

TARGET TV PROJECTOR WITH DYNAMIC RASTER SHAPING FOR  
USE IN DOME SIMULATORS

Richard E. Holmes

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

ABSTRACT

Large dome simulators for air-to-air and air-to-ground aircraft weapons tactics trainers are coming into prominence. In such devices, the training objective is to improve pilot proficiency and coordination by allowing the pilot to train in the use of weapons in realistic operational and threat environments. Typically, the pilot will fight against a TV projected image that is slewed across the field of view. Sometimes neither the pilot's eyes nor the TV projector lens is located at the center of the dome screen. From geometrical considerations, a standard rectangular or square TV image looks distorted to the pilot. The degree and shape of the distortion changes with the shift in location of the "target" on the screen relative to the pilot as it is slewed either by servo pointing the entire projector or by optical means.

This paper describes the design and development of a TV projector that is capable of predistorting the TV raster such that from the pilot's viewpoint the image will look rectilinear at all times. This dynamic raster shaping can be updated at the TV field rate (typically 60 times per second) so that there is no perceptible jumpiness in the image as the shape is varied. In addition, the raster can be zoomed to create the appearance of distance change to the target and rotated to compensate the effects caused by the mirror steering of the target image across the dome.

INTRODUCTION

The layout of a typical aircraft weapons tactics trainer such as presently being developed for the U.S. Navy as Training Device 2E7 is shown in Figure 1. Each of two 40-ft diameter domes houses a simulated cockpit of a high performance jet fighter aircraft--an F/A-18 in the case of Device 2E7. The images from three background TV projectors and four target TV projectors are projected on the inside of the dome to present an all-encompassing dynamic scene to the pilot. The images are generated by digital techniques and the dynamics of the system are controlled by a large central computer. With this arrangement each of two pilots can either engage in simulated combat with each other or each can engage simultaneously in battle against the computer.

Each of the three background projectors is dedicated to a 120-degree segment of the dome and presents the image of the earth and sky environment surrounding the aircraft. Each of the four target projectors provides means to slew the image of a target or friendly aircraft across the field of view of the pilot. Since neither the pilot's eye point nor the target projectors are necessarily located on the geometrical center of the dome, standard rectilinear TV images may look distorted to the pilot. The degree and shape of the distortion changes with the location of the projected target on the dome screen relative to the pilot as it is slewed across his field of view.

DYNAMIC RASTER SHAPING

Systems Research Laboratories, Inc. (SRL) has provided TV projectors for simulation and training where either the whole projector head is mechanically slewed under servomechanism control (as shown in Figure 2) or the projector head remains stationary and the image is slewed across the domed screen by use of articulated optics (as shown in Figure 3a and 3b). In either case, computer controlled servomechanisms are used to

keep the images in focus as the distance to the screen changes with pointing angle. The gimbaling of the whole projector head is better when using wide field-of-view lens, while the articulated lens is more practical with narrow field-of-view lens.

We are familiar with how a slide projector image becomes distorted if the slide projector is not placed squarely to the screen. If it is too low, the image is distorted such that the image of a square looks more like a trapezoid with a larger top than bottom. We also know that a projected picture that is square on the screen can look distorted when viewed off axis. These effects are compounded in the case of the target projectors where the image on the TV projection cathode ray tube is flat and rectilinear and the screen is concave and off-axis to the projected image. The answer to the problem created by such geometrical distortions is to predistort the TV image before it is projected such that it looks correct to the viewer.

Several approaches to predistorting the images can be taken. The digital image generator can be programmed to predistort the video. This requires a large increase in computing power. Likewise, a double ended, optically coupled scan converter such as the SRL Model 342A (effectively a TV camera viewing rectilinear video displayed on a predistorted CRT raster; therefore, generating a predistorted video at the TV camera output, can be used. This method has a built-in time delay of one field time and requires extremely good (but achievable) electro-optics in order not to degrade resolution. The method described in this paper uses an approach where rectilinear video is displayed on a CRT projector which provides dynamic raster shaping.

The development of the predistortion algorithm, though straightforward, is still moderately complex. Fortunately, the predistortion can be implemented in a practical

system by modifying the TV horizontal and vertical sweep signals with a series of linear and nonlinear mathematical expressions in the analog domain. The functions that need to be implemented are:

- position
- size
- linearity
- trapezoidal
- pincushion/barrel
- curvature
- rotation
- orthogonality

The effect of these functions on a rectilinear raster is shown in Figure 4. All terms except for rotation can be solved using linear analog computational techniques. Rotation requires sine/cosine coordinate transformation.

