Integrated Media Technologies for Satellite Decision Support Systems

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ABSTRACT

Within the Aerospace industry, the operational community is facing staff reductions, reduced skill levels, and greater complexity of space assets and space missions. This combination requires that techniques be developed that more efficiently interface a human operator with a complex computer system. Operational support of complex space systems will be greatly facilitated by better presentation of information. The presentation and distribution of complex data must evolve towards formats that are easily and naturally embraced by our sensory systems. Some of the information technologies/techniques that facilitate the presentation of complex dynamic graphical data fall into a category called integrated media.

The cost of implementing integrated media (IM) architectures has decreased substantially within in the past five years. While implementation costs continue to recede, the quality and value of information that can be presented using IM technologies continues to improve. Today's IM architect can select a variety of components including digital interactive video, 3D Navigable Worlds, Multimedia Authoring Systems, standardized compressors for IM data, low cost high volume storage systems, and operating system extensions for temporal data management. Together, these components form a solid foundation for the development of a variety of compelling IM architectures.

Existing satellite support and mission data processing architectures typically present tabular data for assessment. Some "advanced" systems include 2D graphical projections of the data. System experts are generally trained to correlate relationships

between tabular data items. The training required to “learn” these complex relationships is tedious and time consuming. This complexity impedes productivity and as space systems increase in sophistication, these techniques for data assessment are quickly becoming antiquated. The development of a prototype decision support system explores the utility of an integrated media documentation system as part of a full-featured decision support architecture for satellite operations.

Background

The application of advanced information processing technologies as part of an improved architecture for satellite control has been vigorously pursued over the past several years (see [1] - [5]). Initial work concentrated on the application of expert systems towards anomaly resolution in attitude control systems on DSCS and GPS [1]. The utility of the data inferencing/display tools was improved when they were migrated from special-purpose Lisp processors to general purpose workstations [1]. This migration provided an opportunity to explore a general design for decision support architectures used in satellite control. Testing prototypes in an operational environment was essential in distilling the salient components of a decision support system for satellite control. One of these components has been identified as the information navigator (iN) [2], [3]. This component provides an advanced point & click interface to system documentation as well as a host interface for tools that do not require direct access to spacecraft telemetry data [3].

Goals

To improve the presentation and navigation of information it was clear that the iN had to provide a compelling and engaging format for interaction. The traditional layout of linear text documents when translated into electronic form would add little value to the established paradigm for linear text browsing. The users would be better off with a paper text document and its accompanying pictures because of its inherit portability. Through the course of its development the primary goal of the iN has been to provide the user with a richly connected collage of text, graphics, sound, and video. This document, with its network of connections could be browsed/read in a standard linear fashion, but it would encourage (by its very format) the non-linear navigation of “related concepts.” In complex technical documentation, the added value of the hypermedia links between related subject items becomes at least as great as the original information.

A Decision Support Architecture

The iN is a part of the ASW II (Advanced Satellite Workstation II) decision support architecture prototype developed for the UHF Follow-on Satellite Program. The primary components of this decision support architecture are a data server, knowledge server, display manager, and the iN. The block architecture of these primary components is shown in Figure-1.

A PCM telemetry stream and an IRIG-B time signal are fed into the data server. Within the data server, the PCM data stream is frame synced, time-tagged and stored. The stored data and/or real-time stream is made available to the Telemetry Analysis Workstation (TAW) for engineering unit conversion, data inferencing by the knowledge server, and presentation by the display manager. The graphical display of time-valued data on the TAW is complemented by supporting documentation available on the iN. A provision exists for auto-orienting the iN to match supporting documentation within the context of the telemetry measurands being inspected on the TAW.

The Information Navigator

The iN is a substantially enhanced electronic version of traditional support documentation. The traditional format for support documentation is paper. A large complement of paper documentation is delivered as reference material for those charged with managing the performance of a satellite system throughout it's lifecycle. As a reference, this documentation provides satellite operators an owners manual of procedures, schematics, system descriptions, etc, that address maintainence and configuration of the satellite. A primary part of this supporting documentation is referred to as an Orbit Operations Handbook (OOH). In ASW II, the iN was developed from electronic versions of the OOH (and other supporting documents) received from the satellite prime contractor.

Electronic versions of the text were transferred to "containers" within the iN display environment. Initially, an attempt is made to keep the same basic structure as the original document when transferring the material to a navigational format. All diagrams and figures in the electronic documentation are separated and stored according to their reference title in the original documentation. Once a majority of the documentation has been transferred to visual containers within a hypermedia-style display environment, it is formatted to approximate the original document style. After the initial formatting is complete, a variety of hypertext links, and custom hypermedia document browsers are constructed to facilitate navigation through the documentation. When the specialized document browsers are complete, custom menu systems are built as an additional method for document reference.

Information Navigator Hardware

This iN is hosted on an Apple Macintosh IIci computer with 32Mbytes of RAM and a high performance 1.3Gbyte magnetic disk. In addition, the iN includes a CD-ROM drive to support delivery of high-volume information in the future. The display system for the iN is a 19 inch monitor with a 75Hz scan rate and a screen resolution of 24 bits/pixel for full color imagery. ASW I included a video disc player for display of as-built pictures and video material [3]. Commercial extensions to the iN software environment made it possible to access digital movies and high-resolution images as in ASW I, but without the need for specialized video disc players.

