April 1983

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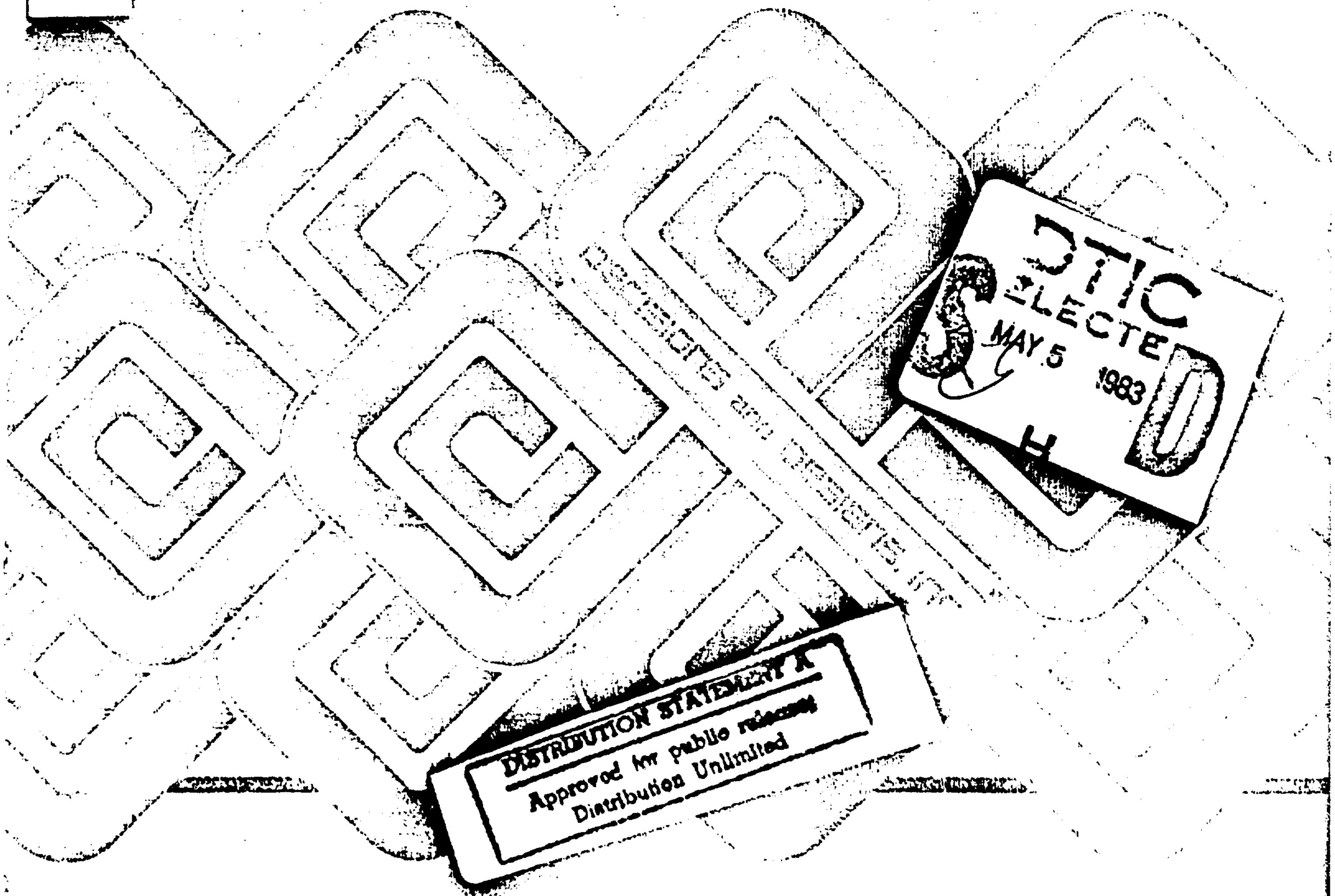

Prepared for
Defense Advanced Research Projects Agency
Defense Sciences Office
System Sciences Division
1400 Wilson Boulevard
Arlington, Virginia 22209

TECHNICAL REPORT DDI/TR 83-4-314.73

Development of Teleconferencing Methodologies With Emphasis on Virtual Space Video and Interactive Graphics

by

Linda B. Allardyce and L. Scott Randall

Sponsored by

Defense Advanced Research Projects Agency
DARPA Order No. 3853
Under Contract MDA903-C-0193
issued by U.S. Department of the Army
Defense Supply Service-Washington
Washington, D.C. 20310

April 1983

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER DDI/TR-83-4-314.73	2. GOVT ACCESSION NO. AD-A127738	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DEVELOPMENT OF TELECONFERENCING METHODOLOGIES WITH EMPHASIS ON VIRTUAL SPACE VIDEO AND INTERACTIVE GRAPHICS		5. TYPE OF REPORT & PERIOD COVERED Final technical report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Linda B. Allardyce L. Scott Randall		8. CONTRACT OR GRANT NUMBER(s) MDA903-80-C-0193
9. PERFORMING ORGANIZATION NAME AND ADDRESS Decisions and Designs, Inc. Suite 600, 8400 Westpark Drive, P.O. Box 907 McLean, VA 22101		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DARPA ORDER NO. 38533
11. CONTROLLING OFFICE NAME AND ADDRESS Defense Advanced Research Projects Agency Defense Sciences Office, System Sciences Div. 1400 Wilson Blvd., Arlington, VA 22209		12. REPORT DATE April 1983 13. NUMBER OF PAGES 88
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for general release; distribution unlimited.

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

18. SUPPLEMENTARY NOTES

For related research, see AD A090502; AD A096106; AD A099035.

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

Telecommunication	Conferencing (Communications)
Teleconferencing	Videodiscs
Video teleconferencing	Virtual space

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

This final report completes three years of research effort conducted by Decisions and Designs, Inc. (DDI) to investigate and implement a prototype video/audio teleconferencing system. This project has included everything from feasibility studies through the transfer of technology to an operational system.

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The most striking outcome of this research has been the development of an interactive videographic subsystem, which has been called the Shared Graphic Workspace (SGWS). By using the SGWS, conferees have the ability to share documents or other visual materials during a teleconference. and annotate the graphic materials if so desired. In addition, this research incorporated a video coder/decoder (codec), which was developed by Compression Labs, Inc. (CLI), to test the effectiveness of severely compressed video images of conferees in various types of teleconference environments. Use of these codecs indicated that even a severely compressed picture is a definite improvement over audio-only conferencing.

Two other significant aspects of this research project were: implementing the virtual space concept (or multiple transmissions of each conferee's image), and developing a user interface suitable for high level decision makers. The concept of virtual space was intended to provide each conferee with a convincing feeling of being present in the same room around a "virtual" conference table. All conferees could see or hear each other at all times from their respective positions around the virtual table.

In order to motivate executives to use an aid, such as the SGWS, touch-sensitive screens and digitizing tablets, instead of keyboards, were tested as input devices. They proved to be very effective, because training is minimal and typing skills are not required.

Suggestions for future research in all four areas described above conclude this report.

ACKNOWLEDGEMENTS

Although the authors did participate in this research project and were assigned the final task of writing up the results, that task was small compared to the efforts of several people who made significant contributions over the course of the past three years.

George E. Dyche and Charles A. King in the Engineering Department designed and fabricated several components of the hardware used in the audio/video switching system and in the control console. They also installed, tested, repaired, and modified, several state-of-the-art hardware components that were often prototype or development systems, and needed considerable attention before they could interface with other devices and operate reliably.

Thomas C. Rayla assisted the authors in managing the software development. V. Carol Cox, Robert M. Esoda, Kenneth J. Frier, and Roger C. Greene developed and tested the software for all three systems, and were involved in hardware integration, installation, and user training.

Charles P. Arnis provided administrative support to keep the project running smoothly, which included coordinating hardware orders and shipments, budget management, and organizating project meetings.

A constant and unfailing effort was made by Susan C. Brewster, the secretary of the Computer Sciences Department. Throughout the duration of this project, she assisted C. P. Annis

in organizing the meetings, processing the paper work, and typing innumerable reports, lists, memos, and other correspondence that kept our work organized and well documented.

Computer Systems Management (CSM) provided the site for the remote station of the DARPA system. Kevin Vest of CSM was instrumental in the installation, testing, and demonstration of that station.

In the early stages of this project, Gregory M. Hunter participated in the system design and hardware selection.

Throughout this project, DARPA personnel provided technical leadership through the conceptualization stages and system development. Clinton W. Kelly, III and Craig I. Fields were instrumental in integrating this research with other work in the teleconferencing field, such as, bandwidth compression, interactive graphics, virtual space, and state-of-the-art hardware developments. This support served to amplify advancement in the technology, and assisted in the dissemination of results and in the transfer of technological advances.

CONTENTS

CONTENTS (continued)

FIGURES

FIGURES (continued)

1.0 INTRODUCTION

For the past three fiscal years, Decisions and Designs, Inc. (DDI) has been involved in a research program to investigate and implement various concepts of video teleconferencing. This program has included everything from feasibility studies through the transfer of technology to an operational system. This report describes the highlights of DDI's research over the three year period, and discusses in more detail certain aspects of the program which DDI feels have been very successful.

Section 2.0 summarizes the research and conclusions over the first phase of the project during FY80. Section 3.0 describes the completion of the effort to implement a multi-station teleconference system. Section 4.0 covers the DDI system that was actually developed and installed in an operational environment as a result of the technology that evolved over the period of the contract. Section 5.0 provides the conclusions and recommendations based on the entire three year effort.

2.0 PHASE I

The first year of video teleconference research at DDI was well documented in a technical report, Research into Teleconferencing[1]. This report included a complete description of the research performed and the prototype system developed, along with a discussion of the original goals of the system and an evaluation of its implementation. The remainder of this section summarizes that FY80 effort and highlights the points which have contributed to continued research.

2.1 Video Teleconference System Goals

The major thrust of the initial teleconference system developed by DDI was to provide a realistic simulation of a face-to-face conference. There were three criteria identified that had to be met to improve upon existing teleconference systems. First, there had to be a natural connection of two or more sites. This meant that the participants should have the impression of being around an actual conference table, interacting with other individuals. Second, the system should facilitate the use of existing or easily obtainable communication skills. To do this, the teleconference system could not ignore the more subtle, but often more powerful, forms of communication, including facial expression, hand gestures, and body movements. The final criterion was the real-time examination of pictorial information and other data. Rarely does

[1]Sticha, Paul et al., Research into Teleconferencing, Technical Report TR 80-9-314, (McLean, VA: Decisions and Designs, Inc.), 1981.

a face-to-face conference occur where the blackboard, 35mm slides, vu-graphs, or hand-outs of some sort are not employed for information sharing. Also, this shared data is frequently augmented or annotated by other conferees.

2.2 Phase I System Description

The initial video teleconference system consisted of four stations fabricated from foamwood, glass, and wood, and equipped with standard video displays, cameras, video distribution equipment, and specially designed electronics for combining video images. The four stations, pictured in Figures 2-1 through 2-4 were designed differently, both to complement the four offices they occupied, and to measure the functionality of design features, such as monitor size and color versus black and white, in terms of teleconference effectiveness. The following paragraphs briefly describe each of the stations.

Station 1 (Figure 2-1) - The most elaborate station contained 19-inch color monitors positioned at three corners of a square. The conferee sat behind a small coffee table that hosted the system controls, the writing area (imaged by the overhead camera), and a 9-inch color Shared Graphic Workspace (SGWS) monitor which was recessed into the center of the table. A "slave" 19-inch monitor, independently located on its own stand, replicated the contents of the SGWS for any other conferees who may have been present in the office, but were not convenient to the embedded SGWS monitor.

Station 2 (Figure 2-2) - This station resembled a conference room. The 12-inch monochrome video monitors were located on pedestals around a conference table, again at the points of a square. The controls rested on the

Figure 2-1

Figure 2-2

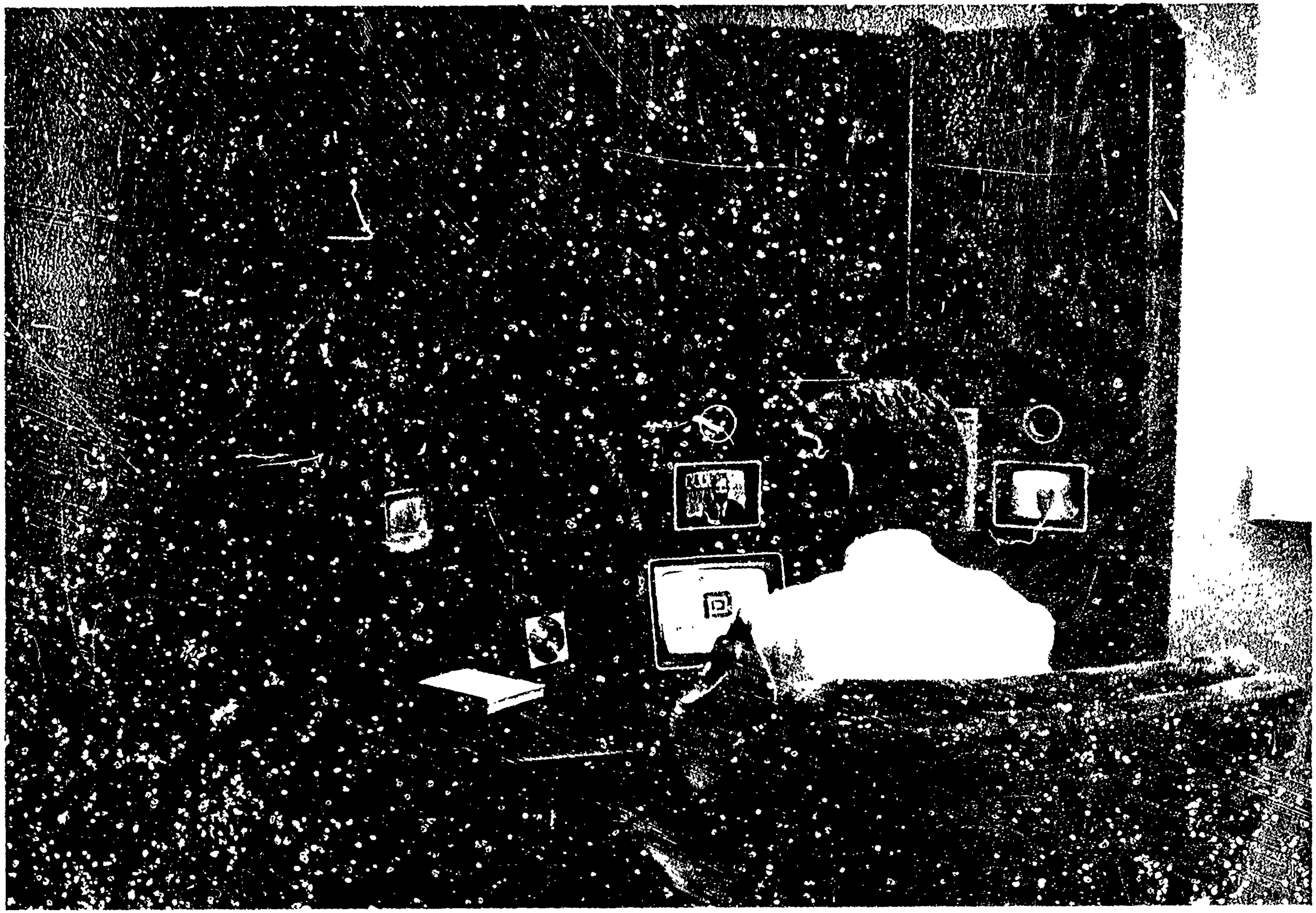


Figure 2-3
TELECONFERENCE STATION WITH 5-INCH

Figure 2-4

conference table, and the monochrome SGWS monitor was recessed into the table.

Stations 3 and 4 (Figures 2-3 and 2-4) - Each of these stations was built into a single cabinet. The monochrome video monitors were 5- and 3-inches wide respectively, and were not positioned as points on a square, resulting in slight distortions of the angular relationships required by the virtual space concept (see Section 2.3).

2.3 Virtual Space

The first two goals of the proposed teleconference research, spelled out in Section 2.1 (the natural connection of more than two sites and the usage of existing communication skills), were addressed by implementing the concept of "virtual space." This concept was intended to provide each participant with a convincing feeling of being present in the same room, basically around a "virtual" conference table. Each of the conferees not actually present was represented by a "surrogate" consisting of a video display presenting his face, a video camera representing his eyes, a microphone representing his ears, and a speaker representing his voice.

All conferees could see and hear each other at all times from their respective positions around the virtual table. The individual audio and video channels for each conferee reinforced the spatial relationships among the conferees. As if around a real table, any conferee could direct his gaze to any other conferee, and could determine the direction of any other conferee's attention. This enabled a deeper level of non-verbal communications where visual or gestural remarks could be directed to a particular person, and facial expressions, gestures, and posture could provid immediate feedback to the speaker on reactions to his statements. This continuous presence also enabled any participant to interrupt or express a desire to interrupt the speaker.

Figure 2-5 illustrates the four-station virtual space arrangement. The realism in conferee relationship is accomplished in two ways. First, at each station, the four conferees (one real and three surrogates) must maintain the same arrangement; that is, A is always on B's left, B is always on C's left, and D is always on A's left. The angle from one position to another in any site is the same as for the corresponding positions in every other site. The second key to accomplishing the realism is the fact that each surrogate has his own "eyes." Instead of a single camera transmitting the same image of the real conferee to all other locations, there is an individual camera for each surrogate transmitting the image of the present conferee to the remote stations from the surrogate's perspective. Thus, the corresponding arrangement of the conferees at each location, and the multiple images of each conferee being transmitted to the other stations, result in the illusion of all conferees sitting around the same "virtual" table.

2.4 Sharing Data

The third goal identified (real-time examination of pictorial information and other data) was addressed by developing the Shared Graphic Workspace (SGWS). Each of the four stations described in Section 2.2 had a SGWS monitor directly in front of the conferee, a writing area on the table or desk, and an overhead camera directed to the writing area. Station 1 also housed a videodisc player and a hand controller. Data was shared on the SGWS monitor by all active conferees through

Virtual Space

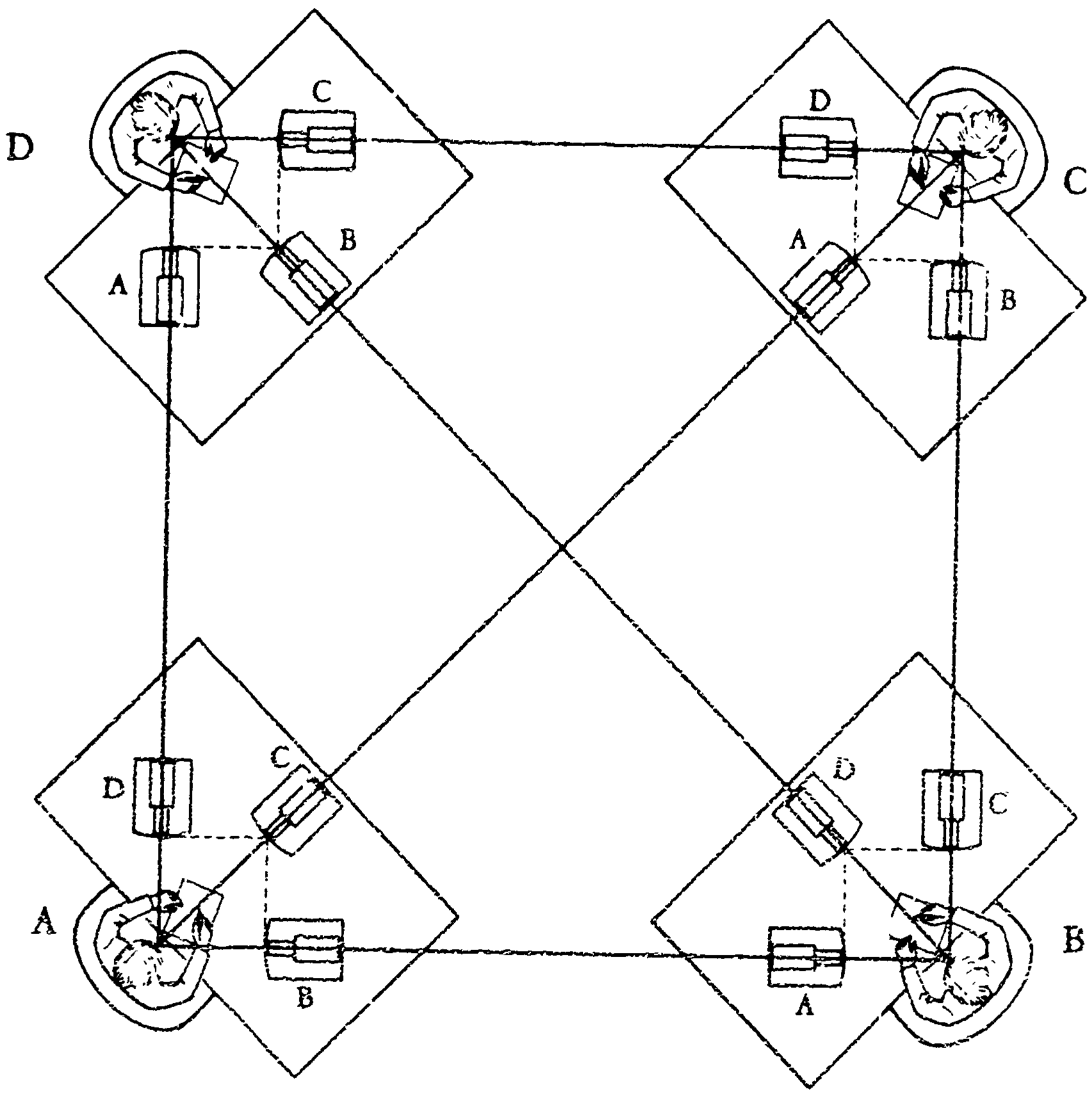


Figure 2-5
VIRTUAL SPACE

a video-mixer or a Spatial Data-Management System.[2] Images from the videodisc could be captured for display on the SGWS monitor. Each conferee could contribute data for display simply by writing on a white surface under the overhead camera. The system ORed (added together) any images under all active cameras along with any selected videodisc image.

