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COLOR-TELEVISED MEDICAL MICROSCOPY

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Approved by: _____

P. Vavra - Chief, Information Systems Division

Approved by: _____

J. Overton - Chief, Data Systems Development Branch

Approved by: _____

O. Patterson - Head, Data Systems Development Section

Prepared by: _____

J. Peck - Aerospace Technologist

And by: _____

M. Heath - Aerospace Technologist

COLOR-TELEVISED MEDICAL MICROSCOPY

SUMMARY

Laboratory-quality microscopy by color television has been shown to be feasible by the Data Systems Development Branch of the Information Systems Division at NASA Manned Spacecraft Center. Experiments followed a medical college instructor's request for assistance in determining if microscopy by color television was possible at the high magnifications used in laboratories.

Demonstrations of an improvised color-video microscopy system were well received by the Manned Spacecraft Center and civilian doctors. Several doctors visualized a number of applications, not necessarily in space medicine, in which microscopy by color television could provide unique and significant advantages.

ACKNOWLEDGMENTS

The authors wish to acknowledge the efforts of: Wesley G. McTaggart, Instructor in Radiobiology at Baylor University College of Medicine, who initiated and took part in these experiments; Craig L. Fischer, M.D.; Walter W. Kemmerer, Jr., M.D.; and Kenneth N. Beers, M.D., all of the Manned Spacecraft Center Directorate of Medical Research and Operations, for their evaluations of the experimental system and assistance with this report; and to the American Optical Company and the W. H. Curtin Company for the loan of equipment.

INTRODUCTION

This experimental investigation of color-video microscopy was made by the Data Systems Development Branch (DSDB) as the result of a request from Baylor University personnel, who felt that medical teaching would find video microscopy in color much more useful than the monochrome systems already available.

Experiments conducted by DSDB in response to this request were justified by the possibilities of using color-video microscopy in the

Manned Spacecraft Center's (MSC) biomedical programs. The experiments were conducted in DSDB's advanced-development laboratory, whose facilities include closed-circuit color television equipment.

DEVELOPMENT HISTORY

The goals of this investigation were to find out if color-video microscopy is effective at laboratory-range magnifications, and if so, to see if a slide image could be reproduced by color television with sufficient fidelity for medical laboratory use.

The experimental setup (figs. 1 and 2) uses an external light source and substage mirror to illuminate the slide, and a blower directed at the microscope stage to reduce lamp heating. The slide's real image, formed by the microscope optics, is projected through the lens opening into the color television camera with the lens removed. Dichroic mirrors at the camera's optical input separate the image into its red, green, and blue components and direct these upon the photosensitive targets of three Vidicon tubes, which are the optical-to-video transducers. Synchronous scanning of these targets produces three video signals that correspond to the optical image's red, green, and blue components.

After processing by the color camera control unit, the red, green, and blue video signals are combined into a single color television signal in the standard National Television System Committee (NTSC) format by the NTSC encoder.

From the NTSC encoder, the encoded video signal is fed either to the display monitor for viewing, or to the video tape recorder for storage, or to both. The standard, commercially available video equipment used in the experiments included a COHU Electronics Series 1000 color television camera, a COHU Electronics NTSC encoder, and a sync generator. The output video was displayed on a CONRAC 17-inch color television monitor, and recorded on an AMPEX Model VR2000 video tape recorder.

Equipment used in the light/optical portion of each experimental setup was borrowed. A commercial supplier loaned a trinocular microscope and two base illuminators for the first experiment. All subsequent experiments used binocular microscopes, the only type available from the MSC biomedical laboratories, and an external light source that was part of the DSDB laboratory video equipment. Microscope optics consisted of X10 oculars and achromatic objectives with X10, X43, and X97 (oil immersion) magnifications.

