A LOW-COST DRIVER TRAINER (LCDT) FOR A TRACKED VEHICLE

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ABSTRACT

A videodisc-based driving procedures training system is under development by General Dynamics Electronics Division for the United States Marine Corps that will provide training for drivers of the new LVT-7A1 tracked landing vehicle. This new system, to be delivered in March of 1984, will provide training and practice to new drivers in correct vehicle operation before they drive an actual vehicle. The system is designed to train 750 students each year in classes of 30 students each. The LCDT consists of a minicomputer with a master control console, five instructor consoles, and five student stations that replicate the driver's compartment of the LVT-7A1.

INTRODUCTION

The LVT-7A1 is an upgraded version of a previous Marine Corps Tracked Landing Vehicle put in service in 1971. The significant portions of the upgrade include a new engine and transmission, as well as a new instrument panel and other mechanical changes. The principal use of the vehicle is transporting troops or cargo from a landing ship stationed off-shore to the beach with minimum risk. In this application, the vehicle carries 25 troops and a crew of three. In an effort to reduce the high maintenance costs caused by the failure of vehicle drivers to follow correct operating procedures, a driving procedures simulator is being developed by General Dynamics Electronics Division for delivery in March of 1984.

The major purpose of the trainer is to train new drivers in proper vehicle operating procedures. The trainer will be used in conjunction with classroom instruction and actual vehicle driving periods and will train 750 students each year in classes of 30 students each. It is not intended to replace actual vehicle driving time, but to train for normal as well as emergency and failure shutdown procedures that must be followed to prevent compound vehicle damage. These procedures can not be taught effectively in the classroom due to lack of real-world conditions, or on the vehicle because of the potential danger to vehicles or personnel.

The major components of the training system are the simulation computer and the five trainee stations with associated instructor stations. Figure 1 is a block diagram of the overall training system.

The simulation computer is a low-cost minicomputer of the SEL 32/27 type which contains and executes the software that runs and controls the training system. The computer system consists of the central processor, and 80 MB removable media disc drive, a tape unit for system rebuild and program archival use, a 200 CPS printer, and a master control terminal.

The computer software, written in FORTRAN 77, is the result of over four man-years of development. It simulates the vehicle responses by modeling vehicle dynamics including engine, transmission, braking, steering, and traction as a result of student inputs and vehicle operating environment. The instructor has the option of changing the operating environment by specifying the simulated outside temperature or by introducing vehicle malfunctions at particular locations during the training session. The procedures to be followed by the student for the various driving conditions as well as those to be followed under malfunction conditions are monitored by the computer software for later review and print out by the instructor, if desired. Student performances that are monitored include the number of times the student exceeds the maximum speed in a gear, the number of stalls, the number of times the vehicle is in the wrong operating mode, and others for a total of 16 parameters.

The five student stations replicate those controls and gauges in the driver's station that are critical to the correct operation of an actual vehicle. These controls include the steering wheel, gear selector, hand and foot throttle, water/land mode selector switch, cold-start switch, and ramp control handle. Figure 2 is a diagram of the student enclosure. The various gauges include the transmission oil temperature and pressure, engine oil temperature and pressure, engine water temperature, air filter restriction, battery voltage, engine RPM, vehicle speed, and compass heading. Figure 3 shows the vehicle control panel. The fire warning and fire suppression system is also simulated so that the student can receive instruction in vehicle fire procedures.

Each student station also has a voice and vehicle sound synthesis system. The voice synthesis system will command the student in much the same way as an actual training instructor using voice commands for such things as "Take the right fork", "Stop the vehicle", "Enter the water", and "Return to the beach". The voice synthesis system is completely solid-state and can play back up to 64 seconds of prerecorded voice commands. The sound synthesis system reproduces the various vehicle sounds necessary for training including the engine, transmission, bilge pumps, personnel ramp, water jets, and tracks for a total of 15 sounds, all under computer control and coordinated with the student actions.