Information Navigator Software

The primary interface environment for the iN is HyperCard™. All of the electronic versions of contractor generated support documentation (OOH, operator training workbooks, program overview documents, etc ...) were migrated into the HyperCard environment. All schematic diagrams, and other still graphic material was saved in a native Macintosh object-based drawing format to retain scaleable and editable qualities. Motion-based graphics including animations and video sequences were formulated using several applications on the Macintosh. Swivel 3D™ was used to formulate a 3D model of the spacecraft (based on simple drawings in the contractor documentation). 3D model animation of spacecraft deployments (solar array, antenna, etc.) were exported to temporary files. These temporary files were later converted to “movie” file formats. An operating system extension for the Macintosh (QuickTime™) provides a method for display of digital movies by synchronizing temporal data.

Information Navigator User Interface

The point-and-click paradigm was maintained throughout the iN. Even a “table of contents” (shown in Figure 2) has an enhanced value when point-and-click operations from a computer keyboard and mouse can bring the referenced section of the document to the foreground of the users viewscreen. Navigation through most all information is done by “pointing-and-clicking” on the word/phrase/diagram component of interest [3]. When a word in text references other text, animation, pictures, or video, it is identified by a grey underline and a bold type style. These references provide a hypermedia link between related material. Several examples of hypermedia links from referenced text to diagrams and full-motion video sequences are shown in figures 3 through 5. Schematic diagrams can also reference text, other diagrams, or digital video. To access these references, the user points to and clicks on the area of interest within the schematic diagram. The supporting material is called to the front of the users viewscreen in direct response to the point and click operation.

Point and click is not the only way to navigate information contained within the iN. To complement the hypertext links within the table of contents and other parts of the iN, a set of menu commands were developed to help the user navigate through the major sections contained within the iN. The primary menu items associated with the iN are shown in Figure 6. Each of the menus in Figure 6 provide either quick access to major sections in the documentation, or additional tools for navigation of the on-line documentation. The workbook menu (shown) and the OOH menu (not shown) can be added/deleted from the menu bar by selecting the menu items “OOH” and “Workbook” from the General menu.

The “auto orienting” feature of the iN referred to earlier incorporates a generalized message passing scheme. This message processor can parse a message of the form: “system, subsystem, unit, component.” Parsing this message generates a list of all sections in the documentation where this sequence is referenced. This list is used as a set of pointers to the referenced sections. Parsing operations take place in the search window shown in figure 7.

When any item in the list is “clicked on” the referenced documentation is displayed. The same communications mechanism supporting the auto orienting function of the iN makes it possible to configure displays on the telemetry analysis workstation (TAW). Configuration of the telemetry displays is initiated by a message sent from the iN to the TAW. Once received, the message on the TAW can be enabled. When enabled, the message will configure the TAW displays to match the context of the documentation reference. An example might me a documentation reference to battery reconditioning procedures. The TAW displays would be configured to show a set of expected voltage and temperature curves that correspond to a nominal battery reconditioning activity.

An additional feature of the iN is a flexible search capability. One of the shortcomings of the ASW I system was its inability to list all references to a specific text search. This left the operators with a vague feeling about whether they had “seen” all there was to see on a specific subject [1]. The iN contains a hierarchically structured search utility. Figure 7 shows the search utility window, the spacecraft attitude control documentation window, and a referenced diagram.

The search utility window was developed to efficiently reference all documentation that corresponds to a specific keyword string. Upon entering the keyword string, the user initiates the search. The search utility returns a list of “systems/chapters” within the documentation where the keyword string is referenced. By clicking on any of these system references, the search utility returns a list of subsystems/sections in the center window. Selection of any of the subsystems calls up a list of elements/subsections in the right window of the search utility. At this point you have a direct reference to a specific point in the documentation and clicking on the element of choice calls up the documentation text window or diagram or video that is being referenced.

The arrangement of system, subsystem, and element corresponds to the three-tiered structure of the implementation environment (HyperCard). Within this structure system corresponds to “stack”, subsystem corresponds to “background in a stack” and element corresponds to “a card within a specific background.” Adding additional levels to this object hierarchy would be desirable and hopefully supported by user-defined object hierarchies in future implementation environments.

Certain elements of the on-line documentation maintained by the iN are presented in a format that allows user modifications. This “living” format allows the documentation to reflect the current system state and accommodate the typical “notes in the sidebars” style annotation that traditional paper documents receive.

In addition to IM documentation, the iN contained an interactive graphical editor for orbit activity planning called Timeliner. The Timeliner program was developed and integrated into the same HyperCard environment as the other portions of the iN. Timeliner provides a visually intuitive projection of time-valued activities. The start times and durations of these activities can be manipulated through the graphical display. These “point, click, and drag” manipulations modify the on-line documentation for each activity. The Timeliner will be used to provide an on-line view of the mission events timeline for the launch and early orbit checkout of the satellite. Ground station visibility data and satellite position data is read from an external file. Mission activities are also read from an external file. The Timeliner application provides a high-level graphical display and edit facility for these textual data files. A portion of the Timeliner screen is shown in Figure 8.

Perspective & Future Directions

Integrated media development tools have improved within the last year. An earlier implementation of an iN [4] used a video disc player, with video imagery displayed on a separate monitor. This technology was effective, but required the production of video discs. In addition, workspace in an operational environment is often at a premium, making the second monitor undesirable. The present implementation of the iN was able to make use of modern digital interactive video playing from a standard digital medium (magnetic disc, CD-ROM, optical disc) on the standard display medium (the computer monitor).

