# Putting Together the SMPTE Demonstrations of Component-Coded Digital Video San Francisco, 1981

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Assembling the system needed to stage the SMPTE Demonstrations of Component-Coded Digital Video required building a laboratory-quality television facility in a production environment. The system had to be measured and its transparency proved; then it had to be operated through four days of subjective assessments and system presentations with no chance to make up for lost time. This paper describes the system, the decisions behind its final form, and the results obtained.

## Arrangements

When the SMPTE committees working on the various aspects of digital video decided to hold a series of subjective picture assessments and system presentations using the component-coded technique, and, furthermore, decided to schedule them concurrently with the Society's 15th Annual Television Conference, a number of criteria were developed for the selection of a location for the demonstrations. Among these were a need for a large space for the experimental and support equipment, a separate space with a controlled illuminational and acoustical environment for the panelists and other invited guests, adequate power distribution facilities as well as a good ground system, and reasonable proximity to the Television Conference so that those traveling to one event could easily attend the other. In addition, the location had to be available for a period of six to eight weeks to allow the assembly, operation, and disassembly of the system.

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Ultimately, an offer from KPIX Television (Group W — Westinghouse Broadcasting Company) of the use of its about-to-be-activated Studio N was accepted by the Working Group on Digital Video Standards (hereafter, called simply "the Working Group"), which was the technical group directly responsible for conducting the Demonstrations. This location met all the criteria: nearly 7000 square feet (650.3 square meters) of space available, acoustically controlled environment, lighting and scenery grid which would allow separation into the necessary spaces, full lighting and power control system, low resistance ground system, and proximity to the Conference site (the St. Francis Hotel in San Francisco). A member of the KPIX staff is also a member of the Working Group and he was able to act as a direct liaison.

Further, the Working Group accepted an offer from Ampex Corporation for the use of its system integration capabilities, facilities, and personnel from nearby Redwood City to install much of the system, construct much of the special equipment to interconnect the system, and to help operate the system during the actual Demonstrations. This Ampex group had previously been responsible for putting together exhibits for numerous trade shows — building temporary systems and making them work reliably — and hence was uniquely qualified for this activity.

## Schedule

With the Television Conference scheduled for Friday and Saturday, February 6 and 7, 1981, it was decided to hold two days of subjective assessments on Monday and Tuesday, February 2 and 3, and two days of system presentations on Wednesday and Thursday, February 4 and 5. Given this schedule for the Demonstrations, the following timetable was worked out for the preparatory phase:

*Week of January 5.* Studio crew at KPIX hangs curtains to divide the space in Studio N. Lights are hung and roughed in. Ground system is extended into the studio. Special power provisions are installed.

Support equipment is delivered to Ampex facilities. All available gear is unboxed, checked, and mounted in racks. Preliminary wiring is begun. Digital patch panel is fabricated.

*Week of January 12.* RGBS interconnections (see section below on *RGBS System*) and switching are fabricated at Redwood City. Equipment in racks plus one-inch 'C'-format VTRs and 24-channel audio recorder are moved from Redwood City to KPIX. Power drops are made from lighting grid into each equipment rack or group. All power and ground connections are made for available equipment. Interconnection of all equipment is begun. Cables are put in place for experimental equipment not yet on site. Preliminary response and timing adjustments are begun.

*Week of January 19.* Video and sync wiring is completed. The first of the experimental equipment arrives. The debugging of the system is begun. Response and timing adjustments continue. The audio system is installed. The communications system is installed and checked out. The viewing area is constructed, dividers installed, and monitors placed. Final lighting work is begun — both in the viewing area and in the equipment area.

*Week of January 26.* Final experimental equipment arrives. All experimental equipment is integrated into the system. Debugging is completed. Response and timing adjustments are completed. The system "proof of performance" is performed. Final adjustments are made to the viewing setup. The special sets and materials for live camera use and for color matting are designed and constructed.

The order of the timetable was followed reasonably well. Slippage occurred, however, in the absolute time at which things were completed, resulting in conflicts that were sufficient to push back rehearsals into actual production time. While the four weeks scheduled would have been sufficient had all the equipment arrived on time and had it been ready to work as soon as it was turned on, in reality, five weeks would have been a more practical schedule.

### Physical Arrangement

The overall physical layouts of the equipment area and the viewing area are depicted in Figs. 1, 2, and 3. Approximately two-thirds of the nearly 7000 square foot studio was utilized for the equipment and viewing areas (Fig. 1). This area was divided, with approximately one-third as the viewing area and two-thirds as the equipment space. Adjacent to the equipment space was a portion of the studio which was used for the live camera and two sets. The remainder of the "unused" third was utilized for a waiting and staging area for panelists and audience members.

Within the equipment area, in order to reduce to the bare minimum the amount of cable equalization required, an attempt was made to arrange things in such a way that cable lengths could be minimized. At the same time, adequate space had to be allowed around each equipment grouping so that installation, troubleshooting, and operation could be done easily. The arrangement chosen was a group of equipment clusters, with sufficient space around each for moving oscilloscopes, monitors, and other test instruments, and allowing for several people to work on each cluster at one time. Within the cluster, however, equipment was close enough together so that the 10-foot (3-meter) maximum allowed for the length of cables without equalization would not be exceeded.

In order to further reduce cable lengths, the switching matrix and distribution system were put into a central cluster (Fig. 4), with the various signal source, experimental, and control clusters placed around it in a circular arrangement of more or less uniform radius. Also located within the central cluster were all of the various test signal generators, relay switches, delay lines, and the like, which were necessary to adjust or prove the system. (See Fig. 1 for the grouping of the equipment in the other clusters and for their relationship to the central cluster.)

