBMS package with a demonstrated capability as a list processor. Since the success of the program has spawned numerous clones, the dBASE standard is transportable to a variety of compatible DBMS software environments. The NPS has designated dBASE as a software product standard for database systems, which means that there is likely to be a large user group within NPS that is familiar with the dBASE environment. This should enhance the prospects for system implementation service-wide, and minimize user orientation difficulties.

- If other NPS data management needs are similarly addressed in dBASE applications, then the potential exists for integrating a variety of data resources into a single software environment. This would enhance the accessibility of a broad range of NPS information resources, provided these data resources are well suited to management in dBASE environment.

- The user interface is simple and reasonably coherent, and the compiled program has clear, well written documentation that facilitates program installation and operation. A conscientious computer novice should experience minimal difficulty implementing the HSPD system.

- The system can be expanded by the system operator to accommodate additional data records and field types. In fact, although contrary to current NPS policy, any application user with knowledge of dBASE III Plus or dBASE IV (or compatible DBMS software) can modify the information content and structure of the HSPD. As stated previously, for purposes of system continuity and content control, only the Keeper is authorized to make system modifications. As additional sources of preservation information become available, the Keeper of the HSPD, acting as an information clearinghouse, can evaluate the veracity and relevance of the new material and determine whether (and where) to incorporate it into the HSPD. Updates can be sent from the "Keeper" to the remote installations on floppy disk, ensuring that the whole system remains uniform and current.

4.1.7. Limitations

- The HSPD uses a predefined word list (a defined vocabulary that constrains the access to information by demanding key word accuracy in specifying search criteria). This is a significant limitation, even though the system permits use of a relatively broad vocabulary. The documentation suggests that "if you can't decide what word to use, try using the word(s) you would normally use. Who knows? It might work!" (Battle, 1988). This broadside approach to data queries diminishes the appearance of a rational, comprehensible, and structured organization of information.

- The use of inclusive specifiers means that a large amount of data is retrieved that may or may not be appropriate to the specific user need. In many issue specific searches, this encumbers the retrieval process with information irrelevant to the specific context of the search. In addition, while pertinent data may in fact be identified, the procedure still does not ensure the completeness of the search and retrieval process.

- Searches within the information text are not yet possible. Although this is an expressed desire of the system developer, the absence of this capability is ascribed to the limitations of the dBASE software and inadequate programmer skills.

- The operation of the dBASE III Plus software shell becomes "extraordinarily cumbersome, memory consumptive, and slow" as searches of increasingly detailed parameters are specified (Battle, 1988).

- The HSPD needs more extensive subject references for the bibliographical database. Again, this is a desire of the Keeper, and the lack of information is ascribed to the limitations of dBASE software and the time required to gather and enter the necessary data.

- Graphics capabilities are needed to supplement the text with reference images and drawings.

- The system is intended to be an inclusive system capable of satisfying a range of preservation management needs, and yet, it is to be modified or annotated only by the Keeper of the HSPD. According to the Keeper, periodic revisions will be made to the system in response to user contributions, criticisms, and programming problems (bugs) (Battle, 1988). In this respect, the system does not achieve the dynamic "smart" status that was a stated objective of the developer. It cannot grow from repeated user interaction, only from the intervention of the "Keeper" in response to user comment and contribution. System growth is obscured by the dBASE structure in the sense that there is no inherent means of informing the user of changes to the system. As a consequence, the user has no indication of the extent or context of the periodic information supplements. Without the ability to convey a sense of context, the information in the HSPD remains raw data more suitable for list processing than for knowledge retrieval.

- The HSPD is a database, not an information system. The system cannot track the decision process of each application, and as a consequence, it cannot become a collection of annotated case studies that convey a sense of the context of preservation management decisions. The system communicates no sense of hierarchical relationships to the user, nor of the relationship between information fields. The DBMS structure presents an inherent difficulty in coherently and comprehensively communicating an understanding of the complete data structure and the relationships that exist between the records and fields which constitute the database.

- Database queries are only as accurate and thorough as the ability of the user to specify the appropriate search criteria. Research has demonstrated that even in the hands of professional users (lawyers), a database system of legal references and court rulings typically provided users with less than 22% of the information which may have been relevant to their query (Larson, 1988). The user of a DBMS remains unaware of what additional information, relevant or related to that already retrieved, may be available in the system.

- The weak user interface requires manual entry of specifications. The use of pull down menus with word lists would enhance the user/machine interface. An interface that permits selection of commands and key words from the menu list display would be more effective than the keyboard entry of search specifiers.

- The HSPD has weak reporting capabilities. The system does not permit the user to backtrack through the data reported to the screen (no "Page Up"). The ability to write data reports to disk file (only to printer in current version) would facilitate the integration of data into word processing files. This could be accomplished with an external, resident program (TSR program; eg. Sidekick Plus: Borland International, Scotts Valley, CA) which allows the user to write blocks of text information from the screen to an ASCII file.

4.1.8. Summary

The HSPD suffers from the various limitations inherent in the use of a DBMS for information management. Relational databases are structured with a presumption that the user has a knowledge of the language of the subject field and a grasp of the set intersection techniques that are required to effectively query the database and retrieve desired information. Without the specification of appropriate query sets using valid key words, a DBMS system such as dBASE has little practical utility. The dBASE software is capable of synonym recognition which can enhance information retrieval performance. However, a search operation will ignore data fields that may closely match search criteria but do not include the key word specified in the user query.

A significant handicap represented by this method of data retrieval is that dBASE and other DBMS software do not communicate to the user a sense of the structural relationships between the information fields contained in the knowledge base. A skillful dBASE user can retrieve information that matches search criteria, and yet not only fail to access all the data relevant to the search (if the system ignores close fits), but also fail to comprehend the patterns of information that are the *foundation of knowledge*. *This failing of DBMS* applications can be attributed to the fact that the system is structured according to individual words rather than ideas.

Why then is DBMS software so often used for the assembly of information management systems? The answers to this question may relate to both an infatuation with programs like dBASE that have a high market profile and which have in fact demonstrated their value as data field manipulators, and to a lack of familiarity with information management alternatives. Data is simply information without structure, without context. Information, on the other hand, has a patterned structure (based on relationships) that can communicate knowledge. The key issue addressed in this research is not data management, it is information management: the access, manipulation, synthesis, and evaluation of ideas.

Even the developer of the HSPD recognizes the limitations of the dBASE environment as an information management system. The dBASE program is a good list oriented data storage and retrieval program, as are other DBMS programs. However, the information contained in the HSPD is text oriented rather than list oriented, and hence not really suited to a database structure (Dave Battle: oral communication 12/05/88).

In recognizing the numerous limitations of the current system, David Battle, Keeper of the HSPD, expressed the desire to see a number of additional features incorporated. Battle cited the following capabilities as being essential to the ultimate acceptance, hence success, of the system :

- Retrieve drawings generated on simple 2-D CADD systems (standard details and diagrams in a raster environment);

- Produce detail drawings generated on sophisticated CADD (AutoCAD, Cadam, etc.) and link them to text files (access to vector graphics);

- Construct links to different types of images (various file and graphic formats);

- Fully integrate a text and graphic information base;

- Implementation of a graphic system with data sorting capability;

- Integration of a cost effective, portable, microcomputer based (IBM-AT compatible) Geographical Information System (GIS) to enhance data acquisition and exchange between various NPS divisions (Maintenance, Design and Construction, Natural Resource Management, Cultural Resource Management, Law Enforcement, Interpretation, etc.).

There is not, as yet, clear indication of the practical utility of the HSPD, nor of its ability to fulfill its objective. A fundamental concern expressed by the "Keeper" of the HSPD was whether the dBASE environment in particular, and DBMS systems on the whole, were appropriate structures for meeting the text and graphic information management requirements associated with NPS cultural resource management responsibilities. The limitations of the DBMS approach suggest that alternatives must be developed that can incorporate a DBMS organizational structure when appropriate to the data type, but which otherwise represent more versatile environments for idea processing using various information resources, including text, graphics, and sound.

In a discussion of "future directions" for the HSPD, the developer pointed out that new innovations in computer technologies will continue to present opportunities for system enhancements. These innovations may ultimately "force abandonment of the [dBASE] software environment, and the development of a new, more powerful system" (Battle, 1988).

The limited objective of the HSPD System was to enhance preservation maintenance activities in the national parks by facilitating the generation of work orders. By describing appropriate responses (in terms of tasks and materials) to specific maintenance problems, the HSPD does have the potential to contribute to the resolution of routine maintenance deficiencies in the NPS. By virtue of this (albeit limited) application, the climate for acceptance of computer related technologies and tools into the operations mainstream of the National Park Service could be significantly enhanced with the widespread promotion of the HSPD by NPS administrators. A concerted effort by the NPS will be required to effectively test the system. No matter how promising the attributes or potential of a preservation information system, if the user group fails to assimilate it as an integral component of their work, then it fails in its objectives and is devoid of practical value.

Unfortunately, it seems that the viability of the HSPD System as a National Park Service management tool is unlikely to be systematically tested. The system does not have the management mandate nor the funding support necessary for implementation, and as a consequence, it is virtually moribund (Randall Biallis: oral communication 06/07/89). System usage is limited in scope and isolated to a few individual professionals within the NPS who understand the potential that such technologies and data management strategies hold for enhancing decision processes (Billy Garrett: oral communication 04/13/89). Such NPS users often become technological pioneers by necessity rather than nature. They are conscientious and resourceful professionals overwhelmed by the magnitude of management crises and the absence of adequate funding or personnel to effectively protect the resources in their care. These lamentable circumstances make these professionals especially receptive to new strategies and tools that demonstrate any promise of assisting them in their Herculean tasks. Under the myopic vision of those who shape current NPS policy and determine the allocation of program funding and personnel, it appears unlikely that any significant changes will be forthcoming in what is a decidedly unfavorable climate for enhancing cultural resource management processes through technological transfer and adaptation.

4.2. CRISTAL

4.2.1. Introduction

The Computerized Relational Information System and Total Algorithmic Language (CRISTAL) system was selected as a prototype development platform for CRM applications because of the capabilities it has for integrating, managing, and manipulating text and image files. CRISTAL is a high level programming environment that capitalizes on proven, contemporary computer hardware and software technologies to facilitate the transmission and combination of complex graphic data forms.

As an application development environment for historic preservation, the strength of CRISTAL lies in its use of interactive computer graphics techniques. These techniques not only facilitate access to a broad range of information types, but can enhance information synthesis and provide a foundation for making better informed cultural resource management decisions. The utilization of a graphics environment for developing and studying resource conservation strategies represents a potentially powerful strategy for giving regulatory bodies, design and planning professionals, developers, and the public a means of more accurately visualizing the increasingly complex issues that must be addressed in managing historic resources. In an environment that permits image manipulation and graphic processing, a thorough examination of design strategies is possible through visual simulation techniques.

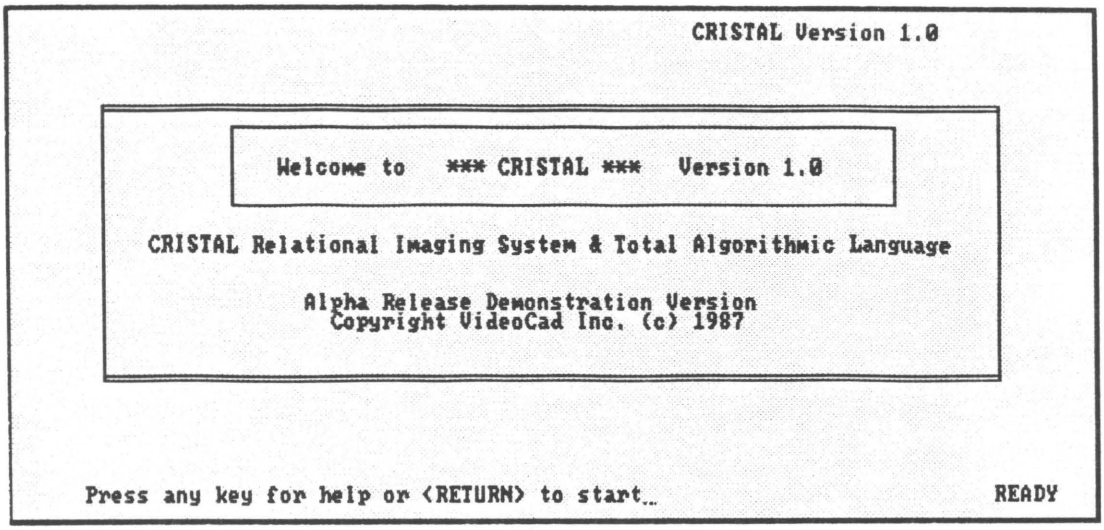


Figure 18. The Initial CRISTAL Screen

4.2.2. Hardware and Software Requirements

The CRISTAL System that was used in this research can be installed on any IBM PC-AT or 100% compatible computer with a minimum of 640K of RAM (system memory) and two floppy disk drives, or one floppy drive and a hard disk. CRISTAL runs under the DOS version 2.0 (or newer) operating system. A computer graphics card (color or monochrome) is necessary to display the various types of graphs that can be created with CRISTAL. A graphics printer is required to generate a hard copy of graphs and images.

Although the basic CRISTAL software will operate without it, a hard disk drive is necessary for practical implementation of the information management and processing capabilities of the system. Similarly, although CRISTAL graphics can be displayed with good resolution in a VGA environment, a video frame grab board is essential to implement the full range of CRISTAL image data management and graphic processing features. These image processing capabilities are the primary attributes which differentiate CRISTAL from most other data management programs. With a frame grab board, an analog video device such as a videodisc player, VCR, or video camera can serve as an image source for the CRISTAL system. Optical scanners can also provide graphic information input in formats supported by the CRISTAL system. These are particularly useful in applications where visual media such as photographic prints, architecture and engineering drawings, an extensive volume of printed materials, or intricate graphic designs are to become part of the CRISTAL image database.

To accommodate the image management and processing functions of this CRISTAL application, an AT&T image capture board (Targa 16 series) and a 40 megabyte hard disk were included as part of the system configuration. Additionally, an optical disk storage system based on "write once read many" (WORM) technology was used to supplement the data storage capabilities of the system. The relatively high resolution of the frame grabbed images (512x480) combined with a display palette of more than 32,000 colors make the Targa 16 images memory intensive. Each full screen color image captured by the Targa 16 board requires more than 400K of memory, and the image compression routine in the Targa Image Processing Software (TIPS) reduces video captured image file size by an average of only 10% to 15%. An analog RGB monitor, composite video monitor, or television with an RF adapter is necessary for the display of the analog image that is output from both the VCR (or videodisc) player and the Targa 16. As alternatives or supplements to the WORM storage system, a videodisc player (capable of storing 54,000 single frame images or 30 minutes of real time video in analog signal format per side) or a CD-ROM system (capable of storing 600 kilobytes of digital data per disk) could also be configured with the CRISTAL System. However, these devices were not available to this project.

To enhance the degree of user interaction with the image processing and manipulation functions of CRISTAL, both a Microsoft compatible mouse and a "trackball" system were used in the prototype applications. Additionally, while a variety of graphics printers (thermal, laser, dot matrix) and film recorders can provide hard-copy output from the CRISTAL image system, only a dot matrix printer and a laser printer were available for use with the prototype system.

4.2.3. Objectives

The primary objective of this portion of the research effort was to use contemporary videographic and computer processing technologies to develop a digital environment for integrating, manipulating, and retrieving graphic information relating to the management of cultural resources. Techniques for manipulating images were investigated in an attempt to supplement the preservation decision process with powerful graphics tools. By applying these emerging technologies to the "preservation process", it was hoped that a multifaceted computer based document that comprehensively describes the cultural environment could be created. An additional objective was to demonstrate that the data acquisition process can be facilitated by the ability to extract single frame digital images of structures and artifacts from real time video recordings.

4.2.4. Description

The key component of the CRISTAL information management system is software that functions as an interactive videographic database manager. This software, developed by VideoCad, Inc. (Blacksburg, VA), enables the user to combine and manipulate data of different types from a variety of visual media sources. As a consequence, it can provide the foundation structure for:

- a graphic database that combines images from scanned or video captured sources with computer generated graphics, text, or numeric data.

- an interactive simulation program that provides access to graphic processing capabilities, enabling a user to manipulate contemporary and historical images to depict evolved or proposed changes to sites and structures. This capability can be used in a variety of research, analysis, and interpretation applications. Graphic simulations can visually demonstrate the contextual fabric of place and convey an understanding of the essential character and integrity of cultural resources, thereby facilitating the resource management decision process.

- resource protection design and planning by enabling a user to generate graphic aids to prescribe appropriate material treatments, maintenance routines, development schemes, or monitoring activities.

In developing this CRISTAL application, the intention was to configure a system that would be appropriate for recording a range of cultural resources, from individual historic artifacts to urban historic structures or districts and rural cultural landscapes. The two prototypes developed to test the viability of the CRISTAL System included an application for a National Park Service site (Mount Rainier National Park), which was primarily a test of image management and information integration capabilities, and one for the management of information relating to the Vigna Barberini on the Palatino Hill (a major nucleus of Roman civilization) in Rome, Italy, which included a demonstration of image manipulation and processing capabilities.

An additional study site was Poplar Forest, Thomas Jefferson's plantation near Lynchburg, Virginia. A major preservation effort is planned for this landmark, which exemplifies Jefferson's mastery of the classical style. The timeliness of the Poplar Forest project and the complexity of the preservation effort presented an opportunity to further test the parameters of the information system by tracking a restoration project over an extended period of time from conception to completion. As yet, this component does not represent a structured application of the CRISTAL System. Rather, it has served as a vehicle for exploring resource documentation, image analysis, and image processing issues. The concerns explored with Poplar Forest have been addressed through real-time video recording, dimensional analysis using planar (two dimensional) geometrical constructs, and 3-D graphics modeling.

Through the ability to merge text, graphics, and video images into an integrated digital environment, the CRISTAL system addresses four key issues in the preservation process.

- documentation of cultural resources by gathering single frame images from real time video recordings, scanned graphics and text, and alphanumeric data generated by computer or entered by keyboard. Buildings that might not prove economically or logistically feasible to document with extensive hand measurements and drawings might be effectively recorded with the videographic system.

- analysis of resources through the extraction of information relating to building dimensions, materials, code compliance, and stylistic character from graphic images. Specific information relating to building character or structure can be generated as required to fulfill management or design needs. Once a videographic database exists, the system user can exercise a high degree of discretion in determining the information to be extracted from the database.

- simulation of the historic context and proposed designs or treatments through the addition of information to the recorded image. A more comprehensive understanding of the environmental and cultural context, and the impact of proposed changes, is possible through the computer manipulation of digital images. These processed images can be supplemented with drawings, photographs, and text. When a new building is designed for an historic district, or changes to an otherwise environmentally or culturally sensitive area are contemplated, the effects of these proposals can be studied by merging the video record of the existing context with a graphic simulation of the proposed project. These visual computer simulations can promote a dialogue between cultural resource professionals, architects, developers, public constituencies, and public administrators that results in more informed decisions about the effects of proposed design or management strategies.

- the specification of prescriptive treatments and the assembly of construction documents, maintenance management guides, and monitoring systems. The development of a highly accessible, interactive, visual information base can contribute significantly to formulating maintenance, rehabilitation, and restoration strategies. In complex or large scale conservation projects, detailed recordings of building parts to be removed during construction can be made and placed in the system's database prior to removal. After repair or replication, these parts can be efficiently identified and correctly replaced according to the specifications or instructions contained in the original video document.

4.2.5. Assembly

Documentation Recording:

The process of assembling a CRISTAL System information base begins with the visual recording of the subject site and its associated resources. A videographic recording can convey the context or "sense of place" of the site through continuous video images supplemented with environmental sounds and verbal commentary. This imagery, sound, and commentary is immediately accessible in the field, providing an instant confirmation of the quality and content of the audio-video document.

The video documentation crew works its way around the exterior of the subject building, recording overall views of the structure and the site. Detailed information about materials, joints, evidence of physical condition, unique or significant features, and specific environmental information may be included as part of the video record. The interior of the building may also be recorded using the same strategy.

The videotape record provides a library of images of the site that can be accessed for reference or analysis through the use of computer hardware and software systems. Images from videotape can be digitally captured and stored in the computer's memory by a process called "frame grabbing". This entails converting the analog video signal (which is in line form) to the computer's digital signal (dot or pixel form). The computer image, which replicates the video image in color and resolution, is then stored in the computer's memory structure (magnetic or optical disk) for future reference and manipulation.

Through the use of frame grabbing techniques with television cameras and videotape recordings, a wide array of information from many media sources, such as sketches, slides, photographs, handwritten notes, and drawings, can be merged into a single environment. Each of the CRISTAL systems reviewed in this research employed this digitizing process to assemble a library of images from various sources.

Information Management:

As the volume of digitized images and associated data files increases, the need for a comprehensive information management tool becomes essential. The CRISTAL System is a spreadsheet based information system that manages information in three basic forms:

- Spreadsheet files: Numeric, tabular, or computational information stored in cells of the spreadsheet; macro commands can be placed in spreadsheet cells to provide the means to automatically execute a set of predefined operations.

- Image files: Graphic and visual information stored in digital form that can be displayed, annotated, or manipulated by the image processing functions of CRISTAL.

- Text files: Descriptive information stored in standard ASCII format, including information created with the built-in CRISTAL editor, or generated by another word processing, database, or spreadsheet system.

Macro Language:

Macro commands are the heart of the application development capabilities of the CRISTAL System. These command statements can access, activate, and control any of the functions of the keyboard or menus, as well as other specific built-in or user defined routines in the macro library. Macro statements enable CRISTAL to perform user programmed operations, such as menu selections, operation specifications, or data input, that can be tailored for specific applications.

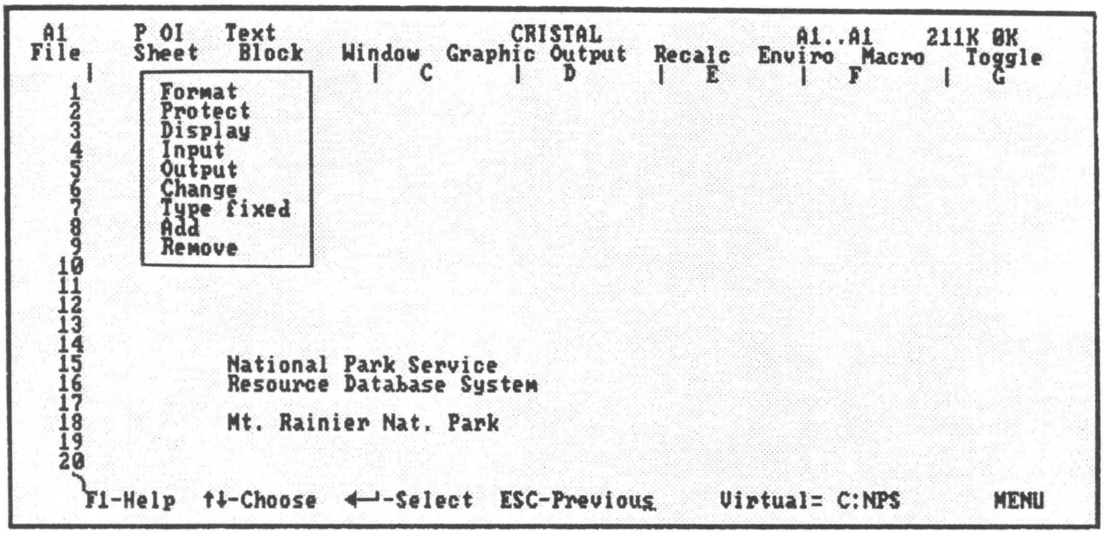


Figure 19. The CRISTAL Authoring Environment: The display of the "Sheet" function menu.

The ability to provide "data links" allows CRISTAL to integrate information in various forms into a common reference database. Different data types can be linked together by implementing a unique set of macro commands. These macros include operations for loading or saving a spreadsheet, image, or text file, sorting and querying a range of cells to form a database, and subroutines to provide users with a menu system for accessing information nodes. Links between data files are created by coordinating the execution of a user implemented macro sequence that activates the nodes specified in the macro statements.

