WIDE-ANGLE SCANNED LASER VISUAL SYSTEM

CARL R. DRISKEL
US Army Office of Project Manager for Training Devices

DR. A. M. SPOONER
Redifon Flight Simulation, Limited

INTRODUCTION

An experimental investigation is being conducted to determine the feasibility of using scanned lasers to generate and display real world scenes for military training applications. The technical objective is to provide high resolution tactical scenes over a continuous wide field of view.

The US Army and Air Force are supporting the development of a breadboard laser camera and display system to investigate the capability of the system and applicability of this approach to military training requirements. Completion of the breadboard system is scheduled for third-quarter 1978.

The prime contractor is American Airlines Incorporated. Redifon Flight Simulation Limited, as subcontractor, is conducting the main body of the work, and the Sira Institute, England, is providing expertise on optical and electronic systems.

Image Generation

Before considering the complete scanned laser visual system, the basic principle of the image generation system will be described with comparison to a conventional television system. The basic components of a conventional television system are illustrated on the left side of Figure 1. The object to be televised is illuminated and the reflected light, over a field of view set by the lens, is picked up by a television camera which generates a video signal for viewing on a picture monitor. The signal is generated as the electron beam in the television pickup tube scans the target in raster format.

On the right side of Figure 1, the same object is scanned by what may be called a laser camera. The laser camera projects a laser beam, scanned in raster format, onto the object. The video signal is generated by a photocell placed where the lamp was placed in the conventional television system.

There are several important points that should be noted in this comparison. Perhaps the most important point is that exactly the same image appears on both picture monitors. This is true as long as the generating and reproducing scanning processes are synchronized and the field scanned by the laser beam is the same as the field of view of the television camera.

Second, the point of perspective or viewpoint with the laser system is the point from which the scanned laser beam leaves the laser camera and not the photocell. Movement of the laser camera produces normal perspective views just as if it were a normal television camera.

Third, lighting effects can be achieved with appropriate placement of photocells. Just as in a conventional model board visual system, where multiple lamps are used to evenly illuminate a terrain model, so in a scanned laser visual system multiple photocells can be used to produce a scene that appears to be evenly illuminated. A concentration of photocells can be used to generate directional lighting effects and fiber optics with photocells behind the model can be used to generate cultural lights.

Now that the basic principle of image generation has been established, the complete scanned laser visual system will be discussed.

Laser Visual System Description

Figure 2 illustrates the complete scanned laser system. As in a conventional camera modelboard visual system, the gantry moves the laser camera in x, y, and z coordinates along the simulated flight path over the terrain modelboard. Instead of a lamp bank, there is a small number of photomultipliers which collect the laser light reflected from the model.

The laser camera uses two high power ion lasers, an argon laser to provide green and blue primary colors, and a Krypton gas to provide the red primary color. The output beams from the lasers are combined and fed through flexible fiber optics to the laser camera.

The laser camera contains line and frame scanners which scan the beam in a raster format with the scanning lines running vertically. In the preferred system about 4400 vertical scan lines are used in an interlaced scan. The probe from which the light is emitted is slender,