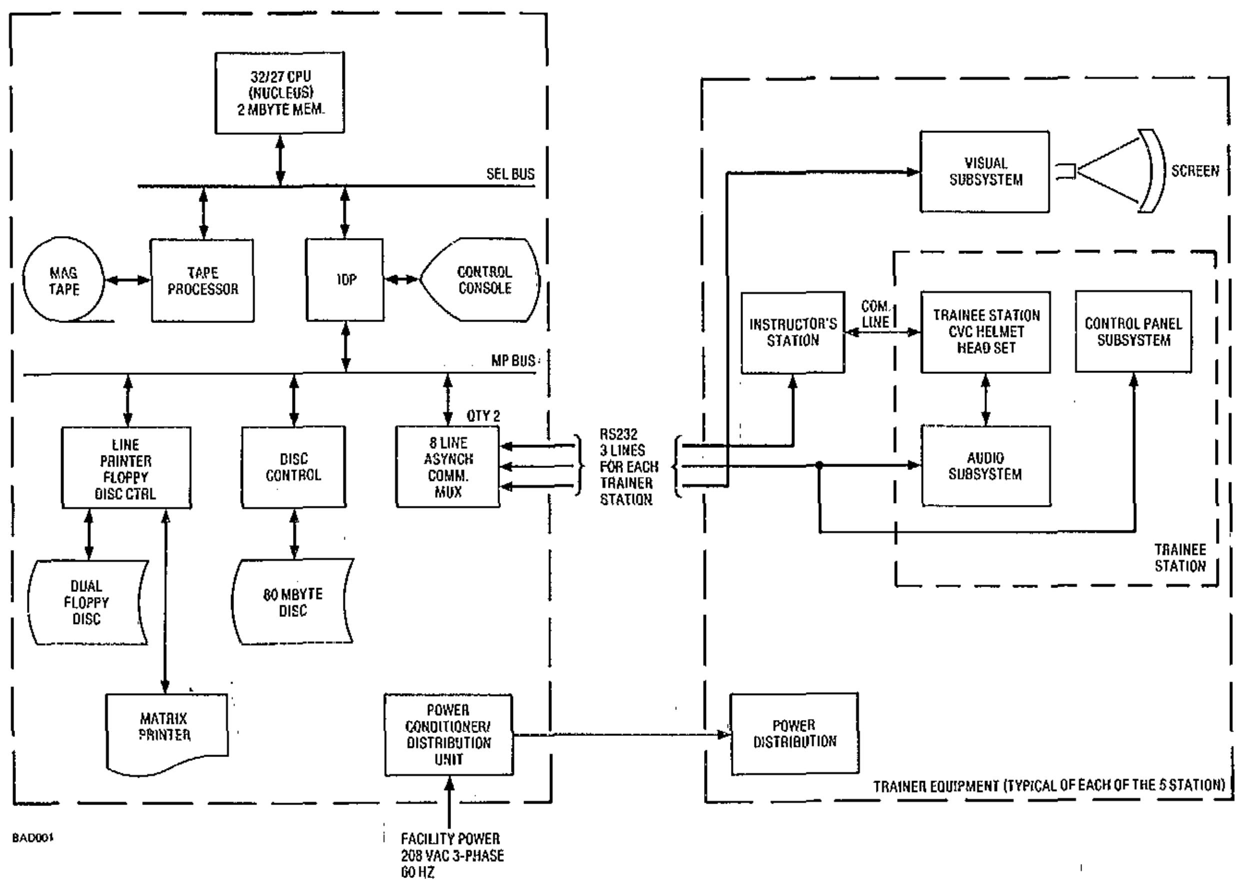

Figure 1. Overall LCDT System Block Diagram

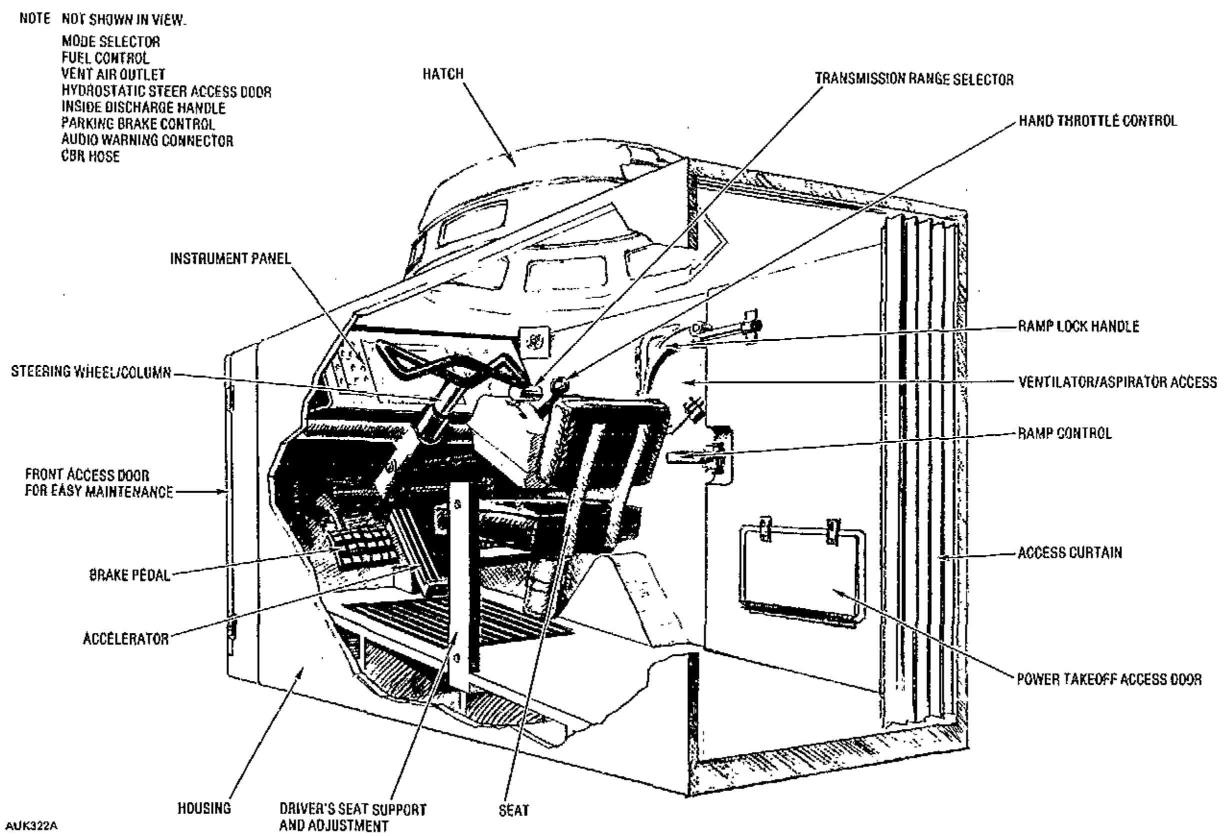

Figure 2. Realism Is an Important Objective in the Trainee Station

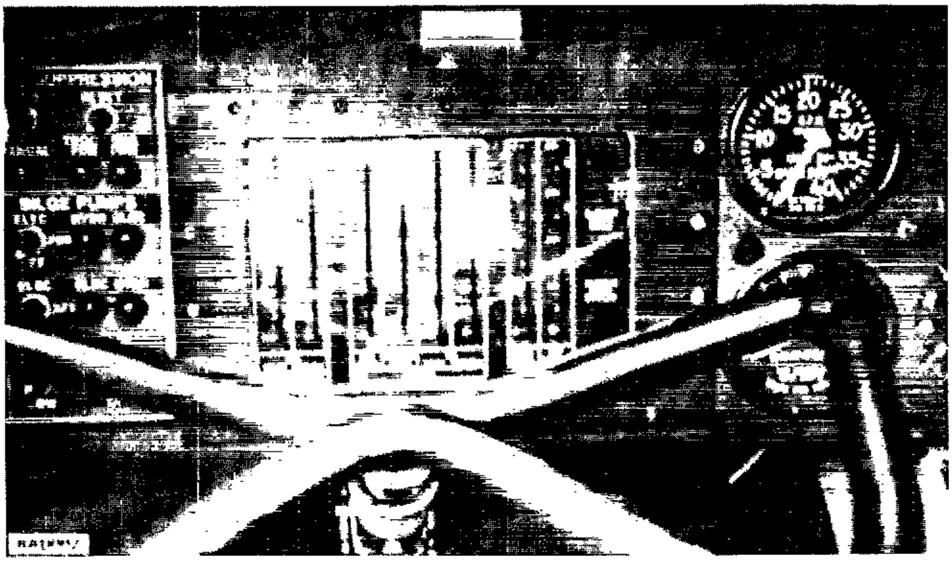

Figure 3. LVT-7A1 Control Panel

Another part of the student station is the visual system which shows the student pictures of the driving course on a 6.5-foot-diagonal projection TV screen. The source of the pictures is a videodisc that was produced expressly for the training system as part of the project. The videodisc is played back on an industrial-quality player under computer control. The video from the disc is processed by the visual electronics hardware under computer control to generate a modified video image that shows the results of the student's steering the vehicle to the left or right of the correct course. The speed of the video presentation is controlled by the computer in response to student manipulation of the throttle, gear selector, and brake. The visual screen also shows computer-generated advisory messages and instructions to the student.

