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An Integrated Knowledge System for the Space Shuttle Hazardous Gas Detection System

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Summary

A computer-based integrated Knowledge-Based System, the Intelligent Hypertext Manual (IHM), has been developed for the Space Shuttle Hazardous Gas Detection System (HGDS) at NASA Marshall Space Flight Center (MSFC). The IHM stores HGDS related knowledge and presents it in an interactive and intuitive manner. This manual is a combination of hypertext and an expert system which store experts' knowledge and experience in hazardous gas detection and analysis. The IHM's purpose is to provide HGDS personnel with the capabilities of:

- Locating applicable documentation related to procedures, constraints, and previous fault histories;
- Assisting in the training of personnel;
- Enhancing the interpretation of real time data; and
- Recognizing and identifying possible faults in the Space Shuttle sub-systems related to hazardous gas detection.

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1. Purpose of the Project

Hazardous gas leakage monitoring of the space shuttle main propulsion system is one of the methods of detecting subsystem faults during space shuttle launch operations. This monitoring is a complicated assignment which involves a large collection of hardware, documents, and experts' knowledge. There is a pressing need to improve the information retrieval, data interpretation, fault recognition, and corrective action assistance of the Hazardous Gas Detection System (HGDS). A computer-based integrated knowledge system, the Intelligent Hypertext Manual (IHM), may provide just the right tool to accomplish this task.

The IHM is a computerized service manual designed to store HGDS related information and present it in an interactive and intuitive manner. It provides a useful tool for hazardous gas leakage monitoring in information retrieval, data interpretation, fault recognition, and assistance in taking corrective actions. The IHM is a combination of hypertext documents and an expert system. In contrast to the traditional expert system, which usually does not include a large volume of information, the IHM stores in computer memory a large volume of text/graphics documentation, such as schematics, optional actions, and service procedures, in a hypertext database. The IHM also assists users in the decision-making process: it provides "quick and easy" access to appropriate information for fault detection with action options. It may also supply a large volume of accessible material in specific areas of space shuttle hardware for assistance in training personnel.

In short, the IHM has the potential to increase the productivity and quality of service for hazardous gas leakage monitoring. It eliminates some human errors and reduces the required resources, including manpower and material cost, to achieve the specified goal.

2. Technical Objectives

The objective of this research project is to build an integrated software shell for the computerized knowledge-based system, the IHM. The IHM has the following features:

- it stores HGDS related knowledge on one personal computer,
- it presents stored information in an interactive and intuitive manner, i.e., the user controls the information presentation flow,
- it provides a friendly graphical user-interface, and
- it has a set of system accessories to make the system more effective and user-friendly.

3. Approach: Hypermedia Technology

The purpose of the IHM is to store knowledge, organize it, and effectively retrieve and display it to the user. The basic technology which makes this possible is hypermedia [Ref. 1-3]. Hypermedia incorporates information in an enriched environment that complements text with high quality pictures, full motion video, and sound. More importantly, hypermedia allows the user to browse through linked, cross-referenced, annotated, and layered information quickly in a non-sequential manner. Figure 1 is an illustration of hypermedia. Information within a hypermedia document contains knowledge-elements (such as notes, papers, books, diagrams, photos, full motion video and sound, and other software packages) and the relationships among those elements. By following the relationships between knowledge-elements, the user has the ability to find and display information in an intuitive and interactive manner. Hypertext, which is used for the IHM, is one branch of hypermedia that deals mainly with text and graphics [Ref. 4 - 7].

