

TRINOSCOPE COLOR DISPLAYS FOR SIMULATION

Richard E. Holmes

Training Systems Group, Systems Research Laboratories, Inc.
2800 Indian Ripple Road, Dayton, Ohio 45440

Dr. F. Gerard Albers

Simulation and Control Systems Department
General Electric Company
1800 Volusia Avenue, Daytona Beach, Florida 32015

ABSTRACT

The resolution capabilities of computer image generators (CIG) used for simulation and training have advanced to the degree that they exceed the capabilities of existing shadow mask, direct view color TV displays and color TV projectors. One solution to this problem is the modern day implementation of a trinoscope color display that uses the optical merging of three high resolution monochrome cathode ray tubes--red, green, blue color phosphors, respectively--to produce a full color image. Such systems are particularly suitable for telescopes and periscopes needed in tank or submarine simulations where the color-combining optics can be integrated into the simulated sight optics. This paper describes the technical advances required to assure maximum resolution and, more importantly, superior color convergence (i.e., the capability to make the three CRT images fall exactly on top of each other so that the resulting full color image is produced without undesirable color fringing).

INTRODUCTION

There are many training situations where it is desirable to view a color TV image through the eyepiece of a simulated telescope or periscope. Examples would be the gunner's and commander's sights of a modern main battle tank or the periscope of a killer submarine. These situations usually carry with them a fairly stringent constraint on the total volume available for the display and optics. This means that the size of the display as well as the size of its image must be minimized while still meeting the criteria of color, resolution, etc. A minimal image size likewise conserves on optical path length, which further reduces display system size. These constraints produce requirements for an image source which are far beyond those of the conventional shadow mask CRT. The one image source which provides the highest TV resolution can also provide full color in a very small raster format. It is the trinoscope.

The Optical Industry and Systems Encyclopedia and Dictionary defines "trinoscope" as "a color-television viewing system with three kinescopes, three lenses, and three deflection yokes used to form the red, green, and blue images required for a tricolor television projection." Kinescope is another name for a cathode ray tube (CRT). The only disagreements with the above definition are the use of the words, "three lenses" and "projection." Various combinations of lenses, mirrors, and dichroic filters can be used--each with its own sources of problems and each with its advantages. Also, as will be seen in Figures 5 and 6 later, the system can be direct view. Figures 1 through 4 show various configurations that have been used in the past and which are now being revived for home color TV projection systems. Figures 1 and 2 show configurations which meet the original definition. In Figure 1, the images of the viewing plane are tipped and must be held within the system depth of focus to provide acceptable image quality. This problem can be resolved somewhat by applying the Scheimpflug

condition, commonly used with view cameras and in photogrammetry.(1) Electronic keystone correction is required. Within the Figure 2 configuration, the lens axes are all parallel and perpendicular to the image plane, but the outer CRTs are displaced laterally outward so that the outer optical axes converge at the screen. This combination reduces the need for keystone correction and provides better depth of field control but places more constraints on the lens.

Figure 3 illustrates a trinoscope system that uses only two lenses and is used commercially for a home TV projector. Figure 4 uses only one lens and is the basis of ESP's Aquavision projector. Even though this system does have a single exit pupil--a necessary feature for a telescope/periscope trainer application--the crossed dichroics become difficult to implement for higher resolution systems. The discontinuity at the intersection of the four dichroic mirror elements acts as a distributed central obscuration, in optical terms, limiting the spatial frequency optical modulation. It is, however, suitable for home and industrial TV projection applications. It also has the practical problem that each of the three CRTs are affected by the earth's, as well as manmade, magnetic fields in a different manner causing long-term convergence problems--particularly on a nonstationary system such as a moving gun turret.

PRACTICAL SYSTEMS

Figures 5 and 6 illustrate two of several configurations which have proved useful in telescope/periscope simulation. SRL has delivered several of each of these implementations during the latter half of 1980 and first half of 1981 for the gunner's and commander's sights in tank conduct of fire trainers (COFT). Both configurations have proved to be capable of providing the required color resolution.

One version used a 127 mm CRT with a 108 mm useful diagonal. Shown in Figure 7, it demonstrated over 1400 TV lines per picture height and width resolution using an SRL designed and fabricated beam

combining optics. The second system, shown in Figure 8, is used in General Electric's successful COFT prototype. It uses a modified color TV camera prism assembly to combine the images of the three CRTs. Even though the CRTs only had a 40 mm useful screen diagonal, it exhibited 1000 TV lines per picture height horizontal resolution. Both of these two systems had a circular format image area where the square CIG raster was overscanned such that the full useful diagonal area of the round CRTs was used as shown in Figure 9. An engineer is shown in Figure 10 aligning the General Electric trinoscope display.