Associated with each student station is the instructor's console which is a standard computer terminal connected to the trainer computer via serial link.

The audio, visual, and procedure monitoring portions of the trainer will be discussed in greater detail in the following paragraphs.

AUDIO SUBSYSTEM

As described previously, the audio subsystem is responsible for generating the voice commands and the vehicle sounds sent to the student as feedback for his actions. Figure 4 is an overall block diagram of the subsystem. The voice commands are the same as those which would be given by an instructor training the student.

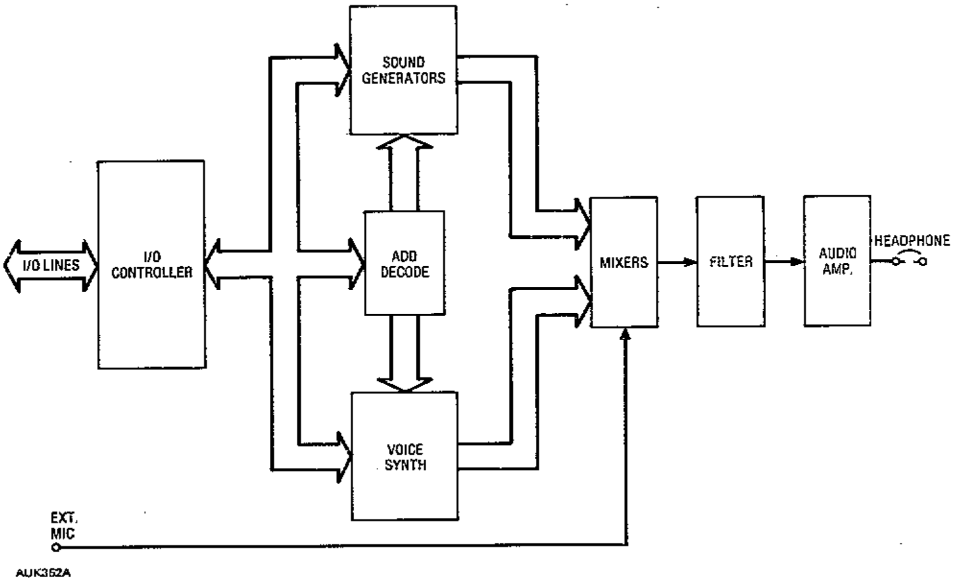

Figure 4. Audio Subsystem

These commands must be easy to understand and natural sounding for effective training. To generate these voice commands, an instructor speaks the desired commands into the speech digitization hardware. This hardware converts the speech into digital data using the Continuously Variable Slope Delta Modulation (CVSDM) technique at a clock rate of 16 kHz with an input low-pass filter cutoff frequency of 5 kHz. The digitized speech is then saved on disc for later use. At the start of the training lesson, this speech data is sent from the trainer computer to each individual student station for use during the training lesson, and is stored in solid-state dynamic memory. When a voice command is required, the trainer computer sends a command to the student station that defines which voice command to speak. The voice hardware then converts the digitized voice data back into natural-sounding speech and sends it to the trainee through his headset.

The sound synthesis subsystem must reproduce the simulated vehicle sounds in a correct and realistic manner because they are cues to the trainee indicating correct or incorrect vehicle operation. These sounds include the engine as it is started under normal and freezing conditions, as it runs under various loads and speeds, and as it stops. The transmission sounds that must be generated include the sounds in each of the four forward and two reverse speeds. Other vehicle sounds that must be generated are the engine cooling fan, plenum doors opening and closing, ramp raising and lowering, ramp hitting deck, hydraulic and electric bilge pumps, audio warning tone, water jet noise, and track noise. The malfunction sounds that are simulated include engine overheating with radiator hissing sound and the transmission gears grinding.