The overhead camera could actually capture any object placed on the designated surface. Consequently, the conferees were not limited to writing in this area. A finger pointing to an item of interest would actually be displayed with the image. A diagram could be captured. Any document or object not too detailed (a regular typewritten sheet required higher resolution than the system provided) could be incorporated into the shared image.

2.5 Functional Capabilities

Each station had a set of labeled switches used to establish the communications with each of the remaining stations. When one station first flipped the switch to "call" another station, a chime was sounded in the other station, an associated red indicator light was illuminated, and the other station answered by flipping the corresponding switch. When both stations had their related switches in the "on" position, full video and audio capabilities were present. Volume control buttons were also available to selectively adjust audio levels.

This method of connecting stations made it possible to configure the system into subconferences. That is, A and B could establish an audio and video link exclusive of a link established by C and D. Taken one step further, A, B, and C

[2] N. Negroponte Spatial Data-Management (Cambridge, MA: Massachusetts Institute of Technology), 1979.

could establish a subconference simultaneously with A and D. In this case, A's audio and video were available to everyone, but station D shared no audio or video with either B or C. The audio did, however, tend to flow through the common station (station A) so that only the video was truly private. The SGWS was common to both subconferences, making this type of subconference feature impractical in an operational environment.

Once the conference was underway, the functional capabilities were rather basic. Any image from the videodisc, and any object or writing on the writing areas imaged by the overhead cameras, were all OR'd for display on the SGWS monitor. The videodisc player was controlled by a hand-held unit, and the overhead camera was active whenever the station was on. No action was required to capture an image.

2.6 Phase I Conclusions and Recommendations

The Phase I system was demonstrated to large numbers of individuals from the military, industry, and research organizations. These individuals were asked to rate the system in six areas. Four areas were associated with meeting effectiveness: oral information quality, effective data presentation, human image presentation, and conference realism. The final two areas were associated with system factors: confidence in privacy and convenience. All the responses were evaluated in terms of the type of user and the station being used. The technical report details the results of the evaluation and presents conclusions and recommendations.

In summary, the system met the three original goals of (1) allowing connection of more than two sites, (2) facilitating the use of existing communication skills, and (3) providing a data communication. The users felt that the teleconferences were realistic; that they compare favorably to face-to-face conferences; that the data was well presented; and that the teleconferences were considerably more convenient than the face-to-face conferences. The areas identified for improvement were security and graphics. The users did not experience a positive feeling of control over security factors as compared to face-to-face conferences. Many users indicated that the graphics should be expanded to include a larger area of coverage and to allow additional inputs.

The recommendations put forth in the technical report addressed both the Phase I weaknesses, as determined from the user survey, and suggested improvements that would be necessary to continue the implementation of valuable teleconferencing concepts. The three major recommendations included:

(1) Provide compression of the conferees video image. The benefits of a compressed image include reducing the bandwidth requirements for transmitting the images (especially meaningful in the virtual space environment with the simultaneous transmission of N x (N-1) images where N represents the total number of stations), and enabling the encryption of images when security is an issue.

(2) Provide more sophisticated graphics and a staff position. Add more flexibility and capability to the SGWS and, because of the additional complexity in operation, add a staff person to perform some of the functions, including locating data to be shared with other conferees.

(3) Provide more sites within the virtual space concept. In doing so, develop a better switching system, and design the stations so that they can be integrated into existing offices and not require special conference areas.

Section 3.0 describes the system developed as a continuation of the teleconference research effort. Subsections 3.1 through 3.3 describe the final virtual space system.

Arriving at the SGWS of the final system was an evolutionary process marked by several modifications in hardware configuration, functionality and implementation. To illustrate this evolution, Section 3.4 describes the first implementation of the digital SGWS, along with the philosophy for accepting or rejecting the various functions or implementations.

3.0 COMPLETION OF VIRTUAL SPACE SYSTEM

The only similarity between the Phase I virtual space system and the final system developed by DDI was the implementation of the virtual space concept, or multiple transmissions of each conferee's image. The FY81 and FY82 effort concentrated on major changes which encompassed the following. developing the entire system under computer control, including a specialized switching system; converting the SGWS from analog to digital, greatly enhancing the capabilities of the SGWS; adding a staff member to perform part of the system operation; and installing a fifth station that was remotely located and required long-distance transmission capabilities. Subsections 3.1 through 3.3 describe the final virtual space system. Subsection 3.4 illustrates the R&D path from Phase I to the final system.

3.1 System Configuration

The final virtual space demonstration system was controlled by software developed on the DEC PDP 11/40 and the DeAnza image processor. One station was located on the premises of Computer Systems Management (CSM) in Rosslyn, Virginia. The remote station employed a DEC PDP 11/23 and a Digital Graphic Systems (DGS) CBX-800 frame buffer. Both implementations utilized the C programming language under the UNIX operating system.

The four stations located within DDI took advantage of the proximity situation and, as a cost savings measure, were all controlled by the same computer and same array processor. The only impact of this approach was a loss of flexibility, because every station viewed the same image on the SGWS. The design of the system compensated for the single frame buffer by making its use as natural as possible. (The two-station system described in Section 4.0 employed independent equipment, and the functional capabilities description illustrates how the two stations can view mutually exclusive images.)

3.1.1 Station configurations - Each station had a slightly different configuration: some designed to demonstrate various levels of capability and environmental factors, and some designed solely in the interest of cost savings. The following subsections describe each of the five stations.

Super Station - The most sophisticated station was located within the president's office at DDI, and was labeled RAE. Figure 3-1 is a photograph of that station. It consisted of a large table-desk combination, where the SGWS monitor could be dropped into the table, leaving a working surface flush for non-teleconference work, or where it could be raised during teleconferences. The four-foot wall built around the front and one side of the desk housed the surrogates for the other four stations and the staff. The wall was integrated attractively into the decor of the office, and was enclosed to keep all wires and electronics out of view.

The surrogate monitors used for displaying the conferee images of the other three DDI stations were 19-inch color monitors, and the associated cameras in each of the other DDI stations were color cameras. Since the four stations within the DDI spaces were connected with coaxial cable, and there were no communication costs as such, this station demonstrated full-color, full-motion video. In contrast, the video shared with the staff station was black and white, and the video shared with the station located at CSM was compressed. (Section 3.2 discusses the compressed images.) A conferee at the RAE station could experience and evaluate all three types of video simultaneously.

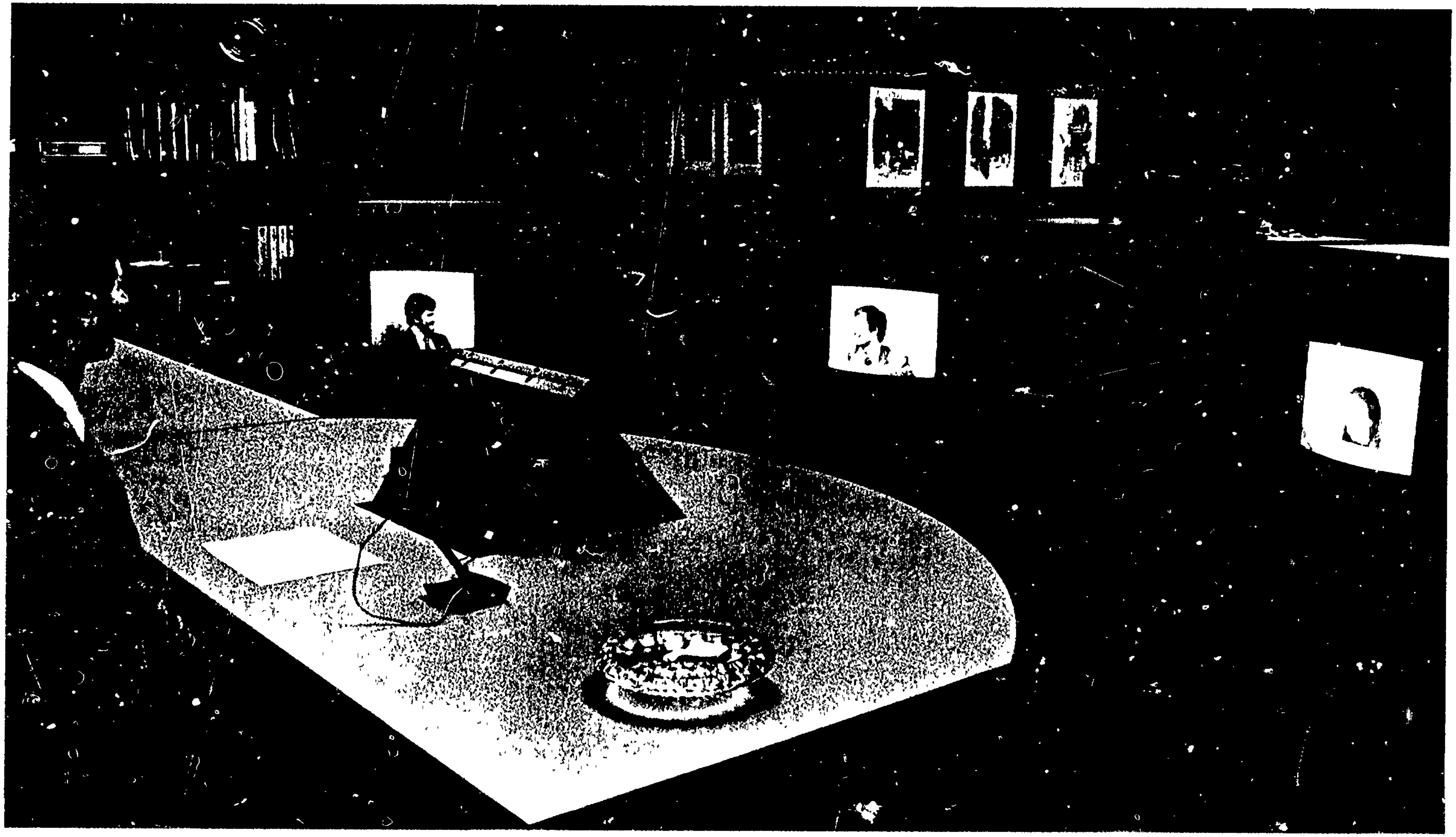


Figure 3-1
ROBERT A. EIDSON STATION

As mentioned before, the RAE station was linked to a "staff" position. A working staff station in a separate location at DDI was developed to support the principal conferee in the RAE station. The staff surrogate was positioned off to the side of the virtual conference table. (Figure 3-2 diagrams this relationship.) The staff functions are discussed in more detail in Section 3.1.2.

The RAE station had full capability with respect to interacting with the SGWS. A touch-sensitive screen was mounted flush on the face of the SGWS monitor, making it possible for the users to interact with the SGWS simply by touching the screen. Also, it was equipped with a digital tablet, so that the user could interact by writing on the tablet with a stylus. These devices are discussed in more detail in Section 3.2, Functional Capabilities.

Group Station - One of the stations within DDI was developed as a "group" station and was labed GRP. Figure 3-3 is a diagram of that station. It was developed with an entirely different concept, allowing several people to confer from one station, appearing on a single surrogate monitor on each of the other stations. This approach was tried to test several concepts, including the viability of using groups within the virtual space environment, and testing the effect of a group versus individuals in a conference environment.

The group station was set up so that one side of a large conference table, normally used for face-to-face conferences was used for the teleconference participants. The surrogate units built into five-foot columns were placed near the corners of the room, again without impacting on the room as a normal conference room. Instead of a SGWS imbedded in the table, the SGWS image was rear-projected onto an four- by

Structured Teleconference

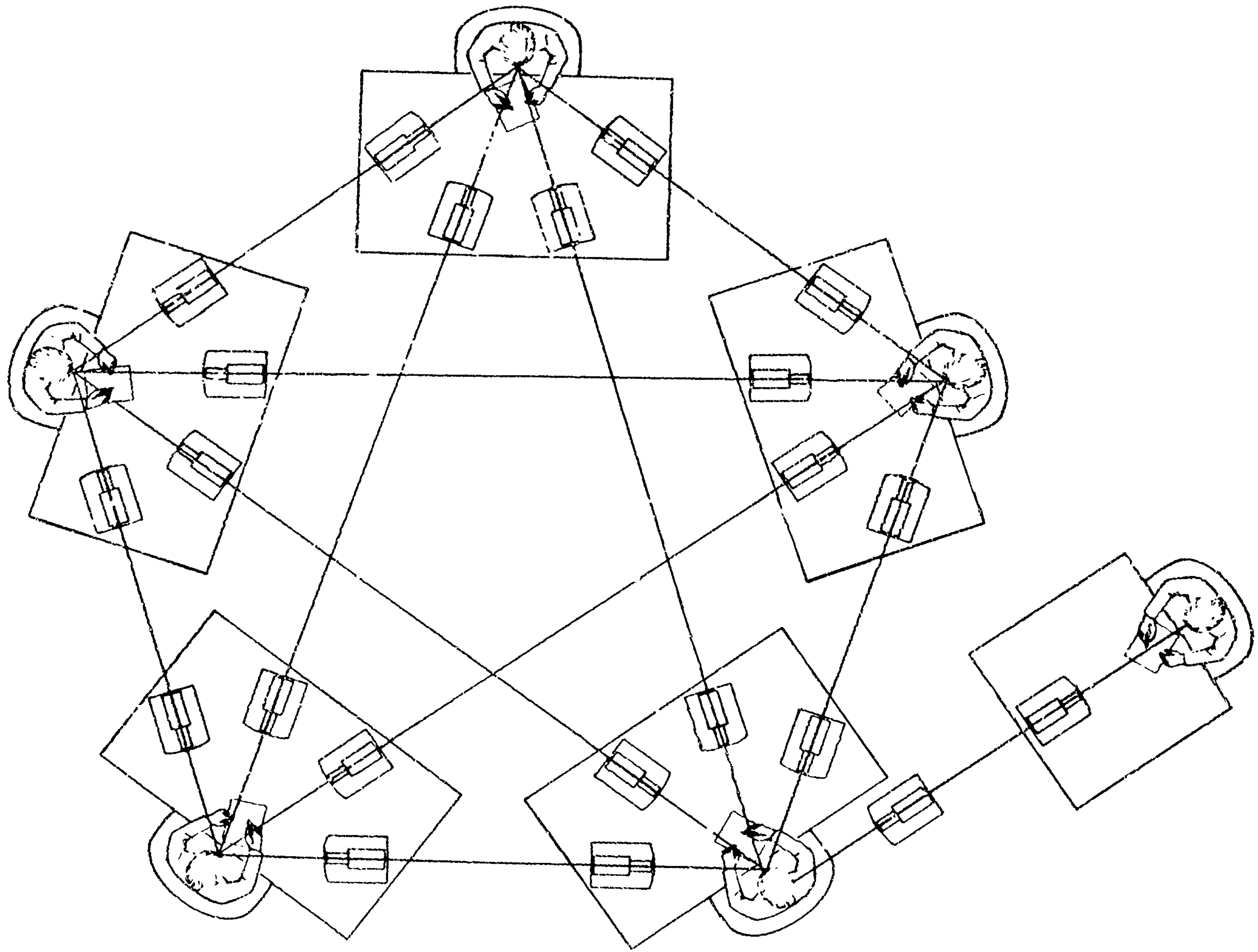


Figure 3-2
FIVE-STATION VIRTUAL SPACE PLUS STAFF

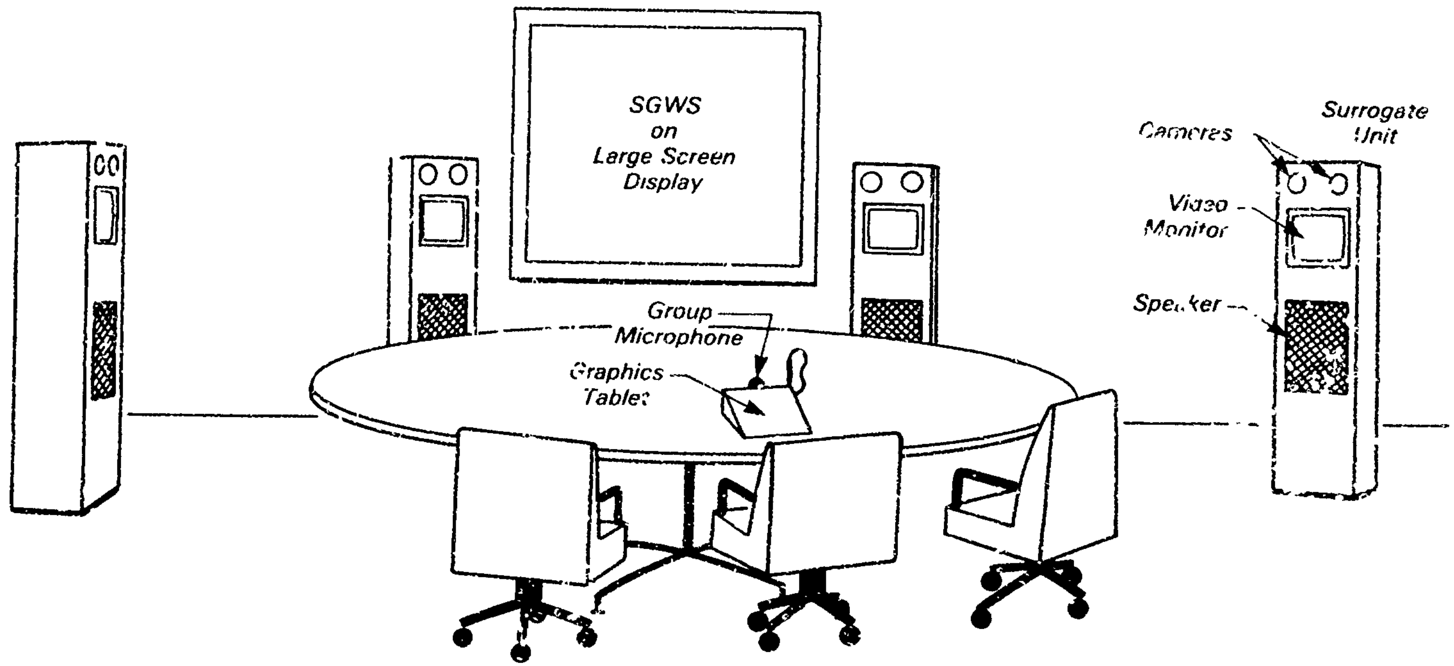


Figure 3-3
GROUP STATION

six-foot screen. A movable digital tablet was placed on the table in front of the conferees, as was a group microphone.