Perhaps the most exciting aspects of this implementation relate to the “average” nature of the delivery platform. Aside from having a large disk drive and a healthy portion of RAM, there is no special-purpose hardware required to support the wide variety of media formats (text, audio, hi-resolution diagrams/pictures, and video) on this platform. The technology for delivery of systems of this variety is ready today and should be embraced by the community.

We are all witness to a surge of technical advances within the computer industry that will leverage integrated media developments. Platforms for multimedia applications exist from a variety of vendors including but not limited to: Apple, Commodore, DEC, HP, IBM, and NeXT. The technical advances in hardware and systems software from our workstation vendors are making it easier to substantially enhance paper documentation as it migrates towards a computerized format.

Rather than follow “yet another implementation” of this proven technology, our future plans call for the introduction of several high-payoff emerging technologies for information navigation. These emerging technologies include: voice recognition, and virtual world data representations. Together with techniques such as those reported on in the present work, we expect these emerging technologies to further improve operator effectiveness in managing increasingly complex space systems.

Acknowledgments

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References

1. Sutton, Stewart, “Advanced Satellite Workstation: Summary, Evaluation, and Lessons Learned,” Aerospace Report No. 91.5814-sas-163., The Aerospace Corporation, Los Angeles, CA, December 1990.

2. Bost, J.D., Le, T.C., Mangan, P.K., Meloan, M.D., Sutton, S.A., Turner, S.R., “Hypermedia and Expert Systems Applied to Space Vehicle Monitoring & Control,” International Telemetering Conference, Vol XXV, 1989.

3. Hamilton, Marvin J., Sutton, Stewart A., “An Integrated Workstation Environment for Operational Support of Satellite System Planning & Analysis,” International Telemetering Conference, Vol XXVI, 1990.

4. Bleier, Thomas, Hollander, Sidney, Sutton, Stewart, “Advanced Satellite Workstation (ASW),” AGARD Conference Proceedings 499, (ISBN 92-835-0628-6), Lisbon, Portugal 13-16 May 1991.

5. Sutton, Stewart A., “Advanced Satellite Workstation,” Space Operations Applications and Research 91 Proceedings, NASA Conference Publication 3127, July 1991.

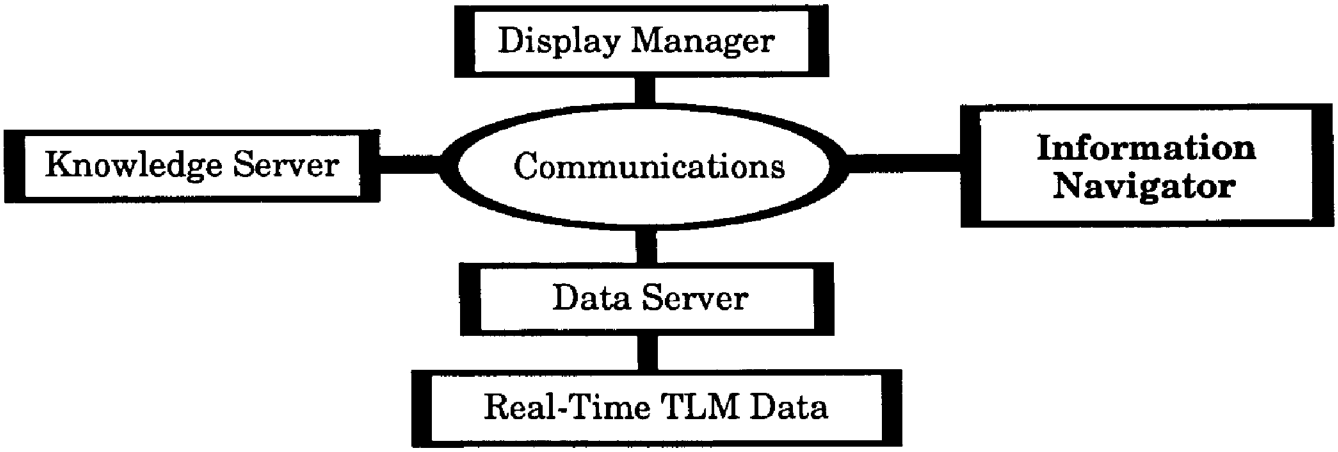
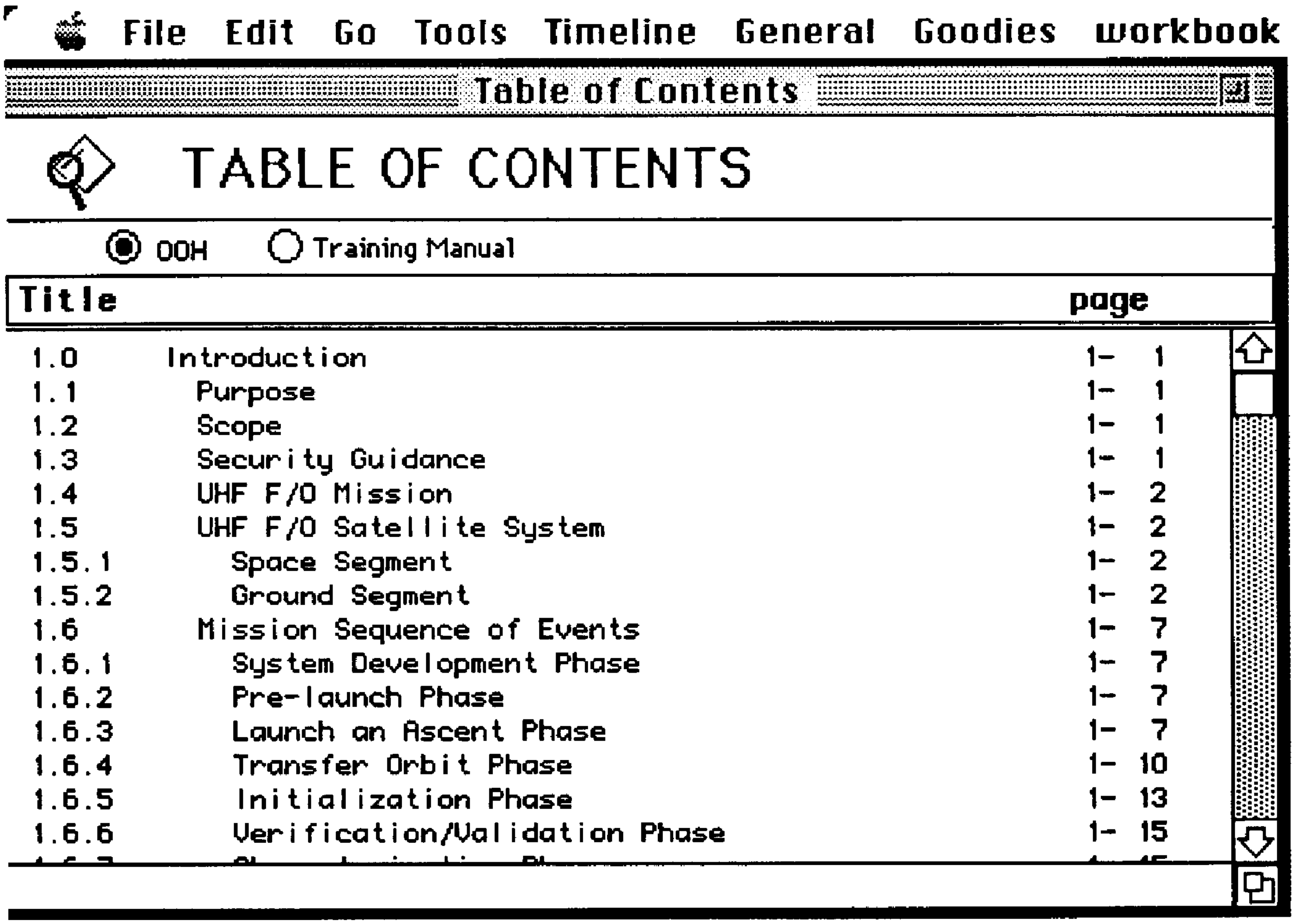