### Viewing Area

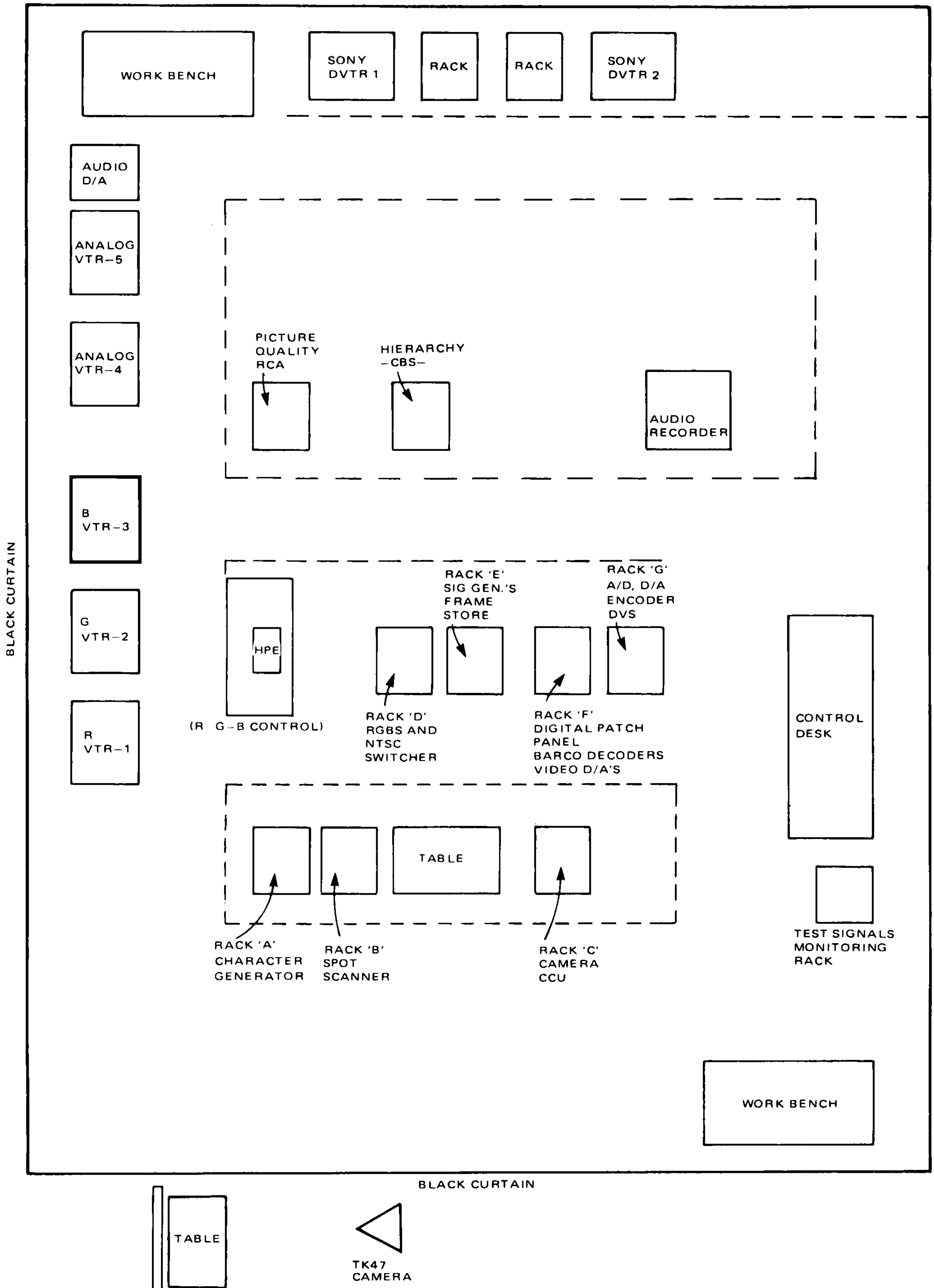
A great deal of effort was expended on making the viewing area come as close as possible to the conditions outlined in CCIR* Recommendation 500. All of the divisions between spaces were created by hanging heavy black velour stage curtains from the studio rigging to the floor. A single layer was used between the viewing/equipment area and the remainder of the studio, while a double layer, with several inches of space between the layers, was used between the viewing area and the equipment area to help control sound. Black cyclorama curtains already present in the studio were drawn around the remainder of the equipment area. The object was to reduce or eliminate any reflected light which might leak into the viewing area.

Within the viewing area itself, a gray cyclorama curtain having 60-percent reflectance was drawn behind the six monitors which were spaced along one side. The gray cyclorama

* CCIR = *Comité Consultatif International des Radiocommunications* (International Radio Consultative Committee).

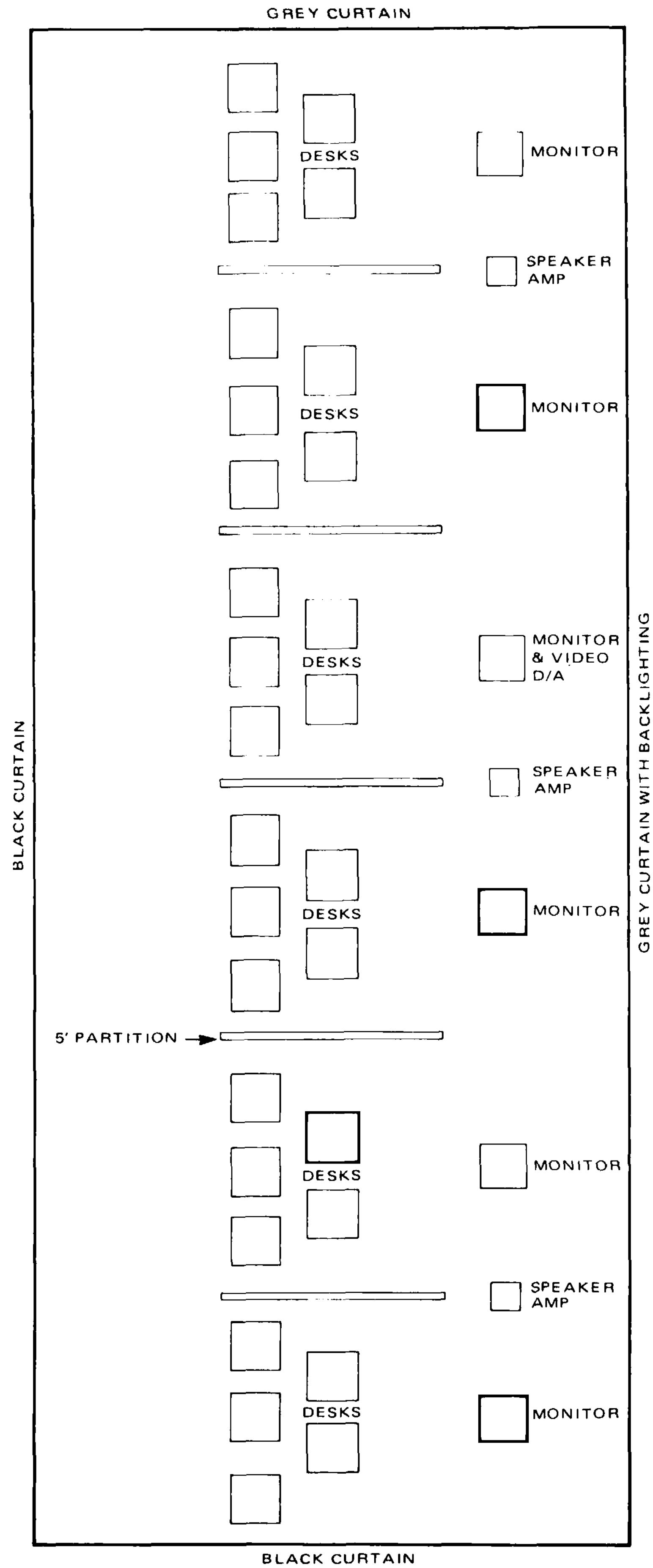
## Abbreviations and Acronyms

| | |
|---|---|
| **CCIR** | Comité Consultatif International des Radiocommunications (International Radio Consultative Committee) |
| **codec** | Contraction for *coder and decoder.* Such a device combines circuitry for coding and decoding |
| **CRT** | Cathode-ray tube |
| **EBU** | European Broadcasting Union |
| **ECL** | Emitter-coupled logic |
| **EIA** | Electronic Industries Association |
| **FIFO** | First-in first-out (register, data structure, etc.) |
| **FIR** | Finite impulse response (filter) |
| $F_s$ | Sampling frequency |
| $f_{sc}$ | NTSC color subcarrier frequency |
| **NTSC** | National Television System Committee |
| **PAL** | Phase Alternation Line (system) |
| **PCM** | Pulse-code modulation |
| **PROM** | Programmable read-only memory |
| **RGB** | Red, green, and blue (signals, channels, etc.) |
| **RGBS** | Red, green, blue, and sync (system, etc.) |
| **SECAM** | Sequential color and memory (system) |
| **spl** | Samples per line |
| **Working Group** | SMPTE Working Group on Digital Video Standards |