Since the full color image from a trinoscope is derived by optically overlaying three separate images, it becomes obvious that means must be provided to converge the three images so that they appear as one. For lower resolution systems, such as home TV applications, the only corrections needed are individual size and position of each of the three rasters. Keystone (trapezoidal) correction is also needed for multiple exit pupil systems such as shown in Figures 1 and 3. But for high resolution systems, more elaborate matching circuitry is required. Not only must this matching circuitry allow for accurate registration, it must be very stable with both time and environmental changes.

Figure 11 shows a simplified block diagram of one of the COFT trinoscopes. From a block diagram viewpoint, the other COFT trinoscope was the same except that raster rotation was performed in the digital image generation equipment instead of in the trinoscope electronics. To keep relative drift between the three channels to the minimum, much of the circuitry is kept common, thus common mode drift is close to zero. This includes the sweep generation circuits, the main deflection amplifiers, and the high voltage power supply.

The convergence circuitry is included to correct for the differences between the electrical, optical, and mechanical characteristics of the three channels. Therefore, each channel must be independent and, as such, can drift independently of each other. Several factors help, however, to make this drift manageable. Without this correction, the three channels would probably match to within one percent due to the selection of matched magnetic components and CRTs and have no more than 0.25 percent drift with time in normal simulator environments. This basic stability is achieved by use of SRL linear current feedback deflection amplifiers which even correct for change in the deflection yoke resistance with temperature. Due to a patented power-on-demand feature, these amplifiers are significantly more power conserving than conventional linear deflection amplifiers and are particularly suitable for TV raster applications. (2) The convergence circuitry then needs only to correct for the one percent residual error. By using temperature stabilized, linear feedback current amplifiers for the convergence amplifiers, it is safe to assume that the convergence circuits also only drift an amount in the order of 0.25 percent of full output. Drift, then, reflected to the CRT is 0.25 percent times one percent, or 1/40th of a pixel element in a 1000 x 1000 pixel element system. Of course, there will be differential heating and other second order effects in the system that will cause some misconvergence errors, but suffice to say, convergence drift can be made to be insignificant.

It is difficult to measure misconvergence through a telescope/periscope optics system. However, SRL was able to consistently achieve a one pixel element center, 2 or 3 pixel element edge misconvergence on a 1400 x 1400 pixel element system. This amount of misconvergence is barely visible with a dot test pattern but is seldom distracting with real life type CIG scenes such as used in simulation and training.

To illustrate the visual system capability, a series of photos from General Electric's highly successful M1 Conduct of Fire Trainer is presented. Figure 12 illustrates the full CIG scene (taken from a conventional 19-inch monitor), which would be observed through the commander's biocular periscope. Figure 13 shows the 3X scene as it would be seen through the Gunner's Primary Sight as he ranges in on the target, and Figure 14 shows the 10X view for the same sight as a hit is scored. Note the high quality of the red recticle and the green numerics of the laser rangefinder produced by the visual system. Figure 15 depicts a "white-hot" thermal image produced from the same data base which further illustrates the flexibility of a CIG visual system. The basic configuration of this mobile trainer is illustrated in Figure 16, which also highlights the premium placed on minimal optical path length.

GE's M1 COFT system consists of four simulated high power sights driven by two trinoscopes and a two-channel CIG. Beamsplitters divide the images such that the commander's two sights are driven by one trinoscope while the gunner's two sights are driven by the other trinoscope. Clever "in-use" sensors tell the CIG which sight is being used so that it will provide the proper scene.

As mentioned previously, the commander also has a rectangular 1X periscope which is driven by a standard 19-inch monitor and collimating optics. Figure 17 shows the interior of the crew compartment. All five sights are clearly visible.

SUMMARY

The use of trinoscopes in telescope and periscope simulation has proved practical in tank simulators. Trinoscopes would be equally effective for submarine, antiaircraft gun, rocket launcher and any other system which views a target or scene through an optical eyepiece and where optical path length is at a premium.

Since there is nothing in the direct view or projection trinoscope concept that limits it to raster scan, a calligraphic (stroke writing) or a dual calligraphic/raster version could be made using existing circuitry.

Although the trinoscope concept is very old, its uses are as new as the next generation simulator or trainer.

References

1. Rudolf Kingslake (ed.), Applied Optics and Optical Engineering, Academic Press, New York and London, 1965.
2. R. E. Holmes and J. A. Mays, United States Patent No. 3,628,083, 1971.

ABOUT THE AUTHORS

Mr. Richard E. Holmes, Chief Scientist, Training Systems Group, Systems Research Laboratories, Inc. is responsible for conceptual development of techniques for visual image pickup, processing and display. A registered Professional Engineer in State of Ohio, Mr. Holmes holds several patents, an EE degree from University of Cincinnati and MSEE from University of Connecticut.

Dr. F. Gerard Albers, Manager, Display Systems Engineering, Simulation and Control Systems Department, General Electric, responsible for simulation systems advanced display design, is a former Air Force Instructor Pilot, with a BS and MS in Electrical Engineering and DE in Computer Engineering, University of Detroit. He taught and directed research at University of Dayton, also consulting with industry, from 1973 to 1979.