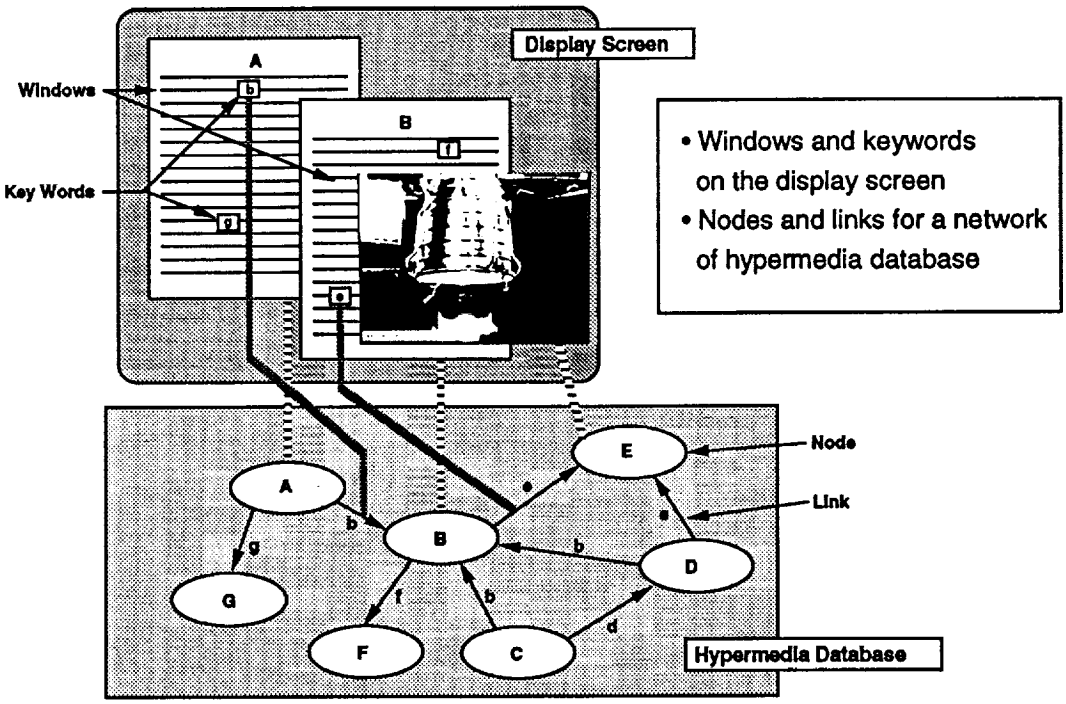

Figure 1. An illustration of hypermedia

Hypermedia is a very flexible tool that can be applied to a wide range of applications. Essentially any information that can be presented electronically can benefit from hypermedia. Theoretically, hypermedia systems do not have size limitations; therefore, they can be expanded to link every piece of electronic information available. A few areas in which hypermedia is often used are technical reference materials, maintenance manuals, and policies/procedures manuals.

4. System Architecture and Implementation

The system architecture of the IHM is shown in Figure 2. The IHM has a user-interface, a set of system accessories, and a knowledge base which consists of many information and knowledge elements. The basic design idea was to construct the IHM using commercial software shells, which are well developed and available for all potential users, so the developer could concentrate on developing the knowledge-elements and integrating them into the IHM. The IHM is built with an open-architecture so that new knowledge-elements can be easily integrated into the system. This design concept will greatly simplify the task of maintaining and updating the IHM.

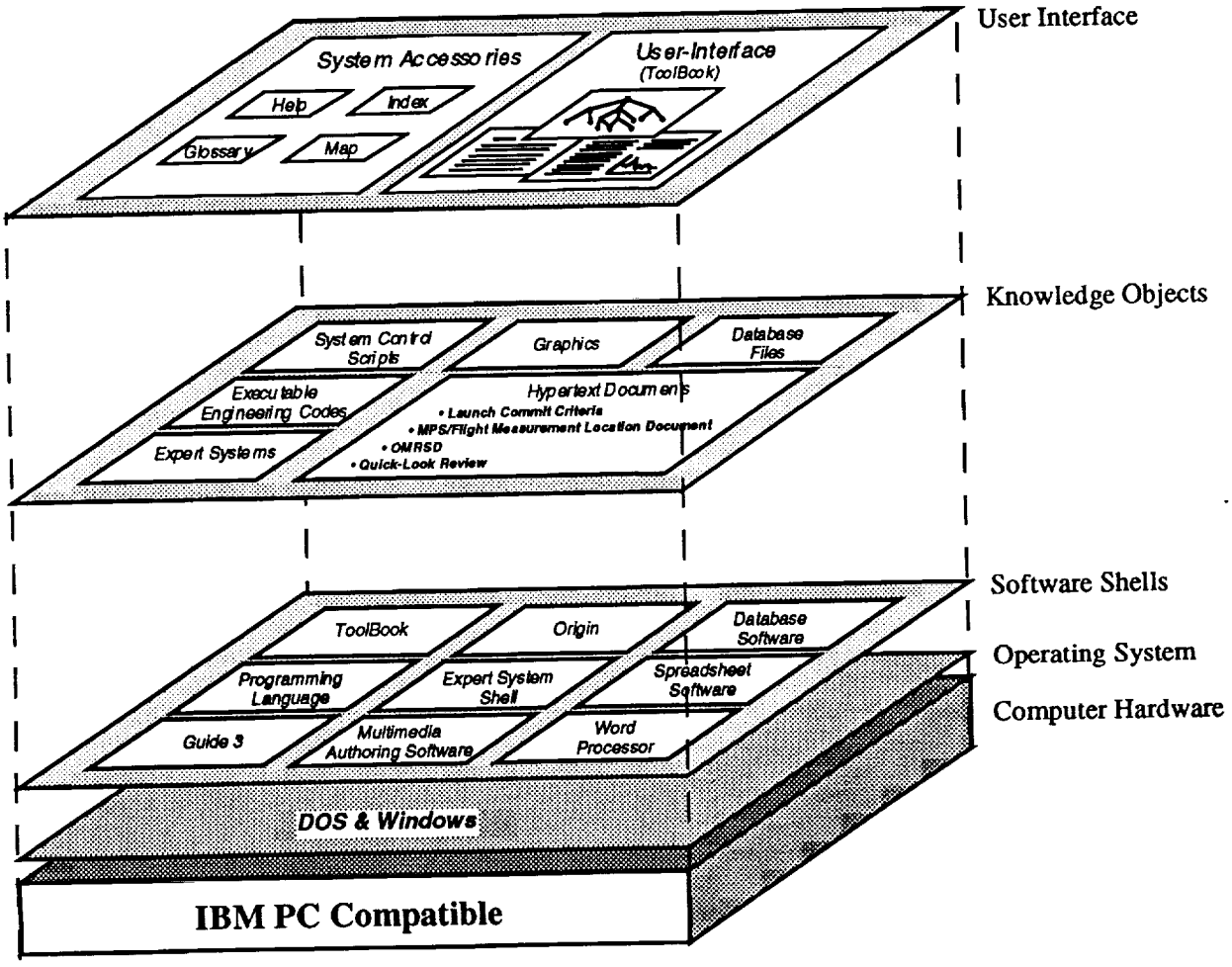

Figure 2. System architecture of the Intelligent Hypertext Manual

Users are not required to know the architecture of the system. The detailed structure of the system provides information only for those who intend to attach some additional information, such as new branches of the system, or to modify it for his/her own specific needs.

