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Design of a Video Teleconference Facility for a Synchronous Satellite Communications Link

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SUMMARY

The design of a video teleconference facility that uses the Communications Technology Satellite (CTS) is presented. This design evolved, as part of an intra-agency teleconference system, from a set of system requirements that define operational characteristics compatible with other NASA Centers. Operational requirements and design trade-offs as well as proper lighting, graphics transmission, and picture aesthetics are considered.

The lighting system used greatly affects the quality of the transmitted picture and also conflicts with human engineering requirements, such as minimizing eye annoyance. A graphics transmission system that uses mirrors and a floor-mounted camera is shown. This system has the advantages over a conventional overhead-mounted camera of easier maintenance and reduction of potential camera damage when using a color camera system.

The delays encountered in a synchronous satellite communications link place restrictions on the audio channel in a teleconference application. The use of echo suppressors and judicious microphone and speaker placement are mandatory for echo control.

INTRODUCTION

Since the introduction of the communications satellite concept by such men as Arthur C. Clarke and R. A. Smith, the idea of video teleconferencing without using expensive leased landlines has become increasingly attractive. With the reality of high-powered broadcast communications satellites, video teleconferencing by using small ground terminals is now possible.

The Communications Technology Satellite (CTS) is a cooperative program of the United States and Canadian governments. The objective of CTS - launched in January 1976 - is to advance the technology of spacecraft and ground components related to high-power satellite communications systems. CTS is currently being used to demonstrate both high-power technology (>200 W at input to antenna) in the 11.7- to 12.2-gigahertz frequency band and its use for various communications services such as health, education, and video teleconferencing.

The key features in a video teleconference facility are system transparency and information transfer. System transparency is affected by a number of human factors such as lighting annoyance and manipulation of graphics material. Although the use of visual aids enhances information transfer, again such human factors as ease of operation are important. The use of a communications satellite imposes restrictions on system operation. Specifically, the delays encountered in the audio channel require special consideration.

This paper considers each of these features and presents a design for a video teleconference facility that is based on these considerations.

SYSTEM REQUIREMENTS

Through a CTS experiment, NASA is investigating the use of video teleconferencing as a supplement to, or substitute for, travel for intra-agency business. The Lewis Research Center, Ames Research Center, and Goddard Space Flight Center have implemented video teleconference facilities to support this investigation.

The design of the Lewis Research Center's video teleconference facility had to meet a set of system requirements. These system requirements, which were governed by existing room limitations and previously purchased video and audio equipment, are as follows:

(1) The facility should have dual capability (i.e., for standard in-house conferences and video teleconferences), with scheduling and usage priority for teleconferences.

(2) The facility should be convertible from a standard conference room to a teleconference room and back with a minimum of effort.

(3) The facility should serve both individuals and groups.

(4) Color video equipment (one camera) should provide coverage of not more than three prime participants; secondary coverage of six to eight participants may be accommodated within the same field of view. Similarly, the primary voice capability should accommodate those within the camera's field of view.

(5) The participants should be able to operate the facility.

(6) The teleconference hardware (cameras, electronics, etc.) should - as much as possible - not detract from, or interfere with, system usage. Electronics racks should not be placed in the teleconference room.

(7) Telephone service is required within the room.

(8) The facility should provide reception and display of color television to National Television System Committee (NTSC) standards.

(9) The facility should provide for transmission of participant-explained visuals (i.e., sketches, notes, or printed material) from a user remotely controllable zoom, overhead, high-resolution, black-and-white video camera.

(10) The system design should be able to accept a high-resolution color camera in place of the black-and-white camera for transmission of visuals.

(11) Cameras, power zoom, and switching should be controlled from simple-to-understand operator controls located in the teleconference table.

(12) The facility should resemble a normal conference room in terms of its light levels. Minimum lighting modifications are a goal although additional lighting with level adjustment may be required.

(13) The audio channels must be continuously open both ways; no form of manual or electronic voice switching is acceptable within the teleconference room. Echo suppression or feedback limiting may be included.

(14) The received sound must be of good quality and loudness. Acoustic feedback must not occur under any circumstances (within normal level ranges).

To obtain a solid information base for fulfilling these requirements, we consulted a number of people including commercial television studio personnel, the project engineer for the Ohio Bell System video teleconference project, and personnel from Westinghouse who are associated with a video teleconference experiment in Baltimore, Maryland. Reference 1, a state-of-the-art survey of teleconference facilities, was also used extensively to gain insight into the associated problems. The conflicts and trade-offs involved in meeting the design requirements are discussed in this section.

Lighting System

The lighting system used in a video teleconference facility is of major concern because of its effects on the final video picture and on the teleconference participants. The first requirement specified a dual-purpose room (i.e., both a teleconference room and a normal conference room). A serious conflict arises between room lighting and required camera lighting. Through consultation and experiment, five key elements have been identified:

(1) Aesthetics of transmitted picture - The teleconference participants should look natural. Wrong light placement will give people an unnatural appearance.

(2) Annoyance of light to participants' eyes - Most teleconference participants are not accustomed to high-intensity studio lighting. Also ambient light levels must be carefully controlled to avoid "flooding" a video monitor and producing a washed out image.

