AD-A167 409

(12)

CSMI/TR-85/02

DESIGN, DEVELOPMENT, AND INSTALLATION OF A TWO-NODE, COLOR VIDEO-TELECONFERENCING SYSTEM FOR THE U.S. NAVY

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November 1, 1985

FINAL TECHNICAL REPORT

CSMI/TR-85/02

DESIGN, DEVELOPMENT, AND INSTALLATION OF A TWO-NODE, COLOR VIDEO-TELECONFERENCING SYSTEM FOR THE U.S. NAVY

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: CSMI/TR-85/02	2. GOVT ACCESSION NO.: AD-A167409
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): Design, Development, and Installation of a Two-Node, Color Video-Teleconferencing System for the U.S. Navy	5. TYPE OF REPORT & PERIOD COVERED: Final Technical Report July 27, 1984-Sept. 28, 1985
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Patrick Jones, Douglas French, Harvey Sachs, Frances Clements, Kevin F. Vest, Raymond Thompson	8. CONTRACT OR GRANT NUMBER(s): MDA903-84-C-0008
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Computer Systems Management, Inc. 1300 Wilson Boulevard, Suite 100 Arlington, Virginia 22209	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: ARPA Order 3829
11. CONTROLLING OFFICE NAME AND ADDRESS: DARPA/EAO 1400 Wilson Boulevard Arlington, Virginia 22209	12. REPORT DATE: November 1, 1985
	13. NUMBER OF PAGES: 46
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office): Defense Supply Service-Washington The Pentagon, Room 1D245 Washington, DC 20310	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for Public Release - Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

Approved for Public Release - Distribution Unlimited

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fast Facsimile System (FFS), C-Band satellite communications, Widcom Codec, Vitalink Communications Corporation, compressed bandwidth, video teleconferencing, teleconference

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report discusses the design of a two-node, color Video-Teleconferencing System for the U.S. Navy and its installation at sites in Suitland, Maryland, and Pearl Harbor. It details the development of the audio, video, and fast-facsimile parts of the system; integration of the system into the communications network; design of a teleconference room; and installation of the system.

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SUMMARY

Between July 27, 1984, and August 28, 1985, Computer Systems Management, Inc. (CSM) participated in a project of the Defense Advanced Research Projects Agency (DARPA) to develop and install a two-node, color Video-Teleconferencing System for the U.S. Navy at sites in Suitland, Maryland, and Pearl Harbor, Hawaii. Besides developing the audio and video systems for this project, CSM also designed a teleconference room that insures maximum comfort for users and the most efficient possible operation of the equipment. In addition, CSM designed and implemented a Fast Facsimile System (FFS), which allows rapid digitization, transmission, and annotation of data images in medium-resolution color and high-resolution black and white. Once these systems were completed, CSM integrated into the Navy Video-Teleconferencing System the Widcom, Inc. VT-56 coder-decoder (codec), which transmits medium-bandwidth color images at 56 kilobits-per-second (kbps), and the Vitalink Communications Corporation's C-Band satellite communications network and then installed, tested, and debugged the entire system.

1.0 GOALS AND OBJECTIVES

Computer Systems Management, Inc. (CSM) has reached the major goal of this contract: to install a two-node, low-bandwidth, color Video-Teleconferencing System for the United States Navy at sites in Suitland, Maryland, and Pearl Harbor. The system was developed for the Engineering Applications Office (EAO) of the Defense Advanced Research Projects Agency (DARPA).

To reach this goal CSM had to design and develop a Fast Facsimile System (FFS) that allows rapid digitization and transmission of data images in medium-resolution color and high-resolution black and white. These images can be displayed at both sites, where participants can annotate them by using a special graphics tablet. This new FFS grew from an earlier DARPA-sponsored system developed by CSM, the Shared Graphics Work Space (SGWS).

While developing the FFS, CSM was also designing, developing, and beginning to install the other major components that compose the two-node Navy Video-Teleconferencing System. The system incorporates the FFS; the Vitalink Communications Corporation's C-Band satellite communications network; and the Widcom, Inc. VT-56 coder-decoder (codec), which uses a minimum of bandwidth to provide an interactive environment. The design and development work involved procuring, integrating, and testing the equipment and writing the software routines. CSM then installed, tested, and debugged the entire system.

The following sections describe CSM's work leading to installation of the Navy Video-Teleconferencing System. Section 2 discusses CSM's previous work in teleconferencing. Sections 3 through 7 detail work done on communications, audio, video, the FFS, and facilities. Section 8 presents a conclusion, incorporating suggestions for further refinements of the system.

2.0 PREVIOUS TELECONFERENCING WORK

CSM's teleconferencing work began in 1980 as a project to design and implement an inexpensive, easy-to-operate electronic notepad that allowed the user to annotate in five colors, page forward, page back, erase, clear the page, store previously annotated material, and later retrieve it. From this developed a four-station network of notepads, called Telepads, which transmitted one user's notations to all the other screens in the network. The system transmitted information from station to station via standard telephone lines and modems. The controlling processor was a 6502-based Apple II Plus. Most of the software written for this project needed to be coded in 6502 assembly language.

Building on the Telepad network, CSM took the next step: to develop a full-fledged teleconferencing system, which had the shared-graphics capabilities of Telepad and which added sound and black-and-white video. This system was designed for use by high-level government officials. In times of national crisis, it allows participants separated by distance to use standard telephone communications to share information as they would in a face-to-face meeting. It was assumed that during a crisis high-bandwidth communications would be unavailable for command-and-control functions.

This first DARPA/CSM Teleconference System incorporated the concept of virtual space, which allows each participant to focus on the speaker; localizes the audio so that the speaker's voice is associated with his or her image; and conveys non-verbal communication signals, like facial expressions. By using the Compression Labs, Inc. (CLI) Sketch Coder, the system can do all this with a remarkably small 19.2 kilobits-per-second (kbps) data channel.

Information shared via earlier Telepad was limited to simple hand-sketched charts and graphs. The next step in information sharing was the Shared Graphics Work Space. Designed for the low-bandwidth Teleconference System, it allowed participants to share and annotate more complex material, such as videodisc images, maps, computer graphics, and textual materials. The SGWS was developed in the "C" language on Digital's LSI 11/23 computer systems, running the UNIX operating system. The SGWS had specially constructed high-resolution monitors, which displayed the data and which had the unique capability of allowing the user to annotate by writing directly on the screen. Participants could manipulate data by using a special menu box, which signals the computer what function to perform next.

CSM further enhanced this early system to improve performance, expand the user interface, and ensure communications security during transfer to secure sites. These enhancements to the SGWS include the following:

1. Increasing data storage space.

2. Adding a user terminal that permits participants to perform more complex functions than those provided by the menu box.

3. Integrating a geographic database containing 10,000 names of major cities around the world, which the computer searches, using location names as keys to maps participants want displayed;

4. Incorporating an electronic-facsimile capability that digitizes and stores an image, allows participants to recall and annotate the image during a teleconference, and uses a standard fax machine to print the annotated version at all participants' sites; and

5. Adding an easy-to-use automated briefing feature that allows senior officials, often untrained in data processing, to prepare and present briefings, using all the capabilities of the SGWS.

(See CSMI/TR-85/01 for a detailed discussion of these features.)

In April 1985, CSM transferred a two-node version of this 19.2-kbps system to the U. S. Air Force. The ribbon-cutting ceremony took place in May. The system links the U. S. Air Force/Foreign Technology Division (AF/FTD), at Wright-Patterson Air Force Base, in Dayton, Ohio, to an intelligence production facility in the Washington, DC area.

As developed to this point the DARPA/CSM Teleconference System transmitted only black-and-white images, via CLI's 19.2-kbps Sketch Coders; used telephones or TSP-2000 voice codecs and dedicated land lines for the audio connection; and allowed teleconference participants to share and annotate information via the SGWS electronic-facsimile feature.

While still working on the design and installation of the AF/FTD Teleconference System, CSM, at the direction of DARPA, began to investigate the possibility of using satellite communications, along with the VT-56 Widcom coder which transmits low-bandwidth <u>color</u> images at 56 kbps. Sections 3 through 7 discuss in detail the addition of color to the Teleconferencing System, as well as CSM's work on the new FFS, a stereo audio capability, and some facilities design.