An example of a CRISTAL data link application is the resource database created for the National Park Service (NPS). This Mt. Rainier National Park (MORA) prototype consists of a database of images and associated tabular information describing the park's historic building resources (Staehli and Kennedy, 1985). A list of descriptive image titles is entered into cell blocks in the spreadsheet, along with a key code that can be used to specify search and sort criteria, and a macro set for linking specified files to other data files. An initial macro execution presents the user with a menu of operations that can be implemented for the database, such as "Insert" and "Delete" records, "Search" for a record, and "Sort" records. If the Sort command is selected first, the list of images is sorted by using the key code to position the image titles in an ordered fashion according to user preference. With the Search command, the user specifies an image title as a search parameter. When a match between the search criteria and an image in the library is found, the image file loaded from memory and displayed on the graphics screen.

Graphical Interface:

An integrated videographic data management system such as CRISTAL can also facilitate access to information in a database by use of a visual (iconographical) interface. By using the Screen Map feature of CRISTAL, image icons and other component parts of an image can be linked to macro commands in a worksheet. When in the Screen Map mode, an image icon displayed on the

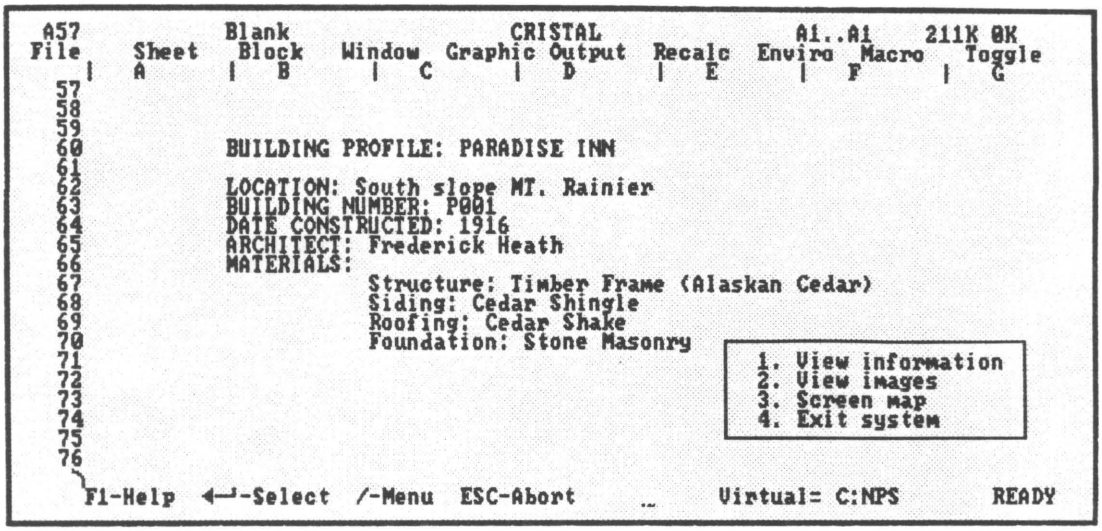


Figure 20. A CRISTAL Information Screen: The display of an Application menu for the Mt. Rainier Prototype.

graphics screen is selected by positioning the mouse controlled cursor on the icon and pressing the right mouse button. The macros in the worksheet that correspond to the icon location in the graphics screen are then executed. These macro commands activate a predefined event or sequence of events, such as:

- displaying an image or a series of images in the graphics screen that are related to the selected graphic icon;

- displaying a worksheet or series of text files containing construction, assembly, or task specifications, descriptive commentary, or numeric data;

- displaying another Screen Map of image icons to provide access to another visual representation of the structure of the information base.

It was this graphical interface strategy that provided the structure for the development of an integrated resource information base for Mt. Rainier National Park. In this prototype application for the National Park Service, reference data pertaining to individual natural and cultural resources, such as statements of significance, descriptive summaries, and dimensional data, were stored in the system's worksheet environment. These data fields were linked to other text files and to the image database through the Screen Map icons in the graphics environment. Macro sequences were developed to allow the user a high degree of discretion in visually interacting with (accessing and displaying) the information base. Image processing capabilities permit the system user to annotate and graphically manipulate individual images, and to overlay or combine component parts of various images to form a single integrated image that addresses particular diagnostic, analytical, interpretive, or prescriptive concerns. The information base can be classified (dissected) to an increasingly particular level of detail by implementing additional layers of icon activated worksheet menus. However many layers constitute the system structure, the user employs the mouse cursor to interact with the graphical prompts (icons) of the Screen Map to navigate the desired path through the contents of the information base.

Analysis:

In addition to the assembly of an information base consisting of graphic, text, and numeric data, visual data analysis processes can be implemented to provide a greater understanding of the architectural resources being documented. Videographic and image processing software can assist in the analysis of digital images in two basic ways:

- graphic simulations of architectural resources that depict historical or proposed modifications through image manipulations;

- dimensional analysis of architectural resources by using videographic methods based on planar geometrical constructs to extract dimensions from an image.

Graphic simulations are useful in re-creating the past appearance of an architectural resource, or in depicting the visual impact of contemporary design proposals. Using the image processing capabilities of the prototype system, the colors, structure, and form of a building image can be restored according to evidence gathered from various analytical techniques and historical reference sources, such as photographs and sketches of the building's original appearance. This simulation method was used to depict the historic appearance of the Hull House, a c.1840 "dog-trot" cabin, by using the Truevision Image Processing System (TIPS) software from AT&T Truevision. The TIPS software provides the capability of painting over an image, cutting and pasting pieces of images together, manipulating image colors, and other image processing functions. Based on the historical evidence, an image of the original Hull House was created by using the TIPS software to edit and manipulate images of the existing house. The processed image was then stored as a new, individual

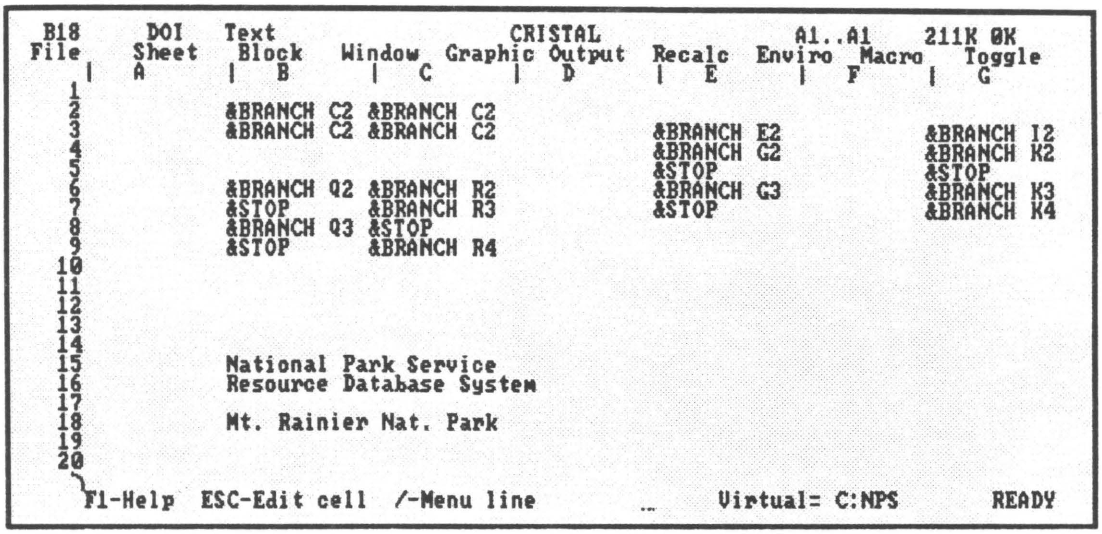


Figure 21. The CRISTAL Worksheet Environment: The display of macro commands for a mapped graphics screen.

file in the information base to serve as a visual reference to supplement the Hull House historical record.

Videographic dimensional analysis is a process which allows dimensional information to be extracted from digital images. This dimensional data establishes a foundation for creating measured drawings or 3-D model representations of an architectural resource. The Videographic Computer Assisted Designer (VCAD), a 2-D and 3-D videographic analysis system currently being developed by VideoCad Inc., was selected for the research effort. The VCAD System has the capacity to construct the necessary geometry for extracting dimensions from digitized (raster) images. A 3-D reference stadia is included in the video recording of each of the building views to be dimensioned. To facilitate retrieval, these key reference views are assigned labels when they are digitized from the videotape source and stored in the digital database.

The VCAD dimensioning process begins with locating and marking the control points on the reference stadia in the digital image. This establishes the basis for the computation of a dimensional grid overlay. Each of these control points is located using a mouse cursor to indicate the reference targets on the stadia. The marking of the control points enables the VCAD software to compute the planar grid construct that is used to calculate dimensions. The computed grid consists of three planes, each of which can be used as a dimensional field: left of the stadia, right of the stadia, and the ground plane. Because the computed grid is a three dimensional construct that can be moved and rotated, the stadia generated grid needs only to be defined once for each image in the database.

Once the planar grid is constructed and adjusted to a known baseline dimension, dimensions can be extracted from the image by using the mouse cursor to mark the two end points of a desired vector that lie on one of the defined planar surfaces in the image. The software computes the actual distance between the two points, as well as the absolute horizontal (X) and vertical (Y) differentials. Component parts of a building image that do not coincide with any of the planes can be dimensioned by adjusting the location or orientation of the grid to coincide with the appropriate planar surface. In order to accommodate this planar variety in any given image, the dimensional grid can be manipulated in three basic ways:

- moving the grid along an X,Y,Z axis to align one of the grid planes with a surface in the image that contains the vector to be measured;

- rotating the grid about an X,Y,Z axis to align one of the grid planes with a surface in the image that contains the vector to be measured;

- extending the grid to allow the dimensional analysis of elements that are located outside of the geometrical construct generated by the original orientation of the stadia.

The dimensional values extracted from the image are reported to the user (displayed on the graphics screen) as an (X,Y) coordinate readout. If desired, the values can be accumulated, or stored, in a predefined numeric database. Dimensions can be organized in a spreadsheet so that quantitative analysis of various building characteristics, such as surface area calculations, can be performed. The dimensional values can also be stored in database records that contain associated information, such as material types. This makes it possible to generate reports for material lists, cost estimating, and specifications. Analyzing the images in the database and obtaining the dimensional results is the final stage in the videographic data acquisition process.

Simulation:

Using the information that has been recorded, assembled, and analyzed by the three previous stages of the methodology, the complex 2-D and 3-D graphic characteristics of architectural resources can then be represented by computer aided design models and drawings. As-built drawings can be assembled and annotated with dimension strings and details that represent a complete, graphic record of the existing structure. The measured drawings also provide a foundation for the development of construction documents that can facilitate maintenance, restoration, and adaptive use projects.

The use of 3-D computer models provides the means to dynamically examine a building in the context of its site from various perspectives. The 3-D construct enables the system user to move around and through the simulated structure (computer model). Colors and textures can be applied to the surfaces of the computer model by using image processing techniques. This surface mapping enhances the realistic appearance of the representational form. Computer models, such as those created by the "Three-dimensional Object Processing and Animation Software" (TOPAS) from AT&T Graphic Software Labs, also allow the impact of contemporary maintenance activities, design proposals, and management strategies to be graphically simulated. The 3-D computer model of the building, as an independent entity in the resource database, can be used to produce accurate design development or production drawings (ie. elevations, plans, sections, etc.). These models and drawings can serve as a basis for design development, project presentation and review, marketing, and maintenance management.

The generation of CADD drawings represents the final component in the integrated videographic system of architectural data acquisition, analysis, and graphic representation. Considered as a whole, the proposed videographic method reflects the effective resource recording, management, analysis, and representational advantages that the image processing technologies hold for the architecture profession. The comprehensive information base assembled by the appropriate application of these technological tools can facilitate resolution of routine and cyclic maintenance, rehabilitation, and new construction issues.

4.2.6. Attributes

- The CRISTAL System integrates image capture, word processing, database management, spreadsheet, and graphics processing capabilities into a single software environment.

- An extensive, sophisticated authoring language based on macro commands is incorporated into CRISTAL to facilitate the development of tailored information management applications. The application authoring capabilities using the resident macro library make a variety of data management structures (including hierarchical and network) possible in application development. A system developer can structure the information in the CRISTAL environment to suit the nature of the information base and the specific application.

- Pull down menus enhance the user/machine interface and facilitate program operation, particularly for low end users. Rather than requiring users to type selected specifiers into the command sequence each time user input is required, CRISTAL permits the selection of commands and key words from menu lists displayed on the screen,

- Output of reports to disk file or printer is possible, which means that selected data can be readily integrated into external word processing files for developing specifications, work orders, historic structures reports, and preservation guides.

- The system interface is a "mapped" graphics screen from which the user activates information paths by using a pointing device (mouse) to select image icons.

- CRISTAL permits the application developer to structure associative links between information nodes. These links permit the user to browse through information paths, making it possible for the user to acquire knowledge by gaining an understanding of information contexts and relationships.

- The CRISTAL software can be adapted to a variety of hardware environments, enhancing upward compatibility and reducing risks of system obsolescence.

- Applications can be protected so that passwords are necessary to implement system modifications or annotations. This can ensure that system changes are executed by authorized operators who have the requisite knowledge of the CRISTAL macro language, and the essential expertise regarding the system's information base.

4.2.7. Limitations

- The current version of the CRISTAL program permits the construction of predefined relationships between data fields which cannot be modified by the application user. Dynamic network linking and "jumps" between information fields (nodes) are not possible. While a CRISTAL application can support a variety of predefined information manipulations, organizations, and displays, the prototype applications do not permit the user to dynamically modify or supplement information networks and relationships. The information nodes in the prototypes can be modified or annotated only under controlled conditions by an intelligent user with an operational knowledge of the CRISTAL macro language and its syntax. This means that user commentary cannot be appended to the information contained in the application.

- There are no path marking capabilities for creating information trails and communicating the sense of context, location, and orientation during information retrieval and synthesis.

- The system is not yet capable of dynamically merging raster and vector based graphics environments. The potential for integrating the Targa 16 with a CADD program in the CRISTAL environment holds promise as a powerful graphic simulation tool, and the system developers recognize the need to develop this capability. The program had not been developed sufficiently at the time that the prototypes were assembled to integrate a full feature 2-D or 3-D CADD program with the raster graphics of the CRISTAL system. The prototypes did allow the system user to manipulate and display raster graphics that were digitized with the Targa 16 or constructed with CRISTAL's built-in graphics processing routines.

- The image files created by the Targa 16 frame grab function are memory intensive, requiring approximately 418K of disk storage each for a full frame, uncompressed image file. Sophisticated image compression routines that can reduce individual image storage requirements by as much as 95% to 99% have recently been developed (i.e. "ALICE"), and these could greatly reduce the memory requirements of image based data systems.

- Data query capabilities are limited to the specification of a precise text or numeric search string. The queries are only as accurate and thorough as the ability of the user to specify the appropriate search criteria. Although the search specifications can be tailored to specific parameters, the query function ignores close fits and typographical errors. This constrains the access to information by demanding key word and syntactic accuracy in specifying search string criteria. This is a significant limitation, even though the system permits the use of a broad specifier vocabulary.

- The user of the CRISTAL prototypes remains unaware of the breadth of the information base because of the inherent difficulty in coherently communicating the complete data structure and the relationships that exist between the records and fields which constitute the database.

- CRISTAL is a spreadsheet based data management application in which structural relationships are transparent to the user. While the system can facilitate information dissemination from predefined data fields, no coherent sense of information structure is conveyed to the user during system operation.

4.2.8. Summary

The objective in the development of the CRISTAL prototype was to demonstrate an information management application which focused on the need to accommodate image acquisition, storage, and manipulation as an essential part of the preservation process. The CRISTAL environment permitted additional explorations into relevant issues concerning image analysis, processing, and integration. It was expected that the graphic techniques explored in the prototype applications would demonstrate their utility in preservation applications by serving as the basis for investigations into building techniques and materials, public perceptions toward existing cultural resources, the cumulative effects of historical change, and the effects of proposed management strategies and modifications on the contextual fabric of "place."

The mechanical framework for this prototype was assembled from technologies relating to videographics, computer-aided design, data management, and image processing. The configuration of the CRISTAL screen mapped prototypes encourage user interactivity with the information base primarily through graphical "browsing". At the most basic level of interactivity, the user can peruse information screens (text, numeric, graphic, image) that have been acquired from various media sources and merged into a digitally uniform, highly accessible knowledge base. Program calls to powerful graphics processors permit the user to construct sophisticated visual simulations of rehabilitation or restoration design proposals. With these capabilities, the CRISTAL system demonstrated that significant potential exists for image capture and processing technologies to contribute to the resolution of preservation information needs.

Because of the limitations of the hardware employed in this research (ie. image acquisition and resolution), the planar videographic dimensioning techniques that are used by the VCAD system do not approach the accuracy of photogrammetric methods. However, the VCAD system may be enhanced by the use of high resolution stereoscopic image pairs from metric cameras, laser calibration systems, and edge detection methods which have demonstrated potential for providing results with an accuracy of exceptional tolerance (within millimeters). Image resolution can be enhanced by using high resolution (1000-2000 dots per inch) digital scanners to transfer drawings, photographs, and slides into the computer, surpassing the image quality of the lower resolution "frame grabbing" process. In addition, opportunities for using high definition video, which can generate digital images with resolutions of up to a thousand lines per inch (or more), should be explored.

A major obstacle in assembling extensive information bases around video imaging technologies is that of permanent data storage solutions (relating to storage cost, volume, and retrieval time). Storage devices such as hard disks or optical WORM drives have inherent limitations in terms of storage capacity and access speed when handling high resolution image files, unless complex image compression techniques, such as fractal geometry algorithms, can be successfully incorporated into the system. There are additional storage and display technologies that represent promising alternatives to the methods explored in this research, including CD-ROM and erasable magneto-optical devices.

While data compression methods can improve upon these contemporary digital storage solutions, image storage on analog rather than digital media may provide a feasible storage alternative for the near term. Videodisc systems continue to offer significant advantages as an image storage medium. A twelve inch laser disk can accommodate 54,000 single frame images or 30 minutes of real time analog video recordings per side. The costs associated with videodisc mastering systems are declining, and systems (nonstandard format) are currently available in the twenty thousand dollar range.

At the current stage of system development, the process of creating computer models and measured drawings with videographically generated dimensional information is a cumbersome task. Whereas videographic dimensioning computes linear measurements that have to be manually accumulated, a Stereoscopic Coordinate System could produce actual three dimensional coordinate information. As dimensions are extracted from an image, this information could be directly imported into the graphic processing system to facilitate the construction of a 3-D computer model. Object oriented programming tools such HOOPS (Hierarchical Object Oriented Programming System) and

XPHIGS (Extended Programming Hierarchical Interface Graphics System) may be able to provide the necessary operational capabilities to support such modeling systems. These programming tools may also represent a common denominator for systems integration, allowing a variety of information types to be shared across different operating environments or systems.

As with any information management system, the operating systems and user interfaces must accommodate the myriad of inherent complexities with coherence, clarity, and (apparent) simplicity. The sheer volume of data resident in an extensive system, and the problem of integrating multiple data types into a unified environment, requires the consideration of alternatives to MS-DOS. Operating systems such as UNIX and OS/2 allow the computer to manage greater volumes of information than DOS based systems permit. For a fully integrated information system, an operating protocol must have the capability to process a multitude of information types, including raster images, vector graphics, analog video signals, and digital text, numeric, and audio data.

Information systems are currently benefiting from the growing availability of development platforms such as hypertext software. These efforts will soon lead to hypermedia environments that can process a vast amount of data in an array of formats, and provide user access to the information base with reliability, consistency, and order. Systems such as CRISTAL (VideoCad Inc.) are beginning to explore the possibilities of integrated information management by accommodating the processing and manipulating of a variety of data types. The development of the dynamic network linking and the ability to create information trails that are characteristic of hypertext systems will allow the CRISTAL System to achieve a comprehensive and efficient integration of knowledge communities in a cost effective environment.

The CRISTAL System is still in the developmental phase and has not yet been released commercially. However, applications using CRISTAL have been successfully developed for individual client applications, and the viability of the system as an information management shell has been corroborated. The research has demonstrated that applications appropriate to the needs of the preservation process can be assembled using the CRISTAL System.

4.3. PC-Hypertext

4.3.1. Introduction

At its most basic level, a hypertext system is a database management system that connects screens of information (idea nodes) by using associative links. A sophisticated hypertext system establishes an environment for professional collaboration, communication, and the acquisition of knowledge. (Fiderio, 1988).

In order to facilitate the research effort, the process of assembling the prototype hypertext system for historic preservation focused on a discrete preservation issue rather than the construction of a comprehensive information management application. The focal issue selected for the prototype was masonry deterioration problems and preservation treatments. The intent was to design a hypertext preservation information module which could serve as a model component for the assembly of a comprehensive preservation information system.

The information for the masonry module was derived from the Historic Structures Preservation Database of the National Park Service, from information assembled by the NPS Technical Preservation Services Division, and from publications by (Addleson, 1972), (Grimmer, 1988), (Oehrlein, 1980), and (Richardson, 1980).

4.3.2. Hardware and Software Requirements

The software system selected for this review of hypertext consisted of a family of three separate programs (MaxThink, HOUDINI, and HyperLink). This programming family permits an application developer to quickly design and construct a hypertext system with information storage and retrieval capabilities uniquely appropriate to the application requirements. These "off the shelf" software packages were developed by MaxThink, Inc. (Kensington, CA). An authored application can be compiled in PC-Hypertext using the HyperLink utilities, allowing the application to operate on a microcomputer running under the "MS-DOS" system with a minimum of 256K RAM and one 360K disk drive (depending on the size of the application) without a resident version of the MaxThink or HOUDINI software. Constructive modification of the information base (ASCII files) can be achieved by linking a word-processing program (text editor) to the authored application. By implementing the editor, a system user can update or annotate existing nodes, create new nodes, and create new nodal links. However, where the inviolability of information content and structure is at issue, the system developer can restrict access to the editing capabilities in the compiled PC-Hypertext program, making access to the development programs (MaxThink, Houdini) necessary to affect data content or structural changes within the information base.

The minimum configuration for the application development system requires DOS version 2.0 (or newer), 300K of RAM (random access memory), and two 360K disk drives. The more sophisticated the application, particularly in regard to graphics components, the greater the hardware requirements. For this research, the MaxThink software was installed on an IBM-AT compatible operating under DOS 3.1, with 1024K of RAM, a 20meg hard disk, and two (1.2Meg and 360K) disk drives.

4.3.3. Objectives

The objective of this phase of the research effort was to determine whether a hypertext system might represent an appropriate strategy for resolving the information management needs associated with the preservation process. The intent was to not only respond to the programmatic demands that guided the assembly of the HSPD (see 4.1.3), but to expand on its capabilities by implementing intuitive and discretionary navigation in an associative reference structure. The product was a prototype application that put preservation information into an accessible, integrated environment which allowed the system user to focus on the evaluation and synthesis of information rather than the gathering of information (Chignell and Lacy, 1988). The attributes of several hypertext systems were reviewed, and after assessing performance, user interface, availability, and cost, software developed by MaxThink Inc. (Kensington, CA) was selected for development of the prototype preservation information system.

4.3.4. Description

The MaxThink programs used in the prototype development were MaxThink (an outline builder or hierarchy manipulator), HOUDINI (a network manipulator), and HyperLink (file manipulation utilities). MaxThink provides the structure to support hierarchical or sequential organizations of an information base. HOUDINI provides the structure to link or reference associated ideas that transcend the hierarchical or sequential information organizations. Although both programs are primarily text based systems that manage ASCII files, recent enhancements permit the integration of graphic files in PC-Paintbrush (.PCX) format into the compiled PC-Hypertext environment. PC-Hypertext includes operational parameters which enhance the performance and versatility of the authoring environment, and facilitate the integration of authored applications with other programming and information processing environments.