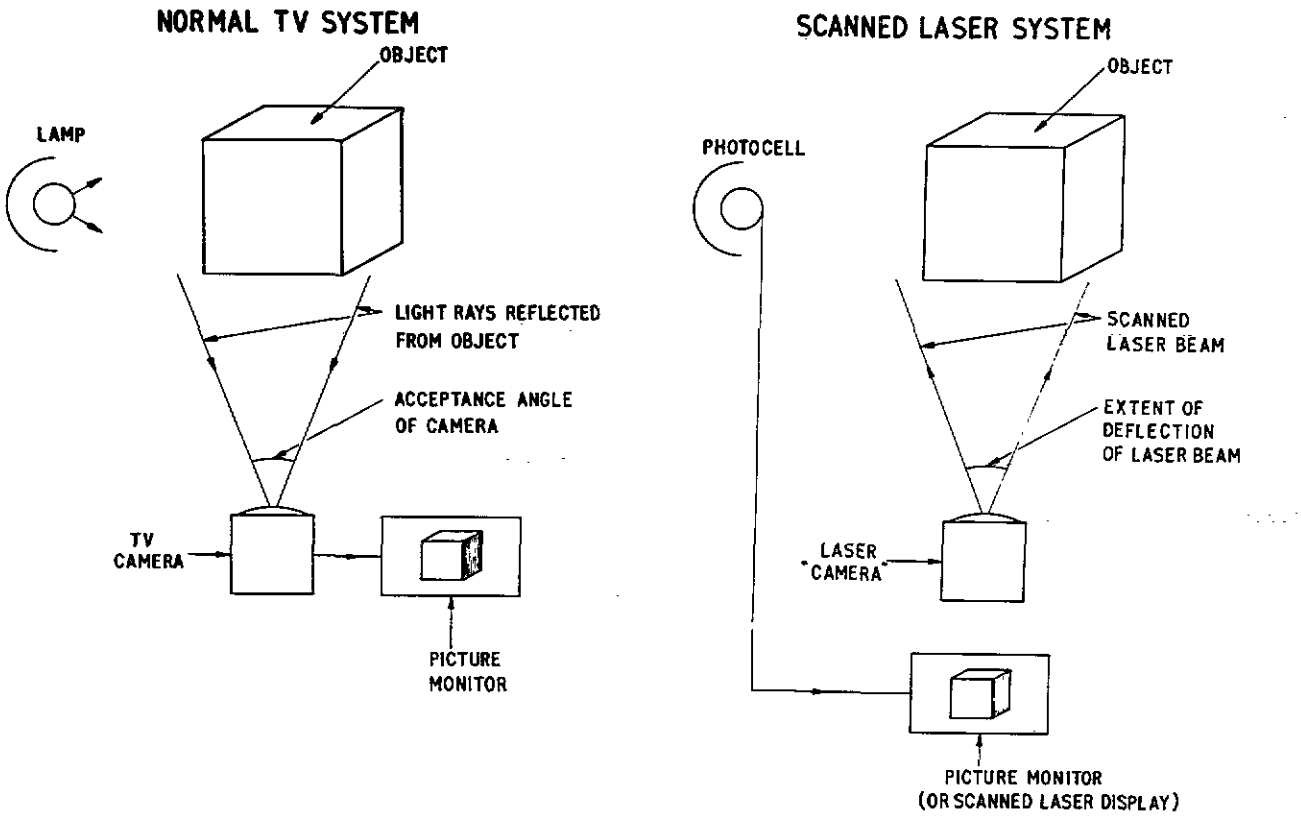

Figure 1. Comparison of Normal and Scanned Laser Television Systems

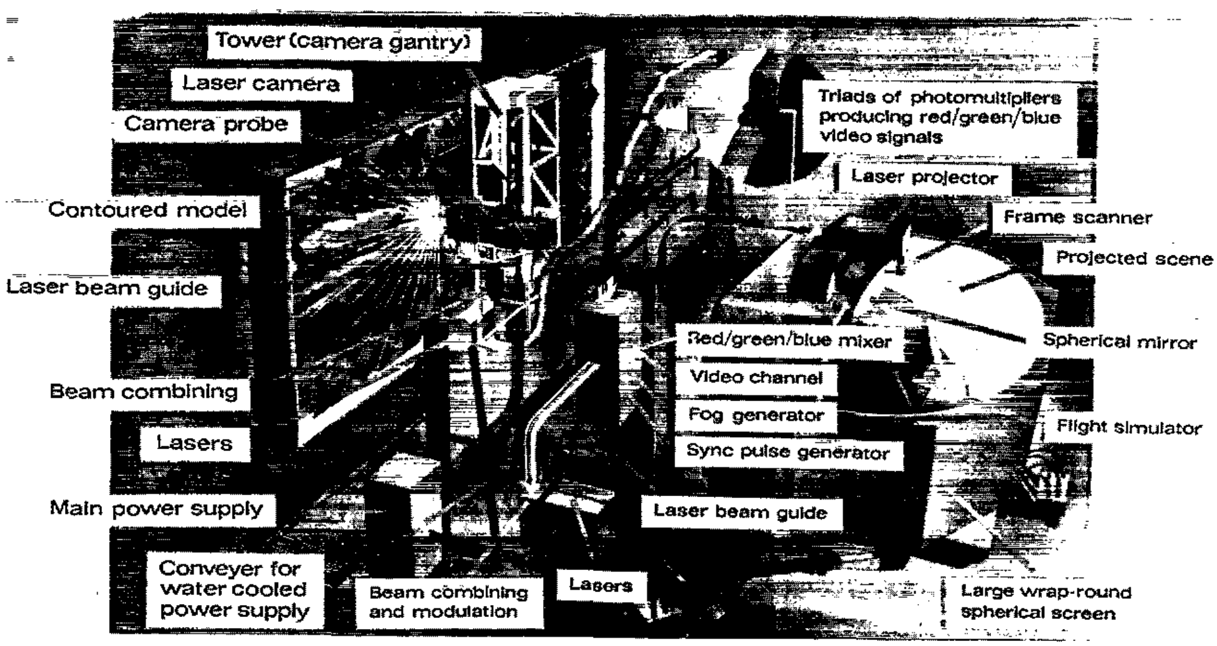

Figure 2. Scanned Laser System for Visual Flight Simulation

allowing close approach to the terrain model surface and between vertical features on the model.

The photomultipliers are arranged in groups of three, or triads; one of each triad sensitive to red light, one sensitive to blue, and one to green. All the red signals are summed, as are the blue and green, to produce red, blue and green video signals. The video signals are processed with blanking, gamma correction, aperture correction, etc., and fed to the display.

At the display, the three primary color beams again are generated by two lasers, but before being combined, the beams are modulated by light modulators driven by the video signals. A flexible fiber-optics light guide is used to convey the composite modulated beam to the laser projector. The projector uses line and frame scanners, accurately synchronized to those in the laser camera, to project the desired scene.

Since it is necessary to project the beam onto the spherical screen without distortion, direct projection cannot be used as the projection point cannot be coincident with the pilot's head. Accordingly, as illustrated in Figure 3, the emerging beam is reflected first from a spherical mirror, giving overall correct display geometry in the wide-angle, high-resolution image.

Field of View and Resolution

The video bandwidth in the system can be 100 MHz rather than 5 MHz for a broadcast type closed-circuit television system. Therefore, approximately twenty times as many picture elements can be generated and displayed as with normal television. Various tradeoffs are possible between field of view and resolution; the higher the field of view the lower the resolution and vice versa.