3.0 COMMUNICATIONS

On July 27, 1984, CSM received a modification to an existing contract with the Defense Supply Services--Washington (DSS-W) to participate as one of three DARPA prime contractors in developing a Video-Teleconferencing System targetted for the United States Navy. The other two were Widcom, Inc. (formerly Widegren Communications, Inc.), which manufactures and supplies the VT-56 codec, and Vitalink Communications Corporation, which supplied the satellite earth stations and the space segment. CSM's job was to design and develop the FFS; procure the audio, video, computer, and special-display equipment; and then integrate the Widcom codecs and the Vitalink communications equipment into the Navy system.

On December 30, 1983, CSM's consultant, Brigadier General H. R. Johnson (U.S. Air Force, Retired), completed a three-volume feasibility study, which recommended the use of C-Band transmission, via Vitalink 6.1-meter, five-watt earth stations with space segment as the most cost-effective way to communicate between Suitland, Maryland, and Pearl Harbor. (See H. R. Johnson and Associates, Satellite Communications Technology Base Report for the Period 1984-1988, 31 October 1983; Report on Satellite Transmission: Network Design and Cost Study, 30 November 1983; and Program Definition Study: Development of Advanced Technology Low Cost Satellite Earth Station System/Ku Band, 30 December 1983.)

In implementing this system, Vitalink conducted a feasibility study to ensure that the system would work; drew plans for the two earth stations, one at each node; got Federal Communications Commission (FCC) clearance; and provided both earth stations and the space segment. (Figure 1 shows the Vitalink configuration.)

Two problems delayed installation of the system: In Pearl Harbor, the 6.1-meter dish antenna proved insufficient, thus requiring a change to a 9.1-meter dish. And in Maryland, the Navy was unable to prepare the site for the earth station. At the direction of DARPA, CSM undertook this site-preparation work, including construction of a concrete pad, as specified in the drawings produced by Vitalink in its feasibility study and the FCC application.

Once the site was ready, Vitalink installed both earth stations and the space segment. The completed Vitalink system consists of the equipment needed to transmit full-duplex, 112-kbps digital data; it terminates at the modem. At each end, CSM interfaces with encryption devices supplied by the Navy, and two multiplexers, which combine outgoing audio, video, and data signals and split incoming ones. One multiplexer interfaces with the CSM electronics. (See Figure 2.)

Incoming signals are directed to the appropriate subsystems that control the audio, video, and FFS functions of the system. Outgoing signals reverse the process. The following sections describe each of these functions.

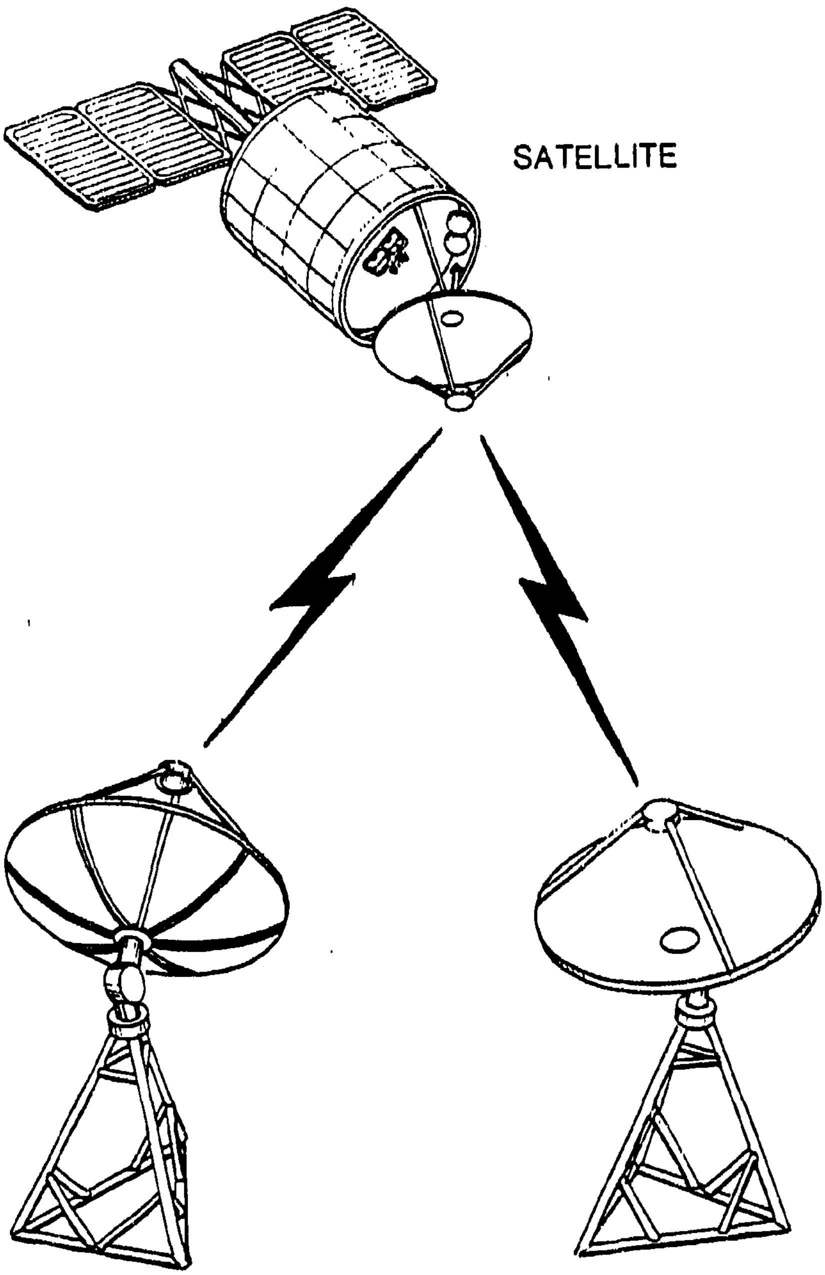

FIGURE 1

VITALINK COMMUNICATION NETWORK

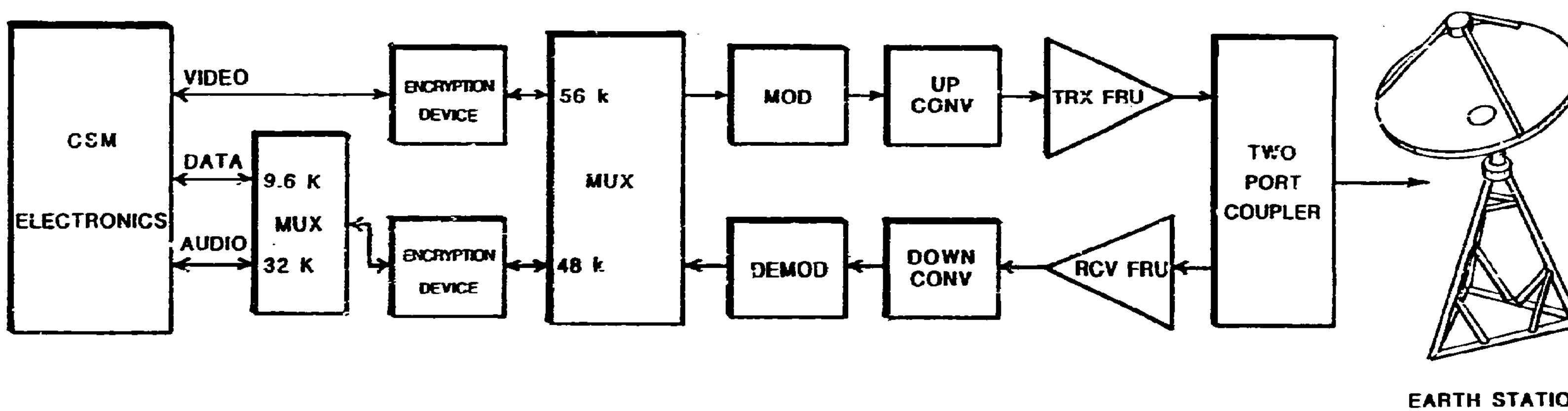

FIGURE 2

INTERFACE OF CSM ELECTRONICS

WITH VITALINK EQUIPMENT

4.0 AUDIO

A common problem in teleconference design is the audio, all too often the most neglected part of a system. The problem of audio-system design is exacerbated by the inability of the design engineer to visualize the system as a whole. Generally, the engineer addresses the problem in terms of the audio system, room acoustics, or the audio channel. These are treated as separate entities, when in fact each part of the system affects overall performance and can interact with each of the others. CSM solved the problem of audio-system design with signal-processing equipment that gives flexibility in room design and compensates for varying audio-channel conditions. (See Figure 3.) This approach means that the same audio system will work generally for all applications.