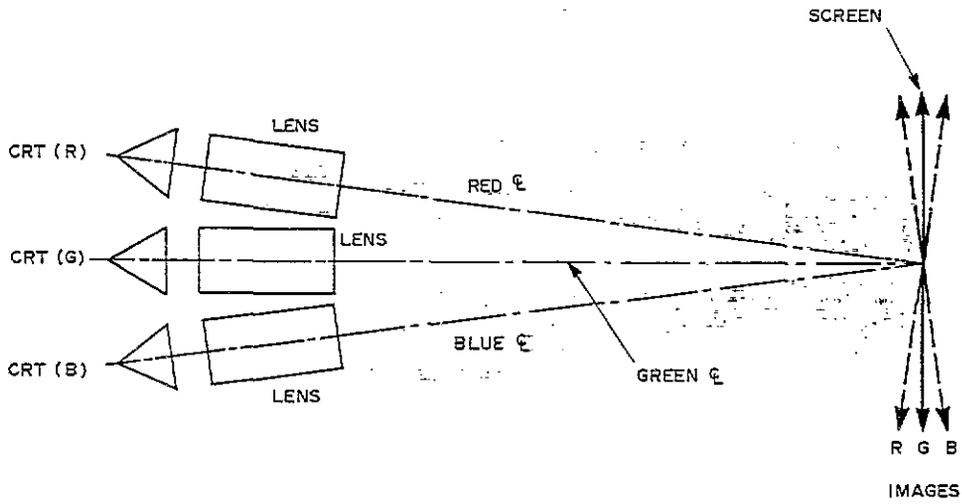


Figure 1. Trinoscope with Three Lenses

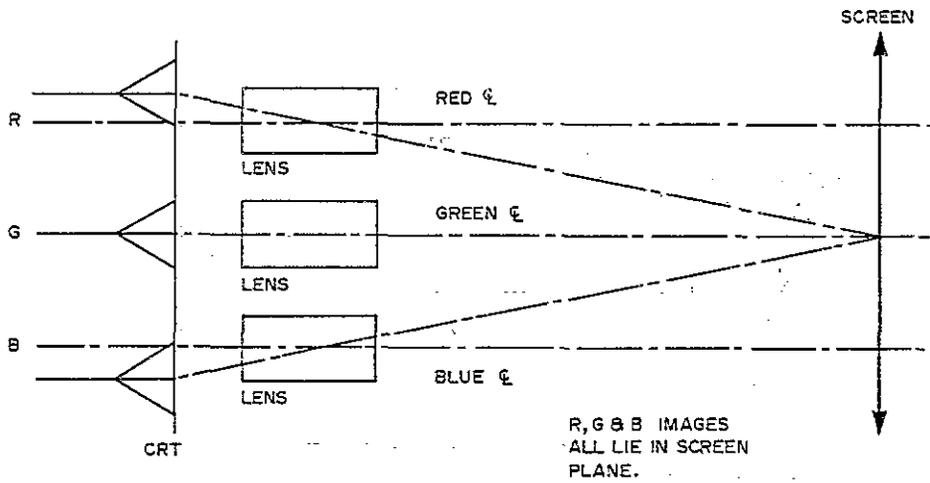


Figure 2. Trinoscope with Three Off-Set Lenses

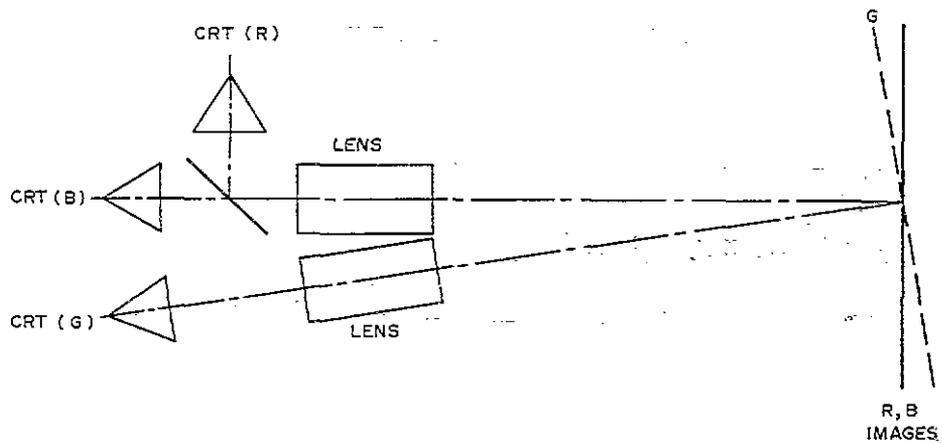


Figure 3. Trinoscope with Two Lenses

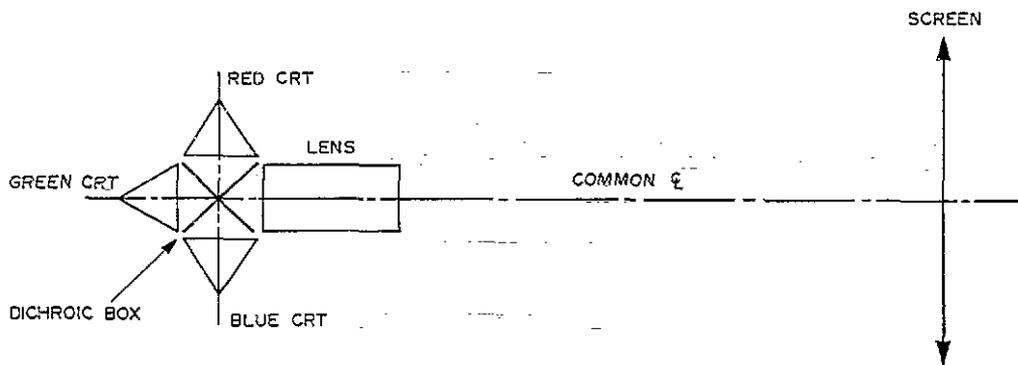