The group station was unique in that it had a camera mounted on one side of the room, pointing to a section of the white board on the other side of the room. Notes, diagrams, or writing of any kind on that section of the whiteboard could be captured for display on the SGWS.

Remote Station - The remote station, labeled CSM, was located within the CSM facility in Rosslyn, Virginia. This station, like the RAE station, was designed to unobtrusively blend with the decor of the host office. Figure 3-4 is a drawing of this office. The SGWS monitor was imbedded in the desk as it was in the RAE station, so that it could be raised during teleconference sessions and then lowered back into the desk to form a solid surface for normal work. The SGWS monitor was equipped with a touch-sensitive screen, and a digital tablet was imbedded in front of the screen. Unlike the RAE station, however, the tablet was off center, slightly to the right of the monitor and rotated counterclockwise about 20 degrees. This placement comfortably accommodated a right-handed conferee.

The surrogate units of the CSM station were built into floor to ceiling columns, taking advantage of the lowered ceilings (typical of most office environments) for hiding the wires and electronics. Since the CSM station was remote from all other stations, the video for each surrogate was compressed.

Vanilla Station - Two of the stations at DDI were located in the same room. Figure 3-5 illustrates the layout of the equipment. These stations were called "Vanilla" (labeled VN1 and VN2), because they were modest in structure

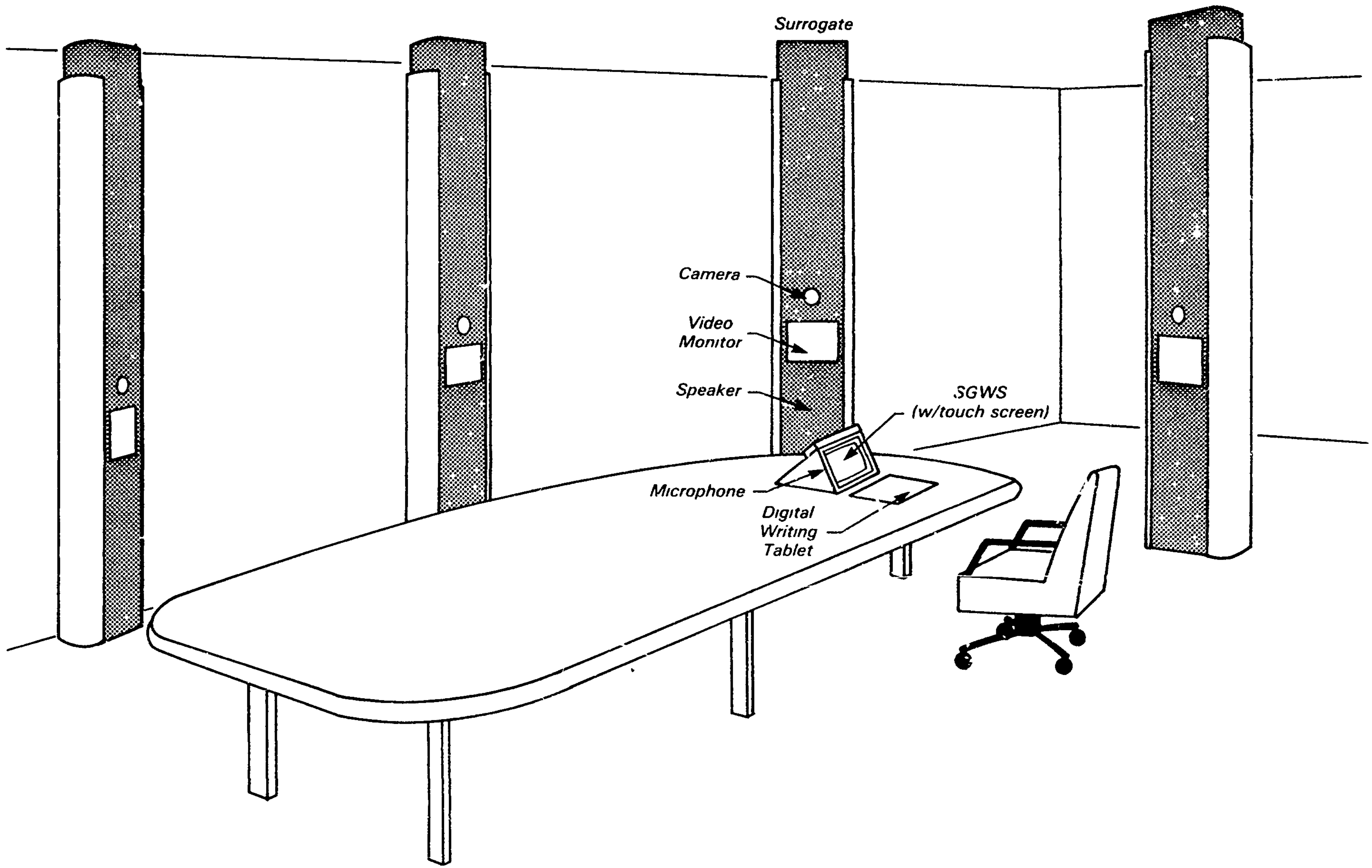
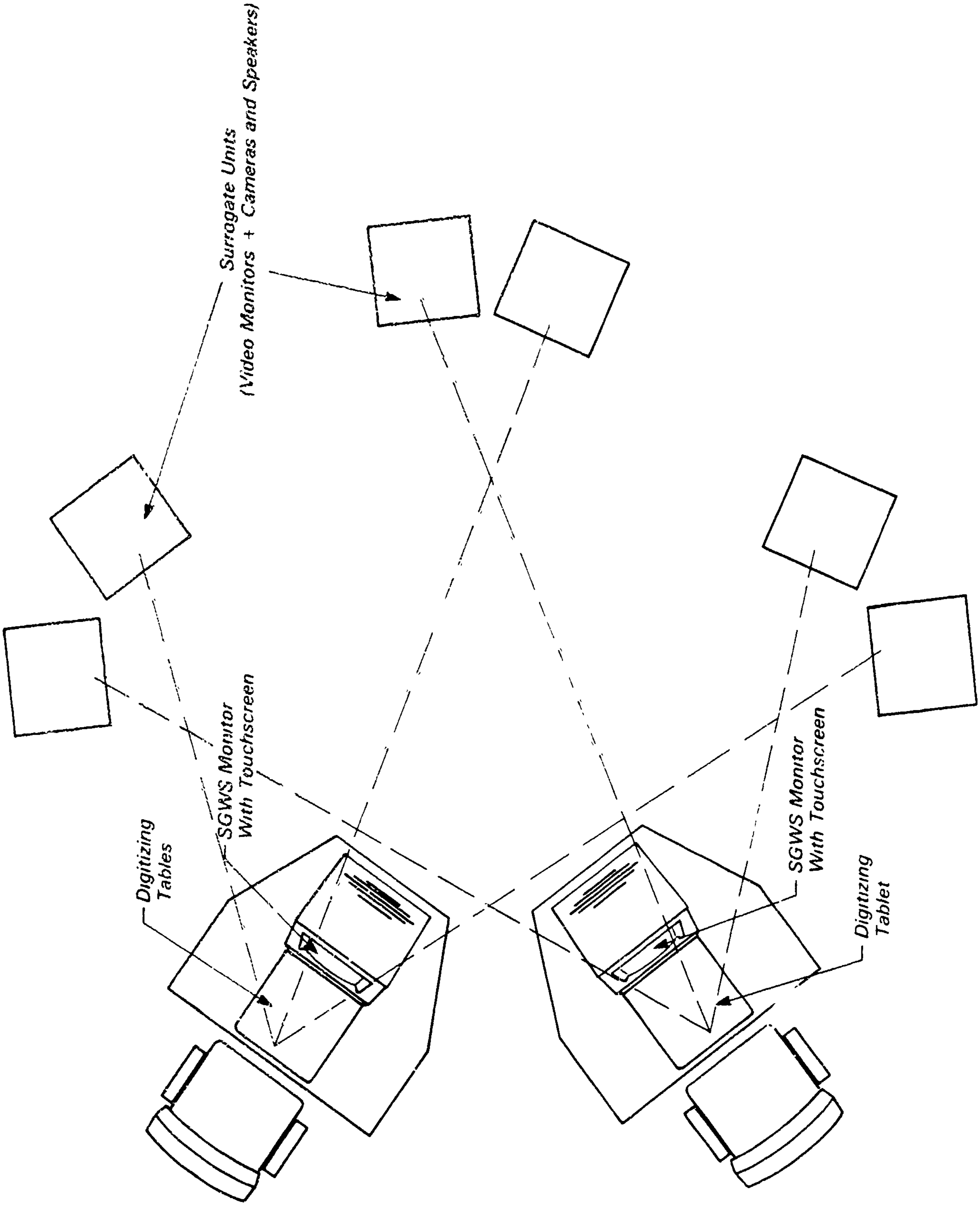


Figure 3-4
REMOTE STATION AT CSM


Surrogate Units
(Video Monitors + Cameras and Speakers)
SGWS Monitor
With Touchscreen
Digitizing
Tables
SGWS Monitor
With Touchscreen
Digitizing
Tablet

and employed cost saving measures. This situation did, however, provide additional information on having two conferees (each of which were viewed on separate monitors by the other conferees) in the same room with face-to-face contact. While other conferees were in a one-on-one situation, the two conferees in the co-located vanilla stations tended to form a coalition when dealing with the other conferees.

Special, less imposing tables were constructed to hold the SGWS monitors. The monitors were installed at a 40 degree angle in the table. The digital tablet was embedded directly in front of the monitor. The surrogate units were the same four-foot columns as those used in the group station, housing 12-inch black and white monitors.

One of the vanilla stations had both a touch-screen and digital tablet installed, while the other had neither. The intent was to have one station from which the system could be demonstrated to visitors seated in the RAE station or CSM station. To cut costs, the other vanilla station, had no input to the SGWS, and was unknown to the users of the other stations. After several demonstrations of the system, the conferee seated in the second vanilla station was at a real disadvantage not being able to interact with the graphic communications.

3.1.2 Staff station configuration - With the increase in functional capability over the Phase I system, particularly in the use of the SGWS, high level decision makers would not be inclined to learn or understand the operation of the system. One approach to solving this problem was to provide the principal conferee with his personal staff person who would be situated at a separate station where he could perform the more complicated or time-consuming functions. The audio and video communications of the staff are limited solely to the principal being supported, as illustrated in Figure 3-2.

The staff station was modest with a table similar to the vanilla stations. It was equipped differently, however, from all principal stations. It had audio and video to the single principal only, and it was not considered a part of the main conference. A digital tablet was the only device for interacting with the SGWS. The overhead camera used to capture images for display in the background of the SGWS was located in the staff station and operated by the staff. The staff also had a VT100 terminal for communicating with the teleconference software.

3.1.3 Automatic switching system - The greatest advancement in the final Virtual Space System over the Phase I prototype was the use of computer control over system configuration and SGWS operation. In order to implement this control, DDI developed an automatic switching system, the System Communications Controller (SCC). The SCC provided the interface between the computer and the teleconference system components. It controlled the communication to and from cameras, speakers, microphones, and amplifiers, and controlled the source of power to most of the other components of the system. Appendix A provides a detailed description of the SCC engineered and developed by DDI.

3.2 Conference Video

One of the recommendations at the completion of Phase I was to use compressed video. This was a concern for several reasons: (1) full bandwidth communications costs for a virtual space system would be prohibitively expensive; (2) during a time of political crisis, full bandwidth may not be available; and (3) a compressed image lends itself to being encrypted for highly classified communications. DARPA sponsored a research program with Compression Labs, Inc. (CLI) to develop a video encoding and bandwidth compression unit capable of reducing a

10 MHZ (nominal) black and white TV signal to a 19.2 Kbps digital data stream. The main design constraint was to preserve the full-motion characteristics of the image. Whereas a standard black-and-white TV image has approximately 512 x 512 pixel resolution, 256 grey levels (intensities), and a 30 HZ refresh (sample) rate, the CLI codec (coder/decoder) unit produces an image with 128 x 128 pixel resolution, 2 grey levels (stark black and white only), and a 7.5 Hz sample rate.

The image presented by the CLI codec (called a "sketchcoder" because of its sketch-like appearance) was a definite compromise over full-motion, full-color video. Users that expected a TV quality image were disappointed in the results. When the sketchcoder was compared to video quality that could be produced at the same cost, however, a totally different conclusion was drawn. A comparably priced unit with similar bandwidth transmission requirements could present a full resolution black-and-white image (512 x 512 pixels and 256 grey levels) approximately every 30 seconds. This image would be considerably sharper, but the sketchcoder provided the more important feature of motion, preserving the feeling of continuous presence essential to the concept of virtual space.

3.3 Shared Data

A quantum jump was made in the capability of sharing data from the Phase I system described in Section 2.0 to the final Virtual Space system. The implementation of computer control, the switch from analog to digital data processing, the additional functionality, and the incorporation of new data inputs resulted in a shared graphic workspace which greatly enhanced the useability of the teleconference system, and displayed a capability which exists on no other known system.

Each station, including the staff station, contained a high-resolution color TV monitor or large-screen display which served as the SGWS display device. Images were stored and manipulated in a digital format. The four stations, located at DDI, used the DeAnza image processor and the remote station used a Digital Graphic Systems (DGS) CBX-800 frame buffer. Users interacted with the SGWS by operating touch-sensitive screens mounted on the SGWS monitors or digital tablets available to each station.

By moving a finger across the touch-sensitive screen, coordinate information was transmitted to the computer for processing. The digital tablets provided two types of information to the system. If the stylus was close to the tablet, or touching the tablet but not pressing down, the coordinates were sent to the computer with an indication that the stylus was in "proximity" mode. The system fed this information back to the conferee by displaying a cursor symbol on the SGWS monitor relative to the location being touched on the tablet. By watching his cursor, the conferee could move the stylus to the exact location he desired. Once the cursor was accurately positioned, he could press down with the stylus and the specific coordinates were sent to the computer to be processed.

Each station had a unique cursor symbol consisting of three alphanumeric characters. In an operational system, the cursor could be dynamically selected, but in the demonstration environment at DDI, the cursor symbols were fixed to represent the installed stations: RAE, CSM, GRP, VN1, and VN2. The conferees always received visual feedback for any actions taken on the SGWS. (This visual indication was available to every station since the conferees were all viewing identical images from a common frame buffer.) The associated cursor symbol was displayed whenever a conferee interacted with the SGWS. In certain menu selections, the cursor symbol was displayed in the menu box while the option was active. (Sections 3.3.1 through 3.3.4 indicate the status of the cursor for each action taken.)

The conferees could independently interact with the screen by pointing to an area of the SGWS (displaying the cursor associated with the station), by drawing in any one of six colors, by selectively erasing any of the annotations, or by clearing all of the annotations at once. They could display an image directly from a videodisc or from one of two cameras installed in the system.

The SGWS was structured so that it had two distinctly separate parts. The eight bit depth of the frame buffer could be thought of as eight 480 x 512 planes. Figure 3-6 illustrates this concept. The bottom four planes, or background, were used to display images that were captured from the videodisc or the cameras. The top four planes, or foreground, served two distinct functions: the very top plane was used exclusively for the display of cursors, the next three planes were used for all real-time drawing and annotating, and for displaying menus designed to lead the users through a teleconference session. Using separate groups of planes for the foreground and background facilitated the capability of allowing users to annotate or erase selective portions or all of the foreground without disturbing the background image.

Even though the images were stored in layers, the colors assigned to any spot on the screen were based on the eight-bit value of the pixel as determined by programmable look-up tables. The top bit was the most significant bit of the eight-bit value, while the bottom bit was the least significant. Consequently, the cursor symbols overwrote, or were visible, regardless of the contents of the other seven planes, and the menus and annotations were visible, regardless of the contents of the background.

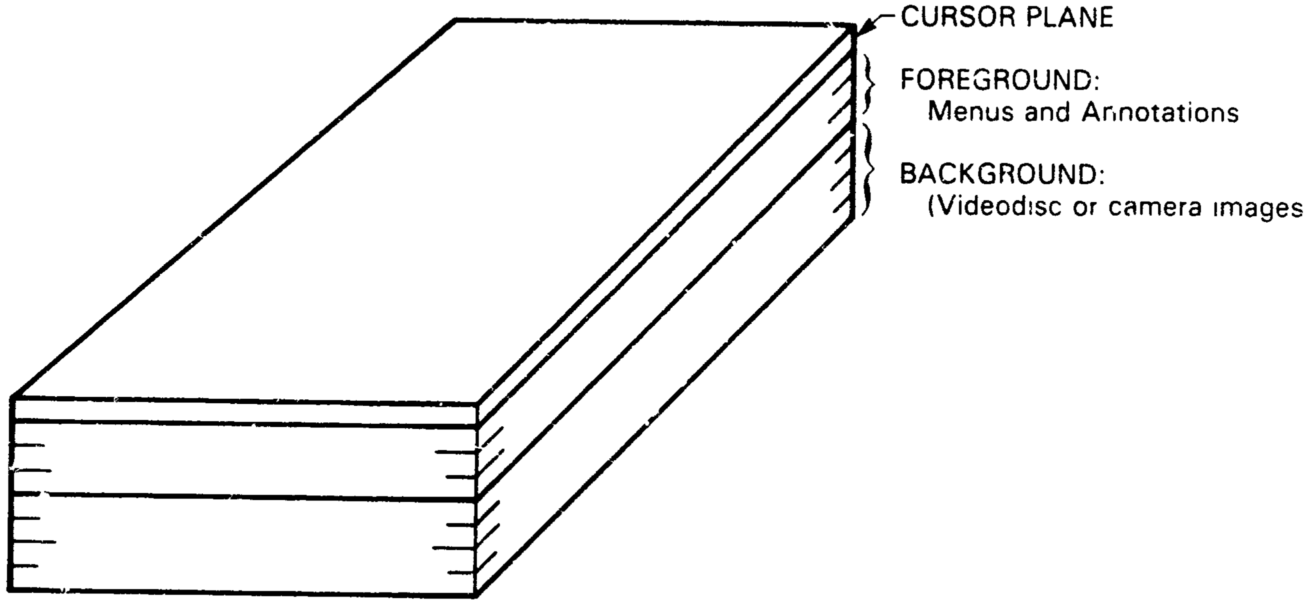


Figure 3-6
8 "PLANES" OF SGWS IMAGE

System operation was invoked by pushing a single power switch that turned on all the associated equipment--the surrogate audio and video, the SGWS monitor, and all the supporting electronic gear. The system was designed to emulate a face-to-face conference and, therefore, when station power was turned on, any conference already in session was automatically entered. (When the door is opened on a face-to-face conference, the participants can be seen and heard.) Audio and video is shared among all stations that have power on.

The user was led through a teleconference session with colorful graphic menus. These menus provided "virtual switches" from which all system control was performed, and provided the selection of all functional capabilities. The menus were displayed in the foreground, using the same three planes of the frame buffer as well as all other real-time drawing and annotation. There were five separate menus in the final virtual space system. The first menu to appear when power was turned on (unless a teleconference was already in session) was the control panel menu. This menu contained the "virtual switches" for adjusting the audio and video parameters, eliminating the need for all other knobs and switches. When the user was satisfied with system adjustments, this menu provided an option to "Access Shared Graphic Workspace." Selecting this option resulted in a blank screen with the main menu displayed across the bottom. The main menu provided the capabilities for conducting the business portion of the teleconference. Three of the main menu options required additional user information and resulted in the display of sub-menus. The "Select Videodisc" option presented a full-screen menu for multiple access methods to the videodisc, and the "save" and "retrieve" options presented a secondary menu for selecting the relative "slot" for saving or retrieving an image. The fifth menu was the staff menu, which was designed specifically for and was displayed only at the staff position. It provided selections available to the staff to assist in the operation of a teleconference.