Based upon current military training requirements and reasonable development goals, a 175 degree by 60 degree field of view was selected for the experimental breadboard model. With this field of view and a 100 MHz video bandwidth, a resolution of 5 arc minutes should be achieved.

Optical Layout

In order to cover a 175 degree field of view on the model board, the frame scan is accomplished by rotating the frame scan prism from which the laser beam emerges about an axis normal to the model surface. This means that the field angle to be relayed through the scanning probe is 60 degrees rather than 175 degrees, and fairly conventional optics can be used. The principle of the scanning probe is illustrated in Figure 4.

The basic principle of the complete wide-angle scanning system involves passing the laser beam, containing red, blue, and green components, through a line scanner which uses a rotating mirror drum to deflect the beam in a sawtooth deflection approximately 132,000 times per second. The deflected beam is then passed through a derotation prism and a wide-angle lens which expands the vertical angle to 60 degrees. Finally, the beam is deflected by the rotating frame scan prism to emerge as a raster of approximately 4400 vertical scan lines. The derotation prism runs at one-half the speed of the final prism, to keep the scanned line vertical as the final prism rotates. Using a single frame scan prism would produce a 360-degree frame scan, but a nominal 180-degree scan is obtained by using two prisms. To allow for a small percentage of dead time during which the black level of the video signals is established, the actual horizontal field of view will be 175 degrees.