Figure 4. Trinoscope with Crossed Dichroics Image Combiner and Single Lens

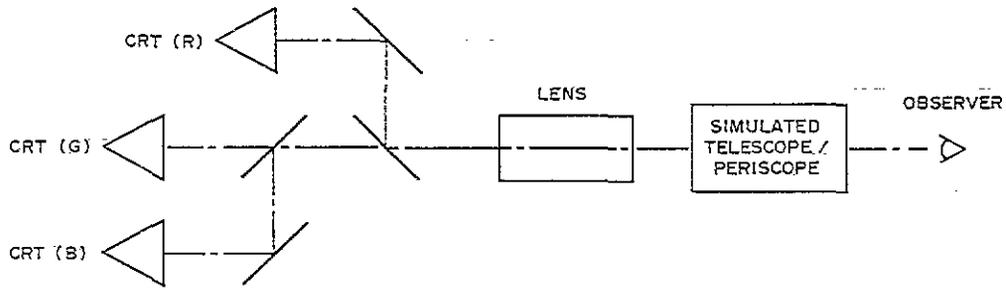


Figure 5. Trinoscope with Mirrors and Dichroic Image Combiners Suitable for Telescope/Periscope Simulation

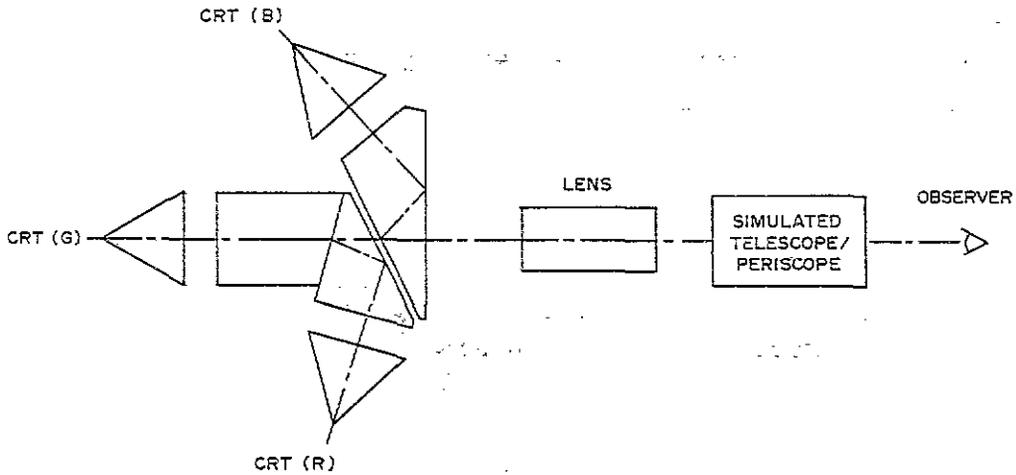


Figure 6. Trinoscope with Dichroic Prism Image Combiner Suitable for Telescope/Periscope Simulation