(a)

**Figure 1 (a and b). Equipment and viewing area floor plan.**




(b)

was lighted with uniform-dispersion, and soft lights were hung down over the tops of the monitors so that none of their light could impinge on the monitor screens. After the monitors had been set up, gels were carefully selected to match the color temperature of the lighted cyclorama to that of the monitors. The level of the lighting was then adjusted to match the output of the monitors when they were fed the mid-gray which was used between the reference and test pictures during the subjective assessments. The object was to normalize conditions surrounding the monitors, insofar as possible, to the average conditions appearing on the monitors. This was so the viewers' eyes would not have to adjust any time there was a picture change or any time they looked away from the monitors.

Monitors were placed on stands at approximately eye level, so that the average viewer was looking squarely at the screen. Student desks were used for the viewers so that a writing space was easily available. Most panels consisted of a total of 30 assessors, divided into six groups, with each group having its own monitor. In each group there were five members, two located so that their eyes were four times the picture height from the screen, and three located so that their eyes were six times the picture height from the screen. One panel consisted of twelve assessors who were divided into groups of two so that they could be located with their eyes two and one-half times the picture height from the screen in order to simulate viewing of large-screen displays. Neutral gray office dividers were placed between groups in such a manner that all the members of any one group could see only their own monitor and neither of the adjacent monitors.

Monitors used were Barco type CTVM 3-51-D/A high-resolution shadow-mask units with 20-inch (51-centimeter) diagonal-measure screens. (Monitor characteristics are shown in Table 1.) These monitors used the European Broadcasting

**TABLE 1 — Monitor Characteristics**

| Characteristic | Description |
|---|---|
| Type | Barco CTVM 3-51-D/A |
| Tubes | High Resolution Shadow Mask |
| Size | 51-cm (20-in) |
| Resolution | 350-micron triad spacing (approx. 1100 lines) |
| Bandwidth | 15 kHz–7 MHz ± 0.5 dB<br>7 MHz–10 MHz + 0, −3 dB |

Plate 1. Boy with toys (courtesy EBU).

Plate 2. Boats (courtesy EBU).

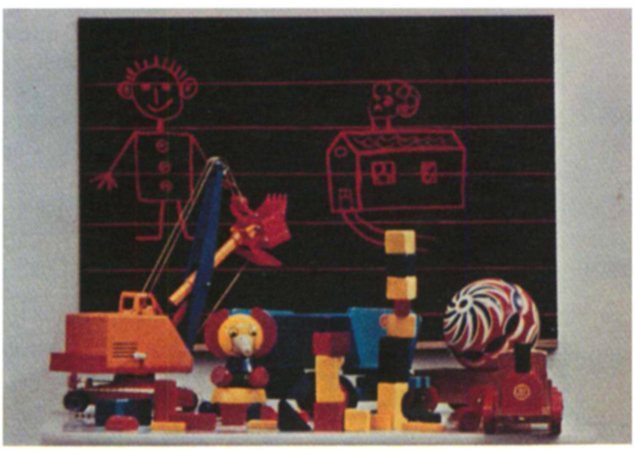


Plate 3. Blackboard (courtesy Philips).

Plate 4. Formal pond (courtesy EBU).


Plate 5. Typical character generator page, from live signal.

Plate 6. Foreground for color matte experiments, from live signal.

Union (EBU) phosphors so those witnessing both the EBU and SMPTE experiments would be using monitors with the same characteristics. As in the EBU demonstrations, it was necessary to reduce the light output from the CCIR recommended value of 70 fL (footlamberts) down to 50 fL in order to reduce the amount of color impurity present. The background lights were adjusted with the monitors set to the 50-fL level.

While the results produced in the viewing area were judged good with regard to elimination of reflections from the faceplates of the monitors at any of the normal seating positions and the color match and intensity of the background, if it were to be done again, an attempt would be made to use three times as many luminaires with gels for the primary colors. Then, all the time spent experimenting to find the correct gels to match the color temperature 6500 K could be eliminated, and a closer color match could be obtained simply by varying the levels of the individual primaries. One problem which would have to be addressed in such a case would be the maintaining of color uniformity across the background.

A problem was that some of the assessors, especially those at the 6X viewing distance, complained of inadequate illumination for writing on their voting forms. This problem was exacerbated by the necessary reduction in output from the monitors and the attendant reduction in background illumination. If it were to be repeated, low-level overhead lighting would be provided, pinpointed on the writing surface of each desk. This illumination, of course, would have to be color matched to the monitors and set to the level of the background, too.

Figure 2. Overview of the equipment area. On the left are the character generator and slide scanner racks. Adjacent is a table with controls for them. At the bottom on the left is the top of the rack for the live studio camera CPU. At the back on the left is the RGB tape recorder. In the center is the center equipment cluster. At the back center are the two NTSC tape recorders. Behind the central cluster are the direct-sampling picture-quality experiment (left) and the hierarchy-conversion picture-quality experiment (right). On the right at the rear is part of the digital VTR. Cables hanging down throughout are power drops from the lighting grid to the equipment clusters.

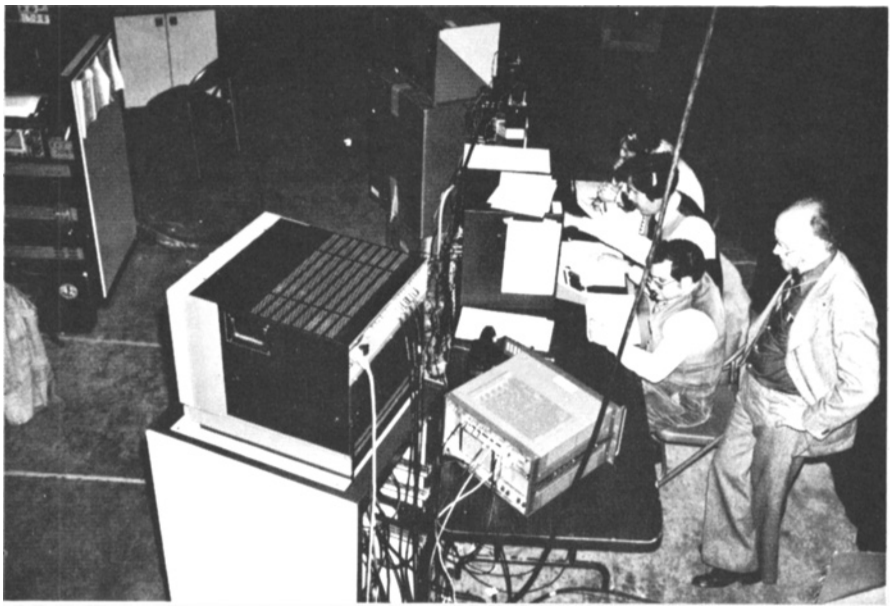


Figure 3. Control desk view. (Front to back) the producer (standing, doubles as Chairman of the Working Group), the assistant director, the director, and the audio operator. Directly behind them is the curtain, and on the other side of the curtain is the viewing area. The rack in the middle of the desk contains all the control equipment. On top of it are radio base stations for the wireless headset system.