Additional media management capabilities are under development and are projected to be available in the near future. These include the ability to link and cross-index information stored on

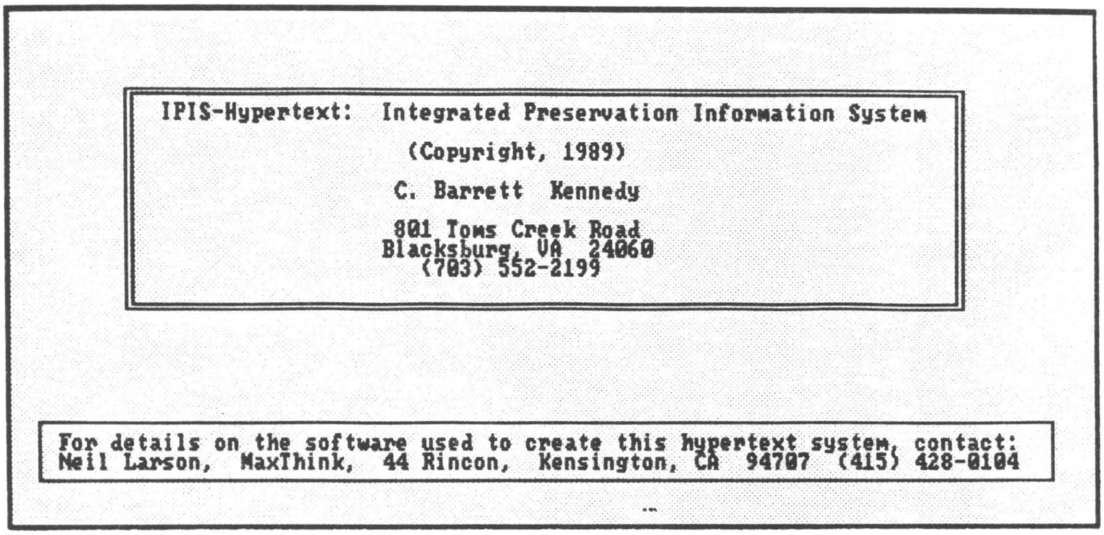


Figure 22. The IPIS-Hypertext Version Screen

CD-ROM and videodisc, an interface with vector graphics (AutoCAD), a software driver for the Targa series image capture boards (AT&T), and extended raster graphics linking and processing capabilities (Neil Larson: oral communication on 12/7/88).

4.3.5. Assembly

Hypertext construction entails the dissection of varied information resources into their component parts based on individual idea entities (nodes). The application development programs, MaxThink and HOUDINI, are initially used to create idea networks from this array of component parts. The PC-Hypertext utilities program, HyperLink, has subprograms (M2H and H2H) that translate the MaxThink and HOUDINI files into the binary file format of PC-Hypertext. The resulting hypertext information base can then be accessed by system users according to their individual needs and perspectives, enabling users to assemble information from the knowledge base in ways appropriate to their need or understanding of the subject matter.

There were five basic steps involved in converting the printed information resources pertaining to masonry into an electronic hypertext system using the MaxThink software:

1. The information was converted into digital format by keyboard entry and scanning. The scanner was an HS-3000 hand scanner capable of 400 dot per inch resolution with 32 gray tones (see Section 3.2.1 for a description of the HS-3000). The use of OCR (optical character recognition) software can greatly facilitate text conversion, eliminating much of the manual transcription of source information. Depending on the typestyle and the clarity of the original text source, the OCR software (CARETS/BY HAND DELUXE, Pattern Analytics, Inc., Raleigh, NC) has demonstrated exceptional accuracy in transcribing the ASCII files from monospaced and typeset (proportional) sources. Graphic information was scanned into a (.PCX) file format using the HS-3000 for future integration into the information base.

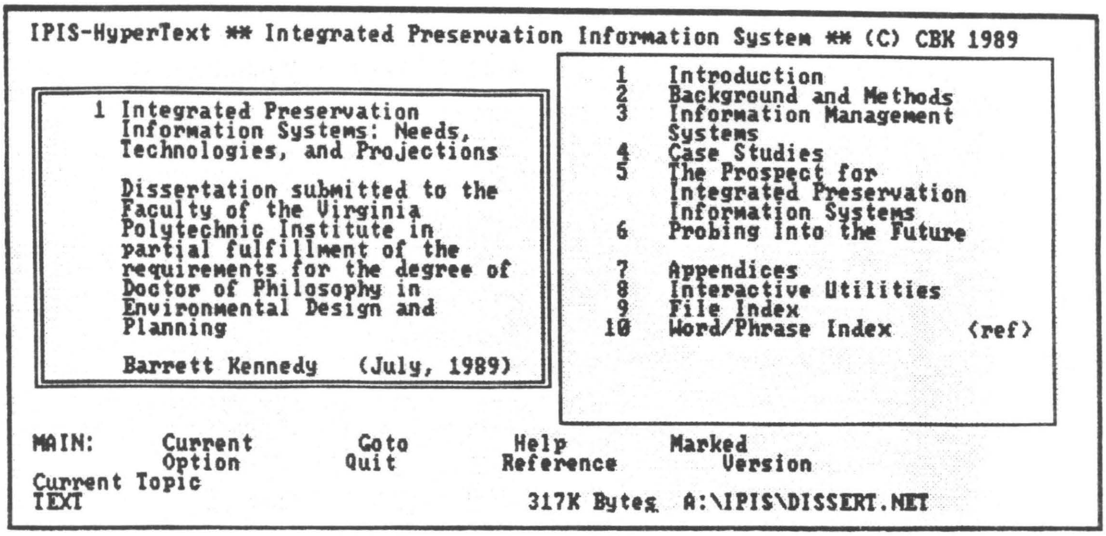


Figure 23. The Initial IPIS-Hypertext Screen: The primary level of the information network.

2. The digital information was parsed (partitioned) into individual nodes (ASCII and graphic files) according to a hierarchical structure derived from the primary reference sources (Richardson, 1980). Each file was assigned a descriptive label (descriptor that indicated the thematic or idea content of the file) and a filename. File size was determined by idea content, with each file representing a single idea as a component entity capable of conveying a specific sense of the contextual relevance and meaning of the information it contains.

3. Each file was assigned a minimum of three links: a reference to the preceding file in a nodal chain, a reference to the subsequent file, and a source reference (title, section, page number). Links were assigned by enclosing the referenced filename and its descriptor in carets "< >" at the desired location in the host file. Additional "explanation" and "choice" links were then added to each file as required. "Explanation" links occur within a paragraph of text, providing access to information supplementing the word or idea expressed at the point of reference. "Choice" links were displayed in lists at the end of a body of text, indicating access to a continuum of associated or parallel ideas in the network.

4. An index (master list) of ideas contained in each file of the system was assembled using Hyperlink utility programs. This step established the taxonomy of the information system. The MaxThink software provided several alternatives for building and validating index references and nodal links.

5. The idea nodes contained in the network were organized into several hierarchies in order to accommodate a variety of user perspectives and needs. By providing alternative paths for information retrieval, the system allows the user to make choices that best suit the context of current information requirements. Choices are designed to be clear and unambiguous, and the delineated paths are structured to indicate a sense of their destination. The intent is to infuse the system with a degree of predictability which will, through repeated use, convey an understanding of the comprehensive structure of the knowledge system.

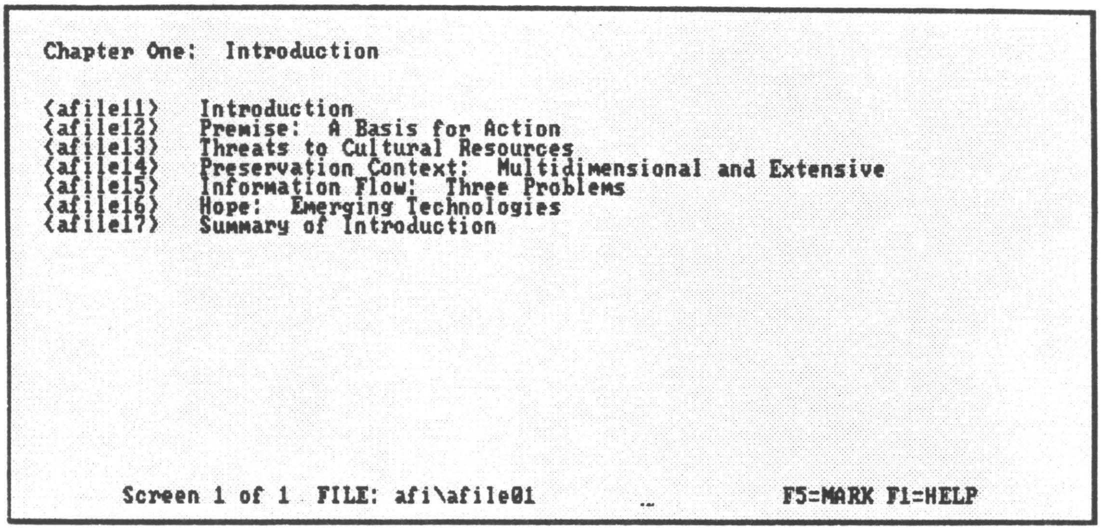


Figure 24. The Screen Display of Partitions for Chapter One (IPIS-Hypertext)

```
Cautions:

"We can anticipate calamities of the emerging, accelerating world
information systems -- sabotage, financial crashes, cultural
pillagings, faux news stories, entertaining dictators.  We must
hope that such information disasters occur early and often, so
that caution is built into us and into the systems." (Brand,
1988)

<ffile11>    A Look to the Future
<ffile15>    Moderation
<ffile20>    Information Glut
<ffile21>    Faux-tography
<ffile22>    Slickness
<ffile23>    Technology for Technology's Sake
<ffile24>    Artificial Intelligence
<ffile25>    Violations
<ffile26>    Computer Literacy
<ffile27>    Blind Faith
<cfile73>    Upward Compatibility

       Screen 1 of 1  FILE: ffi\ffile19        _         F5=MARK F1=HELP
```

Figure 25. An Information Node in the Knowledge Base (IPIS-Hypertext): Note the display of current screen, directory path, filename, and associative network links.

```
abuse of cultural artifacts       <BFILE27>  Public Education
access to preservation info.      <BFILE18>  Meeting Pres. Needs (Current)
accountability                    <BFILE27>  Public Education
Adams, Douglas                    <FFILE58>  StereoLithography
Advisory Council on H.P.          <BFILE15>  Assessments of Pres. Efforts
analog/digital converter          <CFILE47>  Frame Grabbers
analog/digital converter          <CFILE68>  Video Output
analog image data                 <CFILE42>  Data Acquisition
analog monitor                    <CFILE48>  Frame Grab Equipment
analog monitor                    <CFILE68>  Video Output
analog storage                    <CFILE64>  Analog Storage (Videodisc)
analog storage                    <FFILE42>  Analog Storage
analysis                          <BFILE30>  Design and Construction
animation                         <FFILE51>  Animation and 3-D Graphics
animation                         <FFILE52>  Real Time Motion
animation                         <FFILE73>  Historic Simulation
Annenburg ICPB Project            <CFILE55>  Effect of Interactive Video
annotating the decision path      <EFILE18>  Annotations
application development           <CFILE23>  CRISTAL System Macros
architects (technology)           <FFILE26>  Computer Literacy
archival durability               <CFILE61>  Optical Disk Storage
archival photographic films       <CFILE57>  Storage Format
archival stability                <CFILE56>  Data Storage
archival storage                  <CFILE62>  CD-ROM Storage
   ↓↓ Screen 1 of 38  FILE: ref                ...     F5=MARK F1=HELP
```

Figure 26. The Key Word/Phrase Reference List (IPIS-Hypertext)

The user's comprehension of the information structure is a fundamental objective of the hypertext concept. Inherent in that objective is the underlying principle of associative linking first articulated by Vannevar Bush in his description of an information system modeled on the associative thought processes of the human brain. If the system successfully replicates the associative structure of both the individual and the collective memory of the user group (mimics the way group members think as they review, discard, and select the information contained in the system), the system will possess the necessary degree of coherence, and enable the individual users to assimilate the knowledge base that constitutes the system. Understanding the structure of knowledge within the system is the means by which that knowledge is gained.

4.3.6. Attributes

- MaxThink offers a variety of alternatives for organizing, moving, and displaying information (ASCII text). MaxThink can use structural formats that emphasize either transitions (text), sequences (lists), similarities (hierarchies), or boundaries (segmented lists) (Larson, 1987).

- HOUDINI supports generalizing (automatic linking of shared information nodes), abstracting (hierarchical structuring to clarify relationships), completeness (identifying all potential nodal relationships, diminishing the possibility of unanticipated interactions between ideas, processes, or contextual environments), balancing (identifying the solutions that best respond to the context of the query), and indexing (organizing network information according to multiple criteria).

- PC-Hypertext can accommodate hierarchies and networks in a single application, capitalizing on the ability of hierarchical systems to successfully communicate information relationships, and on the ability of network environments to create a cross linked organization without regard to the hierarchical structure.

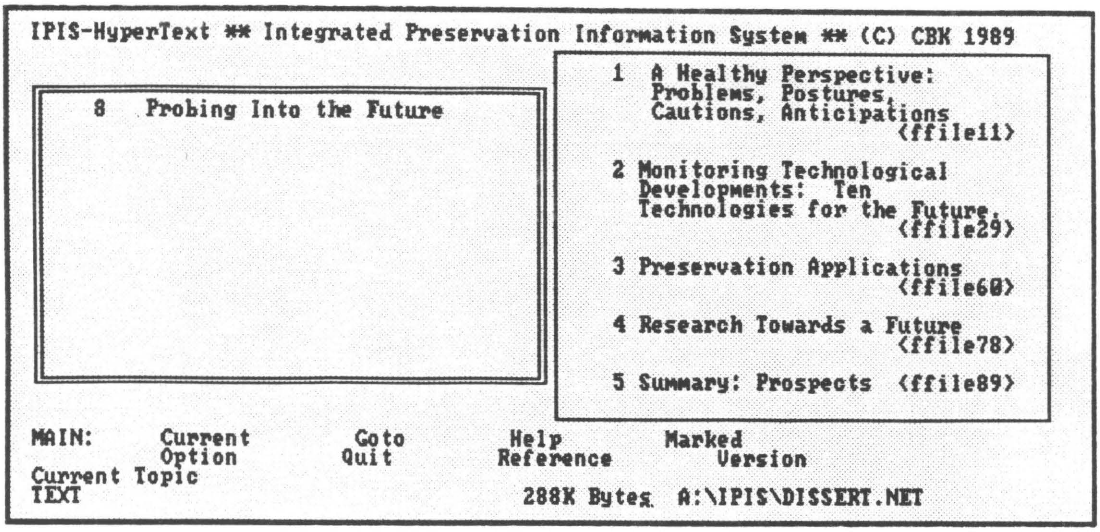


Figure 27. A Secondary Network Screen (IPIS-Hypertext)

- Links connect associated nodes (ideas) in PC-Hypertext. These links remain in place regardless of how many times the ideas are modified, moved, or changed. The development programs (HOUDINI, MaxThink) enable application authors to quickly construct or modify nodal links, and to merge or split nodes (idea topics) without invalidating the links that connect them. Utility routines can create associative links between topics according to the key words, text strings, or parallel existing links that are specified by the system developer. HOUDINI and MaxThink routines also permit system developers to test the integrity of the network links constructed in the system.

- While the modification or creation of associative links in PC-Hypertext is relatively simple, it is important to remember that effective hypertext construction depends on a highly structured information network that is based on the classification and associative linking of idea nodes that might span a broad range of information fields and subjects.

- The Main menu is always displayed as a hierarchical organization, yet it actually represents a network structure in its support of super-sets, loops, and dual path browsing. While PC-Hypertext displays only a hierarchical view of the information base, it retains the network path established by the current user in memory. The user can mark and save the current network path (using the [F5] key), or simply retrace (reverse) the current path by pressing the [Left arrow] key.

- PC-Hypertext can be configured to contain calls to DOS programs external to the authored application. When a system user activates a "program call", the PC-Hypertext program stores the information necessary to describe the current user location in the authored application, and then temporarily exits from memory. The system memory is then allocated in support of the external (called) program. When user interaction with the external program is terminated, PC-Hypertext is automatically reloaded to the system and the user is returned to the last active display prior to the implementation of the external program call.

- The PC-Hypertext System includes nominal security features to ensure the integrity of the system's data and as an aid to application developers and users. These functions corroborate the existence of idea nodes and create the network paths that link the associated ideas. These security functions primarily serve to protect the integrity of the hypertext application by informing application users of the status of system files. When the PC-Hypertext application is implemented, this rudimentary security system validates the requisite information files and the system structure as a guard against accidental or unintended corruption of the information base by negligent or uninformed users.

4.3.7. Limitations

- Weak graphics capabilities currently enable the MaxThink software running in a CGA environment to display only files generated in PC-Paintbrush. However, files acquired from other sources and translated into the .PCX format can be recognized by the PC-Hypertext program running in a VGA environment. An effective hypermedia system must be capable of managing a variety of media types, formats, sources, and storage devices. Attempts to establish standards for graphic processing have been problematical (a variety of formats are competing for acceptance in the marketplace), and low end systems have inadequate resolution and are not acceptable for image display and processing. Hardware demands for input, storage, and output are expensive (with a high possibility of rapid obsolescence as the technologies quickly evolve). However, cost effective strategies for implementing multimedia systems have been demonstrated. The PC-Hypertext system would have significantly greater utility for preservation applications if it had the graphics capabilities to display frame grabbed and scanned image files in .TIF, .PCX, and .TGA formats.

- In graphics based systems, command selection using a pointing device (mouse, track ball) can facilitate program operation. If the MaxThink system acquires more sophisticated graphics capabilities, a user interface that accommodates pointing devices will be essential. A graphical interface that employs icons to represent command selections can facilitate program operation for visually oriented users (architects, landscape architects), provided the icons accurately represent the information nodes and paths contained in the system. The danger implicit in the graphical interface is that the system becomes a celebration of graphics screens and image displays, and neglects the more substantial issues of information hierarchy and taxonomy.

- The most fundamental danger inherent in any hypertext application is that of labyrinthine paths that convolute the information structure and disorient the user to the context, content, and intent of the information retrieval objective.

- PC-Hypertext has no graphics display of the network of nodal relationships in the system. This means that user orientation must be derived from the ability of the individual idea nodes and the indicated nodal links to communicate the structure of the system. However, the user can retrace the current path, mark selected nodes as a reference trail, and jump to the title screen (and the display of hierarchical structure) at any point during system operation, mitigating the lack of a graphic system map. In fact, the complexity of a structural map for a large hypertext system can significantly diminish its effectiveness as a navigational aid. For example, a network of only 100 screens has the potential for 10,000 links. Although a system would be unlikely to contain such redundancy, it highlights the difficulty of coherent graphic mapping. Instead, the successful hypertext system should rely on a capacity to communicate and confirm the structure of the knowledge through the system semantics and the context of each information node.

4.3.8. Summary

The research effort provided valuable insight on the development of a hypertext application. The fundamental strategy guiding information organization was derived from existing masonry information resources. The prototype application established a common location, medium, and set of tools to enhance preservation research and information retrieval. Benefits from using such a system would accrue to high end users who suffer from fragmentation of tasks due to the disparate nature of the information resources that are necessary to ensure a well informed decision process. Less sophisticated users suffer not only from resource fragmentation, but possibly from ignorance of both computer and preservation technologies. The mystique of computer systems can also present a severe impediment to the uninitiated. The simple user interface of the PC-Hypertext program minimizes the time required for orientation, and the program includes a context sensitive "Help" facility. As a consequence, the compiled application accommodates users that might otherwise be intimidated by both the apparent and real complexities of computer information systems (Chignell and Lacy, 1988).

The key to successful application development and systems integration was the availability and suitability of the MaxThink software. The use of this "off the shelf" software permitted rapid prototyping of the information system, allowing the development of several iterations in quick succession based on evaluations of the design parameters and on opportunities for system testing.

While the capabilities of hypertext systems to create associative links between information nodes is significant, the essential value of nodal linking must be perceived as a component of a highly structured taxonomy of information. It is, in fact, the classification and organization of relationships between information nodes that is the foundation for the construction of effective hypertext systems. In building hypertext systems, the HOUDINI and MaxThink development programs are used to classify and organize the relationships between idea nodes. These development programs constitute the tools that structure the information (hierarchies and networks) within a system application. As such, they embody the fundamental means by which system users can ultimately access the knowledge contained in each specific application.

The hypertext environment of this MaxThink application was designed to serve the needs of a range of application users, from the computer jock to the computer neophyte. It was also intended to

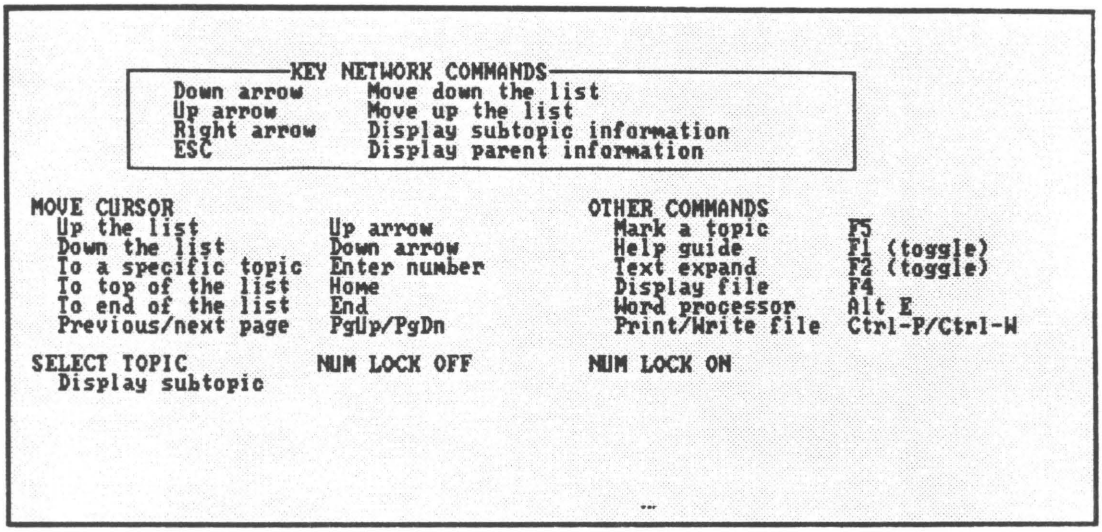


Figure 28. The Network Help Screen (IPIS-Hypertext)

```
                    KEY ASCII-FILE COMMANDS
   Down/Up arrow  Display the next/previous <filename> or screen
   Right arrow    Load the highlighted <filename>
   Left arrow     Load previously displayed file (8 remembered)

HIGHLIGHTER CONTROL - FILE SELECTION
   Move highlight down/up a line          Plus (+) / Minus (-)
   Load the highighted <filename>         Enter or Right arrow

CURRENT FILE CONTROL
   Display the first screen               Home
   Display the last screen                End
   Display the next screen                PgDn
   Display the previous screen            PgUp
   Show more right columns                Ctrl
```

Figure 29. The ASCII Help Screen (IPIS-Hypertext)

accommodate the information needs of both the skilled preservation professional and the amateur. The system has a simple interface that is intellectually coherent and appropriate to a variety of user types. The system design was intended to make the information structure easily comprehensible, and to accommodate a comprehensive preservation knowledge base relating to masonry issues. This design strategy permits the user to develop an understanding of system structure, while allowing system expansion and evolution. As users assimilate the technology, the information structure, and the knowledge base, operational shortcuts (hotkeys) and access to sophisticated information manipulation and annotation processes can make the system even more powerful in the hands of an experienced user.

The software and hardware environment is designed to accommodate modifications that will ensure upward compatibility as new products are brought to market. The current system is primarily ASCII text based, though it does have with some graphics capabilities (the system can retrieve and display PC-Paintbrush graphics files in CGA, EGA, and VGA environments). The ultimate objective is to develop a networked, interactive hypermedia system that fully integrates information from a broad range of image, audio, olfactory, and alphanumeric sources. The creator of the MaxThink software, Neil Larson, has indicated his intent to develop these capabilities in a hypertext (hypermedia) environment (Neil Larson: oral communications on 11/88, 12/88, 1/89).