Figure-1: ASW II Block Architecture

Figure-2: Information Navigator Table of Contents Window



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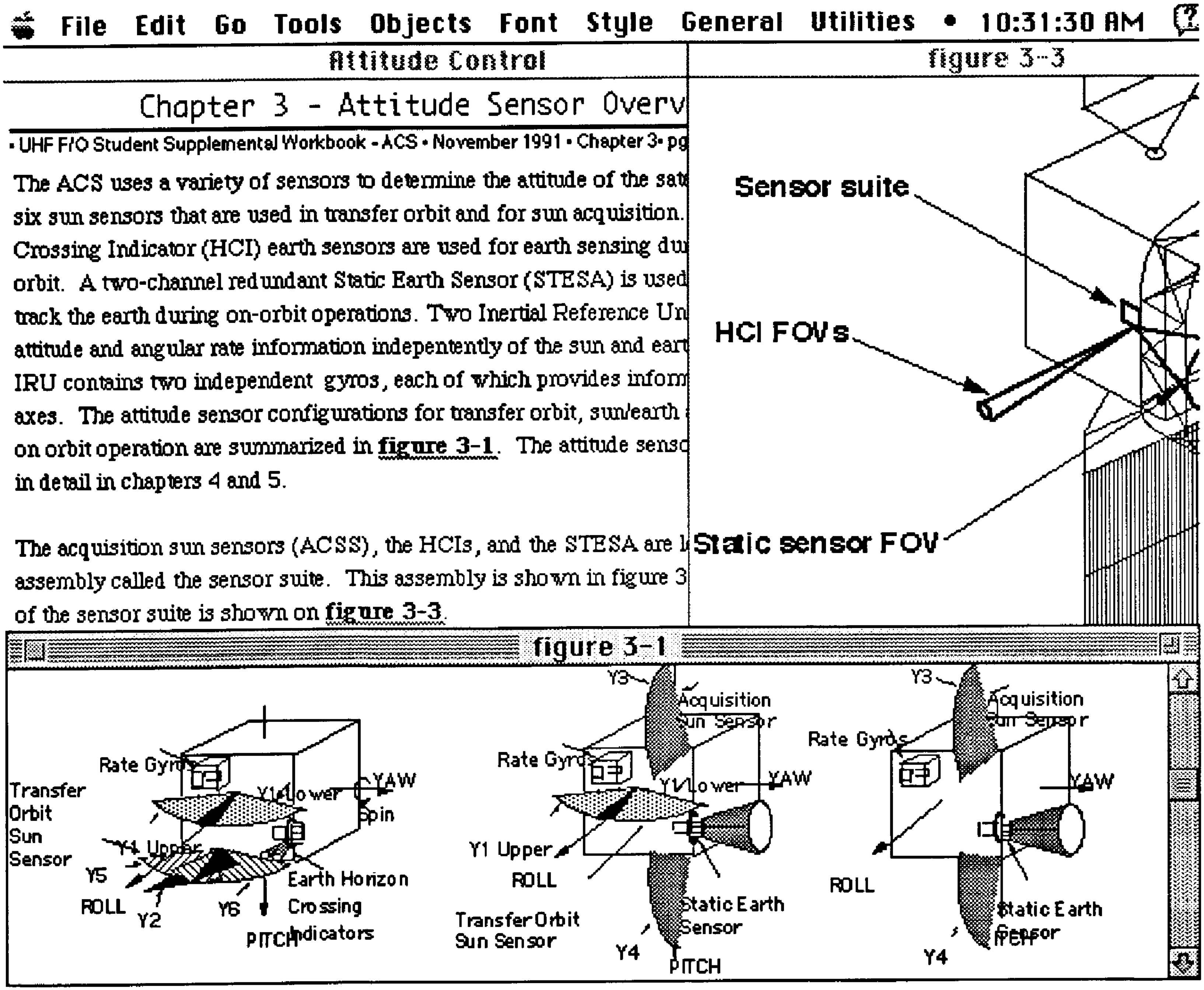