The IHM currently operates on the IBM PC platform. Microsoft Windows 3.1 [Ref. 8] was selected to be the working environment and the user-interface was built using ToolBook [Ref. 9]. Other application software included are an expert system shell and a plotting program.

5. Results

A system shell for the IHM has been constructed during this project. The IHM knowledge-base contains many HGDS related knowledge-elements including hypertext documents, databases, expert systems, etc. The IHM also provides a graphical user-interface and a set of system accessories to make the system more effective and user friendly.

5.1 IHM Knowledge-Elements and Organization

Related information or knowledge is grouped into knowledge-elements (or objects in terms of the object-oriented environment of the IHM) as illustrated in the second layer of Figure 2. The knowledge-elements may be built using different software shells, each according to their own usage and nature. Each knowledge-element is linked to other knowledge-elements both by the user-interface and by links originating within the elements. These links are made during system construction and are implicit to the users.

The knowledge-elements of the IHM include critical information related to the HGDS, such as information from applicable manuals, procedures, criteria, and data. The information included in the IHM is selected based on the access requirement priority in the hazardous gas leakage monitoring process, and availability. The three criteria, on which the topic selections were based, are:

(1) Topic priority, their importance for hazardous gas leakage monitoring,
(2) Topic readiness, such as documents in electronic format and complete documents, and
(3) Support from NASA/contractor expert personnel.

The procedure for constructing the IHM is to first build knowledge-elements based on the existing electronic and/or complete printed documents, and then integrate them into the IHM system. Figure 3 shows the knowledge-base of the IHM and the following sections describe the IHM knowledge-elements in detail.

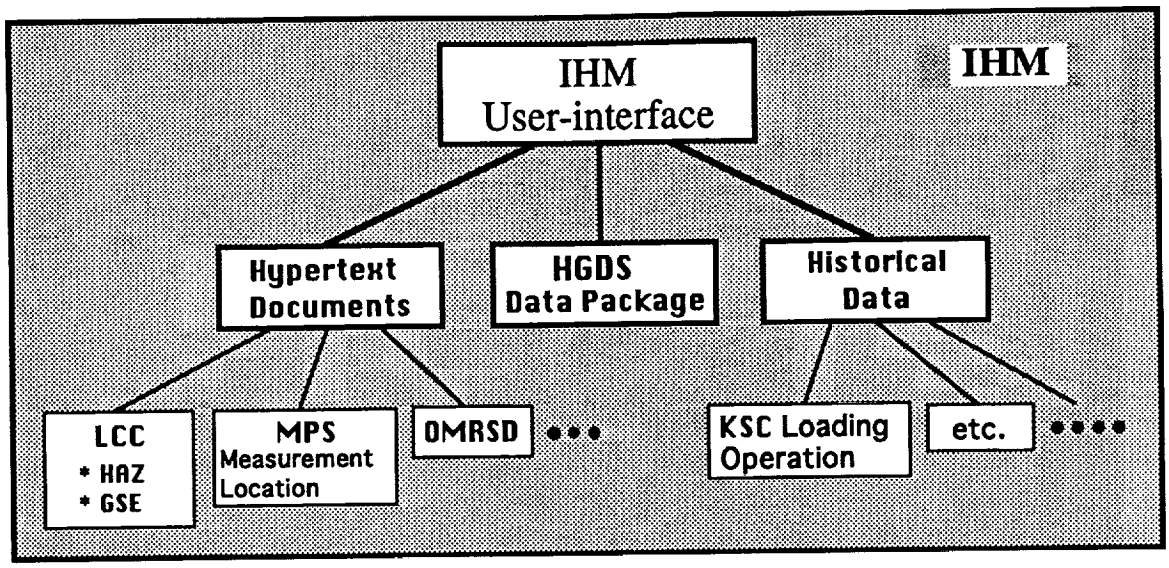

Figure 3. The knowledge-base of the Intelligent Hypertext Manual (IHM)

5.1.1 Hypertext Documents

The hypertext documents were constructed from existing computerized and/or printed documents. The hypertext documents were built using ToolBook, an application construction software designed for use in the Microsoft Windows graphical environment. The specific documents that have been included in the IHM are the following:

A. Launch Commit Criteria documents:

The Launch Commit Criteria (LCC) documents are the most important documents used during launch monitoring. The sections of the LCC/HAZ and part of the LCC/GSE have been implemented into hypertext form and arranged in such a way that the user can easily access any single document either by clicking on its name or by selecting the situation it covers during the launch, e.g. launch period, gas type, and sensor location. Figure 4 shows the hypertext form of an LCC document.