The most recent update of the software (May, 1989) begins to address the graphics deficiency by permitting the display of files in the PC-Paintbrush format (.PCX) from the PC-Hypertext applications program. At the same time, the company has announced that imminent upgrades will include the capability to display graphics files in TIFF, Postscript, and NAPLPS formats, and to display information stored on CD-ROM and videodisc devices. Other projected developments are the graphic display of network relationships and flow diagrams. These capabilities would represent significant enhancements of the MaxThink system, and would establish it as a true hypermedia programming environment. In consideration of the other attributes of that this hypertext system

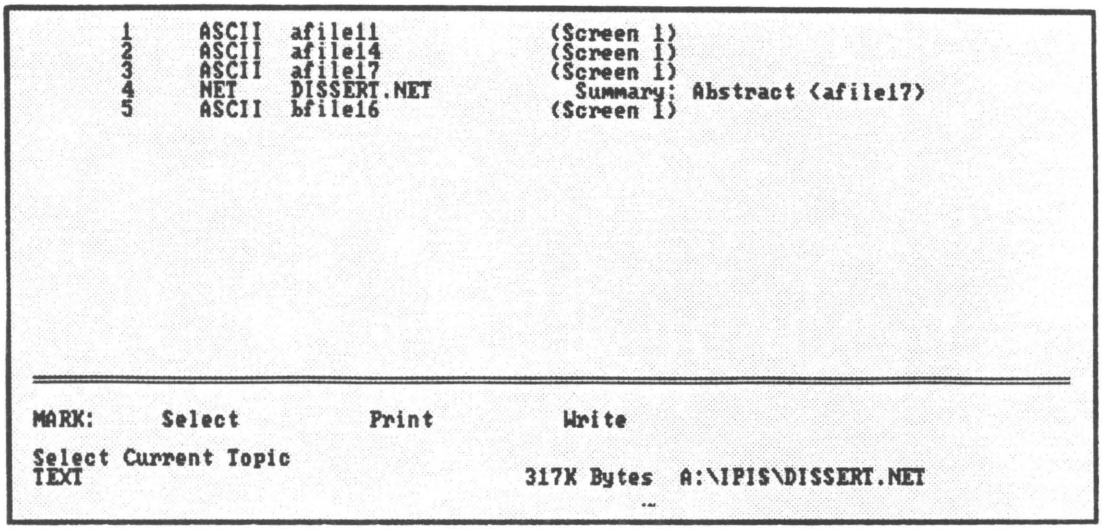


Figure 30. The Display of a User Marked File Path (IPIS-Hypertext)

demonstrated in the study application, these enhancements would make this system an excellent "off the shelf" solution for a broad range of preservation information management applications.

Chapter Five: The Prospect for Integrated Preservation Information Systems

5.1. Integrated Systems

The computer and its attendant technologies are grossly underutilized in the preservation process. Two primary factors are believed to be responsible for this deficiency. The first, an unfamiliarity of the target user group with the technologies, is a serious, but not insurmountable, obstacle. It results from a pervasive failure to comprehend the utility of the tools because of the mystique and misinformation that obscures them. This can be mitigated by improvements in user interfaces, instructional manuals, and tutorials. The second factor is more problematic. It constitutes a failure to develop an effective philosophical basis for integrating the multidisciplinary, information dependent activities and needs of the preservation process. It is hoped that the demonstration of the viability of integrated information environments will contribute to the development of a preservation paradigm based on the concept of a cultural ecosystem as a component of a global ecosystem, whereby the whole is greater than the sum of the parts. The investigation, testing, and adaptation of information technologies is a necessary prerequisite to an operational cultural ecosystem paradigm. The development of a structural foundation for integrating and promoting the information flow that would facilitate the articulation of the cultural ecosystem concept was the focus of this research. On the other hand, it may be that an enduring conceptual basis for CRM will only be realized through the programming and design of an effective Integrated Preservation Information System that brings diverse disciplines and interests together in collaborative CRM efforts.

There is an enormous inventory of hardware technologies and software development environments begging for tangible application. The rapid progress in hardware and software technologies (literally week by week) is outpacing the user community's ability to effectively assimilate these new developments into the work regime. With the broad adaptation of the rudimentary tools of computer processing (word processors, spreadsheets, database managers) in recent years, the preservation community on the whole has gained a modicum of computer skills. Yet, widespread recognition of opportunities to use the computer to develop a new preservation information management paradigm is still lacking. There is no effective, concerted effort by the preservation community to actively identify opportunities to adapt emerging computer tools to facilitate access to the broad knowledge base that will best serve preservation needs.

The paradox of the technological revolution is compounded by the fact that existing computer tools are underutilized due to a failure to accurately comprehend the scope and implications of preservation activities and needs. The primary attributes of the computer as an information communicator and manipulator make it a powerful and appropriate tool for information management. However, notwithstanding the sophistication of a technology nor its vintage, the keys to cost effective and successful application stem first from an understanding and articulation of user needs, and then from the ability to select appropriate technologies to resolve those needs. It is hoped that this research initiative can dispel some of the technological mystique from computer applications, encourage further efforts to make contemporary technologies the servant to the preservation process, and, above all, alert preservationists to the needs and deficiencies of the preservation process.

As the evaluation of information integration and management alternatives proceeded through the course of this research, an additional objective began to take shape in the context of contemporary, commercially available technologies and tools. This objective involved the description of an information management system that would utilize inexpensive "off the shelf" hardware and software. This objective focuses on the integration of proven, cost effective technologies to assemble electronic information management tools that can serve the tasks of the preservation process.

5.2. Design Parameters

The computer functions superbly as a medium for data integration with its capacity to gather relevant information from a variety of disparate sources into a single operating environment. In a digital environment, a broad range of information types can be gathered, merged, manipulated, and applied as an integrated whole to enhance the resolution of management tasks. The major deficiency in the PC-Hypertext and CRISTAL systems was the absence of audio and high resolution image data. Additional constraints that were encountered in the research included the lack of access to a representative range of storage and retrieval devices, and various software bugs, many of which were not resolved during the research.

The fragmentation of knowledge into different records, fields, and storage media creates many subtasks in the decision process. These subtasks include locating resources, developing a search (sort) strategy, collecting and saving information, annotating and organizing information, evaluating collected information for relevance and content, and the essential iterations of these activities to facilitate data synthesis, evaluation of alternatives, and the ultimate reporting of results. These final activities constitute the key components of the decision process. The objective of a computer based information management system is to relieve the system user of the cumbersome tasks associated with the searching and gathering activities. Rather, the organization of information resources into an accessible, integrated environment should allow the researcher (system user) to focus on the key aspects of the decision process, the evaluation, synthesis, and reporting of information.

The preservation decision process must be sensitive to the context of relevant issues and concerns. Criteria for the exercise of decision processes are variable, and the context of a particular cultural resource management decision is seldom fully replicated in subsequent decision processes. Individual users vary by virtue of their level of preservation expertise, general knowledge, and computer literacy. Even users of similar profiles can demonstrate a variety of preferences for decision methodologies. An effective information management system must therefore be as accommodating of user disparity, perspective, and discretion as possible.

Information Management:

In order to facilitate professional dialogue and exchange of knowledge through access to a shared information base, it is essential to mark an information path (audit trail) that documents each facet of a particular decision process and the unique perspective of the decision maker (ie. cost effectiveness relative to other possible choices; resource protection; threats to other resources; implications for other resources). Through the process of marking an information retrieval path, the rationale behind the particular decision can be evaluated from the perspective of the decision maker, and results measured against recorded intentions and expectations. This can facilitate assessment and evaluation of individual decisions and result in a greater understanding of the implementation of policies or management tasks by all levels of participants in the preservation process.

Similarly, by annotating the decision path and establishing the context of the choices made in the process, each management task can become, in effect, a case study which can contribute to subsequent decision processes. The ability to annotate the idea nodes in the knowledge base allows the system user to record the idiosyncrasies of the decision environment. Along with the obvious differentials embodied in the physical nature of a site, the effect of climate on materials, the availability of skilled craftsmen or experienced preservation contractors, and available project funding, annotations can accommodate an expression of cultural values as a reflection of decision idiosyncrasies. The significance of such user input is that it can record and celebrate individual distinction even as a shared knowledge base enhances information integration. This user enacted annotation is essential to the continuing growth of the knowledge base as an effective reference resource.

As interpreted by such electronic media proponents as author Stewart Brand, global interconnectedness is the ultimate objective of information integration (Brand, 1988). In the context of an increasingly integrated global information network, the enduring importance of individual experiences and personal values are increasingly at risk. Personal insight is testimony to the experience and judgment of the individual as important component of the decision processes. Conscientious annotation can capture the knowledge of the individual user, and an information environment that permits this minimal degree of interactivity can mitigate the loss of the nonrenewable (mortal) resource of individual experience and expertise. Annotation capabilities allow knowledge bases to become virtual compendiums of preservation information derived from highly personalized experiences. Electronic books of collective authorship may represent a means of capturing the varied experiences of numerous individuals (system users), and making a wealth of relevant preservation information readily accessible to subsequent users. This capacity to absorb supplementary information is an essential component of a knowledge system.

The whole array of emerging information management technologies offer unique opportunities to revolutionize cultural resource management. Preservationists must begin to view their needs from a better informed technological perspective. In understanding the potential for resolving needs through advanced tools and techniques, the articulation of appropriate preservation applications can begin to drive the development of accessible, cost effective tools and methodologies for preservation information management. In the assembly of a knowledge system, it is important to keep the appearance of the technology simple and user friendly. The specter of technological intimidation can result in user rejection, particularly by those users of minimal electronic sophistication. Preservation professionals must learn how to mold complex technologies into accessible, application tailored tools and methodologies. Above all, they must assist system developers in making the technologies of the hardware and software configuration comprehensible. The complex structure of the system, the hierarchies, and the links between information fields must be transparent to (and hidden from) the user, for it is the degree to which the end user finds the operation, setup, and maintenance of the information system simple and straight forward that determines the utility and success of its application.

A preservation information system, in accommodating a user base of various skills and capabilities, should have the capacity to define the degree of user interactivity. This would allow the application developer to control levels of penetration (level I, level II, etc.) into the information network according to user tasks and the complexity of the decision process. The levels of penetration might be determined according to levels of user responsibility. Annotation, commentary, and the risk of data corruption by unauthorized users could thus be eliminated. The use of simple password authorization represents at least a partial solution to this concern. Not only might passwords be required for system implementation, but appropriate user identification and date of access could be attached to marked decision paths and annotation nodes.

Contrary to the strategy espoused by the developers of "Artificial Intelligence" (AI) systems that are intended to have "decision making" capabilities, this research supports the role of the application user as the decision maker. It is the user (decision maker) who must be prepared to determine what information (assembly of associative ideas) is relevant to the decision processes. The discretion of the user defines an information path through the information base that is appropriate to the immediate context and task. At the same time, the marking, blazing, and charting of the information path can enable other users to review each decision process as a case study. Each marked path should communicate an understanding of the context of the associated decision environment. A path follower can adapt or deviate from a previously marked trail according to the demands of the user's current decision environment.

Similarly, in view of the rapidly changing technological context, it is important to focus on the assembly of components which will meet the required performance parameters, adhere to industry standards (*de facto* standards), and reflect the potential for system modification through upward compatibility. The rapid changes that are occurring in all facets of information technologies make any attempt to assemble the "definitive" information system a time consuming and ill conceived exercise in futility.

5.2.1. Attributes of Reviewed Systems

Each of the three systems reviewed in this research effort have demonstrated attributes which might contribute to the development of a more effective information management system. Since these attributes (and limitations) have been discussed in detail in Chapter Four, an abbreviated review of them will suffice as a prelude to the outline of operational parameters for an Integrated Preservation Information System.

HSPD Attributes:

- Coherent user interface; good documentation; rapid user learning curve for interaction with compiled application.
- System can be modified or expanded to accommodate additional data records and field types by any application user with knowledge of dBASE III Plus or dBASE IV (or compatible DBMS software).

CRISTAL Attributes:

- Integrated image capture, word processing, database management, spreadsheet, and graphics processing capabilities.
- An extensive authoring language based on macro command statements that facilitate the development of tailored information management applications.
- Coherent user interface with pull down menus.
- Generates reports to disk file or printer.
- Graphical interface alternative.
- Associative links between information nodes permit browsing.
- Adaptable to a variety of hardware environments.
- Security against accidental data modifications.

PC-Hypertext Attributes:

- Coherent user interface; good documentation; rapid user learning curve for interaction with compiled application.
- Rapid construction time.
- Variety of alternatives for organizing, moving, and displaying information (text and graphics files).
- Automatic linking of repeated information nodes.
- Hierarchical structure clarifies relationships between information nodes.
- Identifies potential nodal relationships to ensure completeness of associative network structure.
- User navigates system to identify solutions that best respond to the context of the query.
- Ability to index network information according to multiple criteria.
- Accommodates hierarchical and network information structures.
- Associative links between information nodes (ideas) permit system browsing, and the links remain valid when the nodal contents are modified, moved, or changed.

- Permits the rapid construction or modification of nodal links, including merging or splitting nodes (idea topics), and creating associative links between topics according to the key words, text strings, or parallel existing links.

- User can annotate or create new nodes and new associative links.

- Variety of utility software supports applications development and systems maintenance.

- Permits calls to DOS programs external to the authored application.

5.2.2. Limitations of Reviewed Systems

The reviewed systems all have limitations which must be avoided or mitigated in the assembly of an integrated knowledge base. Similar to the discussion of attributes, these limitations have been discussed in detail in Chapter Four, and an abbreviated review of them will suffice as a prelude to the outline of operational parameters for a new information management strategy.

HSPD Limitations:

- Construction time is long and cumbersome, requiring special knowledge and skills in dBASE programming.

- Uses a defined vocabulary (word list) which encumbers the access to information by demanding key word accuracy in specifying search criteria.

- Does not permit text string searches.

- No capability to display graphic files.

- A policy of modification and annotation only by the Keeper of the HSPD.

- Structured as a database of component text fields, not an information system based on associative ideas.

- Communicates no sense of structural (hierarchical or network) relationships between information fields.

- No pull down menus or word indexes to enhance user interface.

- Weak report generation capabilities.

CRISTAL Limitations:

- Construction time is long and cumbersome, requiring special knowledge and skills in the CRISTAL macro programming language.

- Annotations and modifications by application users are difficult.

- No path marking capabilities to create information trails.

- Not yet capable of merging raster and vector based graphics environments.

- Image files created by the Targa 16 are memory intensive, and adequate compression routines have not been integrated.

- Data query capabilities are limited to the specification of a precise text or numeric search string.

- Communicates no sense of structural (hierarchical or network) relationships between information fields.

PC-Hypertext Limitations:

- Weak graphics capabilities (display only PC-Paintbrush and Applause files).

- Keyboard interface (only) limits user preferences.

- Ease of associative link construction can result in an uncontrolled information environment (spaghetti code), causing convoluted information structure and disorientation of application users.

- No graphic display of the hierarchies or networks of nodal relationships in the system.

5.2.3. Synthesis

Introduction:

While the individual systems have distinct limitations, they all represent some degree of viability as data retrieval (HSPD) or information management (CRISTAL, PC-Hypertext) solutions for the preservation community. In addition, opportunities exist for the enhancement of each of these systems through software and hardware modifications. These modifications would redress at least some of the limitations associated with each system, and could make the systems more suitable for the preservation applications considered in this research effort.

However, rather than discuss particular system modifications that might quickly be invalidated in the context of ever changing performance parameters associated with computer hardware components and software packages, it is more appropriate to simply propose a litany of performance specifications that would effectively characterize a contemporary preservation information management system.

Performance Specifications:

The intention (and hope) of any system configuration is to make it as inclusive as possible of de facto standards and flexible enough to accommodate changes to hardware, software, and applications modifications.

The significant attributes of a successful integrated preservation information system include the accessibility, relevancy, annotation, linking, and adaptability of information. In the most basic system, these requirements could be realized in a structure of networks created by the cross linking of related idea nodes throughout hierarchies of information. The system should incorporate user controlled navigating and browsing capabilities, as well as alternatives for information retrieval such as indexing, word lists, and the graphic mapping of network paths.

The fundamental problem in setting up a comprehensive system lies in the design of the linking structure for the information base as a whole. This includes the development of a coherent data structure that can be modified by the user group (under security constraints) to accept new information nodes, annotations, and associative links. Hypermedia systems are progressing rapidly, and although it is unclear when a competent and coherent development platform will finally take shape, these systems offer considerable promise for accommodating these requirements in a fully integrated information environment. Even without strong graphics capabilities, the PC-Hypertext System utilized in this research demonstrated the capacity to effectively serve a broad range of information needs associated with the preservation process, and it is testimony to the promise of an emerging hypermedia paradigm.

A significant issue in the design of an information system is in its ability to grow not only through the addition of new information nodes, but by virtue of its very use. The interaction of each user with the system should contribute to the knowledge base as a whole. The ability of a user to mark and to annotate a decision path is essential to building a body of context sensitive decision paths. Each marked path (and its annotations) reveals the influence of natural, cultural, political, administrative, social, and economic circumstances on decision processes. As a whole, the marked paths reflect the context in which decisions are formulated, and they are the foundation of a "self informing" information management system that evolves through the collective expertise and experiences of its user group.

The system's capabilities for documenting user perceptions and experiences, marking context sensitive paths, permitting participatory research and interactive dialogues are particularly significant for an organization or agency that has a broad moral and legal preservation mandate. For example, in the context of National Park Service cultural resource management obligations, the need is clearly evident for an information gathering, management, and dissemination system that can ultimately represent the collective professional experiences of NPS historical architects (see Section 4.1).

A collaborative system with a broad based user network would facilitate the efficient access to the technical and nontechnical information that will enhance (inform) the preservation management processes which effect the integrity and viability of historic resources. It would lay the foundation for an effective networking of preservation management and research interests so that practical decision making experiences and case studies could be shared across the local, regional, and national spectrum.

The system could also facilitate the inclusion of the public in the decision processes that affect historic resources. The ability to convincingly depict historical change and simulate proposed design or management alternatives by using the videographic, 3-D modeling, and image processing capabilities promises to make the public a better informed participant in the cultural resource management process.

A viable image management capability requires sophisticated compression software that can reduce digital image file size by more than 99 percent (and decompress files within 1/30 second) if real time video and high resolution images (500 to 2000 lines) are to be practically accommodated. Software with these capabilities is currently in development by a number of companies (Intel, Philips N.V., Sony). Although such products are computer intensive and require considerable processing power, the combination of hardware (chip speed, parallel processing, storage technology) and software (compression and decompression algorithms) advances should combine to make cost effective commercial products suitable for sophisticated image management applications available in the near future.

5.3. Hardware and Software Configuration for a Prototype System

A variety of possibilities exist for the assembly of a computer information system that can effectively address preservation issues. In view of the attributes and shortcomings discussed above, a cost effective system of exceptional information management capabilities would have the following components if it were to be assembled today (June, 1989).

5.3.1. Hardware

Intel 32-Bit 80386 20MHz Computer: (80 meg fixed disk, 4 meg ram, VGA graphics card with integrated frame grab capabilities, VGA monitor, serial card, mouse)

AT&T Targa 16 Video Capture Card

RGB analog monitor

WORM optical disk drive (800 meg)

S-VHS Video Camcorder

S-VHS Video Cassette Recorder (w/signal encoder and interface)

Digital Still Frame Camera (w/playback capability)

Optical Scanner (300dpi, flat bed)

Laser Printer

Thermal Color Printer

Film Recorder

5.3.2. Software

AT&T TIPS: Image processing software

AT&T TOPAS: Modeling software

MaxThink System*: Hypertext software

CRISTAL System**: Information processing software

VCAD**: Videographic processing and dimensioning software

CARETS/BY HAND DELUXE: Optical Character Recognition (OCR) software by Pattern Analytics,Inc.

* The PC-Hypertext family of software programs (MaxThink, Inc.) holds significant promise as an integrated information management system. The primary handicap that currently limits the application of this system for preservation applications is its relatively weak graphics capabilities. However, the most recent update of the software (May, 1989) does address this deficiency by permitting the display of graphics files in the PC-Paintbrush format (.PCX) from the PC-Hypertext applications program. At the same time, the company has announced that imminent upgrades will include the capability to display graphics files in TIFF, Postscript, and NAPLPS formats, and to

display information stored on CD-ROM and videodisc devices. Other projected developments are the graphic display of network relationships and flow diagrams. These capabilities would represent significant enhancements of the MaxThink system. In consideration of the other attributes of that this hypertext system demonstrated in the reviewed application, these enhancements would make this system an excellent "off the shelf" solution for a broad range of preservation information management applications (see Section 4.3).

** The CRISTAL System and VCAD (VideoCad, Inc.) are still in the developmental phase and have not yet been released commercially. However, applications using CRISTAL have been successfully developed for individual clients, and the viability of the system as an information management shell has been corroborated. Additionally, this research has demonstrated that applications appropriate to the needs of the preservation process can be assembled using CRISTAL (see Section 4.2).

5.4. Summary

The key components of a basic contemporary system would consist of an S-VHS video camcorder and a digital camera for resource documentation (using the S-VHS tape as the primary resource for storage of field data), a flatbed and/or a hand scanner for text and 2-D graphics data acquisition, OCR software, the CRISTAL System (or the PC-Hypertext System) for information management and processing, the WORM drive for archival storage, and the S-VHS VCR, film recorder, thermal printer, and laser printer for information dissemination.

A more sophisticated configuration would be a complex hybrid, incorporating a videodisc system containing predefined libraries of still image frames, audio frames, and full motion audio/video segments, and CD-ROM based digital audio, text, and numeric data as reference resources in meeting repetitive or generic requirements.

Chapter Six: Probing into the Future

6.1. Considerations

"This century will see changes that will dwarf those of the nineteenth century, as those of the nineteenth dwarf those of the eighteenth." (Wells, 1902)

6.1.1. Prediction Problems

"Everything that can be invented has been invented." (Director of U.S. Patent Office to President McKinley, 1899)

"The radio craze will die out in time." (Thomas Edison, 1922)

"Video won't be able to hold onto any market it captures after the first six months." (Darryl F. Zanuck, 1946)

"Five computers will satisfy the world requirements for the foreseeable future." (Thomas A. Watson, IBM Corp.)

The Mercedes-Benz Corporation did a study at the turn of the century (1900) that estimated the worldwide demand for automobiles "would not exceed one million, primarily because of the limitation of available chauffeurs" (Brand, 1988). This prediction was based on the assumption that only people who could afford chauffeurs could afford automobiles, and that driving a horseless carriage would require as much skill as driving a horse and carriage. In 1968, the same kind of rationale prompted an optimistic RCA Corporation to predict that there might be as many as 220,000 computers in the United States by the year 2000. Computers were large, expensive, highly complex electronic devices that required considerable operator skill. Unanticipated advances in the electronic technologies over the past twenty years were as dramatic in their impact on the computer and computing applications as the electric starter and the assembly line were on the automobile. As a result, the estimated number of computers in the U.S. today (1989) is 45 million (Miller, 1989). RCA is no longer in the computer business.

Endowed with the benefit of 20/20 hindsight, astute scholars can often perceive an apparent discrepancy between past predictions and the actual course of history. The myopic view of experts and public administrators notwithstanding, more visionary technological forecasts are frequently made in the spirit of a blind religious faith in unrelenting, unimpeded "progress", and they can seem outrageously optimistic in the context of the times. Yet, as political scientist Jim Dator has asserted, "projections about the future are really more about the present than about what is likely to happen in the years ahead" (Marien and Jennings, 1987). Consequently, the forecaster more often than not grossly underestimates the true course of scientific and technical advancement.

It is evident that accurate prognostications are difficult at best. In view of the rapid advances in communications and computer technologies, simply staying informed of current opportunities is a significant task. Effectively assimilating the actual technology into the workplace constitutes yet another order of magnitude in terms of the difficulty of the challenge. However, in order to prepare for future opportunities and needs, it is important to project scenarios not necessarily for "the" future, but for a variety of possible futures based on perceptions of technical trends and opportunities. These perceptions must reflect an informed historical perspective derived from an understanding of events that cast unanticipated opportunities and constraints in the path of attempts to fulfill the forecasts of an earlier time. An historical perspective can contribute not only to the formulation of technological strategies for design and planning, but also to an understanding of the social, economic, and cultural implications inherent in proposed technological scenarios.

Moderation:

> "Too much of anything wonderful becomes terrible. Part of the real research on any new good thing is discovering how much is too much, how fast is too fast." (Brand, 1988)

In addition to the effort to anticipate the future, contemporary society would be well advised to moderate the desire for immediate application of emerging technologies. Elegant technological tools of extraordinary capabilities are available as proven solutions to many of the computing needs of cultural resource management. In fact, many existing computer technologies are underutilized by not only the preservation community, but in the broader commercial marketplace. Existing products and systems offer more processing power than most users have effectively assimilated into their work regime. Even as the pace of technological change and the growth of user markets accelerates, the apparent change in the marketplace is more a reflection of attempts to celebrate the "sizzle" of technology than accommodate the fundamental needs of end users.