The audio part of the conference is picked up by three microphones on the conference table. The outputs of these microphones pass to an audio mixer for amplification and level control. The mixer is an Electro-Voice, Model 8208, with eight input and two output channels. It adjusts the individual output levels of the microphones and then combines the three separate signals into one output signal.

After level equalization in the audio mixer, the combined signal passes into the Acoustic Echo Canceller (AEC), a device that lessens the problem of audio wrap-around. When an open microphone and a speaker are placed in the same room, the microphone tends to pick up sounds emanating from the speaker--that is, to wrap the sound around--and thus create an echo. The AEC

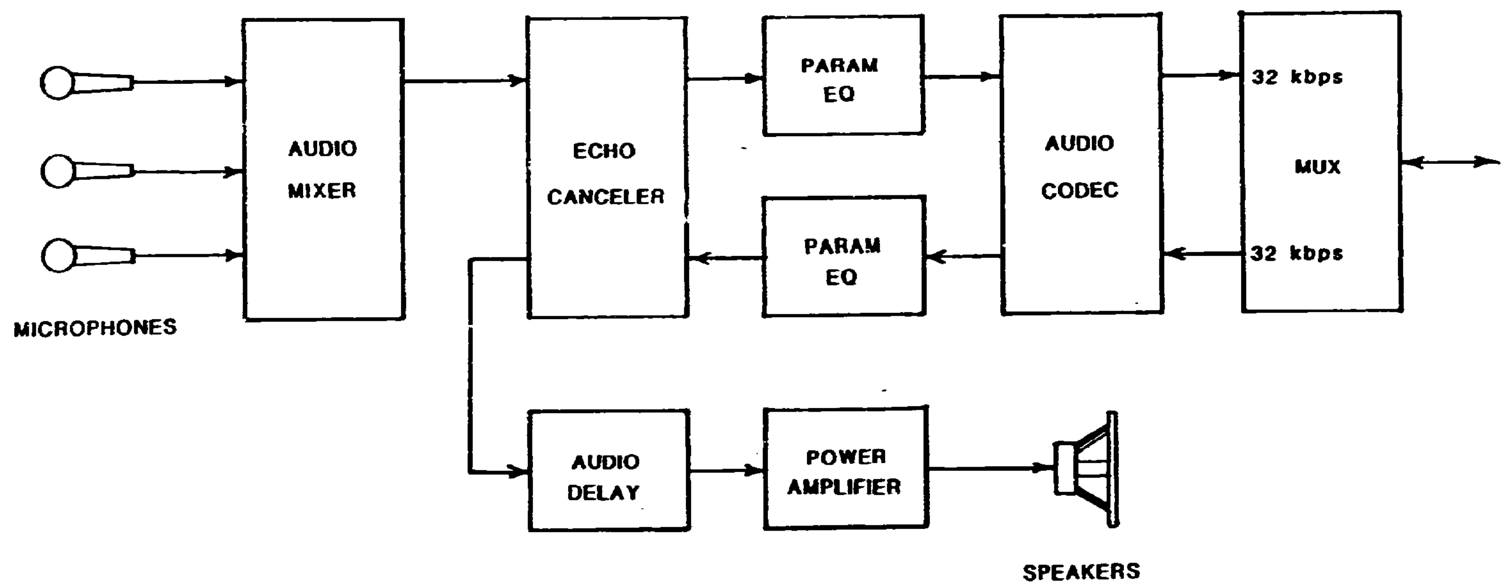

FIGURE 3

AUDIO EQUIPMENT

samples the incoming audio channel, inverts and attenuates the sample, and adds this cancellation signal to the microphone output signal, reducing the echo.

From the AEC, the signal enters a parametric equalizer, which equalizes the audio-signal frequency response and attenuates unwanted frequency components in the signal. The parametric equalizer is tuned to isolate these unwanted frequency components and then subtract them from the main audio signal. It also shapes the overall frequency response for the best signal fidelity and intelligibility at the remote site. In this way, the equalizer compensates for frequency response variations impo· i by the audio channel and room acoustics and reduces extraneous noise, such as that emitted by a fluorescent light.

The audio signal next passes to the audio codec, which samples the analog audio signal and converts the sample into a digital form suitable for transmission over the satellite link. From the audio codec, the signal enters a data multiplexer, which combines the audio and data signals and sends the combined signal through encryption devices. After encryption, the signal passes through a second multiplexer for combination with the video data, then to Vitalink's signal-processing equipment, and out the uplink to the satellite.

The incoming audio signal reverses this sequence in a parallel path. It flows from the downlink to the first multiplexer, then through the encryption device to the second multiplexer, which splits the signal back into its audio and data streams; to the audio codec; and then to another parametric equalizer. This equalizer shapes the overall frequency response of the incoming audio signal and provides additional attenuation of unwanted frequency components.

The audio signal next passes to the audio-delay board in the Widcom codec. Compressing the image information causes a time delay in the video signal relative to the uncompressed audio signal. Although this delay lasts only 250 milliseconds, it is annoying to the conferees and must be reduced to maintain their sense of real-time teleconferencing. The audio-delay board compensates for this time skew by electronically delaying the audio signal relative to the video signal. This added audio delay synchronizes the sound emitted from the local-site speakers with the lip movement of the remote-site conferee. The audio signal is next routed through a power amplifier and, finally, to the speakers.

This audio flow is constant and bidirectional: That is, both incoming and outgoing signals flow through the system at the same time.

5.0 VIDEO

Until now, video teleconferencing has not been cost effective. The high cost of communications and the expense of the video-compression equipment has drastically limited the number of companies that can afford the luxury of a video-teleconferencing system. DARPA's work with low-cost teleconferencing and with the compressed-bandwidth video codecs, however, has made possible the creation of an affordable system that uses full-motion color video.

The Widcom VT-56 is the heart of the Navy Video-Teleconferencing System since video is the focus of the participants' attention. It is a full-motion color video codec that operates at 56 kbps. The video is compressed by a ratio of nearly 1,500 to 1, which accounts for the slow bit rate. This very narrow bandwidth allows for the use of low-cost communication lines, thus reducing the cost of operating the system. The codecs accept the video signal from the video switcher and transmit it to the remote site over the satellite link. To maintain security, the digital signal from the codec is processed by encryption equipment.

The video part of the teleconferencing system is configured to use a low light-level camera to transmit the image of the participants. This three-tube Panasonic WV-555 can be operated with normal room lighting and minimum extra fill lighting. The image goes from the camera to a preview monitor, which connects to the participant's camera. The preview monitor allows participants to see themselves as they appear at the other end of the network and thus to make sure that they are properly situated and in the view area of the camera. CSM modified this monitor so that it shows the image in a reverse left-to-right format. This reversal gives the users a mirror image of themselves so that when they move right, they see the image on the monitor move right; this makes it much easier for them to position themselves in the viewing area of the camera.

Participants at each site see each other via a Sony Profeel, Model KX-2501, color monitor connected to the output of the VT-56. The monitor's 25-inch diagonal picture allows several people to comfortably view the screen.

The video equipment is housed in a custom-designed cabinet, made of wood and covered with black formica; it was designed by Michael and Susan Southworth, of City Design and Architecture, Boston, Massachusetts. Because the camera and monitors are concealed, the teleconference participants are not intimidated by the presence of the equipment. The cabinet also helps protect the equipment by preventing tampering. (See Figure 4.)

