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16. Abstract

Texas Department of Transportation (TxDOT) employs the Pavement Management Information System (PMIS) to effectively manage and maintain its highway system. Pavement surface distress is a very important indicator of the condition of the roadway system. To gather this information in urban areas, TxDOT has purchased a multi-purpose road survey vehicle called the Automatic Road Analyzer (ARAN). The data reduction involves a technician who reviews video tapes of the pavement surface recorded by the ARAN. The review technique is a tedious and fatiguing process. Current advancements in dedicated imaging processing hardware enables the development of a computer processing system to reduce the pavement distress data automatically.

This report describes two important areas of automatic evaluation of the pavement surface distress video. High resolution, sharp, and shadow free images of the pavement surface enable the computer processing to be more efficient and accurate. To attain this goal, a scheme using artificial light inside an enclosed trailer was investigated. Five types of lights and four types of video cameras were experimented upon in a darkroom and open-bottom trailer to determine the most appropriate combination. The stages of the trailer design up to the final proto-type are also described. This report also describes the hardware components of the video image processor system. The selection, justification and configuration of a workstation host image processing system over a PC host system are discussed. Finally, the functionality of individual hardware components and the integration of all components into a comprehensive video image processing system are included in this report.

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System Hardware for Acquisition and Automatic Processing of Pavement Distress Videolog

by

Paul Chan
Ashok Rao
Robert L. Lytton

Research Report 1189-1

Study Title: "Automatic Photo Interpretation System for the ARAN"
Project 2-18-89-1189

Sponsored by
Texas Department of Transportation
in cooperation with
U.S. Department of Transportation
Federal Highway Administration
by
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November 1992

METRIC (SI*) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	2.54	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	6.452	centimeters squared	cm^2
ft^2	square feet	0.0929	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
mi^2	square miles	2.59	kilometers squared	km^2
ac	acres	0.395	hectares	ha
		MASS (weight)		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		VOLUME		
fl oz	fluid ounces	29.57	millimeters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.0328	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

Note: Volumes greater than 1000 L shall be shown in m^3.

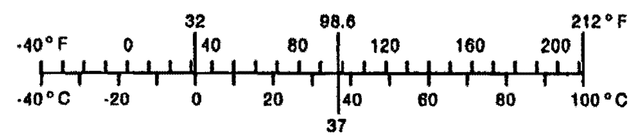
Symbol	When You Know	Multiply By	To Find	Symbol
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

These factors conform to the requirement of FHWA Order 5190.1A

*SI is the symbol for the International System of Measurements

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
yd	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
yd^2	kilometers squared	0.39	square miles	mi^2
ha	hectares (10,000 m^2)	2.53	acres	ac
		MASS (weight)		
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1000 kg)	1.103	short tons	T
		VOLUME		
mL	millimeters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



ABSTRACT

Texas Department of Transportation (TxDOT) employs the Pavement Management Information System (PMIS) to effectively manage and maintain its highway system. Pavement surface distress is a very important indicator of the condition of the roadway system. To gather this information in urban areas, TxDOT has purchased a multi-purpose road survey vehicle called the Automatic Road Analyzer (ARAN). The data reduction involves a technician who reviews video tapes of the pavement surface recorded by the ARAN. The review technique is a tedious and fatiguing process. Current advancements in dedicated imaging processing hardware enable the development of a computer processing system to reduce the pavement distress data automatically.

This report describes two important areas of automatic evaluation of the pavement surface distress video. High resolution, sharp, and shadow free images of the pavement surface enable the computer processing to be more efficient and accurate. To attain this goal, a scheme using artificial light inside an enclosed trailer was investigated. Five types of lights and four types of video cameras were experimented upon in a darkroom and open-bottom trailer to determine the most appropriate combination. The stages of the trailer design up to the final proto-type are also described. This report also describes the hardware components of the video image processor system. The selection, justification and configuration of a workstation host image processing system over a PC host system are discussed. Finally, the functionality of individual hardware components and the integration of all components into a comprehensive video image processing system are included in this report.

DISCLAIMER

This report is not intended to constitute a standard, specification or a regulation and does not necessarily represent the views or policies of the FHWA or Texas DOT. This report is not intended for construction, bidding or permit purposes. The study supervisor of this study is Dr. Robert L. Lytton who is a registered engineer with the State of Texas. (Texas No. 27657).

IMPLEMENTATION STATEMENT

The automatic pavement distress evaluation system can assist the TxDOT in surface distress data collection for PMIS. This system is safer, more objective and consistent than sending rating teams out to the field.

ACKNOWLEDGEMENTS

The authors wish to thank Mr. Thomas Scullion, program manager of Pavement Systems in TTI, with his enthusiastic participation, insightful advice and expertise in the Pavement Management Information system, he has contributed much to the success of this study. The authors also wish to thank the TxDOT project panel chairman, Mr. David Fink for his conceptual contributions at every stage of the study, member Mr. Carl Bertrand for his helpful advice in electronic instrumentation and member Mr. Al Rubio for his recommendations related to the video camera and video cassette recorder.

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CHAPTER I
INTRODUCTION

Pavement surface distress data is crucial information needed in the Pavement Management Information System (PMIS) of the Texas DOT. Surface distress data along with ride quality, structural data, and skid resistance provide a good indicator on the condition of the roadway. [Texas DOT (1992)]

Pavement surface distress data is usually collected by teams of raters. They drive on the shoulder and observe the cracks and other distress. If the traffic condition allows, the rater team will stop every 0.5 mile and evaluate all the distress types in a 200′ long area. The rater teams are at risk when they are out on the highway system. Some of the highly used urban freeway systems are impossible to rate by this method. The labor cost is also high since Texas has a large roadway system.

Therefore, in 1986, the Texas DOT purchased a multiple purpose road survey vehicle called the Automatic Road Analyzer (ARAN). This survey vehicle can collect:

1. Right of Way Video
2. Pavement Video
3. Rutting
4. Roughness
5. Geometrics of Roadway

The video is then brought back to the office for rating of distress types.

In the past 5 years, computer hardware prices have come down, while processing power has increased. In the years before, only minicomputers such as VAX could handle the processing of a large image data set. It is now feasible to process digitized images on workstations or Personal Computers (PC). To give an idea of the sheer quantity of data, one digitized image takes up over 0.25 mega bytes of memory (512 x 512).

In 1988, TxDOT funded a research study entitled "Automatic Photo Interpretation System for the ARAN" to develop a comprehensive image processing system which analyzes pavement images from video tapes. This report describes the hardware aspects of this development effort.

Chapter II describes the various aspects involved in acquiring quality pavement video. Chapter III describes individual components within the video image processing system. The function of individual boards and how each board connected together to work as a system are also discussed. A number of conclusions and recommendations based on the experience gained in this study is reported in Chapter IV. The Appendix section contains a detailed wiring diagram of the video image processing system and a program listing of the VCR control function.

CHAPTER II
VIDEOLOG ACQUISITION UNIT

This chapter describes some options to enhance the quality of the acquired video images. It is important to have high resolution, shadow free images for manual visual evaluation of the pavement video, and this is far more important for automatic evaluation by computer system. Algorithms were designed to differentiate cracks from sparse tree shadows. However, it was observed that the dense shadows from the body of the survey vehicle and the large trees on the roadside masked the whole image. This situation made consistent ratings difficult even for the experienced rater.

Section 2.1 describes a scheme to alleviate the shadow problem with an artificial lighting system. Five types of lights were examined in a darkroom and video recordings were made from a SONY black and white camera shooting at cardboard with grids. Section 2.2. describes the characteristics of the camera required for the road survey. Section 2.3 discusses the design of an open bottom trailer where lights and cameras were mounted inside. Finally, Section 2.4 discusses the existing survey vehicle and how the pavement video was made during the survey.

2.1 Artificial Illumination System

When the survey vehicle travels down the roadway, except when the sun is shining from the back, shadows of the vehicle projected on the pavement surface are videotaped. This severe shadow problem is seen on every image. The shadow is either a triangular or rectangular shape. Since the shadow area is much darker than the sunlit area, the cracks inside the shadow area are masked. Shadows are also caused by passing vehicles, trees, transmission lines, bridges, etc.

Five types of lights were tested for their brightness level and uniform illumination in the target area. Their advantages and disadvantages are listed in Table 1 for comparison. The lighting systems were tested with the shutter speed camera setting at 1/4000th of a second. This shutter setting is necessary to obtain a image free from blurring while the survey vehicle travels at 50 miles per hour.

Automobile Headlight

This type of light is very durable and designed to stand the vibration of the vehicle (see Figure 1). The power requirement for the light is 12V DC. Unfortunately, the darkroom light test showed that the light distribution had rings of varying intensities and caused errors in the detection algorithms. The other problem was that the headlight illuminations was not adequate when the shutter speed of the camera was set at 1/4000th of a second.

Flood Light

The flood light (see Figure 2) gives even illumination and is relatively inexpensive. The power requirement for the light is 110V AC. But the test showed that the brightness level was not adequate for the high speed shutter camera intended to be used during the pavement surface distress survey.

Aircraft Landing Light

These lights are used on aircraft, and have a wide range of beam angles and amounts of lumens. Two sets of lights (see Figure 3) were set up to study the illumination patterns. One set of lights was a 450 watt

Table 1. Summarized Characteristics of Five Types of Illuminary Tested.

Types of Illuminary	Characteristics	
	Advantage	Disadvantage
1. Automobile headlight	1. Can stand vibration	1. Non-uniform light distribution 2. Inadequate brightness level
2. Flood light	1. Durable	1. Inadequate brightness level
3. Aircraft landing light	1. Durable	1. Non-uniform light distribution
4. Quartz light	1. Adequate brightness	1. High power consumption 2. Hot spot
5. High pressure Sodium light	1. Adequate brightness 2. Uniform light distribution	1. High power consumption 2. Requires square wave power supply

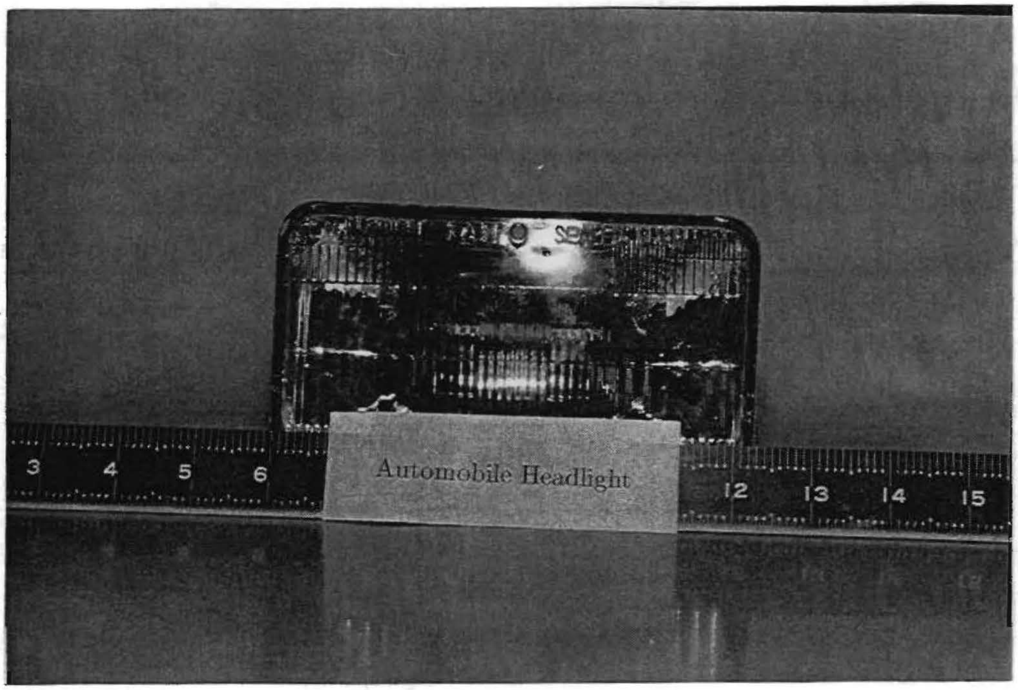


Figure 1. Automobile Headlight.

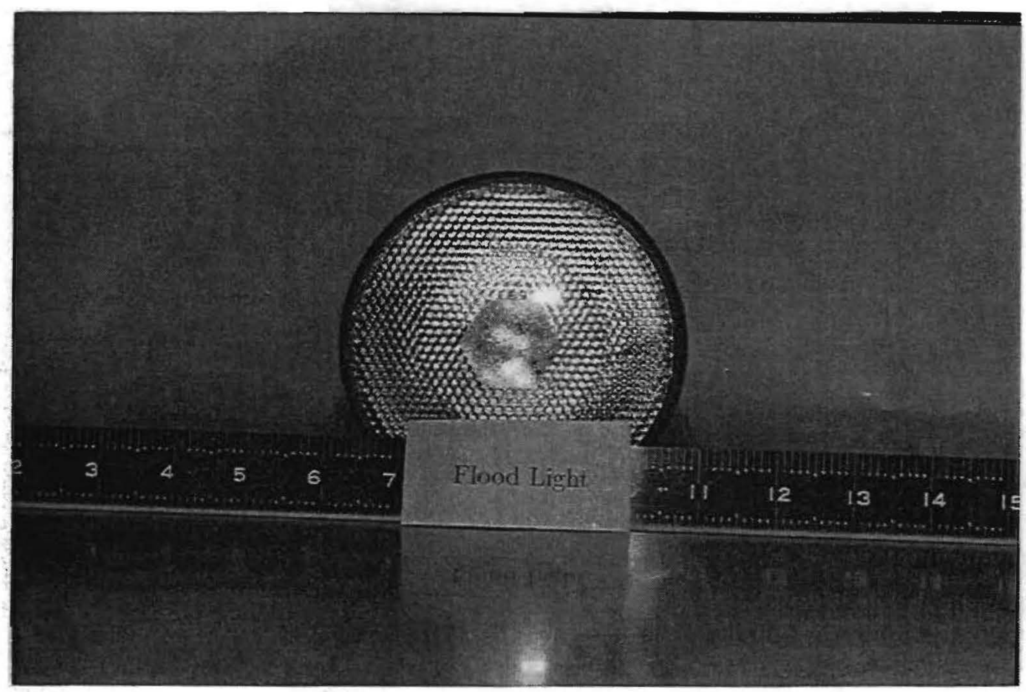


Figure 2. Flood Light.

Figure 3a. Aircraft Landing Light - Narrow Beam

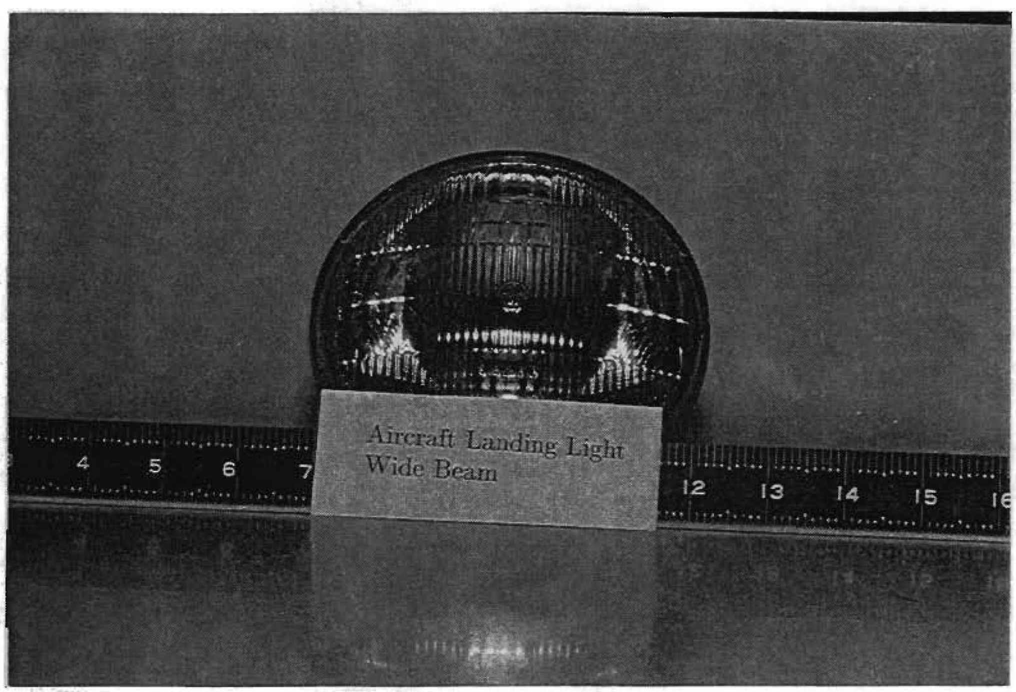


Figure 3b. Aircraft Landing Light-Wide Beam.

spotlight with 400,000 candlepower. The other light was 150 watt wide angle diffused flood lights with 32,000 candlepower. High current step-down transformers were used since the supply voltage for the lights was 28 volts instead of 120 volts.