(3) Lighting fixtures compatible with room decor - Lighting fixtures should be unobtrusive in a teleconference room in order to minimize the feeling of being in a studio environment.

(4) Good color balance - The color television camera should "see" a balanced color spectrum, one that approaches natural sunlight.

(5) Limited contrast range - A television system has a contrast range of 20 to 1. In other words, a television system can display 20 shades of gray. In the real world,

the contrast range is 100 to 1 or greater Thus, adequate light must be available to make full use of the limited television contrast range.

In comparing these key elements to the requirements list, the following conclusions evolved:

(1) Camera coverage for three prime participants and six to eight secondary participants requires that the camera depth of field be 1.8 to 2.4 meters. The greater the depth of field needed, the higher the light level required.

(2) Easy conversion of the teleconference room to a normal conference room implies that camera lighting should be as unobtrusive as possible.

(3) A black-and-white graphics display, with the possibility of using a high-resolution color camera, requires a high light level to obtain the desired resolution.

(4) Reception and display of color television to NTSC standards requires enough light for the camera to operate above its noise threshold.

(5) A goal of normal conference room light levels is not practical. Normal conference room light levels are about 650 to 750 lumens per square meter (60 to 70 footcandles), and most color cameras currently require at least 1345 lumens per square meter (125 footcandles) for acceptable operation. Although cameras are available that perform well at 650 to 750 lumens per square meter (60 to 70 footcandles), their cost is prohibitive for teleconference applications. Normal conference room lighting usually is diffused fluorescent lighting. This diffused lighting illuminates facial features very unevenly (i.e., the forehead looks more prominent than the mouth or chin), which gives a person an unnatural appearance on a video monitor. Therefore some type of fill lighting is desirable to soften and control facial shadows.

Lighting that is pleasant to the human eye is inadequate for a color television system. Higher light levels are required to present the camera with an acceptable input. These higher light levels are generally annoying to teleconference participants. Light placement, light levels, and light spectrum are all interrelated and should not be considered from an electronics or participant point of view separately. Compromises must be made.

Graphics System

The capability of transmitting hand-drawn sketches or printed material by means of a high-resolution, black-and-white, remotely controlled zoom camera system is required. The system design should be able to accept a high-resolution color camera in place of the black-and-white camera.

Using a high-resolution, black-and-white camera for graphics transmission does not necessarily result in a high-resolution system. A high-resolution system requires a good-quality black-and-white camera and a good-quality black-and-white monitor.

The fact that a color monitor will probably be used in most video teleconferences immediately indicates a loss in line resolution as compared with a total black-and-white system. A color system carries chroma information (color) by sacrificing total system frequency response, or line resolution.

The requirement that the graphics system should be able to accept a high-resolution color camera in place of the black-and-white camera eliminates the use of an overhead (ceiling mount) camera. There is a greater risk of damage when current color television cameras are mounted in a vertical position (telephone communication with T. Chrupcala, Amperex Corp.). Damage may occur when a color camera pickup tube is positioned with its cathode (electron emitter) directly over the target (scene being scanned by the tube). In this position any impurities or "flakes" leaving the cathode could fall onto the target surface and cause "spots" to appear on the camera output signal.

The requirement that camera controls be simple to understand and operate and be located in the teleconference table is easily implemented and presents no special problems. Off-the-shelf zoom servosystems are available for most cameras.

Audio System

The audio system for a video teleconference facility has historically been a major problem. Reference 1 (pp. 31-53) discusses the various approaches taken to overcome this problem. Since the facility must be capable of using a synchronous satellite for the communications link, a brief examination of the total system will be helpful in describing the audio problem.

The total ground-to-spacecraft and spacecraft-to-ground communications system is shown in figure 1. An important operational characteristic of the satellite link is the propagation delay. This delay, as computed in figure 1, is approximately one-quarter of a second. That is, one-quarter of a second after an image or voice is transmitted from a ground transmitter site it will be received at a ground receiving site. This delay has a major effect on the audio system requirements for a teleconference facility. Any feedback path in the audio system will cause an annoying echo because of this propagation delay. This echo inhibits conversation and, under extreme conditions, totally inhibits audio communications. The echo problem can be minimized by using echo suppression circuitry. (Ref. 2 discusses the trade-offs involved when echo suppression is not used.) With current echo suppression circuitry, judicious placement of microphones and speakers is required for proper operation. In general, the audio system should be of good quality with professional-grade microphones and low-distortion audio power amplifiers. Public address system components are not acceptable because they produce high distortion levels.

Picture Aesthetics

One of the most important features of a video scene is the background content. A background that falls midway within the 20-to-1 contrast range produces a pleasing video picture. If the background color is at either of the extremes, picture aesthetics suffer. Another important feature of the background is scene separation. Background coloring that blends with the participants should be avoided. Wild colors and textures give the scene a "busy" feeling that is occasionally effective but generally undesirable. For this reason, pleated or multicolored drapery should be avoided if possible.

FINAL DESIGN

The preceding discussion identified conflicts between human needs and electronic equipment needs. The final teleconference facility design evolved from the resolution of these conflicts. In most cases, trade-offs were made that sacrificed electronic system performance in order to minimize human annoyance and thus encourage participation. Portions of this design have been used at the Lewis Research Center in actual teleconference applications.