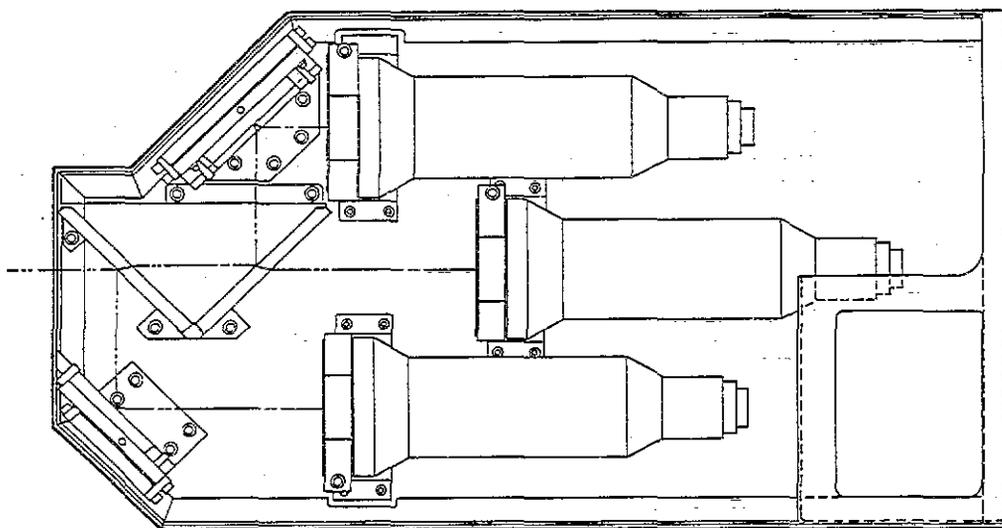


Figure 7. Top View of Beam Combiner Type COFT Electro-Optical Assembly

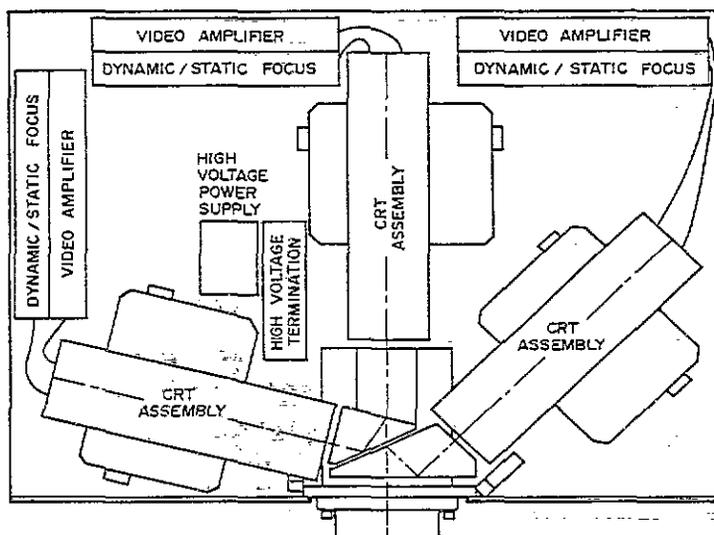


Figure 8. Top View Figure of Prism Type COFT Electro-Optical Assembly

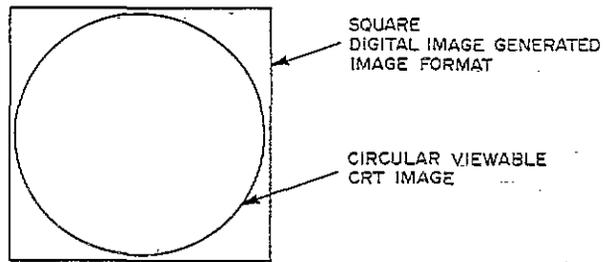


Figure 9. Circular Field-of-View Images of Trinoscope Systems Shown in Figures 7 and 8

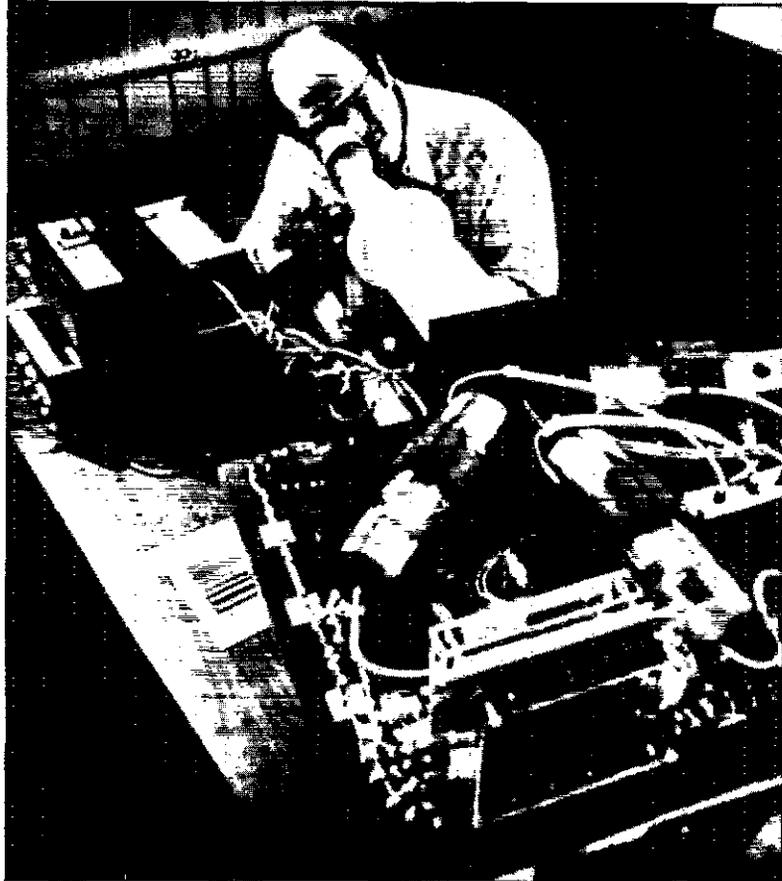


Figure 10. An Engineer Aligns GE's Trinoscope at SRL. The three CRTs are mounted on a base plate assembly along with collimating optics (white tube).