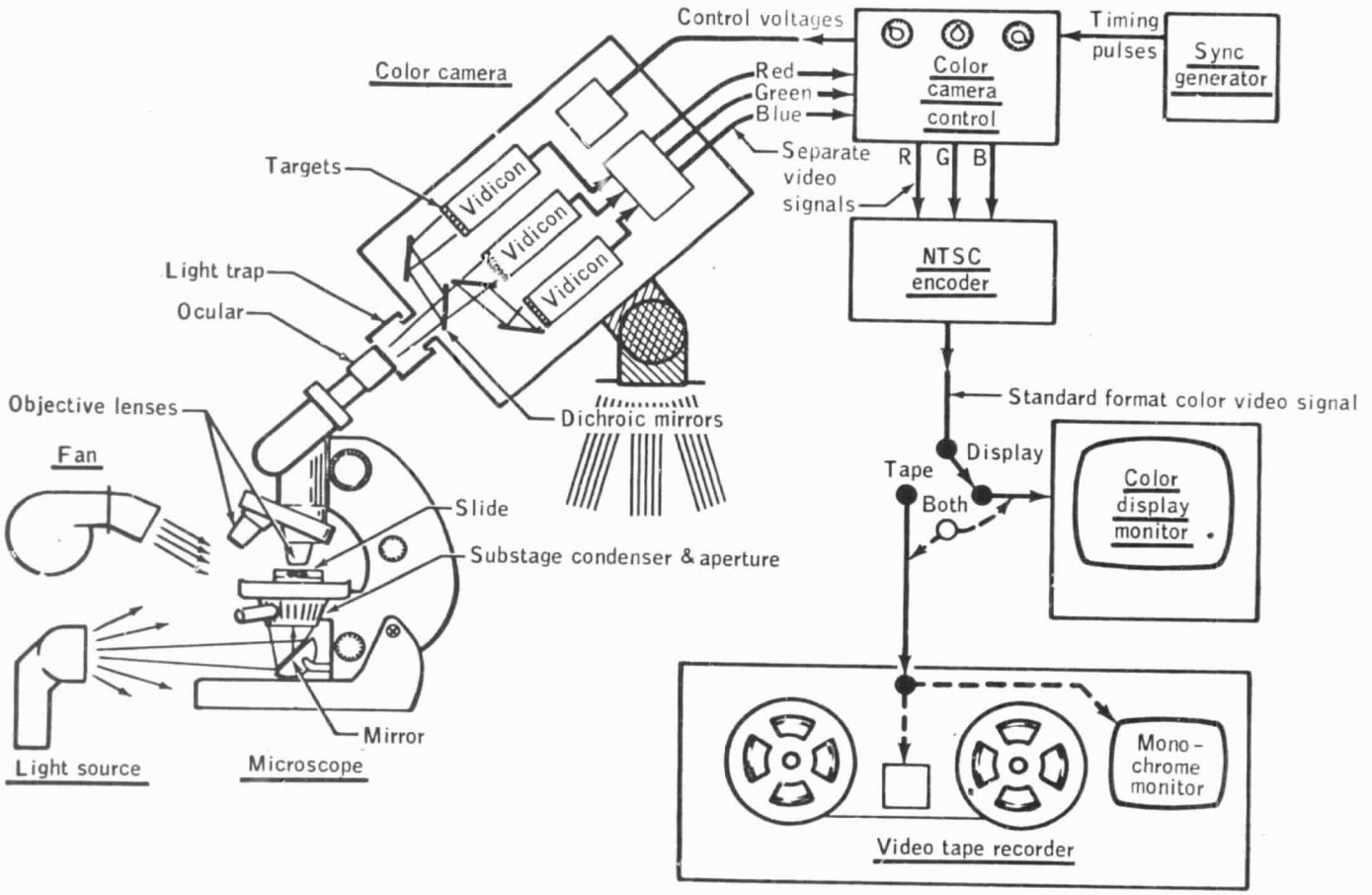

Figure 1.- Color video-microscopy system.