Room Layout

Figure 2 is a side view of the video teleconference room layout. The dimensions shown are based on the characteristics of the color camera used (RCA TK-630), the 0.64-meter (25-in.) color monitor, and the required camera coverage. The camera height was chosen to maximize the teleconference participants' eye contact with the camera lens. Although only one camera is shown in figure 2, two are located in the camera area. One camera is used as a talent camera (views participants) and the other is used as a graphics camera. The backdrop is stretched drapery material extending from floor to ceiling and from wall to wall. It is a neutral beige color but is made to appear colored (red, blue, etc.) on the outgoing video picture by placing easily changeable color filters in front of the lights that illuminate it.

The upper room, labeled "electronics area," contains such setup equipment as video waveform monitors, video test generators, audio monitoring equipment, and auxiliary production equipment. This area is discussed in detail in the section Video System.

Figure 3 is a floor plan of the teleconference room. Extending the backdrop the width of the room minimizes the studio atmosphere. An added benefit of this backdrop configuration is the possibility of seating teleconference observers behind it. The backdrop is mounted on tracks that allow the drapery to be opened for normal conference room use. The space between the teleconference table and the backdrop (2.4 m) was chosen to accommodate six to eight secondary participants.

The table allows for three prime participants. Its construction makes it possible to obtain a narrower field of view than if a rectangular table were used. In the resulting "tighter" camera shot, the participants occupy a larger portion of the television picture.

A three-dimensional view of the room (fig. 4) shows the general room configuration. Floodlighting, backlighting, and microphones are not shown. The window above the camera area is used to view the teleconference area for such system setup as light level adjustments.

Graphics System

The dotted line in figure 2 shows the optical path of the graphics from the tabletop to the graphics camera. Figure 5 is a detailed view of the graphics system. By means of two front-surface mirrors the graphics image is "bounced" from the tabletop to a horizontally positioned color camera. The use of a mirror system has some advantages over an overhead-mounted camera system:

(1) The graphics camera can be positioned in an easily accessible location. This eases installation and maintenance requirements.

(2) The camera can be oriented horizontally. This minimizes potential camera pickup tube damage.

(3) Either a color or black-and-white system can be implemented and easily changed. The only visible component in the room is a 0.40- by 0.40-meter (16- by 16-in.) front-surface mirror mounted directly above the table as shown in figure 4. A second mirror mounted directly in front of the graphics camera is used to avoid image reversal.

One critical factor is this system is mirror alinement. Initial alinement is done by using elementary optics. Fine adjustment is made by trial and error. Once alinement is obtained, no further adjustments are necessary.

Because the optical path length is greater for the graphics camera than for the talent camera, a longer-focal-length lens must be used for graphics. Thus, a 2.5X add-on lens is attached to the graphics camera. With this lens a 0.216- by 0.279-meter ($8\frac{1}{2}$- by 11-in.) paper will fill a television screen when viewed by the camera from up to 7.6 meters (25 ft). This is more than adequate for the graphics optical path length shown in figure 4.

The camera controls for the graphics system are located in the teleconference table. The control is a "joystick" zoom control. Because of the graphics lighting used, the depth of field for the graphics camera is approximately 0.60 meter (2 ft). That is, the camera will keep objects in focus up to a distance of 0.60 meter above the surface of the table. This makes it possible to use three-dimensional objects (e.g., boxes and electronic circuit cards) as well as two-dimensional illustrations for graphics information.

Lighting System

Figure 6 shows the physical arrangement of the lighting system. The two diffused quartz-iodine lights directly in front of the electronics area are used as fill or base lighting. These two lights provide the general picture illumination and are set for 1080 lumens per square meter (100 footcandles). The diffusers reduce glare and eye annoyance. Three other types of light were added to this base light: key lights, backlights, and a graphics light. According to recommended television lighting practice as discussed in reference 3, key lights were added to the base light at a ratio of 1:1. The fluorescent lights shown in figure 6 function as these key lights and ideally should be 1080 lumens per square meter (100 footcandles). However, these are normal conference room fluorescent lights that measure approximately 750 lumens per square meter (70 footcandles) at 1.2 meters (4 ft) above floor level. The function of key (fluorescent) lighting is to accentuate the facial features of the teleconference participants. The orientation of these lighting fixtures is extremely important. In the orientation shown, they approximate the function of key lighting. If these lights were parallel to the conference table, glare and unnatural facial shadows would result.

The two outermost quartz-iodine lights in front of the backdrop have color gel mountings and are used to obtain a colored background. The light level is set at 538 lumens per square meter (50 footcandles). These lights separate the participants from the background and present a more interesting picture. The two quartz-iodine lights between the backdrop lights are used to backlight the prime participants and as auxiliary lighting of the six to eight secondary participants. The intensity of this light is 750 lumens per square meter (70 footcandles). This backlighting accentuates hair and shoulder features.

