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DEVELOPING THE HUMAN-COMPUTER INTERFACE FOR SPACE STATION FREEDOM

Kritina L. Holden
Lockheed Engineering and Sciences Company
2400 Nasa Rd1, MC-C95
Houston, TX 77058-3711

ABSTRACT

The Human-Computer Interaction Laboratory (HCIL) at Johnson Space Center (JSC), Houston is tasked with being responsible for defining the global Human-Computer Interface (HCI) for Space Station Freedom. This responsibility entails the early definition of hardware and software capabilities to support the HCI, definition of requirements for display developers and the identification of stylistic guidelines as well. The charter of the HCIL is uniquely defined in that it supports the applied development work necessary for designing the interface as well as applied research that is necessary for influencing design decisions. For the past two years, the HCIL has been heavily involved in prototyping and prototype reviews in support of the definition phase of the Freedom program. On Space Station, crewmembers will be interacting with multi-monitor workstations where interaction with several displays at one time will be common. The HCIL has conducted several experiments to begin to address design issues for this complex system. Experiments have dealt with the design of ON/OFF indicators, the movement of the cursor across multiple monitors, and the importance of various windowing

capabilities for users performing multiple tasks simultaneously.

INTRODUCTION

Space Station Freedom, scheduled to be completed in the late-1990s, will be equipped with one of the largest and most sophisticated computer systems ever placed in orbit. Freedom's network of computers will control and monitor thousands of automated systems as well as provide an interface to the crew for the command and control of many additional functions.

The importance of the Human-Computer Interface (HCI) for Space Station Freedom cannot be underestimated; astronauts will come to depend on the HCI for all aspects of Space Station life including controlling the onboard environment and life support, the conduct of experiments, communication with earth and emergency procedures. In fact, the core HCI must be in place by First Element Launch, since the computer system will actually guide the assembly of Freedom.

The level of automated monitoring onboard is consistent with a typical process control environment such as that found in a nuclear power plant; however, Freedom's onboard environment is unique in that the computer system will provide extensive interactive capabilities as well. In fact, the interface will be primarily a direct manipulation interface where crewmembers can use a cursor control device to manipulate real objects (e.g., pumps) by pointing and clicking. A command language will be available (User Interface Language (UIL)), but the majority of a crewmembers work will be accomplished using direct manipulation. The complexity and flexibility of a direct manipulation interface, in combination with the process control aspects of the environment, constitute an interesting challenge for HCI designers.

SPACE STATION FREEDOM DATA MANAGEMENT SYSTEM

Space Station Freedom's computer system, called the Data Management System (DMS), is a complex distributed system composed of nine workstations, each having separate processors, connected via a state-of-the-art fiber optics network. The architecture of the component systems is similar to an IBM PS/2 Model 80 workstation, providing capabilities such as multitasking, color and gray scale, windowing and onscreen video.

PHASED HCI DEVELOPMENT PROCESS FOR FREEDOM

The process of designing an HCI for such a large, complex system must involve a phased plan with Human Factors input throughout planning, development and production. The team of HCI specialists at the Human-Computer Interaction Laboratory (HCIL) at Johnson Space Center (JSC), Houston has been tasked with providing that Human Factors input to ensure that Space Station Freedom has a safe and usable HCI.

HCI development for Space Station has been divided into three phases:

- (1) Hardware and Software architecture and requirements definition
- (2) Interface development and review
- (3) Integration and testing.

The bulk of the HCI work has been completed as part of Phase 1, the Requirements Definition phase. Phase 1 is coming to a close and preparations are being made to move into formal review and usability testing that will occur in Phase 2. Actual development of hardware and software for Space Station Freedom is beginning now.

CONSISTENCY IN DESIGN

One of the primary concerns of Space Station HCI developers is the need for consistency throughout the hundreds of displays that will be available for viewing onboard. There are two primary means for achieving

this consistency: (1) the development of interface requirements and standards documents in combination with a Review board to ensure strict compliance, and (2) the development and mandated use of a display builder toolkit (software) that will enforce standards and requirements by making available only acceptable display options. For example, the display builder toolkit will provide one standard shape for a momentary software button. This is the only shape that will be available to the developer. Likewise, the palette of colors provided will contain only sanctioned colors.

The goal of the HCI development team during Phase 1 has been to ensure that all of the hardware and software requirements necessary for providing a safe and usable HCI are in place and officially baselined. To accomplish this task, it was necessary to identify as many design issues and problems as possible within a limited amount of time.