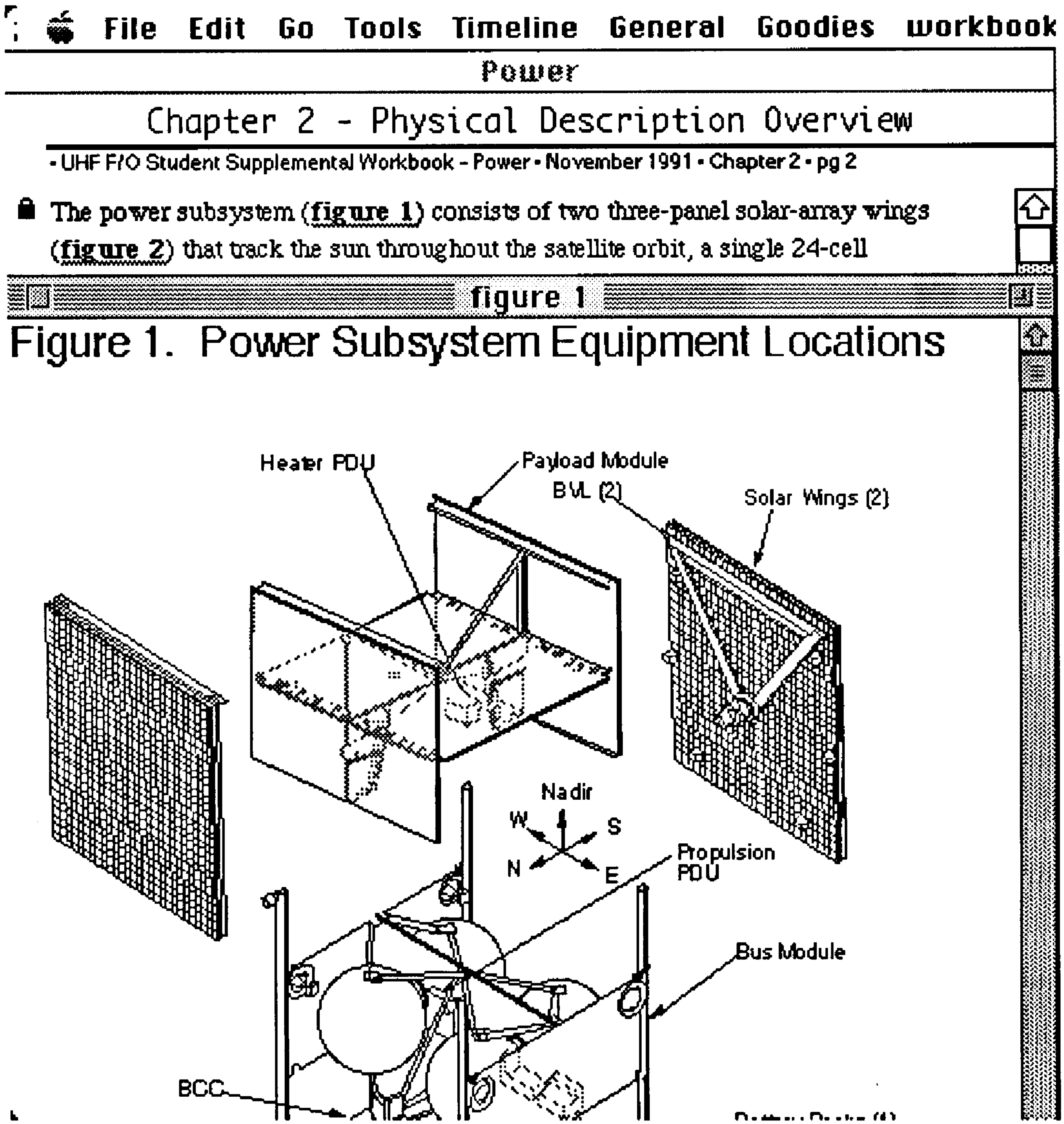
Chapter 3 - Attitude Sensor Overv

• UHF F/O Student Supplemental Workbook - ACS • November 1991 • Chapter 3• pg

The ACS uses a variety of sensors to determine the attitude of the sat six sun sensors that are used in transfer orbit and for sun acquisition. Crossing Indicator (HCI) earth sensors are used for earth sensing du orbit. A two-channel redundant Static Earth Sensor (STESA) is used track the earth during on-orbit operations. Two Inertial Reference Un attitude and angular rate information indepentently of the sun and ear IRU contains two independent gyros, each of which provides inforn axes. The attitude sensor configurations for