The graphics area of the teleconference table is illuminated by a quartz-iodine light directly above the table, offset from the center. The intensity of this light is 1080 lumens per square meter (100 footcandles). This highly directional, high-intensity light is used to fully illuminate the graphics area and to achieve maximum depth of field and maximum line resolution. All lights, with the exception of the fluorescent lights, are mounted on tracks.

The lighting fixtures used and light levels quoted are a compromise between picture aesthetics, human comfort, and electronic equipment needs. Recommended lighting practices are discussed in more detail in reference 4.

An electrical block diagram of the lighting system is shown in figure 7. The switches are in the conference room. The dimmer controls are in the electronics area behind the observation window. This arrangement prevents inexperienced conference room participants from varying the lighting levels.

Audio System

A number of tests were performed with CTS to assess the audio echo problem associated with a synchronous satellite communications link. Because echo suppression circuitry is used in the Lewis Research Center's super-high-frequency ground station, microphone placement within the room is critical. At least 16 decibels of audio separation between the microphones and the speaker is necessary for proper echo suppression. Twenty decibels is preferable. The use of carpeting and other sound-deadening devices in the room aids in this separation.

Figure 8 is a block diagram of the audio system. Two unidirectional (cardioid response) microphones are used on the teleconference table to minimize sound "dead spots." Placing the video monitor directly in front of the table forces the participants to face these microphones and produces a more constant sound pressure level - which further minimizes sound dead spots. An additional unidirectional microphone is placed behind the teleconference table for the use of the secondary participants. Unidirectional microphones minimize sound coupling between the microphones and the speaker. The Altec model 41905A echo suppressors used in the Lewis Research Center's CTS ground station are designed specifically for echo elimination on satellite circuits and long-distance telephone lines.

Participants have been highly critical of the sound systems used in teleconferencing. Therefore, professional-grade microphones and power amplifiers are used.

Video System

The teleconference room is essentially a dual-purpose room. Since production-type video equipment was on hand (character generator, fader, etc.), the room was designed to accommodate both a simple teleconference and expanded production activity. The electronics area shown in figure 3 houses the production equipment as well as camera setup controls and lighting controls.

Figure 9 is a block diagram of the complete video system. Because there are two modes of operation, a master control switch is used to switch in the auxiliary video equipment for the expanded production mode. With the master control switch set to the teleconference position, participants can select transmission of either themselves or graphics. They also can display either themselves or the received signal on the conference room monitor.

Figure 10 shows these controls, which are mounted in the teleconference table. The "talent" button selects the talent camera for video transmission and the receive video signal for monitor display. The "self" button displays the participants on the video monitor. The "graphics" button selects the graphics camera for video transmission and also displays the graphics on the video monitor. The "zoom control" is used to manipulate the graphics camera. The auxiliary mode is used to augment the basic teleconference hardware. In this mode, such special video effects as chroma key, wipe, luminance key, and title insertion may be used to enhance video presentation. Many combinations of special effects are possible in this mode, and the user may specify the actual system operation.

The zoom control is active in either mode and is used to properly frame graphics information. The switches labeled "conference room controls" are located in the rear center portion of the teleconference table.

Since this is a video teleconference application, every effort has been made to simplify operation of the system. Participants control the flow of information from the conference room controls. No other personnel are required for operation. To minimize operator error, the master control switch is used to switch between the teleconference mode and the auxiliary mode. This minimizes the switching necessary to use the room for a teleconference and subsequently minimizes switching errors.

General System Considerations

A number of the original requirements are of general interest. The dual-purpose requirement (standard in-house conference room and video teleconference room) is easily accommodated by opening the drapery backdrop and moving the teleconference table to a storage area. A minimum of electronic components (video monitor, microphones, and speaker) are present in the conference room.

A large-screen projection system was evaluated and the following conclusions reached:

(1) A large-screen projection system requires low ambient light levels. High light levels result in loss of contrast. The lighting requirements of current color cameras are in direct conflict with this requirement.

(2) The nominal viewing distance for any projection system is four to six times the picture height. Thus for a 1.2-meter- (4-ft-) high screen, the picture should be viewed from no closer than 4.8 meters (16 ft). This calls for a large room. A 0.64-meter (25-in.) monitor at a distance of 1.5 meters (5 ft) is adequate for three to six people and imposes less stringent requirements on the lighting system. A large-screen projection system is most effective for large groups of people in a low-light environment.

Therefore a large-screen projection system was not incorporated in the final teleconference room design. (Ref. 5 lists the various large-screen projection systems and reviews their operational characteristics.) Portions of the final room design have been incorporated into the Lewis teleconference facility shown in figure 11.

The availability of some of the video production equipment mentioned (e.g., video production switches) made it possible to expand the capabilities of the teleconference room. The RCA TK-630 color cameras are studio quality and produce excellent pictures. If higher light levels could be tolerated, low-cost color cameras could be substituted. These cameras would produce acceptable color pictures and substantially reduce the system cost.

CONCLUSIONS

The teleconference facility design incorporates many ideas currently being used in the television industry. Compromises were made, based on such human factors as eye comfort and the need for a relaxed conference room atmosphere.