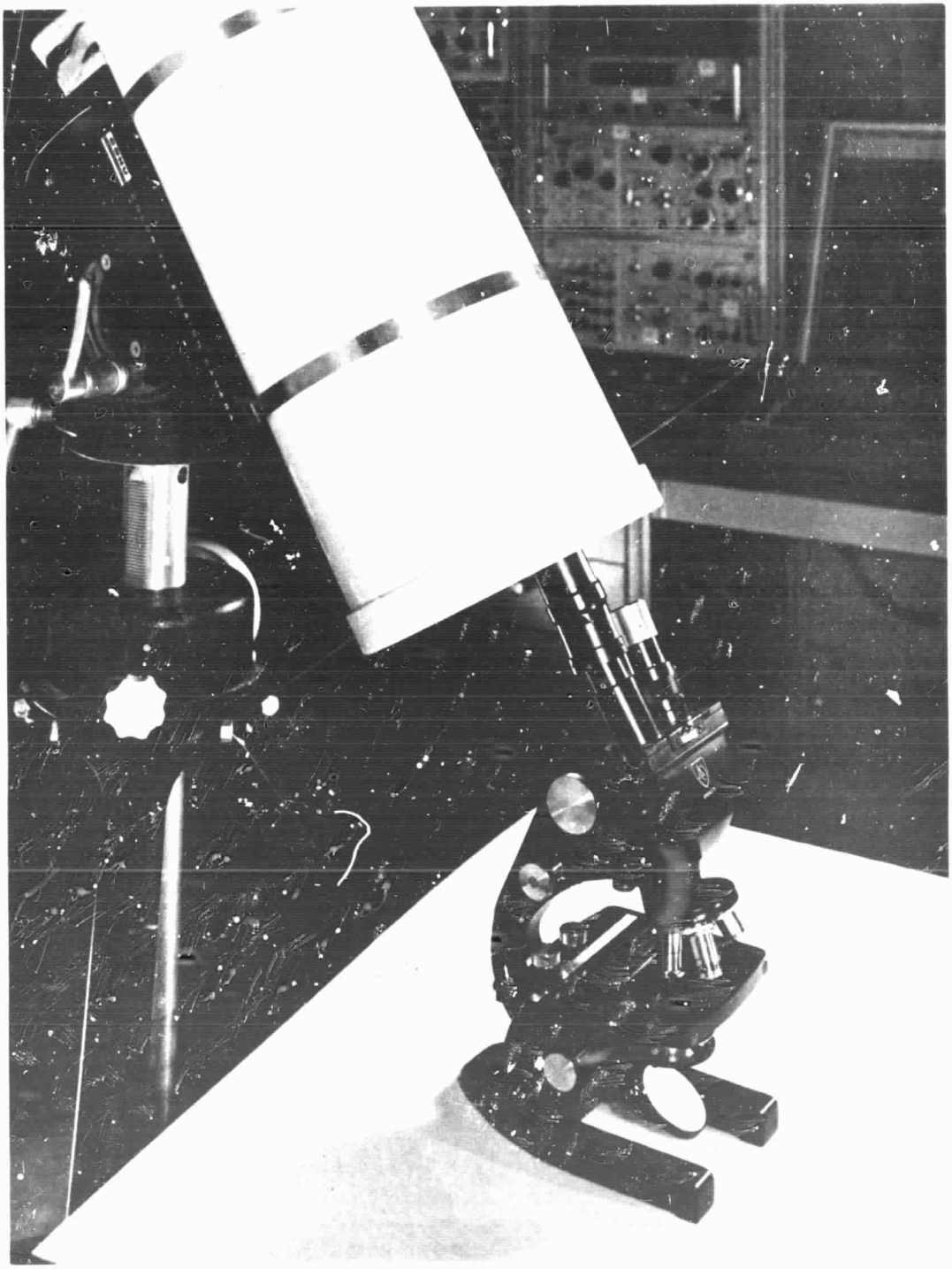

Figure 2.- Camera/microscope configuration.