Both light systems were found to be inadequate. The 450 watt spotlights were bright enough for the required shutter speed, but rings of different brightness level were observed. This unevenness in the light distribution caused problems in detection of pavement crackings. The 450 watt spotlights have a very short life due to the high amount of heat generated within the lamp.

The 150 watt flood lights diffused the light very evenly over the surface with very few shadows appearing on the test grid board. The wide-angle flood light however, could not produce enough light to get a clear image at 1/4000th of a second shutter speed.

Quartz Light

Two types of quartz lights, the 500 watt and the 1500 watt units, were selected for light testing. The power requirement for 500 watt and 1500 watt lights were 110V AC and 200V AC respectively. The 500 watt lights did not produce enough light to give a clear image. The 1500 watt lights (see Figure 4) gave adequate light intensity during the dark room testing. The 1500 watt lights were then installed inside the trailer and tested on the pavement sections at the Texas Transportation Institute (TTI) research annex. Hot spots were observed on the pavement images during these tests. Since four lights were required to illuminate one wheel path, two generators with a total power of 6000 watts were needed to power up all four lights. With the lights on, the temperature within the trailer rose to over 120°F. A cooling system will be required for the Sony remote CCD camera to function properly because the specified operating temperature of the camera is between 40°F to 104°F.

High Pressure Sodium Light

The high pressure sodium lights tested are used for street illumination (see Figure 5). The power requirement for the lights is 440V AC. The high pressure sodium light is one of the most efficient

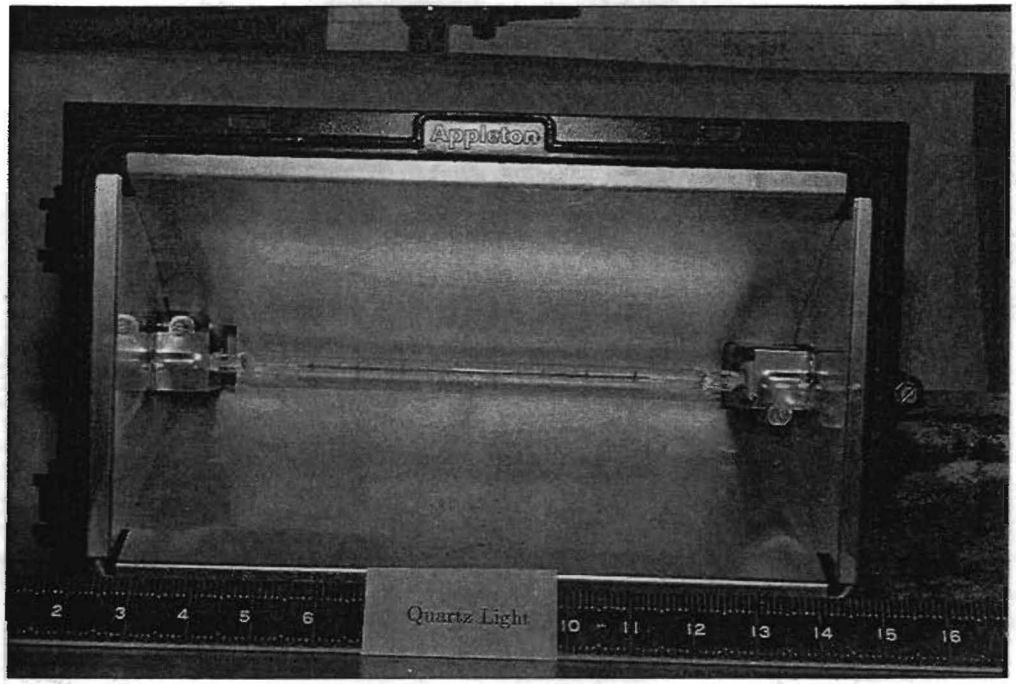


Figure 4. Quartz Light.

Figure 5. High Pressure Sodium Light.

lights since it converts 85% of the supply wattage to light. The illuminated area was observed to be even and bright. But a strange phenomenon was observed when the recorded video was viewed. The brightness of the playback video faded in and out in a cyclic fashion. This effect could not be observed with human eyes in the field. The explanation for this phenomenon was that sodium light is a gas-discharge light, and its level of illumination fluctuates with the applied line voltage. Since the line voltage is a 60Hz sinusoid (see Figure 6a) and with the shutter camera set at 1/4000th of a second shutter speed, the camera captured the instantaneous brightness level of the light. The reason that the human eyes could not observe this phenomenon was that the line voltage varied too fast (60 cycle per second).

To overcome this phenomenon, a DC line voltage or a square wave AC line voltage is needed. The DC voltage source maintains a constant electrical potential on the pair of electrodes thus providing constant brightness (see Figure 6b). The AC square wave line voltage has a very short time interval during the phase change thus reducing the effect of light intensity fading (see Figure 6c).

Of the five types of lights that were tested, only the high pressure sodium light has the required characteristics to illuminate the pavement surface with adequate brightness and uniform distribution of light. Two technical challenges must be overcome to give the needed performance mentioned above. The first is a DC line voltage or a square wave voltage supply to maintain a constant brightness level. The second is to test the ruggedness of the light to stand the vibration of the vehicle. Since the jacket of the light is pressurized, breakage of the light bulb will be hazardous to operation personnel.

In the upcoming implementation study, three types of lights will be investigated. They are the high pressure sodium light, high intensity strobe light system, and the illumination system that is used by the PASCO's ROADRECON distress survey vehicle.

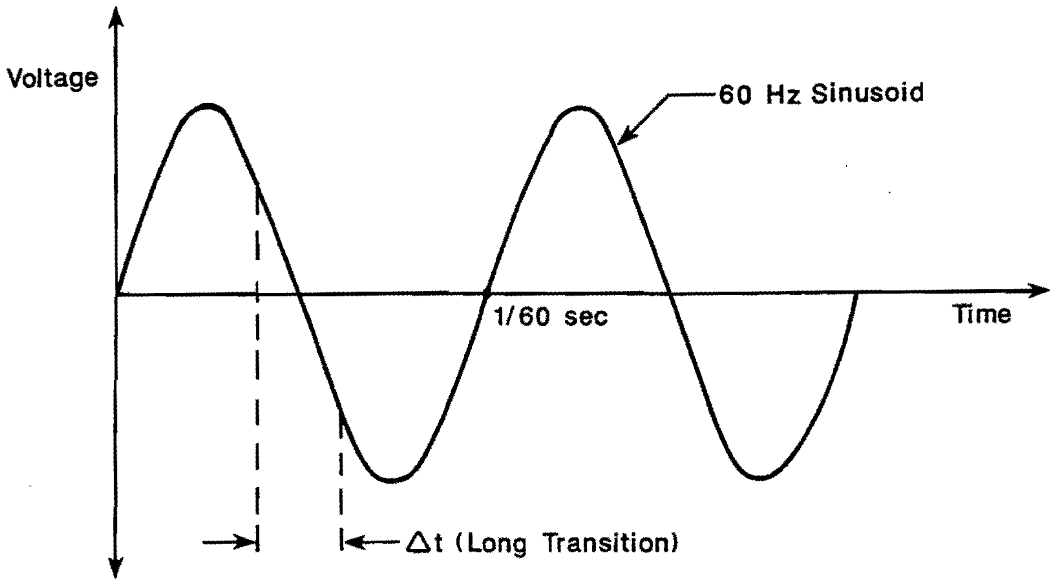


Figure 6a. AC Line Voltage (Sinusoid).

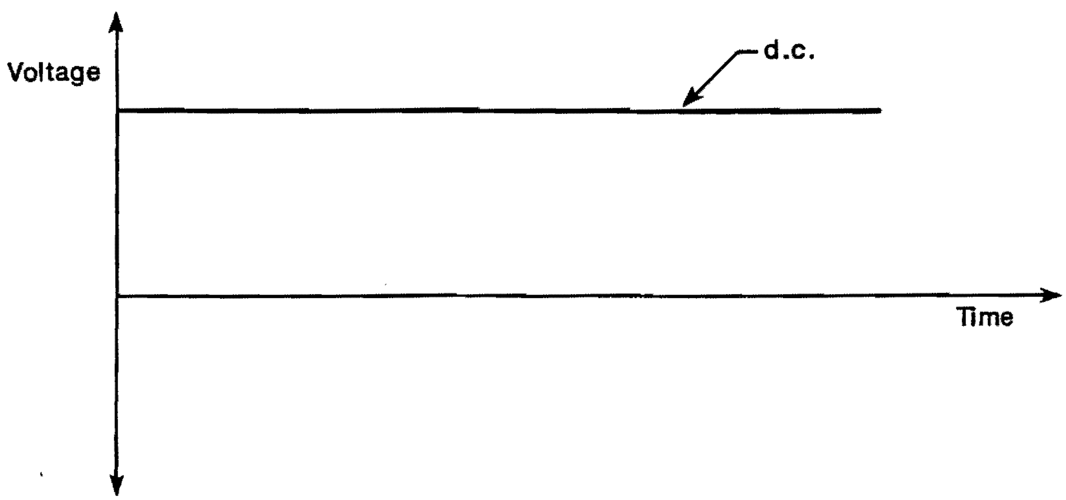


Figure 6b. DC Line Voltage.

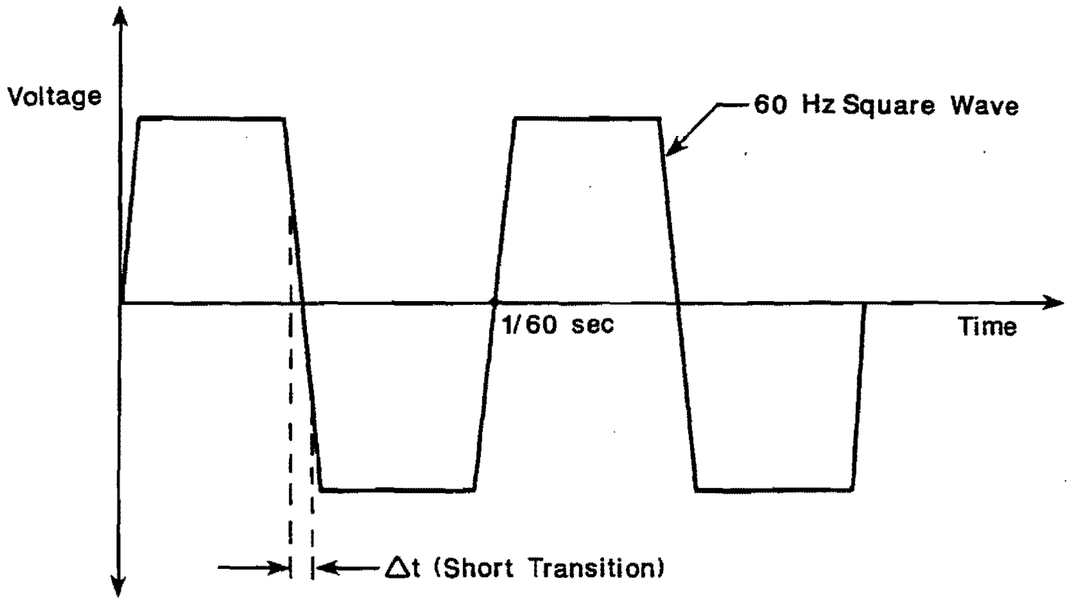


Figure 6c. AC Line Voltage (Square Wave).

2.2 Camera Unit

Five video camera manufacturers were contacted to compare different camera types. It was determined that a shutter speed of 1/4000th of a second was adequate to videotape pavement surfaces at 50 mph with no distortion. Five companies sent specifications on various types of high resolution shuttered cameras, and a comparison was prepared to evaluate each. Four cameras were picked as appropriate for the project. Each camera was chosen based on the total price and the different characteristics listed below:

1. Shutter Speed
2. Number of Picture Elements
3. Number of Television Lines
4. Signal to Noise Ratio
5. Vibration Resistance
6. Shock Resistance
7. Minimum Illumination

Since the system required two cameras, a resolution/cost ratio was used to choose a camera. Color video cameras were excluded because the computer image processor relies on various grey levels to determine distresses.

Four cameras were chosen and were either rented by or loaned to TTI on a trial basis for testing. Each camera was inspected for the characteristics needed and performance under different conditions. A grid board was made up with grid lines of different widths to simulate cracks on pavement. This board was used to check the resolution quality of each camera under different lighting conditions. Each evaluation was performed equally and the results were tabulated for the final comparison (see Table 2).

The SONY XC-77RR was chosen to be the best suitable for the system (see Figure 7 and 8). All four cameras were in the same price range, so the choice was made based on the characteristics. The SONY XC-77RR had the highest resolution and signal-to-noise ratio when compared with the others. Also, the SONY XC-77RR had a remote camera head for easy mounting in the trailer. The SONY XC-77RR camera was purchased for preliminary tests with the trailer and lighting system. This camera had been delivered and was being used for a number of lighting system studies discussed in the previous section.

Table 2. Comparison of Five High Speed Shutter Video Cameras.

MANUFACTURER	SONY	C-TECH	PULNIX	SONY	XYBION
MODEL #	EVO-9100	TK-66	TM-745	XC-77RR	SVC-10
SHUTTER SPEEDS	1/60, 1/100, 1/250, 1/1000, 1/2000, 1/4000, 1/10000 sec.	1/125, 1/250, 1/500, 1/1000, 1/2000, 1/4000, 1/10000 sec.	1/60, 1/125, 1/250, 1/500, 1/1000, 1/2000 1/4000, 1/10000	1/100, 1/120, 1/250, 1/500, 1/1000, 1/2000, 1/4000, 1/10000	1/500, 1/1000, 1/2500, 1/5000, 1/10000 sec.
# OF ELEMENTS	710(H)x535(V) TOTAL 380,000	768(H)x493(V) TOTAL 380,000	768(H)x493(V) TOTAL 380,000	768(H)x493(V) TOTAL 380,000	384(H)x245(V) TOTAL 94,000
TV LINES	450 (H) x 460 (V)	570 (H) x 485 (V)	570 (H) x 350 (V)	570 (H) x 485 (V)	280 (H) x 172 (V)
S/N RATIO	45 dB	50 dB	50 dB	56 dB	45 dB
VIBRATION RESISTANCE	5 G	7 G	7 G	7 G	
SHOCK RESISTANCE	N/A	70 G	70 G	70 G	
MINIMUM ILLUMINATION	4 lux (F1.4)	0.5 lux (F1.4)	0.5 lux (F1.4)	5 lux (F1.4)	3 lux (F1.4)
ACCESSORIES NEEDED	1. AC POWER ADAPTER MODEL# AC-V55	1.C-MOUNT LENS COSMICAR MODEL# C30808 2.CAMERA CABLE MODEL# CCXC-12P20/25 3.JUNCTION BOX MODEL # JB-77	1.C-MOUNT LENS COSMICAR MODEL# C30808 2.CAMERA CABLE MODEL# CCXC-12P20/25 3. AC POWER ADAPTER MODEL# K25-12V	1.C-MOUNT LENS COSMICAR MODEL# C30808 2. AC POWER ADAPTER MODEL# DC-77RR	* *
CAMERA PRICE	$2,300.00	$1,700.00	$1,595.00	$1,900.00	* * * * * * * *
PRICE OF ACCESSORIES	1. $185.00	1. $180.00 2. $385.00 3. $70.00	1. $180.00 2. $385.00 3. $72.00	1. $180.00 2. $300.00	* * * * * * * * * * * *
TOTAL PRICE	$2,485.00	$2,335.00	$2,232.00	$2,380.00	* * * *

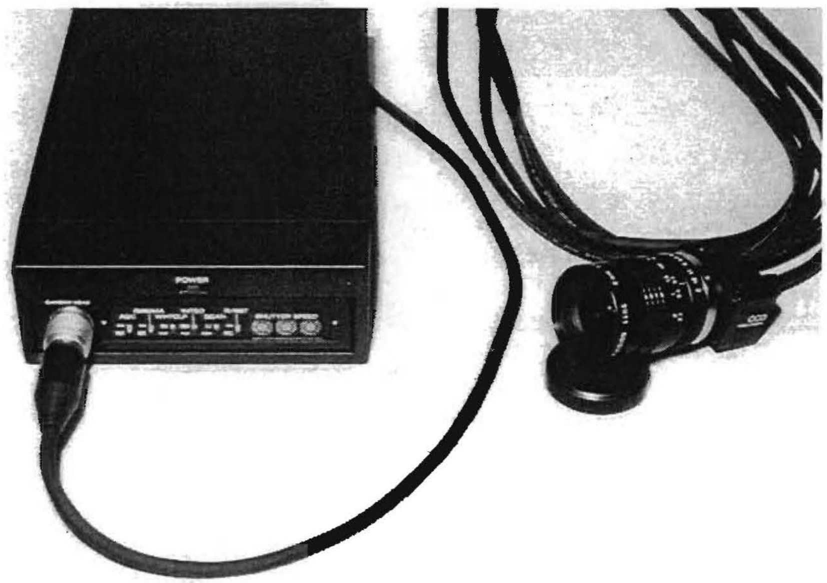


Figure 7. SONY XC-77RR Remote Head Video Camera.