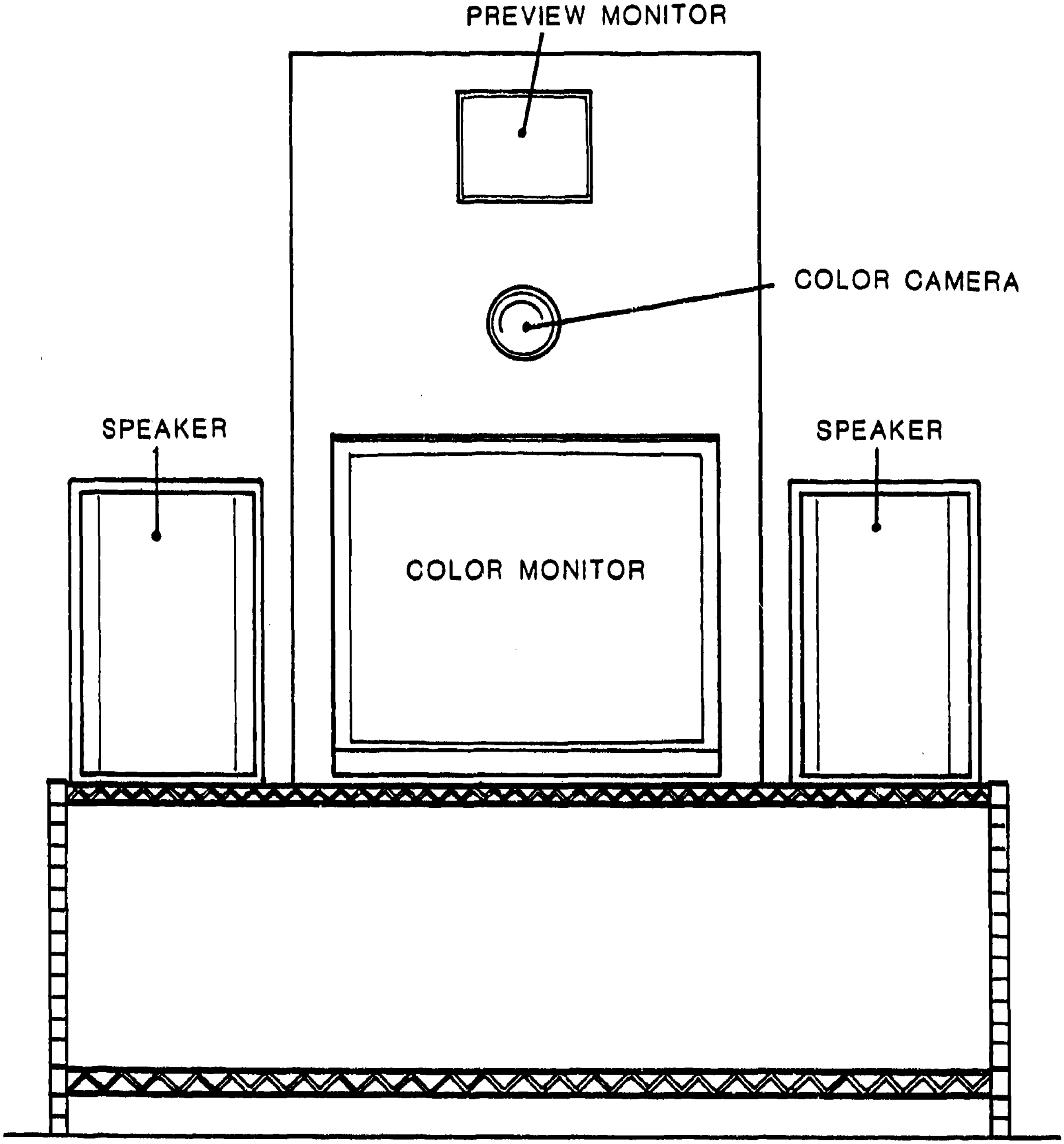

FIGURE 4

TELECONFERENCING MODULE

6.0 FACILITIES

To solve the problems of facilities design, CSM tested lighting and camera angles and experimented with different arrangements of equipment. These experiments were essential to creation of the most comfortable environment possible for teleconference users and one that allows the system to work most effectively.

6.1 Facilities Design Problems

Probably, more than any other factor the architectural design of the room determines how readily users accept and feel comfortable with a teleconferencing system. Careful attention to the participants' needs for space, lighting, and acoustics is essential to creating a productive environment. By the same token, space, lighting, and acoustics also affect the operation of the video, audio, and graphics equipment. Therefore, the equipment should be selected and the room designed with these factors in mind; attention to these details will ensure both comfort and utility for the conferee and compatibility with the needs of the equipment.

6.2 Facilities Design Solutions

To test lighting and camera angles for the most suitable arrangement, CSM used detailed mockups and demonstrations when designing the rooms. These mockups and demonstrations allowed CSM staff to decide where to place monitors for maximum visibility and minimum glare from the screens. They also helped the staff to find the most effective way to design and install the document stand, a critical piece of equipment that conferees need ready access to when conducting briefings. (See Figure 5.)

Technical specifications of the equipment configuration were examined closely for compatibility, and the electronics needed little in the way of special cabling or interfaces. However, where necessary, interfaces were provided to allow for the use of equipment with the best available specifications for the job.

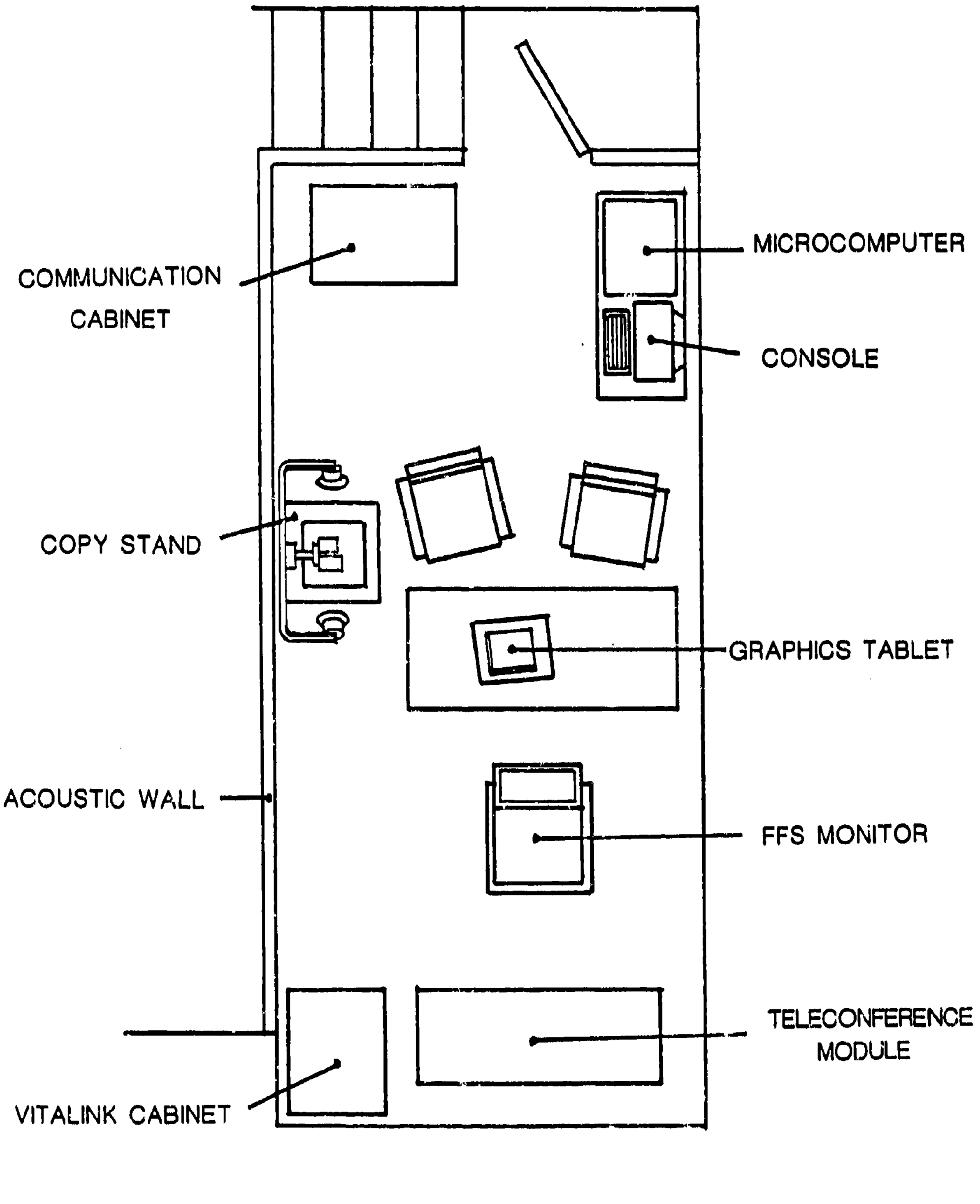

FIGURE 5
LAYOUT OF
NAVY TELECONFERENCE ROOM

7.0 FAST FACSIMILE SYSTEM

Teleconference participants often need to share graphics, text, and other information; to quickly access this material; and to transmit it without elaborate preparation. To meet this need, CSM developed the FFS, building on its earlier research for the SGWS, an information-sharing capability incorporated in the AF/FTD Teleconference System. (See CSMI/TR-85/01, pp. 3-12.)