The sounds are generated using 16 commercially available sound generator ICs. Each IC can generate three individually-controlled frequencies with noise and a modulation function. The outputs of several ICs are mixed together and filtered to form more complicated sounds. The most complicated sound, the engine, requires six frequencies, two modulation functions, and two noise components to duplicate the actual vehicle sound. The least complicated sound, the hissing sound from the radiator, requires only a single noise component. The software in the trainer computer monitors the simulated vehicle operating conditions and outputs the control words to the sound synthesis system which defines the actual frequencies and amplitudes to be generated by each IC.

Since the vehicle sounds are such an important feedback cue to the student, it is necessary that they be as correct as possible. The first step in the sound synthesis process is recording the actual vehicle sounds. This was accomplished by recording a vehicle under known operating conditions. These conditions were chosen to isolate and reduce interaction between sounds to the greatest extent possible. First, the sounds that are independent of the engine operating such as the horn, ramp opening and closing, ramp hitting deck, bilge pump, and starter motor were recorded on a high-quality tape recorder located near the sound source. The absolute amplitudes of these sounds were then recorded using a sound-level meter at the driver's station. The same procedures were followed for the sounds of the engine running at various RPMs, but with the vehicle stationary. The procedures were again followed for the engine cooling fan and the plenum door opening and closing. Finally, the vehicle was driven over actual terrain to record and measure the sounds of the transmission in the various gears, as well as the track and the water jet sounds.

The recordings of these sounds were then digitized, stored on a magnetic disc, and analyzed using an FFT analysis program which extracted the principal frequency components. These frequency values were then used as inputs to a sound development program which reproduced the sounds using the sound synthesis ICs. These synthesized sounds were then compared to the actual sounds using audio analysis techniques. The more complicated engine sound, which had several components that changed as a function of engine RPMs, was analyzed at several recorded RPMs to determine the relationship between the amplitude and the frequency of the components. Once this relationship was determined, the sounds at the intermediate RPMs could be determined so that a continuous spectrum of sounds can be generated during the training session. Sound generation in the trainer required that the software generate the various data words required by the sound synthesis system so that the sounds would be correct and natural.

VISUAL SUBSYSTEM

The visual subsystem is responsible for providing the scenes of the driving course that match the operation of the simulated vehicle by the trainee. To add realism and acceptance by the students, the visual system provides a simple interactive steering approach that keeps the student busy during the simulated driving so that malfunctions are not the only thing that the student must respond to. The major components of the visual system are the videodisc player and videodisc, the visual electronics, and the projection TV system. Figure 5 is a block diagram of the visual subsystem.

The visual subystem uses a videodisc to store the visual scenes. There are four different types of driving situations portrayed on the videodisc: stall test, land driving, water driving, and surf operations. The stall test is a simple, straight-ahead driving sequence that is part of the preoperational tests on the vehicle each day. As part of the training, the instructor can select the normal stall test or the stall test that simulates and shows a vehicle fire in the engine compartment. The land driving portion is a 3.6-mile sequence that requires the student to demonstrate correct operation of the engine, transmission, steering, and brake as the vehicle is driven over various types of terrain. As part of this sequence, the student must also follow the hand signals given by a ground guide. The water driving portion requires that the student demonstrate correct water operating procedures including water entry and exit as well as turns, stopping, and backing up in the water while operating the vehicle in a protected jetty area. This sequence also requires that the student follow a more complicated set of ground-guide hand signals and maneuvers. The surf operations portion is a six-minute sequence that exposes the student to the conditions and procedures required when entering and leaving the surf from the beach. The sequence starts on the beach, goes through the surf zone, turns parallel to

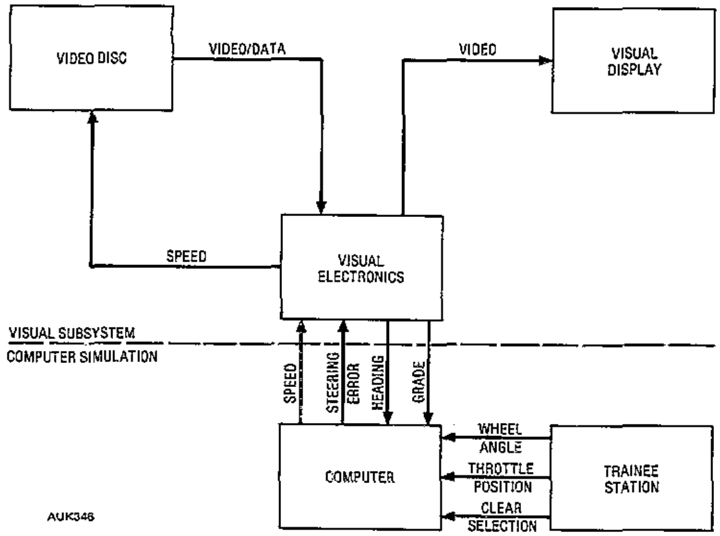

Figure 5. Visual Subsystem

the beach for about 100 meters, and returns to the beach through the surf zone.

