

N94-23917

DEEP SPACE NETWORK (DSN), NETWORK OPERATIONS CONTROL CENTER (NOCC) COMPUTER-HUMAN INTERFACES

Alvin Ellman and Magdi Carlton

California Institute of Technology
Jet Propulsion Laboratory
Pasadena, California, USA

ABSTRACT

The Network Operations Control Center (NOCC) of the DSN is responsible for scheduling the resources of DSN, and monitoring all multi-mission spacecraft tracking activities in real-time. Operations performs this job with computer systems at JPL connected to over 100 computers at Goldstone, Australia and Spain. The old computer system became obsolete, and the first version of the new system was installed in 1991. Significant improvements for the computer-human interfaces became the dominant theme for the replacement project. Major issues required innovating problem solving. Among these issues were: How to present several thousand data elements on displays without overloading the operator? What is the best graphical representation of DSN end-to-end data flow? How to operate the system without memorizing mnemonics of hundreds of operator directives? Which computing environment will meet the competing performance requirements? This paper presents the technical challenges, engineering solutions, and results of the NOCC computer-human interface design.

Key Words: computer-human interfaces, control center, automation, operations

1. INTRODUCTION

The Network Operations Control Center (NOCC) of the DSN is responsible for scheduling the resources of DSN and monitoring all multi-mission spacecraft tracking activities in real time. Operators monitor network performance and identify, isolate and correct network problems. This is done from workstations at JPL connected to over 100 computers worldwide. The old system was failing to meet the users' needs, required modernization and needed redesign to allow for growth. A replacement project was begun in 1988, and the first release of the new system was

implemented in 1991. Significantly improving the computer human interface became the dominant theme of the replacement project. However, the project team was faced with problems. There was no standard methodology in place for operability and computer-human interface design, and there was resistance from the users who had little or no experience with the technologies to be employed in the replacement. A "user-centered" design process evolved to address these issues. This paper presents the aspects of the process that had the greatest impact, and its effect on the resulting system.

2. USER-CENTERED DESIGN

The NOCC replacement involved 25 software engineers and support staff; development of over 200 K lines of code; 4 years duration; 26 computers connected to 4 Local Area Networks; and a significant amount of commercial off-the-shelf (COTS) software. Design decisions and technical trade-offs were made with a bias towards usability and operability. At the start of the project an approach was established to identify and address the key issues facing the developers. The following discussion describes the three steps in the process and examples of how they were applied.

Step #1 - Determine the design criteria for user concerns This required three considerations. First establish the area to be considered. Then specify how it might affect data representation. Finally consider how the presentation to the user should be made. For example:

How can the user interpret the data, given that NOCC receives several thousand status, configuration and performance parameters every five seconds from 15 antennae and associated ground equipment? By grouping information into a hierarchical structure and

providing algorithms to "bubble-up" interpretations, the amount of data that a user needs to work with at any one time is minimized. The presentation to the user is accomplished through navigation aids that traversed such a hierarchy.

How can an operator identify a problem and isolate its cause in a timely manner? The hierarchical structure of the data assists in this area. The presentation identifies a problem to the user by using color coding or flagging of problems and provides navigation aids that lead from the high-level aggregate view to detailed causes.

With operator turnover increasing how can the system aid in allowing use without in depth knowledge of DSN? Data representation has little impact in this area. This is in the purview of presentation. Consistent application of color coding and user interface simplifies training of new users.

Step #2 - Assess the impact of design decisions on the users Since the user community had little or no experience with this technology, getting them to participate was difficult. Some resistance early in the project was noticed. These areas were addressed through two steps. A formal Operability Design Document (ODD) was established that stated in user terms the criteria for system design. Then, during the entire development process a liberal use of prototypes was made. A DSN user interface prototype laboratory was established and experimentation with COTS software begun. This was all aided through collaboration with other JPL projects. For example:

The prototype of the hierarchical displays was widely demonstrated and led to a greater understanding of the idea of graphical user interfaces by those not yet exposed to the idea. Also acceptance of the hierarchical data representation and navigation aids was achieved.

Step #3 - Determine the technical aspects of the implementation (tools, platforms, etc.) Due to procurement requirements, the operating environment and hardware configuration were established earlier than would have been ideal. UNIX was specified as the operating system, and prototypes established an architecture for handling data rates and storage

capacities. However tools selection, changes to hardware to accommodate the user interface and other considerations evolved. For example:

Whereas DV-Draw tool was used during prototype development, other tools were used in final development. Demonstration to users established Motif with X-Windows as the presentation interface. Even with reduction of the data through hierarchical organization, a need evolved to display more data than was possible with a single monitor. A multiple monitor system was proposed even though it meant added difficulty to the developers. This yielded a twelve-fold increase in display area.