The first experiment succeeded in color televising microscope slides at X970 (oil immersion) magnification, despite inadequate base illuminators. A 100-watt incandescent base illuminator was tried first, but was inadequate because its output intensity was too low. At least 150 foot-candles, as measured by a light meter at the microscope/camera interface, is required. The second illuminator, a 200-watt mercury-vapor unit, produced enough light for the system, but the severe spectral imbalance of its output prevented good color fidelity. In all following experiments, an external light source was used instead of base illuminators. This source was a 650-watt G-E Model MG "Movie Light" that was available in the DSDB laboratory. This source proved satisfactory in both intensity and spectrum, although it also produced a heating problem, which is discussed later.

Most of the slides used in the experiments were blood smears (fig. 3), although several histological slides were also used. Usually, slides were viewed at the X970 visual magnification to provide a more rigorous test of the system's performance. The system's suitability for gross scanning was judged during trials using X430 and X100 visual magnifications.

At all magnifications, the video monitor displayed only a fraction of the slide area that could be seen through the microscope directly (fig. 4). For each magnification used, stage micrometer measurements were made by direct microscopy and through the video system, and then the corresponding areas of slide display were calculated (table I). The video system displays approximately 6.5 percent of the total slide area viewable by direct microscopy.

This enlarging effect in the system can also be stated as an additional linear magnification factor of X3.83, a ratio produced by comparing field widths measured through the video system with the observed diameters of the directly visible fields (table I). The video field widths are 26.1 of the corresponding visible field diameters (fig. 4), and the linear magnification factor is the reciprocal of this percentage.

The color camera's physical layout enlarges the image because of its long optical path between lens opening and Vidicon targets. The dichroic mirrors require a long path, but the image provided by the microscope is a real, not virtual, image that is enlarged by projection across that distance. (An identical effect occurs in photomicrography when the eyepiece-to-film distance is increased.) This effect can be neutralized by optical compensation in the color camera lenses; however, the resultant magnification was desirable to increase the resolving power of the system.