The quality production of these sequences was important to the acceptance of the trainer by the instructors and the students. Both film and video were used to take the pictures of the various scenarios. The land portions were filmed using a 35-mm step-frame camera that was connected to a speedometer output shaft on the right-hand track. A new frame of film was taken whenever the vehicle went 1.5 feet forward, thus providing a maximum simulated vehicle speed of 30 mph when the film is converted to video on a videodisc. The use of the freeze-frame capability of the videodisc allows the trainee to go as fast or as slow as desired and still provide a correct visual presentation. The water sequences were shot using video since there is no distance-traveled indication to control the film camera. However, the sequences were shot using a constant, known engine RPM so that the simulation program would have a reference from which to speed up or slow down the videodisc to portray the student's actual speed.

The two cameras were mounted on a specially-constructed camera mount which was welded to an actual vehicle just ahead of the driver's station so the same relative view would be retained in the simulator. The focal lengths and, thus, the angles that each camera covered were set to be the same and to match the field of view that would be portrayed from the trainee's position onto the projection TV system.

The visual electronics system has three purposes. The first is to provide the interface between the trainer computer and the videodisc player. The second is to provide the interactive steering capability. The third is to generate warning and advisory messages.

The data from the trainer computer provides the controlling information for the videodisc player and tells it to search to a particular video frame, to step forward or back to the next frame, or to play the disc at normal speed. The interface electronics formats the data received from the trainer computer and sends the data to the videodisc player. The electronics also reports videodisc player status information to the trainer computer.

Implementation of the interactive portion of the visual electronics system requires that data be recorded that defines the direction that the camera system was pointing at the instant the picture was taken. It is also desirable to record the inclination of the vehicle so that the simulation program would know when the vehicle was going up or down a hill to accurately simulate the vehicle speed and sounds during a training session. This data logging took place during filming by using vertical and heading gyros from an aircraft navigation system. The readings of these gyros were converted to digital data as the pictures were taken and were recorded on each film frame and each video frame in the active image area. When the film and video are put on a videodisc and later played back, special circuits in the visual electronics will recover the data and send it to the simulation program for incorporation into the vehicle model solution. This method eliminated the need for the training program to store and retrieve data that describes the course heading and grade for each video frame. Any scenerio changes in the driving course that might have rquired a change in the course data were handled automatically by the editing process since this data was actually part of the film or video. The data recorded was 12 bits of heading data for a resolution of 0.079 degrees and 8 bits of inclination angle information for a resolution of 0.351 degrees. Figure 6 shows the location of the data bits within the active video area. This portion of the picture is blanked so that it is not visible to the student.

The interactive steering portion of the visual electronics receives trainee steering error data from the trainer computer and uses this data to rotate the visual scene from the videodisc right or left, depending on the error made. When the student's error is large and the