There is no compelling rationale to justify the race to match contemporary use with technical advancement stride for stride. This compulsion more accurately reflects a syndrome of "technology for technology's sake". While many emerging technologies present wonderful potential for innovative applications, they are invariably complex, poorly understood, and wrought with bugs and unforeseen complications that disrupt a premature attempt at application. Often the need for the technology is inadequately defined, and the development of effective applications usually entails a costly and frustrating process. If an emerging technological tool does in fact represent substantial potential to enhance some aspect of the work regime, then it must be developed through a rational research process that will yield carefully crafted and reliable commercial products. Contemporary society must devise coherent strategies for assimilating technological achievements through a thoughtful, productive pacing of technological application. As Stewart Brand expressed so concisely in ***The Media Lab: Inventing the Future at M.I.T:*** "It's a way of probing into the future instead of lurching there" (Brand, 1988).

6.1.2. Active/Reactive Postures

> "The sociological problem we face in guiding developments in this area is society's propensity to wait to be negatively impacted before taking notice, and to attempt after the fact of the negatively impacting reality, to correct the situation rather than taking a pro-active stance." (Joseph, 1987)

How can we use the computer to better serve preservation?

Preservation professionals need to gain a better understanding of the specific information management needs of the preservation process, and of the opportunities that contemporary technologies represent as solutions to those preservation needs. As a consequence, the preservation community will be able to effectively define and articulate the basic concerns to be addressed through the process of technology transfer. In expressing these concerns, it is essential to anticipate the range of future issues that will confront the CRM process. A new statement of "(Cultural) Rights and (Preservation) Grievances", modeled on the Venice Charter, would give the whole of the preservation community a basis for acting with a single voice. With a well defined foundation, CRM professionals can begin to understand more coherently the present and future dangers that threaten to diminish the integrity of historic resources, and thereby devise viable strategies for mitigation and resource protection. By this act of anticipation, the preservation community can assume an active rather than reactive posture in forcefully preserving this nation's cultural heritage.

The major deficiency in this process is the fact that, on the whole, current methods and techniques of the CRM process are archaic, costly, and cumbersome. The very failure to effectively assimilate contemporary technological tools into the preservation process is itself a significant threat to the integrity and continuity of a cultural heritage. Rather than acquiesce to the eventuality of facing guns with spears, preservationists must acquire the necessary skills that can ensure thoughtful adoption of emerging electronic tools to the tasks of the preservation process. Only then will a resounding cry of "To arms!" find preservationists reaching into an appropriate technological arsenal. By conscientiously projecting preservation needs and the promise of electronic technologies to resolve those needs, the preservation community can be conditioned to recognize and capitalize on those technological opportunities that will facilitate active resource management efforts.

6.1.3. Cautions

> "We can anticipate calamities of the emerging, accelerating world information systems -- sabotage, financial crashes, cultural pillagings, faux news stories, entertaining dictators. We must hope that such information disasters occur early and often, so that caution is built into us and into the systems." (Brand, 1988)

Information Glut:

> "... mankind's unthinkably complex consensual hallucination, the matrix, cyberspace, where the great corporate hotcores burned like neon novas, data so dense you suffered sensory overload if you tried to apprehend more than the merest outline." (Gibson, 1987)

A paradox of the Information Age has become manifest between an increasingly accessible global information network and the inadequate means of determining information relevancy for the end user (audience). For example, news editors determine what information is retrieved for publication from the information networks and wire services. Because of space and budget constraints, it is estimated that a maximum of 10% of the available information is actually published, and that only 10% of published news is relevant to the individual (Brand, 1988). As technological advances have enhanced the capacity to gather and disseminate information resources, the Information Age has spawned an information glut. Yet, in spite of the massive volumes of information available to decision processes, the individual is still not assured of its relevance nor its completeness in responding to a specific decision context. The relevancy and completeness of retrieved information is of critical importance in the ability of contemporary society to effectively harness the technological opportunities of the Information Age. The seriousness of the issue is gaining broader recognition as information overload threatens paralytic consequences for decision processes.

Faux-tography:

> "Once this new technology gets out there, we're going to have a helluva time telling what's real and what's unreal." (Tom Wolzien, vice president at NBC: Brand, 1988)

Image processing technologies have made it possible to manipulate the content of digitized film and video sources so that it is virtually impossible to distinguish between factual and fictitious representations of events. Digital images are comprised of thousands of component parts called pixels (picture elements). Each pixel can be individually modified in terms of color, brightness, and density. This means that a system user can seamlessly edit digital images, changing the information content by deleting existing components, modifying the interrelationship of component parts, or by merging new information into a scene. Even the ***National Geographic Magazine*** has used the technology to manipulate two Egyptian pyramids in order to make a stronger graphic composition for the cover of the publication. It's clear that the technology can be effectively utilized for more sinister objectives by less scrupulous end users.

Slickness:

> "This system is made possible by the same fact that enables Ecotopian book publication to be so much more rapid than ours: authors retype their edited final drafts on an electric typewriter that also makes a magnetic tape. This tape can be turned into printing plates in a few minutes, and it can be simultaneously fed into the central storage computer, so it is immediately available to the printout terminals." (Callenbach, 1975)

Desktop publishing and CADD systems, benefitting from a plenitude of highly sophisticated graphic and typographic capabilities, and enhanced by the development of low cost laser printers, multicolor plotters, film recorders, and color thermal printers, represent a dangerous potential for subordinating content to packaging. The skillful use of the text formatting, graphics processing, and output capabilities of relatively inexpensive computer systems can produce a slick memo, newsletter, or pamphlet with minimal effort and cost. As a result, the production of reports and reference materials with a professional, authoritative appearance proliferates, and it becomes increasingly difficult to distinguish between credible and specious information resources.

This cautionary observation reveals another fundamental paradox of the Information Age. While contemporary technology permits the professional looking publication of virtually everything written, not everything written should be published. Notwithstanding those who would intentionally mislead or misinform a target audience, editors must play a key role in making this determination of the credibility and accuracy of the published information. However, by providing direct user access to primary sources in a global information network, individual discretion may play a larger future role in judging the relevancy and veracity of information content.

Technology for Technology's Sake:

> "... we buy what we like and believe we can build, rather than what we need." (Cetron, 1985)

Another pitfall of human innovation is the adoption of an alluring new technology in the workplace simply because its new. The inappropriate application of any technology can result in excessive (or inadequate) capability, complexity, and cost relative to the programmatic needs of the designated user group. Because of a misunderstanding of user needs or a failure to match programmatic requirements with technical capabilities, the electronic technologies of the Information Age are often unable to resolve the targeted information management problems. The capabilities of the technologies themselves are often misunderstood by users or misrepresented by overzealous manufacturers and distributors. In an effort to stay competitive (or to gain an edge), developers and users alike often rush to adopt technical solutions before the application protocol is fully articulated and the programming bugs are resolved. Technologies that are not yet ready for market applications are promoted as "state of the art" solutions. As a consequence, instead of contributing to the resolution of needs, they are more likely to become a major part of the problem.

Artificial Intelligence:

> "Anything that you hear about computers or AI should be ignored, because we're in the Dark Ages. We're in the thousand years between no technology and all technology. You can read what your contemporaries think, but you should remember they are ignorant savages." (Minsky in Brand, 1988)

Expert systems are artificial intelligence systems that are intended to facilitate the data synthesis and the resolution of management problems. They embody the tasks that the computer does best, the rapid and accurate retrieval of information from a massive memory. Sophisticated expert systems that extract knowledge from a large information base are being developed to supplement human expertise and judgment in a variety of applications.

As decision tools, expert systems are designed to apply inference engines to a knowledge base in response to user specified criteria. By comparing these criteria with a set of predefined system rules, action alternatives sensitive to the context of the user's query are retrieved from the knowledge base. Some systems are self-informing, expanding with the information input of each use. Some can calculate the statistical probability of particular diagnostic processes. However, highly complex expert systems with an extensive rule base have proven to be costly and time consuming to assemble, and as yet, they have not matched the associative thought processes of the human mind. In view of the capabilities of current technologies, an appropriate objective of these systems is one of informing the decision process, not supplanting it.

Violations:

> "All the chemical and energy activities in a body (or a society) have a word for their sum action -- 'metabolism' -- but there's no equivalent word for the sum of communications in a system. The lack of a word signals a deeper ignorance. We don't know what constitutes healthy communications." (Brand, 1988)

As society becomes more interconnected by virtue of massive information networks and shared databases, the danger of information corruption increases dramatically. The threat of proliferating software viruses represents the darkest side of electronic information exchange. Precautionary measures dictate that the individual user, as well as the systems operator, religiously maintain standards that will guard against system corruption and data loss. Information sources should be checked before entry into the system, and data integrity should be corroborated. It is critical to backup (archive) information resources and to routinely maintain the backup system. These standards are intended to guard against both the intentional and accidental compromise of system integrity, and to ensure the optimal responsiveness of the system in fulfilling design parameters.

The whole of the process is analogous to sailing. A considerable interactive effort is required to attain an objective in variable winds and treacherous waters. With the activities of trimming sheets, piloting, identifying hazards, selecting a course, and adding or reducing sail occurring above and below decks, a concomitant effort to reduce the clutter generated by systems operation is essential. Maintaining a shipshape vessel ensures the capability to respond quickly and efficiently to navigational problems, opportunities, and desires. If the attempt to master the wind fails completely, a motor constitutes a sensible, and welcome, backup system. An attitude that demonstrates the same degree of care and common sense towards electronic information technologies will be amply rewarded.

Computer Literacy:

"Human history becomes more and more a race between education and catastrophe." (Wells, 1920)

As the computer has gained acceptance and widespread application in the workplace, the gap between the computer literate and illiterate has become more profound. Those who fail to develop a facility with the computer will constitute the lowest tier of the workforce. A subtle, but pervasive fear of technological displacement persists among many work groups. The merest suggestion of a change in the technological status quo in the workplace can provoke a "Luddite reaction" among the group whose tasks the system is meant to facilitate. This is particularly true if the proposed change is perceived (accurately or not) as a threat to jobs or power centers.

The reaction of many educators to the advent of interactive video instruction systems constituted precisely that kind of Luddite reaction. As a response to the failure of those reactionary educators to recognize that interactive video was simply a format for an electronic book, another teaching tool to supplement the skills of the individual, the development and implementation of constructive interactive video applications was constrained, and its effective contribution to the education process was significantly diminished. Remarking on the inherent irony of this teapot tempest, writer and futurist Arthur Clarke rightly suggested that: "Any teacher who can be replaced by a machine -- should be" (Clarke, 1984).

In expecting the cooperation of a target user group, system developers must be careful to solicit the contribution of the group to the development process, and to avoid discounting the necessary role of those users in the application itself. The initial negative reaction of the architecture profession to the CADD technologies was in response to a perceived threat to the sanctity of the design process. This was exacerbated by the fact that the early CADD systems were expensive and had fairly crude graphics capabilities. As architects began to participate in the CADD development process and the technological capabilities became more sophisticated, appropriate systems did evolve. As a result, CADD has become not only a cost effective production tool, but a powerful design tool for architects. The profession has been, and will continue to be, well served by those architects who asserted themselves in this technological development process. As to those who continue to fear that they might be replaced by a machine -- they should be.

Blind Faith:

> "But there came a day when, without the slightest warning, without any previous hint of feebleness, the entire communication system broke down, all over the world, and the world as they understood it, ended." (Forster, 1964)

Time is required for system developers to install and debug even the most carefully conceived technological applications. When a direct interface exists between the user and the new component or installation, adequate time is also required for the user group to assimilate the new technology into the work regime. The difficulty encountered in the installation of an optical search and retrieval (OSAR) system for California's statewide property lien records illustrates the unreasonable expectations that often surround new technologies. The system developer requested a 30 day start-up period, and advised the state to keep the existing system operational until the new system was fully functional. The state budget office refused the request to maintain the existing database and deactivated it. As systems engineers worked to install and debug the new OSAR system, it was able to operate at only 30% of designed capacity. In the ensuing confusion, over 50,000 lien search requests were backlogged. This meant that bankers couldn't make loans, and commercial businesses couldn't borrow. The California Banking Association estimated that costs to both banks and businesses will be in the millions of dollars. According to the system developer, the state "just wanted to turn on the switch on and have our new system running at 100%. That's impossible in the start-up phase of a project this complex" (Miles, 1989).

This incident demonstrates the danger of uninformed decisions based on an unrealistic expectation of technological capabilities, and it underscores the need to carefully choreograph the adaptation of new technologies into the work regime. In subscribing to the promises of increased effectiveness and cost benefits that emerging technologies appear to offer, it is essential for end users to work closely with the experts who best understand the technology. Additionally, simple common sense dictates the maintenance of an existing system as backup until its replacement is operating efficiently and according to design parameters.

6.1.4. Anticipations

"We'll see computers as big as utility plants, costing hundreds of millions of dollars." (Handler, 1989)

Even as the hardware of information technologies becomes more compact and less expensive, technological developments are likely to permit a range of networking and parallel processing configurations that are not only unattainable today, but virtually inconceivable. Future computing machines will almost certainly be characterized by a fundamental portability made possible by the miniaturization of component parts. A highly sophisticated, powerful computer with the capabilities of contemporary minicomputer workstations will be available as a small, electronic notebook, or perhaps as an article of clothing: a hat, a vest, or a wristwatch. Such a computational device will constantly process the contextual information of the user's (wearer's) immediate environment, providing advice or context sensitive counsel on demand. It will respond to queries by accessing the portable information base carried in a jacket pocket, and cellular telecommunications technologies will link the individual to a global knowledge network. Graphic display will be through a device analogous to a pair of eyeglasses. Technologies effecting this development will include those relating to superconductors, superchips, spatial data management, natural language processing, neural sensors, information integration, fiber optics, and lasers. Advances in these same technologies will permit the development of immense supercomputer installations capable of information processing at a global scale.

The very fact that change is unpredictable means that preservation professional must remain particularly well informed about CRM needs, and particularly sensitive to technological developments. The experience of the architecture profession serves as a successful model of technology adaptation through active participation. The ability to recognize and participate in opportunities for viable preservation applications will enhance the preservation process and radically change the manner in which CRM responsibilities are fulfilled.

6.2. Monitoring Technological Developments

> "The human mind is lit by an elemental sense of wonder, a probing restless curiosity that is our primate heritage and that from its beginnings has sought a knowledge of the future." (Tenn, 1975)

A variety of technologies can be expected to have a profound influence on the preservation process of the future. The development of applications using these technologies will center on the fundamental attributes of the computer as a CRM tool, and will capitalize on what the computer does best: manage large and diverse information bases to facilitate data integration, rapid data retrieval, and interdisciplinary networking.

6.2.1. Superconductors

> "The average computer in 1990 will do 200 million operations a second, and the machine coming out in 2000 will do eight billion operations a second. In a computer no bigger than a filing cabinet, those speeds will approach the speed of light." (Cetron and O'Toole, 1982)

Superconductive materials, ceramic composites that include small amounts of elements known as rare earths, have been developed which permit electrical current to flow without any resistance (Ferrell, 1988). Research indicates that materials may be developed which consistently and reliably demonstrate these properties at room temperatures and above. The efficient power transmission and storage capabilities of these superconductive materials will have a profound impact on computer processing technologies. The use of superconductor materials in electronic components will virtually eliminate electrical resistance, permitting faster processing rates without generating heat (a by product of electrical resistance). This will make it possible to build significantly faster, smaller computer systems of much greater processing power. Development of this technology will lead to the miniaturization of sophisticated processing systems. A significant reduction in power demand will make remote installations that can function as data collection and monitoring systems more enduring and reliable. Superconductors will greatly facilitate the configuration of massive parallel processing arrays. The power intensive applications of image processing, such as image compression and decompression, 3-D graphic animation, and real time digital video, will be within the capability of affordable desktop systems.

6.2.2. Super Chips

> "We are in the middle of a true revolution in media -- the change from chemical processes to electronic ones." (Michael Schulhof in Miller, 1989)

Current chip technology appears to impose a limit of 20 million devices per chip. At that density, interconnections become so narrow that the electron flow is insufficient to turn the chip's transistors on/off (George Heilmeier, Texas Inst.). Designers are now working on the billion transistor chip that future applications will demand. It is believed that these capacities can be achieved by either stacking transistors in layers on a single chip, or by making wafers that consist of many chips. Either strategy promises powerful processing components and significant increases in processing speed. Superchips will be self-contained processing units capable of multiple tasks. These advances will contribute to the development of parallel processing systems appropriate to a broad market of users and applications. Power intensive applications such as 3-D animation in real time will become more cost effective, permitting desktop systems to have sophisticated graphic simulation capabilities (Waldman, 1989).

As an example of a super chip application already making its way to market, the NeXT computer has a microchip digital signal processor (Motorola, Inc.) that controls the system's audio capabilities. The chip contains three subprocessors that work simultaneously to manage massive quantities of digital audio data, enabling the system to produce music, songs, and speech. The input audio signals are converted from analog to digital format, compressed, and stored to disk. Output is converted back to analog for broadcast over conventional speakers. The digital signal processor also serves as a high speed modem (9600 baud), and can be used for computer to computer network links. Future versions of the NeXT computer are expected to use the chip to support complex graphics capabilities. Pixar, Inc. is already using the chip technology for animation applications, significantly increasing the speed of graphic display in an attempt to generate real time animation (Waldman, 1989).

6.2.3. Artificial Intelligence

> "There are machines that exhibit a crude sort of memory... it seems reasonable that they can be developed to display a certain amount of judgment, according to a predetermined pattern." (Furnas, 1936)

The ability of the computer to process serial (or sequential) data far outstrips the serial processing capability of the human brain. However, the computer is strictly a processing tool incapable, as yet, of emulating the associative thought processes that characterize the human brain. On the other hand, in terms of the information glut that threatens to disrupt rather than enhance decision processes, the computer may mimic the limitations of the brain more closely than we would hope, since:

"... the more information you give the computer, the slower it gets. So it's a kind of paradoxical situation; if you try to make it smarter by giving it more information, you're making it stupider by making it slower" (Danny Hillis in Brand, 1988).

Parallel processing offers an alternative to the way that computers currently process information (serially), and this computational strategy more closely imitates the way the human brain functions. Parallel processing also enhances the computer's speed advantage by applying the computing power of numerous processors (simultaneously and in concert) to a single task. Reduced instruction set computers (RISC) have recently been developed to support parallel processing. However, the RISC CPU's by themselves are not able to simulate the complex associative thought patterns and processes of the brain.

Neural networks represent a concept for a computer architecture that may more accurately emulate human thought processes. Neural networks in the brain share the information base and the processing demands, working in parallel (simultaneously) to exchange and reinforce patterns of information structure, including associative links, experiential clues, and response memories. Although working at a slower rate than the electronic serial computers, each component neuron is itself an information processor (Clarkson, 1989). If computers can accommodate an effective network of associative links (shared associations), with many processors dividing the computational tasks among themselves while running in parallel, then the computer will more closely mimic the structure and process of human thought. Additionally, such systems could be self-informing, developing new associative links and creating new patterns of relationships in the knowledge base, and reinforcing old ones through repeated recognition and utilization.

This technology has significant implications for the computer as a true decision making machine (in addition to serving as an information source). Computers based on neural networks are expected to be capable of discretionary tasks, responding to particular environmental conditions and contexts. Powerful monitoring systems with the capability to intervene in the resource protection process may be possible. Analytical systems for remotely sensed data relating to building systems and material components could become part of a facility's environmental control system. The predictive modeling capabilities of neural network systems may be able to indicate the effects of weather, pollutants, visitation demands, planned maintenance activities, and design decisions on the integrity of a cultural resource.

Expert systems based on neural networks will have real decision capabilities. The whole of the decision process from electronic data acquisition to data structuring, manipulation, and dissemination will be integral to the neural network system. This will facilitate the assimilation of data and the creation of associative relationships between all information nodes relevant to user needs. Neural systems will be capable of accessing a global knowledge base, and then contextually filtering through the massive volumes of information in order to retrieve only that which is relevant to user need or preference. The processing of information will culminate in the formulation of discretionary responses to the specific context of the current decision process.

6.2.4. Hypermedia

> "Contemporary society's dramatic increase in reliance on information and knowledge is giving computer based information systems central roles in sociological, government, technological, scientific, business, political, cultural, factory, and even in some interpersonal relations and endeavors. Indeed the collection, storage, retrieval, processing, dissemination, and application of data has become society's primary method for assisting critical inquiry for amplifying society's capacity to learn, 'know,' build, manage, design, and to organize." (Joseph, 1987)

The hypermedia concept is based on the integration of all information resources into a readily accessible, coherently structured, digital environment. Hypermedia systems are similar to expert systems in terms of their capabilities for associative information management and decision enhancement. Recent developments in computer memory, data integration, and connectivity have fostered significant advances in the hypermedia concept. However, for the development of a system that functions as an information clearinghouse at the global scale, the fundamentals of a coherent, efficient data structure represents major design constraint.

The Xanadu project of Ted Nelson, which has been under development since 1960, represents an attempt to impose a new structural paradigm on the integration and management of multimedia data resources. A document in the Xanadu data structure consists of "native bytes" which originated with the document, and "inclusions" which are bytes native to other documents but are represented in the current document by virtual association (Nelson, 1988). A structure of "pointers" (hidden and maintained by the storage system) reference or attach the inclusions to the current document. The inclusion source document can be rapidly accessed to further supplement the current document if additional corroboration or source material is required. By reducing the structure of associative links to a common denominator at the byte level of digital structure, the Xanadu System permits the rapid construction of associative links. The Xanadu strategy represents an innovative means of accommodating extensive data storage requirements in a highly controlled information structure. Nelson believes that his structural paradigm represents a truly efficient storage system with the capability to track "arbitrary links between arbitrary portions of arbitrary documents" (Nelson, 1988). This capability is essential in maintaining system coherence and order, and permits the on-line expansion of an information base through path marking, data annotations, and the creation of new associative links (Nelson, 1988).

By pooling information in a massive digital knowledge base, systems such as Xanadu will permit the user to combine, fragment, manipulate, and disseminate information resources in a form that is most appropriate to the context of need and application. The hypermedia systems of the future will represent a pooling of knowledge not only in a common media format, but as a global information network that is constantly updating and validating information content and use. A self-informing capability will expand not only the content of the information base, but also the associative structure with each user interaction. The software interface and programming shell of hypermedia systems will be modular constructs that will not require sophisticated programming skills, readily permitting user modifications in response to particular needs. Alan Kay, a key developer of the Xerox and Apple Computer innovations in computer systems, has asserted that the ultimate goal of these electronic systems "is in letting ordinary people make tools for themselves" (Kay in Rogers, 1988).

Interactive hypermedia systems will become "virtual reality" workstations that combine computers, holography, 3-D animation and video sources, and audio to simulate the objects, tasks, tools, and machinery of a user designated environment. Computer models that simulate material conditions will sharpen diagnostic skills. Networked hypermedia systems will allow on-line consultations and the exchange of expertise in the preservation decision process, allowing a broader application of knowledge to preservation problems. Continuing education for professionals will be based on individual interactions with a thematic information base, allowing professionals to stay abreast of developments in particular areas of interest. The place of learning will be increasingly important, as computer miniaturization will make hypermedia systems transportable, permitting the computer to accompany the user to the best environment for assimilating the designated skills or knowledge.

6.2.5. User Interface

> "He sat down at the computer as he spoke and placed his hands on the markings that received them. The computer, finely attuned to his mind, did the rest." (Asimov, 1986)

A variety of man/computer interface initiatives are being developed as alternatives to simple key board and pointing devices. Tablets are now available to translate handwriting into ASCII files, and voice activated systems of limited vocabularies have been recently introduced to serve the needs of visually impaired users (NPR, 6/26/89). Similarly, visually activated systems that correlate eye or hand movements to graphic icons on a display screen are being explored (Brand, 1988). Other developments in interface technologies are broadening the capabilities for additional sensory interactions and simulations. The full range of sensory experiences are being explored, and future systems will enable a computer/user exchange of information about heat, cold, wet, dry, smell, taste, rough, smooth, and other sensory perceptions.