## RGBS System

Early in its discussions of component-coded digital video, the Working Group had settled upon $Y$, $R - Y$, and $B - Y$ (henceforth $Y$, $C_R$, and $C_B$), as the components which would be utilized. In preparing for the Demonstrations, however, it quickly became apparent that all of the signal sources, monitors, and other support equipment could be obtained or made to work directly only in $R$, $G$, and $B$. Therefore, the decision was made to build the central distribution system based on $R$, $G$, and $B$ signals, and to require the experimenters to generate their own $Y$, $C_R$, and $C_B$ signals. Such an arrangement had a number of advantages. The central system could be built using standard, noncomposite video techniques without setup. Sources could be directly displayed on monitors without any intervening conversions, thereby retaining the "purity" of the original sources as references. Further, it allowed investigation of whether the conversion from $R$, $G$, $B$ to $Y$, $C_R$, $C_B$ should be made in the analog or the digital domain. Since a digital interconnection between experiments was contemplated, it would allow for the use of back-to-back connections of each of the various types of conversions, since at least one experimenter was planning to implement each type of conversion.

The relationships established by the Working Group between the $R$, $G$, and $B$ signals and the $Y$, $C_R$, and $C_B$ signals were:

$$Y = 0.299R + 0.587G + 0.114B$$

$$C_R = 0.500R - 0.419G - 0.081B$$

$$C_B = -0.169R - 0.331G + 0.500B$$

The remaining problem to be addressed was that of system timing. Since a three-level distribution switcher was already required, the decision was made to utilize a four-level switcher with the fourth level carrying sync signals. Each experiment was required to accept 1 volt of composite sync in time with the video on its $R$, $G$, and $B$ inputs and to put out 1 volt of sync in time with its $R$, $G$, and $B$ outputs. In this way, experiments could be cascaded at will without deleterious effects caused by sync timing. A transient picture jump could occur on the monitors as any given experiment was switched in or out, due to delay changes. The amplitude of the transient is a function of the time constants in the display monitors and is completely unrelated to the performance of the switching equipment.

**Figure 4. Central equipment cluster. The rack on the left contains the switching matrices. To the right is the rack with test signal generators, the UltiMatte, sync generator, and zone plate generator. Further right is the rack with the analog decoders at the top, processing amplifier, digital patch panel, and routing switcher control. The rack on the extreme right has converters for analog RGB to digital components and for digital components to analog RGB plus an encoder for digital components to analog NTSC.**

## Central Switching and Distribution

It became evident early in the planning that it would be necessary to interconnect virtually every output to every input at one time or another, and that the changes would have to be accomplished rapidly. Accordingly, a central routing switcher became the only means to accomplish the task at hand. The unit utilized was the System 21, provided by Dynair Electronics. It had four 10 × 10 matrices operating in parallel to handle the RGBS switching and another 10 × 10 matrix for NTSC switching.

The original estimate of 10 inputs and 10 outputs was found inadequate, but the commitment to a 10 × 10 matrix was already made; hence, some preswitching had to be fabricated to allow primary inputs to be shared by multiple sources. A block diagram of the system is shown in Fig. 5. The Redwood City group came up with an assembly using crystal can relays in die-cast boxes which substantially exceeded the performance specifications for the system, and which could be arranged in singles or quads as necessary. Output sharing was accomplished by using the two outputs of the routing switcher or with distribution amplifiers, as necessary.

Because of the requirement for cascading sources and experiments and monitors, the signals had to be routed in and out of the switching and distribution system several times for each setup. Consequently, any distortions or cross talk appearing in the signal path were multiplied by the number of times through the system. Since much of the switching involved A–B comparisons, small errors were easily discernible. As a result, careful attention had to be paid to the performance of the components and to the adjustment of the system. Tight control over the system was maintained by providing active equalization in any signal path over 10 feet in length. Performance results for the switching and distribution system are shown in Table 2.

**TABLE 2 — Switching and Distribution System Performance**

| Characteristic | Description |
|---|---|
| Path | One pass, comprising two equalizing amplifiers, one switching matrix path, and two 50-ft (15-m) cables. |
| Frequency Response | 0.1 MHz–6 MHz ± 0.1 dB<br>6 MHz–10 MHz + 0, −0.4 dB |
| Differential Gain | 0.2 percent |
| Differential Phase | 0.2 degree |
| K-Rating, Bar | 0.3 percent |
| K-Rating, Pulse & Bar | 0.2 percent |
| Gain Difference, P/B | ±0.2 dB |

## Signal and Picture Sources

A wide range of signal and picture sources was available to permit system alignment, to provide material for the subjective assessments, to demonstrate performance of the experimental equipment, and to permit measurements by members of the Working Group and others. Each of the available sources, other than the experiments themselves, will now be described in turn.

The gray generator consisted of a resistor matrix which provided equal outputs on the $R$, $G$, and $B$ channels at approximately 20 IRE units, together with 1 volt of sync on the $S$ channel. It was used to provide the monitor signal separating the reference picture and the test picture during the subjective assessments. It was also switchable to black for use in the system setup procedures.