The SGWS method of transmitting data images required several minutes per image for digitization, decoding, and distribution among the nodes, a process that participants found disruptive when attempted during the meeting itself. Therefore, this time-consuming data preparation had to be done before the scheduled conference. Unfortunately, briefing materials often do not arrive until participants reach the conference site, minutes before the conference begins. And sometimes during a meeting, discussions require documents that have not been digitized in advance. These situations demand a method for rapidly transferring images.

The FFS not only provides this rapid transfer, it also transmits both translucent view graphs and opaque documents in medium-resolution color as well as high-resolution black and white. Merely by pressing an electronic pen to the graphics tablet, participants can send documents, control black-and-white contrast, annotate the documents in four colors, erase their annotations, and clear their writing or the document. (See Figure 6.)

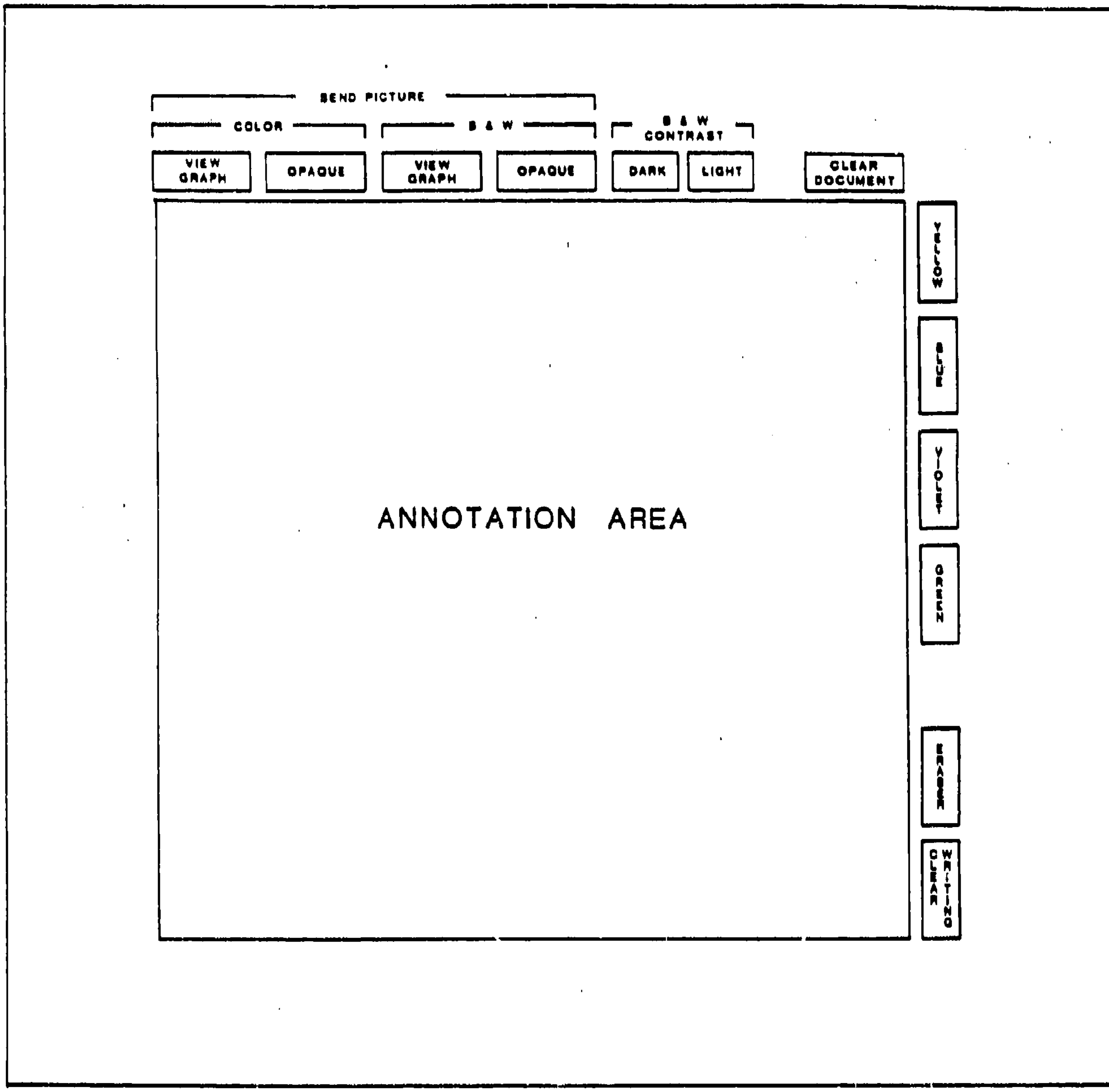

FIGURE 6

GRAPHICS TABLET COVER

7.1 Hardware Configuration

The document to be transmitted is placed on a plexiglas rectangle, inset in a color-core formica copy stand. This inset serves as a guide to the proper placement of the document for the best camera angle; and it evenly diffuses the light from two fluorescent bulbs inside the copy stand, which are used for photographing view graphs. Another sheet of plexiglas, placed between the bulbs and the inset, further diffuses the light, thus ensuring an even copy. (See Figure 7.) The copy stand also contains the power supply for the Zenith VC 1000 medium-resolution color camera and a lighting control box, developed by CSM, that switches from fluorescent to overhead incandescent lights when opaque documents are being sent.

The copy stand, lights, and two cameras--for color or black and white--form a self-contained unit that can be wheeled about the teleconference room to the most convenient location. The unit permits cameras and lights to be raised or lowered to adjust the focus or change the intensity of the lighting.

7.1.1 Color Transmission

Selecting the color mode causes the switcher, controlled by the Columbia microcomputer, to select the Zenith VC 1000 camera as the image source signal. The video switcher splits this source signal into two signals, sending one to the frame buffer for storage and display on the local monitor, and the other to the Widcom codec, which digitizes this image for transmission to the remote site. (See Figure 8.)

