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ACTIVATION OF THE I-394 LABORATORY FOR ITS OPERATIONAL TESTING: PHASE I

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Department of Civil Engineering

HUMAN-CENTERED TECHNOLOGY TO ENHANCE SAFETY AND MOBILITY

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This and other related research have two primary objectives:

1. To develop practical operational tools which can be deployed for use in traffic-management and transportation-planning activities.
2. To develop a laboratory infrastructure which will facilitate future advances in traffic modeling and other ITS initiatives.

The objectives of this particular research project are as follows:

- A thorough examination and documentation of the I-394 system's specifications.
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- Negotiation and implementation of a repair plan
- Establishing a communications connection between the ITS Lab and the Traffic Management Center (TMC).
- Activation of the I-394 Lab, which will include a user's guide that describes the steps a user should take to access video, make a connection to the TMC and the I-394 system, and configure the system for traffic detection and data collection.

A completed I-394 Lab would be a unique and valuable tool for obtaining information that loop-detectors have been unable to supply. This information includes flow dynamics, incident behavior, capacity, and other traffic-flow characteristics. This information is vital for fine tuning operational tools and schemes to be deployed in a future TMC, and will also provide an information foundation for future research and development.

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ACTIVATION OF THE I-394 LABORATORY FOR ITS OPERATIONAL TESTING

Final Report for Phase 1

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EXECUTIVE SUMMARY

A critical attribute of robust Intelligent Transportation Systems (ITS) is a flexible and open environment for testing traffic-management and traveler-information strategies prior to full-scale implementation. The Minnesota Department of Transportation (Mn/DOT) initiated the development of such an environment along Interstate-394 (I-394) by utilizing machine-vision detection systems as a test-bed for collecting traffic-measurement data to support advanced traffic-management systems (completed in 1993). Machine-vision technology can detect and record the following traffic parameters:

- vehicle presence and passage
- vehicle speed and length classifications
- traffic flow rate, volume, lane occupancy
- traffic headway over time and level of service

Furthermore, machine-vision is a suitable tool for incident detection.

The University of Minnesota initiated a research project with an ultimate objective of investigating and developing new traffic-sensor data collection and database technologies to support decision making in a next-generation traffic management center (TMC). Toward that end, the research project's objectives were to activate the I-394 test bed and, later, to integrate the test bed's associated machine-vision equipment with the University's Center for Transportation Studies (CTS) ITS Laboratory (ITS Lab). Ultimately, operational testing of various traffic-management strategies applied to I-394 traffic should be possible with such a system.

This project is the first of multiple research phases, and is therefore referred to as "Phase 1." The specific work required in Phase 1 included:

- Examination and documentation of the I-394 system's specifications.
- Diagnostics of the working condition of the entire system, and the negotiation and implementation of a repair plan.

- Establishing a communications connection between the ITS Lab and the TMC to allow for remote control of the I-394 system.
- Writing a user's guide that describes the steps a user should take to access video, make a connection to the TMC and the I-394 system, and configure the system for traffic detection and data collection.

The work required in Phase 2, which should extend the work from Phase 1, will include:

- Design and development of a Traffic Data Management System (TDMS) for traffic-sensor data collection, storage, and dissemination. The TDMS should be easy to use, available to a general audience, and scaleable to a large operational system.
- Design and implementation of a Machine-Vision Laboratory (MVL) which will use live video feeds (from I-394 or elsewhere) and local machine-vision devices to configure detection experiments and collect data for research. In addition, the MVL will be useful for machine-vision training and instruction.

Upon the completion of Phase 2, the traffic-sensor data collection and database technologies developed will be integrated with other research work in traffic simulation to facilitate automated simulation and control.

The project (Phase 1) was a partial success. The work completed includes:

- A thorough examination and documentation of the I-394 system's specifications, most of which did not exist prior to this project.
- Diagnostics of the working condition of the system (dormant for nearly three years). A number of problems were detected among cameras, communications, and machine-vision devices. By far, it appears the communications problems are the most common and the most difficult to repair. Also, some of the computer equipment/software had become outdated, and needed upgrading.
- A repair plan was negotiated and attempted. Some of the aforementioned problems were fixed, including the machine-vision devices, some bad cabling, some upgrades to computers, and some system-design changes. Many of the

problems, including the communications, were beyond the project's control and therefore not thoroughly rectified.