The live studio camera was an RCA

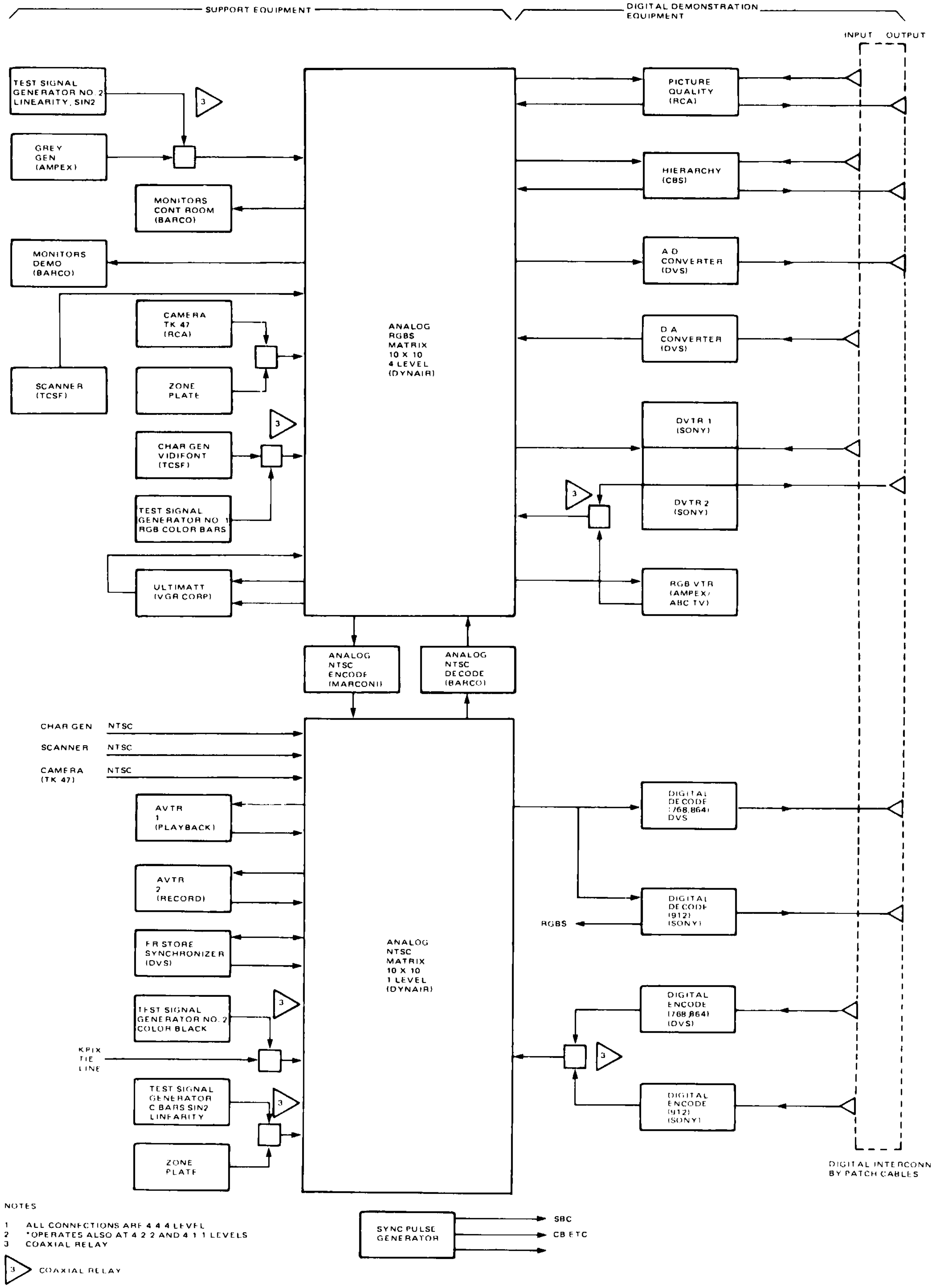



**Figure 5. System block diagram.**

TK-47. Only the *R*, *G*, and *B* outputs were used during the assessments and presentations, although the NTSC output was available on the NTSC matrix. The camera was operated with *Aperture Correction* turned on and set to 51 percent. *Contours* were turned off. Electrical setup was performed twice daily utilizing the automatic setup system and the internal diascope. Performance results obtained using BBC Test Card 52 and EIA* Gray Scale are shown in Table 3.

Two scenes were shot with the live camera. The first was a grouping of colored cards, mounted on wallpaper having many luminance and chrominance transitions in all directions, with a group of toys and other objects having high detail and chrominance content sitting on a table in front. This came to be called the "Busy Scene." (See the color illustrations on page 930.) Included on a blue card in this scene was a series of red wedges that came to a single point. This was used to show the worst possible color-difference transitions. Also included in the scene during the assessments were some live flowers. Photographs of the busy scene were taken with high accuracy for purposes of the record and to allow its use in any future demonstrations or quality assessments. During the system presentations, a doll was moved into the "Busy Scene," and this is the arrangement shown in the center of Fig. 6.

The other scene shot with the live camera was the "Color Matte" scene. During the assessments, this consisted of the toy doll just mentioned sitting on a table in front of a blue background with twisted crepe paper ribbons on either side of her. The twisted crepe ribbons were used as a means for examining the bandwidths required for accurate color matting since, when seen in two dimensions by the camera lens, they come to a very fine point. During the system presentations, the doll was moved into the "Busy Scene," and a live model was substituted in the "Color Matte" scene, as seen on the right in Fig. 6. The twisted crepe paper ribbons were retained. The model held out her hair with a comb so that the ultimate resolution of the color matte could be studied. Also, the comb itself was matted through at various sizes and angles to investigate the required bandwidths for accurate matting.

A Thomson CSF Model TTV 2705 flying-spot slide scanner was utilized for all slide presentations. Performance measurements on the scanner, made using BBC Test Slide 52 and a gray scale slide, are shown in Table 4. As in the case of the live camera, the scanner was available on the NTSC matrix, but only the *R*, *G*, and *B* outputs were used for the assessments and presentations.

A number of slides are recommended by EBU for digital systems testing. Those used for the subjective assessments (see the color ilustrations on page 930) were "Boats," "Blackboard," and "Formal Pond." The slide "Boy with Toys" was used as the background for color matting during the assessments. During the system presentations, "Blackboard" and "Formal Pond" were used, with "Formal Pond" serving as the background for color matting and as the

**TABLE 3 — Live Studio Camera Performance**

| Characteristic | Description |
|---|---|
| Type | RCA TK-47 equipped with Fujinon 14X H.R. zoom lens. |
| Setup | Electrical setup by RCA microprocessor-controlled automatic setup system using internal diascope. |
| Operation | *Contours* selected to OFF. *Aperture Correction* turned ON and set to 51 percent. |
| Measuring Technique | BBC Test Card 52 and EIA gray scale. Tektronix 1485 Waveform Monitor, Rohde and Schwartz UPSF Noise Meter, Tektronix 465A/DM44. |

Frequency Response

| | Frequency (MHz) | | | | | |
|---|---|---|---|---|---|---|
| | 1.4 | 2.7 | 3.4 | 4.3 | 5.0 | 6.0 |
| *Y* | 105 | 99 | 103 | 88 | 94 | 75 |
| *R* | 103 | 93 | 95 | 80 | 85 | 73 |
| *G* | 105 | 102 | 107 | 94 | 100 | 78 |
| *B* | 110 | 95 | 101 | 80 | 88 | 63 |

Note: Values expressed in percent relative to nearest adjacent black/white step.

Signal-to-Noise Ratio (dB relative to 0.7 V p-p)

| | Unweighted | Weighted |
|---|---|---|
| *Y* | 50 | 56 |
| *R* | 44 | 44 |
| *G* | 49 | 55 |
| *B* | 40 | 46 |

Note: Measurements taken @ 50 IRE, *Aperture* OFF, *Contours* OFF, *Gamma* OFF, *Camera Sensitivity* set to 0.7 V out @ 125 fc @ f 4.