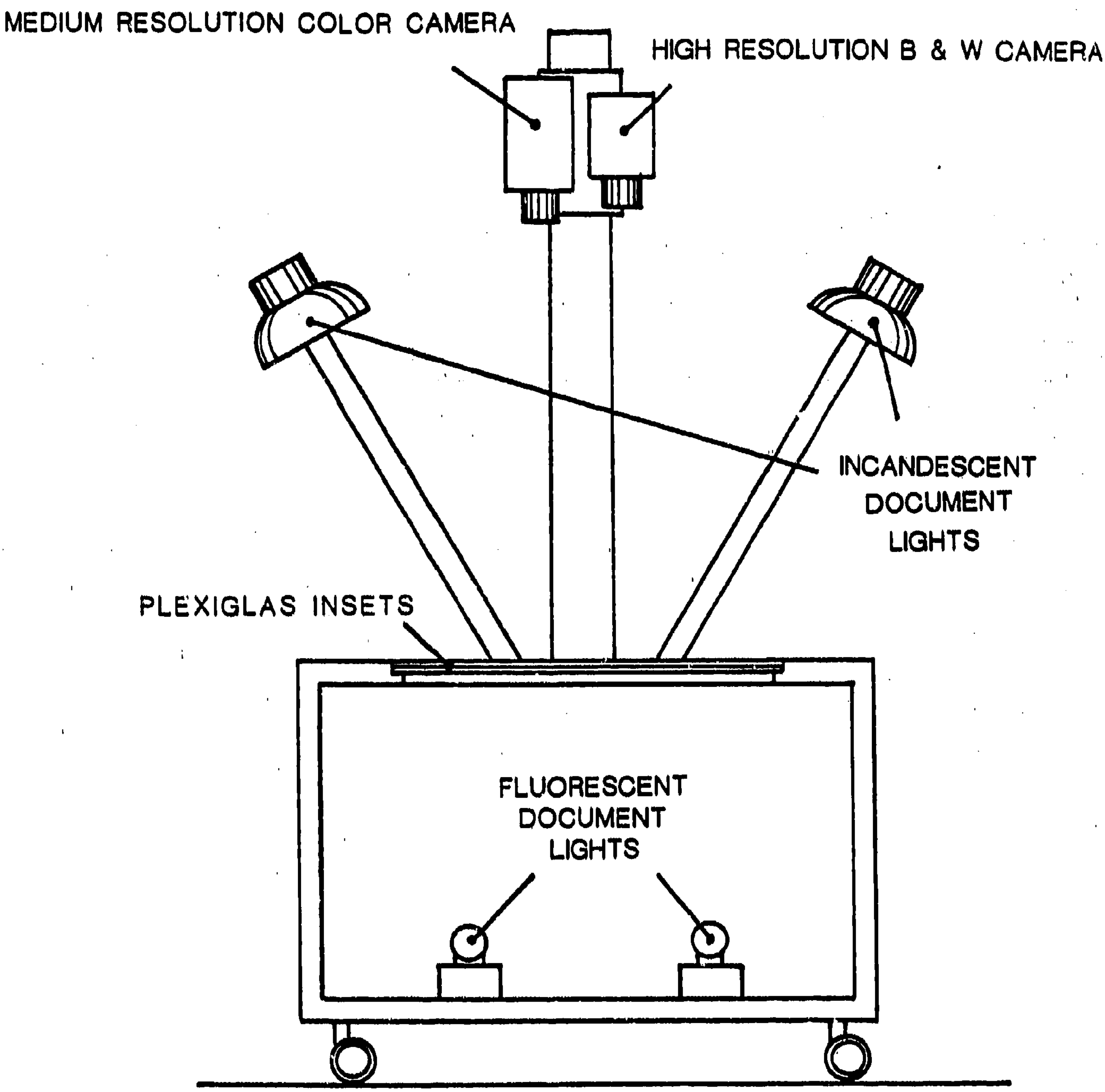

FIGURE 7

CROSS SECTION OF DOCUMENT STAND

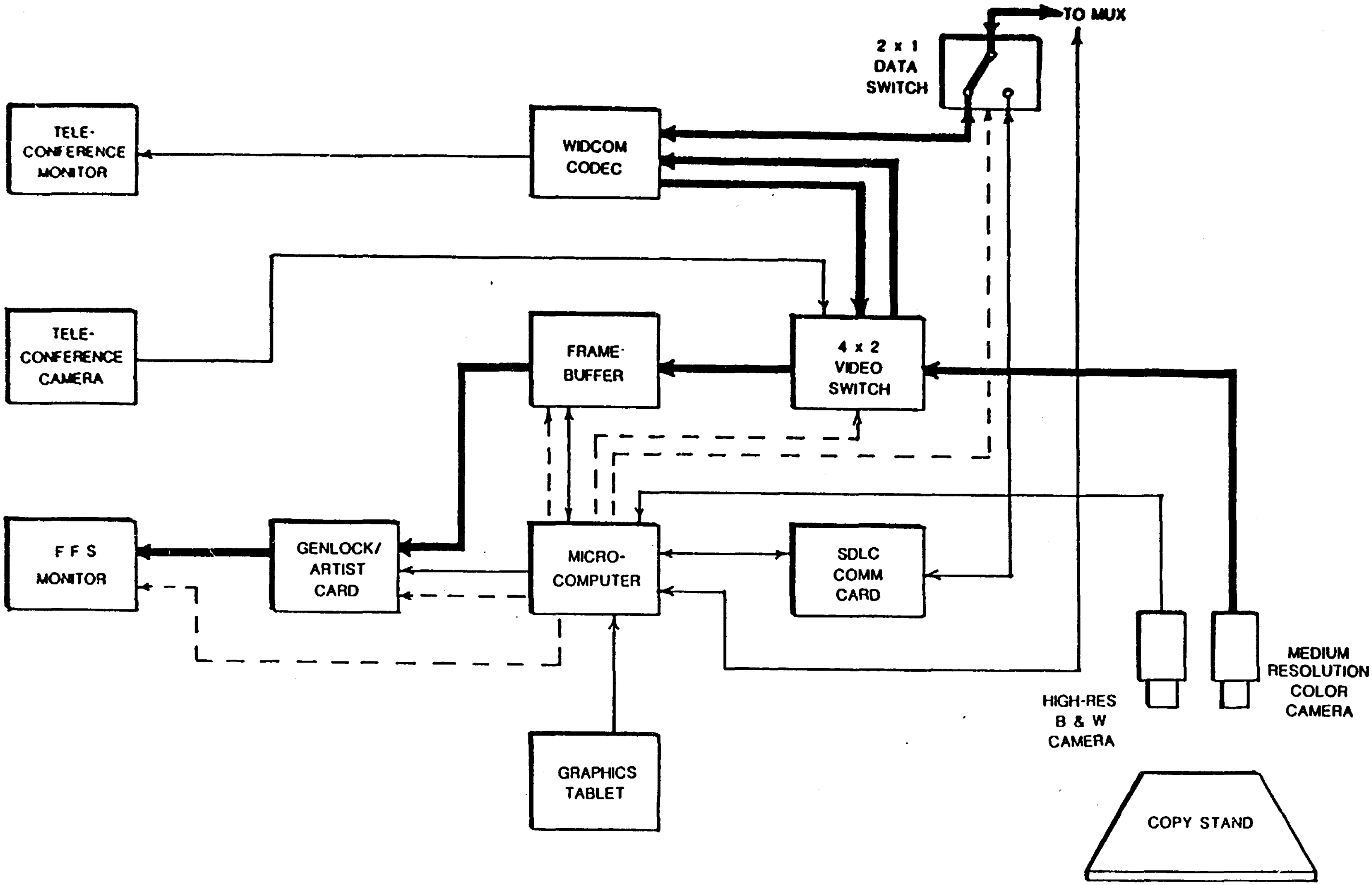

FIGURE 8

COLOR TRANSMISSION

When the sender annotates the image, the data stream of coordinates for the annotation points goes from the graphics tablet to the microprocessor, which directs the stream to the Control Systems (CS) Artist Card in the microcomputer. The Artist Card combines the annotation data with the image from the frame buffer and displays the annotation image on the local FFS monitor. The annotation data is also multiplexed in with the teleconference data and sent to the remote site. Annotations from the receiving site go through the same process.

The multiplexer combines the audio and data signals and sends them through the encryption device and on to the Vitalink communications network.

At the receiving end, data from the downlink enters the multiplexer, which separates two data streams, one for video, the other for audio and graphics. From the multiplexer, incoming image data goes through a data switch to the Widcom codec, where it is returned to analog form; to a frame buffer for storage; and finally to the remote FFS monitor. Incoming annotation data goes from the multiplexer to the microprocessor, which sends it to the CS Artist Card, where it is combined with the image, and then to the remote FFS monitor.

7.1.2 Black-and-White Transmission

Selecting the black-and-white mode activates the high-resolution, black-and-white camera, a Datacopy, Model No. 610. The image-data stream passes from the camera to the Columbia microcomputer, where it is stored in memory, via DMA (direct-memory access). From memory storage, one image-data stream goes to the CS Artist Card, where it is sent for display on the local FFS monitor. (See Figure 9.)

Another data stream flows from the microprocessor memory to the SDLC (synchronous data link control) communication card and immediately goes out over the 56-kbps data line to the data switch. From this point, the black-and-white image data follows the same communication route as the color image data--until it reaches the data switch at the remote site.

This remote data switch routes the black-and-white stream over the 56-kbps data line to the SDLC communication card, which interfaces with the microprocessor bus. Using DMA, the microprocessor sends the data to its local memory and then to the CS Artist Card, where it is stored on one of four bit planes and sent to the remote FFS monitor.