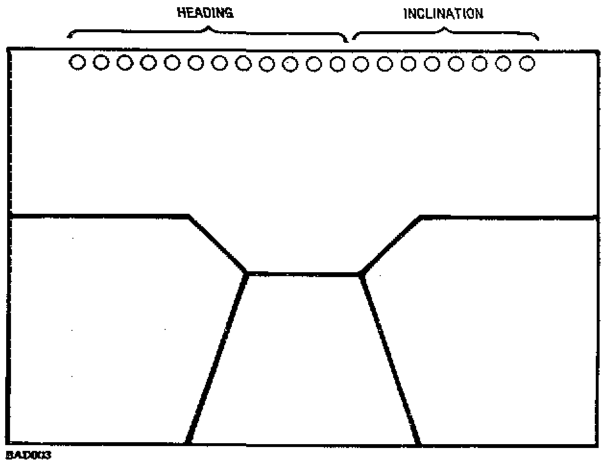

Figure 6. Data Bits in the Film or Video Frame

amount of rotation is such that there is no data from the videodisc for the scene, the visual electronics generates synthetic video for that portion not on the videodisc. Figure 7 shows the shifting scene and the computer-generated color when the shift amount is large. Thus, as the student drives around the course, the correct path must be driven and maintained or the scene will shift off the screen in the direction of the error made and the student will see nothing but synthetically-generated color. This shifting is accomplished by synchronizing to the video from the videodisc, generating new sync signals that are shifted from the incoming signals an amount determined by the student's steering error, combining these with the incoming video to generate the new shifted video, and sending these to the projection TV system. Figure 8 is a block diagram of the visual electronics portion of the system. The visual electronics system also generates computer-controlled warning and advisory messages and sends them to the projection TV for display.

The various driving scenes and messages are shown on a commercially-available, high-brightness, 6.5-foot-diagonal-screen projection TV system that is eight feet away from the trainee's position. To provide the student with a straight-on view of the screen while maintaining the correct student-to-screen distance required that the optical path be folded using a flat mirror and that the image from the projection TV system be reversed electronically.

DRIVING PROCEDURE MONITORING

Monitoring the student's driving procedures is an important part of the training program. The goal of the training school is to graduate drivers from the program who have knowledge of and are able to demonstrate the correct vehicle driving procedures. To grade the students