The most effective technique for quickly identifying interface issues is rapid prototype iteration. Once issues have been demonstrated via a prototype, design decisions can be made or applied research can be performed if necessary to select a particular design.

ROLE OF PROTOTYPING IN SPACE STATION FREEDOM HCI DESIGN

Prototyping in the HCI domain differs somewhat from that done in other disciplines. In industrial settings,

the term "prototype" usually implies that there is an end product that will be built. In HCI design, often times the end product is merely a display concept or idea for a method of interaction. In fact, many of the prototypes created in the HCIL do not necessarily reflect detailed technical information, but demonstrate display concepts and methods of interaction. Often times a display containing realistic technical details is not necessary to demonstrate a single concept, and thus it is most time efficient to prototype only to the level of realism necessary for the particular goal. When required, the prototypes progress into more mature phases to include interactive capabilities, realistic technical details and possibly connection to a database or network simulating realistic data.

PROTOTYPING TOOLS

Prototyping often begins as paper and pencil sketches of system components and relationships. Once enough basic information is available, a working prototype is put together using a tool such as Hypercard® (Apple) or Supercard® (Silicon Beach). These tools are excellent for rapid, interactive highly graphical prototyping. Much of the prototyping can be done without programming. When programming is necessary, English-like languages are available with these tools (Hypertalk® and Supertalk® respectively) so that HCI designers who are not programmers, can, without much difficulty, build an interactive prototype. If

capabilities are needed that are beyond those available in Hypercard and Supercard (e.g. more speed, flexibility and connectivity), the prototypes are recreated on more sophisticated tools such as Dataviews (V.I. Software) or Scientific Software Intercomp's Advanced Man-Machine Interface (SAMMI).

THE DEVELOPMENT OF GUIDELINES, REQUIREMENTS AND STANDARDS

Initial development work on the HCI began approximately three years ago, before the prime Space Station contract had been awarded. The HCIL was tasked with providing an HCI guidelines document for Space Station Freedom. In order to accomplish this task, a set of representative Space Station tasks was selected for task analysis and prototyping. Performing task analyses for tasks and systems whose designs had often not been completed was quite a challenge. Nevertheless, a set of concept prototypes based on the task analyses was created to address global HCI issues. Prototyping was accomplished on a Macintosh using Hypercard® software. Creating these prototypes proved to be very beneficial in raising technical issues and testing out design ideas. It provided a starting point for identifying the kinds of concerns and issues that needed to be addressed in an HCI guidelines document. The final product (Space Station Freedom Program Human-Computer Interface Guide Ver 2.1; USE 1000)

was completed in May, 1988 and has been distributed throughout the Space Station Freedom program and world-wide for use in interface design.

Following the award of the Space Station prime contract to McDonnell Douglas Space Systems Company (MDSSC), the need arose to develop hardware and software requirements and HCI style standards. Once again, a cycle of prototype generation and review proved to be very successful for identifying necessary hardware and software capabilities and issues needing more work. To ensure that all pertinent technical and experiential viewpoints were represented in the HCI design solutions for Freedom, an HCI team was formed consisting of representatives from the HCIL, MDSSC, Huntington Beach, CA (prime contractor), Mission Operations Directorate (MOD), JSC, Houston and the Astronaut Space Station Support office, JSC, Houston. MDSSC created an interface prototype and sent it to the team at JSC for review and comment. The group at JSC independently and collectively reviewed the prototype, compiling a list of suggested changes and issues needing resolution. Every two weeks a teleconference was held so that all HCI team members could discuss the prototype and the suggestions. HCI team members worked together on almost a daily basis by phone or in person to continue refining the requirements definition. Once again, the use of prototyping for identification of software and hardware requirements and identification of major design issues

was very effective and time efficient. It became clear through prototyping that issues such as how a crewmember navigates within a very large hierarchical system displayed on three physical monitors are very important and are much more complex than they appear on the surface. As major issues were identified, each was approached individually as a new concept to be prototyped. Three documents are the products of the HCI team's Phase 1 work: (1) detailed requirements for the DMS User Support Environment (software requirements), (2) HCI standards (design/style standards) and (3) display examples (onboard).