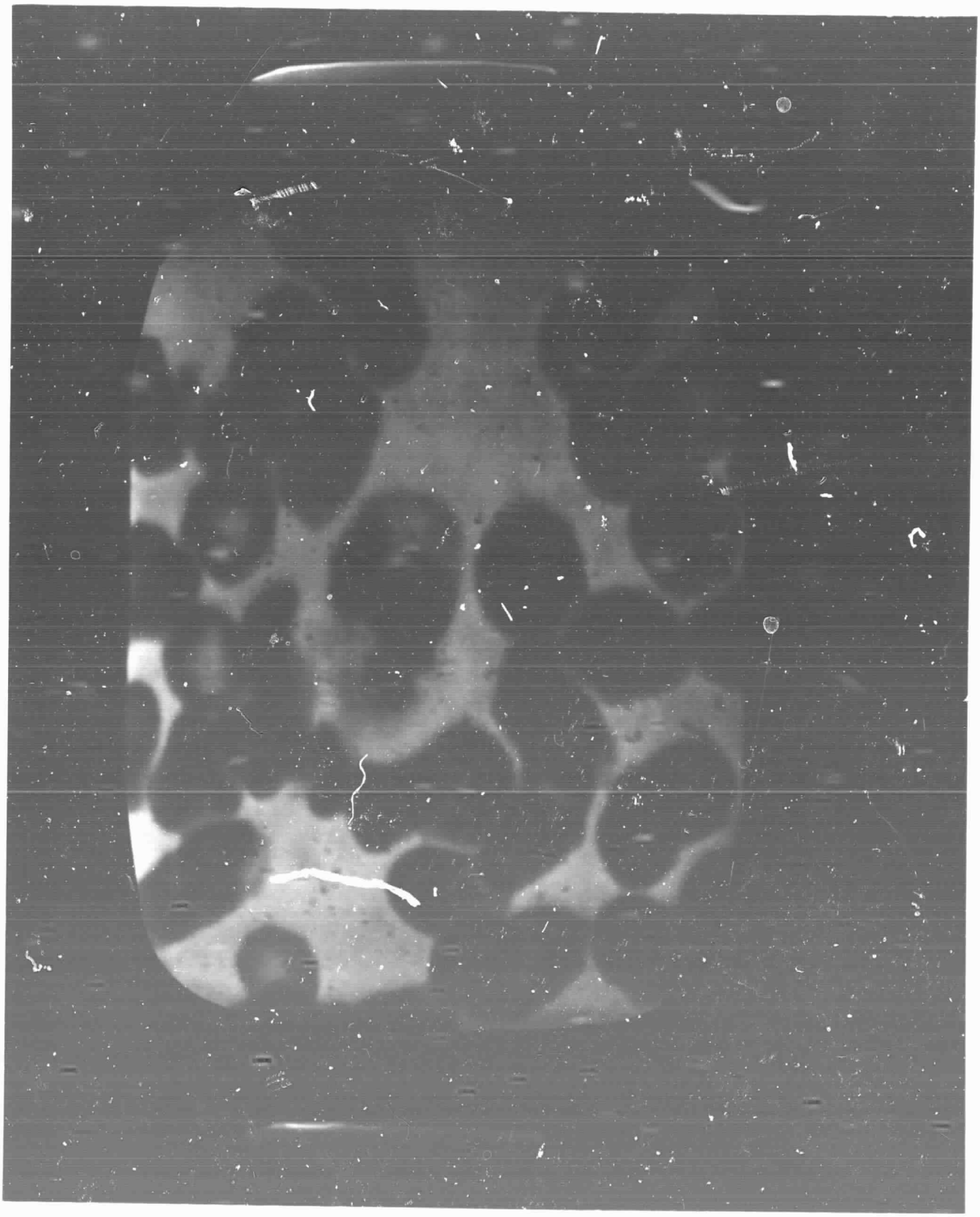

Figure 3.- Color-televised display of (Gemini) blood smear at X970 (oil immersion) magnification.

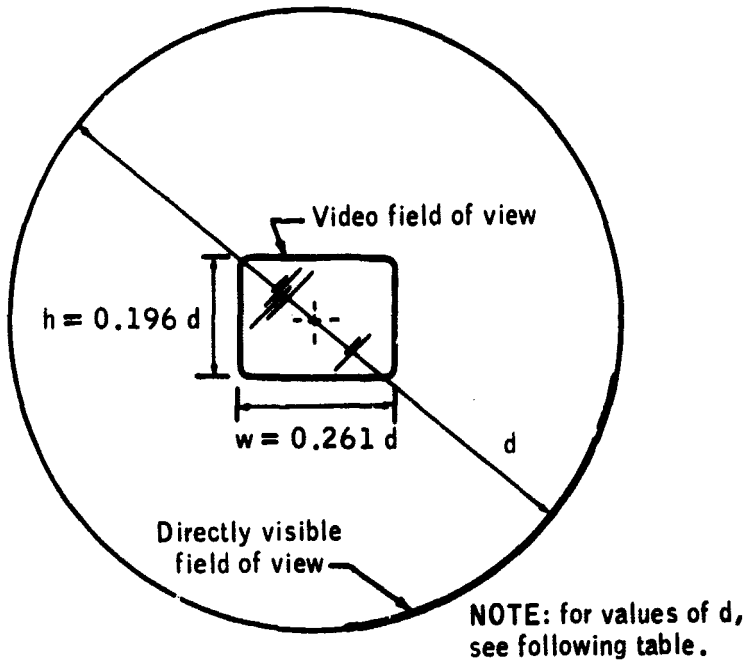

Figure 4.- Relative fields of view.