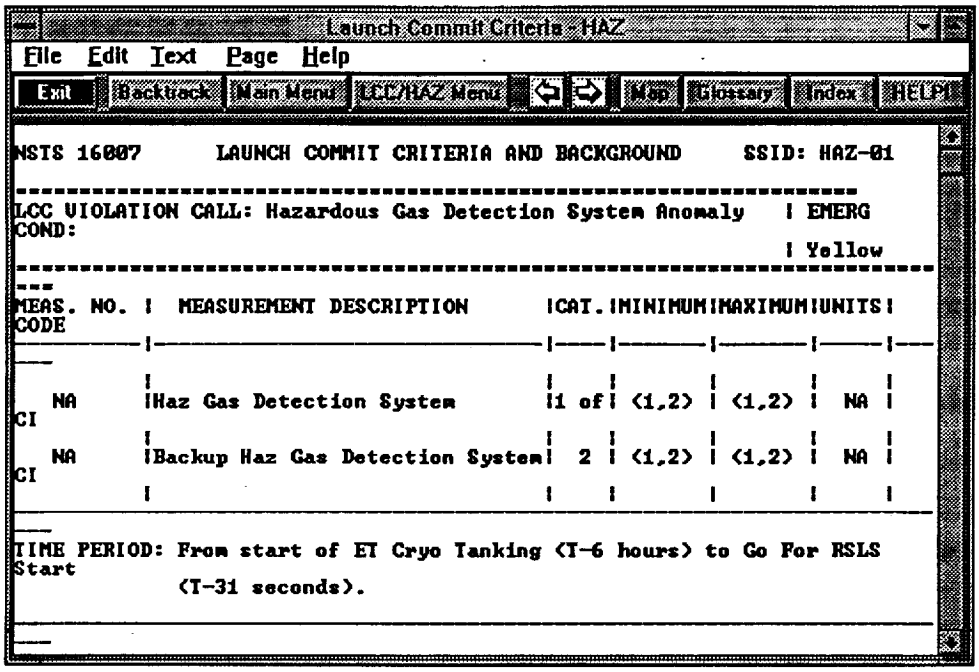

Figure 4. A screen display of an LCC document

B. Main Propulsion System/Flight Measurement Location Document:

The Main Propulsion System/Flight Measurement Location Document (MPS/MLD) has been built into hypertext document format. The original documents, provided by the Rockwell, Inc., were converted to Windows-readable graphic-image files. Hyper-links facilitate movement either sequentially through the document, or directly to a pertinent section via menus. Figure 5 is a screen display of an MPS/MLD figure. An automatic feature is included to easily update the document by incorporating new graphics images when desired.

C. Operations and Maintenance Requirements and Specification Document:

Material from the Operation and Maintenance Requirements and Specifications Document (OMRSD) has been provided by Rockwell which includes information pertaining to events occurring before External Tank loading, during the T-6 to T-4 hour time frame, and during the T-10 to T-1 minute time frame. This material has been implemented in the system. Some detail requirements and specific criteria relevant to the Hazardous Gas Detection System have also been built into the system. Figure 6 shows a display screen of an OMRSD document.