THE ROLE OF RESEARCH IN HCI DESIGN

Throughout all of the various prototyping efforts undertaken in the HCIL, design reviews have identified problems and issues needing empirical resolution. The unique charter of the HCIL is such that facilities and personnel are available to do on-the-spot applied research to answer design questions. Because the HCIL performs phased prototyping, questions raised early in the prototype can be resolved prior to the completion of the prototype. Two examples of applied research performed for the express purpose of design resolution are studies dealing with (1) indicators and (2) multiscreen Issues.

ON/OFF Indicator Study

A fairly early prototype of the Power System for Space Station Freedom employed the use of many ON/OFF indicators. These indicators were not controls, but were status indicators for various components of the system. The display technique used to denote the active state of an indicator was reverse video, which is a commonly used equivalent code for a hardware light. Many direct manipulation interfaces that employ the use of selections or mode indicators, use reverse video to denote the active or selected state. During a preliminary design review of the interface, several reviewers commented that the active state as coded, was ambiguous. In other words, it was not clear whether a series of indicators read "ON" or "OFF". Although the majority of reviewers reported that the coding was clear, the possible serious impact of ambiguous coding led to the decision to perform a study. The study evaluated confusability and response time for subjects reporting the state of an ON/OFF indicator within a display similar to that in the Power system prototype. Several proposed designs were compared, including reverse video, check mark, reverse video with check mark, color (cyan) and bold frame. Half of the trials were shown on a black background and half were shown on a white background. The effects of background color and indicator type were not significant for the response time measure. The effects of background color and indicator type on response classification (i.e. whether subjects

responded "ON" or "OFF") were not significant. Thus, it appears that while a few persons may have trouble distinguishing the active state when coded with reverse video, empirical tests do not indicate that this is a general problem. This result enabled the HCI team to proceed ahead with using reverse video for coding, while remaining aware that a consistent method of coding active states will be necessary to help users generalize among displays. The results are currently being written up as a NASA Technical Report.

Multiscreen Studies

Space Station Freedom will provide a workstation to crewmembers that is equipped with three physical display devices/monitors. The workstations will include one keyboard, one cursor control device and one cursor. This configuration has raised several major issues centering around how crewmembers will interact with multiscreen systems.

During the prototype review cycle, the issue of how a crewmember would move the one cursor among three monitors was raised. Several methods were proposed: (1) continuous cursor movement (i.e., one virtual display surface where the cursor flows smoothly among monitors), (2) a direct, single action method of moving the cursor among the monitors, such as with fixed function keystrokes, clicks on a software button or the depression of a programmable display pushbutton

(3) a cyclic method involving the cycling of the cursor in a predetermined (e.g., counter-clockwise) direction by means of repeated fixed function keystrokes, repeated clicks on a software button, repeated depression of a programmable display pushbutton or the repeated double clicking of the selection button on a cursor control device. The HCIL has designed an experiment to compare these seven separate methods. Subjects will use each of these methods to perform tasks requiring keyboard entry or tasks requiring control device entry. Each method of cursor movement has advantages and disadvantages. The primary purpose of the empirical study will be to determine which cursor movement methods are the least disruptive to the primary task at hand. The study will be completed this summer and written up as a NASA Technical Report. Preliminary review by several astronauts reveals a preference for the direct address fixed function key method where a function key is associated with a particular monitor. Astronauts expressed an interest in the continuous flow method, but there were many concerns about accidental movement of the cursor and subsequent unintended clicks or typing within the wrong monitor.

Additional work is ongoing in the area of user multitasking. One of the first experiments deals with the importance of windowing capabilities for a user performing one, two or four simultaneous tasks. This experiment will be conducted on a single monitor as well as a multi-monitor system and the

results will be formally written up at completion.

CONCLUSIONS

Developing the HCI for Space Station Freedom is a challenging task and one that requires the coordinated efforts of many organizations. The HCIL is completing it's role as the lead during the architecture and requirements definition phase. As we move toward actual design, the HCIL will take on a new role to: (1) ensure that completed interfaces are compliant with the Standards document and (2) conduct usability testing to ensure that the interfaces are safe, usable and technically and operationally correct. As new issues arise in development, the HCIL will continue to use rapid prototyping as a means of quickly demonstrating several alternate design solutions and will conduct research as necessary to select the best design solutions. The work ahead will take several years to complete and there are many issues yet to be solved. The early human factors input provided by the HCIL at JSC is helping to ensure that crewmembers onboard will be able to do their jobs safely, comfortably and with ease as they interface with the computer system onboard Space Station Freedom.