3. THE RESULTING NOCC SYSTEM

NOCC is a data acquisition system, configured as a network of two dozen identical Sun SparcStation 2 computers. Data acquisition and evaluation are performed with front-end computers connected to antennae around the world. These units broadcast to the back-end user workstations. Work consoles are equipped with triple screen monitors, mouse, printers and other needed facilities. Display data are refreshed every five seconds. Specialized computers handle the network management and file management functions. The system is fully redundant including the Local Area Networks. The NOCC hardware architecture is presented in Figure 1.

A graphical model of the DSN was constructed that represented the hierarchical structure of the data. The highest level display is a "checker board" where each square represents a DSN antenna-spacecraft pair. (Refer to the DSN Spaceraft Summary Display in Figure 2.) The next level shows a left-to-right data flow with assemblies represented by boxes connected by lines representing links. (Illustration is provided by the Telemetry Summary Display in Figure 3) The lowest level shows details of the assemblies and a performance history plot. A "bubble-up" algorithm allows proper representation of status at each level. (An assembly in a red or non-functional condition does not necessarily imply a red condition at the top level.)

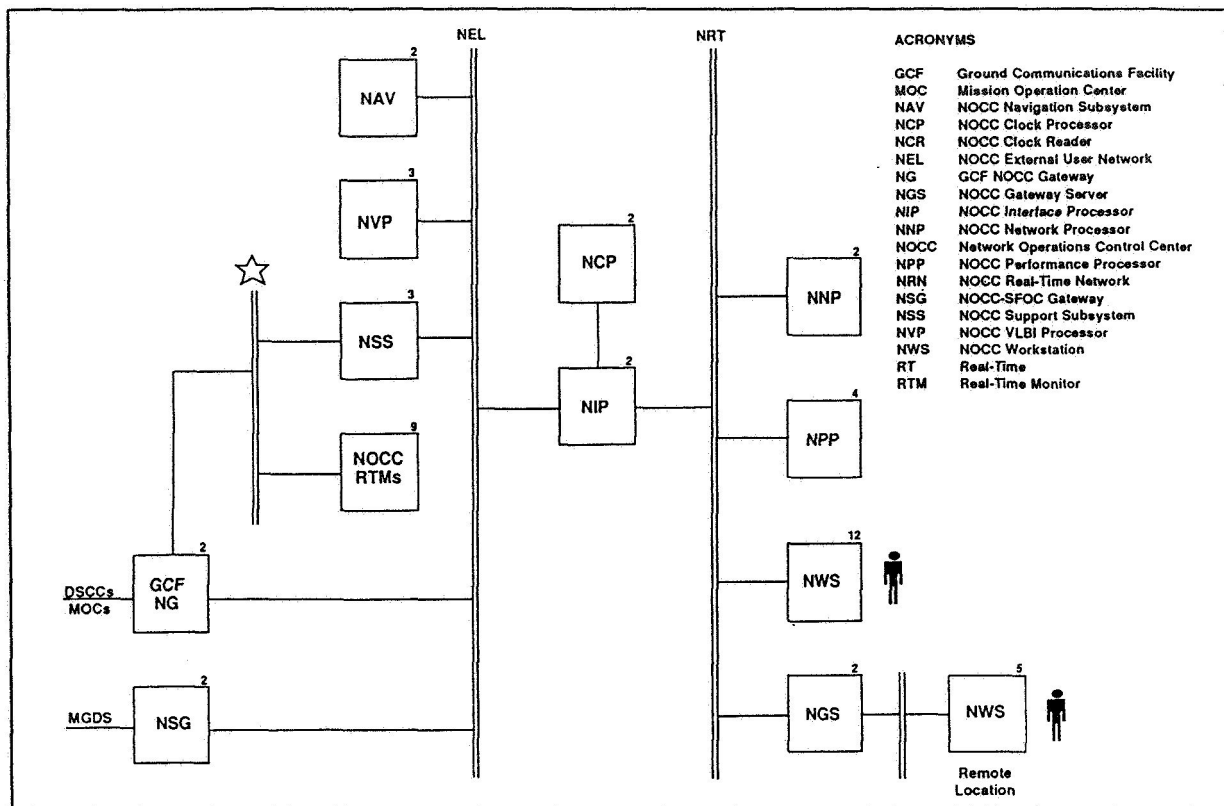


Figure 1. NOCC Hardware Architecture

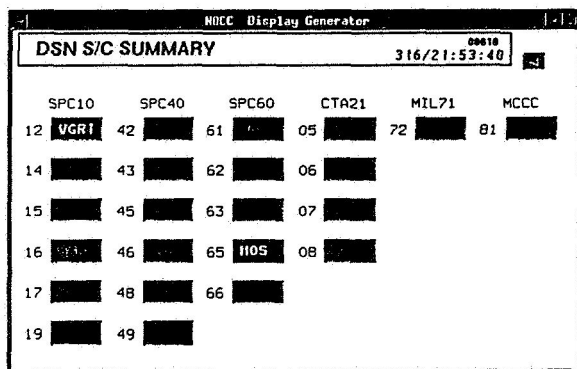


Figure 2.
DSN Spacecraft Summary Display

Navigation from top-to-bottom is accomplished by clicking the appropriate button for the element about which the user wishes more detail. Bottom-to-top and side-to-side navigation are accomplished with arrows.