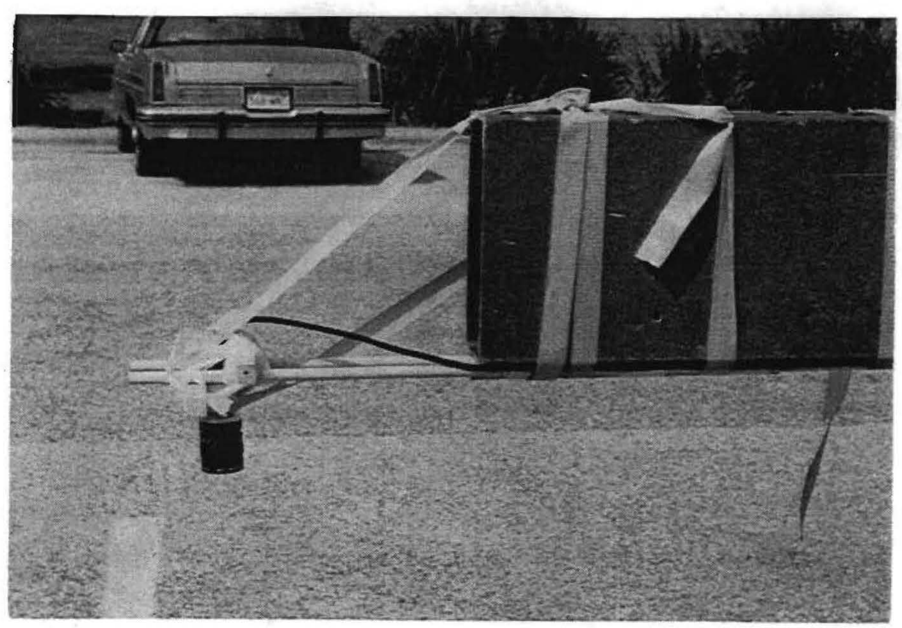


Figure 8. Temporary Boom Mount SONY Remote Head Camera.

2.3 Trailer Unit

Four problems encountered with the current ARAN videolog system for automatic crack detection are listed below. The schematic of the vehicle is shown in Figure 9.

1. Variations in natural light
2. Shadows
3. Camera viewing angle
4. Inadequate resolution

The intensity of sunlight varies with the time of the day. This change of illumination level required an adaptive threshold used in classification rules and added complexity to the processing algorithms.

Shadows caused a major problem in crack detection and analysis. When the sun was directly in front of the ARAN, the shadow of the van obscures most of the image. The algorithms detected the edges of the shadow area incorrectly as cracks. Also, shadows projected from trees, road signs, bridges, and passing vehicles were recorded on the image causing errors in crack detection.

Another problem that the current ARAN system posed to computer analysis is the camera viewing angle. The pavement camera is currently mounted on the back of the vehicle. It was tilted at an angle to the surface of the pavement (Figure 9). Thus, the camera coverage was the area of a trapezoid, and part of the image was out of focus because of the distance variation from the camera to the pavement surface.

It was difficult to detect a 1/8" crack as required by PMIS with one camera to record lane-width coverage because the pixel resolution was 0.3".

Two conceptual configurations were developed to eliminate the four problems discussed above. These two approaches are:

1. Trailer
2. Boom system

The prototype trailer is an open bottom trailer with rubber skirt to block out the sunlight. The width of the trailer is 8 feet in order to cover both wheel paths. Two cameras and two sets of lights were installed inside the trailer. Each wheel path has a camera and a set of lights to record the condition of the pavement surface (see Figure 10).

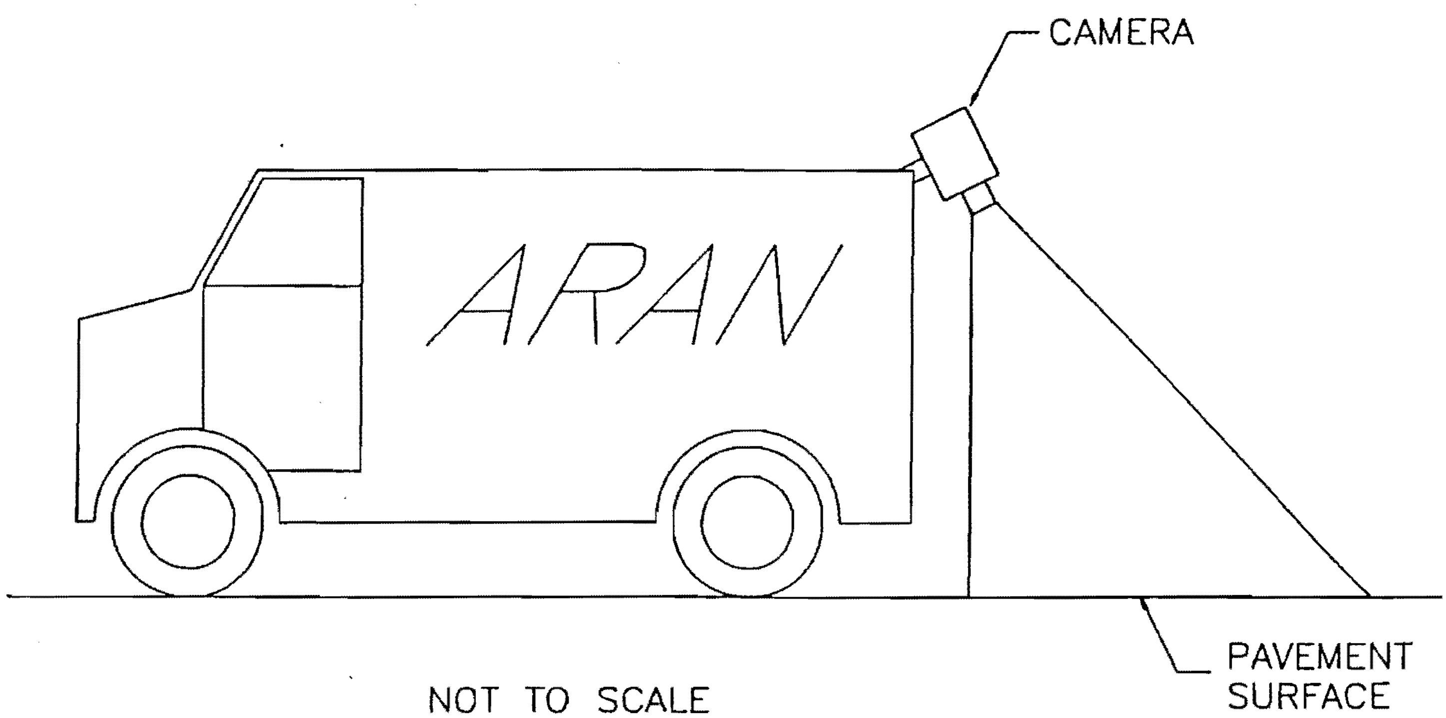


Figure 9. Current Video Recording System on ARAN.

The trailer design concept has the following advantages and disadvantages:

Advantages

1. The box design of the trailer eliminates all shadows.
2. The camera placement gives the true picture of the pavement surface.
3. The ceiling of the trailer provides an easy mounting surface for lights.
4. The trailer is easy and inexpensive to maintain.
5. The trailer can be operated at any time to avoid traffic problems.
6. The trailer design reduces the amount of vibration on the camera.

Disadvantages

1. The length and width of the trailer have design limitations.
2. The trailer can cause driving difficulty while being towed.
3. Limited visibility for the driver.
4. Limited mobility.
5. Vibrations can cause the image to be distorted.
6. Light infiltrates through the corners of the rubber skirts.
7. Pebbles and debris are collected by the rubber skirts during survey.

The boom is mounted on top of the ARAN. A camera and a set of lights were installed on the boom (Figure 11). The survey vehicle videotapes the condition of the pavement surface at night.

The concept of having a boom system attached to the ARAN has the following advantages and disadvantages:

Advantages

1. By using it at night, the problem of shadows is eliminated.
2. The camera position gives the true image of the pavement.

Disadvantages

1. Vibrations can cause the image to be distorted.
2. Design of an operative system can be difficult to achieve.
3. Light requirements are difficult to overcome.
4. The boom requires a clearance space for trailing traffic.
5. Human factors can make night operation difficult.

Of the two proposed design concepts, the trailer design was determined to be a better alternative for the prototype videolog vehicle. The decision was made to go with the proto-type trailer after consulting with Texas DOT staff and a local trailer manufacturer. A preliminary design was drafted and sent to TTI for approval (see Figures 12 and 13). A stability study was performed on the trailer to verify if it is

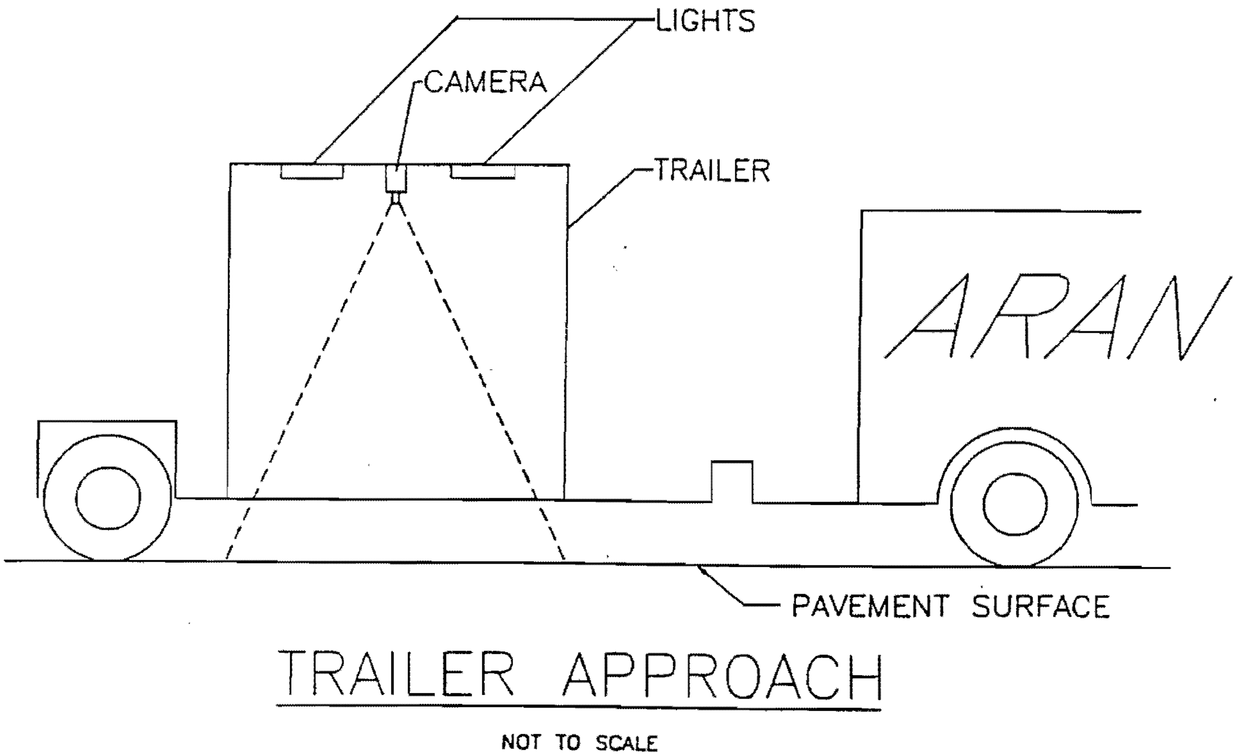


Figure 10. Trailer Approach.

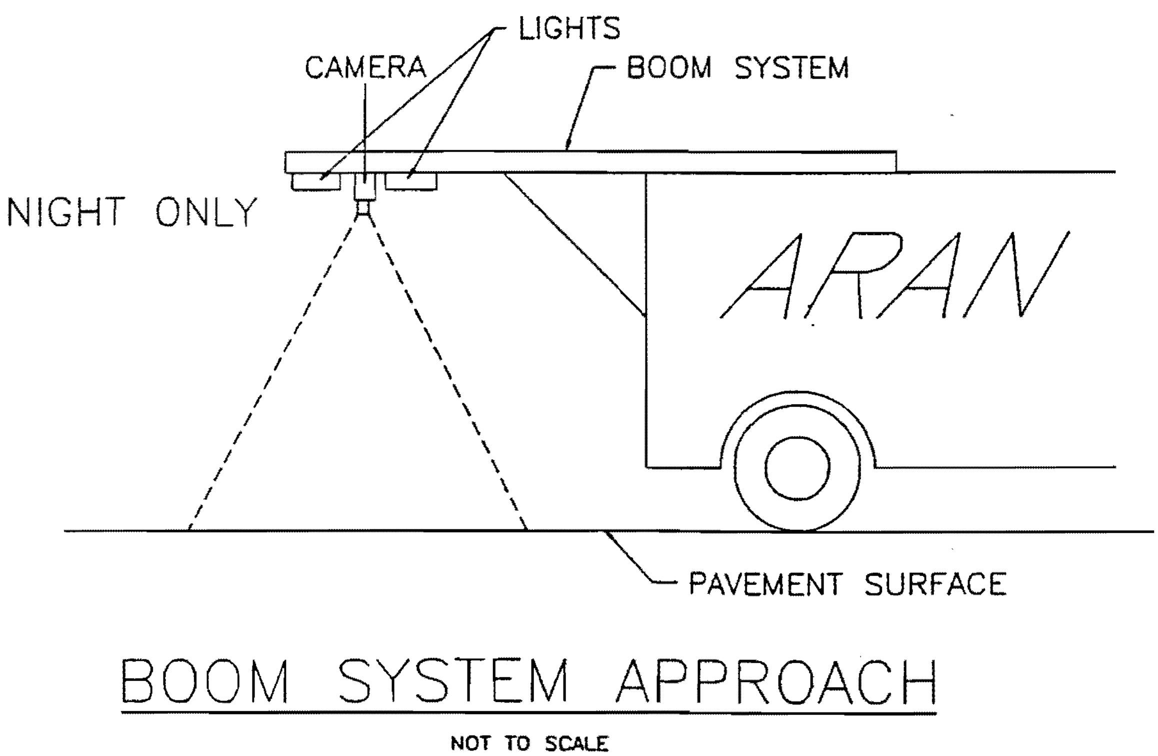


Figure 11. Boom System Approach.