At the end of each 180-degree rotation of the prisms, the line scanned beam has to be switched rapidly by a galvanometer mirror between these two prisms so that the emerging beam is always in the forward direction. This process of changing the beam from one prism to the next inverts the line scan so that the beam deflected by the galvanometer has to be taken through a further prism for correction.

The optical layout in the projector is similar to that of the probe as far as the line and frame scanning processes are concerned. As mentioned earlier, the emerging beam, covering 175 degrees by 60 degrees, is directed first onto a spherical mirror and then onto the spherical screen for viewing by the pilot. The display layout is illustrated in Figure 3.

Roll, Pitch, Heading

The next aspect of the system to be considered is attitude control. In a conventional camera model visual system, the optical probe has servo-controlled optical elements to change pitch and roll, and the complete lower part of the probe structure is usually rotated about an axis normal to the model surface to provide heading changes. With the laser probe, the prisms from which the beam emerges are already rotating continuously. By altering the phase of this rotation at the probe in relation to the corresponding rotation at the display, heading changes can be simulated.

In order to allow close approach to the model surface and easy passage between obstacles, simulation of roll and pitch

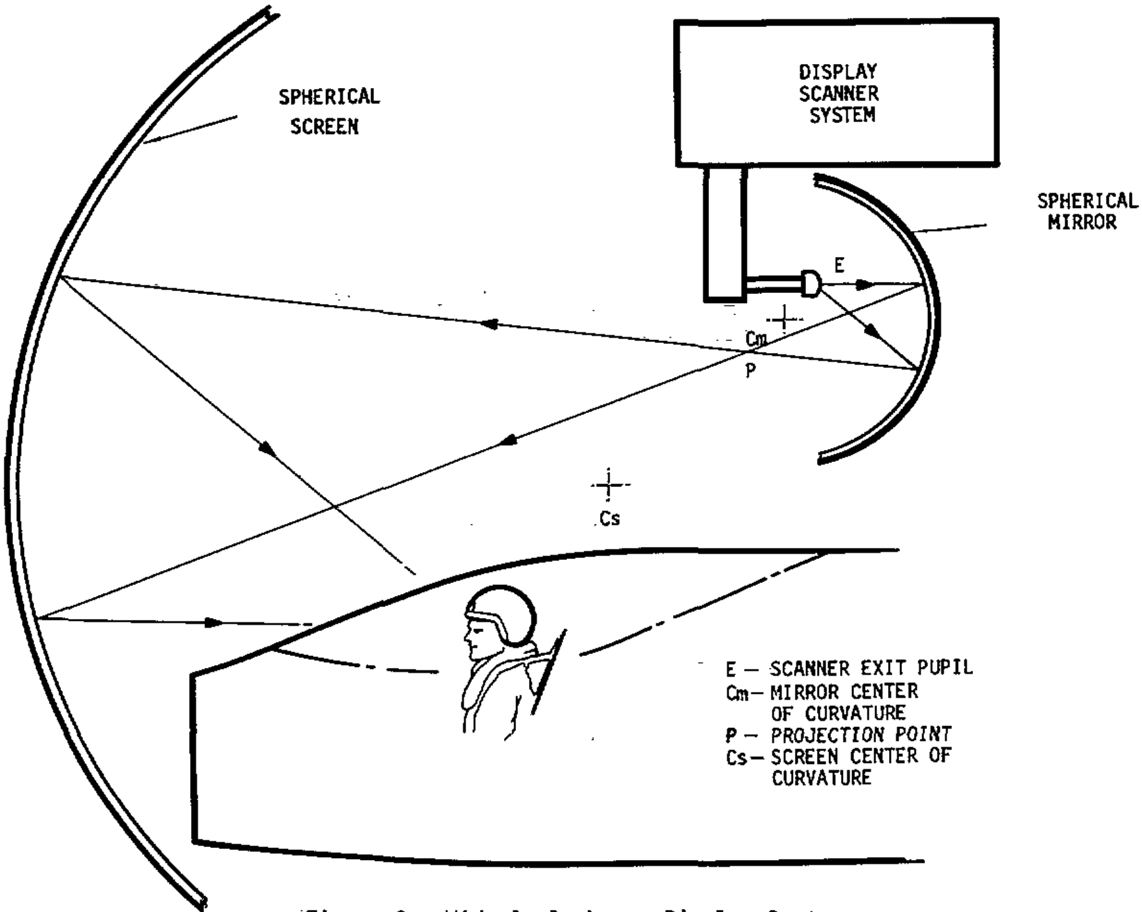

Figure 3. Wide-Angle Laser Display System

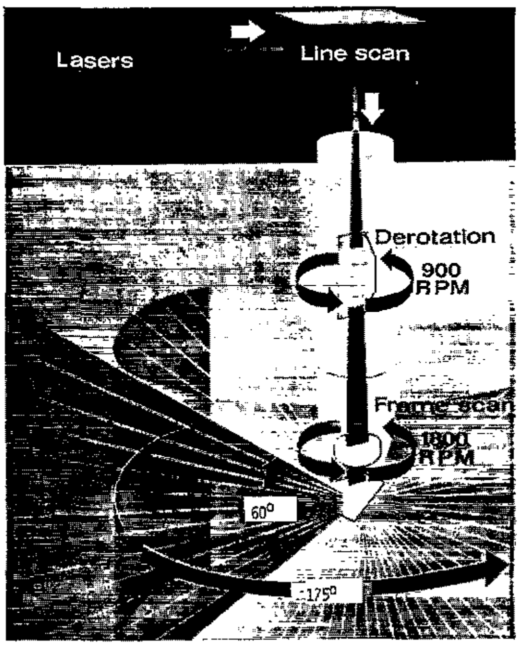

Figure 4. Principle of Wide-Angle Laser Probe

at the display is preferred. There is plenty of room at the display for the mechanisms necessary to achieve this, as shown in Figure 3.

There are several advantages of simulating roll and pitch at the display. First, objects that appear within the vertical field of view continue to be displayed during pitch maneuvers since the entire display format is pitched; Second, targets are not lost off the top or bottom of the screen during roll maneuvers since the entire display format is rolled; and third, it is not necessary to waste television scanning lines in reproducing blank sky. The sky can be simulated with an auxiliary optical projector attached to the main projector.

The primary disadvantage of simulating pitch and roll at the display is that an area of terrain beneath the aircraft cannot be viewed at any attitude and parts of this dead area appear under extreme conditions of roll or pitch.