- Two communication connections were established between the ITS Lab and the TMC.
    1. A microwave system was used to transfer the live Autoscope video to the ITS Lab.
    2. "Remote-control software" was used, which uses a regular telephone line and a modem to allow a user to control a Personal Computer (PC) from a remote location. In this way, control was gained over much of the I-394 machine-vision system. Completion of this task inaugurated the "I-394 Lab."
- The I-394 Lab was activated. A user's guide was written which describes the steps a user should take to access video, make a connection to the TMC and the I-394 system, and configure the system for traffic detection and data collection. Any data collected in this way will be stored in a supervisor computer at the TMC, and the user can use the remote control software to transfer the data files to the ITS Lab.

The significant results that occurred because of this project are:

- The documentation of system specifications and diagnostics will serve as the foundation for any future modifications and repairs to the system. A deeper knowledge of the system's design, condition, strengths, and weaknesses will help in making decisions regarding future research.
- The difficulties encountered serve as a lesson that a plan and financial support is needed to maintain ITS-initiative equipment, and that Mn/DOT, the University, and other related entities need better cooperation.
- A connection exists between the ITS Lab and the TMC to allow remote configuration of the I-394 machine-vision system. This "I-394 Lab" is currently available for use, although in a limited capacity due to equipment condition.

- It was concluded that the I-394 Lab cannot be used effectively until improvements are made to the system, and funding for ongoing maintenance and support is in place.
- Small-scale experiments are still possible using live video and local machine-vision devices in the ITS Lab.

1. INTRODUCTION

1.1. Background

Motivation

A critical attribute of robust Intelligent Transportation Systems (ITS) is a flexible and open environment for testing traffic-management and traveler-information strategies prior to full-scale implementation. The *traffic-detection system* is a key component of such an open test environment is. It must be easy to learn and use, while being adaptable enough to work with a wide variety of traffic-control strategies. Responding to the need to develop a test environment of this sort, the Minnesota Department of Transportation (Mn/DOT) initiated the development of the Interstate-394 Machine-Vision System (I-394 MVS) that utilizes machine-vision detection systems for the purposes of implementing traffic-management strategies and collecting traffic-measurement data.

The University of Minnesota undertook a research project in which the objectives were to activate the I-394 MVS and integrate its machine-vision equipment with the University's Center for Transportation Studies' (CTS) ITS Laboratory (ITS Lab). Ultimately, operational testing of various traffic-management strategies applied to I-394 traffic should be possible. Activation of the I-394 Laboratory (I-394 Lab) means the I-394 MVS can be configured (for the collection and transmission of machine-vision traffic information to Mn/DOT's Traffic Management Center) remotely from the University's ITS Lab.

Machine-Vision Methodology

The machine-vision detection system being utilized in the I-394 MVS is called Autoscope™ (from this point forward, simply referred to as "Autoscope"). Autoscope, initially developed at the University of Minnesota as a part of Mn/DOT funded research, is now an official product of Image Sensing Systems, Inc. (ISS) and is manufactured by Econolite Control Products, Inc. Like other machine-vision traffic-detection systems, Autoscope provides a way to automate traffic surveillance. Using machine-vision technology, Autoscope is able to receive live or recorded roadway images and analyze them in real-time. Vehicles can be detected and the vehicle-detection data is passed to either a personal computer (PC) or traffic controller. The data can then be used by a person, computer program, or traffic controller to take appropriate actions.

Autoscope can determine the following traffic parameters:

- vehicle presence and passage
- vehicle speed and length classifications
- traffic flow rate, volume, lane occupancy
- traffic headway over time and level of service

Furthermore, machine-vision is a suitable tool for incident detection. Autoscope ascertains traffic parameters by way of "detectors." Each detector type serves a different purpose and allows different traffic data to be collected. Figure 1.1 summarizes the traffic-detection process, as employed by Autoscope. The steps corresponding to the numbers in the figure are:

1. A video camera is used to monitor the roadway.
2. The video images are sent to the Autoscope.
3. The video images are passed on to a PC, which has the capability of accepting and showing live video.
4. The Autoscope software is used to "lay detectors" on the video image.
5. The detector locations are sent to the Autoscope via serial communications.
6. The Autoscope's processor uses the detector locations, the video images, and machine-vision processing technology to detect vehicles and take measurements.
7. The measurement data collected is stored to the Autoscope's memory, or