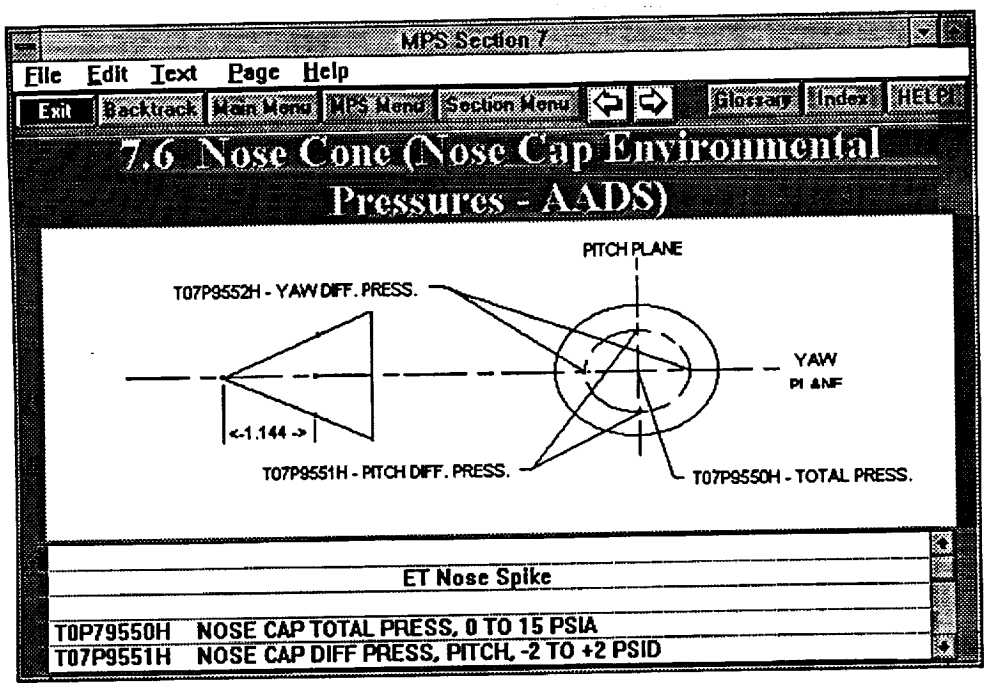

Figure 5. Display of an MPS/MLD screen

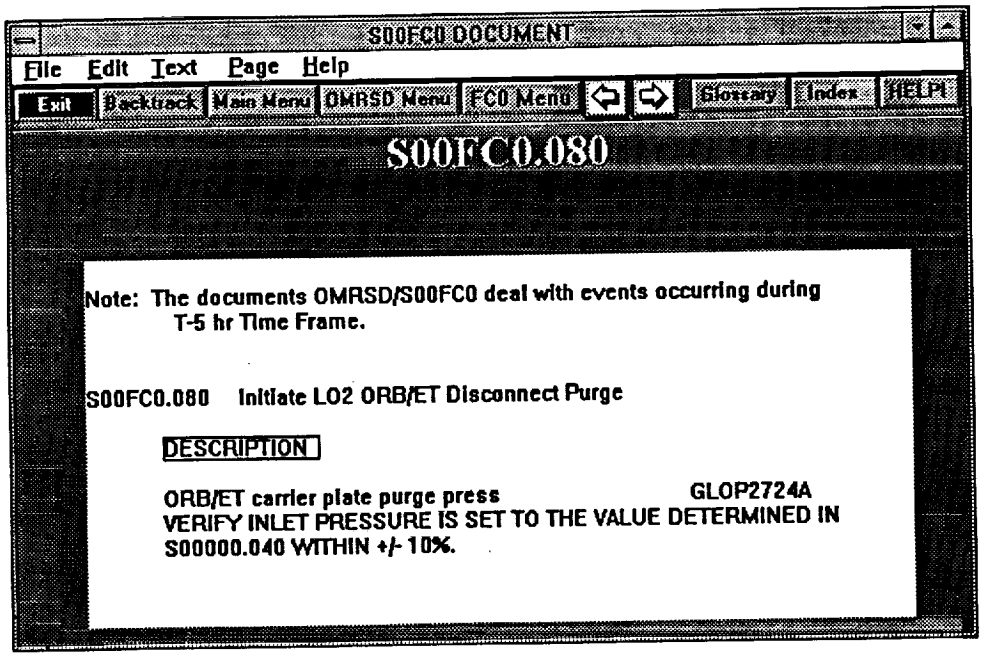

Figure 6. A display screen of an OMRSD document

D. Quick-Look Reviews:

The Quick-Look Reviews for several launches have been incorporated into the IHM in hypertext format. These hypertext documents include written prefaces and tables as well as the graphs that make up the bulk of these reports. The hypertext Quick-Look Manual allows users to navigate quickly to the portion they want to review. Figure 7 shows an example of a hypertext Quick-Look preface.

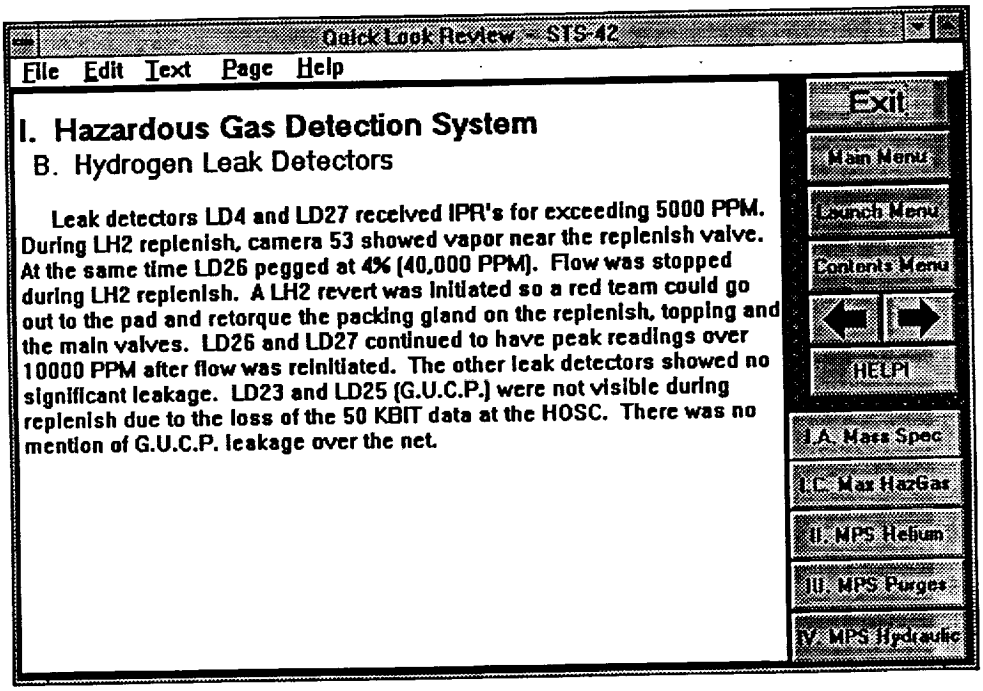

Figure 7. An example preface from the hypertext Quick-Look Reviews

5.1.2 Expert System for Data Retrieval

A document, the "Hazardous Gas Detection System Summary", which contains information about hazardous gas leakage measurements for all shuttles' loading operations, was provided by Rockwell, Inc. This document has been built into a dBASE file for easy access. For future updates of this information, only this database file needs to be changed. A ToolBook interface has been designed for this database to intelligently retrieve the data from it. The user can quickly retrieve the data sorted in several ways:

(1). by launch vehicle name, date, and come out results

(2). by launch ID, or

(3). by gas concentration limit

Figure 8 shows one of the sorting menus. The retrieved data is written into an ASCII report file and can be read, printed, or plotted as the user chooses. Figure 9 shows the data display screen.