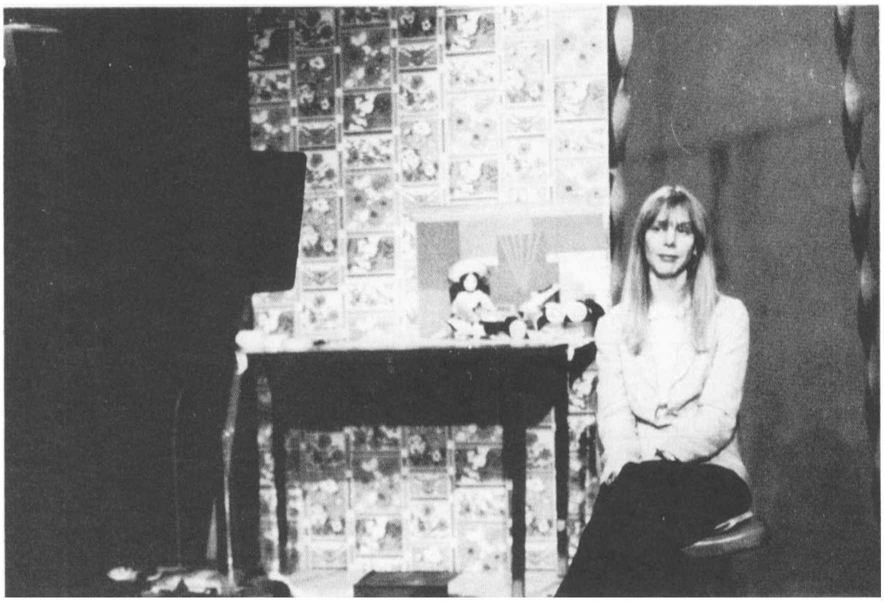


**Figure 6. Scenes used for the live studio camera. In the center is the "Busy Scene" material mounted on the wallpaper and sitting on the table. On the right are the model and the twisted crepe paper ribbons used for color matting.**

* EIA = Electronic Industries Association.

**TABLE 4 — Slide Scanner Performance**

| Characteristic | Description |
|---|---|
| Type | Thomson CSF Model TTV 2705 Flying Spot Scanner |
| Setup | Electrical and Mechanical size, position, and focus adjusted using RCA aperture mask, grating slide, and multiburst slide. |
| Operation | Channel response trimmers adjusted for best overall frequency response. *Automatic black and white level control* ON. |
| Measuring Technique | BBC Test Slide 52 and gray scale slide. Tektronix 1485 Waveform Monitor, Rohde and Schwartz UPSF Noise Meter, Tektronix 465A/DM44. |

Frequency Response

| | Frequency (MHz) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0.5 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 3.5 | 4.0 | 5.0 | 6.0 |
| *Y* | 100 | 100 | 97 | 100 | 100 | 105 | 110 | 103 | 70 | 50 |
| *R* | 100 | 95 | 100 | 105 | 110 | 112 | 113 | 105 | 60 | 50 |
| *G* | 100 | 100 | 98 | 100 | 105 | 110 | 112 | 102 | 60 | 50 |
| *B* | 100 | 96 | 100 | 105 | 110 | 115 | 115 | 110 | 60 | 70 |

Note: Values expressed in percent relative to nearest adjacent black/white step.

Signal-to-Noise Ratio (dB)

| | Unweighted | | Weighted | |
|---|---|---|---|---|
| | 20 IRE | 50 IRE | 20 IRE | 50 IRE |
| *Y* | 44 | 44 | 51 | 52 |
| *R* | 35 | 35 | 44 | 44 |
| *G* | 44 | 46 | 50 | 56 |
| *B* | 41 | 44 | 50 | 56 |

subject for the horizontal picture expansion demonstration.

The character generator used was a Thomson CSF Vidifont Mark IV-A. It provided titling information for the instruction tapes used during the subjective assessments and for the system presentations, and it served as a high quality picture source for both functions. Although its clock frequency of 22 MHz provided picture elements in 45-nanosecond increments, its *R*, *G*, and *B* outputs were passed through 5.5-MHz low-pass filters to represent a more realistic picture source. For the assessments and presentations, a message was composed using very sharp color and luminance transitions between the foreground characters and the color background. (See the color illustration on page 930.) This was another excellent means of probing the limits of the systems being tested. As in the cases mentioned previously, the character generator was available directly on the NTSC matrix, but only the *R*, *G*, and *B* outputs were used for the assessments and presentations.

For finding the differences between television systems and standards, one test signal stands out among all the rest. It is the time-varying zone-plate signal and was provided for the Demonstrations by the VG Electronics Model 1032. This unit permits horizontal, vertical, circular, and hyperbolic frequency sweeps, or zone plates, and will also produce moving patterns by adding a temporal component. Furthermore, sweeps of the temporal component are possible, in addition to those of the two spatial components, thereby allowing a test signal which examines motion effects. This also allows examination of the effective bandwidths of systems in all directions and the easy location of aliasing components. The zone plate was available both as a monochrome source and as a magenta source in the RGBS system, and as a monochrome source in the NTSC matrix.

A wide range of other, standard test signals was available. These included RGB color bars from a modified Tektronix 1410 signal generator, digitally generated NTSC color bars from a Tektronix 1900, NTSC color bars over a red field from a Tektronix 1410 for looking at decoder performance, and the normal range of multiburst, modulated stairstep, frequency sweep, window, pulse, composite, and other signals.

Also available as sources in the RGBS matrix were the outputs of the *Direct Sampling* picture quality experiment, the *Hierarchy Conversion* picture quality experiment, the color matte generator, the analog NTSC decoder, a digital NTSC decoder, the analog RGB videotape recorder, and the demonstration digital VTR. Many of these sources are described in other articles in this special issue. Some will be described later in this article.

## Outputs and Processing

Most of the outputs from the RGBS system served as inputs to the various experiments or fed the setup and control or viewing-area monitors. The outputs to the viewing area, in fact, fed distribution amplifiers which were located with the monitors and which provided the necessary equalization for the longer cable run. In addition, several different encoders were fed to make the interface into the NTSC system. Other outputs fed the RGB VTR and the digital VTR.

Two outputs served as the input to one device which proved to be the most critical path from the standpoint of determining the differences between systems. Those two outputs fed the *Foreground* and *Background* inputs of the UltiMatte Color Matte Generator supplied by VGR Corporation. Color matting provides a linear matte where the background signal replaces the foreground signal proportionally to the foreground blue level, resulting in a very high quality effect. In the process it makes use of the functions of addition, subtraction, and multiplication of the video signals; it is therefore a good example of the kinds of processing to which video signals will be subjected in future component systems. Even though it is an analog device, the algorithms that would be applied in the digital domain are the same. Therefore, if the bandwidths of the foreground components fed to it are inadequate in the analog domain, they would also be inadequate in the digital domain. During the work, differences in sampling rate or in hierarchy level which were hardly discernible when directly viewed became quite noticeable through the UltiMatte, and those which were noticeable when directly viewed became quite objectionable. Passing signals through one of the experiments and then into the UltiMatte foreground before display became one of the best ways of judging the adequacy of a given hierarchy level or sampling rate for many of the participants in the Demonstrations.