transfer orbit, sun/earth on orbit operation are summarized in **figure 3-1**. The attitude senso in detail in chapters 4 and 5.

The acquisition sun sensors (ACSS), the HCIs, and the STESA are l assembly called the sensor suite. This assembly is shown in figure 3 of the sensor suite is shown on **figure 3-3**.

Figure-3: Hypertext Diagram Access



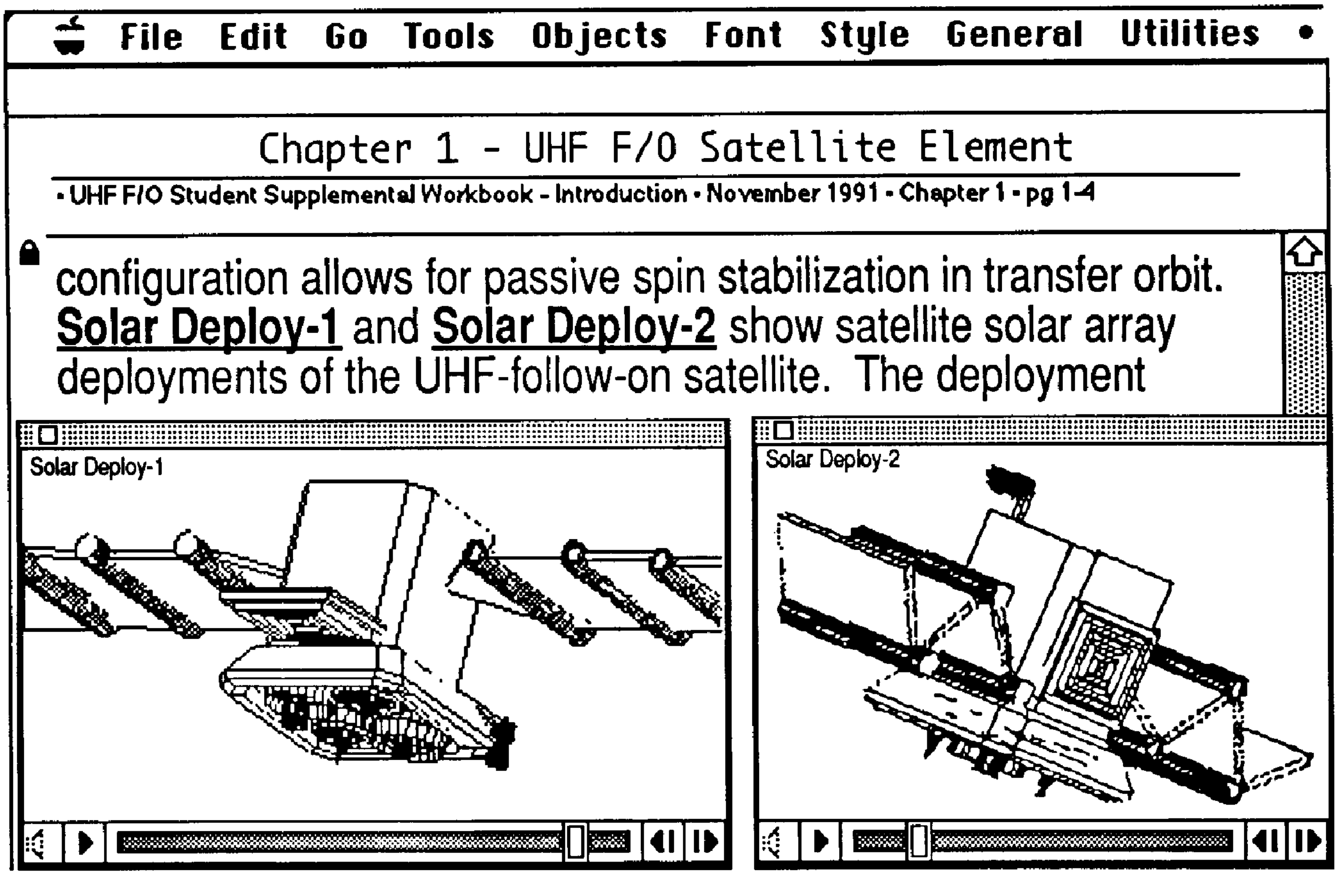
Chapter 2 - Physical Description Overview

• UHF F/O Student Supplemental Workbook - Power • November 1991 • Chapter 2 • pg 2

The power subsystem (**figure 1**) consists of two three-panel solar-array wings (**figure 2**) that track the sun throughout the satellite orbit, a single 24-cell