The following sections, ordered by menu, describe the functional operation of the system, and indicate the flow of control through a teleconference session.

3.3.1 Control panel menu - Figure 3-7 illustrates the Control Panel menu as it appeared at system start-up. It provided the following functions:

Call - Any station had the ability to call any other station by touching the call patch associated with the station to be called. The color of the patch changed from dark blue to light blue, and a chime was sounded at the called station.

Because of the intent to simulate on open meeting situation, no "ANSWER," per se, was required to establish a communications link. The call simply notified the station being summoned that someone was waiting to teleconference.

Volume Control - Each station had independent control of the audio levels from each of the other stations. On the control panel menu, an "up" arrow and a "down" arrow associated with each station was used for volume adjustment. Each time an up arrow was touched, the audio for the associated station was increased one level. Conversely, each time a down arrow was touched, the associated station's audio was decreased one level.

Hang-Up - The hang-up option on the final version of the system provided no function. It was included on the control panel menu because of the many alternatives that were considered for implementation for the combination of the "call" and "hang-up" functions. Several possibilities included:

(i) Keeping a teleconference a closed meeting; that is, when one station turned power on,

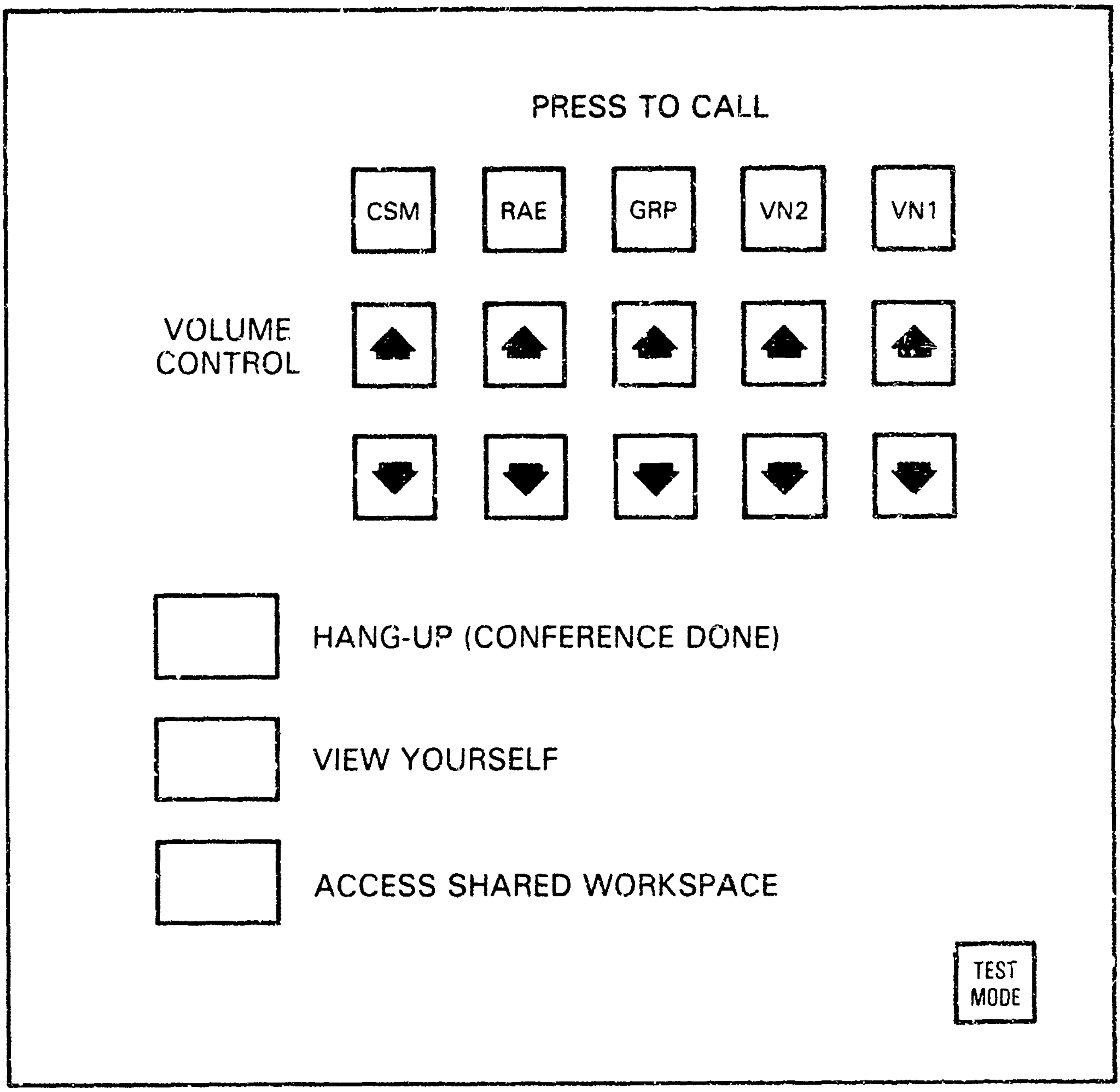


Figure 3-7
CONTROL PANEL MENU

the conferee would have to "call" another station (knock on the door) and the other station would have to answer the "call" (invite him in). At some point in time, then, one station could ask to leave and select "hang-up" to sever the communications (close the door behind him).

(2) Allow sub-conferences; that is, if station A, B, and C wanted to confer at the same time as D and E, they could establish independent subconferences using the "call" and "answer" techniques. The "Hang-Up" function would then allow one station to leave one subconference and enter another, if desired. For example, station A could terminate communications with B and C, and then call D or E. This approach would probably be the one used in an operational environment, because it offers the most flexibility in system use. Within the DDI environment, however, all the in-house stations shared the same frame buffer to minimize system cost, so that a separate subconference could not independently control the SGWS.

(3) Allowing a "stand-alone" mode. This is essentially a one station subconference. If each station had its own frame buffer, the station could use the functions available on the SGWS without establishing a communication link with any other station. This would be beneficial in preparing and saving a briefing or meeting agenda in advance, and then "recalling" any SGWS

images from storage during the real conference. In this case, the "call" and "hang-up" would be used to initiate and terminate links with other stations, allowing the user to operate in a "hang-up" or "stand-alone" mode.

View Yourself - Conferees frequently wonder how they appear to the other conferees on camera, or worry about their appearance in some way. The "View Yourself" option gave the conferee an opportunity to see the exact image being transmitted to each of the other stations. When this option was selected, the cursor symbol for the selecting station was written on the menu patch, and the video image in each of the surrogate units was replaced with the video being transmitted to each of the respective stations. Once the conferee could see himself in each surrogate, he could adjust his chair or position to best center himself in each monitor (and make sure his hair was in place, etc). Touching the "view yourself" patch a second time removed the cursor symbol from the patch and returned the surrogate monitors to their normal state of displaying the video from each of the other stations.

Access SGWS - This option cleared the control panel menu from the screen, and displayed the main menu along the bottom of an otherwise empty screen. Again, because the final system shared a single frame buffer, all the stations simultaneously viewed the SGWS and main menu, regardless of which station selected the option.

3.3.2 Main menu - The users could control the contents of the SGWS through the options provided on the main menu. The shared workspace, active during the display of the main menu, was indeed a common display, incorporating the actions from each station. The following paragraphs describe the actions that could occur on the SGWS as provided by the main menu, illustrated in Figure 3-8.

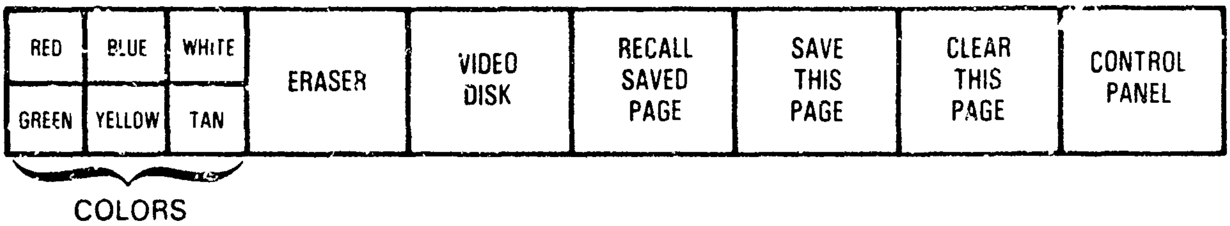


Figure 3-8
MAIN MENU (DARPA SYSTEM)

Pointing - The one function always available to any conferee regardless of any other option selected, was the ability to "point" to the screen. Whenever the touch-sensitive screen was touched, or the stylus used on the digital tablet, a cursor symbol was displayed on the screen to reflect the location being touched. Though this was the simplest form of graphic communication, it frequently proved to be an adhesive element of a graphic conversation. Not only did the cursor symbol direct the attention of all the remotely located conferees to a single point, it identified the specific conferee who was pointing.

Colors - As an enhancement to pointing, the conferee could select a color of "ink" which would follow his finger or stylus. Each conferee had independent control, in that all six colors were available to all five conferees who could draw simultaneously if they so desired. The current color selection of each conferee was indicated by the display of the associated cursor symbol in the selected color directly above the palette of colors on the main menu. Any conferee could change his color selection by touching a different color, could switch to erase mode (see ERASER paragraph) by touching the eraser patch on the main menu, or could revert back to the "pointing" mode by touching the selected color a second time.

ERASER - The eraser option allowed the conferees to selectively erase any of the drawing or annotation in the foreground of the SGWS display. The stylus or finger, instead of depositing "ink," became an eraser and cleared any annotation in its path, regardless of the originator. When a conferee selected ERASER mode, the associated cursor symbol was displayed in the ERASER box. ERASER mode could be terminated by touching the ERASER box a second time, or by selecting a new color for draw mode.

Select Videodisc - The selection of this option resulted in a secondary menu (see Section 3.3.3) used exclusively for selecting images from the videodisc. The videodisc menu emulated the hand controller of the videodisc in that the users could access a relative location within the possible 54,000 frames, could enter a specific frame number, or they could move forward or backward through the videodisc one frame at a time or up to 30 frames a second. In any case, the selected frame was displayed in the background for previewing. When the desired frame was found, the selected image was kept in the background, the videodisc menu was cleared, and the main menu was redisplayed along the bottom of the screen.

Save/Retrieve - Any SGWS display (foreground and background) could be saved for recall at a later time. Another secondary menu (see Section 3.3.4) was presented whenever SAVE or RETRIEVE were selected. When an image was to be saved, the user could select one of ten slots in which to save it. To recall an image, he could select RETRIEVE on the main menu, and then the appropriate slot on the SAVE/RETRIEVE menu.

When the SAVE or RETRIEVE was complete, pressing FINISHED kept the current image, cleared the SAVE/RETRIEVE menu, and redisplayed the main menu.

Clear - The CLEAR option provided the capability to clear the entire foreground or the entire image. Selecting CLEAR once cleared the foregound. Selecting it a second time (or the first time if there was no foreground) cleared the background.

Control Panel - The CONTROL PANEL option provided the capability to return to the initial Control Panel menu after a conference was already in progress. This might be necessary to readjust volume, or to call another station. Whatever the reason, when the ACCESS SGWS was reselected, any previous image returned to the screen with the main menu displayed along the bottom.

3.3.3 Videodisc menu - As illustrated in Figure 3-9, the videodisc menu emulated a videodisc hand controller. It provided capabilities to grab a frame from a relative position on the disc, to select a specific frame by number, or to search forward or backward at variable speed through the disc. In each case, the selected image was displayed in the background, superimposed by the select videodisc menu.

Relative frame select - Of the possible 54,000 frames of video images stored on a single disc, a frame from a relative location could be accessed by touching the relative frame select bar across the top of the menu. This capability, along with searching forward and backward, allowed the user to search for a specific frame when only a general idea of its location is available.

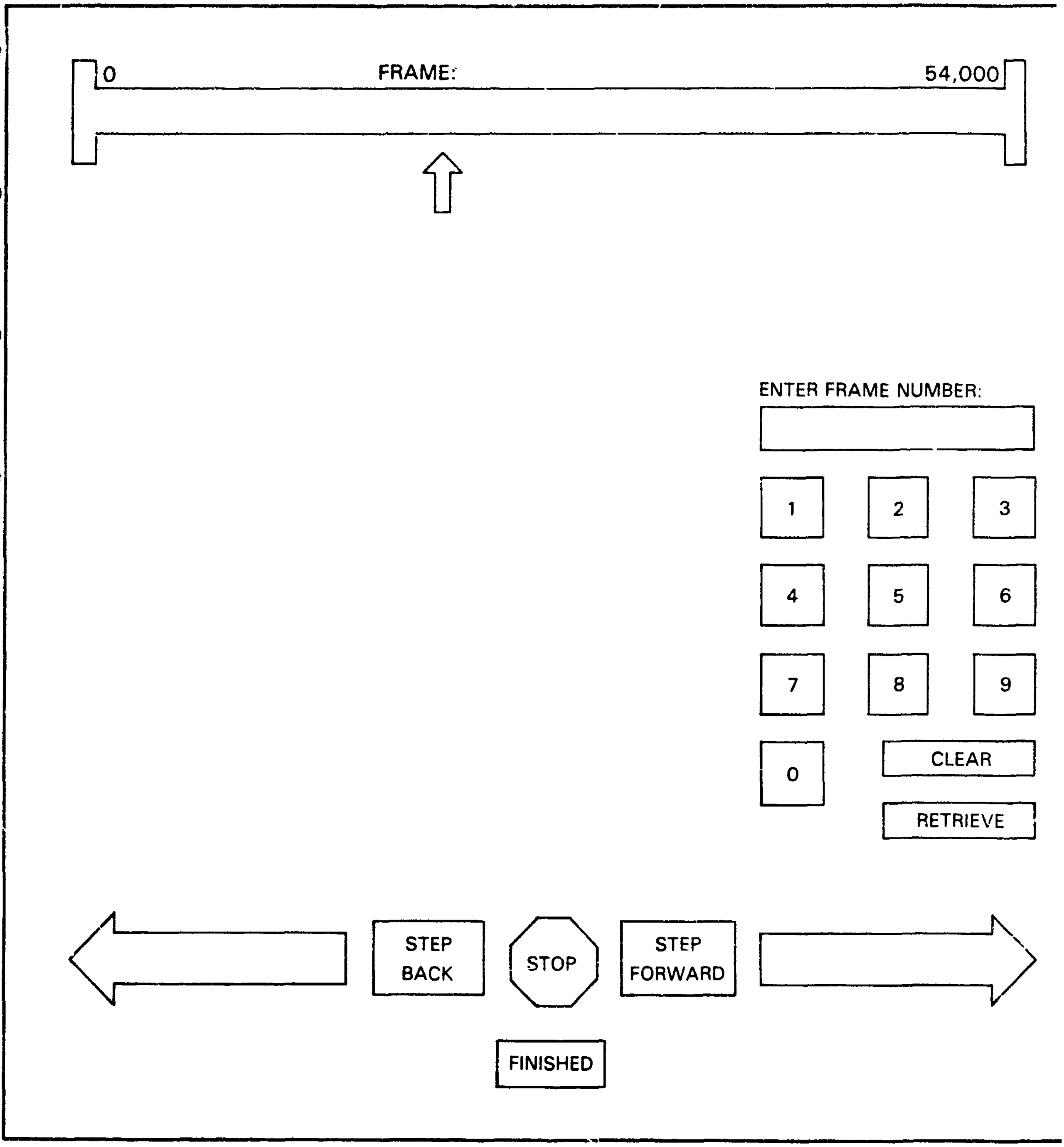


Figure 3-9
VIDEODISC MENU
(DARPA SYSTEM)

Numeric keypad - The videodisc menu contained the equivalent of a numeric keypad by allowing direct entry of a specific frame number. As digits were selected, the developing frame number was displayed along the top of the keypad. If an entry error was made, the entire number could be cleared with the CLEAR key. Once the correct frame number was entered, the ENTER key was used to access the specified frame and display it in the background.

Searching forward and backward - The STEP FORWARD, STEP BACKWARD, and left and right arrows were used to search forward or backward one frame at a time, or up to 30 frames a second. For each selection of STEP FORWARD or STEP BACKWARD, the next sequential frame (forward or backward) was displayed in the background. The arrows were used to effect a faster search. Touching the blunt end of either arrow resulted in approximately one frame per second being accessed and displayed. The closer to the apex that the arrow was touched, the faster the search, to a maximum of 30 frames a second, or standard TV rate. The STOP patch was used to terminate the "Play" sequence, and the last frame accessed remained in the background.

Finished - Once the desired videodisc frame was displayed, the FINISHED option was used to clear the videodisc menu from the foreground and to redisplay the main menu along the bottom of the screen.

3.3.4 Save/retrieve menu - An identical secondary menu was presented in response to the SAVE or RETRIEVE options on the main menu. As illustrated in Figure 3-10, it provided ten slots for saving a current SGWS image, or retrieving a previously saved image. Once the menu was displayed, the user could elect to save an image in more than one slot, or retrieve any number of images. Selecting the FINISHED patch resulted in clearing the Save/Retrieve menu and redisplaying the main menu. If a SAVE was performed, the image was retained. If a RETRIEVE, the new image was displayed.

SELECT PAGE NUMBER TO SAVE/RETRIEVE										
1	2	3	4	5	6	7	8	9	10	FINISHED

Figure 3-10
SAVE/RETRIEVE MENU (DARPA SYSTEM)

3.3.5 <u>Staff menu</u> - The menu provided on the staff SGWS was unique to the staff position. As illustrated in Figure 3-11, it was formatted along the bottom of the screen like the principal's main menu. Since there were no secondary menus for the staff position, this menu was always displayed. The following paragraphs discuss the functions provided to the staff.

GROUP WALL CAMERA	STAFF OVERHEAD CAMERA	PASS TO PRIMARY	SYSTEM VIDEO OFF	GROUP WIDE ANGLE LENS

Figure 3-11
STAFF MENU (DARPA SYSTEM)

<u>Group wall camera</u> - A camera mounted on the wall in the DDI group station was focused on the white board

on the opposite side of the room. The conferees in the group station could record any kind of information on the whiteboard (schedules, lists, etc.). Whenever the staff person selected GROUP WALL CAMERA from the menu, the current contents of the whiteboard were displayed in the background of the staff SGWS. When the staff was so instructured, he could pass the image to the principals' SGWS. If desired, all the conferees could watch the board being developed by having the staff select the wall camera several times during the development of the full picture. (In this situation, the image would also include the conferee standing at the board.)

Staff overhead camera - The staff station had a camera mounted on a copy stand to capture virtually any object or document for displaying in the background of the SGWS. Selecting the STAFF OVERHEAD CAMERA option would result in the image being displayed on the staff's SGWS. Upon request, or when the staff was satisfied with the clarity of the image being captured, he could pass it to the principal's SGWS to replace any other image that may have been displayed.

Pass to primary - This option was used by the staff person to replace the principals' SGWS image with the image currently in the background of the staff display. The staff display could have originated from the group wall camera or the staff overhead camera. Requiring a second action to actually make the image available to the principal conferees allowed the staff to verify the clarity or readability of the image, minimizing the chance of disrupting the main conference.

System video off - This function was used to demonstrate the difference between a full audio/video conference and an audio only conference. It effectively eliminated the "continuous presence" experienced with the virtual space video, but because the surrogate units also housed individual speakers, the "virtual audio" still remained. The speaker could be identified by the direction of his voice. This situation was considered to be superior to listening to several conferees through a single speaker.

Group wide angle - The group station was equipped with two cameras on each surrogate unit. Both cameras had a zoom lens; one adjusted to view a single conferee in the middle of the table, the other adjusted to a wider angle to view three conferees. The staff could switch the camera being used by selecting the GROUP WIDE ANGLE option on the staff menu. When it was selected, the surrogate video representing the group station at each of the other stations automatically switched from close-up to wide angle or vice versa.

3.4 Evolution of the Virtual Space System

Section 3.3 describes the SGWS as it existed in the final virtual space system. A few of the functions were "compromise" functions because (1) the system was developed to demonstrate the concepts as opposed to being an operational version, and (2) several cost saving measures were taken which slightly impacted the functionality. It does, however, within these constraints, demonstrate a comfortable, friendly teleconferencing system with a graphic workspace unlike any other known system.