## NTSC System

As can be seen in the block diagram (Fig. 5), a separate switching matrix and a substantial amount of equipment were provided for a separate NTSC system. As outlined in the Preface to this special issue by Ken Davies, one of the questions presented by the Task Force on Component Digital Coding concerned the ability to interface any proposed digital system with the existing analog system. This will be necessary for a number of reasons, the most important of which are that the ultimate distribution of programs into homes will remain in the NTSC format in the foreseeable future, and that material already recorded in NTSC, and available from archives, will need to be handled for just as long or longer.

Consequently, it became important to be able to view the results of the digital experiments through an NTSC "window," and it also became important to explore the various ways in which the interface between the component digital and analog NTSC domains might be achieved.

In addition to the function of simply "passing through" NTSC, a few other functions were performed by the NTSC system. One was to allow the introduction of pure, high quality NTSC test signals into the devices making the transition to components, and to allow the careful measurement of the NTSC outputs of the devices providing the interface in the other direction. Another function was to allow the composite NTSC signal to pass through a $4f_{sc}$* digital device of current technology to see what effects might arise, since this is likely to happen in practice, and also to allow the NTSC signal to be "unsynchronized." This was all done with a Digital Video Systems DPS-1 Frame Synchronizer which could be locked to or unlocked from the rest of the system. Unsynchronizing was necessary because there is a great deal that is not yet known about the effects that changes in the input/output relationships have on the digital interfaces.

## NTSC Interfaces

In order to explore the interface between NTSC and digital components, in both directions, as fully as possible, a number of interfacing devices were provided. First of all, acting as references for all other such devices were an analog encoder and an analog decoder, utilizing the latest available techniques and technology. The encoder was a Marconi Type B3373 which takes *R*, *G*, *B*, *S* (sync), blanking, and subcarrier inputs and makes an NTSC composite output. This unit has a 10-MHz luminance channel, uses the FCC specified bandwidths for *I* and *Q* signals, and uses no comb filtering of the luminance channel. The latter specification was felt to be important since it is in keeping with the specifications of the FCC Rules.

The analog decoders used were Barco units of the two-line comb filter type. Comb filtering was used here because this type of separation is finding its way more and more into home receivers, and it was felt by the Working Group that this will be the prevalent method of decoding in the home of the future. Prior to the decoders, a specially modified Grass Valley Group Model 3240 processing amplifier was used to remove the setup from the incoming NTSC signal, add the gain needed to reach 0.7 volt of video, and remove the sync from the composite input, thereby giving the decoder the noncomposite NTSC signal it required, without modifying that signal in any other way.

The other encoders and decoders that were connected to the NTSC system were part of the experiments. They were a digital encoder at 912 samples per line from Sony, a digital encoder at 768, 864, and 912 samples per line from Digital Video Systems, and a digital decoder at 912 samples per line from Sony. Each of these could be cascaded with either of the analog interfaces, as appropriate, and digitally interconnected to interfaces into the RGBS system. In this way, all of the possible combinations of analog and digital devices and directions of signal flow could be tested and, in fact, were demonstrated during the system presentations.

## Digital System

An important part of the Demonstrations was the ability to interconnect the experimental equipment in the digital domain. For this first attempt at interconnecting various pieces of equipment from different manufacturers in a component format, we relied heavily on the work of the Working Group in developing a composite interface. The digital interfaces for the Demonstrations each utilized three flat, twisted-pair cables with ten pairs per cable. One cable was used for each of the signals $Y$, $C_R$, and $C_B$. The digital signals were positive linear, 8-bit PCM (pulse code modulated) versions of these signals, scaled and offset as follows:

$$Y = 16 + 0.299R + 0.587G + 0.114B$$

$$C_R = 128 + 0.500R - 0.419G - 0.081B$$

$$C_B = 128 - 0.169R - 0.331G + 0.500B$$

$$16 \geq Y, C_R, C_B \geq 240$$

The ten pairs were utilized to carry eight data signals, clock, and composite sync, each in a balanced ECL-level configuration. The full television signal, including horizontal and vertical blanking periods, was transmitted.

Because of the complexity of switching 28 or 30 ECL signals at a time, and since there were a total of six outputs and six inputs to be switched to one another, it was decided to fabricate a rudimentary patch panel to serve the switching function. As can be seen in views of the central equipment cluster (Fig. 4) and a closeup view across the cluster (Fig.7), "patch cables" *per se* were not used. Instead, a system devised by the authors and built in Redwood City brought all the outputs directly to fixed connectors mounted to the patch panel. A vertical column of three connectors constituted one output. The three cables for the related input were passed through a slot at the bottom of the column of connectors and held there until needed. When a connection was necessary, the input cables for a device were connected to the output connectors from the device from which the input was to be fed. In this way, any path could be created with only two cables and one midpoint interconnection between the two pieces of equipment involved.

In addition to the requirement for the digital interconnection during the assessments and presentations, the patching arrangement allowed for much of the experimentation that was carried on by members of the Working Group during the days that the system was kept together following the formal Demonstrations. As part of that experimentation, the digital interface was fully characterized to provide more data for the Working Group as it works toward an interface standard.

## Control and Monitoring

The value and consistency of the subjective assessments would be maximized when the distractions to the

* $4f_{sc}$ = four times the NTSC color subcarrier frequency.

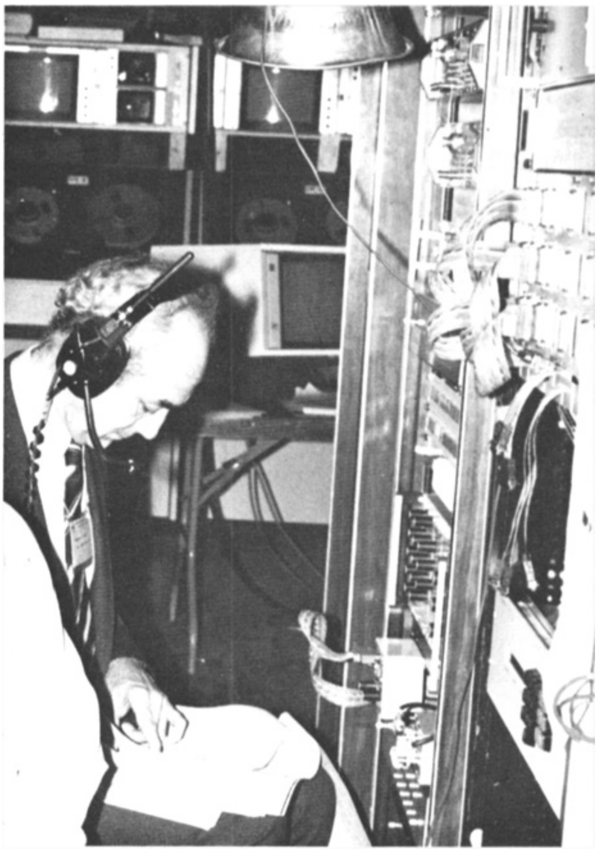


**Figure 7. Closeup view across the central equipment cluster, showing the digital patch panel on the extreme right.**

panelists were minimized. Furthermore, the system presentations were to be viewed by an audience of several hundred skilled technical television personnel from around the world. These factors meant that the assessments and presentations had to be carried out with the best production techniques and in the most professional manner possible.