In the case of the Navy's F/A-18 weapons tactics trainer Device 2E7, the central computer, either from canned programs or from the responses of the two adversary pilots, keeps track of the position of the target aircraft and generates the pointing angles of the respective target projectors. This information is translated to servomechanism information which is transmitted to the projector focus servo and to the articulated lens azimuth and elevation mirrors. It also generates at a TV field rate (60 fields/second) the coefficients for all the linear predistortion functions and both the sine and cosine of the rotation function in a digital format. Within the control unit of the TV projector electronics, this digital data is converted to analog and the remainder of the computation is accomplished in the analog domain. Figure 4 is a series of drawings showing the components of the various raster distortion terms that can be applied to the sweep circuits. These predistortion terms are shown only for the horizontal axis for ease in visualizing the effect. In actuality, a portion of each of these corrections in both the horizontal and vertical axis as well as rotation would be present, creating a very complex raster such as shown in Figure 5.

#### OTHER CONSIDERATIONS

Dynamic raster shaping places several other major requirements upon the projector. Normal TV displays and projectors use resonant horizontal deflection amplifiers due to their power conserving characteristics and due to their relative simplicity. Though some raster correction can be accomplished in resonant deflection amplifiers, only those corrections which are symmetrical about the center of sweep can be implemented simply. This eliminates curvature correction which is needed anytime the projector's optical axis is not colinear with a line drawn from the center of the dome to the dome itself--a situation that occurs at only one pointing angle with each projector. Also, raster rotation is not possible since the rapid TV retrace can be made in only one direction with resonant circuits. For continuous raster rotation, both the vertical and horizontal amplifiers must be equally as fast in both directions and as fast as each other. With these restraints on the system, it is necessary to use identical linear current feedback amplifiers for both the horizontal and vertical deflection amplifiers.

To conserve power, an SRL patented smooth actuating voltage boost is used whenever the deflection amplifiers sense it is in a flyback mode--independent of direction of flyback. (1) In practice, in each dome the four projectors are used in two pairs allowing the projection of two independent targets in order that one projector can take over from the other when it is slewed to a position such that the image would be obstructed by the simulated aircraft fuselage. Again, in order to conserve power, which would require an additional load on the dome's air conditioning system, the SRL projectors have a deflection amplifier powerdown feature which is used whenever the projector is not selected by the computer.

Up to 250:1 raster zooming is also available in the projector to create the effect of variable distance to the target. However, small rasters on a TV projector operating at up to 60 watts screen dissipation are potential problems due to phosphor burning. The SRL projector calculates the actual raster area and limits the video drive to a safe short-term value. This allows the display of bright objects for short periods of time, but long-term protection is up to the central computer.

#### CONCLUSIONS

Dome simulators are proving to be effective training aids. Steerable TV projectors are also proving to be practical means of providing the image of the target. As more realism and precision are required to keep airmen proficient in weapon tactics, more emphasis needs to be given to image fidelity. This requires not only higher resolution, but higher geometrical fidelity. The concept of providing dynamic raster shaping in the TV projector instead of in the digital image generator or an intermediary black box is both technically superior and cost effective and should find its place in more advanced visual systems. I visualize its use spreading to air-to-ground as well as present air-to-air weapons tactics trainers.