Lighting greatly affects a color video picture. The need for auxiliary lighting was verified through subjective tests. The auxiliary lighting consists of fill lighting, used for uniform picture illumination; key lighting, used to accentuate facial features; background lighting used to separate the teleconference participants from the background and produce a more interesting picture; and graphics lighting.

A graphics system that uses mirrors and a floor-mounted camera facilitates camera maintenance and minimizes the possibility of camera pickup tube damage. The mirror system also allows easy camera substitution to accommodate either color or black-and-white television format. More importantly it can be easily changed with changing graphics requirements. Special attention to the graphics lighting is necessary to produce clear, sharp pictures.

Because of the delay encountered in a synchronous satellite communications link, echo suppressors and judicious placement of microphones and speaker are mandatory to control echoes. Professional-grade audio equipment is also necessary to minimize audio distortion. The placement of the microphones, the video monitor, and the graphics area forces the teleconference participants to face the microphones and produces a more constant sound pressure level. Control of both the graphics camera and the talent camera was simplified to allow teleconference participants to control the information flow with minimum effort.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, August 31, 1978,
610-22.

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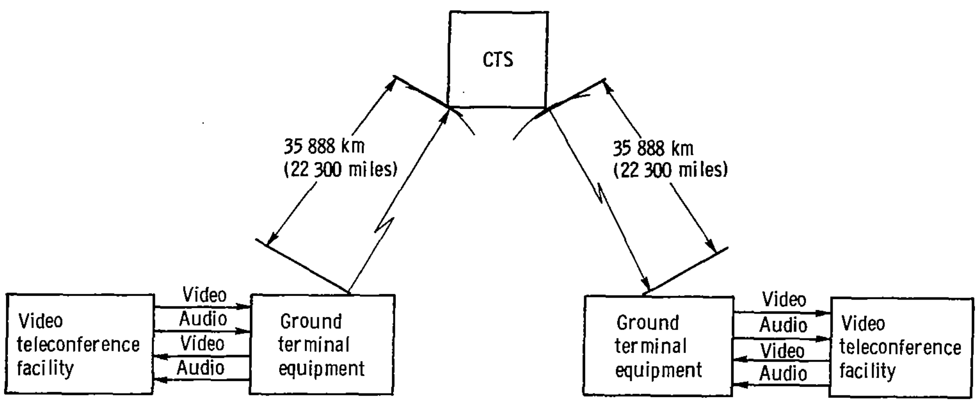

Figure 1. - Satellite-to-ground system. Propagation delay ≈ 0.24 second.

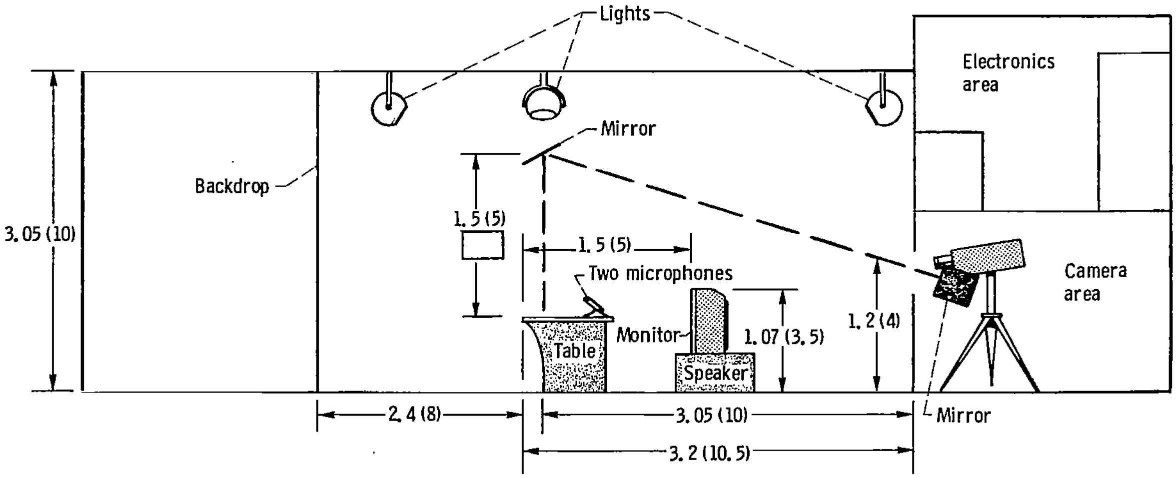

Figure 2. - Teleconference room layout. Graphics optical path length, 4. 75 meters (15. 59 ft). (Dimensions are in m (ft).)