Focus

The next aspect of the proposed scanned laser system to be considered is that of focussing the beam on the terrain model. Focussing of the beam on the display screen is constant and presents no problem.

Depth of field is a very important consideration in conventional camera model visual systems. The optical probe attached to a conventional television camera has an entrance pupil whose size determines the depth of field in which objects will appear to be in sharp focus. The larger the aperture the worse the depth of field, but the smaller the aperture the more the resolution is limited by diffraction.

With the laser system, in which the scanned laser beam leaves an exit pupil to strike the model, the same basic tradeoff exists. The laser system has the advantage, however, that the laser beam can be put through any chosen aperture. This is unlike the conventional camera model system which needs a minimum aperture to get enough light through for a noise-free picture. Another significant advantage of the laser system is that only one spot on the model is illuminated at a time. Therefore, changes of focus and aperture can be accomplished during scanning to give optimum results. By contrast, within a conventional camera model system, the whole field of view is continuously imaged and techniques to improve the depth of field must operate on the whole field at once.

Two main types of focus correction may be used in the scanned laser visual system; the choice depends on the visual mission. For missions where the modelboard may be considered to be flat for focussing purposes, the tilt lens techniques used for conventional television optical probes may be adopted. An analysis shows that good results will be obtained by using a high aperture tilt lens in the optical system such that the beam is focussed at a short distance when it scans the near part of the model and at a greater distance when it scans the far parts. The absence of roll and pitch motions in the probe makes the design easier.

For missions where the model board can not be considered to be flat, the instantaneous focus may be changed dynamically to give optimum focus for each object struck by the scanning beam.

The technique for carrying this out is to use electrooptic cells to vary the width and convergence of the laser beam before scanning. At the exit pupil of the laser probe the emerging beam is rapidly focussed on the object being scanned and the width of the beam is varied to change the depth of focus.