TABLE I.- COMPARATIVE STAGE MICROMETER MEASUREMENTS

Optical magnification used (objective X ocular)	Directly visible field of view		Video field of view			
	Diameter, mm	Area, mm^2	Height, mm	Width, mm	Area, mm^2	Viewable area seen, percent
X100	1.896	2.823	0.371	0.495	0.184	6.5
X430	.441	.152	.086	.115	.00989	6.5
X970	.195	.0299	.038	.051	.00194	6.5

NOTE: The relationship of these dimensions is shown in figure 4.

The dimensions measured were diameters of directly visible fields of view, and the widths of the video fields of view.

Video field heights were calculated as 0.75 of field widths, and areas of both types of field were figured geometrically.

APPRAISAL

The experimental system's performance was evaluated by the three MSC physicians whose assistance is previously acknowledged. Each of these doctors viewed one or more of the DSDB laboratory experiments, either as they were conducted, or by video tape recordings, or by both means.

Their appraisals of the experimental system's performance, offered below, were paraphrased from their comments in recorded interviews.

Dr. Fischer's comments followed a recorded demonstration early in the experimental series. As a hematologist, he felt that a slide could be evaluated as effectively from its video display as it could through direct microscopy, and that technical problems of color balance and microscope alinement would be easy to correct. He regarded the overall quality of the system's performance as excellent for its stage of development.

No significant differences in quality were observed by Dr. Beers when the live video displays were compared with those reproduced from the video tape recording of the experiment. He rated the color fidelity and resolution of detail in the video displays as "good" for the trials using a tissue section, and as "very good" for the blood smear.

From a live demonstration, Dr. Kemmerer appraised the system's resolution of detail and color fidelity as "very adequate" for medical use, and added his opinion that color-video microscopy systems of similar quality could become very useful in the medical field.

All three doctors envisioned a number of possible medical uses for color-video microscopy that would exploit the electronic medium between specimen slide and viewer. Electronics permits any number of simultaneous remote displays, slide-image storage by magnetic tape recording, and digitizing the video for input to a computer. The computer could be programed to analyze and classify slides, or to process the video signal to improve the displayed image's quality.

FUTURE DEVELOPMENT

These speculative uses, of course, are based upon color-video microscopy systems more refined than this experimental setup. However, improvements in the light/optical portion of the present system can easily remedy several of its limitations.

The binocular microscopes used in this study cause a slight loss of picture definition as the result of light scattering in the prism, and provide the camera with only half of the total image intensity available because the remainder is lost in the unused ocular. Both of these undesirable conditions can be eliminated by using a reflex-type binocular microscope, which would also offer greater convenience for coupling to the camera by the photomicrography fitting provided.

The lamp used in all but the first experiment radiated an objectionable amount of heat toward the microscope and slide. This heat tended to bleach the stains used in the slides, and also made frequent refocusing necessary until a slide reached the ambient stage temperature. Forced-air cooling did not completely eliminate these effects, and it would seem worthwhile to try cooling cells and field apertures in future experiments.

Minor problems were encountered in electronically setting the camera's color balance for these experiments because the camera/microscope arrangement prevented using conventional color standard charts, and because the experimenters lacked the medical background to determine color balance accurately from a slide's video display. Operation of a color-video microscopy system by persons experienced in medical microscopy would not present this problem.

Although not a part of this study, one further improvement in equipment has been reported to the experimenters by Wesley G. McTaggart, whose research now continues independently. In an experiment/demonstration made recently at the COHU Electronics factory in San Diego, he observed a significant improvement in the apparent resolution of detail in the displayed video image, and attributes this improvement to a vertical aperture correction circuit which was installed in the camera system.

A complete report on his research in color-video microscopy is understood as being readied for publication, and may be expected to include further details on that experiment and the equipment used.