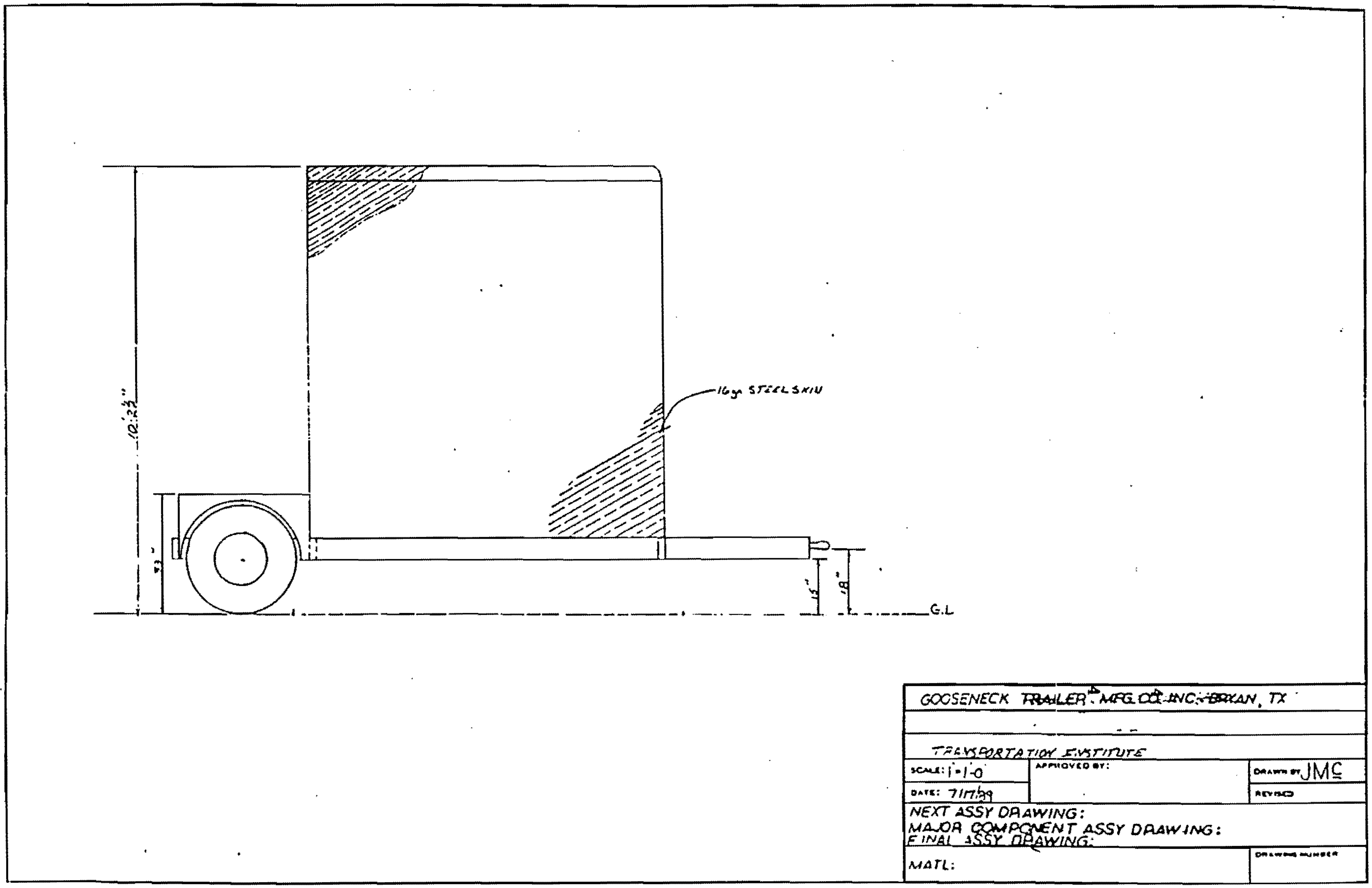


Figure 12. Preliminary Trailer Design (Plan View).

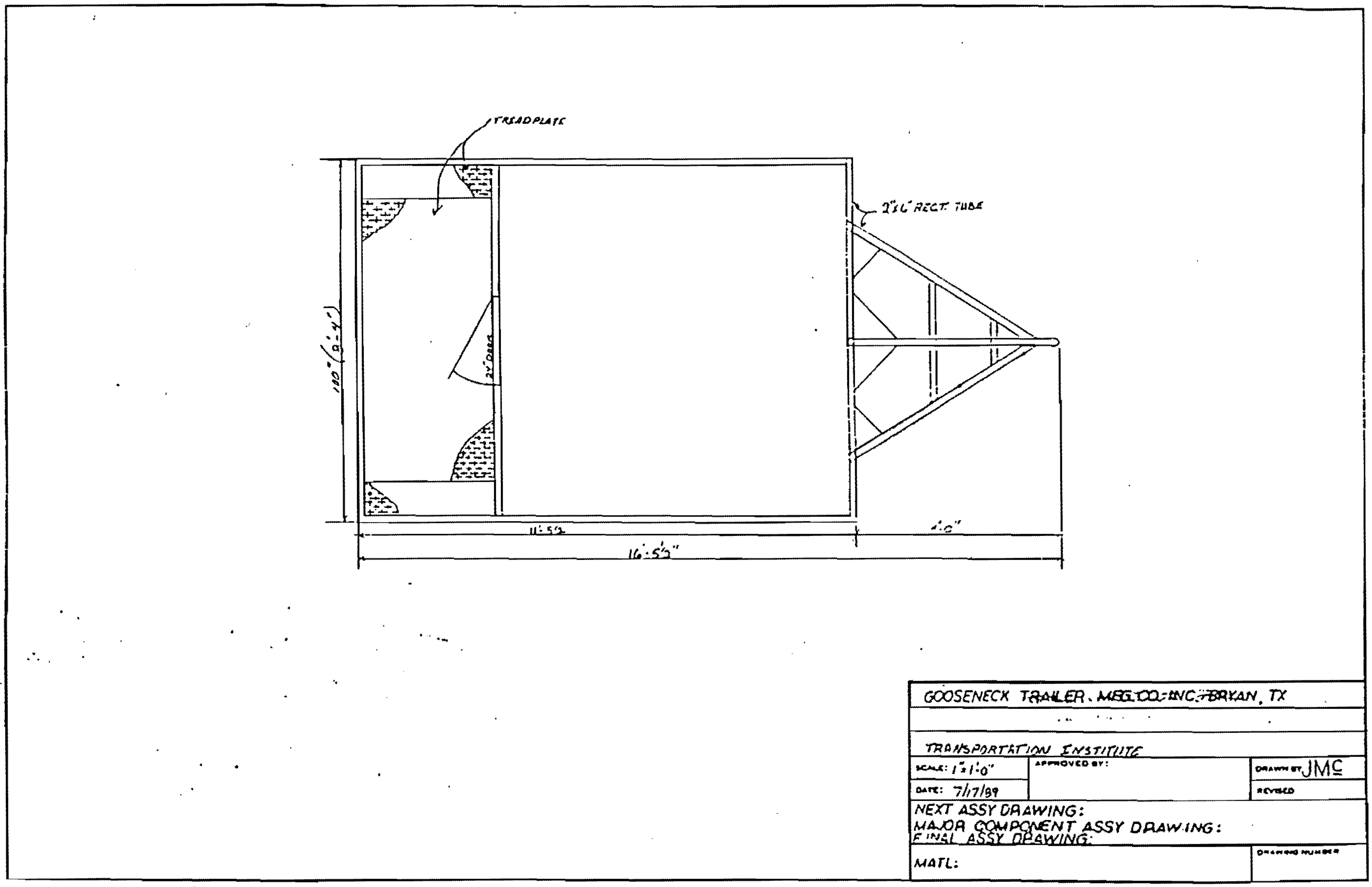


Figure 13. Preliminary Trailer Design (Top View).

durable and secure. The weight of the trailer, and the drag forces by the wind exerted on the front of the trailer were determined to calculate the moments about the trailer wheels. In the opinion of the trailer manufacturer and TTI, the trailer was thought to be unstable and studies were conducted for a new design. Two other trailer manufacturing companies were contacted to improve the trailer design.

To obtain a more stable trailer, the height of the trailer was shortened to reduce the amount of the drag force (see Figures 14 and 15). The only difficulty that exists with the trailer is that the legal width coverage is 8.5 feet of a 12 foot wide lane. The wheelpaths could easily be covered, but the shoulder distresses cannot be detected. This problem can be resolved with an extra camera installed on the side of the ARAN vehicle to record pavement edge and shoulder condition. After the final design was approved by the manufacturer, the proto-type trailer was built and delivered to TTI for lighting and camera system testing (see Figures 16 and 17).

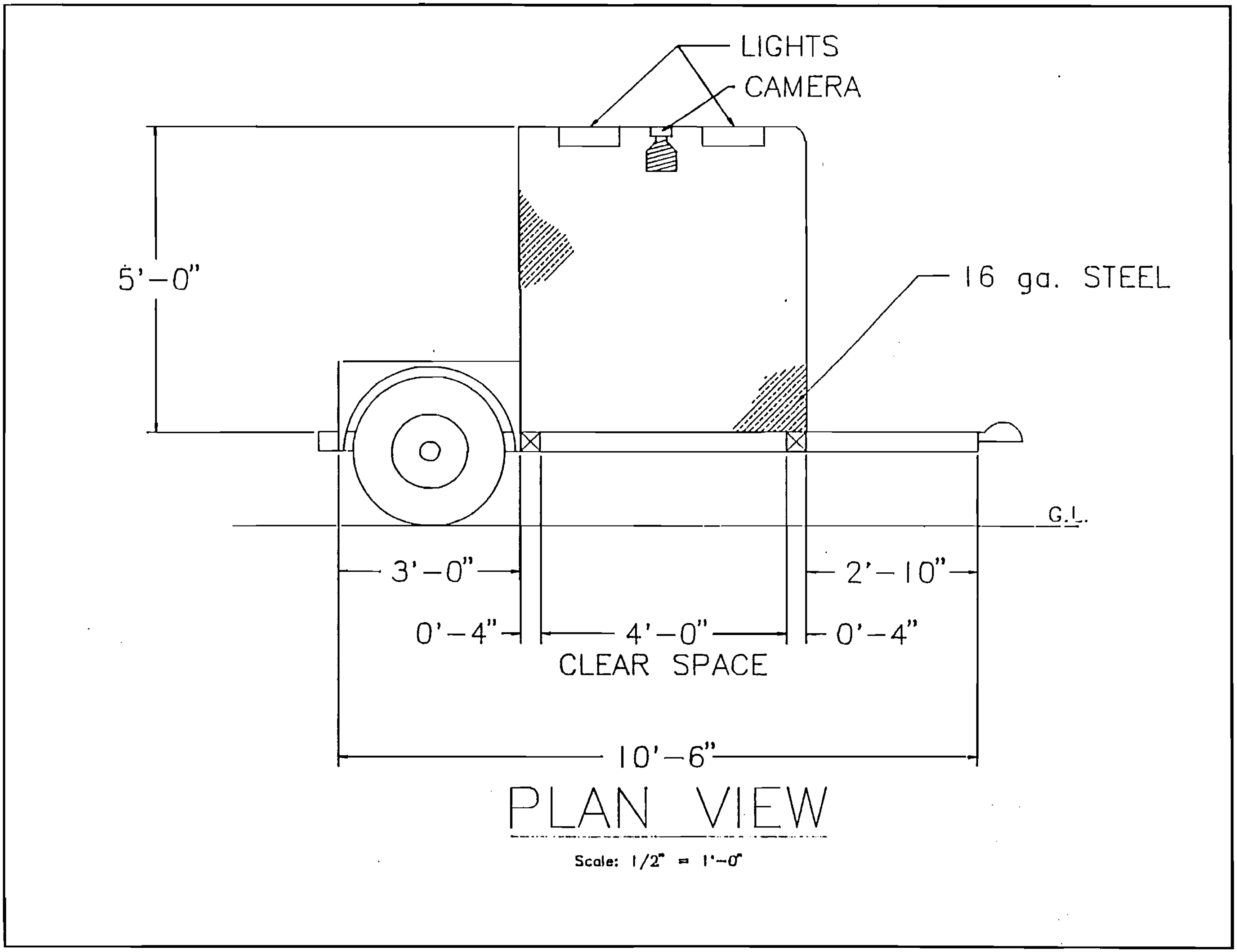


Figure 14. Modified Trailer Design (Plan View).

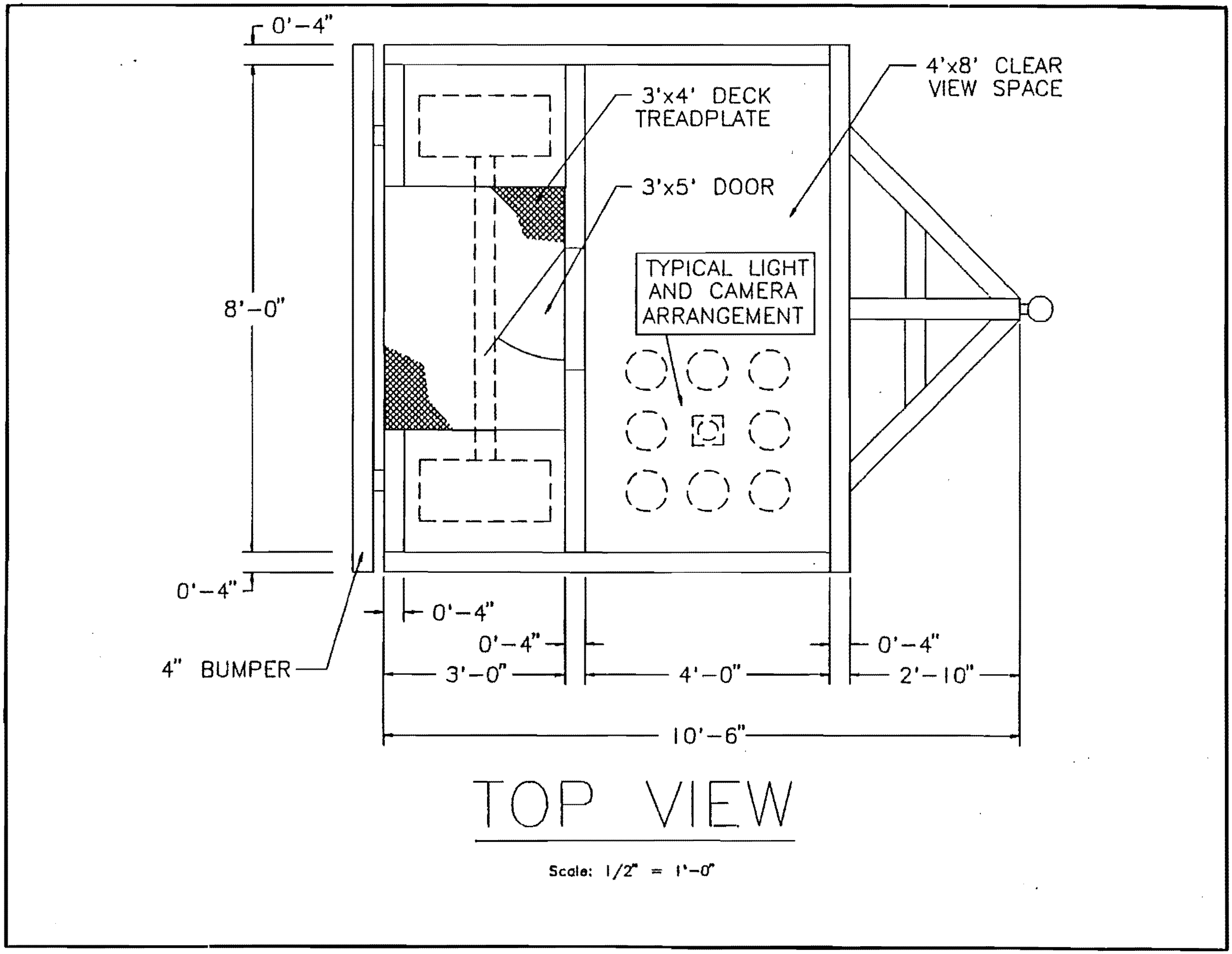


Figure 15. Modified Trailer Design (Top View).