Figure 5 shows the laser beam passing through an electrooptic cell. The control signal is applied to the cell which can switch the polarization of the emerging beam through 90 degrees. The beam is passed through a calcite lens which has different refractive indices for the two polarizations. Therefore, two different degrees of convergence of the beam can be obtained.

By using up to three such cells, eight different focus conditions are sufficient to give smooth change of focus with distance. By correct design of this focussing system, the increased convergence of the beam needed to focus on near objects can be linked with a decrease in pupil size to give a better overall result.

CONCLUSIONS

An advanced, high-resolution wide-angle visual system for military flight simulation has been described. The basic feasibility has been established but the practical realization of the system remains to be proven. Satisfactory conclusion of this work will provide a substantial advance in visual simulation.

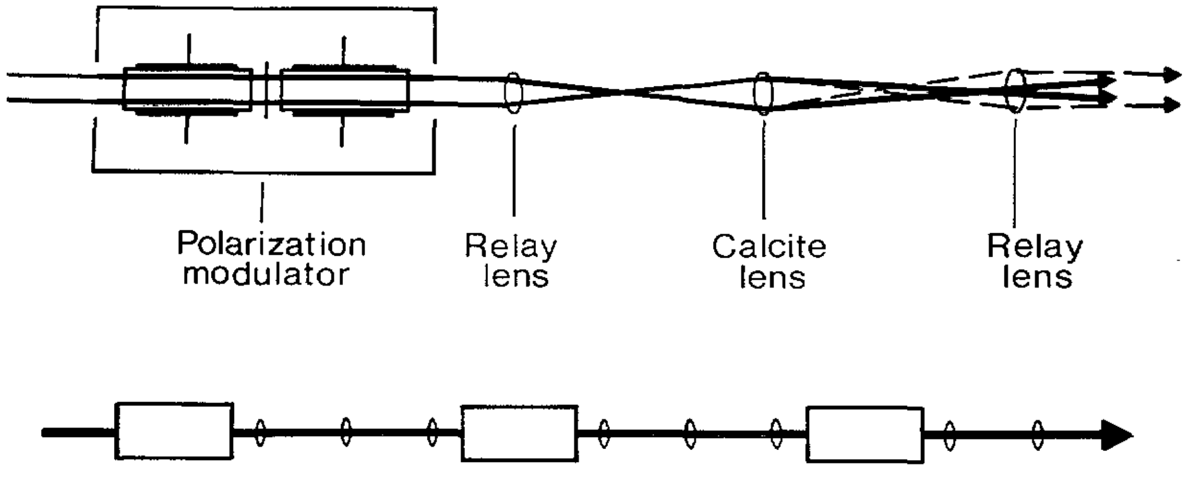

Figure 5. Electrooptic Method of Focussing

ABOUT THE AUTHORS

MR. CARL R. DRISKELL is Project Director at the US Army Office of Project Manager for Training Devices, Naval Training Center, Orlando, Florida. He is responsible for the development of advanced training devices with special interest in the area of visual simulation. He began work in the area of visual simulation in 1968 as a Research Electronics Engineer at the Naval Training Equipment Center and directed several significant developments in submarine and aviation visual simulation research. Upon receipt of his M.S.E.E. degree in 1964, Mr. Driskell worked as a Research Engineer at the Georgia Tech Engineering Experiment Station, where he performed research in the areas of electromagnetic compatibility, acoustic-radio interaction of doppler radar, and piezoelectric network design.

DR. ARCHER MICHAEL SPOONER is Chief Scientist for Redifon Flight Simulation Limited, England. He joined the Redifon Group in 1968 and has been responsible for a number of technical advances in visual simulation. As Chief Scientist, he is responsible for the research activities of Redifon Flight Simulation, Limited. Formerly, he worked as an electronic development engineer for several British companies. He has made significant contributions to the recording of televison programs on film, and to electronic special effects for broadcast television. Dr. Spooner holds a B.S. degree in Electrical Engineering and a Ph.D. in Electron Path Plotting from London University.