The SGWS did not go directly from the analog system of the overhead cameras, using a video mixing technique described under the Phase I system, to the functional organization of the digital, computer-controlled system described in Section 3.3. Through several iterations of design and development, the best ideas and implementations were selected. Both DARPA and DDI made judgments as to the value of the various functions and implementations. In some cases, the system evolved from A to B to C, and in others, it actually reverted back (e.g. from A to B to A). This section is included in this document to describe some of the problems encountered, and the design refinements involved, in developing the final Virtual Space System.

To illustrate this evolution, the initial design for the digital SGWS is described. This design included a myriad of functions: some were intended to demonstrate the capabilities of the computer-controlled, digital imaging system; some were intended to test the feasibility of various concepts; and some were the basic requirements that made it possible to share graphic information. It is interesting to note that the final system went "back to basics," compromising a high degree of functionality, ease of use, and understanding. This initial design consisted of nine menus (as compared to five in the final system). Three of the menus were for exclusive use of the principal conferees, five of the menus were exclusively for the staff, and one (configure conference menu) was presented to the principal in one instance and to the staff in another.

The main menus for both the principal and staff were restricted to using a small area across the bottom of the screen since the screen had to be available for data sharing while the main menu was being displayed. The main menu had to include options that provided all the functions needed to control the contents of the SGWS. The actual number of options was limited by the number of patches that could fit on the screen and be comfortably selected with a fingertip. Because of this limitation, careful consideration was made as to which options should be included on the principals menu, and which should be offered to the staff. Since the initial design contained a large number of functions, determining the split was particularly difficult. To ensure that any function could be accessed, the staff menu included an option that allowed his principal to work from the staff menu. The staff could make a menu selection, passing the staff menu to his principal, and when the principal was finished he could return the menu to the staff. (In this situation, the principal was not reviewing the same screen as the other principal conferees.) Options described as staff functions could then be selected by a principal, but it was intended that the staff control those functions, and they are described in that light.

Sections 3.4.1 through 3.4.9 describe the functions provided by each of the menus, discuss the intent of some of the options and, where applicable, the reason for rejection.

3.4.1 Configure conference menu - This menu, illustrated in Figure 3-12, was designed to accommodate seven stations where up to five could be configured into a primary conference, and the remainder would automatically be configured into a sub-conference with full audio and video, but no SGWS. The symbols used on the menu were representative, since it was unknown at the time just how many stations there would be or where they would be located. The first station to turn on power was given the responsibility of configuring the conference, though all stations with power turned on viewed the menu.

When the conference originator selected a station, the station's symbol flashed, the station's chime sounded, and the station was configured into the primary conference. If (or when) the called station had power turned on, the symbol would stop flashing, but remain lighted with high intensity. If a configured station should turn power off, the symbol would revert back to flashing. The station could reenter the conference by turning power back on or, while the power was off, it could be excluded from the conference by the conference initiator. If the initiator selected the flashing station-ID patch on the configure conference menu, the patch would return to low intensity, and that station would automatically be configured out of the main conference and into the sub-conference.

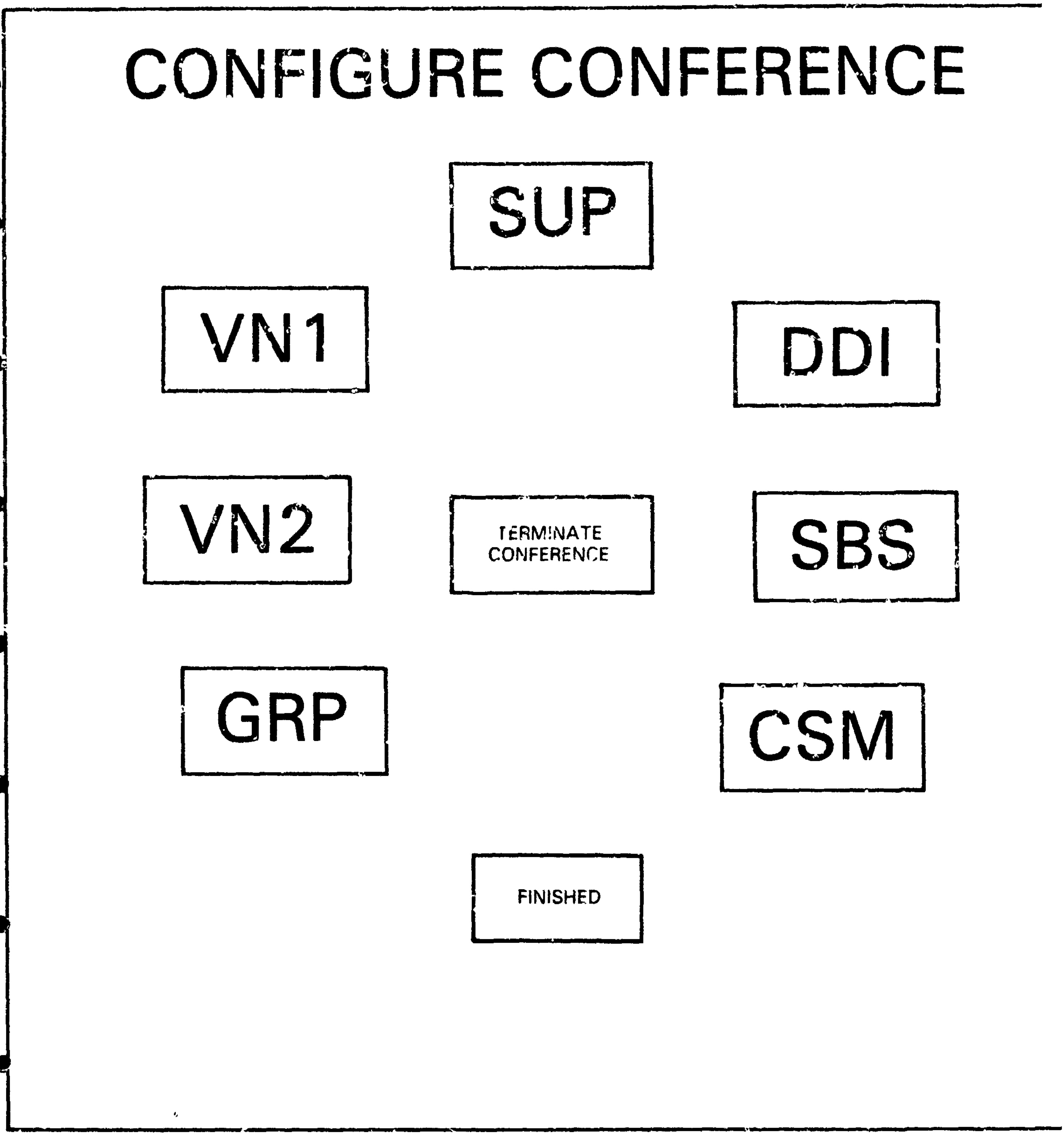


Figure 3-12
CONFIGURE CONFERENCE MENU

In this scheme, the conference initiator had full control over who could enter the main conference. Each station was configured into the conference when the conference initiator called the station, regardless of whether or not they responded by turning station power on. Consequently, if a called station was turned on sometime later, but while the main conference was still in session, it automatically became a part of the main conference and could not join the sub-conference without assistance from the conference initiator or staff. In addition, if the main conference participants decided that they wanted to invite another station into the conference, one already involved in a sub-conference, the act of inviting him would automatically pull him out of the sub-conference and configure him into the main conference without his knowledge or approval.

It is apparent why this design was unacceptable, but it serves to illustrate the large number of alternatives available in what seemed to be a straightforward function. Each alternative had to be analyzed from a user's perspective, from one extreme of having a single conference that anyone could enter (the final choice), to the other extreme of allowing any number of simultaneous conferences, where each station participating in any single conference had to accept the invitation extended by mutual agreement of all other participants. The ultimate choice of an open conference was made possible by the fact that the final system consisted of five installed stations, and the virtual space configuration could accommodate five participants.

3.4.2 <u>Main menu</u> - Figure 3-13 illustrates the main menu, which included all the functions originally assigned to the principal conferees for SGWS control. The differences between the original main menu and the final one were: (1) the original menu included the setting of the audio and video parameters, which in the final version were isolated to the control panel menu; (2) some of the options on the final main menu (SELECT VIDEODISC, SAVE, and RETRIEVE) were originally included on the staff menu; and (3) some of the original main menu options were eliminated (ALTER AUDIO/VIDEO, AUDIO ANNOTATE, DRAW, and two colors of ink).

CLEAR SCREEN	SELF VIEW	VOLUME CONTROL	ALTER AUDIO/ VIDEO	AUDIO ANNOTATE	ERASE	DRAW	BLACK	BLUE	YELLOW	PUR
							WHITE	RED	GREEN	ORA

Figure 3-13
MAIN MENU (DEVELOPMENT SYSTEM)

Presenting the audio and video parameters on the control panel as the initial entry into the teleconference session on the final system proved to be a logical breakout of function. Having everyone adjust their "physical" parameters before getting involved in the conference was more natural in that it related to the beginning of a face-to-face conference. When entering a room for a normal meeting, selecting a seat, adjusting position, and mentally preparing yourself to relate to the specific participants, is an automatic setting of "physical" parameters. Also, this is the logical time to make introductions and exchange pleasantries. Adjusting parameters on the control panel provided a natural "ice-breaking" ceremony, encouraging small-talk conversation, while each participant familiarized himself with audio and video settings. One final advantage of the control panel cannot be overlooked. The users were encouraged to interact with the system immediately, so that they became comfortable with the electronic meeting prior to becoming involved in serious conference topics when system timidity would be distracting.

Determining which functions logically belonged on the principals' main menu, and which ones belonged on the staff menu, was never cut-and-dried. In fact, some may argue that there was no need for a staff position at all. Nevertheless, several iterations of menu design prior to final system design altered the relationship between the principle and the staff. Moving the functions to save and recall images, and to select videodisc images from the staff menu to the main menu, served three purposes. First, it became apparent that the actual conferees wanted control of these functions, because they were frequently used and could be performed by the conferees without the awkward wait associated with having the staff person perform them. Second, they were not so complex that they required a specially trained person to perform them, nor did they require leaving the table or the room for additional information. Finally, a conference could not be conducted without a staff person present, as long as these critical functions were available only on the staff menu.

The deletion of several options was a natural evolution of system design. The ALTER AUDIO/VIDEO option turned out to be relatively useless. This option gave each participant the ability to turn on and off his own audio or video to his staff or to the rest of the conferees. The original intent was to prevent the staff from overhearing sensitive information, or to spare the conferees the distraction of a principle talking to his staff. The communications and switching system (system communications controller) developed by DDI would easily perform these selective audio and video connections, but the actual implementation of the function was more distracting than the problem it was intended to alleviate

The AUDIO ANNOTATE option was never implemented since the GFE audio digitizer did not operate as anticipated. This device was used in the audio link between the remote station at CSM and the stations located at DDI, to illustrate that compressed audio was feasible and would make encryption of the audio possible. The audio quality was unacceptable, however, and the audio digitizer was taken out of the communications link, which reverted to normal audio channels. In addition to the compromised audio quality, this specific digitizing unit had other deficiencies making it inappropriate for the audio annotation application. The synchronous device put out a non-standard synchronization header stream that was not suited for saving on a magnetic storage device. The software did anticipate incorporation of this function, and was implemented to allow both the audio annotation and readback of any previous annotation, making it possible to perform future implementation with minimal software impact.

The DRAW option was eliminated only because it was an unnecessary step. The option was initially included to differentiate between the default or "point" mode and the selectable "draw" mode. Drawing cannot be performed without a selection of ink color, however, so it became more logical to use the single step of color selection to define the "draw" mode.

The number of available colors changed because of final software implementation techniques. The foreground annotation was allocated three bit-planes of the frame buffer, resulting in the definition of eight colors. One color had to be reserved for "shine-through" which was the selected method of performing the erase function. There were, then, seven colors that could be defined for the user, but six could more attractively be presented on the menu.

3.4.3 Volume control - The volume control option, accessible from the main menu, presented the secondary menu illustrated in Figure 3-14. This menu provided the control to individually increase or decrease the audio level from each of the other configured stations. This degree of volume control was maintained in the final system, but it was incorporated into the Control Panel menu to be normally exercised at conference initiation. The Control Panel menu proved to be a more logical place for the function, and it eliminated the need to access an extra secondary menu from the main menu.

3.4.4 Alter audio/video - The Alter Audio/Video menu was another secondary menu invoked from a main menu option selection. This function was not included in the final system, but Figure 3-15 illustrates the original implementation. Any principle conferee could turn off his audio or video (represented by the microphone and camera, respectively) to all other principles or to his staff. He could also turn off the audio (represented by the speaker) from all other principals or from his staff. Whenever an audio or video option was off, the cursor symbol of the station that selected the option was displayed in the associated menu box. By reselecting an option, the associated audio or video would return to normal, and the cursor symbol would be cleared.

3.4.5 Staff menu - The original staff menu was far more inclusive than the final version, as illustrated in Figure 3-16. Several of the original options were dropped, and some were moved to the principal's main menu. The original staff menu accommodated a variety of functions that demonstrated the overall capabilities of the system, as well as functions that provided a high degree of flexibility in system operation. As the system evolved, however, the focus shifted from total flexibility to ease of operation.

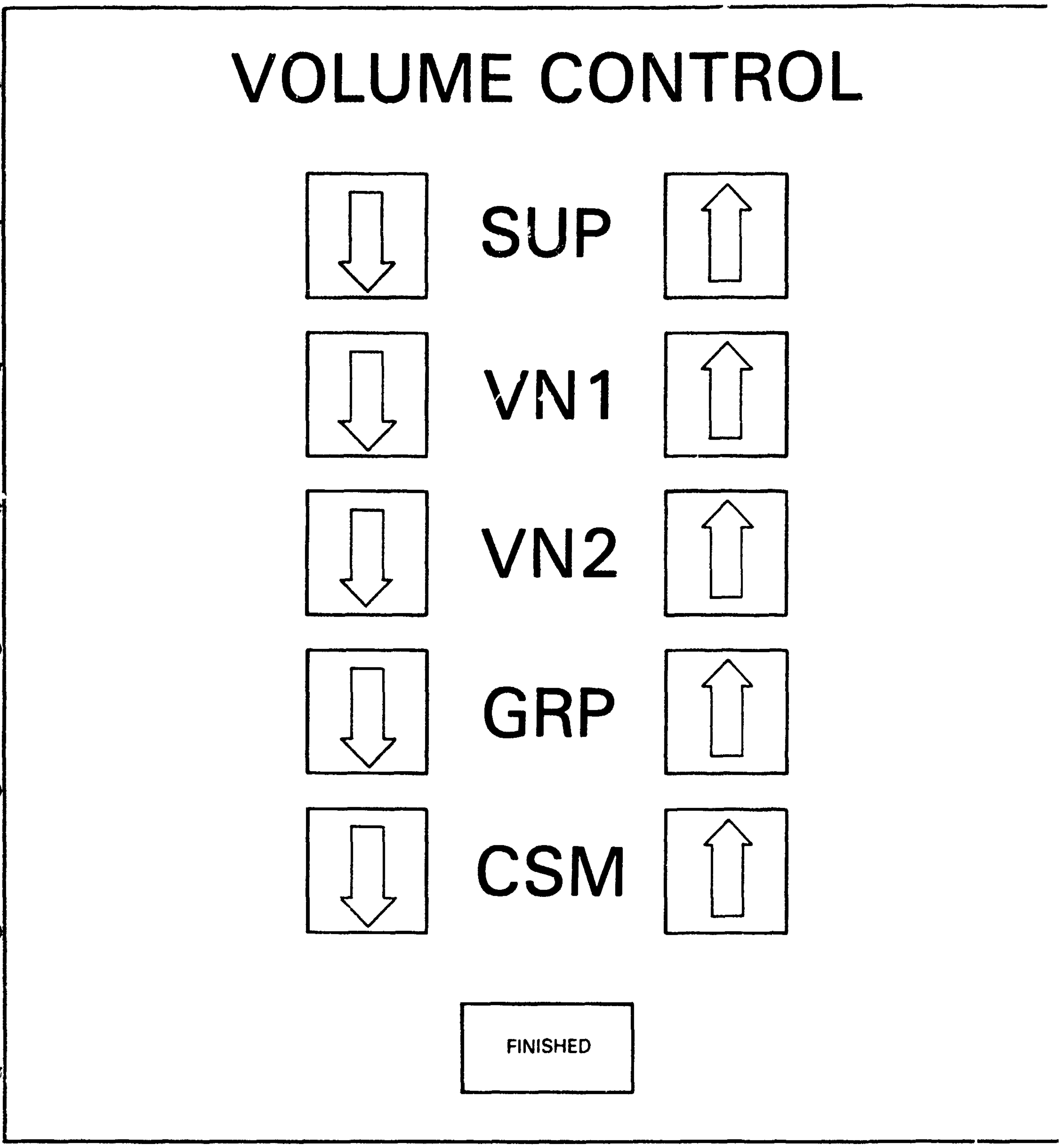


Figure 3-14
VOLUME CONTROL OPTION
(DEVELOPMENT SYSTEM)

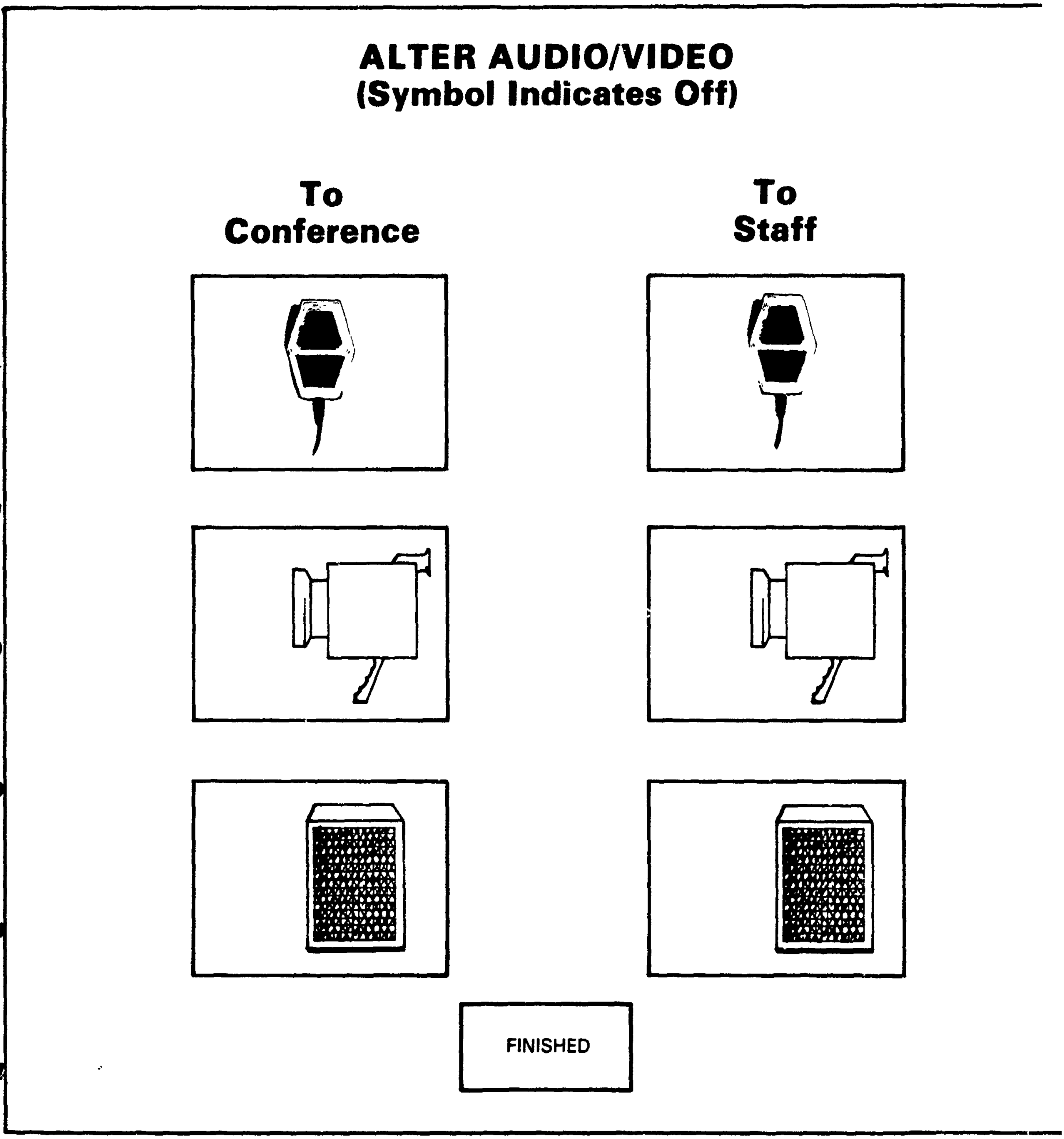


Figure 3-15
ALTER AUDIO/VIDEO MENU
(DEVELOPMENT SYSTEM)

DRAW	ERASE	SELECT VIDEO SOURCE	SAVE IMAGE	CONFIGURE CONFERENCE	SWITCH TO PRIMARY	ENABLE PRINCIPAL PREVIEW	DEMO STAFF FUNCTIONS	SE CONF M

Figure 3-16
STAFF MENU (DEVELOPMENT SYSTEM)

The DRAW option was intended to be the vehicle for the principal and his staff to communicate via the SGWS, but it introduced more problems than it solved. For instance, if the staff selected an image for the principal, annotated it to communicate some idea, enabled it for the principal's preview, and finally passed it to the primary (making it the new background image at every station), what should have happened to the annotation? Should it have been kept, or automatically cleared? One choice might have been better in one situation while the other was better in another. The final decision made was that no SGWS communication was necessary between the principal and his staff and, consequently, the DRAW option and its companion ERASE, were eliminated from the staff menu.