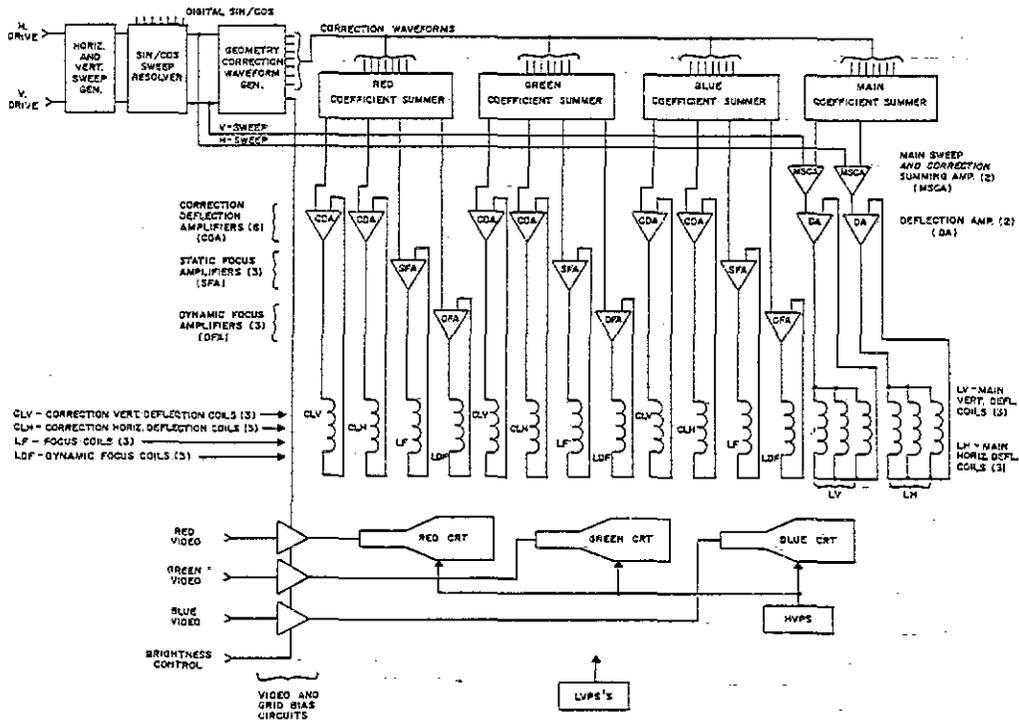


Figure 11. Block Diagram of Typical Trinoscope Electronics Used in Telescope/Periscope Trainers

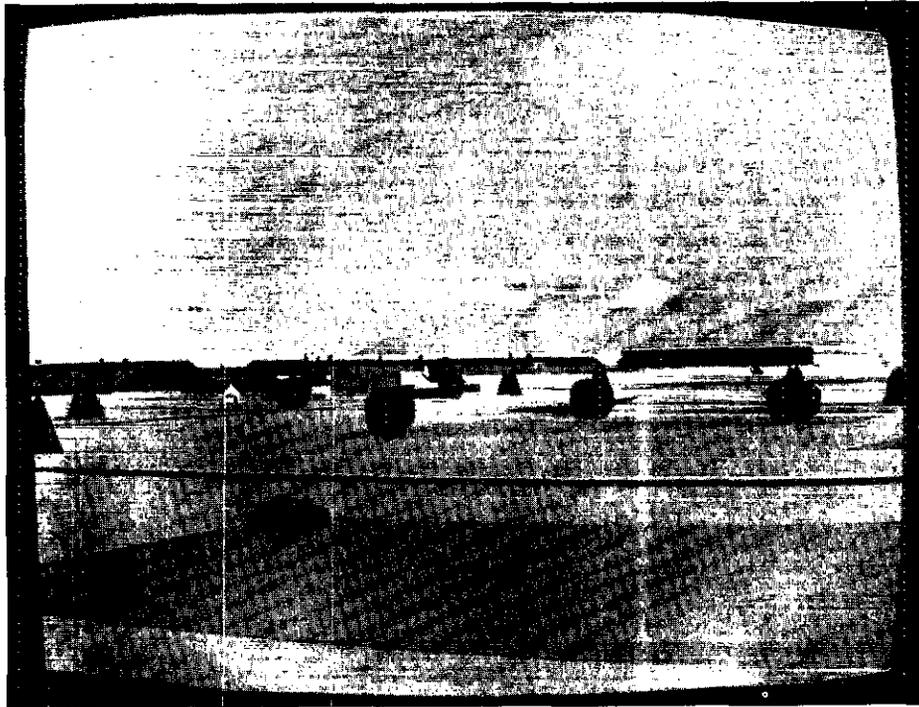


Figure 12. CIG IX Scene Presented to the MI Commander's Periscope Sight. Note middle of scene for subsequent figures.