The communication between computers and man has progressed from machine code to assembly language, high level language, and finally fourth generation language. Natural language processing is a departure from this progression, representing a new approach to the man/machine interface. Natural language processing is no more precise than language itself, with the context of language being essential to understanding the meaning of the words. Speech recognition is an essential component of natural language processing, as the computer must have the capability to hear, recognize, and differentiate individual words. The advent of a sophisticated voice interface will particularly facilitate interaction between man and the computer environment. Developments in chip design and storage media have enhanced the viability of natural language processing and voice recognition systems. Machines will soon be capable of word recognition surpassing the average human vocabulary, and machine language will encompass "every language from English to Chinese and Hebrew to Arabic" (Cetron and O'Toole, 1982).

To this end, the IBM Corporation has initiated a variety of natural language and voice recognition projects, including:

Tangora: recognizes and responds to 20,000 words of human speech;

Newselector: natural language processing to help the computer understand text and provide intelligent archiving and retrieving;

Translator: English to Spanish or Chinese; translation systems require particular sensitivity to language context because of colloquialisms and idiomatic expressions;

Paper-Like Interface: recognize handwriting entered on a digitizing tablet (Rogers, 1988).

6.2.6. Storage

> "Records don't last forever, Hari. Memory banks can be destroyed or defaced as a result of conflict or can simply deteriorate with time. Any memory bit, any record that is not referred to for a long time eventually drowns in accumulated noise." (Dors in Asimov, 1988)

Analog:

An analog alternative to the standard format videodisc technology is the recently introduced I-Star image system (Goddard Technology Corp., Atlanta, GA). The I-Star system does not require the disk mastering process of the standard videodisc format. The user can record selected images directly to the storage medium. The system has the capacity to store up to 2,450 color images at 300 line resolution on a modified hard disk drive. Image input/output is via a composite video signal. System costs are under $5,000.

Digital:

In computer based systems, the integration and manipulation of information is facilitated if all data is in a digital format. Digital data resources are far more flexible than those in an analog format, and the quality of digital data transmission is higher. Since the digital format is a noise-free medium that can error correct, eventually all media will be stored, processed, and transmitted in digital form. Nicholas Negroponte, the director of the M.I.T. Media Lab, has asserted that he "can see no reason for anyone wanting to work in the analog domain anymore -- sound, film, video. All transmission will be digital" (Negroponte in Brand, 1988).

Magnetic:

Hard disk storage systems continue to benefit from technological advances. Contemporary systems can reliably accommodate up to 800 Mbytes of data, and access times for such high capacity disks have dropped to 20 msec or less (Kalstrom, 1989). Hard disk systems are relatively inexpensive mass storage solutions, and the increased reliability and miniaturization of components has made them more appropriate for portable applications. Additionally, the use of perpendicular recording technologies will make low cost, high capacity magnetic disks available with the capability to store 10 times more data per inch than now permitted (Ozawa, 1986).

Optical:

Laser technologies have made it possible to develop digital data storage systems (WORM, CD-ROM) that have the have the capacity and flexibility to store a variety of information types (sound, real-time video, images, text). Because a laser device can read a bit of data of microscopic proportions (40 u), extremely high density optical storage is possible. While a 5.25 inch removable cartridge currently can hold 200 to 500 Mbytes of data per side, laser optical systems are being developed that can accommodate 1 Gbyte of data per side. Although data access times are slower than those achievable with hard disk technologies, the data retrieval time for optical disks has improved rapidly and dramatically (faster than 40 msec). The stability of data and portability of immense information bases make the optical storage systems appropriate for many applications. Whole libraries, such as that planned for the University of Southern California Center for Scholarly Technology, will be optical disk based, with the information accessed by remotely located computer terminals (Sabelhaus, 1988). All resource materials in the library, including books, audio recordings, movies, and slide collections will eventually be accessible from anywhere in the campus network.

Magneto-optical:

A technology hybrid, magneto-optical storage systems combine the attributes of both digital storage formats. Like an optical system, the magneto-optical disk can efficiently store massive volumes of data on a removable cartridge. Data is stable, with the danger of head crashes diminished by the use of laser readers that never touch the surface of the disk. A magnetic coil is a component part of the data recording process, enabling the data track to be erased and reused. Advances in both the magnetic and optical technologies promise to decrease costs, improve data access times, and increase the capacities of the magneto-optical medium.

Digital Video Interactive (DVI):

Developed by RCA and now owned by Intel, Digital Video Interactive is not a storage medium ***per se***, but rather an information management protocol that promises to be the technological successor to the analog videodisc medium. DVI is a hardware and software system for the IBM PC-AT computer (or compatible) that constitutes an interactive, multimedia environment in an all digital format. It accommodates real-time video (30 frame per second), still images, computer animation, and stereo audio as well as text and tabular data on an IBM PC-AT compatible microcomputer system. As a digital medium, the data quality and real-time video capability mark its most significant attributes. The key to this capability is an image compression and decompression algorithm that reduces image storage requirements to less than 1% of the original file size. An audio compression algorithm and a memory buffer permit continuous audio playback. With video data compression approaching the ratio of 10,000 to 1, DVI permits approximately one hour of video and multichannel audio on a 500 megabyte CD-ROM (Compact Disk-Read Only Memory) disk. Displayable resolution can range from 256x240 to 768x480 pixels with 24 bit RGB color. Additional improvements in CD-ROM technology promise greater storage capabilities, extending disk playtime and making a system of higher resolution images feasible. DVI also includes an edit-level video feature which allows single frame image compression ratios of 25-to-1 in one to two seconds on the PC-AT. Compression ratios for highly detailed images or technical graphics are limited to ratios of 2-to-1 or 3-to-1. As compression routines become more sophisticated and hardware components become more powerful, compression ratios and speeds will improve further. DVI is compatible with a variety of digital mass storage media such as magneto-optical and WORM (Write Once-Read Many) systems.

Advantages over competing systems include DVI's integrated digital format (versus the computer controlled analog audio and video of videodisc technology), and its extended real time video capability as a result of the fast image data compression and decompression algorithms. Less efficient algorithms employed in the Sony and Philips compact disk interactive (CD-I) system place significant limits on its ability to display real-time video. However, CD-I, a hardware/software system that also integrates CD-ROM with a computer controlled environment, does possess higher quality audio than DVI.

6.2.7. Connectivity

> "The clumsy system of public gatherings had been long since abandoned; neither Vashti nor her audience stirred from their rooms. Seated in her arm chair she spoke, while they in their arm chairs heard her, fairly well, and saw her, fairly well." (Forster, 1964)

Communications media is fundamental to society, and all of the social, cultural, economic, and political processes of the human experience are organized around information exchange. The dual keys to global networking and a global information base are the development and implementation of appropriate conduits for the efficient flow of information. Mitch Kapor (founder of Lotus Corporation) envisions these conduits as a "national infrastructure that will be the information equivalent of the national highway-building of the 50's and 60's" (Rogers, 1988). These conduits must be able to accommodate the whole range of data types, including audio, real time video, and high resolution graphics. The fiber optics technologies and satellite networks are capable of transmitting error free data at high speeds and in the wide band widths required to accommodate the large data structures of high resolution graphics. The development of this technological infrastructure will make the portability of powerful computers analogous to the cellular telephone. It will eventually be possible to log onto an information service, exchange data, participate in a video conference call, and manipulate complex graphics from virtually anywhere in the world. Immense digital information bases will subsequently be developed to service a truly global information network.

A communications protocol called the Integrated Services Digital Network (ISDN) has been developed as an international standard for linking public and private information networks. This standard promises to lower data transmission costs and accommodate large volumes of data over long distances. The ISDN will facilitate global connectivity, information exchange, and interdisciplinary collaboration (Brand, 1988). As individual professionals become more specialized (or generalized) they will increasingly be able to connect to the necessary general (or specialized) information resources to supplement their own knowledge base. The ISDN protocol may prove to be the key in realizing the capability for on-line consultations between professionals at remote locations, and as a consequence, foster a significantly better informed CRM decision process.

Groupware systems constitute network software environments in which users can simultaneously collaborate on processing tasks. These systems facilitate not only the exchange of information, but also the joint manipulation and annotation of information nodes. These software environments will permit interactive electronic dialogue between professional colleagues, with locally implemented changes to nodal information content depicted instantaneously throughout the project network (Winograd, 1988). The ISDN protocol permits participants in groupware networks to literally be located around the world, and yet participating in a real time collaborative effort.

6.2.8. Animation and 3-D Graphics

"As her fingers closed around the cool brass knob, it seemed to squirm, sliding along a touch spectrum of texture and temperature in the first second of contact.
Then it became metal again, green painted iron, sweeping out and down, along a line of perspective, an old railing she grasped now in wonder.
A few drops of rain blew into her face.
Smell of rain and wet earth.
Below her lay the unmistakable panorama of Barcelona, smoke hazing the strange spires of the Church of the Sagrada Familia. She caught the railing with her other hand as well, fighting vertigo. She knew this place. She was in the Guell Park, Antonio Gaudi's tatty fairyland, on its barren rise behind the center of the city. To her left, a giant lizard of crazy-quilt ceramic was frozen in midslide down a ramp of rough stone. Its fountain-grin watered a bed of tired flowers.
'You are disoriented. Please forgive me.'" (Gibson, 1987)

Developments in hardware technologies (super chips, parallel processing, superconductors, storage, display) will dramatically improve the display resolution and color rendition of graphics systems, and will make increasingly sophisticated animation and 3-D modeling packages possible. The development of powerful data compression algorithms based on fractal mathematics will make the compression and decompression of digital images more efficient, permitting real time (30 frames per second) display of action graphics. One software strategy that will facilitate the display of real time animation and digital video involves the replacement of only the pixels (picture elements) that vary in the serial progression of images. By manipulating only the minimum number of pixels necessary to depict movement and color changes, the storage requirements are reduced and performance capabilities of decompression algorithms and CPU's are more efficiently exploited (Cottram, 1989).

Real time simulations in 3-D will revolutionize CADD applications, allowing designers and builders to virtually walk through construction decisions to better understand the implications of the spatial (sensory) experience and of component assembly before decisions are actually implemented. Animated 3-D systems installed on high resolution graphics workstations will enable users to observe the dynamics of processes that might not be fully understood otherwise. These developments will culminate in the ability to simulate a "virtual reality" of experiential interaction that will be difficult to differentiate from a video recording of the real world.

Display:

High resolution, flat screen displays (2000+ lines with full color) with 3-D stereographic capabilities will facilitate dimensional analysis of images, and will enhance the veracity of graphic simulations. Compact screens will increase portability without diminishing image quality, freeing the high end workstation from the office environment by endowing laptop systems with display capabilities of exceptional sharpness and color rendition. IBM and Toshiba Corporation are currently developing a flat (1.5″) LCD screen (14″ diagonal) with the ability to display 16 colors in a field of 1.5 million pixels (Rowell, 1989).

Graphics display research is working on concepts that will enhance the perception of 3-D space. Developments include a user/computer interface that is worn as one would wear a pair of eyeglasses. The small, lightweight device gives the wearer a free space perspective as the data display appears to float in front of the user's eyes (Rowell, 1989). Research initiatives at the Media Lab (M.I.T.) have developed a helmet device that places the user within a computer generated 3-D construct, so that as the user turns, the view into the modeled space changes (Brand, 1988).

6.2.9. Holography

> "Herr Virek," she said, "I saw you lecture in Munich, two years ago. A critique of Faessler and his Autistiches Theater. You seemed well then ..."
> "Faessler?" Virek's tanned forehead wrinkled. "You saw a double. A hologram perhaps. Many things, Marly, are perpetrated in my name." (Gibson, 1987)

Holography is a graphic technology that uses laser light to produce 3-D images. Holographic research has demonstrated the viability of constructing holograms that convey 3-D information from a variety of imaging sources, including CAT scans, MRI (magnetic resonance imaging), and laser photography. There are currently display and size constraints in the use of holography due to the sensitivity required of the laser photographic techniques and the processing power required of the computer generated techniques. However, research at the M.I.T. Media Lab is exploring solutions to these constraining factors. By splicing holograms in 4 ft. widths together with imperceptible seams, immense 3-D representations may be achieved (Brand, 1988).

Computational models developed from a database have also been used to generate holographic constructs displayable in free space. Holographic images projected into free space provide viewers with graphic information that is unavailable from 3-D models that are confined to a flat screen environment. A research project for General Motors has demonstrated the viability of these projected holograms, allowing viewers to literally walk around three sides of the displayed object (Brand, 1988). While these holographic techniques currently require extensive processing power and sophisticated laser equipment operating in highly controlled environments, developments across the range of computer and laser technologies will make free space applications more accessible and cost effective in the near future.

As projected holography becomes a more cost effective imaging technology, its value as a simulation technique will be exploited throughout the whole spectrum of resource interpretation, assessment, evaluation, design, and planning activities. Holography will become an invaluable teaching tool, enhancing the graphic access to (and as a consequence, the understanding of) a visually powerful knowledge base. The enhanced efficiency of holography as a medium for the compaction of knowledge will facilitate the assembly of vast libraries of computerized holographic images. It has been estimated that by the year 2000, the technology will have developed to the extent that "the entire contents of 26 miles of bookshelves can be holographed and stored in eight file cabinets" (Cetron and O'Toole, 1982).

6.2.10. StereoLithography

> "On the delivery plate of the Nutri-Matic Drink Synthesizer was a small tray, on which sat three bone china cups and saucers, a bone china jug of milk, a silver teapot full of the best tea Arthur had ever tasted and a small printed note saying 'Wait.' " (Adams, 1980)

The technology of StereoLithography is a newly developed method for producing physical objects from CADD generated data. A product of interdisciplinary collaboration between chemistry, laser engineering, and computer science, the technique uses a CADD database to control a laser energy source which forms the 3-D object from a liquid bath of photosensitive polymer.

Models and prototypes are essential to understanding the implications of design decisions. However, while contributing to a better informed design process, the production of models and prototypes is expensive and time consuming. Experience suggests that on average, physical prototyping can account for over half the time required to bring a design to its final manifestation (Leonard, 1989). Electronic processes that promise to transform graphic designs and simulations (virtual reality) into tangible 3-D objects represent an essential component in the process of reconciling virtual realities with real needs and applications. The StereoLithographic Apparatus (SLA) can dramatically reduce the time and costs required for model building, and can enhance the design process by permitting the iterative testing of design decisions with rapid prototyping.

The SLA method forms 3-D objects by successively layering thin, cross sectional profiles of the object on top of one another. The plastic matrix in which the object is created is a liquid photocurable polymer that transforms into a solid state when exposed to an ultraviolet laser light source. A scanner device driven by computer generated coordinates controls the movement of the laser in the "X-Y" coordinate plane across the surface of the polymer bath. The object is formed on an elevator which moves the object through the "Z" coordinate plane in the resin bath (Rowell, 1989).

StereoLithography represents a significant development in the ability to translate ideas into tangible constructs. As a modeling tool for preservation applications, it can benefit architects in testing and presenting designs, and can be used to quickly produce complex building elements and templates. The technology can facilitate the interpretation of archaeological data by modeling and assembling artifacts that are too rare or fragile to handle. On the whole, SLA technology can facilitate the exchange of ideas concerning preservation issues by virtue of its ability to make graphic representations into tangible, three dimensional objects. Future developments in the properties of the polymer matrix may lead to accurate simulations of the density and tactile characteristics of the modeled object, further enhancing the value of the technology as a design tool.

6.3. Preservation Applications

Three basic concepts that guide professional forecasters:

Is it technically feasible ? (can it be made)

Is it economically feasible ? (are costs prohibitive)

Is it socially and politically acceptable ? (will the government permit the sale and will the consumer buy) (Cetron and O'Toole, 1982).

"Every successful politician , businessman, or human being of any calling must make these estimates of the future and do it fairly well or he or she would not be successful."
"They do it without mathematics."
"True. They do it by intuition." (Asimov, 1988)

6.3.1. Education

"We can no longer afford, as a nation, to underuse the full capacity of our minds. The complex global problems and international competition demand that we guide our children to use all the processes of the mind in a disciplined way, and re-educate adults to again tap their full range of creative and intuitive abilities." (Hunter, 1987)

Early:

Not only is it essential to introduce students at the earliest possible age to the fundamental computer technologies that are the foundation of the future, but also to the cultural fabric that embodies the history of human experience. Elementary schools are preparing the application developers, system designers and innovators of the future. If a rich and varied cultural history is to be preserved, then the preservation community must ensure that these young and eager minds gain an understanding of the significance of this cultural heritage and the forces that threaten its integrity.

The Hennigan School project of the M.I.T. Media Lab represents an initiative to place computer technologies in the hands of the youngest users possible based on the premise that computing skills are simply another language skill that can be readily learned at an early age. Along with developing a basic understanding of the computer, students (6 years old and up) assimilate programming skills and gain important insight about the learning process itself: that you seldom get it right the first time with the computer, that mistakes (bugs) can be of benefit by forcing us to look at tasks from various perspectives in finding resolution to problems, and ultimately, that there is a negotiable approach to knowledge (Brand, 1988). For the kids at Hennigan, computers have diminished the barriers between school knowledge and that required in their ordinary lives. In the process, this generation of user, unlike any other to date, will become the designers of the applications that will push the current capabilities of the technologies to their limits and beyond.

Often:

Emerging technologies are rapidly gaining influence over contemporary society. In a world that has just witnessed the advent of the interactive video grocery cart, audio greeting cards, and a 3-D television commercial for Coca Cola, it's evident that every aspect of social and economic activity will be penetrated by these emerging technologies in ways that are now inconceivable. The increasing technological sophistication of many consumer products is making society more familiar and comfortable with the entrenchment of an Electronic Information Age. Familiarity is the key to greater acceptance and application. At the same time, a technology is only as good as the ability to appropriately match it with an application.

In adult education, computers and telecommunications technologies will play an increasingly important role. Laptop computers will in fact be electronic books that permit student discretion in selecting the place and pace of instruction. Interactive programs with real time graphics capabilities will provide individualized training to suit the user's interest or need. Natural language processing will permit a voice interface between user and machine, with the capability to translate between English and French, Spanish, Italian, German, Russian, Chinese, Arabic, Swahili, Japanese and other languages using expandable, preprogrammed ROM chips.

Computing Virtual Reality:

> "A square of cyberspace directly in front of him flipped sickeningly and he found himself in a pale blue graphic that seemed to represent a very spacious apartment, low shapes of furniture sketched in hair-fine lines of blue neon. A woman stood in front of him, a sort of glowing cartoon squiggle of a woman, the face a brown smudge.
> '...What is this? I mean, if you could sort of explain...' He still couldn't move. The window showed a blue-gray video view of palm trees and old buildings.
> 'How do you mean?...'
> 'This sort of drawing. And you. And that old picture...'
> 'Hey, man, I paid a designer an arm and a leg to punch this up for me. This is my space, my construct. This is L.A., boy. People here don't do anything without jacking. This is where I entertain.'"
> (Gibson, 1987)

Surrogate Tools:

Interactive systems that create experiential simulations will provide instructional or interpretive information about objects and tools that would not ordinarily be encountered or handled. In these systems, the user will wield an electronic baton, analogous to a joy stick, as an interface device in free space. The user will be presented with selections from the system menu which will endow the baton with the traits of specified preservation tools and historic implements. After a selection is made, the computer controlled sensory encounter will allow the user to experience the qualities that characterize the tool and the techniques for using it: the subtleties of style, balance, and presentation. The 3-D display of the surrogate experience will show the system user attired in the appropriate period costume. The motions of the baton in free space will be monitored by the system and displayed on the 3-D screen in the context of the task activity assigned to the baton as the surrogate tool. The system will constitute an environment for interactive learning, providing instantaneous feedback from the computer information base about the handling and application of the implement. Both visual (on the screen) and audible (the sound of the tool in use and verbal commentary) sources will instruct the user.

Time Traveler:

An interactive 3-D media system will be a fundamental means of resource interpretation. The system, configured as a multimedia workstation built into a small, hemispherical "media" room, will provide a user controlled 3-D travel experience through an electronically simulated cultural environment. Through 3-D video and holographic projections in free space, the computer information base will permit the user to view and participate in the dramatization of selected historic scenes. A range of the sensory experiences associated with each historic scene will also be available to system users. The virtual reality created by the surrogate time traveler will communicate sensory impressions about tactile, visual, olfactory, and audio characteristics as appropriate to the particular experience.

To convey a sense of the socioeconomic context of the site and historic time, the 3-D system will display the human activities of the daily routine, interpreting the community events and historic values associated with each simulated scene. The building technology and construction process for each structure will be accessible for viewing, and the mechanics of industrial exhibit will be demonstrated in the animated 3-D presentation. The system will depict natural and man induced changes to the buildings and sites portrayed in the scenes. The system will also display the processes of building restoration to demonstrate contemporary rehabilitation techniques and uses of substitute materials.

Users will be able to tailor the information presented according to their own sensitivity, interest, and need. User selections will be specified by eye contact with objects in the display, and by spoken responses to voice queries presented in simulated dialogue with characters portrayed in the historic scene. Choices as to the issue path (natural, social, economic, folk, scientific, design, technological) that the user wishes to follow through the information base will be presented at each nodal segment in the unfolding of the cultural scene. As progressive selections are made, the system's information "filter" will recognize preference patterns, and will progressively offer information choices more relevant to the taste of the user.

6.3.2. Resource Management and Planning

> "The process of analytical policy development has a prodigious appetite for information. It is in the provision of better information than might otherwise be available that technology assessment can have a useful role -- in the formation of public policies as distinct from their execution." (Menkes, 1985)

The primary goal of cultural resource management is to maintain the capacity of the cultural environment to meet and sustain human needs and aspirations. This goal is best achieved when CRM is integrated as part of the whole planning process, and yet differentiated according to the special circumstances and needs of individual historic resources (Loeks, 1985). Efforts to manage individual cultural resources (artifacts, events, materials, buildings, sites) must acknowledge and respond to the context of the larger environment (urban, rural, regional planning zone) which encompasses all of the relevant factors that affect the individual resource.

The Electronic Memory Palace:

Spatial Data Management Systems (SDMS) are those which rely on spatial clues as an indication of where specific information is located. Knowledge communities are assembled by the user in ways that ultimately assist in the retrieval of information. This concept can be implemented though the use of iconographic keys, or by association with the physical placement of the clues on the screen. The concept is applicable beyond the physical confines of the computer screen, and will be operable in 3-D spatial constructs configured into the fabric of rooms and buildings.

The Electronic Memory Palace (EMP) will be the ultimate personal computer that can discern and assimilate the user's idiosyncrasies (vagaries, inconsistencies, ambiguities) by monitoring the interaction between the user and the SDMS construct. Based on that assimilation, the computer will assemble a predictive model of the user's associative thought patterns and verbal expressions. Interactivity between the computer and the user in this construct will become increasingly familiar as the computer assimilates the context sensitive criteria that characterize user preferences. The EMP will invoke the necessary contextual inferences to interact with the user on the highest personal level. As a result, the user will be able to engage in intimate conversation (dialogue) with the (personal) computer to bring forth ideas and concepts that neither user nor machine working alone could have produced.

Predictive Preservation:

A computer system that integrates geographical information system (GIS) capabilities with data acquisition components and a global information base will serve as a tool for predictive preservation. The system will use predictive modeling software to process remotely sensed data from satellite, aerial, and ground platforms using multispectral scanners, side looking and ground penetrating radar, thermal infrared scanners, sonar, magnetometry, high resolution stereoscopic digital video, and other sensory devices. Additional data resources will be acquired from oral histories, archival sources, and existing resource inventories.

This integrated predictive system will become the foundation for a variety of the activities of the preservation process. The predictive system will aid in the discovery and analysis of historic and prehistoric sites. It will facilitate the documentation of culturally significant resources and the description of sought after cultural events. The system will be effective in understanding physical threats to cultural resources, and in prescribing treatments to ensure the preservation of the integrity of individual resources. With an interface to meteorological and geological databases, the predictive system will also serve to mitigate the threat of imminent natural cataclysms by providing advance risk analysis in response to detected patterns of environmental stress.

GIS Solid Modeler:

This graphic system will represent a convergence of image processing, animation, GIS, and remote sensing technologies. The information gathered, manipulated, and processed by this system will facilitate resource evaluation, management, and public interpretation. The assembled GIS information base will describe the cultural site at the scale of an historic district, park, or region. The system will graphically integrate spatial data relevant to the natural and cultural resources within site boundaries, as well as those environmental influences in close proximity to the site which will impact resource management decisions. The information layers generated by sensing techniques will be analyzed and digitally integrated into a graphic 3-D model of physical landscape characteristics that will assist resource managers in understanding the multidimensional character of the cultural scene.