Originally, the staff was responsible for selecting every possible background image. The SELECT VIDEO SOURCE presented the staff with a secondary menu that provided seven options for video source (several were psuedo-options for increasing communication flexibility, see Section 3.4.6). This scheme made it virtually impossible to conduct a conference when a staff person was unavailable. As mentioned before, the videodisc image selection, and the retrieving of previously saved image options, were transferred to the principal's Main menu, the group wall camera and staff overhead camera options were put directly onto the staff Main menu, and all other options were eliminated. Once all the video source options were redistributed, the SELECT VIDEO SOURCE option was deleted from the staff menu, and the select video source secondary menu was totally eliminated.

The staff person alone had access to the computer video terminal associated with the teleconference software package. This terminal was to be used by the staff to assign a name to the images to be saved. Selecting the SAVE option on the staff menu resulted in a list of previously saved images on the terminal display, and a request for a name for the current image. The staff could either select one of the previously saved images, which would cause the current image to replace the selected image, or enter a unique name to indicate that the current image is new and to be saved in a unique location.

This Save function was the only function within the entire teleconference system that required a keyboard entry. It became apparent that the principals should be able to save images without staff assistance, but they should not be required to make keyboard entries. Ultimately, the final scheme devised allowed the principals to save or recall images from ten available slots presented on a SGWS secondary menu, as illustrated in Figure 3-10. (The save and recall scheme became even more functional in the two-way video teleconference system described in Section 4.0.)

There was no vehicle for the principal to return to the Configure Conference Menu once the main menu had been invoked. Consequently, the staff was given the responsibility of performing all reconfiguration functions. If the participants wanted to invite an additional station to join them, or if a particular station wanted to be configured out of the conference, the staff person would request the configure conference submenu. The menu operated in exactly the same fashion as it did when a principal had control of conference initiation. Since the call function was incorporated into the Control Panel Menu, this option was deleted from the staff menu, and the secondary menu was eliminated from the system.

The PASS TO PRIMARY option was used by the staff to convert an image selected via the SELECT VIDEO SOURCE option from an exclusive staff SGWS image to a primary SGWS imaged shared by all conferees. This option was retained on the Staff Menu in the final system, but it only transferred two types of images: those captured by the staff overhead camera, and those captured by the group wall camera.

The option designed to enable principal preview was intended to enhance communications between the principal and his staff. Since the staff had the responsibility of selecting every possible background image, this option allowed the principal to "preview" the selected image before it passed to all conferees as the new background. If the image was not the one requested, the staff would have another opportunity to locate the correct image. The actual option on the staff menu operated like a two-way switch. The staff had to select it to enable the preview, which presented the principal with the new image and the staff menu. The principal then had to deselect the option to give it back to the staff. This option became less important when the only backgrounds selected by the staff were those captured by the cameras, and the switching by the principal back and forth between the primary image and staff image become more confusing than was worthwhile. Consequently, it was eliminated from the final staff menu.

The majority of the capabilities of the virtual space system were initially assigned to the staff position.

When the system was demonstrated to visitors, the visitors were always seated in the principal stations so they could experience the concept of virtual space. This limited the number of SGWS capabilities that could be experienced. The DEMO STAFF FUNCTIONS option was included on the staff menu strictly as a demonstration aid. When this option was selected, the entire staff screen was shared with all conferees. The system demonstrators could then perform staff functions for the visitors, and the results were viewed by everyone. When the functions had all been demonstrated, the demonstrator reselected the DEMO STAFF FUNCTIONS option, and the primary image returned along with the primary main menu. When the functions were redistributed to give the principals more control, the need for this option was eliminated.

The option to SELECT CONFERENCE MODES was also intended to illustrate system capabilities. It would have been advantageous to develop an R&D system, so that the audio and video capabilities could be dynamically selectable; then, the users could experience every capability from full-color, full-motion video with full fidelity audio, all the way down to no video and compressed audio. Even though the idea was sound, the equipment required to support the function was unavailable. This option provided another secondary menu described in Section 3.4.9.

3.4.6 Select Video Source menu - Figure 3-17 illustrates the secondary menu presented to the staff when the SELECT VIDEO SOURCE option was invoked from the staff menu. This menu allowed the staff to select a background image from any video source linked to the system (and then some). Each of the first two options on this menu (the VIDEODISC and PREVIOUSLY SAVED IMAGE options) resulted in a third level of menu. Sections 3.4.7 and 3.4.8 describe the operation of the two submenus. Since both of these options were frequently used and needed

SELECT VIDEO SOURCE

- VIDEO DISC
- PREVIOUSLY SAVED IMAGE
- GROUP CAMERA
- STAFF CAMERA
- TERMINAL
- BLANK IMAGE
- PRIMARY IMAGE

Figure 3-17
SELECT VIDEO SOURCE MENU (DEVELOPMENT SYSTEM)

to be available, even if a staff person was not, it simplified system operation to transfer them to the principal's main menu so the principals could control them.

The group camera and staff camera options were reallocated to the final staff main menu.

The TERMINAL option was intended to capture an image from a video terminal associated with a totally different computer system, such as a data base system or graphics display system. This function was never implemented, because no external video system was identified during the development of the virtual space system, whose terminal output would enhance the teleconference concepts.

The last two options on the Select Video Source menu were designed to give the staff position total flexibility. The BLANK PAGE option was the staff's method of clearing the screen, and the PRIMARY IMAGE option was the only way the staff could view the same image as his principal. In conjunction with the DRAW and ERASE options (and the ENABLE PRINCIPAL PREVIEW), the PRIMARY IMAGE option allowed the principal and his staff to communicate extensively via the SGWS. The entire concept built complexity and distraction into the system, and in the final analysis, there was no need for the staff to have such flexibility. His role of assisting the principal in the operation of the system had become one of controlling the system operation and making it more cumbersome than was necessary.

3.4.7 Videodisc menu - As illustrated in Figure 3-18, the Videodisc menu remained the same on the final virtual space system. However, the method of invoking the menu did change. In the original design, it was a third level menu accessed from the staff position. The SELECT VIDEO SOURCE

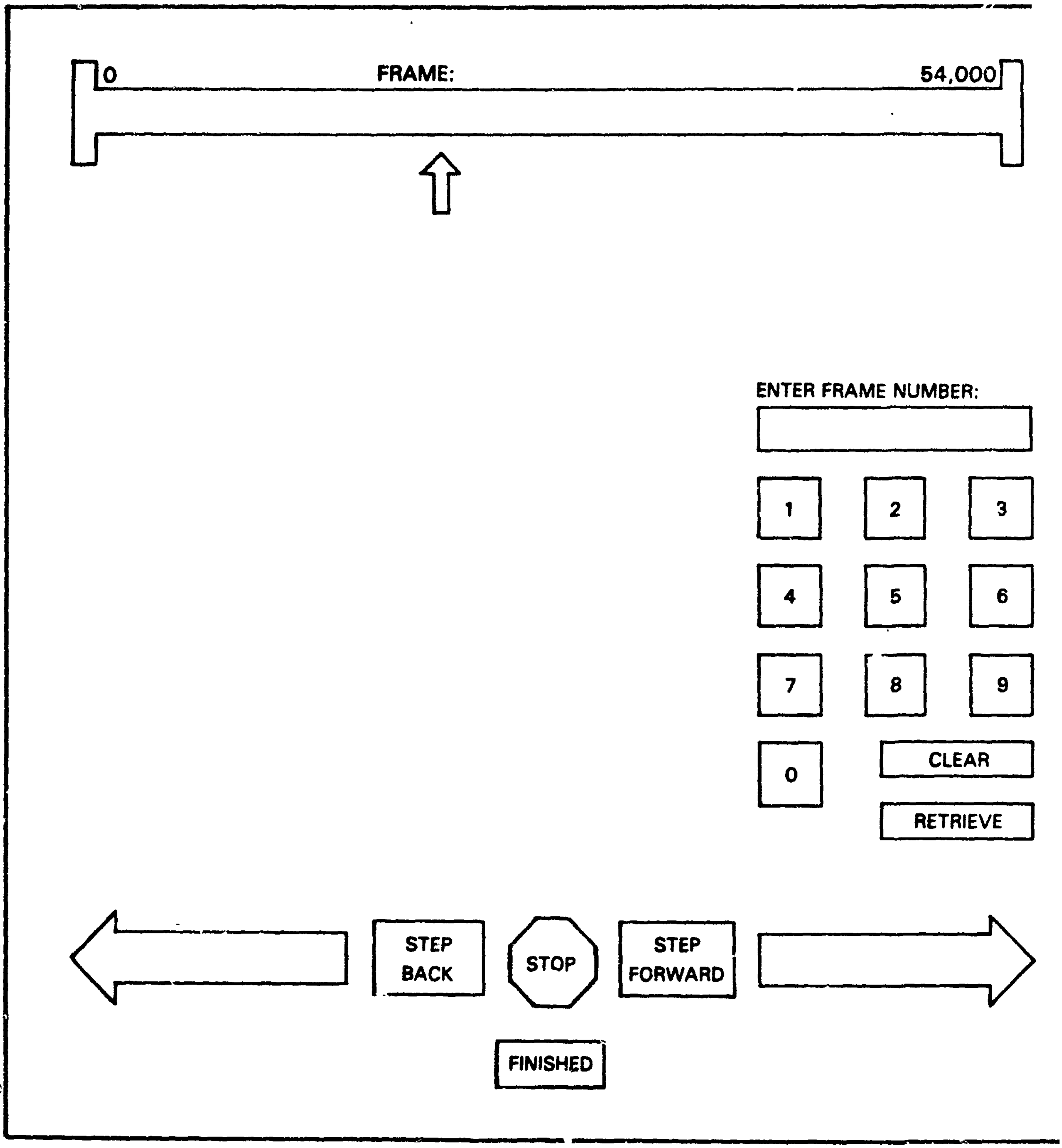


Figure 3-18
VIDEODISC MENU
(DEVELOPMENT SYSTEM)

option on the staff menu presented a secondary menu of video sources, and the VIDEODISC option from that menu resulted in the Videodisc menu. In the final system, the Videodisc menu could be accessed directly by selecting the VIDEODISC option from the principal's main menu.

3.4.8 Retrieve image menu - The capability to recall a previously saved image was, again, a staff function accessible through the Select Video Source submenu. Figure 3-19 represents an example of a Retrieve submenu. As images were saved by the staff, they were named by entering titles on the terminal keyboard. The retrieve menu was dynamically generated to reflect one option for each saved image, identified by the name entered at save time. The menu would present from zero to ten images by name, and the desired image could be retrieved by selecting the associated menu option.

This menu was superseded by the save and retrieve menu accessible directly from the principal's main menu. In addition to giving the principal the capability to save and retrieve images at will, the new menu provided a smoother and friendlier operation.

3.4.9 Select Conference Mode menu - The final menu (see Figure 3-20), included in the original implementation of the system, was designed to demonstrate the audio and video capabilities of the virtual space system. Given that the system already had the capability to automatically configure the audio or video mode via the DDI built SCC, this would have been a straightforward implementation. From a hardware standpoint, however, a complement of color cameras, color monitors, audio compression units, and video compression units would have to be installed to effectively demonstrate this capability. Because of hardware costs, the unavailability of video compression units, and the unacceptability of the GFE audio compression

RETRIEVE IMAGE

☐ IMAGE 1

☐ IMAGE 2

☐ IMAGE 3

☐ IMAGE 4

Figure 3-19
RETRIEVE IMAGE MENU
(DEVELOPMENT SYSTEM)

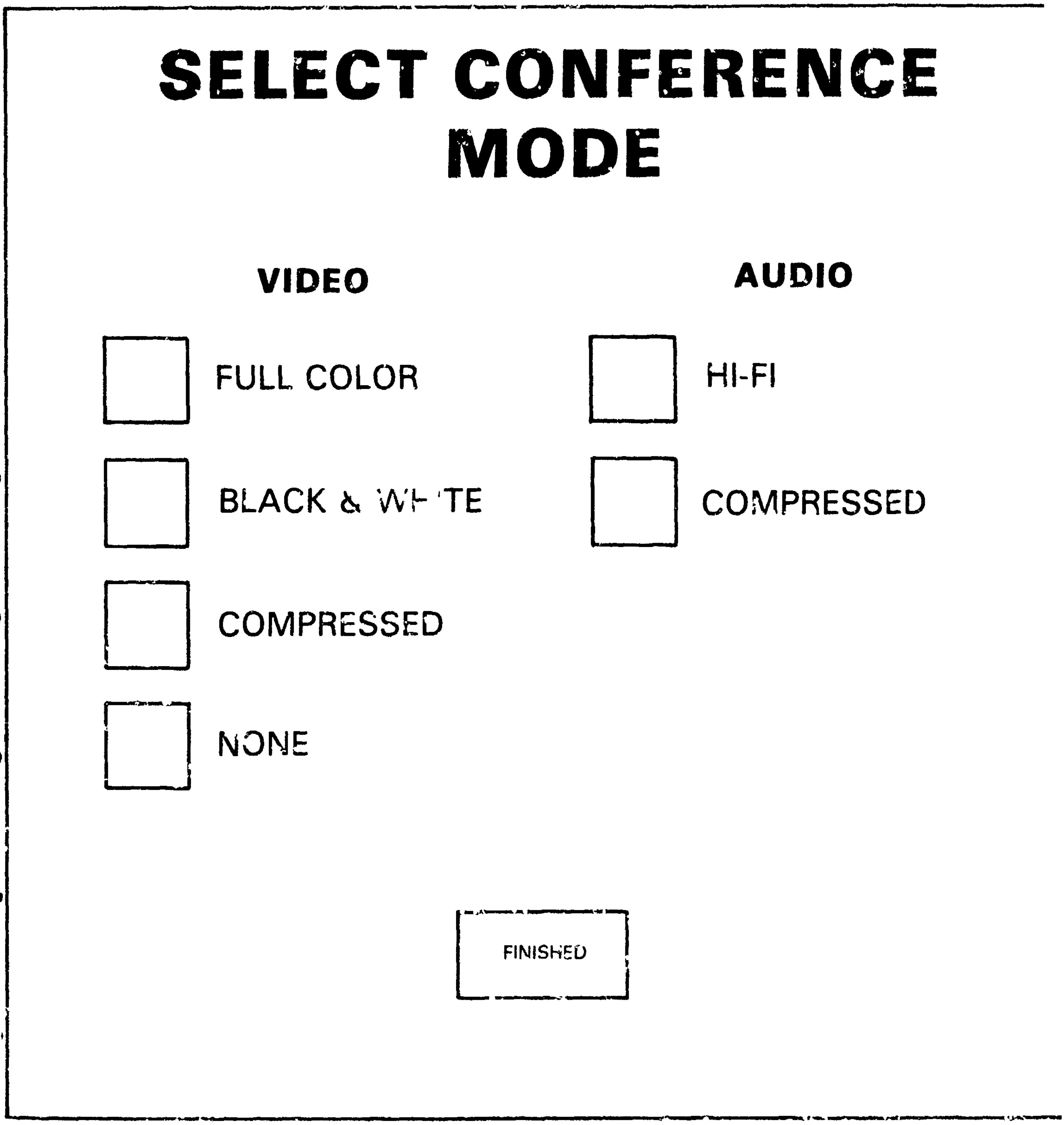


Figure 3-20

SELECT CONFERENCE MODE MENU (DEVELOPMENT SYSTEM)

units, there was never an opportunity to implement an effective demonstration. Also, there was concern expressed as to whether compressed images and compressed audio would ever be accepted if they were demonstrated simultaneously with full video and audio capabilities. Consequently, this menu was eliminated from the final virtual space system.

Thus far, this report has described the design and implementation of a virtual space teleconferencing system in three specific stages of evolution. Section 2.0 described the initial implementation of the virtual space concept, augmented with an analog data sharing capability. Section 3.0 described the final implementation, including a sophisticated digital graphic workspace which replaced the analog data feature. To illustrate the evolutionary process in developing the system, Section 3.4 presented a design of the first digital workspace. These three descriptions represent snapshots of time within a constantly changing R&D development cycle. The various functions and capabilities provided by the system and the division of responsibilities between the principal and his staff were under constant scrutiny and analysis. Several times the flexibility of functions had to be weighed against ease of operation of the system, and the role of the staff was continually rethought. Would the ultimate use of the system be restricted to only the highest level decision makers that would desire staff people to control the total system operation, or would it also be used by middle management in making everyday business decisions? The philosophy adopted for final implementation accommodated both operational environments. The system was designed so that executive management could operate the system without extensive assistance, and yet the basic functionality was available to accommodate the working sessions of middle management.

4.0 TECHNOLOGY TRANSFER

In the course of developing the virtual space system for DARPA, DDI had the opportunity to transfer the acquired technology to an operational system environment. The Air Force Manpower and Personnel Center in San Antonio, Texas needed for a two-way video teleconference system with a Shared Graphic Workspace capability similar to the virtual space system. After DDI and AFMPC personnel discussed the actual requirements for the AFMPC system, DDI developed a comprehensive functional specification that described all the system components, the functions and capabilities to be included, and a detailed description of each display format and of system operation. The system was developed according to the specification, and both stations were installed in San Antonio on schedule. The system has been used extensively in this trial environment, but in early 1983, one station will be removed from San Antonio and installed in the Pentagon.

Section 4.1 describes the configuration of the AFMPC system, Section 4.2 discusses the functional capabilities, and Section 4.3 points out the major differences and the rationale for the differences between the virtual space system and the Air Force two-way system.