Annotation data from the electronic graphics tablet goes to the microcomputer. The microcomputer sends this data to the CS Artist Card, where it is stored in two bit planes and then combined with the black-and-white image data also stored in the Artist Card. This annotated, high-resolution image is then displayed on the local FFS monitor. The microcomputer also sends this annotation data out through a 9.6 kbps serial data port to the multiplexer for transmission to the remote site. From there it follows the same communication path as annotations for color images until it reaches the data switch at the receiving end, where it is routed to the 56-kbps data line. It then follows the same route as the image-data stream, to the SDLC communications

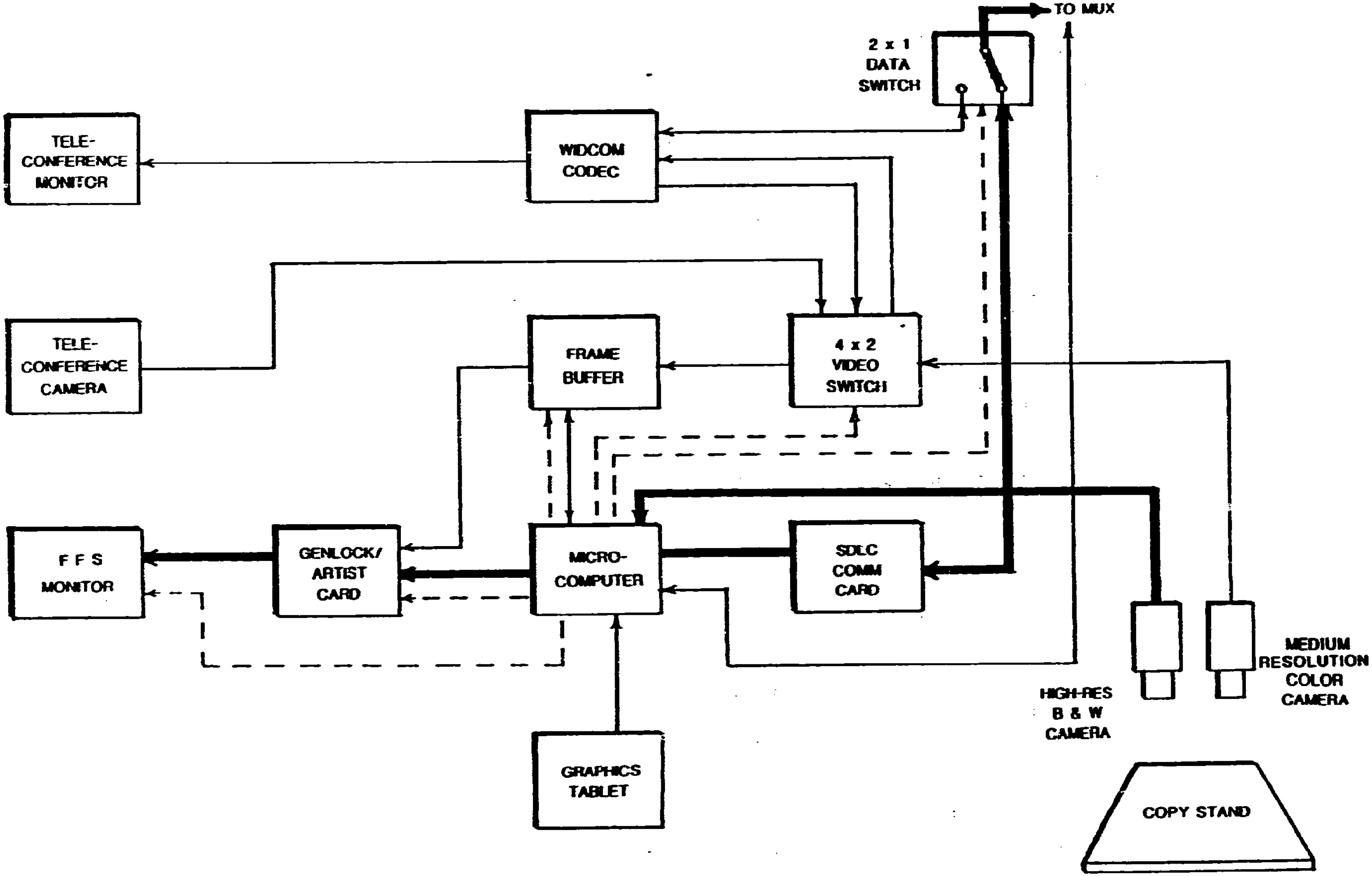

FIGURE 9

B & W TRANSMISSION

card, the microprocessor, the CS Artist Card, and the receiving monitor.

7.2 Software

However sophisticated the FFS hardware may be, proper operation of the system demands an equally sophisticated software. The QNX operating system on the Columbia computer is the environment under which all software was developed and now runs; 95 percent of this software is written in the C language and the other 5 percent, or two routines, in assembly.

To make the system work, the software running on the Columbia controls several pieces of hardware, including the graphics tablet, used to both "write" and select menu items. The tablet has an active area of approximately 10.5 x 10.5 inches. In that area it senses about 2,000 x 2,000 points. When the pen passes over one of these points, the tablet sends five bytes of information to the computer. This information gives the X Y position of the pen and determines whether the pen tip is pressed against the tablet surface or merely resting lightly on top. After error checking has been done on these coordinates, they are transmitted to the remote site to be displayed.

The software at both sites takes the X Y position supplied by the graphics tablet and scales it to a position that can be displayed by the CS Artist Card on the local monitor. The monitor can display either 1,024 x 1,024 in high-resolution mode or 1,024 x 480 in medium-resolution mode. Once a display location has been computed, if the pen is pressed down, a command goes to the Artist Card to draw a line from the last point read to the current point just read. If the pen is not pressed down, the cursor is drawn and the previous cursor is erased.

7.2.1 Menu Selections

After the program has read the graphics-tablet data, it checks to see if the point sent is in the menu area shown on the tablet. (See Figure 6.) If it is, the tablet is commanded to beep once; and then the requested operation takes place. If the pen is pressed down on one of the menu colors, the Artist Card is commanded to set the chosen color. All drawing commands will use that color until it is changed. If the eraser mode is chosen, the cursor is drawn and the area beneath it is written in black, which erases the writing below the cursor. If the Clear Screen is chosen, the entire screen is written in black.

Besides the Artist Card and the graphics tablet, the software controls the video switch and the freeze-frame unit. The video switch allows any one of four inputs to be routed to any of two outputs under software control (See Figure 10.) In normal operation the image from the video camera which points at the participant, goes through the switch and is output to the Widcom codec. However, if either of the color-document transmit commands is issued, the switch sends instead the image from the Zenith data camera to the Widcom and to the freeze frame for several seconds. The freeze frame is told to freeze the image; and then the switcher is commanded to go back to the normal mode, which once more sends the video image to the Widcom. At the remote station software on the Columbia computer receives the X Y

4 x 2 VIDEO SWITCHER							
CONTROL WORD				FUNCTION			
D7	D6	D5	D4	INPUT TO	OUTPUT	INPUT TO	OUTPUT
Ø	Ø	Ø	Ø	1	A	1	B
Ø	Ø	Ø	1	3	A	1	B
Ø	Ø	1	Ø	2	A	1	B
Ø	Ø	1	1	4	A	1	B
Ø	1	Ø	Ø	1	A	3	B
Ø	1	Ø	1	3	A	3	B
Ø	1	1	Ø	2	A	3	B
Ø	1	1	1	4	A	3	B
1	Ø	Ø	Ø	1	A	2	B
1	Ø	Ø	1	3	A	2	B
1	Ø	1	Ø	2	A	2	B
1	Ø	1	1	4	A	2	B
1	1	Ø	Ø	1	A	4	B
1	1	Ø	1	3	A	4	B
1	1	1	Ø	2	A	4	B
1	1	1	1	4	A	4	B

OUTPUT	DESTINATION
A	WIDCOM-IN
B	FRAME BUFFER IN

INPUT	SOURCE
1	CAMERA 1
2	CAMERA 2
3	WIDCOM OUT
4	SPARE

FIGURE 10

VIDEO SWITCHER STATE LISTING

coordinates and determines that it is supposed to get video data. It changes the switcher to feed the Widcom data to the freeze frame, freezes the image, and then commands the switcher to return to the normal mode, in which the Widcom passes data to the Profeel monitor.

When a color document is transmitted, the software must also make sure that the monitor is in the right mode. The monitor for a color document must be in 1,024 x 480 resolution mode; if it is in 1,024 x 1,024 mode, then a command is sent to change the mode. The Artist Card is also commanded to change its resolution.