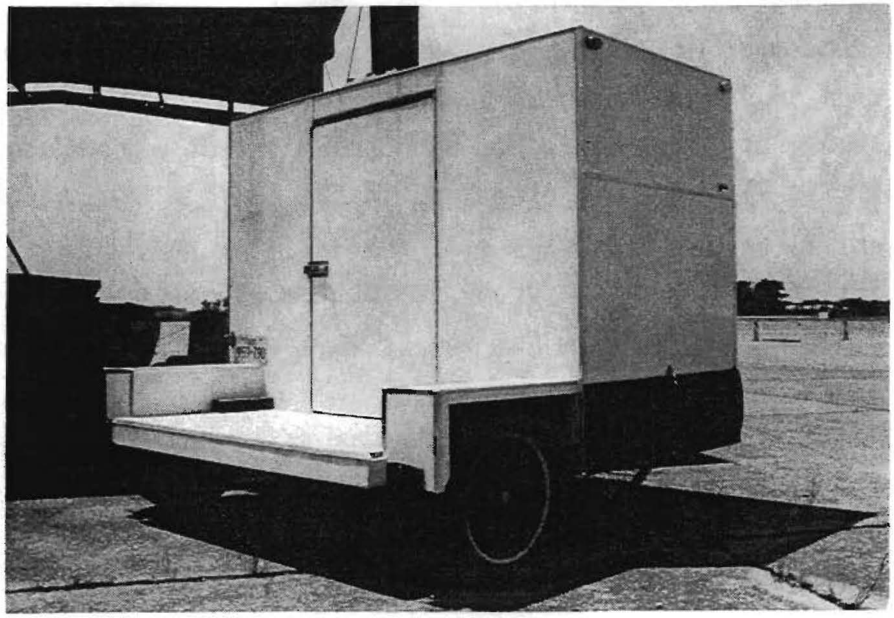


Figure 16. External View of Proto-type Trailer.

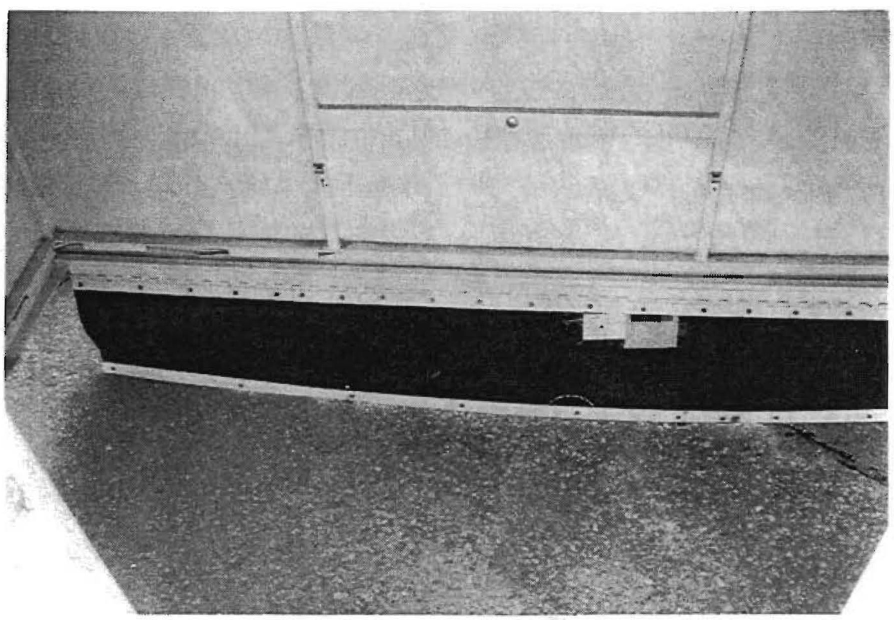


Figure 17. Internal View of Proto-type Trailer.

2.4 ARAN Unit

The Automatic Road Analyzer (ARAN) vehicle was produced by Roadware Corporation of Paris, Ontario, Canada. The ARAN vehicle (see Figure 18 and 19) acquires video images of both the right-of-way and the pavement surface. The right-of-way camera is installed in a compartment above the driver while the pavement camera is installed at the back of the vehicle. To obtain a burr free video frame, a shutter speed of 1/1,000 and 1/10,000 second is required for the front and the rear cameras respectively.

The ARAN unit also collects rut depth information with up to seven ultrasonic sensors mounted next to the front bumper. Roughness measurement is recorded by accelerometers mounted on the body and the axle of the vehicle. The central engineering workstation controls the continuous videolog with overlay Distance Measuring Instrument (DMI) information, and the rut measurement at user selected distance interval. Two gyroscopes are also installed in the ARAN to determine the direction of travel, radius of curvature, grade, and crossfall of a roadway.

A modified camera mount (see Figure 20) has been installed on the rear bumper of the ARAN. This camera mount allows the remote camera to be installed to record one wheel path. The recorded video view does not require any geometric correction since the camera is shooting vertically down on the pavement. The one wheel path video image can in principle resolve down to 0.1 inch since each pixel corresponds to 0.1 inch x 0.1 inch area, meeting the 1/8" inch crack width requirement in PMIS.

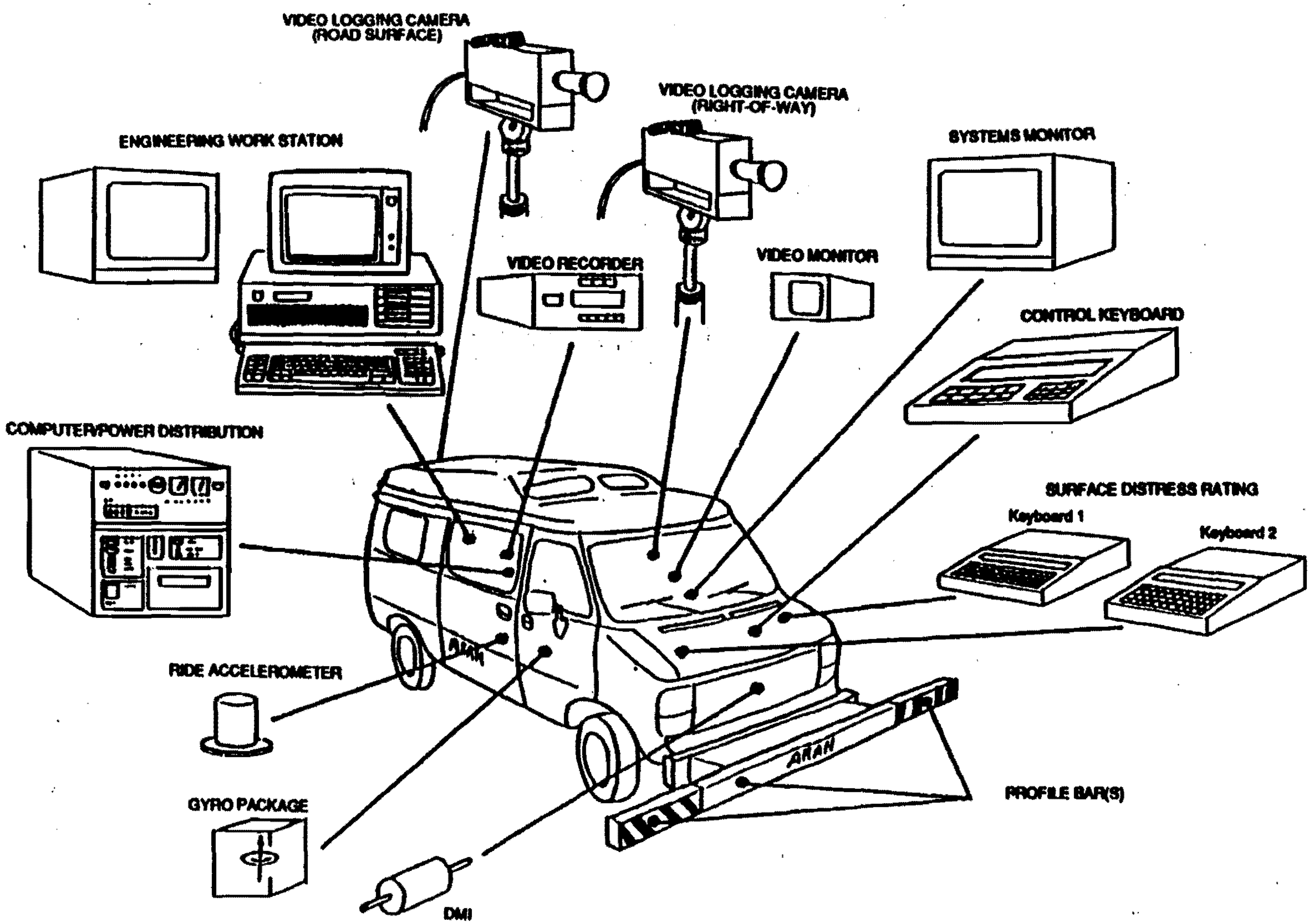


Figure 18. Functional Schematics of ARAN Vehicle [ARAN - Product Bulletin].

Figure 19. External View of ARAN Vehicle.

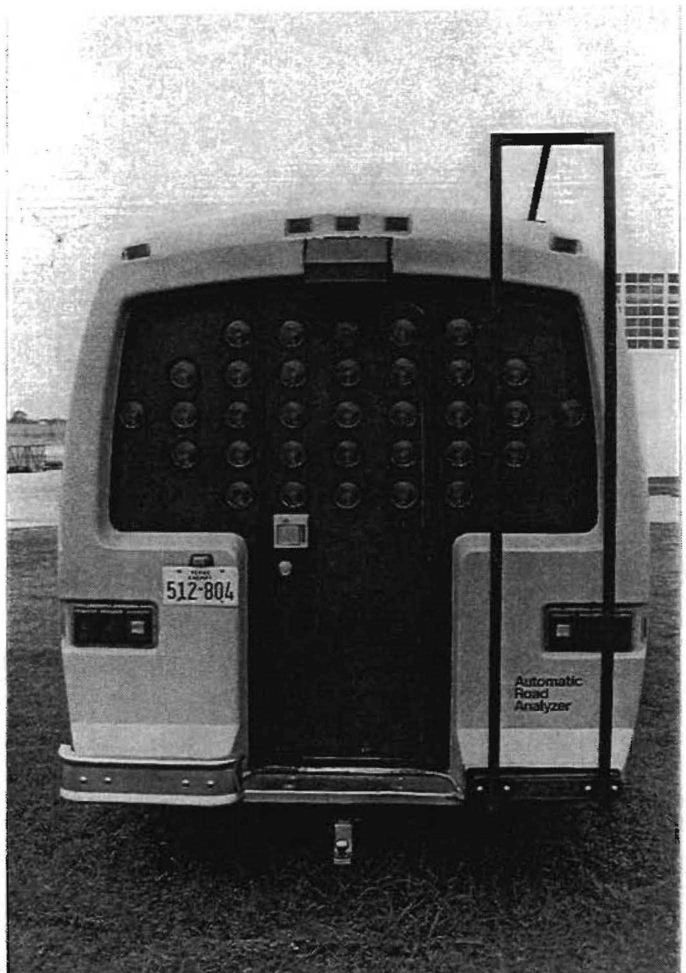


Figure 20. ARAN with Modified Camera Mount.

CHAPTER III

IMAGE PROCESSING SYSTEM

Once the pavement surface conditions were recorded on videotape, the video images were transformed into a form recognizable by the computer for automatic processing. A device that converts an analog video image into a digitized image is called a frame grabber. It acquires a frame or a field of video and digitizes it into a 512 x 480 picture elements. Each element is assigned a greylevel to indicate how bright that element is.

At the onset of this project in 1989, TTI analyzed and compared two computer platforms to build the image processing system, namely, the personal computer (PC) and the workstation. PCs are widely available, low cost, and user friendly. However, the PC has the limitations of being a single user system and slow when compared to a workstation. Processing power is important because a digitized image is a large data set. Furthermore, a workstation is a multi-user system that facilitates software development.

3.1 Sun IPX Host

The choice of the host is critical to the successful implementation of an image processing workstation for automatic reduction of pavement surface distress data.

During the initial period of this research project, the mid-range image processing system was a workstation host system using a Versa-Module European (VME) bus. The VME bus is a 32 bit bus which has a higher data transfer rate than an Industrial Standard Architecture (ISA) bus used in the PC-AT system. The initial cost of the host workstation was $30K for a Sun 3/160 (See Figure 21). This host was connected to a Imaging Technology Series 151 image processor subsystem.

In 1991, with the technological improvement in the Reduced Instruction Set Computing (RISC) development and chip fabrication techniques, RISC processors and Scaleable Processor Architecture Reduced instruction set Computer (SPARC) processors were readily available for use as workstations. A new Sun SPARC IPX (see Figure 22) was purchased for less than 1/3 of the original cost of a Sun 3/160. The IPX is five to ten times faster than Sun 3/160 depending on the amount of integer and floating point calculations in the algorithm.

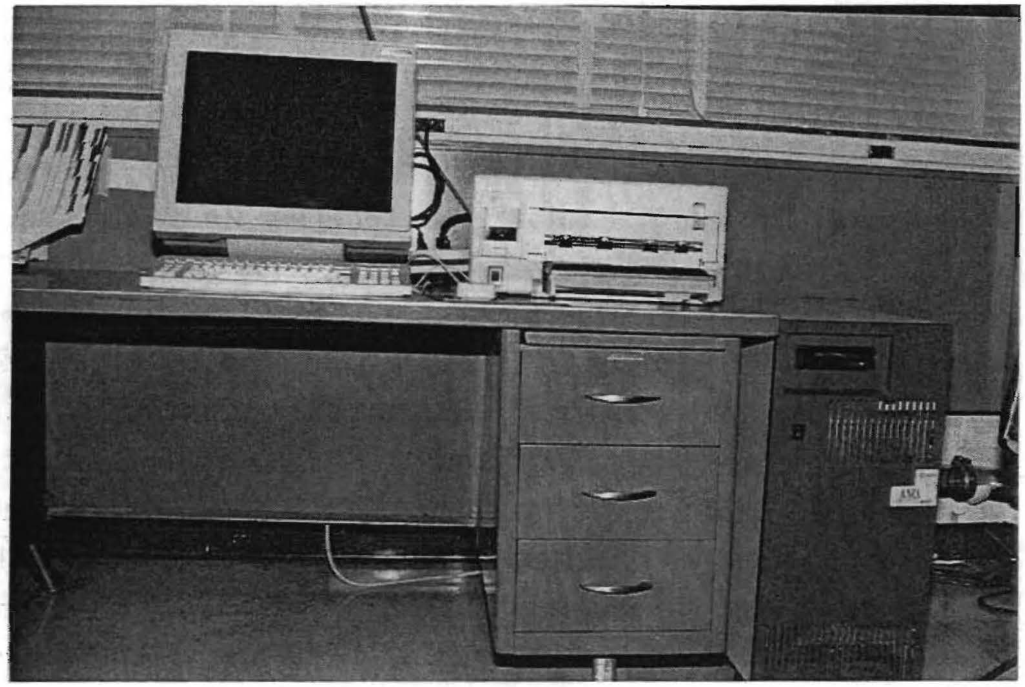


Figure 21. Sun 3/160 Host Monochrome Workstation.

Figure 22. Sun SPARC IPX Greyscale Workstation.

The functions of the host in the video image processing system include controlling the program flow and image data flow as shown in Figure 23. Table 3 shows the corresponding equipment of each component in the system.

Table 3. Equipment List for Pavement Video Image Processing System.

Equipment	Manufacturer and Model
1. Host Workstation	Sun SPARCstation IPX
2. Interface to Video Cassette Recorder (VCR)	National Instrument SCSI-IEEE 488 Adaptor
3. VCR with Modified Remote Control Unit	Panasonic AG-1830 Digital Effect VCR
4. Time Base Corrector (TBC)	Panasonic TBC 100
5. Image Processor	Imaging Technology Series 151 Analog Digital Interface Frame Buffer Arithmetic Logic Unit Real Time Convolver Histogram Feature Extractor Image Processing Accelerator
6. Interface to Image Processor	Bit 3 VME-S bus adaptor Bit 3 S bus repeater

The pavement view video from the ARAN are played back with a "digital effect" Video Cassette Recorder (VCR). This VCR digitizes the frame and stores each frame before it is converted back to analog and sent out via the Video Out connector. Because of this feature, no frame dividers (noise lines) are seen during the slow playback. The video signal is further stabilized with a Time Base Corrector (TBC) before it is routed to the Analog Digital Interface of the Series 151 image processor subsystem for image digitization. The digitized image data is temporarily stored in the memory of the Frame Buffer and transferred to the host workstation via the 5-bus (Sun bus). During the full speed processing, the program is downloaded into the memory of the Image Processing Accelerator housed inside the Series 151 image processor to minimize the image data transfer. The following sections describe the components within the automatic video image processing system.