Figure 1. Power Subsystem Equipment Locations

Figure-4: Hypertext Diagram Access



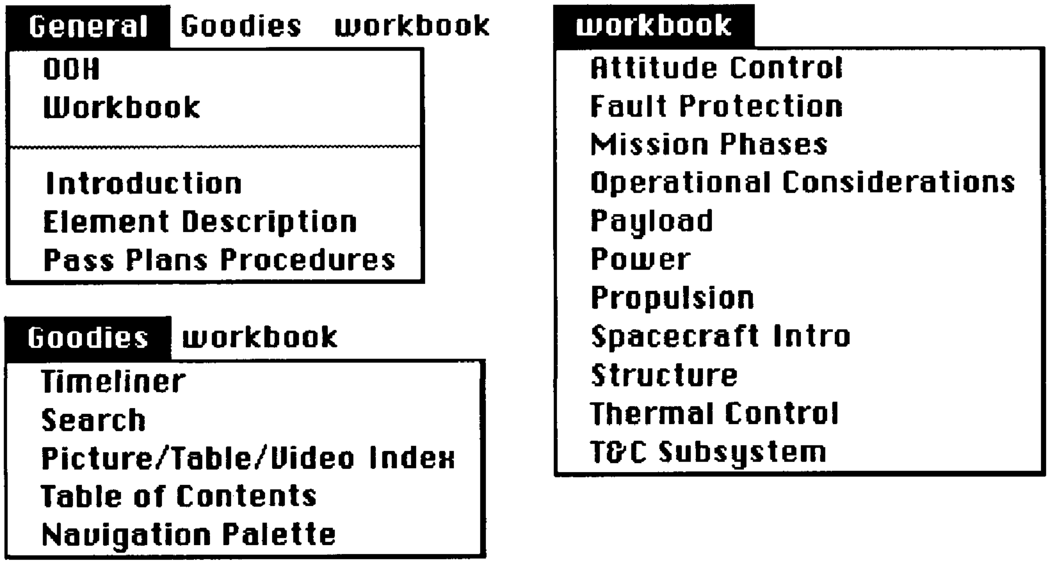
Chapter 1 - UHF F/O Satellite Element

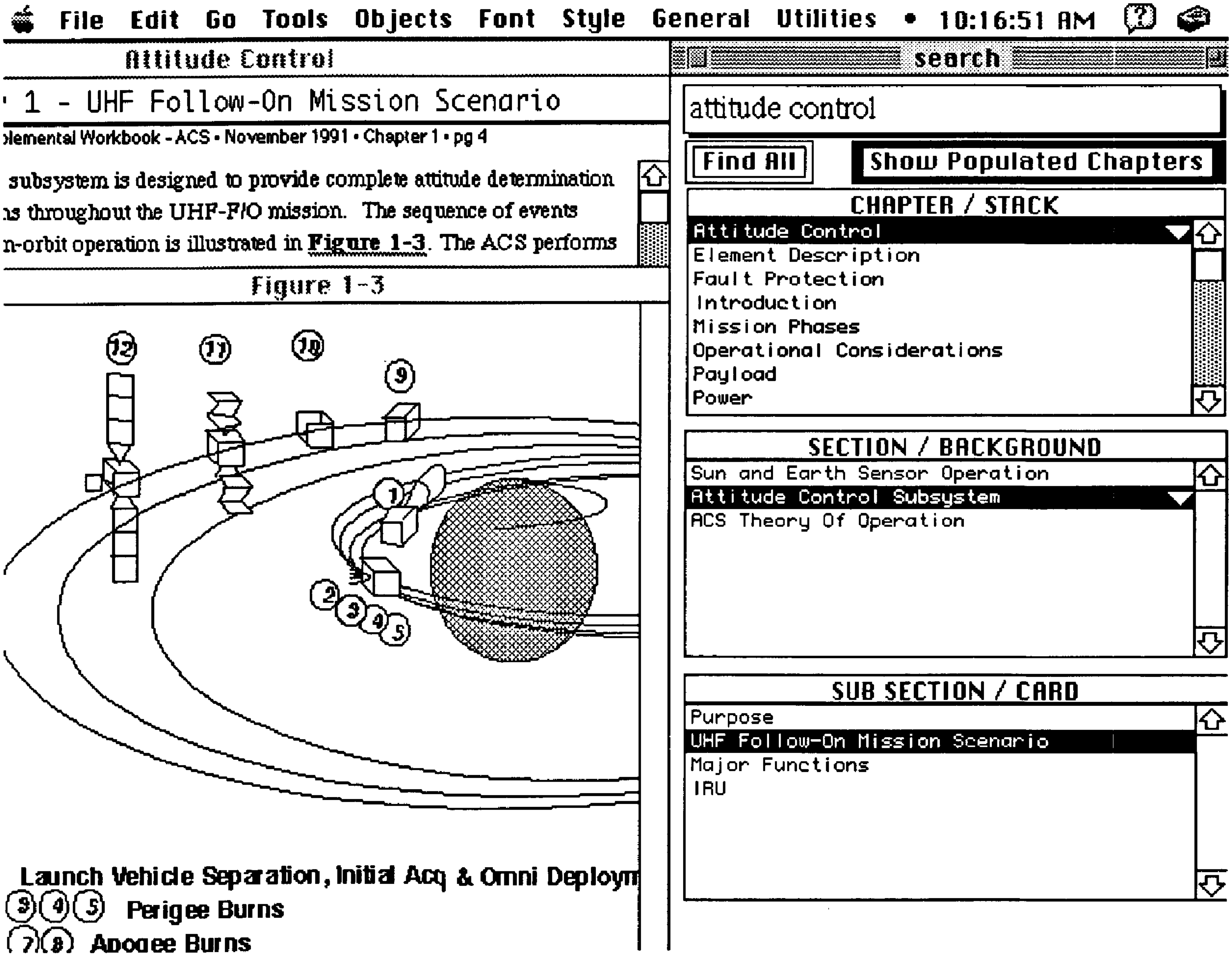
• UHF F/O Student Supplemental Workbook - Introduction • November 1991 • Chapter 1 • pg 1-4