When a menu item is chosen to transmit a document, either black and white or color, the software also controls the lighting. (See Figure 7.) If the document is a view graph, the lights inside the document stand remain on. However, if an opaque document is to be transmitted, those lights go off; and the overhead lights turn on. After the document is transmitted, the overhead lights turn off; and the interior lights come back on.

When a black-and-white high-resolution document is transmitted, the data moves via DMA, the fastest-way of sending large amounts of data from one device to another. A block of data on one device is copied directly to memory on another. Instead of the Central Processing Unit's (CPU's) having to handle each byte, the two devices take care of the transfer themselves. The data is sent via DMA from the Datacopy camera to the Columbia, and then from the Columbia to the Artist Card for display and to the SDLC card for transmission. Because of limited memory, not all of the data can be sent at once via DMA; so this process continues until all data from the Datacopy camera is displayed and transmitted.

When the FFS's software is first started, it initializes all of the hardware devices that it controls, including the Datacopy camera, which must be told how to scan the document to be transmitted. The camera is told to use a technique called ditherizing. Though this technique does not use a gray scale, it nevertheless gives a "halftoned" look to the document. The ditherizing values are set up by the software on the assumption that the document is of a certain darkness. However, if the document is too dark or too light for the ditherizing pattern, the camera can be given new values. If the user chooses to darken or lighten the document via the menu control, the software sends the camera new values that will change the ditherized image the next time the document is transmitted.

7.2.2 Interrupt Routines

An important design criterion of the FFS is that the annotation has to be in real time. When a user writes with his pen on the graphics tablet, the "writing" must appear on the screen immediately; and it must also keep up with the pen movement. Unfortunately, the standard input and output (I/O) routines supplied by the 'C' compiler with the QNX operating system are not fast enough to read annotations from the tablet, write them out to the other node, and still leave time for the CS Artist Card to draw the information on the screen. To solve this problem, CSM substituted its own interrupt-driven I/O routines for the relatively slow QNX routines.

Interrupt routines enable a device or program to notify the computer during normal processing that special conditions exist--in this case, that the computer is ready to write data to the network or that data is ready to be read from the graphics tablet or the network. When an interrupt has been signalled, the computer puts aside its current program as quickly as possible and executes instead a special routine supplied by CSM. In the case of input, this special routine quickly puts data from the network or graphics tablet into a special buffer set up for that purpose. In the case of output, it writes out the data.

The advantage of interrupt-driven I/O is that data is input or output only when the computer is ready for I/O to take place. The computer does not waste time waiting for data to be sent by a comparatively slow input device, such as the graphics tablet. Also it writes to the network only when the network is ready to accept another byte. It doesn't have to wait around doing nothing while the byte is being sent.

Knowing that other computer users also need fast I/O and not wishing to "reinvent the wheel," CSM researched existing I/O software now in the public domain. A software program written in assembly language for an IBM PC proved suitable. Because the assembly code was not compatible with QNX, CSM translated it and then customized it to meet the exact needs of the FFS.

As a result, the I/O runs at least ten times faster than the standard QNX I/O routines and, thus, allows simultaneous display of local and remote annotations.

8.0 SUMMARY OF THE TRANSFER ACTIVITIES

CSM's work on teleconferencing culminated in the design of a low-bandwidth, two-node, color Teleconferencing System and its installation in August 1985 at naval facilities in Suitland, Maryland, and Pearl Harbor.

8.1 System Design

CSM used Widcom codecs and the FFS to produce the integrated Video-Teleconferencing System for the U.S. Navy. This work involved the design of conference rooms, the communications network, and equipment configurations at both sites.

Drawings were provided to the Navy, specifying space, electrical, lighting, and furniture requirements for the conference rooms. Mockups of these designs were then made. With these, CSM staff could decide how best to set up equipment and light the facilities for a comfortable teleconference.

The communications network was specified in conjunction with Vitalink, another DARPA contractor, which provided the data communications link for this work. This cooperative venture ensured that equipment procured by CSM interfaced properly with that supplied by Vitalink.

Equipment configurations and wiring lists were generated to facilitate a timely installation of the equipment. Inter-room wiring lists were provided to the Navy so that proper security procedures could be met. At the same time, power requirements were generated. The Navy agreed to be responsible for intra-room wiring and providing adequate electrical power.

CSM designed a data-communications switch to direct the data multiplexer to either the Widcom codec or the computer I/O port. A switch was constructed that connected the multiplexer, the codec, and the computer. The switch was placed under software control, allowing maximum flexibility in the system design and use.

The satellite communications link conformed to CCITT V.35 specifications. The data multiplexers chosen by CSM converted the signals to the RS-422 standard signals, as required by the satellite equipment.

8.2 System Installation

CSM has delivered and installed the audio, video and graphics systems for a two-node Video-Teleconferencing System, one in Suitland, Maryland, the other at Pearl Harbor. The system reached its initial operational capability on August 26, 1985.

This work included packaging, shipping, installation, and testing of the teleconferencing equipment. The teleconferencing equipment was shipped via air by North American Van Lines. All equipment was packed in original boxes or was crated by North American for safe arrival. The shipment left the CSM facilities on July 19, 1985, and was delivered to Pearl Harbor on August 1, 1985.

The U.S. Navy, working from drawings and information on cable type supplied by CSM, ran lengths of cable from the equipment rack to the teleconferencing rooms. When CSM staff arrived on site, connectors were then put on the cables. Also at this time intra-room cables (those that run from the microcomputer to various system components) were installed, ready to be connected when the system components were installed.

Once on site, CSM staff completed the installation by racking the equipment, placing it in the right place in the room, wiring it together, focussing the cameras, and tying the cables down to make them safe and attractive.

8.3 Maintenance

CSM is now providing labor and materials for the maintenance of the audio, video, and graphics equipment used with the Video-Teleconferencing System. However, under separate DARPA contracts, Widcom Communications, Inc. maintains the video codecs employed in the system; and Vitalink is responsible for insuring the continued operation of the data-communications link.

9.0 CONCLUSION

The two-node, low-bandwidth, color Video-Teleconferencing System installed for the Navy at Suitland, Maryland, and Pearl Harbor embodies the results of more than five years of CSM research and development in teleconferencing, especially in the areas of shared high-resolution graphics and text.

Several developments have made this system a real breakthrough in inexpensive video teleconferencing. First CSM incorporated in the system the Widcom VT-56 codec, which transmits low-bandwidth color images at a remarkable 56 kbps. Second, the development by CSM of the Fast Facsimile System allows the rapid digitization and transmission of data images in medium-resolution color and high-resolution black and white. Third, the audio system was especially designed by CSM to provide high-quality sound. When combined with the video image and the shared textual and graphics data, this important feature can greatly enhance the teleconference participants' sense of taking part in a face-to-face meeting. Finally, CSM took an organic approach to facilities design. The video, audio, and graphics equipment is integrated into a total design that ensures the most efficient operation of the equipment. At the same time the design ensures that space, lighting, and acoustics provide users with the most comfortable environment possible.

Though much work has been done, the system will need further refinements. In particular, it still needs some means of producing hard copies that give participants a record of data exchanged in a meeting. Navy personnel mentioned this need almost as soon as the system was installed. Technical improvements in printing can now solve this problem.

Additional nodes should also be provided to allow access to the current network from more than two locations. The Navy has already identified locations that could profit from these enhanced communications.

Furthermore, the audio system needs additional work and equipment before it can produce the full stereo sound it was designed to give. Once implemented, this stereo audio will allow participants to associate the sound of a speaker's voice with his or her location and thus enhance even more their sense of taking part in a face-to-face meeting.

Because of the many delays in completing the system, CSM ran out of time and funds for a full year's maintenance of hardware and software. Nevertheless, the system will need periodic adjustments and preventive maintenance, as well as additional spare parts, such as another IBM PC/XT and associated special-purpose boards.

Finally, there are additional features that should be incorporated in the system. Though requiring minor effort and expense, these additions would have a major impact on the system's capabilities. The data multiplexer, for example, has additional voice and data channels; software could be written to allow offline use of the satellite transmission by other digital equipment at each site. And since the system was designed with spare video input, the inclusion of a remote camera and the modification of software to control it would be simple tasks. CSM recommends that additional funds be made available for these modifications.

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