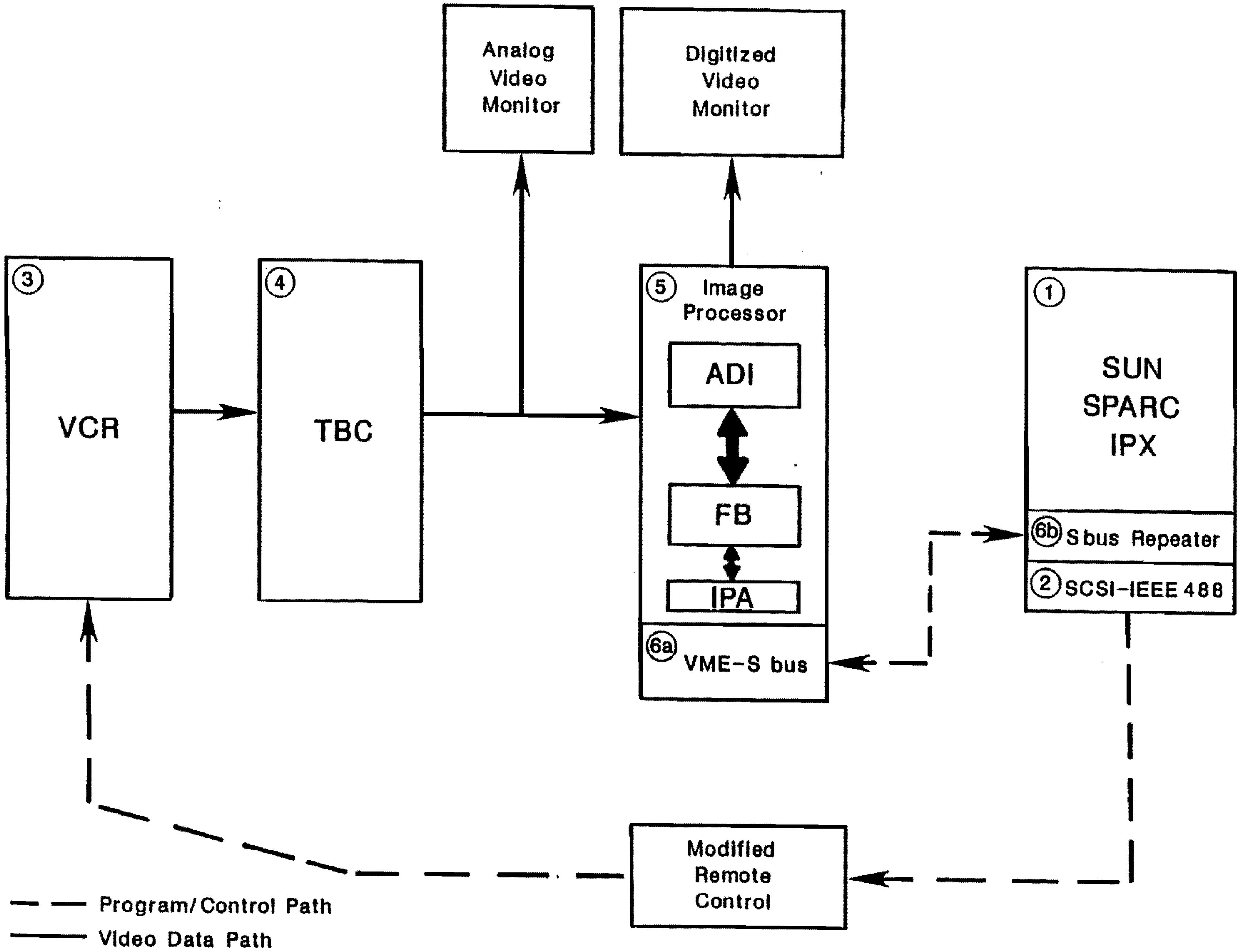


Figure 23. Block Diagram for Pavement Video Image Processing System.

3.2 Image Processor Subsystem

The Imaging Technology Series 151 image processor subsystem has six modules (See Figure 24 and Figure 25). Each board carries a unique function within the system and together they can perform both real-time image operations and programmable image analysis. [Imaging Tech Inc.(1992)]

(a) Analog Digital Interface (ADI)

The Analog Digital Interface (ADI) board accepts a standard RS-170 video signal and digitizes the video frame into 512 x 480 picture elements. Each picture element (pixel) has a corresponding greylevel or intensity that ranges from 0 to 255. The greylevel is a measure of light intensity. Greylevel 0 represents black while greylevel 255 represents white. The video input is digitized by an 8 bit A/D at a sampling rate of 10 MHz. It is capable of digitizing images in real time at normal playback speed (30 frames per second).

The internal sync stripper extracts the composite sync from the input composite video signal. A sync separator will extract the vertical sync while phase locked loops (PLL) provide stable horizontal lock. This board also converts digitized video data back into analog form for display purposes. The analog output is a Red, Green, Blue (RGB) video with the sync connected to Green.

(b) Frame Buffer (FB)

The digitized image is stored in one of the three memory buffers. The "A" frame store has a full 16-bit 512 x 480 memory for storing the results of addition or where precision is required. Two "B" frame stores have 512 x 480 x 8-bit memories. The image functions include pan, scroll, and zoom. The Area of Interest (AOI) operation is also supported. The user can select an M x N pixel frame.

(c) Arithmetic Logic Unit (ALU)

The Arithmetic Logic Unit provides sixteen different arithmetic and logical operations. It is also capable of operating on a specified bit plane. Sixteen 256 byte Look Up Tables allow point processing of image

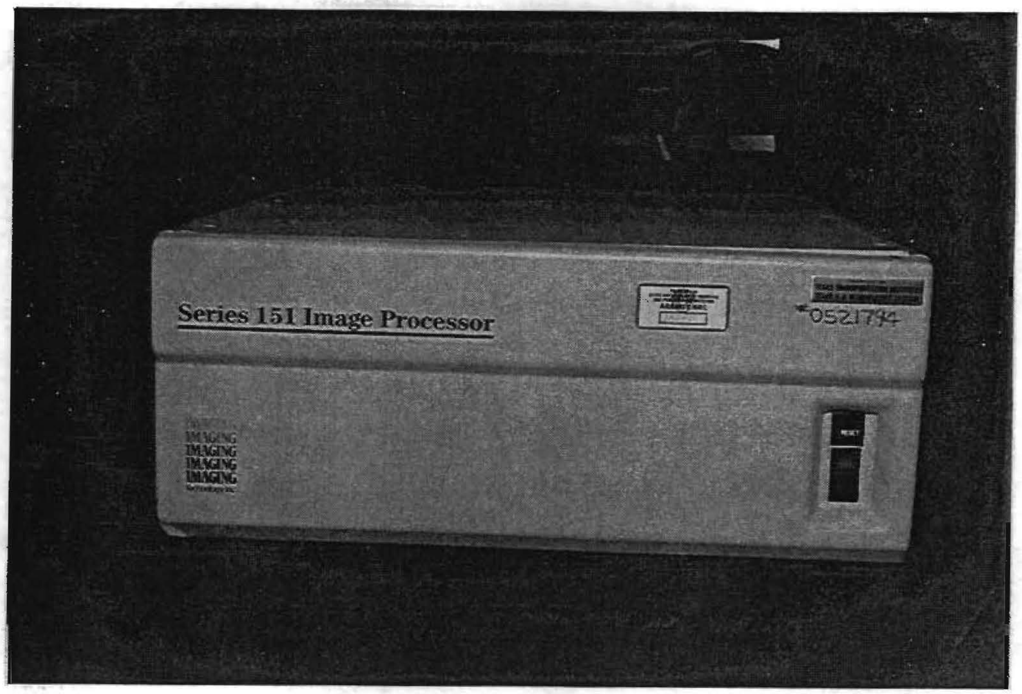


Figure 24. External View of Series 151 Image Processor.

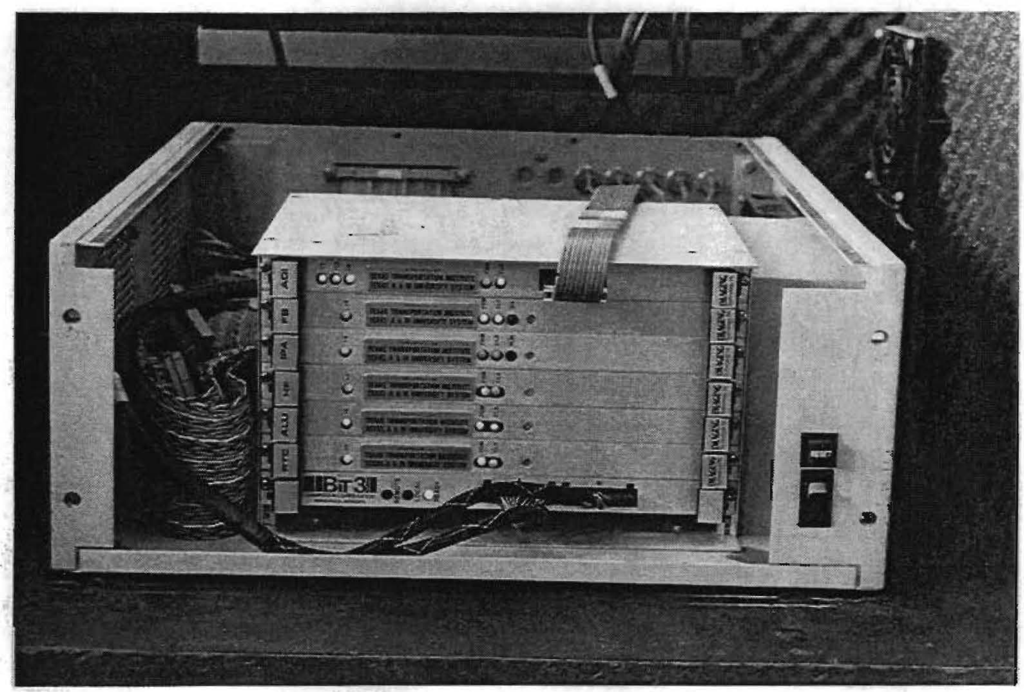


Figure 25. Internal View of Series 151 Image Processor.

data prior to output on the pipeline bus. The configuration of a basic subsystem includes ADI, FB and ALU.

(d) Real Time Convolver (RTC)

The RTC is specialized hardware to carry out convolution operations. The kernels or the masks used in this operation can be as large as 4 x 4 or 16 x 1. The convolution operations include edge detection, noise removal, and averaging.

(e) Histogram/Feature Extractor (HF)

The Histogram/Feature Extractor board computes the frequency distribution of pixel intensities for a full frame. It can also accumulate intensity information over multiple frames. In the feature extraction operation, the co-ordinate pairs of a pixel together with its intensity level are recorded. Such feature extraction operations accelerate the calculation of certain image processing operations such as centroid finding and dimensional measurement of the object.

(f) Image Processor Accelerator (IPA)

The IPA is a general purpose numeric processor that has its own frame buffers, program and data memory, and video interface formatter. Programs can be downloaded to the IPA for execution on the Weitek XL 8032 numeric processor. The XL 8032 is a fast and high performance processor running at 10 Million Instructions Per Second (MIPS) and 20 Million Floating Point Operation Per Second (MFLOPS).

The six boards described above are connected together to form a Series 151 Image Processor Subsystem as shown in Figure 26. Each board plugs directly into a VME bus backplane using the VME bus P2 connector for the high speed PixelBus video buses. The modules are connected by the PixelBus video buses, thereby eliminating the overhead associated with transferring image data between the boards via the host computer bus. Pixel data flows through these high speed buses at a rate of 10 MHz, which is equivalent to 30 frames per second. The buses connect modules in a sequential fashion so that additional boards can be easily incorporated into the pipeline.

A cross-Port Switch (CPS) handles all the switching necessary for the PixelBus interface on the six modules. This provides flexibility in the flow of pixel data through the subsystem. The CPS contains four independent four to one multiplexers, allowing any 8 bit input to be independently selected to any of the four 8 bit outputs.

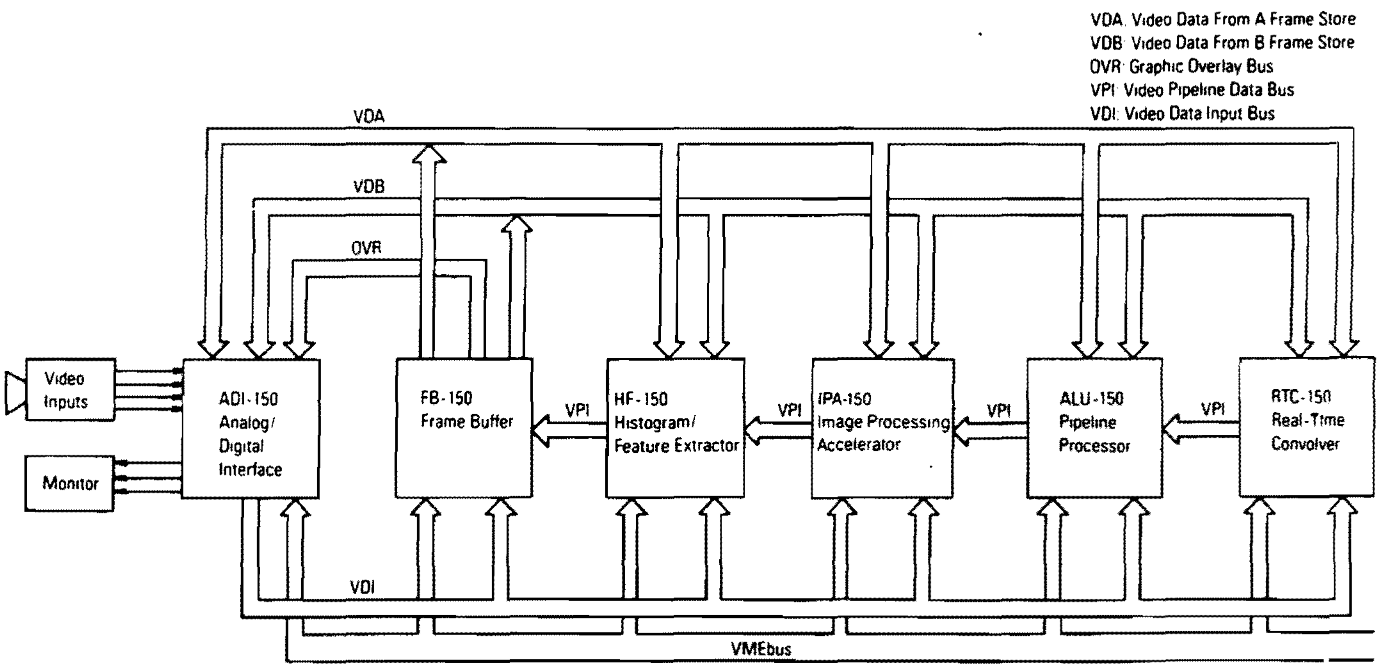


Figure 26. Block Diagram for Series 151 Image Processor Subsystem.

The PixelBus uses a VME bus P2 backplane that eliminates the use of cables for connecting the different boards in the subsystem, reducing electrical noise and improving reliability.

Analog video signals output from the VCR are acquired and digitized on the Analog Digital Interface, then output on the Video Data Input (VDI) bus as 8 bit digital image data. The processing pipeline (VPI) starts with the RTC. The convolved pixel stream is then passed through the pipeline to the ALU where additional image processing functions can be performed. The pixel stream continues through the pipeline to the IPA, HF and finally to the FB where it is stored in frame memory. Pixels are processed through the video pipeline at a rate of 10 million per second.

Data on the pipeline bus can be either passed through or passed through and stored into the IPA. An innovative memory architecture incorporates two on-board frame stores that allow the IPA to perform full image operations.

The image data coming from the ADI module on the VDI bus is directly available to the other modules in the subsystem. There are also separate video buses (VDA and VDB) to transfer image data from the frame memory to other modules. The VDA is a 16 bit video data bus from the "A" frame store, while the VDB is a 8 bit video data bus from the "B" frame store.