POSSIBLE APPLICATIONS

The possibilities visualized by the MSC physicians for fully developed color-video microscopy systems ranged from applications in general medicine to suggested uses in MSC's space-biomedical programs.

One of the possible MSC uses is in the medical experiments that will follow the Apollo Program lunar expedition. For these tests, the returned astronauts and selected medical personnel will remain in a biologically isolated Crew Reception Area (CRA) for 2 weeks. The CRA

will contain a Lunar Receiving Laboratory (LRL) where studies such as hematology, microscopic urinalysis, and feces examinations will be made. In addition to these studies, the LRL must also provide facilities for the immediate diagnosis of crewmember illness to determine etiology as well as treatment: a requirement implying a need for consultation from almost any medical specialty.

If and when such consultation is needed, the consulting specialists will remain outside the CRA and use a remote display system such as color-video microscopy to examine specimens inside the LRL. Their evaluations will be reported to and discussed with the LRL physicians by intercom or telephone. Locating consultants outside the CRA reduces the number of doctors and the logistic support needed inside, without sacrificing the LRL's medical resources. The remote display system this arrangement requires will normally be used to permit senior MSC staff members outside the CRA to keep up to date on results of LRL experiments.

Remote display methods being considered for the LRL system are color-video microscopy; photomicrography, sending film through an airlock for processing and viewing outside the CRA; and optical microscopy, using a microscope installed through the CRA wall with its stage inside and its eyepiece outside that biological barrier. A video system would use more equipment than either of the other methods, but also would have more advantages and fewer disadvantages. Photomicrography requires waiting while film is developed; optical microscopy allows only individual viewing, and the installation through the CRA wall risks contaminating the quarantine.

The MSC doctors also visualized using color-video microscopy on board future space flights for quality control of slides made in inflight medical experiments by the astronauts, whose medical training is necessarily limited. Televised slide images would be relayed by microwave communications for display to MSC physicians in the control center, enabling them to immediately inspect and verify the quality of each slide as it was made.

In speculating about the system's possible uses in general medicine, each of the MSC doctors suggested another application which would combine microwave communications with color-video microscopy: use between doctors in remote areas and the major medical centers. Tissue or fluid specimens would be televised at the remote hospitals and relayed by microwave to specialists at the medical centers, who could then evaluate the specimens similar to the way EKG and EEG interpretations are now made by telephone.

Another possible use was visualized in the larger hospitals, where the system could be used between operating rooms and pathologists. In

this application, a biopsy would be processed directly in the operating room but have its pathology evaluated outside through color-video microscopy, with the pathologist reporting his findings to the surgeon by intercom, telephone, or headset.

Current usage of computers in genetics to classify chromosome patterns suggests two more applications in which the video signal(s) corresponding to a slide image would be digitized and fed to a computer. In one such use, standard differential blood counts would be made by a computer using pattern recognition programs and an input of digitized color-video signals from blood smears. The second application is similar in principle, but would use more sophisticated pattern recognition programs to enable a computer to screen, sort, and classify various pathological specimens. This application might also require supplementing the digitized color-video input with data from other instruments, such as an ultramicrospectrophotometer.

The potential values of color-video microscopy to medical education were also recognized by the MSC physicians, who agreed with Wesley G. McTaggart that medical teaching's efficiency and effectiveness should benefit from the system's ability to display a slide in color to an entire class simultaneously.

CONCLUSIONS

These experiments have demonstrated the feasibility of medical microscopy through a color television system. Despite an improvised nature and the use of off-the-shelf components, an experimental system achieved a high quality of performance that was acceptable to the medical personnel who judged it. Furthermore, substantial improvements in performance could be obtained by using a more precise microscope/camera interface, a more efficient light source, and better developed operating techniques.

The quantity and variety of possible applications suggested for color-video microscopy indicated that it may become a valuable and adaptable medical tool. Accordingly, further development of color-video microscopy, both generally and for specific application, appears justifiable and is recommended by Data Systems Development Branch.

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