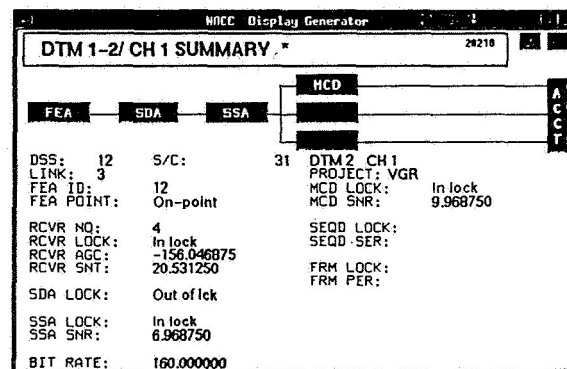


Figure 3.
Telemetry Summary Display

Color coding provides a visual means of representing status, performance and configuration. Green, yellow and red are used to denote normal operation, marginal conditions and critical alarms respectively. An unassigned link is highlighted with grey. Since more

than one lower level assembly can contribute to a condition, algorithms have been developed to relate the conditions. Algorithms are based on decision tables, Figure 4 explains the conditions and decisions for color coding the Antenna Summary button.

CONDITION	a	b	c	d	e
1. Data Validity valid invalid	Y				Y
2. Ant Operating Status out-of-service operational critical		Y		Y	Y
3. Ant Pointing Status on-point off-point			Y		Y
ACTION					
1. Set Antenna Summary Status = "blue"	X	X			
2. Set Antenna Summary Status = "green"					X
3. Set Antenna Summary Status = "yellow"					
4. Set Antenna Summary Status = "red"			X	X	

Figure 4.
Antenna Color Decision Table

The use of a command line interface and operator directives has been minimized through use of point and click, pop-up menus and pull-down menus.

An operator's workstation is a fully functional system providing support for a variety of tools. Along with the NOCC system are terminal emulation, screen or window dump/print, file transfer, word processing, spreadsheet, calculator and E-mail. Refer to Figure 5 for a specification of the NOCC Workstation.

Configuration tables and stored profiles control nearly all aspects of the system. A work station can be customized at login by use of stored profiles. Configuration tables specify items such as supported spacecraft and antennae, history and operator log entries, and what functions are authorized by user type.

Expandability can be accomplished through the addition of more workstations. Added functions or new user types can be supported on the same hardware with new profiles and custom programs. This type of expansion does not compromise usability or performance.

4. CONCLUSION

The user-centered approach not only led to a superior system, but also provided a high level of user satisfaction. NOCC has become a model for other development efforts.

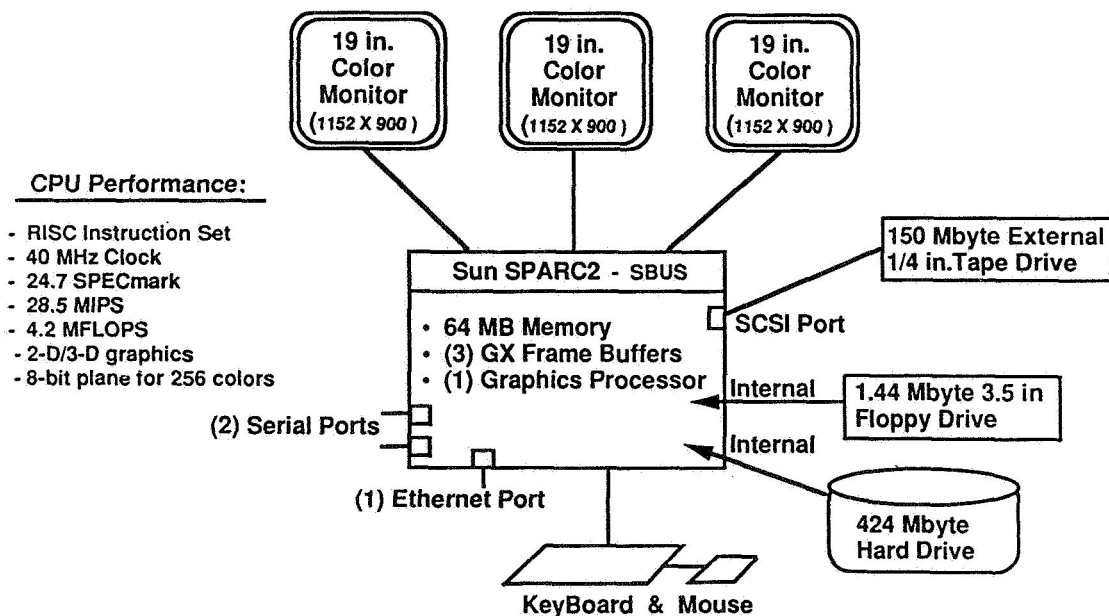


Figure 5. NOCC Workstation