4.1 Station Configuration

The AFMPC teleconference system consisted of two identical stations configured as illustrated in Figure 4-1. During a teleconference, the conference room could accommodate several people, but at most, only three attendees at each station could actually interact with the system. The three main conferees were seated in front of the conference table, facing the

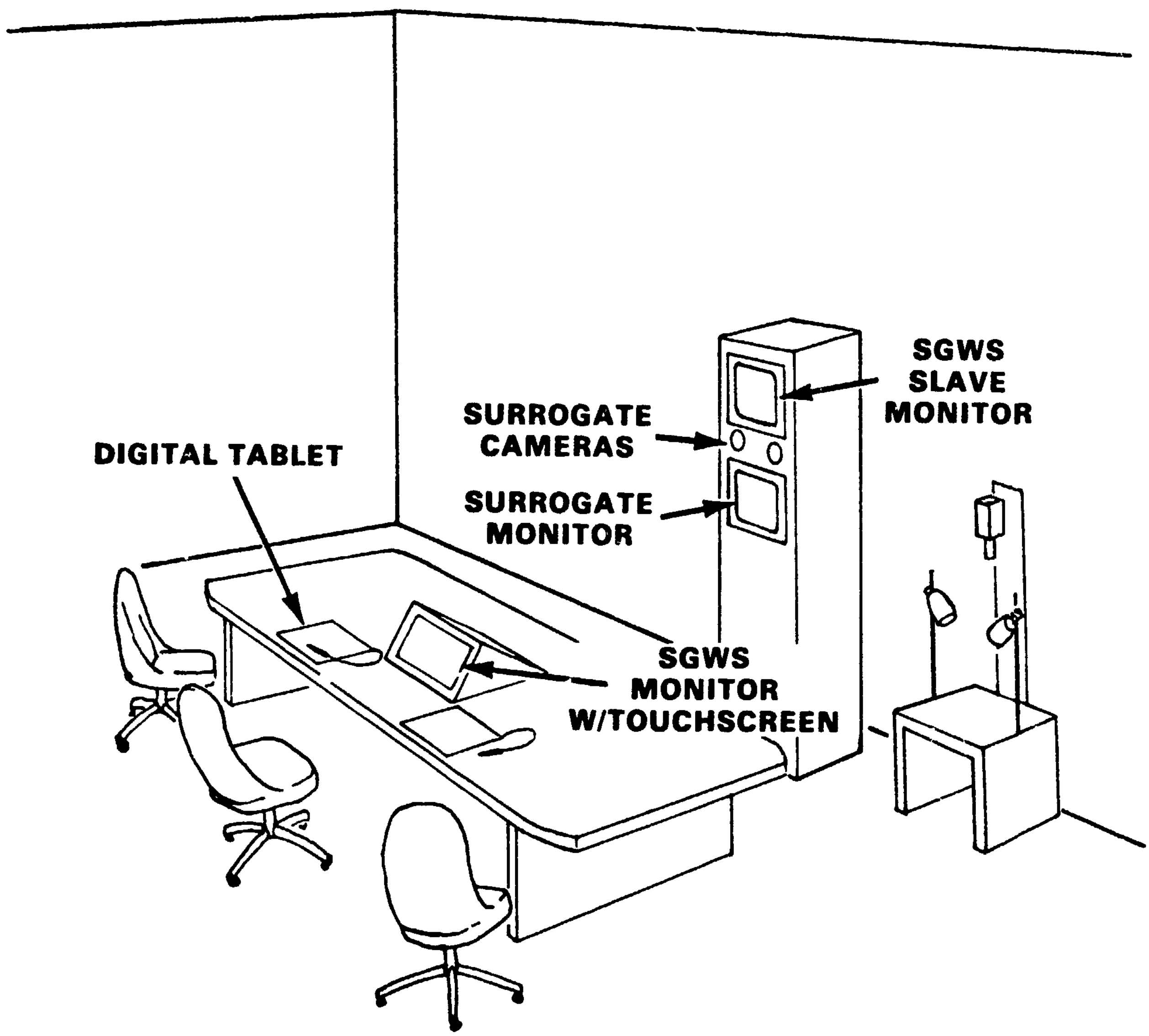


Figure 4-1
TELECONFERENCE STATION CONFIGURATION

surrogate unit positioned across the room. The surrogate unit consisted of a monitor that displayed a video image of the conferees seated at the other station, a speaker that transmitted the audio communication from the other site, and two video cameras that were individually selected to transmit a close-up or wide-angle image of the conferees to the other station. The surrogate unit, for convenience, also contained a large color monitor to replicate the SGWS display for any conferees or observers that could not easily view the monitor imbedded in the conference table.

The conference table served as the conferees' work area. The SGWS monitor, which was a vehicle for sharing video and graphic data, was mounted in the table in front of the center conferee. A touch-sensitive screen, which allowed a conferee to interact with the SGWS, was mounted flush over the face of the monitor. Two digital tablets, imbedded in the table on either side of the SGWS monitor, allowed two additional conferees to interact with the SGWS.

The special chairs used at the teleconference table could be easily adjusted for seat height, front-of-seat inclination, and back inclination by pressing three mono-static buttons on the bottom surface of the chair. A pneumatic cylinder in the base allowed the seat to be adjusted to various heights while the user was seated. This allowed the conferees to be centered in the surrogate image, particularly important when the camera, which showed a close-up view of the center conferee, was activated.

The conference table was designed for face-to-face conferences while teleconferencing was not in session. To offer some protection for the equipment from accidental coffee spills or other conference hazards, the SGWS monitor had a locking cover, the microphone was built into the SGWS housing and the the stylus connected to each digital table was removable.

In addition to the surrogate unit, and the conference table and chairs, the conference room contained a movable "overhead camera" stand. While not in use, the stand could be positioned out of the way in an unused corner. During a teleconference, when an image was to be captured for display on the SGWS, the stand could be rolled to a position convenient to the conference table.

All of the other equipment required to teleconference (e.g., computer, disc drive, switching system, frame buffer, videodisc player) was located outside of the teleconference room, out of view, and out of the consciousness of each conferee. This aided in simulating a normal face-to-face conference, both physically and psychologically.

4.2 SGWS Operation

The SGWS, an enhanced version of the virtual space SGWS, provided the conferees with the capability to share documents and prepared briefing materials, to generate spontaneous graphics, and to share previously generated videodisc images. The SGWS image consisted of two distinct parts: the background image, and the foreground annotation. The background was used to display an image from a videodisc frame or from the overhead camera, and both were displayed in shades of gray. The conferees' interaction with the SGWS occurred in the foreground, which was used to display the colored menus, the conferees' annotations, and the cursor, all without disturbing the background image.

Like the virtual space system, the AFMPC system automatically directed the users through a session employing specially designed menus that displayed options on the screen. The conferees interacted with the SGWS to select the desired option in one of two ways. The center conferee simply touched the screen directly over the desired option. The touch-sensitive screen transmitted coordinate information to the computers so that the selection could be processed. The other conferees used a stylus to enter the selection via the digital tablet. The digital tablets provided two types of information to the system. If the stylus were close to or touching the tablet, but not pressing down, the coordinates were sent to the computer, indicating that the stylus was in "proximity" mode. The system fed this information back to the conferee by displaying a cursor symbol on the SGWS relative to the location being touched. By watching his cursor, the conferee could move the stylus to the exact location of the option he desired. Once his cursor was positioned directly over the desired option, he pressed down with the stylus, and the computer interpreted the selection. (A pad of paper with the "Main" menu printed along the bottom, exactly as it appeared on the SGWS monitor was attached to each digital tablet. When the user selected options from the "Main" menu, he could go directly to the option, using the printed menu as a guide.)

Whenever a conferee selected a menu option, auditory feedback indicated whether or not he had made a successful selection. A short, high-pitched tone (beep) was sounded for successful menu selections, and a longer, lower-pitched tone (blat) was sounded for unsuccessful attempts. On occasion, a menu selection resulted in both a "beep" and a "blat." If a particular selection could not be honored, because of a conflicting action occurring at the other station, a "beep" was sounded to indicate a valid hit, but the "blat" followed to indicate that it could not be processed. The menus were designed for ease of understanding and use. The system was forgiving of procedural errors, and required confirmation from the user before performing certain irreversible functions.

In addition to interacting with the various menus, the conferees interacted with the screen area above the "Main" menu as if it were a piece of paper. (All three conferees at each station independently interacted with the page.) They could point to an area of the SGWS without "ink" being deposited, or they could draw in any one of six colors. They could selectively erase an annotation as they would with an eraser, or they could clear all the annotations at once. As with an entire tablet of paper, if the conferees advanced to the next "page," the old page would not be lost; it was saved for future reference. Saving the previous page when the next page was requested was performed automatically by the system as an aid to the user.

The system prevented the two stations from performing any conflicting actions. For example, if one station attempted to page forward at the same time the other station attempted to page backward, both stations sounded a "blat" and no action was taken. The "blat" indicated that the selection could not be honored. If the options were not selected at exactly the same time, the first request interpreted was honored, but no potentially conflicting action from the other station was honored until the first operation was complete.

4.3 Conference Modes

The teleconference system could be used in two different modes: stand-alone mode and conference mode. Stand-alone mode allowed conferees at either or both stations to independently utilize the SGWS functional capabilities in developing briefings for future conferences, all without actually entering into a conference. Conference mode occurred when communications were fully established and all interactions with the SGWS were shared between the two stations.

4.3.1 Stand-alone mode - Stand-alone mode allowed users to prepare briefings in advance of actual conferences. Using the "paging" concepts, the select background capability, and the user annotation function, up to twenty-five "pages" of material could be generated at each site. The advance preparation of materials had two advantages. First, the preparer had the opportunity to organize his materials in privacy, and second, the information could be transmitted to the other station prior to an actual conference. This is particularly important if the briefing contained any images captured from the overhead camera; these images could each take several minutes to transmit from one station to the other.

To enter stand-alone mode, the computer and disc drive power, and the equipment rack power must have been on with the main teleconference program executing. The conferee turned the station power on (using a switch mounted on the side of the SGWS monitor), and a "Control Panel" menu was displayed. A patch associated with the "Hang-Up" function was intensified, indicating that the SGWS communications had not been established. This state automatically defines the stand-alone mode. The surrogate audio and video controls on the menu (Volume, Contrast, 1 Person View, 3 Person View, and View Yourself) were not active, since there was no communication link with the other station. The user could press "Access Shared Workspace" to perform all the desired functions in this stand-alone state. When the session was finished, he turned off the station power, and the images just developed were transmitted to the other station and saved on magnetic storage.

4.3.2 Conference mode - The conference mode was entered in the same fashion as placing a telephone call. Either station could place the call, and the communication link was established when the other station answered the call. When the station power was first turned on, the Control Panel was displayed. The "Hang-Up" patch was intensified, indicating that the phone was on the hook. To call the other station, the user simply touched the "Call" patch. The "Hang-Up" patch deintensified, the "Call" patch intensified, and a chime rang at the other station.

The other station then had the option to answer the call or to ignore it. To answer, the user pressed his "Call" patch. The "Call" patch became intensified, the "Hang-Up" patch deintensified, and a chime rang in the original station. In addition, at both stations the surrogate audio and video were activated, indicating that the link had indeed been established.

Should the second station decide not to answer the call, the first station had two options. He could leave the call outstanding, so that the second station could answer at any time, or he could cancel the call by pressing the "Hang-Up" patch. The "Call" patch would deintensify, the "Hang-Up" patch would intensify, and if either station subsequently desired to establish the link, the entire procedure would have to be repeated.

Once communications were established, the system was in conference mode, and the actions performed via the SGWS were shared. With the exception of accessing the "Control Panel" or the "Select Background" menus, each station had instant feedback of the actions being performed at the other station. The conference could be terminated from either station simply by pressing the "Hang-Up" patch, or by turning off the station power. As with a telephone, the link was disconnected, and a new call was required to reestablish the communication.

4.3.3 <u>System operation</u> - The functional capabilities of the system fell logically into three groupings that were available to the user via three unique "menus." When the station power was first turned on, the first menu (the Control Panel) was displayed. Through this menu the user could adjust all the environmental parameters (e.g., audio and video characteristics, system mode). This menu also provided access to the SGWS, which resulted in the display of the "Main" menu. The "Main" menu provided the SGWS interface controls (e.g., drawing/pointing/erasing modes, paging capabilities, etc.). The third menu (Select Background) was accessed through the "Main" menu and provided the controls to select a new background image.

Environmental control parameters - The "Control Panel" menu, as illustrated in Figure 4-2, provided the control of the audio and video link between the two stations. These controls are discussed in logical groups in the following subsections.

Call/Hang-up - The "Call" and "Hang-Up" boxes were used to control the system mode: conference mode or stand-alone mode. As functionally described in Section 4.3.2, they operated like a telephone. Conferees at both stations pressed "Call" to establish a two-way communication. Either station could terminate the conference by pressing "Hang-Up," or by turning off the station power. When the "Call" button was pressed, the patch was intensified, the patch associated with "Hang-Up" was deintensified, and a chime was sounded at the other station. When both stations had selected "Call," the surrogate audio and video were activated, and the conference was in session.

When one station selected "Hang-Up," the surrogate audio and video were turned off, leaving both stations in stand-alone mode. If the other station did not "Hang-Up," it the "Call" state and was still active could be rejoined by the first station when "Call" was reselected. Turning the station power off produced the same effect as the "Hang-Up" function.

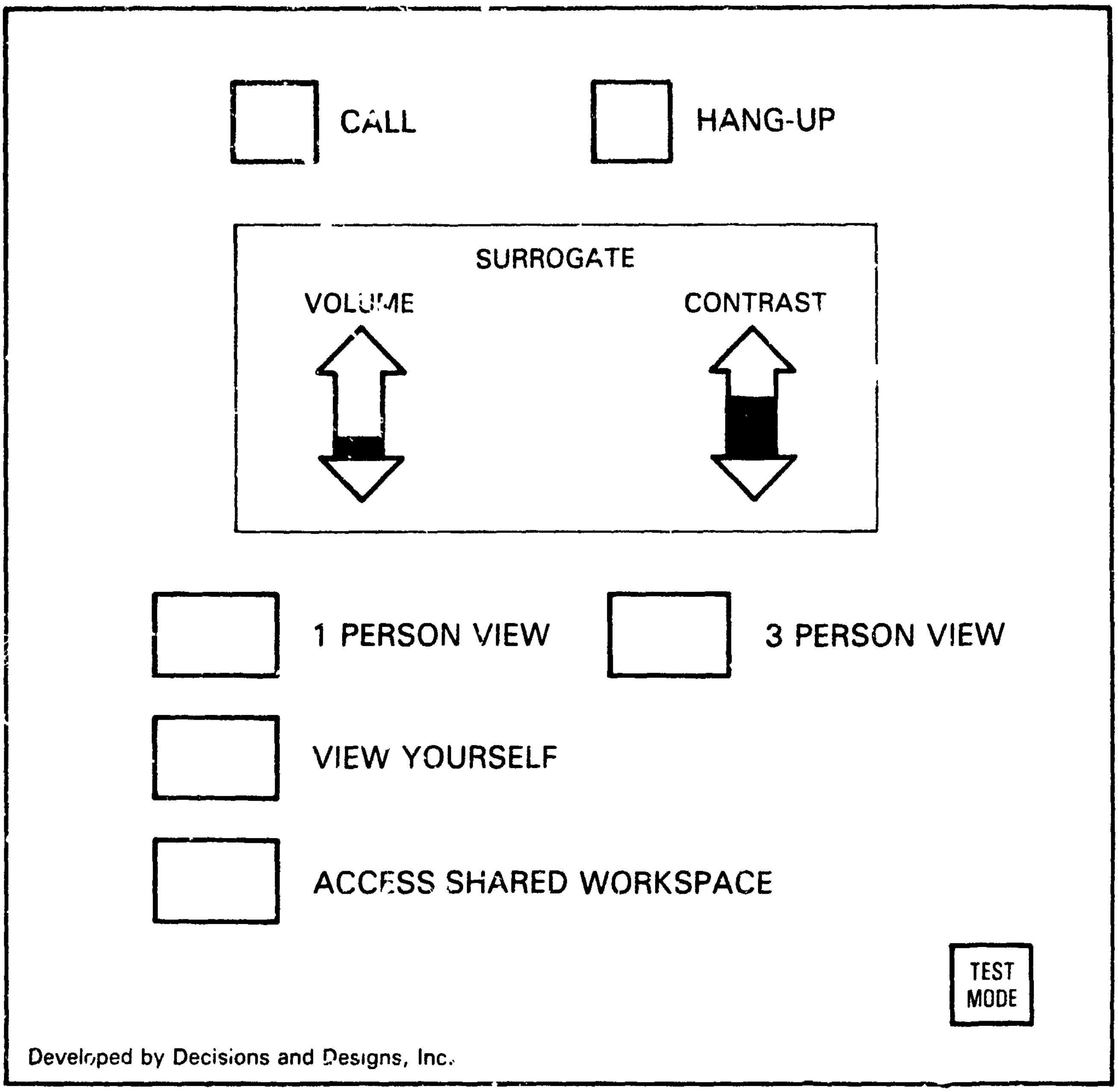


Figure 4-2
CONTROL PANEL MENU (USAF SYSTEM)

The site with power still on would be in stand-alone mode with a "Call" outstanding.

Volume control - Once the audio link was established, the user had the capability to adjust the audio being received from the other station. The volume arrow on the "Control Panel" was initially set to indicate that the volume was half way between the minimum and maximum settings (which it was). The volume level could be increased or decreased by pressing the upper arrow or lower arrow respectively. With each hit, the volume changed by one level, and the indicator went up or down to reflect the current setting.

Surrogate contrast - The surrogate monitor displayed a compressed image of the conferees at the other station. Because of the compression technique employed, the image varied in quality based on the complexion and hair color of the conferee(s). The contrast arrow could be used to adjust the parameters being used by the compression unit to allow fine tuning of the image being generated. Touching the upper arrow tended to darken the image, while touching the lower arrow lightened the image. The level indicator in the arrow moved with the current selection. Due to the nature of the communications with the compression unit, it could take several seconds for each contrast level change to occur.

Surrogate monitor view - There were three images that could be displayed under user control on the surrogate monitor. The first two were wide-angle and narrow-angle views of the conferee(s) at the other station. If a single person was conferring from the other station, the "1 person view" provided a closeup view of the one person. If there were two or more people, the "3 person view" provided a wider angle view that encompassed up to three people. The current selection was intensified. The "3 person view" was the default setting.

The third image possible on the surrogate monitor was the self view. When the "View Yourself" option was selected, the picture being sent to the other station was displayed on the surrogate monitor. This allowed the users to adjust their chairs or positions to center themselves within the viewing area. The image displayed under the "View Yourself" option could be wide-angle or narrow-angle, based on the current selection at the other station; but the image was full screen size, unlike the one transferred to the other site. When only one station was in the "view yourself" mode, the other station viewed a frozen image. The contrast control was inoperable while "view yourself" was in effect (it was intended to offer tuning of the other station's image). The "View Yourself" option was a two way switch. Selecting the option once caused the patch to be highlighted and the self view to appear on the surrogate monitor; pressing it a second time caused the patch to be displayed in normal intensity, and caused the surrogate view of the other station to return.

Access shared graphic workspace (SGWS) - This button was used to access the "Main" menu, which provided all the functions associated with either stand-alone briefing preparation or a two-way conference session. If both sites were in the "Call" state, the two stations were in conference mode and share all the SGWS functions. If either or both stations were in the "Hang-Up" state (constituting stand-alone mode), the SGWS functions were not communicated, and all actions were reflected only at the station performing them.

SGWS functions - The "Main" menu, as illustrated in Figure 4-3, provided the functions to interact with the SGWS. The following subsections discuss the available functions.