Because the order of presentation of picture material and test conditions would be randomized by a computer, no two switching patterns would be alike. Additionally, the quality of some of the techniques under investigation was so high that no method was available to record their results fully. Consequently, it was mandatory that the images shown in both the assessments and the system presentations be generated in real time. To further complicate matters, the system presentations required multiple switching functions to happen every five to ten seconds for a period of 50-plus minutes.

All of this led to two conclusions fairly early in the planning: Each experimenter would be responsible for controlling the selection of inputs for his experiment; and, the task at hand would require the services of a professional television director. This was, after all, a television show that was being put together — especially in the case of the presentations. The latter decision was implemented quite well when Hal Grant, a director at KPIX who had previously been a technician and who understood what was being attempted, was persuaded to "volunteer." The inclusion of a director as part of the operation is highly recommended to anyone attempting a project of this sort. On many occasions, he was the only one who held the show together.

The next step was to set up control of the system so that it was physically manageable. This was accomplished by placing control panels for the routing switcher adjacent to each experiment and at other locations where the inputs to equipment had to be switched. Then, a control location was established at which were placed the controls for the switcher busses feeding the viewing-area monitors, the preview and line monitors and their controls, controls for all the relays which expanded the matrix inputs, the audio control center, and the communications control center. During the assessments, the director did all his own switching of the relays and preview and output busses, in addition to calling out directions over the communications system. During the system presentations, things went so fast that it was necessary to have an assistant to the director who did most of the preswitching and helped keep things in order. Behind the scenes, the presentations were more than 50 minutes of "organized chaos."

In addition to the line and preview monitoring at the control point, a special "quality control" monitoring arrangement was provided in a roll-around rack for the purposes of setting up and maintaining the system. This consisted of a color picture monitor, a monochrome picture monitor, a 1485 waveform monitor, a 520 vectorscope, and a switching arrangement which allowed looking at the $R$, $G$, $B$, and $S$ signals individually or at the NTSC signals. The ability to have all these signals available on monitors independently and to be able to move them near to where one was working proved to be a critical factor, at times, in keeping the system going. This setup turned out to be especially valuable in setting up the UltiMatte, which was one of the more important functions which had to be performed well to assure the success of the Demonstrations.

## Audio System

While the principal function of the system was to provide for the transparent switching and distribution of video signals, in order to make those video signals useful to the assessors and viewers it was necessary to also have an audio system as part of the setup. The audio facility built consisted of a straightforward public address system with tape recording and playback capability added. Its primary inputs were a number of microphones in the equipment and viewing areas and the tape recorder. These sources were all fed to a mixer whose outputs fed amplifiers and loudspeakers in the viewing area, the input to the tape recorder, and an input to the communications system.

The audiotape recorder provided was a multichannel unit which allowed for voice tracks on one of several channels, control instructions on several channels in various languages, as necessary, and time code on one channel.

During the subjective assessments, since it was necessary to pace the announcements to the switching operations at times when the switching did not go as planned, all the announcements were made live, in real time. For the system presentations, which were repeated over and over, just the opposite arrangement was used. The audio was all prerecorded and the switching done to the pace set by the voice track. When switching fell a little behind, the audiotape was stopped momentarily until the video could catch up.

### Communications

If the assessments and presentations were to appear on the viewing monitors correctly, the activities of as many as a dozen people had to be carefully coordinated. This was done using a full-duplex wireless headset system (Fig. 7), which was tied into a separate audio mixer to provide all the material necessary. The headsets operated in conjunction with a radio system which utilized a combined transmitter and receiver in a single case which could be worn on a belt. The transmitter and receiver could be operated simultaneously on two separate frequencies. All of the receivers used by individuals were tuned to the same frequency, with a single transmitter operating on this frequency continuously as the base unit. Each of the portable transmitters was operated on a push-to-talk basis, sharing a common frequency on which was a single receiver at the base.

The base transmitter was fed from the output of the communications audio mixer and was on the air all the time. The output of the base receiver was one input to the mixer. In this way, when any individual transmitted, all the others were able to hear what was said repeated back, and the speaker heard himself and thus knew he was getting through. The other inputs to the mixer were a microphone for the director and an output from the mixer which was feeding the viewing-area loudspeakers. The director wore stereo headphones with "program" on one channel and "communications" on the other.

This setup allowed the director to pace his commands to the program and to hear responses from members of the crew. Crew members were able to hear the director, the program, and their own responses simultaneously. Because the crew was able to hear program as well as commands, it was often possible for the director to allow the crew to take its cues from the program and thereby reduce the need for additional talking on the communications system. The combination of sources used proved ideal, and the system operated reliably for the entire week of its use.

### Power Distribution and Grounding

The availability of the Studio N lighting system not only made it possible to provide specialized lighting arrangements but also made it an easy matter to distribute power to the various equipment clusters. Lights were hung before and behind each of the equipment groups and placed on separate dimmers. The front lights were aimed and focused to gently bathe the front panels in light. Normally, the lights were all set at a relatively low level — enough to be adequate for operating. If it became necessary to work on any particular piece of equipment, the lights for just its equipment cluster were raised to a level sufficient for doing maintenence work.

Power for the equipment was patched from the non-dim circuits in the lighting patch panel to points in the lighting grid immediately above the various racks. Extension cables were then dropped from the rigging to the floor at the back of each equipment cluster (see Fig. 2). Twist-lock connectors were used throughout, so that power could not accidentally be interrupted. Power for the monitors in the viewing area was separately supplied from the KPIX technical power system which uses regulated ac power.

The green safety wire was left disconnected in each of the plugs connecting the equipment groups to the power drops. Instead, all grounding was carried with braided bonding straps to a single, large, copper ground bus bar in the center of the equipment area. The bus bar was connected to the KPIX ground system, which provided both safety and signal grounds.

The results achieved proved the value of the precautions taken. From the time the setup began, other than installation according to the predetermined plan, no attention had to be paid to the grounding of the equipment. Raising the sensitivity of monitoring oscilloscopes to maximum and viewing on picture monitors showed no traces of hum or other system-induced noise or distortion for the duration of the four-week setup, operation, and experimentation period.

### Conclusions

Building a laboratory experiment and operating it to produce television programs can be done. With care and pre-planning, the experimental facility can be made sufficiently flexible so that the material produced with it can be both interesting and instructive to the viewer. At the same time, the supporting system can be of such quality that the results obtained from the experiments are derived solely from the experimental equipment.

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