Figure 13. CIG Scene Taken Through the Gunner's Primary Sight (GPS) at 3X. Note excellent registration.

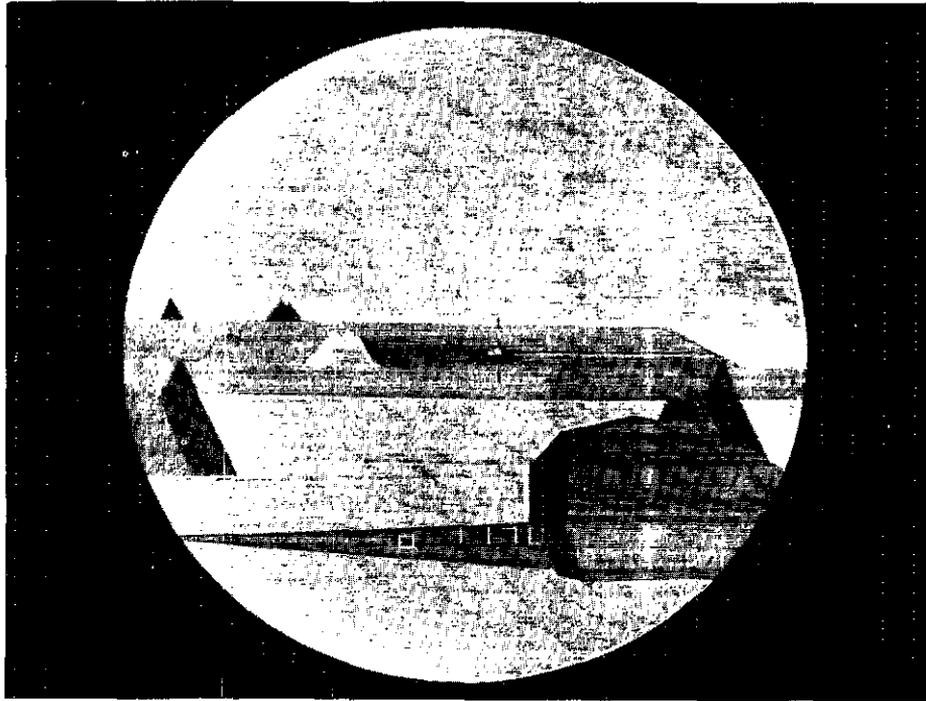


Figure 14. *CIG Scene Taken Through the GPS at 10X*

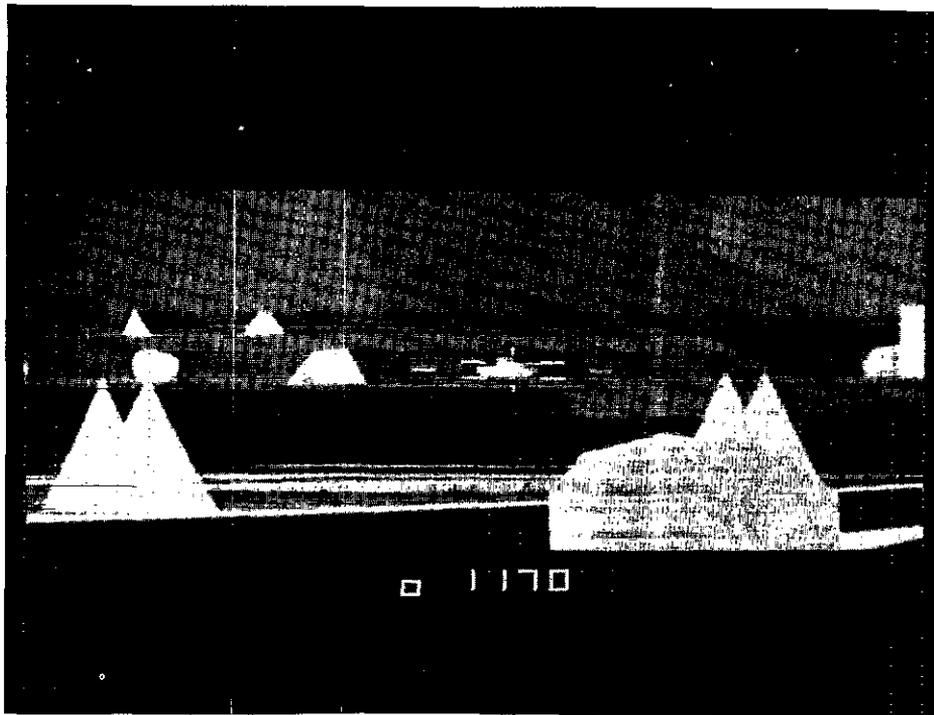


Figure 15. *"White-Hot" Scene Taken Through the GPS in the Thermal Imaging Mode*