configuration allows for passive spin stabilization in transfer orbit. **Solar Deploy-1** and **Solar Deploy-2** show satellite solar array deployments of the UHF-follow-on satellite. The deployment

Figure-5: Hypertext Interactive Video Access

Figure-6: Information Navigator Menus





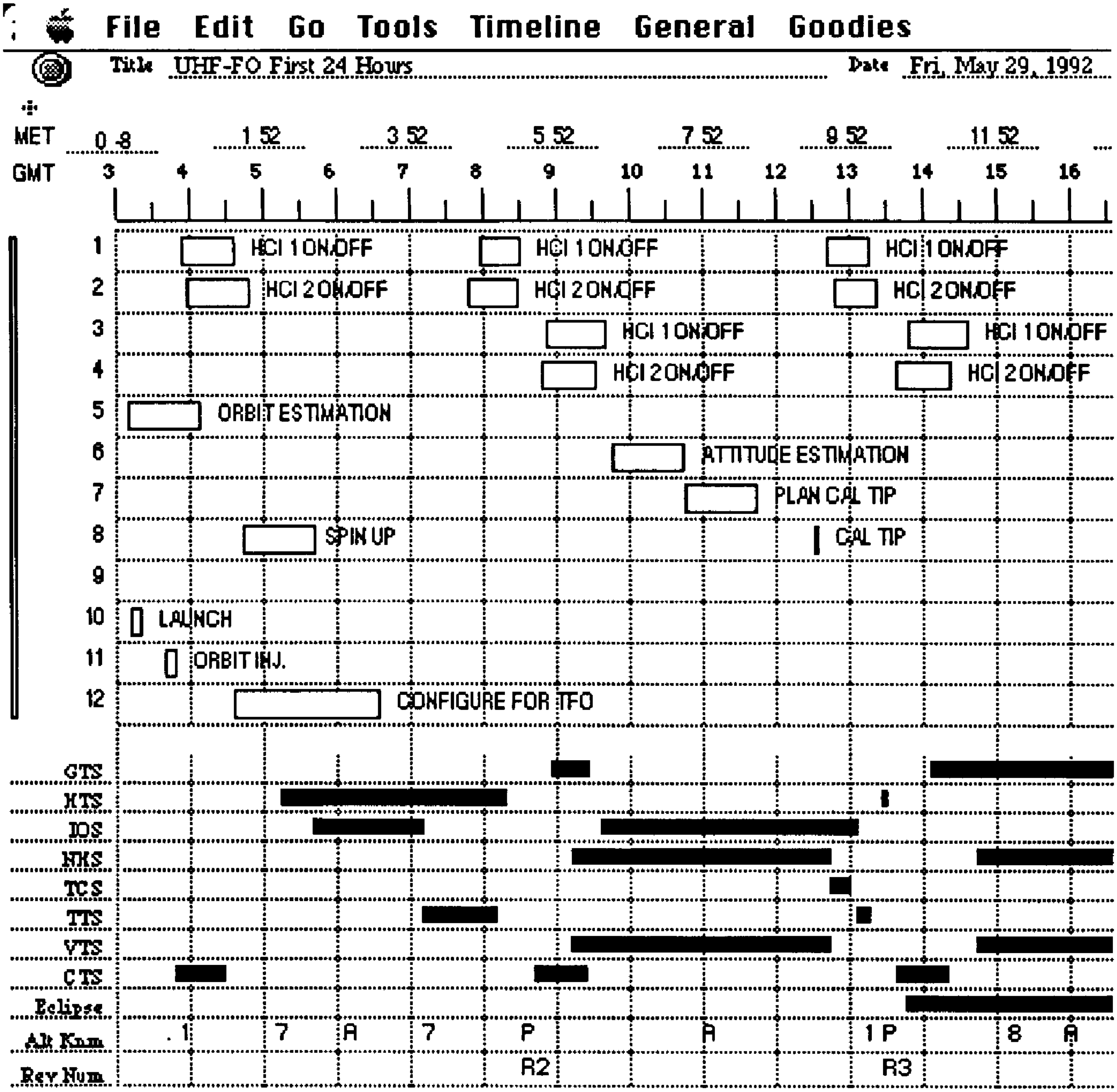
attitude control

' 1 - UHF Follow-On Mission Scenario

lemental Workbook - ACS • November 1991 • Chapter 1 • pg 4

subsystem is designed to provide complete attitude determination
as throughout the UHF-F/O mission. The sequence of events
n-orbit operation is illustrated in **Figure 1-3**. The ACS performs

Figure-7: Information Navigator Search Utility



Title UHF-FO First 24 Hours

Date Fri, May 29, 1992

Figure-8: Timeliner Application Window