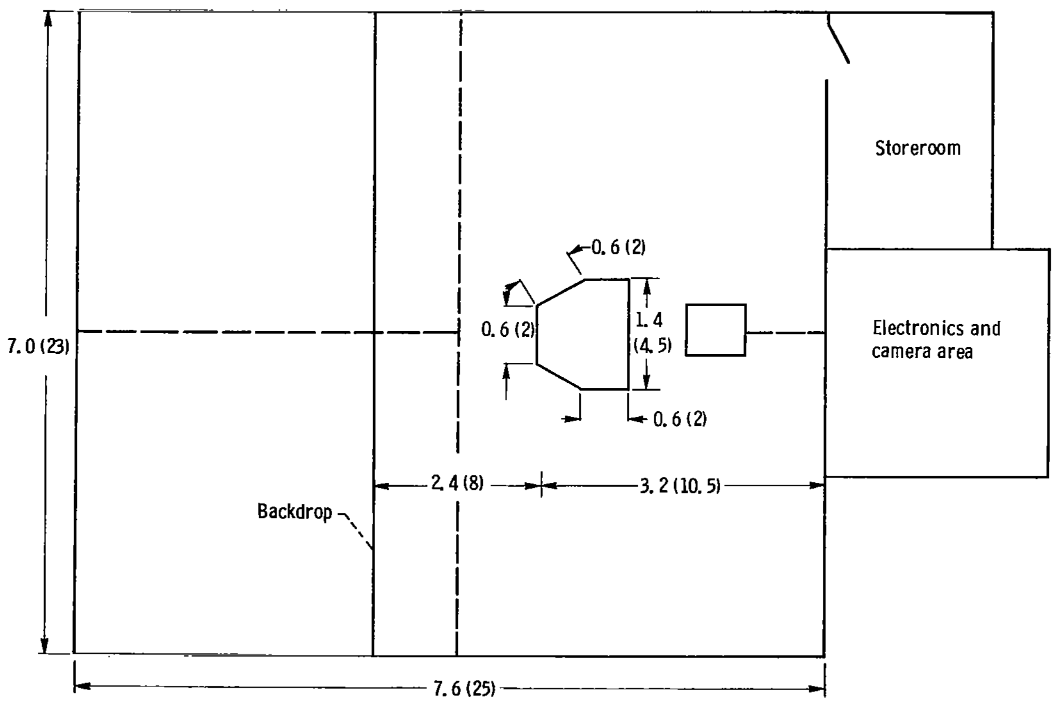

Figure 3. - Teleconference room floor plan. (Dimensions are in m (ft).)

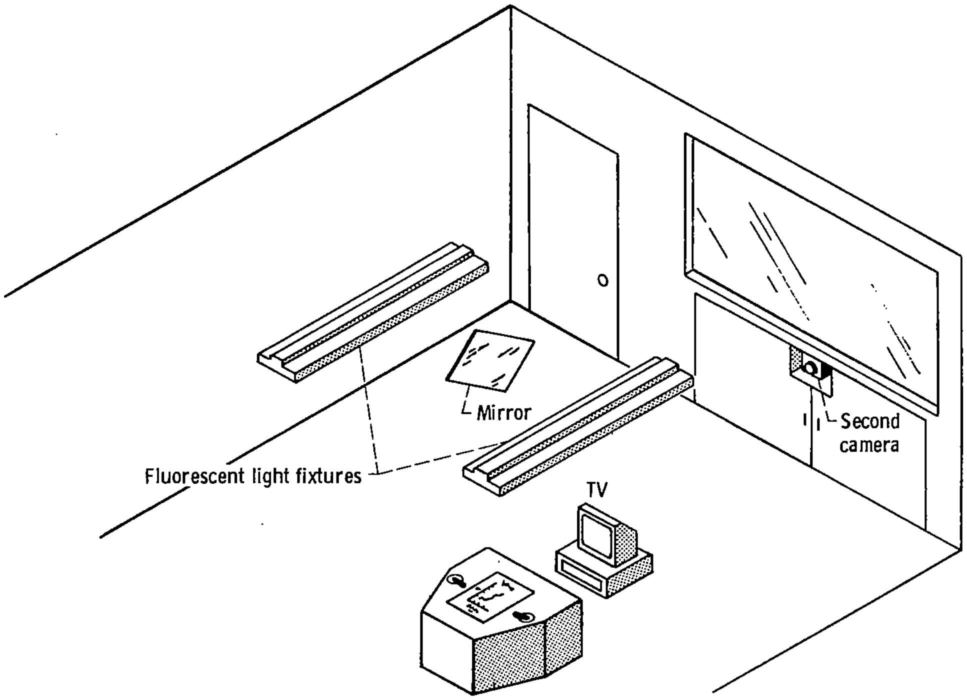

Figure 4. - Teleconference room - orthonormal projection.

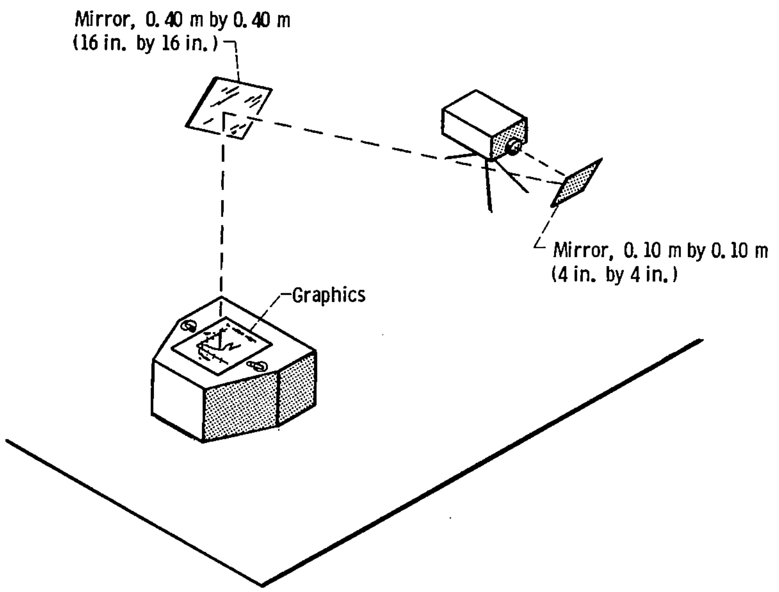

Figure 5. - Graphics system. Optical path length, 4.75 meters (15.59 ft).