#### REFERENCE

1. R. E. Holmes and J. A. Mays. United States Patent No. 3,628,083, 1971.

#### ABOUT THE AUTHOR

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

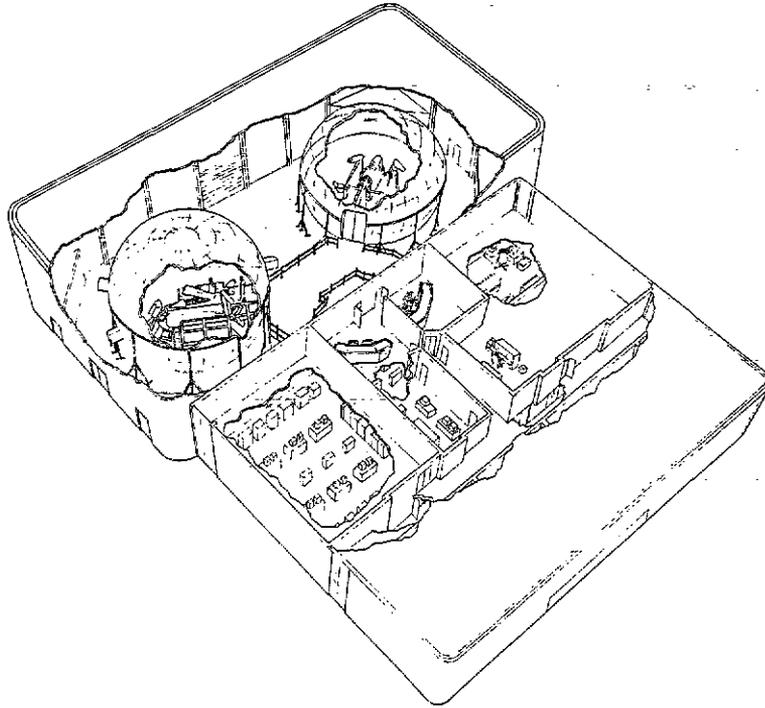


Figure 1. Typical Dome Weapons Tactics Trainer

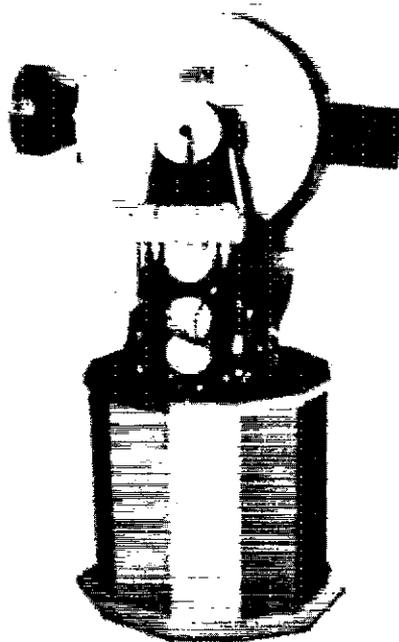


Figure 2. Steerable TV Projector Head with Servo Azimuth and Elevation

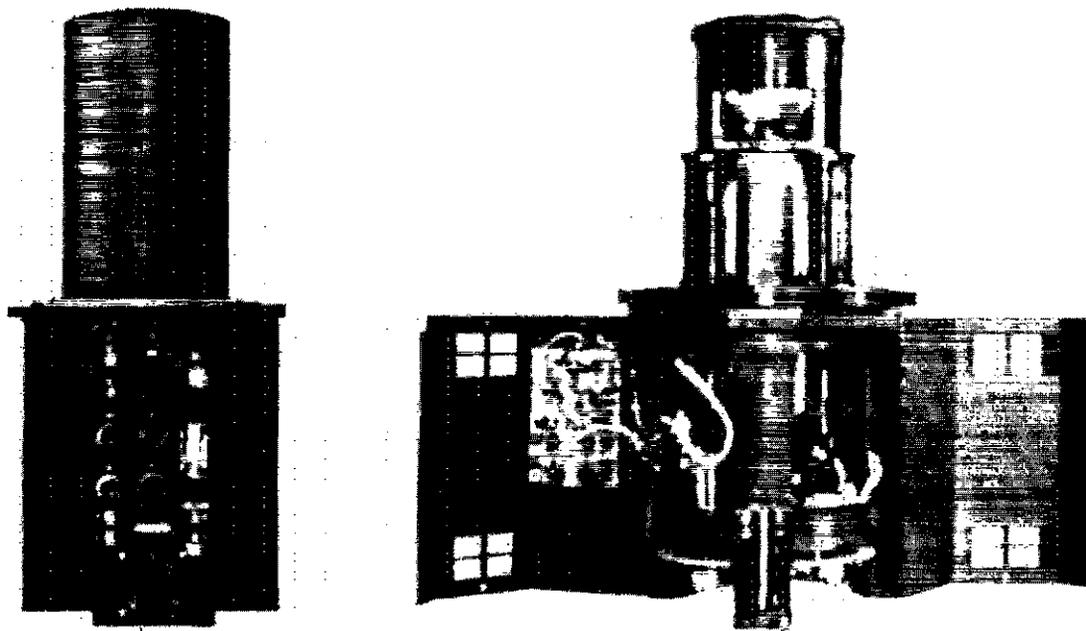