8. The data can be sent to the PC via serial communications.

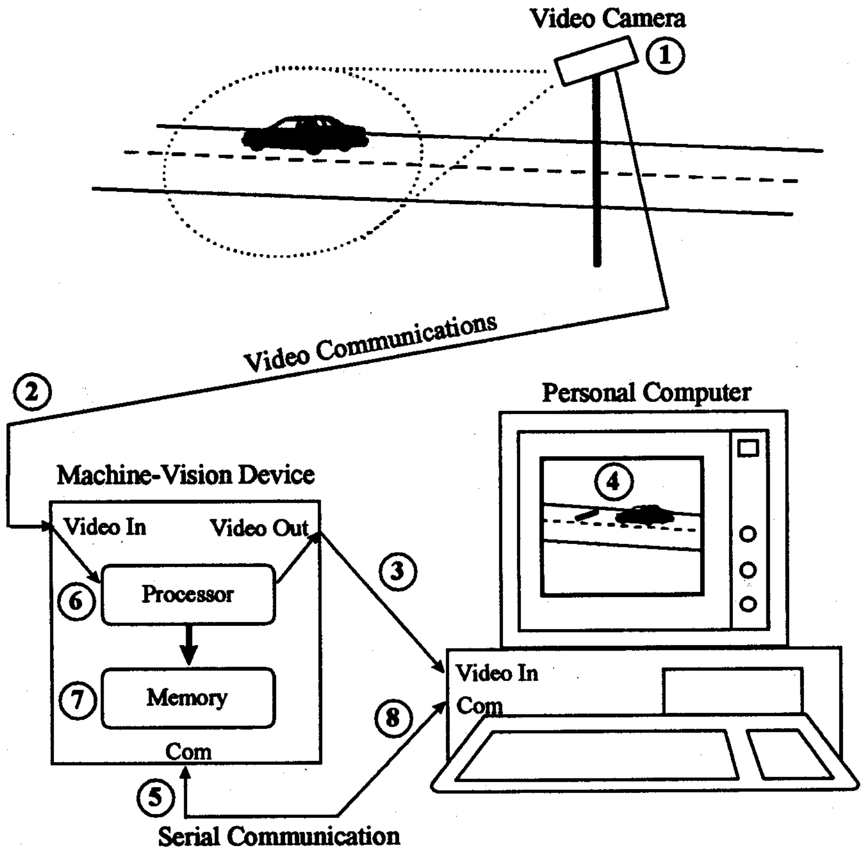

Figure 1.1 - Machine-vision detection methodology

Note that besides the camera, there are no physical structures in or near the roadway that assist this process in any way. Hence, the detection process is almost entirely non-intrusive. (See Appendix A for a detailed list of Autoscope detector types.)

The I-394 Machine-Vision System

In 1993 Mn/DOT completed installation of the I-394 MVS, which has thirty-six cameras strategically placed along a three and one-half mile stretch of I-394. This portion of I-394 is just west of downtown Minneapolis and approximately bordered by Penn and Louisiana Avenues. The intent of the I-394 MVS was to provide continuous detection coverage in every lane of the freeway, including shoulders, reversible lanes, ramps, and significant interchange connections. This allencompassing camera coverage is deemed essential for studying traffic-flow characteristics and developing effective models for freeway simulation, incident detection, and freeway-ramp control.

The I-394 MVS was originally constructed in two phases. The first phase used fifteen cameras approximately located between Penn Avenue and Wirth Parkway, and will be referred to as "Zone 1" from this point forward. (Twelve of these cameras were chosen to be kept as part of the final design after the second phase.) The second phase added twenty-four more cameras between Wirth Parkway and Louisiana Avenue, and will be referred to as "Zone 2." The implementations of the two zones differ enough to merit a distinction between these two zones. See Figure 1.2 for approximate camera locations and zone boundaries. (See Appendix B for a more detailed list of camera characteristics.)