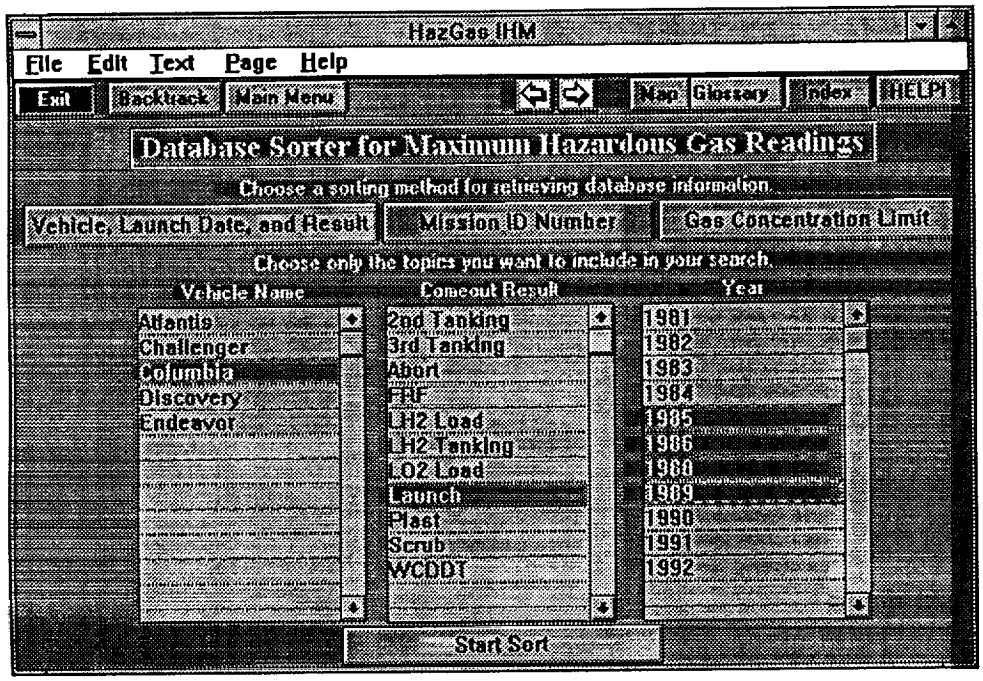

Figure 8. User-interface for retrieving data from the database

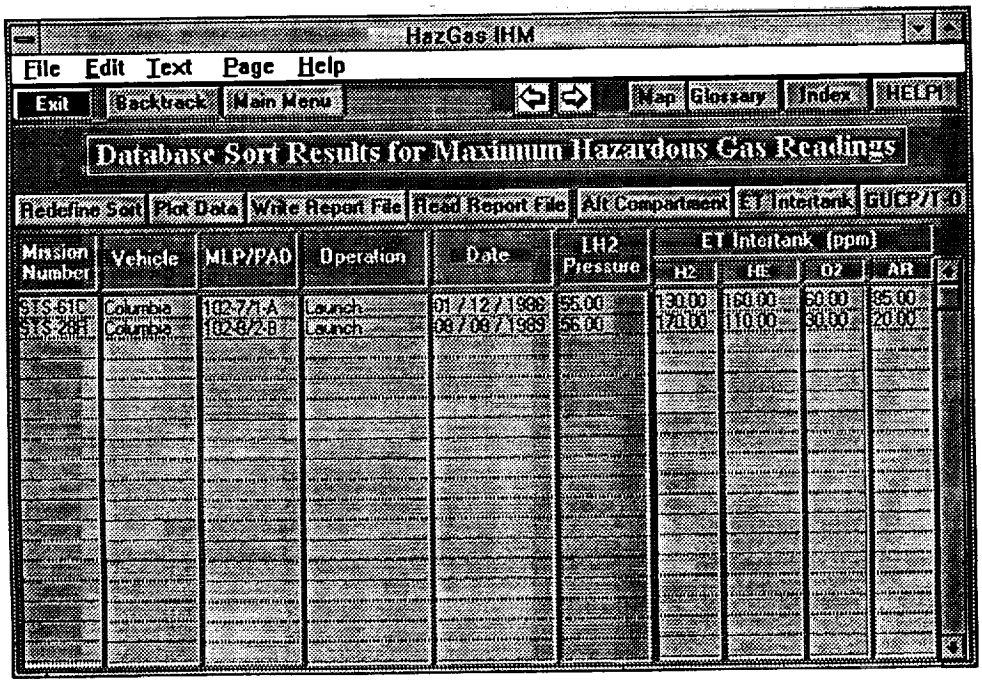

Figure 9. The data display screen

5.2 IHM's User-Interface

The design of the user-interface is one of the most important aspects in developing the IHM because the user relies on it for information retrieval. The IHM's user-interface is constructed to provide easy access to all knowledge-elements such as hypertext documents, databases, and expert systems, and to allow the user to navigate through the system. Therefore, the interface must be simple to use and easy to understand.

The layout and operation of the IHM's user-interface is consistent throughout the entire system to promote user familiarity. The information in the IHM is formatted in distinct, screen-size pieces (or "pages") so that it can be instantly available and easily assimilated by the user. The main elements of the user-interface are buttons or other types of instant command objects which carry out pre-defined actions. The IHM's user-interface has two types of these objects, navigational and special function buttons. The navigational buttons provide quick and easy access to any piece of information within the IHM. These type of buttons are consistent in their location and function throughout the IHM. The special-function buttons are specific to a certain page or page-type. They carry out the operational needs of the page in which they are contained.

The IHM's user-interface was built first using Guide 3 [Ref. 10], a hypertext software package for Windows environment. The user-interface, however, was completely re-built using ToolBook during the second year of the project. ToolBook has been chosen to replace Guide 3 because:

1) ToolBook has more functions and is more flexible than Guide 3.
2) A ToolBook interface not only appears more professional, but is easier to use and understand.
3) The scripting language of ToolBook is easier to program in than that of Guide 3.

5.3 IHM System Accessories

System accessories, such as Help, Map, Index, and Glossary, are designed to increase the IHM's efficiency and user-friendliness. Because of the nature of the IHM, these accessories are in hypertext format and the user may access them from anywhere within the IHM.

The context-sensitive Help provides assistance depending on where the user is in the system. Users can easily get the specific help they need rather than search through long help-menu screens.

A Map is a navigational aid. It shows a graphical representation of the system and the current location of the user within the system. The map also allows users to travel to different locations

within the system by clicking on the icon of the desired location. Figure 10 shows part of the IHM Map.