Figure 3a. Projector Head (without optics) Used with Device 2E7 Target Projector

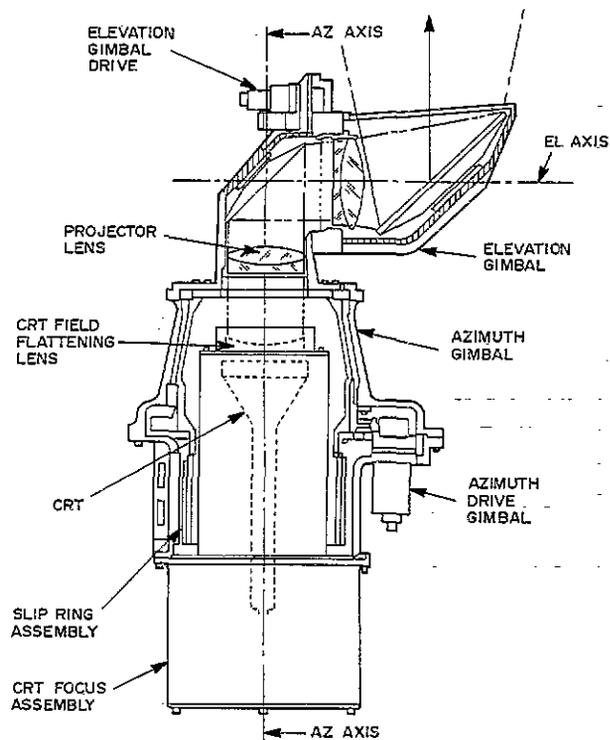


Figure 3b. Outline Drawing of Projector Head Showing Typical Steering Optics

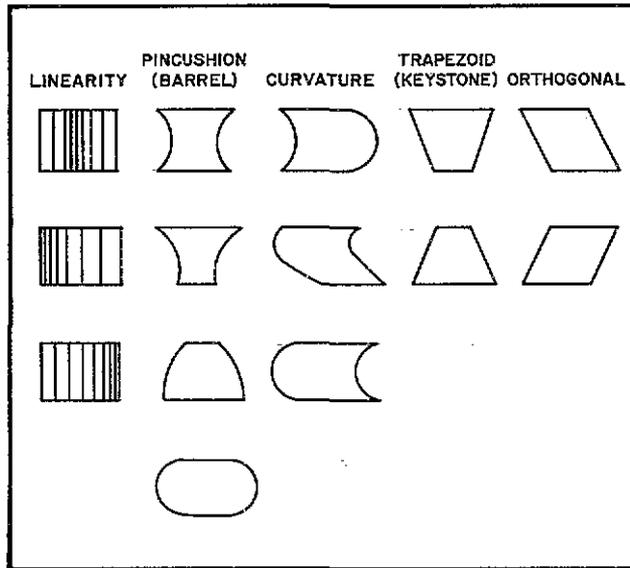


Figure 4. Photograph of Predistorted Rectilinear Raster

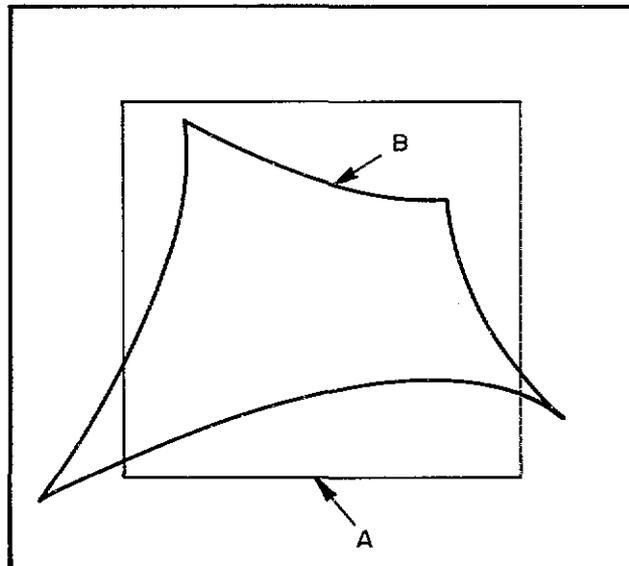


Figure 5: Typical Raster

A - Uncorrected

B - With Dynamic Raster Shaping