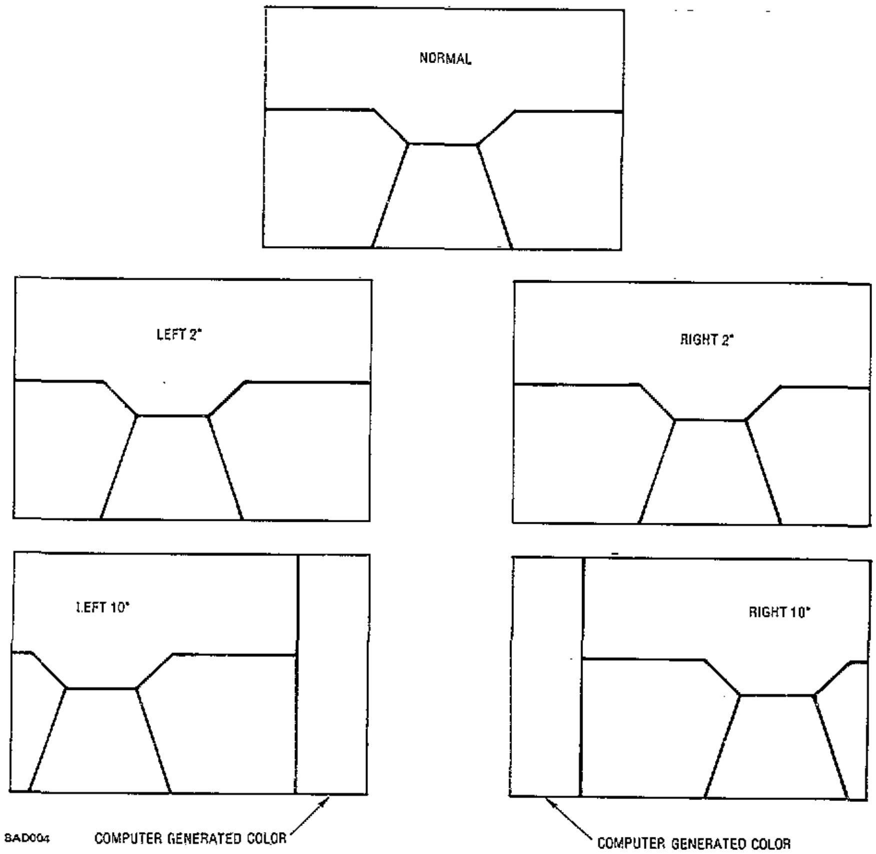

Figure 7. Examples of Scene Rotations

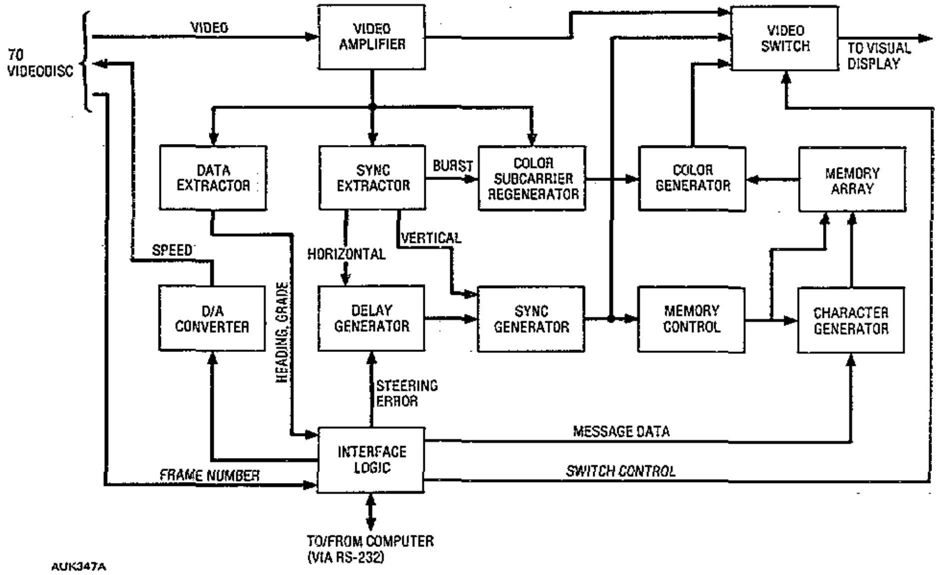

Figure 8. Visual Electronics Detailed Block Diagram

on their performance, the computer program must know the correct procedures to use as a standard. It would also be desirable for the training course instructors to be able to make changes to the driving procedures monitored by the program so that any changes in the actual vehicle operating procedures would be reflected in the simulated driving course. To accomplish these two goals, an English Language procedure file system was developed that expressed the actions to be performed by the student in real vehicle terms and conditions. Thus, anyone familiar with the operation of the actual vehicle could read the procedure file to determine if the actions and responses were correct without having knowledge of computer programming. Any changes to the procedures are simply entered by modifying the procedure file using a text editor. This procedure file is then read, parsed, and analyzed by the monitoring program during the course of the training session to test the correctness of the student's actions and performance. Since the procedure file read and changed by the course instructor is the same as that used by the program to monitor student performance, there can be no translation errors between the desires of the instructor and the student's actions checked by the program. Figure 9 is an example of the engine start procedure file for normal temperature.

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* ENGINE START PROCEDURE FILE NORMAL TEMPERATURE
*
* SET PARKING BRAKE
IF "PARKING_BRAKE = RELEASED" THEN
   POSITION "FOOT_BRAKE" TO "PRESSED"
   POSITION "PARKING_BRAKE" TO "SET"
END IF
*
* SET UP STARTING CONFIGURATION W/OUT FUEL
POSITION "SMOKE_GENERATE" TO "CLOSED"
SELECT GEAR "NEUTRAL"
POSITION "THROTTLE" TO "IDLE"
POSITION "FUEL_CONTROL" TO "OFF"
POSITION "MASTER_CONTROL" TO "ON"
*
* ENSURE PLENUM DOOR OPEN ON LAND/CLOSED IN WATER
IF "VEHICLE_ON_LAND" THEN
   POSITION "MODE_SELECTOR" TO "LAND"
ELSE
   POSITION "MODE_SELECTOR" TO "WATER/JETS"
END IF
*
* TEST-CRANK THE ENGINE
POSITION "STARTER" TO "PRESSED"
IF "BATTERY_VOLTAGE_LOW" THEN
*
* SIMULATE LOW_BATTERY_VOLTAGE RE
   POSITION "STARTER" TO "RELE
   POSITION "TRANSMIT_KEY
   CLEAR "BATTERY
   RESTART
ELSE
   WAI
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SA0005

Figure 9. Partial Engine Start Procedure File

CONCLUSIONS

When installed in March of 1984, the LCDT will provide the desired procedures training on the LVT-7A1 vehicle for the Marine Corps.

The technology used in this driver trainer is directly applicable to other vehicles that require driving procedure training.

ABOUT THE AUTHOR

Mr. JOHN ABRAHAM is a Principal Engineer with General Dynamics Electronics Division. He is currently responsible for the visual subsystem of the LVT-7A1 Driver Trainer as well as other videodisc-based training projects. He holds a master's degree from the University of Southern California in Electrical Engineering. He has worked in the area of videodisc-based systems for the past three years and in training systems for the past 12 years.