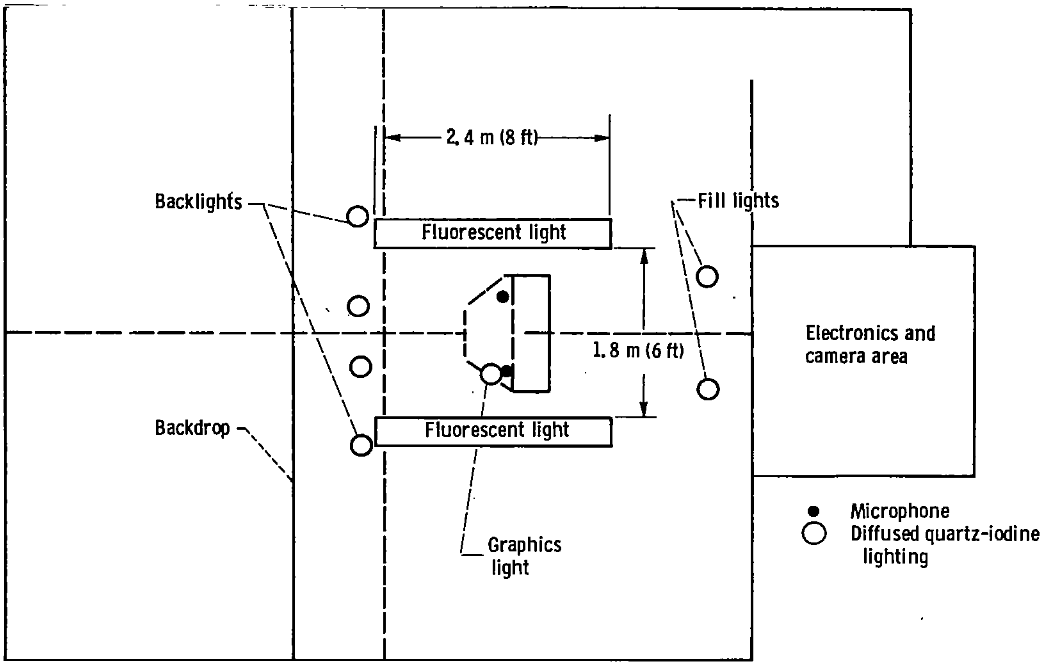

Figure 6. - Light placement.

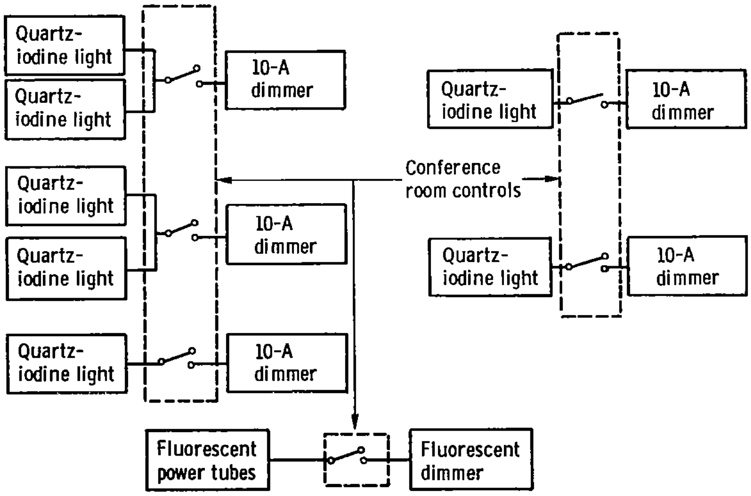

Figure 7. - Block diagram of lighting system.

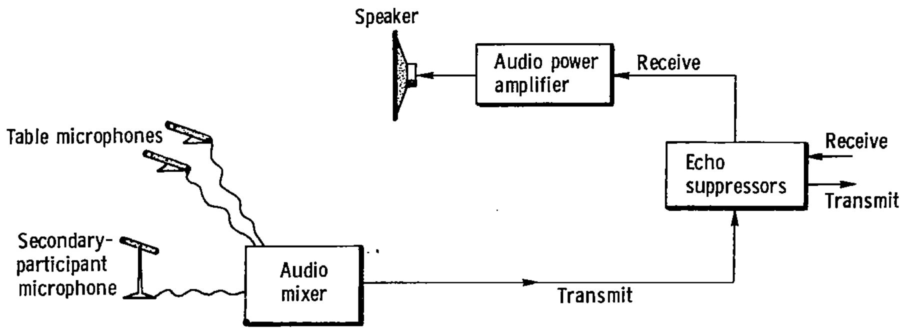

Figure 8. - Block diagram of audio system.