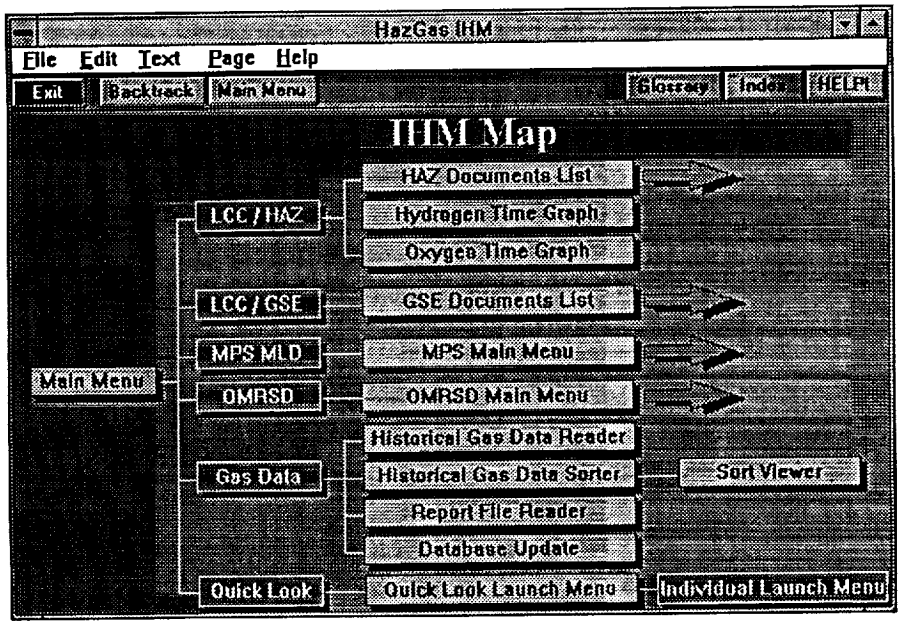

Figure 10. Part of the IHM Map

The Index is an alphabetical list of topics contained within the IHM, as shown in Figure 11. The hypertext nature of the Index allows the user to navigate directly to the topic he/she wishes to see by clicking on the topic. The Glossary contains specific definitions of terminology in the IHM.

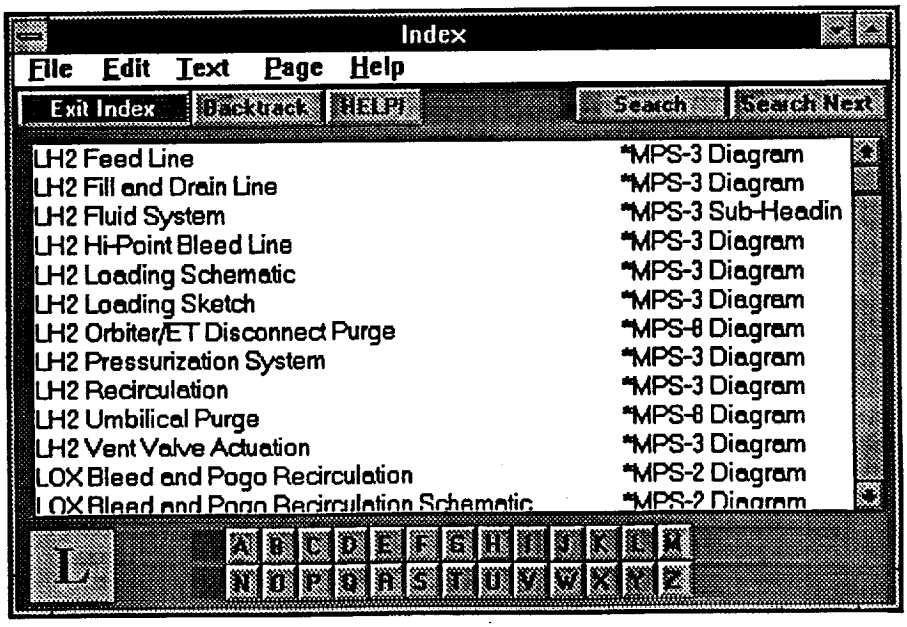

Figure 11. A screen display of the Index

5.4 IHM's Plotting Capability

The IHM has a plotting capability which utilizes Origin [Ref. 11], a Windows-based scientific and technical graphics software package by MicroCal, Inc. The transition from the IHM into Origin is smooth because the user stays in Windows. Origin's user-interface is very "friendly" and supports the use of a mouse. The user is able to: zoom to portions of the graph, view the numerical data, print portions of the plot, and manipulate the data with curve-fitting, statistics, arithmetic, etc. Origin also allows for pre-programming, which reduces the amount of input and learning required for the user to plot data in the IHM.

The IHM has been set up to run Origin directly when asked to plot the data sorted by the expert system. Upon choosing the plot command in the IHM, Origin is launched and the data is automatically loaded. A plot is then automatically produced and scaled for that data. Figure 12 is a screen-print of a plot of sorted data from an expert system session.