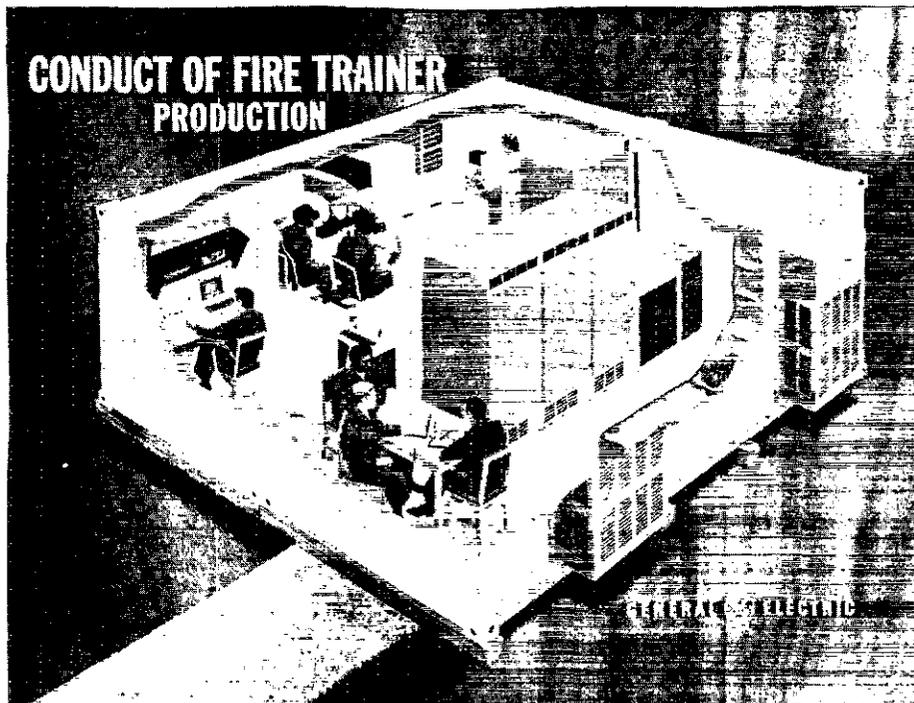


Figure 16. The General Electric Conduct of Fire Trainer (COFT).

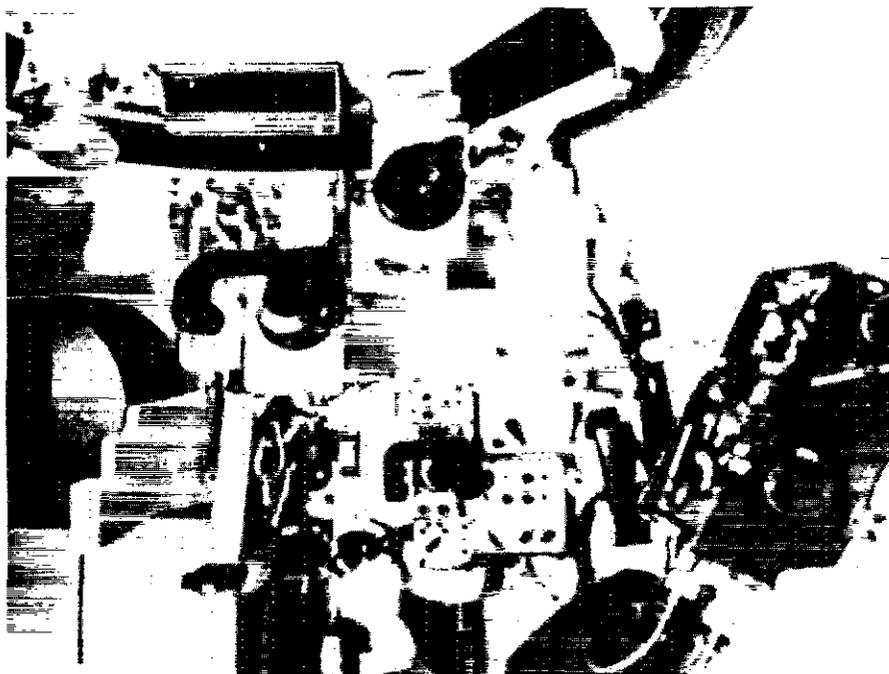


Figure 17. The Interior of GE's COFT Crew Compartment. Note the two gunner's high power sights (lower).