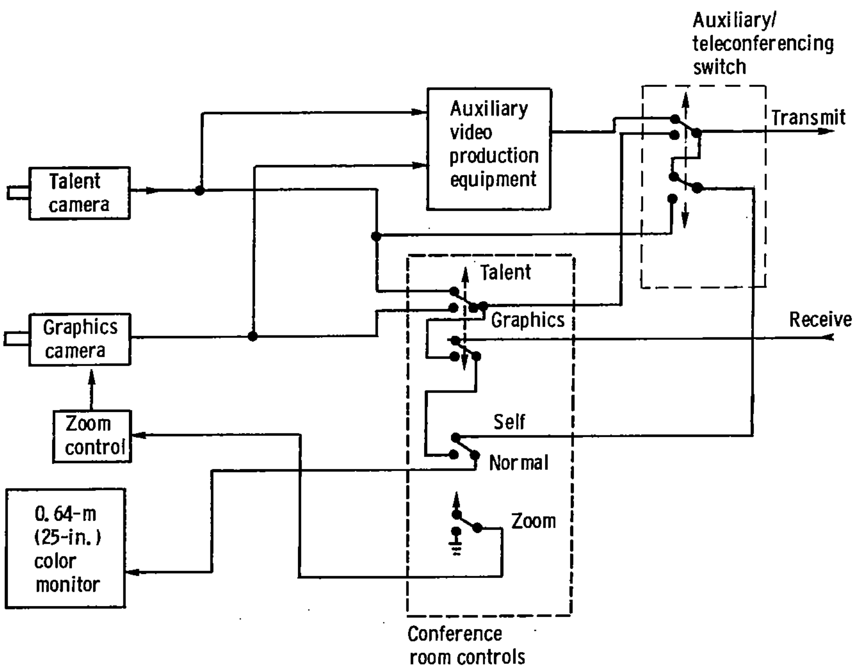

Figure 9. - Block diagram of video system. (Switch is shown in auxiliary position.)

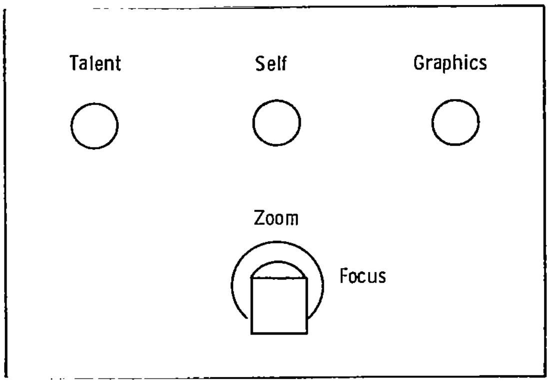

Figure 10. - Teleconference participant controls.

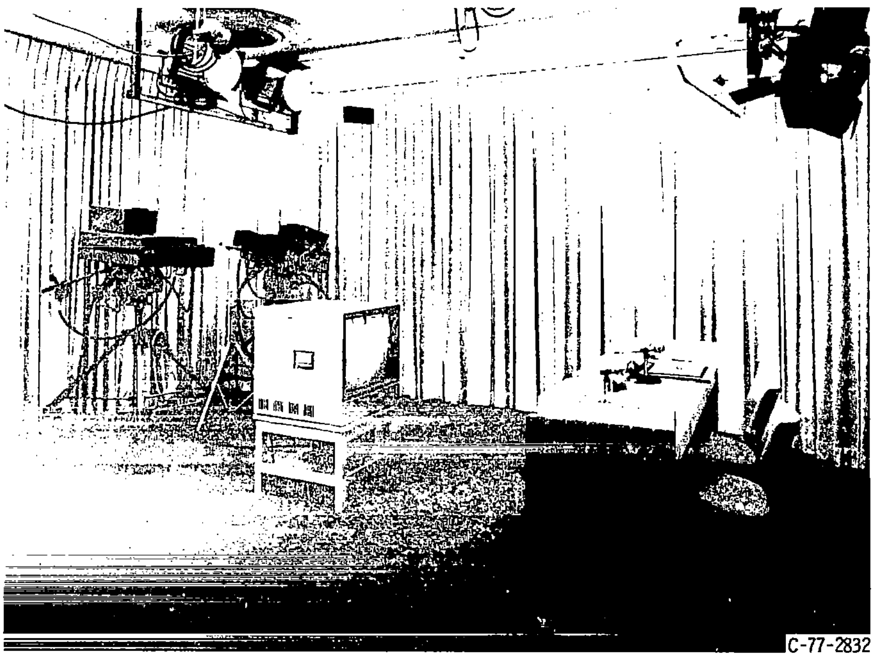

Figure 11. - Lewis Research Center's teleconference facility.

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16. Abstract

The system requirements, design trade-offs, and final design of a video teleconference facility are discussed, including proper lighting, graphics transmission, and picture aesthetics. Methods currently accepted in the television broadcast industry are used in the design. The unique problems associated with using an audio channel with a synchronous satellite communications link are discussed, and a final audio system design is presented.

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