The animated 3-D GIS will provide the basis for the generation of a surrogate landscape that will assist resource managers in understanding the evolution of the historic resource, and the interaction between the cultural and natural landscape. Predictive modeling will be used with the animated GIS solid modeler to discover landscape sites of cultural significance, such as prehistoric sites of human settlement, sites of historic activity, and the subtle, unrevealed imprints of the cultural experience on the landscape as a whole. Further animation efforts will generate simulations depicting identified cultural sites in their historic or prehistoric context.

Preservation News Monitor:

The amount of information ("news") which may have an impact on the management of a cultural site as a multidimensional resource is immense. Not only might local political, economic, and environmental circumstances affect the integrity of the resource, but distant events could also have a significant impact. The preservation news monitor (PNM) is an electronic news network which will have access to a global news and information base. The preservation news monitor will filter these accumulated media resources, gathering those which will impact preservation concerns. The PNM system will have national, regional, state, and local nodes to facilitate access to the layers of information appropriate to the context of CRM needs and responsibilities. An on-line retrieval system will also be installed for each publicly administered (national and state) cultural site. The system will constantly monitor the global information base for events, research, technologies, case studies, and management policies relevant to the specific context of the cultural resources within each administrative unit. The system will facilitate the extraction of knowledge from the global information base by filtering massive volumes of information to ensure that the "news" necessary to the informed administration of specific CRM responsibilities reaches the appropriate personnel.

The individually tailored PNM filter will automatically download customized information to the desktop workstation of each of the personnel involved in the CRM process. System users will also be able to access and navigate the information base at any level to retrieve or annotate information nodes. Users will have full discretionary control over the techniques of database grazing, browsing, and hunting.

6.3.3. Design and Construction

"Maybe a house is a home only once it can appreciate your jokes." (Negroponte, 1975)

Preservation Design:

Through the development of artificial intelligence capabilities, computer aided design (CADD) systems will become interactive environments capable of learning the spatial and stylistic preferences of individual users. The input of preferential information will activate a filtering mechanism which will permit the computer to retrieve information tailored to the individual's particular needs from a large database. With each use of the system, the computer will assimilate a greater "understanding" of the user's preferences and design methods. As a consequence, the relevance of information provided automatically by the CADD/AI filter will increase, ensuring an efficient information retrieval process and mitigating the threat of information gluttony.

Historic Simulation:

Simulations based on 3-D animation techniques will facilitate an understanding of the dynamic performance characteristics of structures. Real time graphic simulations will depict how historic bridges and buildings respond to environmental forces. Simulations will also portray the sequential degradation of building materials in response to natural and man induced factors. Artificial intelligence capabilities will enable computers to integrate materials performance criteria relative to the physical placement, use, and environmental context of historic and contemporary building materials. AI will enable computer systems to assimilate knowledge about the durability of construction materials and systems as components of an evolving building ecology.

Animation capabilities will simulate the evolution of the building and the site from its historic context to the present. Projections of future utilization, material conditions, and the impact of maintenance activities will be graphically modeled. The preparation of the original site for construction, the construction process, the weathering and aging of the structure and materials, and additions and modifications will be depicted in the animated model. This simulation of buildings in their historic context will be produced primarily as an interpretive tool for the public, but the animation will also find practical application in the restoration, adaptive use, and management processes.

The creation of a virtual reality for the study of materials and systems performance capabilities will provide designers and engineers with a mechanism for rapidly manipulating and testing the physical fabric of the building assembly process. Predictive modeling of material performance will be illustrated in animation sequences as an aid to designers in selecting appropriate techniques for rehabilitation actions in the context of a specific site. Systems will be capable of modeling materials performance, changes to the cultural landscape, and interactions between environmental forces and cultural resources.

A tactile interface board will convey to the system user the textural qualities of the materials of construction. The tactile memory will assist preservation architects in selecting appropriate strategies for preserving the textural character of materials in rehabilitation work. These sensory perceptions will also contribute to the design review and resource interpretation processes. Prototype design models and, where original materials have disappeared or deteriorated beyond repair, replacement components will be produced using a StereoLithographic process integrated into the CADD/3-D modeling system.

Interactive Buildings:

The building inspection process will capitalize on computer interfaces capable of communicating a broad range of sensory information about the qualities of buildings that stimulate the tactile, visual, audio, and olfactory senses. To retrieve information about a particular building component, the inspector will activate an electronic processor located on that component. Information that comprehensively describes the component will be transmitted to a hand held receiver which will record the digital information to memory. This device will be capable of broadcasting the data to the user or transmitting it to a central information processor and database through a cellular communications link.

Preservation Spatial Data:

Data acquisition will entail a multitude of tasks, including videography, photography, photometry, multispectral scanning, archival research, and oral histories. These techniques will provide an enormous amount of data as a comprehensive record of an individual resource. Additionally, it is essential to thoroughly document any interventions that may affect the integrity of the resource. For instance, it may be necessary to dismantle portions of the structure as part of the rehabilitation process, and the exact placement of these parts must be recorded so that they can be properly replaced. It will be possible to integrate this whole body of information into a single digital information network to facilitate processing and storage.

More than just a documentation system, a Preservation Spatial Data System (PSDS) will use sensory clues (sight, sound, smell, touch) to integrate associatively structured information into a multidimensional knowledge base. By incorporating the electronic components of this data processing system into building fabrics, buildings themselves will become computer environments, with built-in data acquisition, storage, and retrieval capabilities. These electronic components will be capable of monitoring a structure during the rehabilitation process to ensure that the integrity of the building is not threatened and significant materials are not damaged. The system will be able to confirm the correct installation of specified materials and the appropriate use of tools. After restoration is complete, the PSDS will continue to monitor the building as the heart of its maintenance management system.

Relocation:

Holographic techniques will be used to graphically simulate the results of a proposed building relocation project by providing a projected (free space) 3-D model of the structure in its new location. This will assist preservation architects in overall site selection and building placement, and in other design and planning considerations. Examination and evaluation of the structure prior to the move will depend on holographic modeling to facilitate X-ray and CAT scan analysis of component building parts. The computer generated holographic representation will not only facilitate the relocation decision process, but it can also be used to simulate the spatial and aesthetic impact of proposed changes to the historic scene, and will contribute to the assessment of the effect of development projects that threaten the integrity of the historic resource. Holographic techniques will also assist in the interpretation of the historic structure to the public during and after the move.

6.4. Research Towards a Future

> "The time to understand a subject whole is when it's changing. Understanding is easier then because everything -- even the deep premise structure -- is up for grabs." (Brand, 1988)

The preservation community needs to become "active" rather than "reactive" in assimilating new techniques and technologies for cultural resource management. The readiness to take advantage of emerging technologies will be essential to ensuring the integrity of this nation's cultural heritage. In a technical climate of unpredictable, but relentless change, the most effective strategy arises from a fundamental understanding of programmatic responsibilities and technological needs to ensure a balanced progression into the future.

In pursuing a preservation agenda, these questions provide appropriate points of departure for articulating and addressing the research needs of cultural resource management:

*1. **Basic Inventories:*** What resources have been lost, what remains, and where were/are they? Where is the information about the resources is located?

*2. **Assessment:*** What is significant about the resource, and why or how does it relate to the whole?

*3. **Preservation plan:*** How much of the resource should be preserved, and how do preservation priorities effect other resource needs and concerns?

*4. **Prescription:*** What intervention is needed and how is that determined?

*5. **Treatment:*** What tools can be adapted to facilitate preservation activities?

The formulation of a foundation for addressing these questions requires preservation professionals to make a concerted effort to:

- ***assimilate basic technical skills;***

- ***understand current preservation needs and responsibilities;***

- ***understand the potential inherent in existing technologies;***

- ***anticipate impending technological developments;***

- ***anticipate possible preservation applications for emerging technologies.***

Strengthening the Preservation Process:

1. Improve information management (Hypermedia, Storage, Data Compression, User Interface, Flat Screens): Information must have clearly defined goals and priorities in order to be effective. Not only are preservation experiences in assimilating tools and methods from other disciplines largely fragmented and poorly documented, but there is little conscientious effort to record and exchange preservation expertise.

2. Broaden assessment processes (Predictive Modeling, Stereo Analytics, Remote Sensing): Preservationists need the cost effective tools that will significantly improve upon contemporary labor intensive methods of resource discovery and documentation. As a corollary need, it is essential to develop recording tools that will provide a basic understanding of materials performance issues in the context of use and place.

3. Increase and strengthen tools for design development and simulation (Animation, 3D Graphics, Holography, StereoLithography): Drawing from an understanding of historic context and contemporary need, the tasks of architects and planners can be facilitated through a capability to create virtual realities as a basis for testing the decisions of the design process. These same simulation methods could be used for broader educational purposes by capitalizing on the ability to graphically communicate preservation values and threats.

4. Strengthen institutional capacity to accommodate and enhance interdisciplinary collaboration (Groupware, Network, Fiber Optics): Preservation is inherently a collaborative activity, requiring skills and experiences that span a broad range of professional disciplines. Individuals must be facile with a multidisciplinary understanding of the implications of preservation challenges and needs. There is not an adequately integrated planning and management process for historic buildings because the preservation community has not successfully devised a strategy for assimilating the diverse, fragmented, and complex information base that is both relevant and necessary to ensure cultural heritage conservation in the face of threats from neglect, decay, demolition, and uninformed interventions.

Research Areas:

The application of technological capabilities in the areas of information acquisition, storage, retrieval, processing, and dissemination is fundamental to all CRM projects. It is these areas that are so critical in resolving the most serious needs of preservation as a whole.

6.4.1. Understanding Multidisciplinary Perspectives (man to man)

> "Imagery enables us to explore perspectives different from our own or experience what it is like to be someone or something else in order to gain new insights and understanding." (Hunter, 1987)

Issue:

There is not yet an adequate mechanism for integrating preservation activities into the whole of the planning and resource management process.

Research:

Many human impacts cannot be physically managed at the site of the resource. These are impacts of economic and social forces that affect the integrity of the resource directly and indirectly. These can range from public perception of the values represented by historic structures, zoning regulations, building codes, availability of appropriate craftsmen and materials, tax incentives; to the sensitivity demonstrated by architects, developers, owners, and users of historic buildings. General strategies to strengthen the interdisciplinary capacity to achieve such integration are incomplete and inadequate regarding the merging of fundamental information resources.

Hypermedia: environments for interactive collaboration; associative linking of information nodes and multidisciplinary knowledge communities; media integration.

Expert Systems: acquisition and dissemination of knowledge based human and inferential expertise; self-informing systems to amplify human based skills and supplement decision processes; context sensitive information filters.

6.4.2. Integration of Technologies (machine to machine)

> "The most ethical of all tools are tools of adaptiveness, tools that make tools, tools that remake themselves." (Brand, 1988)

Issue:

Research in the development of preservation technologies suffers from the confusion caused by rapid technological developments that make the configuration of coherent systems difficult, and by the lack of universal standards and protocols for data exchange and storage, software and hardware environments, adaptor cards (emulators), communications links, and operating systems.

Research:

The seamless configuration of multidisciplinary networks is essential to the rapid, reliable flow of information. The progressive conversion of all data resources into a common digital format will ultimately permit the merging, manipulation, and dissemination of discrete information resources throughout a global communications network.

Bridges: cross network, black box translators, network peripherals, information filters, global connectivity.

Storage: uniform digital formats that integrate various media types and permit free exchange of the storage medium between different retrieval and processing units.

6.4.3. User Interface (man to machine)

> "What needs to be articulated, regardless of the format of the man-machine relationship, is the goal of humanism through machines." (Negroponte in Brand, 1988)

Issue:

A danger exists by virtue of the inability of users to efficiently use the complex and unfamiliar technologies of the Electronic Information Age, and to effectively assimilate the massive volumes of information made available to the decision processes.

Research:

Concerted efforts to make the man/machine interface user friendly can broaden the application base of emerging technologies. In order to fully integrate electronic devices into the ordinary human experience, the operation, set-up, maintenance of systems must be simple and straight forward. The configuration of the system and the information contained therein must be coherent and comprehensible. Programming capabilities should be accessible to a wider user group, and a full range of sensory stimuli should be fundamental to the exchange of information between man and machine.

Graphical Interface: visual interaction.

Natural Language Processing: voice; spontaneous translation.

Object Oriented Programming: sophisticated, tailored applications development by intelligent users.

Sensory Interface: experiential interaction; tactile, olfactory; holography; intuitive interaction.

Portability: miniaturization; computers that can be worn by people and integrated into building systems; spatial data management in free space.

6.5. Summary

"It is possible to believe that all the past is but the beginning of a beginning, and that all that is and has been is but the twilight of the dawn. It is possible to believe that all that the human mind has ever accomplished is but the dream before the awakening. We cannot see, there is no need for us to see, what this world will be like when the day has finally come. We are creatures of the twilight. But it is out of our race and lineage that minds will spring, that will reach back to us in our littleness to know us better than we know ourselves, and that will reach forward fearlessly to comprehend this future that defeats our eyes. All this world is heavy with the promise of greater things, and a day will come, one day in the unending succession of days, when beginnings, beings who are now latent in our thoughts and hidden in our loins, shall stand upon this earth as one stands upon a footstool, and shall laugh and reach out their hands amidst the stars." (Wells, 1902)

It seems likely that the familiarity of the notecard (or notebook) as a visual (screen display) metaphor and literal model has made neophyte computer users less intimidated by the complex implications of the technology. However, the notebook metaphor is patently inadequate in its failure to stimulate users to comprehend the extraordinary media integration potential of computer systems. The contemporary failure to spur imagination with an appropriately stimulating language of suggestive graphic imagery is analogous to calling an automobile a "horseless carriage". The constraints of the past can effectively obscure the real promise of the future. New metaphors are needed to define the relationship between man and machine, metaphors that inspire innovative applications for emerging technologies and contribute to the meaningful realization of technological potentials.

Technologies that support interconnected global networks will lead to fully integrated information systems that have access to immense volumes of data. With the development of discretionary tools that selectively filter task relevant information from the data reservoir, the dilemma of information overload is diminished. However, unless the systems can respect the individuality of not only the user, but of the user group as a whole, the greater threat may be to cultural differentiation and regional peculiarities. Society must take care to preserve the individual, as well as the cultural equivalent of the "toute ensemble". The information revolution needs an historical perspective to guard against homogeneity.

Emerging technologies offer the potential to radically change the nature of the tasks that constitute the preservation process. The adaptation of new technologies to CRM has positive implications for the multidisciplinary training of preservation professionals. Increasingly, new computer processing and communications technologies are offering these professionals opportunities to span a broad range of information sources. As preservation professionals assimilate a multidisciplinary language of increasing complexity and sophistication, they will become more adept at the synthesis of relevant data into the decision processes. The ultimate benefit of this application of emerging electronic technologies to CRM processes will be better informed decisions, and as a consequence, better and more cost effective protection of this nation's cultural heritage.

The thrust of preservation research efforts must be directed towards articulating applications and harnessing technologies in ways that can make an appreciable difference in the preservation process. This objective demands that the research itself be fully interdisciplinary, bringing a variety of the perspectives to bear on the task of devising preservation applications for emerging computer and communications technologies. Diverse professional backgrounds can create a synergism that has the capacity to develop innovative and creative solutions to CRM needs. The breaking down of traditional interdisciplinary boundaries is essential to the resolution of the complex problems challenging the preservation community on all fronts.

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Appendix A. CRISTAL Macro Programming

CRISTAL's ability to integrate image processing and worksheet environments makes it a versatile, hence, appropriate tool for building information management systems. The Mt. Rainier National Park (NPS/MORA) prototype application demonstrates the diverse range of information organization tasks that can be addressed using the CRISTAL System.

The description of the prototype application is divided into two sections. The first section provides a description of both applications and the major CRISTAL components that were implemented in the development process. The second section describes the process of using the CRISTAL macro authoring language to create the application program. This section includes a description of the assembly of the image and worksheet database structure.

As mentioned previously, a fundamental and recurring challenge of effective cultural resource management is the efficient organization and management of data resources. The objective of the development of the CRISTAL prototypes was to produce a system that successfully organizes and integrates a variety of data types (images, text, graphics) in order to enhance access to data resources. This consolidated database can be as complex and inclusive as the nature of the resources and the needs of the resource manager's demands.

Basic resource records consist of the information fields that are included in the National Park Service's (NPS) List of Classified Structures. A more comprehensive record would include information concerning maintenance, building system components, special conditions and treatments, and drawings of construction details. In either case, the text and graphic information fields are linked to a collection of digital images of the historic resource, site views, historical photographs, and any other relevant visual information.

Macros:

Macro commands are the heart of the application development capabilities of the CRISTAL system, as they provide the means to automatically execute a set of predefined operations without operator intervention. A macro is a recorded sequence of commands or keyboard equivalents that can be invoked by a single command (key stroke or mouse action). When a macro is executed, CRISTAL performs the processing actions that are recorded in the macro statement. Macros are stored in the worksheet in much the same way an equation is stored (ie. specific to the individual sheet). Each sheet therefore has a unique set of macros associated with it. CRISTAL macros can access, activate, and control any of the functions of the keyboard or menus, as well as the command routines contained in a special macro library. Macro statements enable the CRISTAL system to perform programming operations that can be tailored for specific applications. As the engine behind the interactivity between the application user and the application information base, macros can prompt the user for menu selections, operational specifications, or data input.

Macro commands in CRISTAL provide an extensive range of programming functions, such as looping, branching, and subroutines. Because macro commands can be utilized in a variety of task specific applications, the level of complexity, sophistication, and perhaps most importantly, the effectiveness of the macro procedures is dependent on the application requirements and the abilities of the system developer.

In CRISTAL, the application developer can implement macros to create the program structure necessary to resolve the information management demands of specific applications. Macro statements can initiate an automated sequence of actions or program functions, such as incremental movement through a block of worksheet cells to facilitate data entry or to validate data type. Macro statements can prompt the application user for passwords or data input, and retrieve program data from inactive files stored in disk memory. Macro routines can also be assembled for loading a series of images, graphs, or worksheets to automate an information management system or an interactive education program.

An application developer with a good grasp of the CRISTAL macro language can assemble appropriately tailored programs for a user base possessing varied levels of computer and professional skills. These application users would only require operational knowledge of the specific application interface, and could become skillful system operators without possessing any understanding of the CRISTAL program itself.

As the application developer becomes more familiar with the structure, utility, and application of the CRISTAL macro command set, complex command sequences and routines can be used to assemble the comprehensive structure for a tailored program application.

The prototype NPS/MORA application integrated images that graphically represented the character, condition, and setting of individual resources with text fields that included statements of historic significance, maintenance records, site descriptions, and notes relating to special conditions that affect the integrity of the resource.

Building a Macro:

Macro command statements can be created from a library of CRISTAL macro functions. These macro functions are the basic building blocks for developing program applications. A macro command from the built-in macro list is written to a cell in the worksheet just like any other data entry operation. The parameters specified within macro commands can be modified or changed with the same cell editing procedures that are used to edit numeric, formula, or text cells.

A macro is created by opening a cell with the ampersand symbol, "&". As the first character of all macro commands, the "&" initializes the cell data contents as a macro procedure. Macros must be accurately expressed in a predefined syntax, or the statements will not be recognized by CRISTAL and an error flag will be displayed in that cell.

A macro statement records specified keyboard functions and commands into a cell or a sequential column of cells. Having completed the macro entry, a name can be assigned to the macro by pressing the <Alt F10> key sequence to activate the Macro Manager. The developer must select the "Add" command from the Manager menu and use the arrow keys to position the Highlight Bar at the desired line in the Manager list. The developer enters the macro name and the cell address (location) where the macro command set begins. The [Name,Cell] label can be a maximum of 27 contiguous characters. (Example: CYCLIC_MAINT_88,W250) Once named, the specified macro can be executed from the Macro Manager index by referencing the assigned name.

Placement of Macros:

CRISTAL macro statements are stored in cells in the worksheet environment. Although macro statements can be located anywhere in the sheet, proper positioning can be important to the efficient structuring of program applications. A location unlikely to interfere with other worksheet procedures or data sets such as the lower right hand corner of the sheet is recommended, and this remote location will not have an adverse effect on the amount of memory required by the worksheet file. Although each macro location might have a particular rationale behind its placement, it may be best to avoid placement of macros directly adjacent to a block of cells where worksheet data is located because of the possibility of conflict between worksheet manipulations and the macro commands. For example, Macros can be adversely affected or lost altogether by insertion or deletion of rows or columns in the area of the worksheet that holds macro statements, or by sorting a cell block which contains a macro statement.

Application Development:

The prototype system (MORA/NPS) was assembled as a test of the information integration and management capabilities of CRISTAL's macro authoring commands. Macro command routines included menu building, screen mapping, image processing, text editing, and linking between text and graphic fields. The CRISTAL worksheet environment was used to build and store the application command sets. The prototype application demonstrates how the worksheet data fields can be organized to facilitate data retrieval and integration.

The prototype represents one strategy for a menu driven information management system that can be activated from the graphics display screen. The application also demonstrates how the graphics screen can be mapped with cell references to allow interaction between the graphics and the worksheet environments.

The CRISTAL program makes the integration of text and numeric information with images possible by mapping the graphics screen that displays the images with a grid of cell references that can be used to activate additional information fields in the worksheet environment.

Image Capture and Storage:

Step 1:

In the prototype, video images that supplement each resource record were digitized (frame grabbed) and stored in the graphics database using an image capture board. The images were captured from videotape (VCR) and directly from video camera. Because of the higher resolution and sharper image quality inherent in bypassing the intermediary [1/2" VHS] VCR environment, the video camera was used to capture images directly from historical photographs, slides, and drawings.

Example: From the CRISTAL worksheet environment, the system operator presses the < / G I C > key sequence to select the video camera as the signal source. When this command is activated, a live video image can be displayed on the graphics screen. The image is "frame grabbed" (digitized) by pressing the left mouse button. This freezes the selected image on the graphics screen in a digital format. The image can then be saved to disk as a [.TGA] or a [.PIC] file. Each digitized image must be assigned a unique filename, with a maximum of eight characters possible for the filename. The current default extension, [.TGA] or [.PIC], will be automatically appended to the filename assignment. Unless specified, images will be written to the default image directory as specified in the Environment menu of the CRISTAL program (press < / E D I > from the worksheet to display the Environment settings). Images not saved after digitizing will be overwritten (replaced) by the next digitized image. After the first image is digitized, the user can return to live video by pressing and holding the left mouse button. Releasing the button digitizes another image. Pressing the right mouse button terminates the "frame grab" procedure.

Step 2:

The next step in building the prototype information management systems was to create the structure in the CRISTAL worksheet that was to contain the historic resource data records. In the prototype systems, the first block of cells is reserved for the initial commands referenced by the screen map (matrix). Each cell in this block of 100 cells directs the program execution to the cell (or block of cells) in the worksheet that contains the macro commands related to the icon displayed on the mapped graphics screen.

Example: In the NPS/MORA (Mt. Rainier) Prototype, the [B3] matrix location in the graphics screen contains an icon of Mt. Rainier. When the icon is selected (by placing the cursor over the icon and pressing the left mouse button), the program activates the command in cell [B3] in the worksheet environment. Cell [B3], in turn, contains a macro command that sends the execution of the program to cell [C25]. Cell [C25] contains a string of macro commands that load a sequence of images depicting a representative range Mt. Rainier's natural and cultural resources to the graphics screen. Each image is displayed for a period of time specified by the system author. The user can prolong the duration of display by pressing <Shift-NumLock> to pause, and then any key to continue execution of the sequence. After the execution of the macro string, the user is returned to the graphics screen where other icons can be selected, and other information paths explored.

Step 3:

This step involved the assembly of the CRISTAL macro statements necessary to synchronize the loading of the image files in the graphics environment with the display in the worksheet environment of the alphanumeric data associated with the displayed image. If the structure of the information associated with each image is essentially the same, then the only difference between each macro will be the unique filename assigned to the images associated with each particular resource record. The macro used in the example is:

&ILOAD FILENAME

Filename is simply the unique name (and directory or path) assigned to each particular resource image. The default file extension assigned to each Targa image is [.TGA]. Other extensions can be specified according to the format of the image file. In any case, a valid extension must be included with each specified image filename.