3.3 Computer Interface to Video Cassette Recorder

Currently, pavement distress videotapes are evaluated visually by trained personnel operating the VCR via a computer. To automate this manual evaluation process, computer algorithms were developed to detect the presence of cracks and quantify the types and their extents, and an interface unit was designed for the computer and VCR.

Before the arrival of the Sun 3/160, a scheme was devised to interface a PC with a Panasonic AG-1830 VCR (See Figure 27). The developed circuitry and program will be adapted to work with the Sun workstation. In the personal computer, the two most common ways for the computer to communicate with an external device are by means of a serial port or a parallel port. Since each port works differently, information on each of the two types of ports was gathered to determine which one would be the best choice.

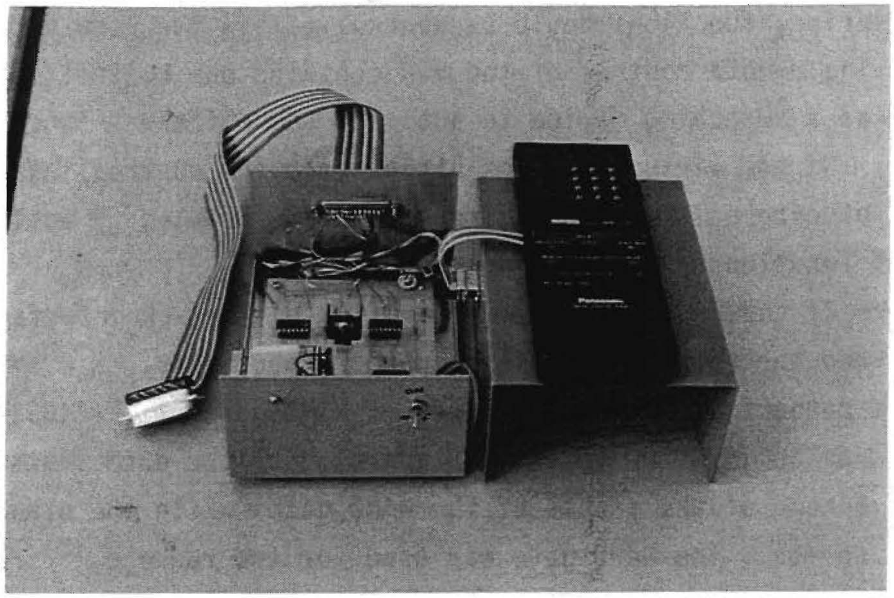


Figure 27. Computer Interface Device for VCR.

A serial port can be used for asynchronous communication between a PC and any serial device such as a laser printer. A serial port employs an RS 232-C interface protocol. Both DB9 and DB25 can have up to 9 working pins for data transfer and handshaking. The digital data is sent in serial form as a stream of eight bits in sequence. Therefore, the receiving device at the other end is capable of storing these eight bits in series and converting them into parallel form for the device to interpret the data.

The parallel port is commonly used with a parallel dot matrix printer. A parallel port is used when there is a short distance between the transmitting and receiving devices. A short distance can be defined as the distance between devices that are in the same office. Unlike a serial port, a parallel port provides a pin for each one of the eight data bits for byte transfer. This results in fewer conversion circuits when compared with the serial port.

The hardware developed was capable of controlling six functions of the VCR. They were play, pause, slow play, frame advance, fast forward, and rewind. Since the AG-1830 did not have a serial port, it was decided that the various functions would be controlled via the remote control of the VCR. The remote control of the VCR contains one controlling chip that acts as a switching device to activate the different functions available. Direct wiring could be attached to the controlling chip and some type of external switching circuitry could be used to activate the individual functions.

Figure 28 and Figure 29 show schematics of the VCR interface circuitry and the remote controlling chip respectively. Six of the data wires were connected to the six inputs of NAND gates (TTL-7400), which functioned as an inverter in this case. Each of the data lines was connected to one of the inputs of the NAND gates while the other was connected to +5V. The NAND gate was used for two reasons. First, a buffer chip was needed to protect the computer port and second, inverse logic was needed to drive the opto-isolators.

The output of each NAND gate was connected to a limiting resistor, and the resistor was connected to one of the inputs of the opto-isolator package. This input is the cathode of the photo-diode. The other input of the opto-isolator package, the anode, was connected to +5V. The outputs of the opto-isolator packages were connected to the inputs of the remote control chip.

One of the outputs of the opto-isolator was connected to one of the VCR functions, and the other output was connected to the common of the remote control. Table 4 shows the function control and its corresponding data line.

By setting the corresponding data line to HIGH, the VCR function was activated. Since one of the inputs of the NAND gate was tied to +5V, by setting the other input to +5V, the output would be LOW. When the output of the NAND gate went LOW, it allowed current to flow through the photo-diode which emits infrared light. The light excited the base of the photo transistor and set the emitter to go LOW, which in turn set the function for the remote control.

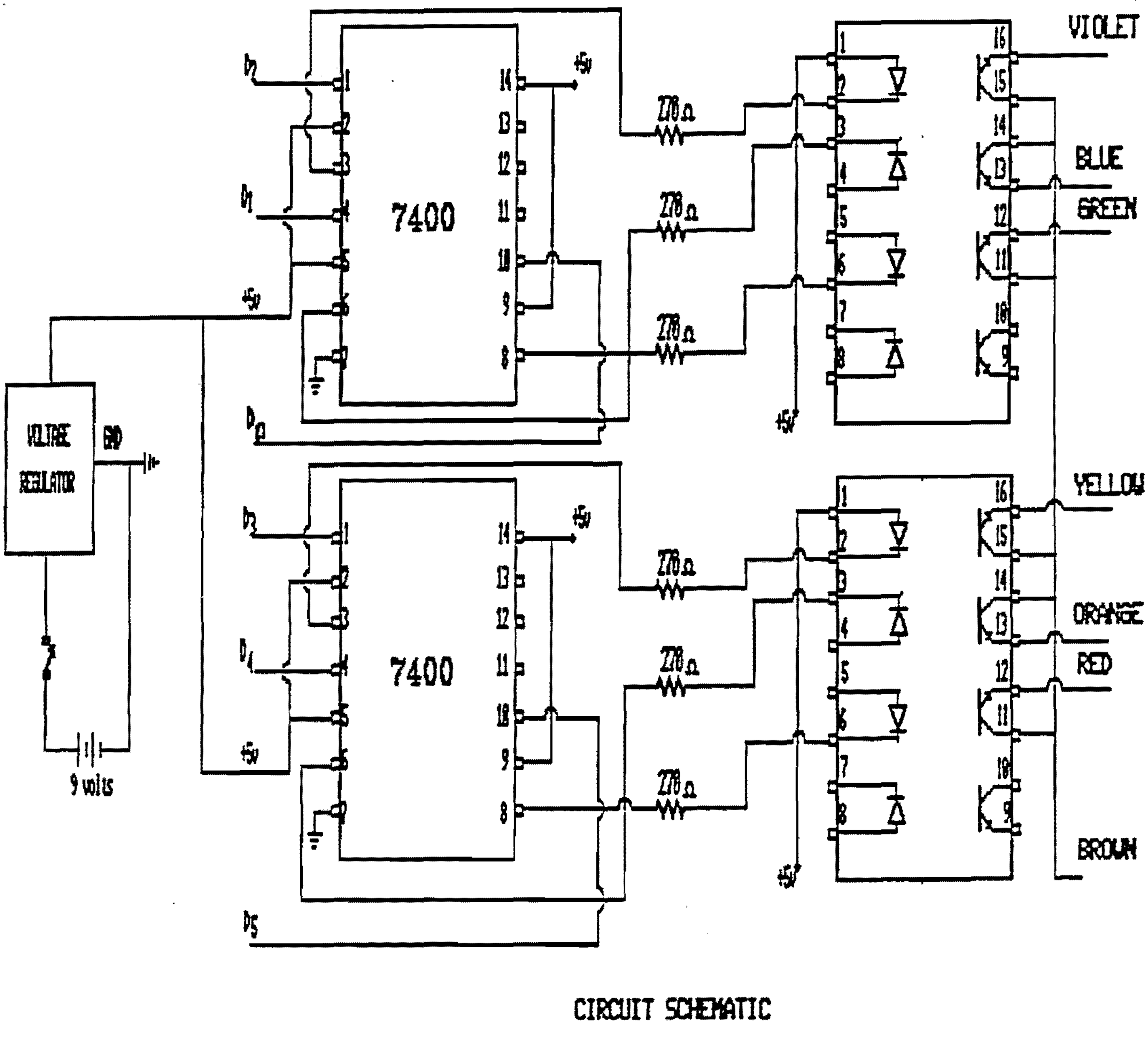
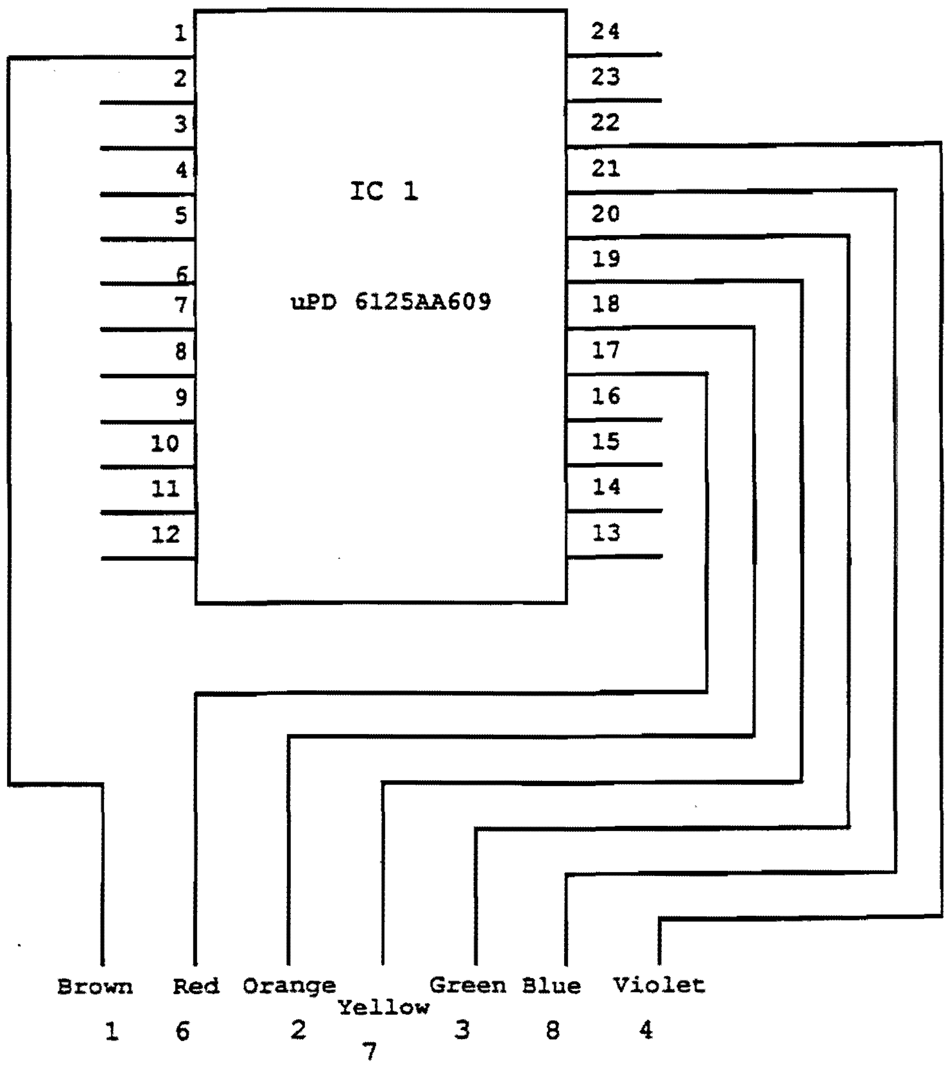


Figure 28. Schematic of VCR Interface Circuitry from Parallel Port.

Remote Control IC



Pins 1,17,18,19,20,21,22,
were solder to a external
DB 9 Female Jack.

Figure 29. Schematic of Remote Control Integrated Circuit of the VCR.

Table 4 VCR Function Control and its Corresponding Data Line.

Function	Port Data Line	Remote Control
PLAY	D1	blue
REWIND	D2	violet
FAST FORWARD	D0	green
SLOW PLAY	D3	yellow
FRAME ADVANCE	D4	orange
PAUSE	D5	red

3.4 Video Cassette Recorder (VCR)

The Video Cassette Recorder/Player is a crucial component of the video image processing system. Pavement video recorded by the ARAN or video survey vehicle is brought back to the lab for post-processing. Since the computer is used for automatic evaluation of the video, the computer also controls the VCR and its playing speed to match the processing speed of the video frame by the computer.

The current processing speed for the pavement surface distress video is about 4 mph which is equivalent to about 1 frame/sec. This speed requires the VCR playback speed to be slowed down. Most of the S-VHS VCRs and even an editing S-VHS VCR, will display horizontal white streaks between frames on the image known as frame dividers when the playback speed is slower than normal. This effect is not acceptable for automatic computer processing of pavement distress videos because the noisy white streak lines will be erroneously classified as cracks.

The current VCR, a Panasonic AG-1830, is a digital effect VCR. It has a built-in digitizer where all video frames are temporary digitized and stored, and thus free of noise. The digitized frame is then converted back to analog form and output to a video monitor. This digital effect feature allows zooming, rotating, and other manipulation of the video frame. Figure 30 shows the AG-1830 VCR. This digital effect capability is suitable for the automatic computer processing because the slow playback of the AG-1830 is free of the frame-divider.

Figure 30. Panasonic AG-1830 Digital Effect VCR.

The ideal VCR should have the following three features: dynamic tracking, time code, and computer control capability. Dynamic tracking allows the tape head to be tilted to maintain a good contact with the tape when the speed of the tape slows down. This will result in a noiseless frame during slow play back. Time code is used as a video frame locator. The time hr:min:sec:frame is coded as an audio signal and recorded on either one of the audio channels or a special time code channel. This feature enables the computer to advance to the beginning of any survey section and locates any specified frame on the videotape.

New models of VCR have an RS-232 serial port as an option. This will allow an easy interface with a computer. Protocols and example control programs are usually available with this option making custom control of the VCR by computer relatively easy.

A S-VHS VCR with the above three features was not available on the market during this research project. Of the three features, the most critical feature is the dynamic tracking because it will affect the accuracy of the automatic evaluation. TTI is currently making arrangements to evaluate new S-VHS and Hi-8 VCRs. Some of the units have a feature called digital frame store which may provide adequate image quality for computer processing.

CHAPTER IV
CONCLUSIONS AND RECOMMENDATIONS

This report has described the hardware aspects of Study 1189 entitled "Automatic Photo Interpretation System for the ARAN." The following conclusions and recommendations are drawn from this study.

CONCLUSIONS

(1) After reviewing and processing the ARAN pavement video, apparently the shadows projected on the recorded image have a devastating effect on the processing result. Five types of lights were investigated, and the High Pressure Sodium Light was determined to be the most suitable to overcome the shadow problem.

(2) The camera resolution and sensitivity to light are the two criteria used in the selection of a video camera. The best of the four, the SONY XC-77 remote camera was chosen during the study. Much of pavement video used in the software evaluation is recorded with this camera. This camera has also been used in various light testing.

(3) The open bottom trailer is a prototype unit to facilitate the camera/light study. When a final configuration of camera/light system is determined, a custom vehicle will be made with a "bottomless" tail section. It is relatively hazardous to pull the existing trailer in heavy traffic areas such as in Houston and Dallas.

(4) The Sun IPX host for the current image processing system functions well and is very reliable. On the other hand, a lot of time was spent in the image subsystem to debug the interface problem between the Sun and series 151 subsystem.

The problem was finally located after two months effort by Imaging Technology Inc. that a programming error was embedded in the Electrical Erasable Programmable Read Only Memory (EEPROM). Another delay occurred when the Image Processor Accelerator (IPA) was implemented. A number of errors were observed when the example program was downloaded and executed on the IPA.

RECOMMENDATIONS

(1) Recently ARAN's manufacturer has used a strobe light system with a shroud for shadow free videotaping. A strobe light system required less power and thus less heat is generated. A strobe light system should be tested in future research to determine the brightness level, uniform illumination, durability, and synchronization capability with video cameras.