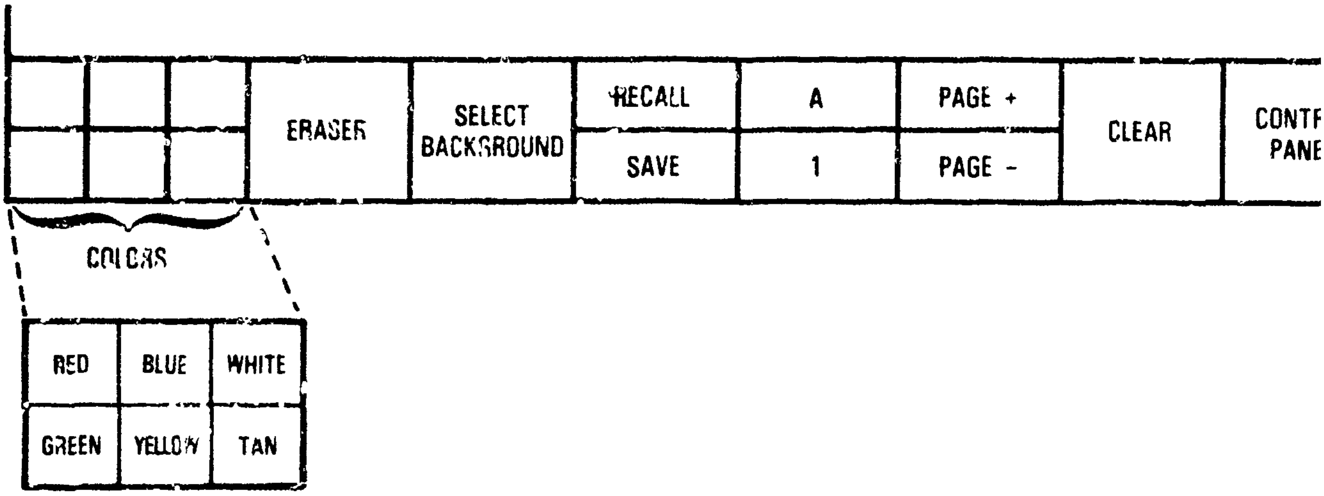


Figure 4-3
MAIN MENU (USAF SYSTEM)

<u>Drawing, pointing and erasing</u> - As the user moved his finger across the touchscreen or drew on the digital tablet with the stylus, the system provided visual feedback via a cursor symbol. The cursor symbol was displayed on the image at the point of contact. The cursor symbol was unique for each conferee. The AFMPC system identified the San Antonio conferees with SA1, SA2, and SA3; the Pentagon conferees were identified by DC1, DC2, and DC3. The cursor symbol always appeared in white, followed any movement associated with the point of contact, and was independent of the imagery displayed in both the foreground and the background. It provided visual identification of the point selected (especially valuable in the use of a digital tablet) to all conferees simultaneously.

The cursor behavior for the digital tablet varied in one respect from cursor behavior for the touchscreens. When the stylus was placed on the digital tablet, the relative location on the SGWS monitor was not obvious. The conferee might want to position his cursor accurately prior to drawing, erasing, or making menu selections. Consequently, the system displayed the cursor symbol as soon as the stylus was brought near the digital tablet, but drew, erased, or made a menu selection only when the point of the stylus was pressed down, activating a microswitch within the stylus.

To draw, the user selected a color from the palette on the "Main" menu by simply touching the desired color with the stylus on the digital tablet or his finger on the screen. When a color was selected, a replica of the cursor symbol in the selected color was displayed just above the color palette. Every time the user touched the screen or drew on the digital tablet, ink was deposited. While ink was actually "flowing," the cursor symbol did not appear.

To exit from draw mode, the user could either reselect the same color, causing the colored cursor symbol to disappear, or select the eraser box. In the latter case, the colored cursor symbol disappeared from above the color palette and was displayed in the eraser box. Then, when the user touched the screen, any ink beneath his finger was cleared from the display. The center character of the cursor symbol defined the contact point for erasing. Eraser mode was deactivated by reselecting the eraser box or by selecting a draw color.

Paging - The paging functions served two purposes: they automatically kept a history of any teleconference session, and they provided the vehicle for preparing and presenting a formal briefing. The use of the paging functions was directly analogous to using a tablet of paper. The conferees discussed and added to the contents of a page and, when the page was full, it was torn from the tablet, and a clean page was started. If the conferees wished to refer back to issues discussed on a previous page, they located the old page and reviewed its contents.

Instead of a paper tablet, the teleconference system maintained a file of fifty SGWS "pages." The file was organized into ten sections with five pages in each section. Each section was identified by a letter (A-J), and each page within a section was identified by a number (1-5). The user could recall any of the fifty pages, but was restricted in his ability to save pages. When both stations were in conference mode, any page could be accessed or saved by either station. However, in stand-alone mode, the Pentagon station could save pages in Sections A through E only, and the San Antonio station could save pages in Sections F through J only. Figure 4-4 illustrates the read-only and read/write privileges of both stations in either mode.

During a conference, the conferees would normally progress through the pages via the "Page+" key. When a new page (or the next page of a previously prepared briefing) was desired, the current page was saved in the slot reflected on the letter/number keys, the letter/number keys were incremented to reflect the next sequential slot, and any image already saved in that next slot was displayed. (The "Page-" provided the opposite function--it saved the current image in the current slot and retrieved the previous image.) If a previously prepared briefing was being presented, the "Page+" key provided the "next slide" control, or if an ad hoc conference was in session, it provided a history of the proceedings.

The letter and number keys were provided to allow random access to the fifty pages. These keys were used to locate the initial page of a briefing, the start page of a conference record, or random access to any page in the system.

	A	B	C	D	E	F	G	H	I	J
STATION 1 IN STAND-ALONE MODE	R/W	R/W	R/W	R/W	R/W	R/O	R/O	R/O	R/O	R/O
STATION 2 IN STAND-ALONE MODE	R/O	R/O	R/O	R/O	R/O	R/W	R/W	R/W	R/W	R/W
BOTH STATIONS IN FULL TELECONFERENCE MODE	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

5 pages per section

R/W — Read or Write
R/O — Read Only
There is no write capability to the shaded pages in stand-alone mode

Figure 4-4
READ/WRITE ACCESSIBILITY OF PAGES

Each time the page letter key was pressed, it incremented alphabetically from A through J, and then wrapped back to A without affecting the number key. The number key incremented from 1 to 5, and then wrapped back to 1 without affecting the letter key. Whenever the letter and number keys were used, the "Page+" and "Page-" functions were removed. This was to protect the user from accidentally destroying a page from someone else's domain. For example, if a user was preparing a sequence of slides in pages D1 through D4 and wanted to use some information he knew was stored in C2, he could use the letter and number keys to retrieve C2. Once he was in this other area, he might realize that the image he really wanted was in page C3. If he pressed "Page+" to get to the next page (not realizing that the "Page+" does a "Save" and a "Recall"), the current image would destroy the image saved in C2. Consequently, the system removed the capability to perform a "Page+" or a "Page-" immediately after the use of the number/letter keys. He must first do a "Recall" or "Save" to reactivate the paging functions.

The system also removed the "Page+" and "Page-" functions. as well as the "Save" function, when a user was in stand-alone mode and was accessing pages outside of his read/write area. He could locate and recall any of those pages, but could not perform any function that might save over one of them.

Clear screen - The clear screen function allowed the user to clear all of the annotation (foreground) at once, or to clear the background image. It was implemented as a two-step function to prevent someone from inadvertently clearing an image that the other conferees were still developing or discussing. When the "Clear This Page" option was selected, the "Clear This Page" button was intensified, and two new patches were displayed on either side--"Verify" and "Cancel" (see

Figure 4-5). At this point, the user was not allowed to take any action other than the selecting of "Verify" or "Cancel." If "Cancel" was selected, the right-hand portion of the "Main" menu was redrawn and no action occurred. If "Verify" was selected, the entire foreground was cleared, leaving the background intact. Once the foregound was cleared, or if there was no foreground, tne background was cleared by the same process.

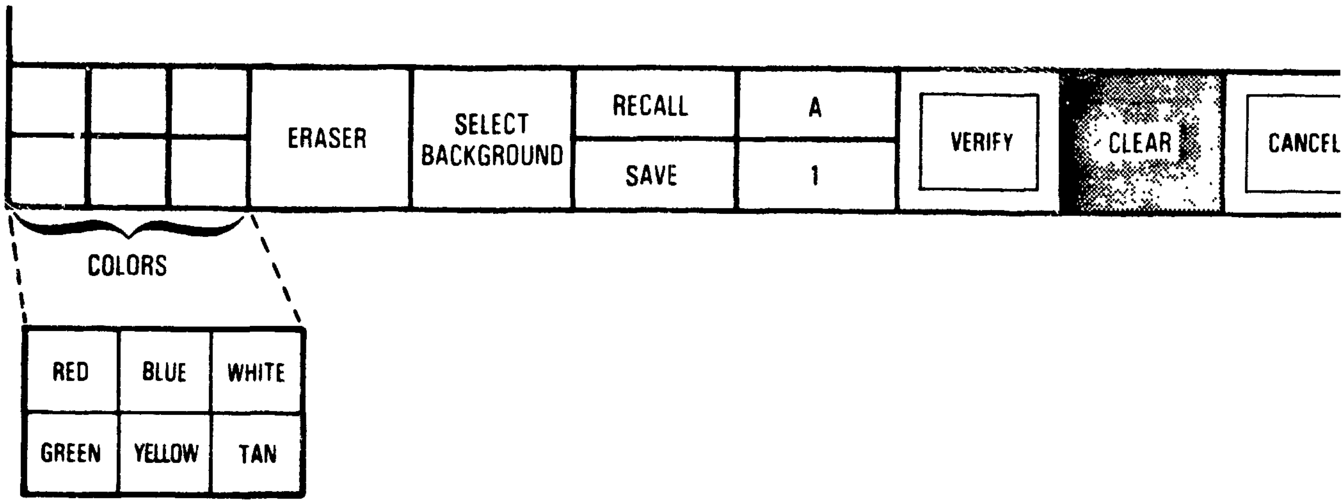


Figure 4-5
"CLEAR" VERIFICATION (USAF SYSTEM)

Control panel - This option provided the vehicle for a station to return to the "Control Panel" menu to adjust parameters or to "Hang-Up". This option was station independent; that is, one station could go to the "control panel" while the other stayed on the "Main" menu. When a station returned to the "Main" menu, any actions taken by the other station while the Control Panel was in effect were reflected on his SGWS.

Select background - The "Select Background" option provided an entire menu for selection of a videodisc frame or for capturing an image via the overhead camera. This option was also station independent. As long as one station was displaying and interacting with the "Select Background" menu, the other station still had full control of the "Main" menu and the current image. However, if a new background image was ultimately selected, the new background became the current image for both stations.

Select Background menu - The "Select Background" menu (as illustrated in Figure 4-6) provided the capability to capture an image for display via the overhead camera, or to select a videodisc frame. The videodisc frame selection emulated the use of the videodisc hand controller.

Overhead camera - The overhead camera was mounted in a copy stand with its own lighting and monitor. When an object was placed under the camera, the monitor built into the stand could be used to verify the positioning and focusing of the object prior to making the "Overhead Camera" selection on the SGWS. The camera lense was readily accessible for setting the "F" stop, the zoom control, and the focus, as appropriate. The brightness and contrast controls of the monitor were preset for optimal camera output, and the adjustment knobs removed. Once the copy stand monitor displayed a good image, the image could be transferred to the SGWS by selecting the "Overhead Camera" option.

Videodisc frame selection - A videodisc frame could be accessed in one of three ways: (1) a numeric keyboard allowed the user to enter a specific frame number, (2) a relative frame bar allowed the user to position the disc at a relative location, and (3) step forward and backward selections allowed the user to step through a portion of the disc one frame at a time. For all three methods, the selected image was displayed in the background, the relative frame bar indicator

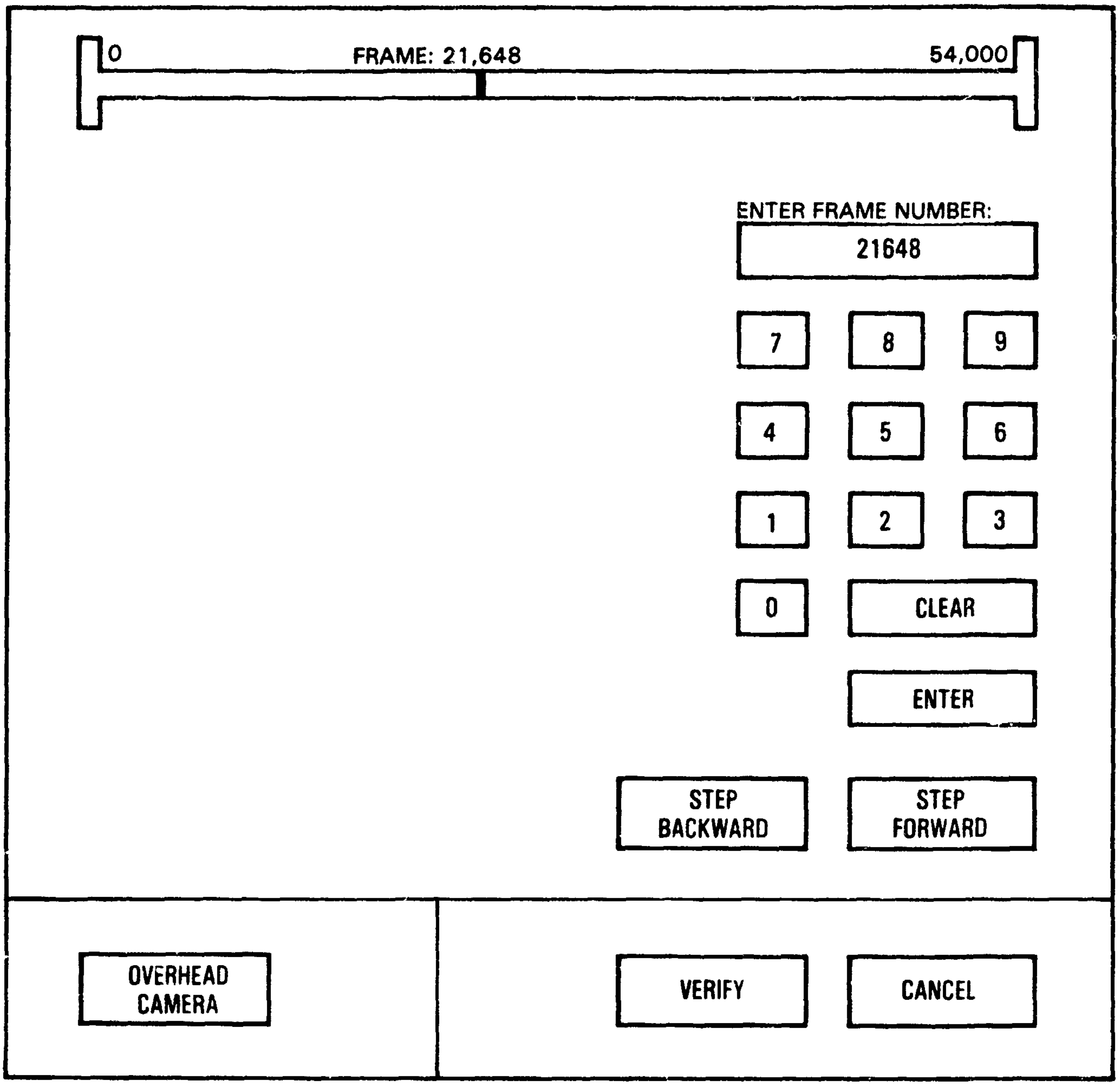


Figure 4-6
SELECT BACKGROUND MENU (USAF SYSTEM)

was displayed at the appropriate relative position, and the current frame number was displayed at the top of the screen.

To retrieve a specific frame, the frame number could be entered through the numeric keyboard. As each digit was entered, it was displayed along the top of the keyboard. If an error was made, the "Clear" key would clear the digits entered thus far, and the correct number could be reentered. Once the full number was correctly entered, pressing the "enter" key caused the selected frame to be displayed.

The relative frame bar was convenient when a specific frame number had been forgotten, but an approximate area was remembered. Each touch of the relative frame bar caused the relative area on the videodisc to be accessed and a videodisc frame to be displayed. A few touches of the bar could allow the user to get close enough to the desired frame so that the "Step Forward" or "Step Backward" options could be used to locate the specific frame. The frame number of the frame being displayed was indicated over the relative frame bar.

The "Step Forward" and "Step Backward" keys allowed the user to step through videodisc images one frame at a time. They caused the next sequential or previous videodisc frame to be displayed, respectively.

Cancel/verify - All the operations associated with the videodisc and overhead camera had no effect on the other station until "Verify" was selected. Should the conferee select "Cancel," the "Main" menu would reappear along with the previous image, and the two stations would continue to communicate as if the "Select Background" option had never been selected. However, if the user selected "Verify," the selected background image became the current image at both stations, with the "Main" menu displayed along the bottom.

5.0 CONCLUSIONS AND RECOMMENDATIONS

This research effort has explored several aspects of the very rapidly evolving field of teleconferencing. It has served as a testing ground for the earliest implementation of a fully operational (albeit in a test environment) virtual space system. Considerable effort has also gone into the development of a system for high-level decision makers, such as the National Command Authority, which will be user friendly and easy to operate with a minimum of training. The most striking outcome of this research has been the development of an interactive videographic subsystem, which has been called the Shared Graphic Workspace (SGWS). In addition, this research incorporated a video coder/decoder (codec), which was developed by Compression Labs, Inc. (CLI) under a DARPA contract, to test the effectiveness of severely compressed video images of conferees in various types of teleconference environments.

5.1 Virtual Space Teleconferencing

The experience that was gained from the four-station and five-station virtual space configurations indicated that the concept does provide a very realistic simulation of a face-to-face group meeting. Users often commented on the natural feeling it provided and its beneficial effect on conducting the conference. The ability to naturally maintain eye contact, observe direction of gaze and gesture to a particular person was preserved.

Although the increased number of video links required for a virtual space system drives the communication costs up, it should not be ruled out as an option. There are several situations where it would not be necessary to pay a common carrier for the communication links, and putting in dedicated links would be feasible. If all sites are in line-of-site, such as an industrial park or campus environment, microwave equipment is an excellent means of providing video links. Coaxial or fiber-optic cables would work is within a single large building like the Pentagon or a large office complex.

5.2 The Shared Graphic Workspace (SGWS)

The SGWS is a powerful tool for video teleconferencing, and is probably the most worthwhile outcome of this research. The ability to share documents or other visual material, and interact (e.g., point, draw, annotate, etc.) with them in real time during a teleconference over a low bandwidth link (dial-up telephone line or 4800-9600 bps digital data line) is really quite an enhancement to audio/video teleconferencing. With the integration of personal computers and networked word processing into today's offices, the desk-to-desk conferencing capability is not far away.

The SGWS needs to be enhanced by the addition of "office automation" capabilities. It should incorporate capabilities found on many of the emerging personal computers, such as "visicalc" type functions, business graphics, text handling, and mathematics.

The videodisc also needs to be evaluated further and tested as a storage device for both video information and as an economic storage device for digital data. The current system clearly demonstrates the functionality of the videodisc for storing relatively static data, and the output is of high quality. However, the companion effort to integrate real-time updates to that information needs to be developed. Again, the rapid advancement of the technology in this area for write-once videodisc systems and read-write devices should produce hardware to solve these problems.

5.3 User Friendliness

One of the goals of this research into teleconferencing was to develop a user interface suitable for high level decision makers. The use of touch-sensitive screens and digitizing tablets as input devices, instead of a keyboard, proved to be very effective for interaction with the menus that were developed to control the system functions. This combination of hardware and software, which reduces user input to logical choices from hierarchical sequences of menu options instead of keyboard entry of codewords and symbols, is a definite step in the right direction for motivating executives to use this type of aid, mainly because training is minimal and typing skills are not required.

There is a lot of work yet to be done in this area to take advantage of new hardware and software that is currently being developed for automating the work environment. The draw and erase functions need to be faster and easier to control accurately. Computer-generated graphics should be integrated into the SGWS to make composition of figures easier and the results more professional in appearance. The default conditions for the touchscreen and digitizing tablet could be more functional to minimize the amount of training required. The most obvious addition to the system would be a hardcopy output device to enhance the value of any conference that generates graphics.

5.4 Video Coder/Decoder (codec)

The codec used during this project was the Compression Labs, Inc. Sketchcoder, which operates at 19.2 Kb/s and produces a near full-motion, black and white (with no grey scale) sketch-like picture. The compression of a full-bandwidth video picture to that level is very significant, and may be a breakthrough in the technology that will eventually result in a high quality color image with full motion in the 56-64 Kb/s range, instead of the 1.5 Mb/s, which is currently required by commercially available codecs.

Use of these codecs indicated that even a severely compressed picture is a definite improvement over audio-only conferencing. The continuous presence they provided was much better than a freeze frame image for conveying non-verbal communication, such as attentiveness, body language, direction of gaze, gestures, and eye contact.

Therefore, the cost-benefit tradeoff between transmission cost and image quality is clearly in favor of video compression below 1.5 Mb/s; however the 19.2 Kb/s level is too severe. As the technology advances in the next year or two, a codec in the 64 Kb/s or 128 Kb/s will most likely be available, which will optimize that tradeoff, and provide images that will be acceptable to high level users of teleconference systems.