Example: The Paradise Inn, an historic hotel at Mt. Rainier, has an associated image file named "RPARA1.TGA". The macro statement located in cell [C25] is "&ILOAD RPARA1.TGA". In this case, the macro assumes that the image file "RPARA1.TGA" is located in the current (or default) image directory.

The default directory can be changed by activating the Environment menu, < / E D >, from the worksheet environment and specifying another default image file directory. An alternative to changing the image directory in the Environment menu is to specify the path in the macro statement itself (i.e. "&ILOAD C:\NPS\MORA\RPARA1.TGA"). In this case, the image file "RPARA1.TGA" is located in the "MORA" subdirectory of the "NPS" directory on the "C:" disk drive of the system.

Once the image management macro statements were created, the worksheet was saved under the filename "MORA.CRS" before proceeding to the next step. This was done by pressing the < / F

S R> key sequence and responding to "Save Sheet Filename" query with "MORA.CRS". The quick save Function key <F2> can also be used to save the current worksheet to the current filename.

Running The Application:

Step 1:

To run the NPS prototype application, first load the Master worksheet by pressing the </ F L N> key sequence. Respond to the "Load Sheet Filename" query with the filename "MORA.CRS".

Step 2:

Once the filename has been specified and the appropriate file loaded to the worksheet environment, a data search can be initiated by pressing the <F3> Function key. CRISTAL responds with the query "Find:" on the Message Line. Type the keyword associated with the desired resource (the search string), and press <Enter>. The following possible search parameters then appear on the Message Line:

"Options: Search Preview Global Upper Words Back Count"

Specify the desired options by pressing the first letter of the respective choices. If no options are specified and <Enter> is pressed, a non-case sensitive search for the specified text string will be performed. If a case sensitive search is desired, specify the "Upper" option.

The "Find" command, <F3>, will locate all occurrences of the specified string in the worksheet. When a match with the search string is located, the occurrence is highlighted in the worksheet and the query "Continue Search? Yes No" appears on the Message Line. If [Y]es is selected, the next occurrence of the specified string will be located. When no other occurrence is found, the screen prompt "Searched to end of sheet. Press <Esc>" appears on the Message Line.

Step 3:

To display an image that is associated with the resource record in the worksheet, press the macro function key <F10> and <Enter>. The execution of the "&HLOAD" macro will load the image file (or sequence of files) that is specified in the macro statement to the graphics screen.

Step 4:

Repeat Steps 2 and 3 to locate another resource record and display another set of associated images. Quit the application program by pressing the </ F Q> key sequence.

The user interaction with the CRISTAL information management system can also be directed through sets of customized menu commands. Each resource record in the NPS/MORA prototype includes a descriptive profile, statement of historic significance, maintenance record, site description, and statement of special conditions that may have an effect on the resource. The underlying structure of this CRISTAL application is a primary (or foundation) worksheet that contains the system's basic information structure, including primary references to all of the entries in the resource inventory. This foundation worksheet is the primary search environment. From this primary level, the system user can branch to a resource specific worksheet file that contains detailed information on each historic resource at Mt. Rainier National Park. This secondary worksheet is where the information pertaining to a descriptive profile, statement of historic significance, maintenance record, site description, and special conditions for each resource is stored. Similar to the assignment of unique image filenames, each resource is assigned a unique worksheet file. The worksheet filename can be the same as the filename associated with the primary resource image, with the exception that the default file extension for worksheet files is [.CRS] (instead of [.TGA]).

The following list is a summary of the macro commands used to implement the menu driven component of the NPS/MORA (Mt. Rainier) information management prototype:

&CHOOSE: Multiple branch to a specified cell where macro execution continues.

&GLOBAL: Switches the current environment from the Virtual to the Global worksheet.

&GOTO: Sends the display to a specified cell location.

&HALT: Halt the execution of the current program and return to the DOS environment.

&ILOAD: Load an Image file from disk to the graphics display.

&LOADG: Load a file from disk to the Global worksheet.

&LOADV: Load a file from disk to the Virtual worksheet.

&MENU: Create a menu from a specified block of cells.

&VIRTUAL: Switch execution to the Virtual worksheet.

Application Development (the resource worksheet file):

Step 1:

A model "resource record" worksheet was developed which served as the template for each specific resource work file. The worksheet contained data fields consisting of a descriptive profile, statement of historic significance, maintenance record, site description, and special conditions for each resource. Since this worksheet served as a template for all the individual resource records, each data field in the worksheet was predefined to hold the necessary information. Row [A1] through [A3] contained the resource data field located in the primary (foundation) worksheet of the prototype application. In the system template, rows [A7] through [A26] became the "Profile" field; rows [A28] through [A46] the "Historic Significance" field; rows [A48] through [A66] the "Maintenance Record"; rows [A68] through [A86] the "Site Description"; and rows [A88] through [A106] the "Special Conditions". Since this format was used for all resource records, this worksheet template was named "RESOURCE.CRS". This generic sheet can be activated (loaded) whenever necessary to create a new resource record. Each time the template sheet is used for a new record, the resulting sheet is saved under a filename corresponding to the unique resource name or identification code. To change a filename after a sheet has already been saved, use the Rename option in the Applications Command menu by pressing the < / F B > key sequence from the worksheet environment.

Step 2:

This step involved the modification of the primary (or foundation) worksheet to increase the sophistication of the resource management system. This primary worksheet was configured to contain the resource labels (or keywords) and the primary image management macros commands. To activate the primary worksheet, use the [L]oad sheet command located under the [F]ile menu by pressing < / F L N > from the worksheet environment. Respond to "Load Sheet Filename" query by typing the filename "MORA.CRS".

Step 3:

The first step in modification of the primary worksheet was to create a menu through which detailed information on the resource could be retrieved. The macro that was used to create the menu structure is &MENU. The &MENU macro must be located in the worksheet so as not to interfere with the areas that are used for resource information fields. For the NPS/MORA application, the menu macro was placed in cell [K2] of the "MORA.CRS" (primary) worksheet. The assembly of the menu that was to control access to the information in the secondary worksheet began with specification of menu selection choices. These choices were placed in a column in adjacent rows in the worksheet. The entries that were be included in the NPS/MORA resource record menu are:

A. Profile

B. Historic Significance

C. Maintenance Management

D. Site Description

E. Special Conditions

F. Image Processing

G. Return to Main Level

"Profile" was placed in cell [O2], "Historic Significance" in [O3], "Maintenance Record" in [O4], "Site Description" in [O5], and "Special Conditions" in cell [O6]. The macro statement implementing a return to the "Main Level" (primary worksheet) of the resource management application to begin a new search was placed in cell [O7]. The macro statement to "Quit System" and terminate the execution of the resource management application was placed in [O8]. The contents of the &MENU macro statement located in cell [K2] is as follows:

&MENU(O2,O8,M2,50,7,3,1,RESOURCE RECORD)

[&MENU] The label that defines the "menu" macro.

[02] Defines cell [O2] as the first entry in the menu.

[O8] Defines cell [O8] as the last entry in the menu.

[M2] Defines [M2] as the cell location in which the response from the menu selection is placed. If menu item "A" is selected, a value of "1" is placed in cell [M2], if "D" is selected, a value of "4" is placed in [M2].

[50] Corresponds to the horizontal coordinate of the menu location on the worksheet display screen. This number (50) places the upper left hand corner of the menu 50 characters from the left margin of the worksheet.

[7] Specifies the vertical coordinate of the menu location on the worksheet display screen. This number (7) places the upper left corner of the menu 7 rows below the top row of the worksheet.

[3] Foreground color assignment from the color table:

0 = Black	8 = Dark Gray
1 = Blue	9 = Light Blue
2 = Green	10 = Light Green
3 = Cyan	11 = Light Cyan

4 = Red	12 = Light Red
5 = Magenta	13 = Light Magenta
6 = Brown	14 = Yellow
7 = Light Gray	15 = White

[1] Background color assignment from the color table (Same color table as Foreground color).

[RESOURCE RECORD] This specifies the title label that will be placed at the top of the menu.

Step 4:

It was necessary to link the "Resource Record" menu to each unique resource record. The linking permits the secondary menu associated with each resource to be displayed on the monitor after the execution of the first &ILOAD macro has displayed the initial resource specific image on the graphics screen. The linking of the two macros was accomplished by "chaining" the &ILOAD macro command that is activated from the mapped graphics screen with an additional macro statement.

Example: Cell [F4] is the location of the image load (&ILOAD) macro for the initial image associated with the Sunrise Lodge. The following macro statement was appended to the end of the image load macro command.

&LOADG RSUN &BRANCH K2

The resulting chain of macro statements in cell [F4] is this:

&ILOAD RSUN1.TGA &LOADG RSUN &BRANCH K2

The component parts of the macro chain are:

[&ILOAD] Image Load Macro

[RSUN1.TGA] Image filename to be loaded

[&LOADG] Load a specified [.CRS] file into the Global worksheet

[RSUN] This is the [.CRS] worksheet file to be loaded into the Global worksheet environment. The worksheet extension [.CRS] does not need to be included in the file specification since it is the default worksheet filename extension recognized by CRISTAL.

[&BRANCH] Continue execution of a macro statement at a specified cell location.

[K2] The cell location of the macro statement to be executed by the &BRANCH command. In the MORA application, the &MENU macro statement is located in cell [K2].

This macro statement must follow each resource label in the primary worksheet. The application authoring process was expedited by copying the same macro statement for each resource record included in the system. After copying, the filename for the image and worksheet specifications was changed to correspond to the unique filenames assigned to each resource record for Mt. Rainier National Park.

Step 5:

This step created a monitoring mechanism that activates a program operation or displays a data field based on the user's menu selection. In Step 3, the &MENU macro was used to create a selection menu (RESOURCE RECORD). To activate the macro in cell [K2], move the cursor to cell [K2] and press <F10> <Enter>. The five item menu "RESOURCE RECORD" is displayed in the upper right hand corner of the monitor screen. If item "D" is selected (press "D"), the value "4" is placed in cell [M2]. The following &CHOOSE macro monitors cell [K2] and implements the selection specified from the menu by moving to the secondary worksheet environment (Global) and displaying the data field that corresponds to the specified menu choice. The format of the &CHOOSE macro statement is as follows:

&CHOOSE(M2,N2,N3,N4,N5,N6,N7,N8)

[&CHOOSE] The label that defines the "choose" macro.

[M2] This is the cell location that will be monitored for the selection key value. This cell location is the same as that specified in the &MENU macro statement for the placement of the menu selection value.

[N2] This is the cell address at which a macro will be executed when item "A" (Resource Profile) is selected in the menu.

[N3] This is the cell address at which a macro will be executed when item "B" (Historic Significance) is selected.

[N4] This is the cell address at which a macro will be executed when item "C" (Maintenance Management) is selected.

[N5] This is the cell address at which a macro will be executed when item "D" (Site Description) is selected.

[N6] This is the cell address at which a macro will be executed when item "E" (Special Conditions) is selected.

[N7] This is the cell address from which a macro will be executed when item "F" (Image Processing) is selected.

[N8] This is the cell address from which a macro will be executed when item "E" (Return to Main Level) is selected.

The macro statements located in cells [N2] through [N6] are identical except for the cell location that they reference. The macro that is located in cell [N2] is as follows:

&GLOBAL &GOTO A7

[&GLOBAL] Switches the current environment from the Virtual to the Global worksheet. This macro displays the Global worksheet that was loaded in Step 4 (RSUN.CRS) as the current worksheet environment.

[&GOTO] Sends the display to a specified cell location.

[A7] This is the specified cell that becomes the current displayed location when &GOTO is executed. Cell [A7] is the starting location for the "Resource Profile" data field which is referenced by menu item "A".

The macros located in cells [N3], [N4], [N5], and [N6] have the identical structure, differing only in the cell locations that are referenced. For example, the macro located in [N3] sends a display to cell [A28] which is the "Historic Significance" field of the individual employee's record. The macro in [N4] references cell [A48] which is the "Maintenance Record" data field.

The macro statement located in cell [N7] activates the graphics processing environment of the CRISTAL system. This enables the application user to annotate or modify images that are displayed on the graphics screen. Processed images can then be saved under a new filename or output to the printer.

The macro statement located in cell [N8] returns the application user to the screen map of the prototype NPS/MORA Information Management System. From this primary level of interaction, a new information retrieval path can be initiated. The format for this macro is:

&HOME

Step 6:

This step created the procedure to return the application user to the Virtual worksheet environment so that a new data search can be implemented. The controlling macro statement is located in the Global worksheet. In order to create the macro statement, the application programmer switched the current environment to the Global worksheet by pressing <Alt C>. Pressing the <Alt C> key sequence from the Global environment switches the current environment to the Virtual worksheet.

In the example, the macro statement that switches the current environment to the Virtual worksheet is located in cell [B1]. The format of the macro statement is:

&VIRTUAL &GOTO A1

[&VIRTUAL] Switches the current environment from the Global to the Virtual worksheet.

[&GOTO] Sends the display to a specified cell location.

[A1] The cell location that becomes the current cell when the &GOTO macro statement is executed.

After viewing the desired resource data field, the application user can return to the RESOURCE RECORD menu by pressing the <F10> <Enter> key sequence. The user can activate the image processing capabilities of the CRISTAL system by specifying "F" ("Image Processing") in the menu. The user can return to the primary level of the MORA System by specifying selection "G" ("Return to Main Level") from the menu.

CRISTAL Graphics Mapping:

Map Screen:

The Map Screen command provided the mechanism for linking the graphics environment with the worksheet environment. A "screen map" makes it possible to run program applications and execute macro commands directly (and transparently) from the graphics screen. In the Map Screen function, a grid (10 X 10) consisting of references to cell addresses in the worksheet is superimposed on the graphics screen. When the screen map status is activated, a mouse is used to position the cursor in the graphics screen at the desired grid cell. When the left mouse button is pressed, the macro located in the corresponding cell in the worksheet is executed. The display of the grid, which can contain 100 cell references, can be hidden during the setup procedure so that the screen map remains active without interfering with the image display.

Once the Screen Map is constructed, each grid cell in the graphics screen can contain an icon produced from a compressed digital image, or the grid can map a single image dissected into 100 parts. To create the screen map for NPS/MORA, the "Map Screen" function was activated from the CRISTAL Graphic menu. When "Map Screen" was activated, the current image displayed on the graphics screen became the foundation image for the screen map. The application developer then specified an image filename to place in the screen map. The program query, "Show the Grid: Yes/No", allowed the operator to specify whether the grid was to be displayed superimposed over the foundation image on the graphics screen. Each grid cell was labeled with a worksheet cell address corresponding to the default cell block (A1..J10), or to another specified cell block. The mouse was then used to indicate the location in the grid matrix for the placement of the compressed, specified image. The process was repeated by the application developer to until the map was completed.

The creation and display of a maximum of 100 image icons on a single screen is possible with the "Map Screen" function. Additional map layers can exist behind the master screen map, with single icons on the master map providing access to other fully mapped screens.

Once a Screen Map has been assembled, the application user positions the mouse cursor at the desired icon (or component part of a full screen image) and presses the left mouse button to access the corresponding information base. This action initiates the execution of the macro command (or macro chain) that begins in the corresponding cell in the current worksheet.

Macro Manager:

The Macro Manager allows the user to execute, name, change, erase, or debug Macro commands for each individual worksheet file. Press [Alt F10] to activate the Macro Manager. Select Manager commands from the Manager menu by pressing the first letter of the desired command, or use the Highlight Bar method. In the Manager list, use the arrow keys to position the Highlight Bar at the desired line of the Manager list where selected commands are to be implemented. Press [Enter] to record actions, or press [Esc] to return to the menu without implementing the selected command. The Macro Manager menu displays the following commands:

Help: activate the Macro Manager help file.

MacroX: execute the Macro specified (highlighted) in the Manager list.

Add: assign a name to a Macro located at a specified cell address in the current worksheet. A maximum of 27 contiguous characters is allowed in the list for the Macro name and cell address. Example: TEST_11,AA250

Change: modify a Macro list name or address. Position the Highlight Bar at the desired name and type the necessary changes.

Erase: delete a named Macro from the Manager list. The erasure of a name from the Manager list does not delete the Macro itself from the worksheet.

Debug: step through a named Macro execution path in the worksheet environment. The Debug command is used to confirm the contents of the Macro chain. The Macro can be edited during the Debug procedure.

Quit: exit the Macro Manager and return to the current worksheet environment. The [Esc] key can also be used to quit the Macro Manager.

Macro Execution:

Execution of a Macro can be initiated from the worksheet environment by pressing the [F10] Macro key. Type the desired Macro name at the Message Line query, or press [Enter] to execute the next Macro located in the worksheet (relative to the current cell location).

1. Activate the Macro Manager by pressing [Alt F10].

The Macro Manager displays a list of named Macros (if one exists for the current worksheet). Use the arrow keys to position the Highlight Bar at the named Macro that is to be executed.

Press [Enter] to execute the indicated named Macro. If no named Macros are listed in the Macro Manager, press [Enter]. CRISTAL will then search forward from the current worksheet cell location for a valid Macro. The first valid Macro encountered relative to the current cell location is executed.

2. Press [/ M] to activate the Macro Command from the worksheet.

Use the arrow keys to highlight the name of the Macro to be executed. Press [Enter] to execute the selected Macro.

3. Press the Macro key [F10].

At the Message Line query, type the name of the Macro to be executed, or press [Enter] to execute the next Macro located in the worksheet (relative to the current cell location).

Note: For any of the execution alternatives, if no valid Macros exist in the worksheet the system beeps and displays the message:

"No Macro in sheet!!! Press any key to continue"

The Automatically Executable Macro:

If the user assigns the name "AUTOEXEC" to a Macro, it will automatically be executed every time its worksheet file is loaded to the system. This can be effectively employed to invoke a special application procedure.

There can be only one auto-execute Macro per worksheet. If the automatic execution of a Macro is no longer required, change the name or delete the Macro altogether from the MACRO applications command menu in the main menu of the worksheet.

Note: A Macro can be stopped at any time by pressing the [Esc] key.

Macro Command Categories:

Macro commands are classified into the following categories:

- Movement commands allow movement through the worksheet.

- Sheet commands affect operations between worksheets.

- Screen commands affect the screen display.

- Interactive commands create interactive Macros that pause for the user to enter data from the keyboard.

- Program Flow commands allow the user to develop branching and looping programming sequences.

- Cell commands affect the data stored in specified cells.

- File commands work with data within files other than the current worksheet file.

Output:

The Output facility provides the basic means of generating worksheet reports and images from the CRISTAL system. This includes formatted worksheet output and cell listings that can be printed to either a printer, disk file, or the screen.

Sheet Output:

Sheet Output can be sent to Printer, Screen, or Disk file. Note that the worksheet cells with [NO] Display or [NO] Output attributes assigned to them will not be sent to the specified output device. These cell attributes can restrict cell output so that specified worksheet data does not appear in the output medium.

Image Output:

Image Output can be sent to Printer, Screen, Disk file, Color printer, or Film recorder. Image data can consist of drawings, graphs, digital images, or combinations of these graphic data types. The image can originate from any of the menu options in the Graphics Command menu.

Cell Output:

Cell Output sends a report of the contents of all the current worksheet cells to Printer, Screen, or Disk file. The report includes each cell's address, data type, status, attributes, cross references, and the literal data contents of the cell (text, formula, macro, numerics). The cell report procedure is particularly useful in debugging the programming of a CRISTAL application.

Appendix B. Glossary of Hypertext Terminology

(Larson, 1988)

ASCII (PC-Hypertext): Nodes are compatible with other programs. Network is useful in printed format since links are text based and can be manually followed in hard copy. Efficient in disk usage. Runs fast on the base of installed machines (8088 to 386 CPUs).

Button-dominated: Text jumps (embedded buttons) work for 1-5 branches on a screen. If poorly done, buttons can disrupt the continuity of the information on the screen. Network associations cannot be printed since link information is hidden in program code. (limitation)

Circular (wandering): If built primarily using a word processor or one screen at a time, the linkages between files are poorly classified. The better approach is to separate information creation from information categorization and linking. (limitation)

Hacker (spaghetti): Convoluted linkages fail to communicate the language and structure (taxonomy) of a knowledge area. (limitation)

Non-hierarchical: User cannot comprehend the relationships, location, or structure of information in the system. (limitation)

Structured: User can comprehend associative relationships between information nodes, and hence, the consequences of navigational paths existing in the system. (attribute)

Pictorial: Emphasis on graphics as a significant component of the information base, including the use of a graphical user interface. The system construction time can be lengthy and the storage requirements for system graphics can be extensive. (limitation)

Pirate Hypertext: Uses copyrighted material (pictures and text) without the permission of the creators or copyright holders. As a consequence of the unresolved legal clouds that surround the development of global information networks, most information bases that utilize a hypertext structure will initially contain material that is in the public domain, such as federal, state, and local information, laws, rulings, and specification standards or guidelines. (limitation)

Star Hypertext: The linking of ASCII files that contain references to the same subject material to the most important file of the group. In that file, footnote links are added to connect it to all of the other files. This "star" hypertext linking is both easier and faster to build and use than the cross referencing of all individual files. (attribute)

Appendix C. Expert Systems and Hypertext

(Larson, 1989)

An expert system moves through a set of rules in much the same way as an individual who selects paths in a decision tree.

AUTOMATIC PATH SELECTION An expert system can monitor time, pressure, temperature, etc. to automatically eliminate certain decision paths in the search for answers. In contrast, hypertext systems depend upon operator responses to make selected paths to answers. (limitation)

CALCULATED DECISIONS: Expert systems often include formulas that convert any number of variable inputs into a single path selection. Instead of this parallel processing (multiple inputs - single answer), hypertext decision systems use a sequence of decision points (serial processing) in order to convert multiple inputs into a single path. (limitation)

SPEED An expert system may reach the appropriate decision within a fraction of a second (ie. avoiding an aircraft collision). With hypertext, speed is limited by the ability of the user to complete multiple sequences of reading, understanding, and selecting choices at each decision point. (limitation)

However, hypertext has several significant advantages over expert systems in dispensing information or finding solutions: construction speed, time to learn, knowledge representation, ease of modification, sensitivity analysis, and transmission of knowledge.

CONSTRUCTION SPEED A good 200-rule expert system may take a team of knowledge engineers two years to build. In contrast, most experienced computer users can quickly build a 200-node decision tree to provide relevant advice. (attribute)

TIME TO LEARN It often takes many years for experts in other fields (e.g., PROLOG, LISP, SMALLTALK) to efficiently embed their knowledge into automated expert systems. In contrast, experts can quickly master the tools required to assemble hypertext systems. (attribute)

KNOWLEDGE REPRESENTATION Two major difficulties exist in building expert systems. First, how can users acquire expert-level knowledge? Second, how can this knowledge be represented so that a machine can generate solutions from it? In hypertext systems, the knowledge is represented using familiar formats (i.e., text, diagrams, pictures). (attribute)

MODIFICATION EASE Once completed, expert systems tend to be notoriously difficult to update or modify (many interactions are often hidden from users), and then to validate again (who knows when an expert machine starts or stops producing expertise?). With ASCII hypertext systems, annotations, modifications, and improvements are simple to implement with a text editor. (attribute)

TRANSMISSION OF KNOWLEDGE Expert machines generally do not explain to users the actual methods that will lead to a particular decision. With hypertext, users directly participate in each and every decision that leads to a synthesis of knowledge. This process of openly displaying the knowledge structure facilitates the assimilation of it by users of hypertext systems. (attribute)

SENSITIVITY ANALYSIS Expert machines usually provide a single answer supported by a confidence factor (ie. 82 percent certainty). Hypertext systems allow users to rapidly test alternative paths to see how sensitive the advice may be to changes in the initial assumptions. (attribute)

Appendix D. Decision Process

1. Task defined.
2. Program the needs and objectives.
3. Information gathering (prior experience, knowledge, factual evidence) from existing sources.
4. Information gathering in response to new or unique information processing needs.
5. Identify case studies and models appropriate to the current decision context.
6. Synthesis (identify, process, and structure context relevant information).
7. Identify decision choices and alternatives.
8. Ranking of decision choices (preferred, recommended, not recommended).
9. Select choice (make decision; annotate the decision process with regard to the rationale for selection and rejection of choices).
10. Implement choice.
11. Monitor effects of the implementation process.
12. Evaluate: critique the decision and implementation processes.
13. Annotate: append critical commentary to the decision path in the information base.