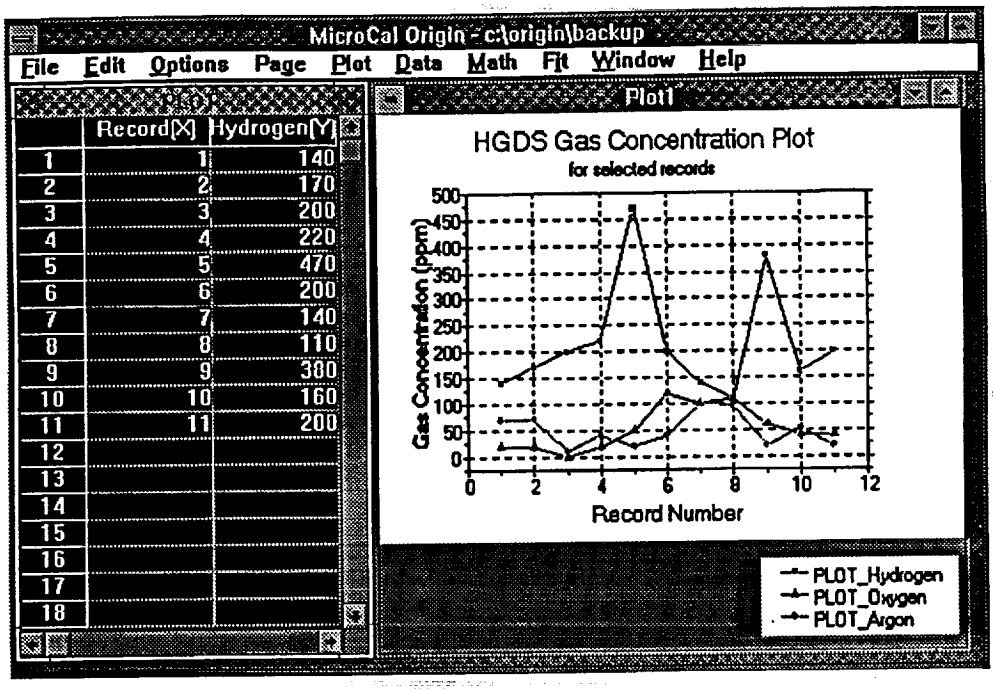

Figure 12. A Plot of sorted data from an expert system session

The IHM also allows the user to plot off-line, time dependent gas concentration data for a single launch. This gives the user a quick way of reviewing this form of the gas concentration data.

5.5 Hypermedia Implementation Investigation

The possibility of incorporating full motion video and sound into the IHM has been investigated. A VideoLogic DVA-4000 video board and MIC System software [Ref. 12] have been installed in a IBM PC-386 computer. A laser-disc player is used to retrieve video images from pre-made laser discs. Command-buttons, which launch the player and put the desired video images on the computer screen, can be placed within text documents so the user can view these images while reading the documents by simply clicking the buttons. This would give the IHM the capability of demonstrating a particular task to the user visually, rather than attempting to relate the task strictly with words. A photograph of a sample hypermedia screen display is shown in Figure 13. We believe that the hypermedia IHM could be extremely useful and much more efficient.

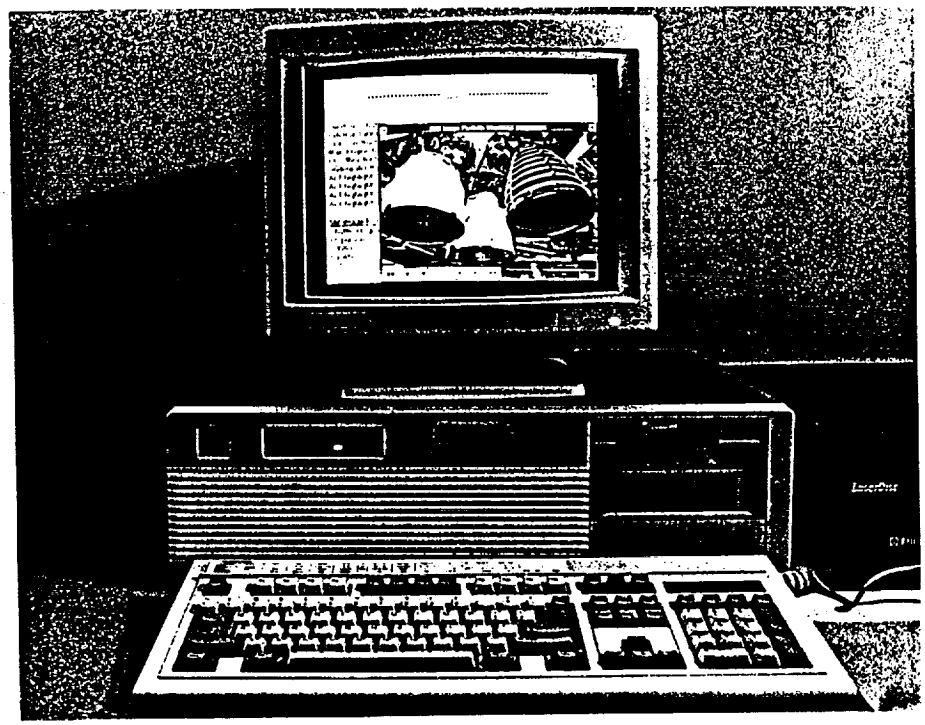

Figure 13. A sample hypermedia screen display

6. Concluding Remarks

A Knowledge-Based System (KBS), the Intelligent Hypertext Manual (IHM) for the Space Shuttle Hazardous Gas Detection System (HGDS), has been developed for NASA/MSFC. This system holds much promise in improving the efficiency of personnel and increasing productivity in

aerospace applications. A well-designed KBS does more than merely present its stored knowledge to a user; it will:

(1). Store information and present it quickly and efficiently.

(2). Filter that information down to the essentials.

(3). Help the user make a good decision.

The rich knowledge-base related to space shuttle hazardous gas leaking monitoring included in the IHM will provide HGDS personnel with a useful tool.

The IHM is planned to be installed at MSFC, where its operational capabilities will be tested. This system is now only a framework for a complete system: knowledge and data should be continuously built into the IHM to keep it current and useful.

Acknowledgements

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