(2) A new low light, highly sensitive camera was developed by Cohu recently. It can acquire clear images even indoors, with shutter speeds at 1/4000th of a second. This camera technology is important in the implementation of an automatic pavement distress evaluation system. With a lower light intensity requirement, it may enable a less exotic light system, possibly a conventional light system, such as a flood light, to provide enough illumination for pavement recording.

(3) A proto-type videolog should be implemented with a survey vehicle pulling an open-bottom trailer. An integrated video system for video data acquisition should be implemented, and the pavement camera and the lights should be installed inside the trailer. The functionalities and durabilities of each component of the videolog system will be tested thoroughly before the final design of the videolog vehicle is implemented.

(4) Operator input of the count of non-cracking types of distress is recommended. With a special keyboard or a electronic clipboard, the operator can enter the relevant non-cracking distress counts. This information will complement the results of automatic cracking evaluations. This information may include:

   a. Patching and Failures count for ACP.
   b. Patches and Punch-out count for CRCP.
   c. Failures, Shattered Slabs count, and Concrete Patches count for JCP.
   d. Overall Visual Evaluation of the Survey Section.

The overall visual ratings have Excellent, Good, Average or Poor as the four categories for each survey section. Based on the overall rating, a sampling scheme will be developed for each category. For example, an "Excellent" section may only need 10% of the video frames to be processed while the "Poor" section requires 100% sampling.

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Murdoch, J. B. (1985), *Illumination Engineer*, Macmillian, New York.

Edgerton, H. E. (1979), *Electronic Flash, Strobe*, MIT Press, Cambridge, Mass.

APPENDIX A

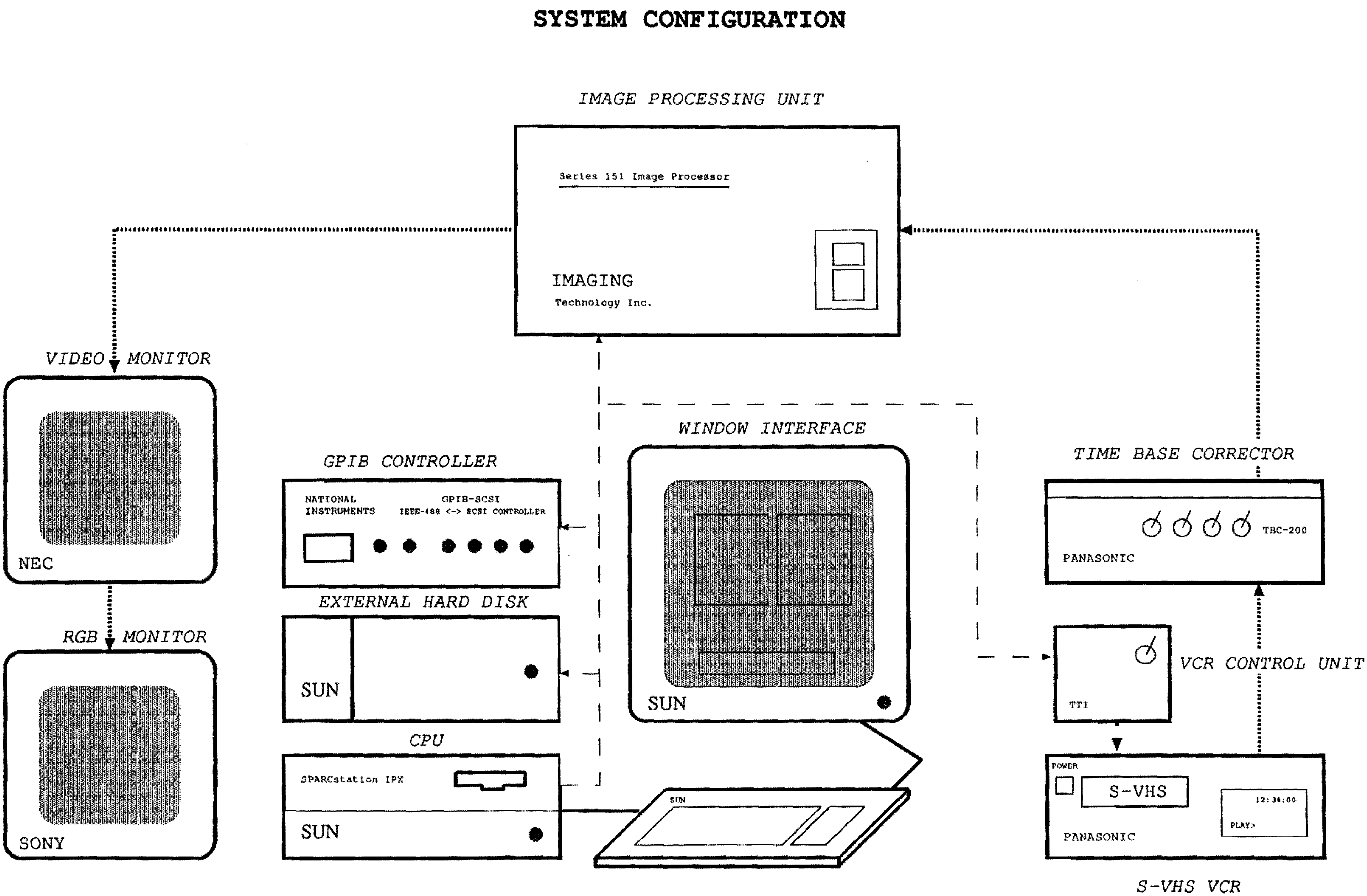

Figure A-1. Video Image Processing System Configuration.

ING DIAGRAM

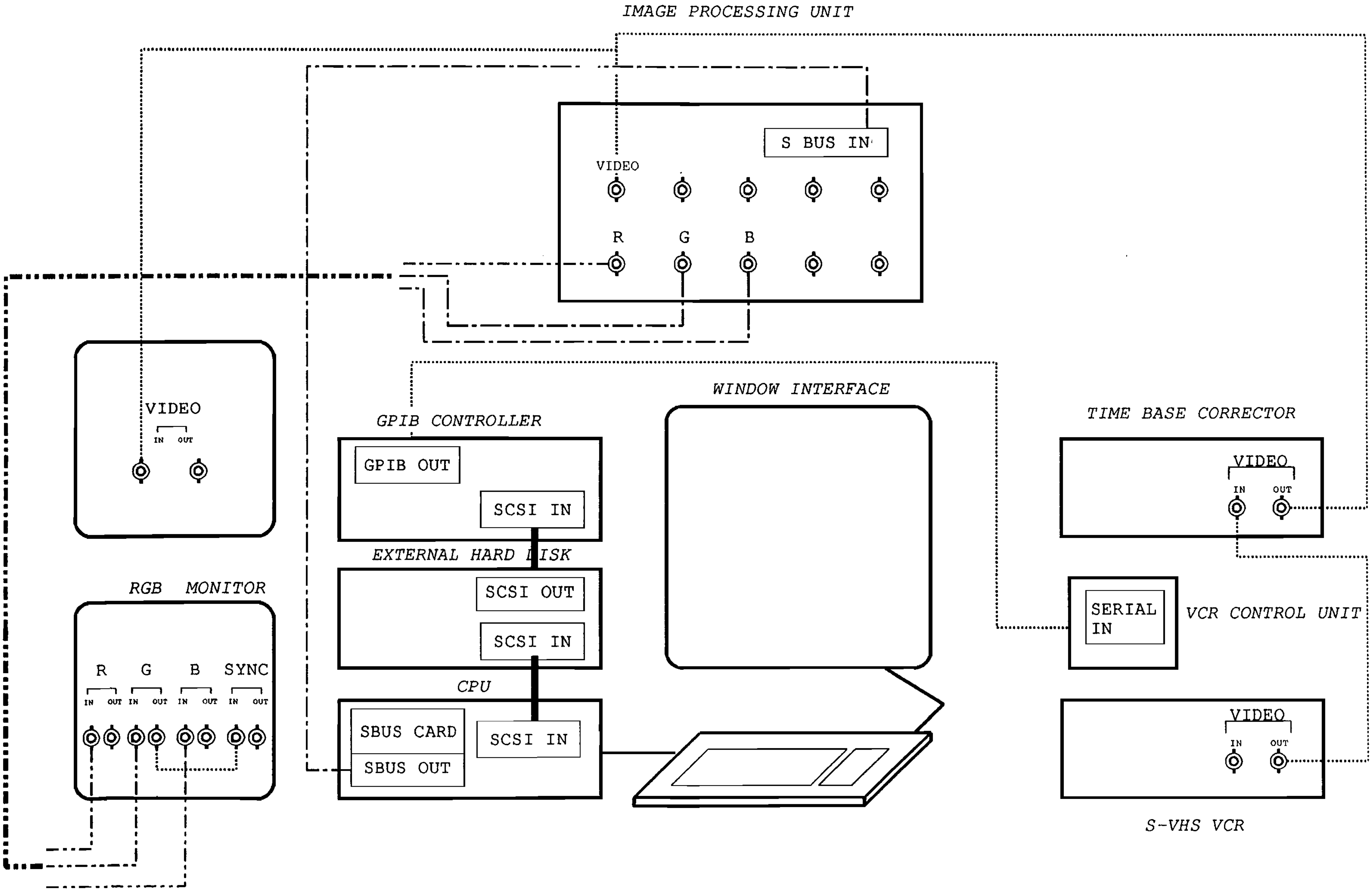

Figure A-2. Video Image Processing System Wiring Diagram.

```
/*****************************************************

Program : vcr.c

Author : TTI Div 2.

Date : Nov 92.

Copyright: TTI

Function : Program to control the basic functions
of the AG-1830 VCR. The basic functions include stop,
play, frame advance, pause, rewind, fastforward and
slow play. The VCR is controlled through its infra red
remote control which in turn is controlled through a
GPIB controller. The GPIB controller is connected to a
SUN workstation through the SCSI port. The GPIB controller
can also control other instruments and devices. VCR's are
likely to have a GPIB interface in the near future and this
program provides easy upgradeability. The program
displays a graphical user interface (GUI) based on the
SUNVIEW window system.  Buttons are displayed for each of
the VCR functions which can be activated by moving the mouse
pointer over the button and depressing the left key on the mouse.

The VCR functions can also be controlled without the
display of the GUI and this is how other programs
control the VCR.

*********************************************************/


#include <stdio.h>
#include <suntool/sunview.h>
#include <suntool/panel.h>
#include <suntool/icon.h>
#include <sys/ugpib.h>
#include <suntool/alert.h>
static void quit_proc();
static void stop_proc();
static void play_proc();
static void fast_proc();
static void rew_proc();
static void pause_proc();
static void adv_proc();


/* Global variables */

Frame frame;
Panel panel;
Icon icon;
int vcr, flag1=0, flag2=0, flag3=0,alert;

/* ICON creation */

static short icon_image[]={
#include "video.icon"
};
mpr_static(video,64,64,1,icon_image);



main()
{
```

```
vcr=ibfind("dev1");      /* Initialize GPIB device */
ibwrt(vcr,"?",1);        /* Clear GPIB device */


icon = icon_create(ICON_IMAGE,&video,0);


/* Create window with buttons */

frame = window_create(NULL,FRAME,
FRAME_LABEL, "vcr functions",
FRAME_ICON, icon,
WIN_ERROR_MSG, "can't create window",
WIN_X,350, WIN_Y,350,
0);
panel=window_create(frame,PANEL,WIN_MOUSE_XY,430,380,0);
panel_create_item(panel,PANEL_BUTTON,PANEL_LABEL_IMAGE,
panel_button_image(panel,"stop",0,0),
PANEL_NOTIFY_PROC,stop_proc,0);
panel_create_item(panel,PANEL_BUTTON,
PANEL_LABEL_IMAGE, panel_button_image(panel, "play", 0, 0),
PANEL_NOTIFY_PROC, play_proc,
0);
panel_create_item(panel,PANEL_BUTTON,
PANEL_LABEL_IMAGE,panel_button_image(panel,"fast fwd",0,0),
PANEL_NOTIFY_PROC,fast_proc,
0);
panel_create_item(panel,PANEL_BUTTON, PANEL_LABEL_IMAGE,
panel_button_image(panel, "rewind",0,0),
PANEL_NOTIFY_PROC, rew_proc,0);
panel_create_item(panel,PANEL_BUTTON,PANEL_LABEL_IMAGE,
panel_button_image(panel, "pause",0, 0),
PANEL_NOTIFY_PROC, pause_proc,0);
panel_create_item(panel,PANEL_BUTTON, PANEL_LABEL_IMAGE, panel_button_image(
panel,"frame adv",0,0),PANEL_NOTIFY_PROC,adv_proc,0 );
panel_create_item(panel,PANEL_BUTTON,PANEL_LABEL_IMAGE,
panel_button_image(panel,"quit",0,0),PANEL_NOTIFY_PROC,quit_proc,0);
window_fit(panel);
window_fit(frame);
window_main_loop(frame);
}



/*
Function: Quit
Inputs: -
Outputs: -
Task: Destroys window and stops vcr */
*/
static void quit_proc()
{
window_set(frame, FRAME_NO_CONFIRM,TRUE,0);
window_destroy(frame);
ibwrt(vcr,"/",1); /* stop vcr */
sleep(1);       /* wait 1 second before sending out new commmand */
ibwrt(vcr,"?",1);  /*clear GPIB port*/
}



/*
Function: Stop
Inputs: -
```

```
Outputs: -
Task: Stop vcr.
*/
static void stop_proc()
{
ibwrt(vcr,"/",1); /* stop vcr */
sleep(1);
ibwrt(vcr,"?",1); /* clear GPIB port */
flag1=0;
}


/*
Function: Play
Inputs: -
Outputs: -
Task: Initializes the Image Processor.
*/
static void play_proc()
{
flag1=1;
ibwrt(vcr,"=",1); /* play vcr */
sleep(1);
ibwrt(vcr,"?",1); /* clear GPIB port */
}



/*
Function: Fast
Inputs: -
Outputs: -
Task: Put vcr in fast forward mode.
*/
static void fast_proc()
{
if (flag1==1){
ibwrt(vcr,">",1); /* fast forward */
alert_proc();
}
else{
ibwrt(vcr,">",1); /* fast forward */
sleep(1);
ibwrt(vcr,"?",1); /* clear */
}
}

/*
Function: Rewind
Inputs: -
Outputs: -
Task: Rewinds vcr.
*/

static void rew_proc()
{
if (flag1==1){
ibwrt(vcr,";",1);  /* rewind */
alert_proc();
}
else{
ibwrt(vcr,";",1); /* rewind */
sleep(1);
ibwrt(vcr,"?",1); /* clear */
}
```

```
}


/*
Function: Pause
Inputs: -
Outputs: -
Task: Put vcr in pause mode */
*/
static void pause_proc()
{
ibwrt(vcr,"_",1);  /* pause */
sleep(1);
ibwrt(vcr,"?",1); /*clear */
}


/*
Function: Advance
Inputs: -
Outputs: -
Task: Advance vcr by a single frame.
*/
static void adv_proc()
{
ibwrt(vcr,"7",1);  /* advance */
sleep(1);
ibwrt(vcr,"?",1); /*clear */
}


/*
Function: Alert
Inputs: -
Outputs: -
Task: Check status  of vcr.
*/
alert_proc()
{
alert = alert_prompt(
(Frame) panel,
(Event*) NULL,
ALERT_MESSAGE_STRINGS,
" Hit play to return",0,
ALERT_BUTTON_YES, "play",
ALERT_BUTTON_NO, "cancel",
0);
switch(alert) {
case ALERT_YES:
ibwrt(vcr,"?",1); /* clear */
sleep(1);
break;
case ALERT_NO:
break;
}
}

/*
Function: Advance
Inputs: -
Outputs: -
Task: Advance vcr by multiple frames.
*/
advance_proc()
{
alert = alert_prompt(
```

```
(Frame) panel,
(Event*) NULL,
ALERT_MESSAGE_STRINGS,
"Hit pause to return",0,
ALERT_BUTTON_YES, "pause",
ALERT_BUTTON_NO, "cancel",
0);
switch(alert){
case ALERT_YES:
ibwrt(vcr,"?",1); /* clear */
sleep(1);
break;
case ALERT_NO:
break;
}
}
```