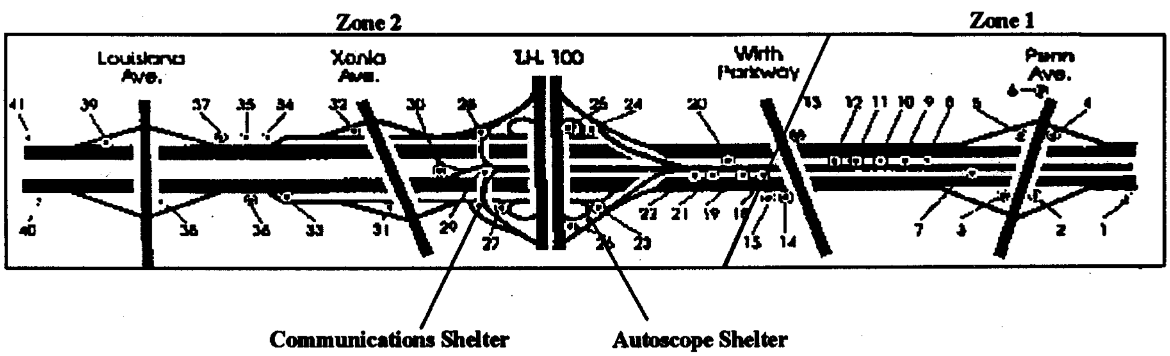

Figure 1.2 - I-394 Machine-Vision System

1.2. Research Objectives

This and other related research have two primary objectives:

1. To develop practical operational tools which can be deployed for use in traffic-management and transportation-planning activities.
2. To develop a laboratory infrastructure which will facilitate future advances in traffic modeling and other ITS initiatives.

The objectives of this particular research project are as follows:

- A thorough examination and documentation of the I-394 system's specifications.
- Diagnosis of the working condition of the I-394 system.
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- Establishing a communications connection between the ITS Lab and the Traffic Management Center (TMC).
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A completed I-394 Lab would be a unique and valuable tool for obtaining information that loop-detectors have been unable to supply. This information includes flow dynamics, incident behavior, capacity, and other traffic-flow characteristics. This information is vital for fine tuning operational tools and schemes to be deployed in a future TMC, and will also provide an information foundation for future research and development.

1.3. Report Organization

This report documents the final results from the I-394 Laboratory project (Phase 1) in the following order:

CHAPTER 1: This chapter – an introduction to the project.

CHAPTER 2: A thorough description of the I-394 system specifications, including cameras, communications, machine-vision devices, computers, and other necessary hardware.

CHAPTER 3: A description of the working condition of the different system components, based on a set of diagnostic tests.

CHAPTER 4: A description of the repair plans formulated and attempted, and a discussion of the different entities involved in those attempts.

CHAPTER 5: A description of the communications solution proposed and implemented to connect the ITS Lab and the TMC, organized by system component type.

CHAPTER 6: The conclusion of the report, including recommendations and a discussion of future direction.

APPENDIX A: A description of the different Autoscope detector types.

APPENDIX B: A table of the I-394 camera characteristics, including direction of sight, direction of traffic, number of main lanes, number of high-occupancy vehicle (HOV) lanes, and number of ramps in the field-of-view.

APPENDIX C: A user's guide for the completed I-394 Lab.

APPENDIX D: A description of the real-time video capabilities in the ITS Lab, authored by the ITS Lab Manager, Lowell A. Benson.

2. ORIGINAL SYSTEM SPECIFICATIONS

2.1. Camera Placements and Video Communications

Zone 1

There are fifteen cameras located in Zone 1, numbered 1-15. Three of these cameras were not included in the I-394 MVS specification after the implementation of Zone 2 (3,6, and 10), although the cameras are still physically present at their respective locations. Hence, there are twelve cameras in Zone 1 which are considered part of the I-394 MVS. Refer to Figure 1.2 for the approximate locations of these cameras, and Appendix B for characteristics. Zone 1 cameras are the older surveillance cameras that the TMC uses throughout much of the Twin Cities freeway system. Some specific characteristics of these cameras *as they existed at the beginning of this research* were:

- Cameras were pan-tilt-zoomable (PTZ) from the TMC.
- Wipers exist to clean camera faces (machine-vision cameras typically do not use wipers).
- Camera housings are not designed for machine-vision use.
- Video signals are converted to fiber-optic signals near the base of the camera poles.
- Fiber-optic lines carry the signals directly to the TMC.
- At the TMC, the fiber-optic signals are converted back into normal video, and sent to the TMC's large video switcher.
- The TMC has assigned identification numbers which differ from the numbers used by the I-394 MVS. (See Table 2.1)
- Viewing these cameras' images at the TMC requires a monitor and a keyboard or software-switching device (to map a given output, or "monitor," number with a particular input, or "camera," number).

These characteristics are illustrated in Figure 2.1.

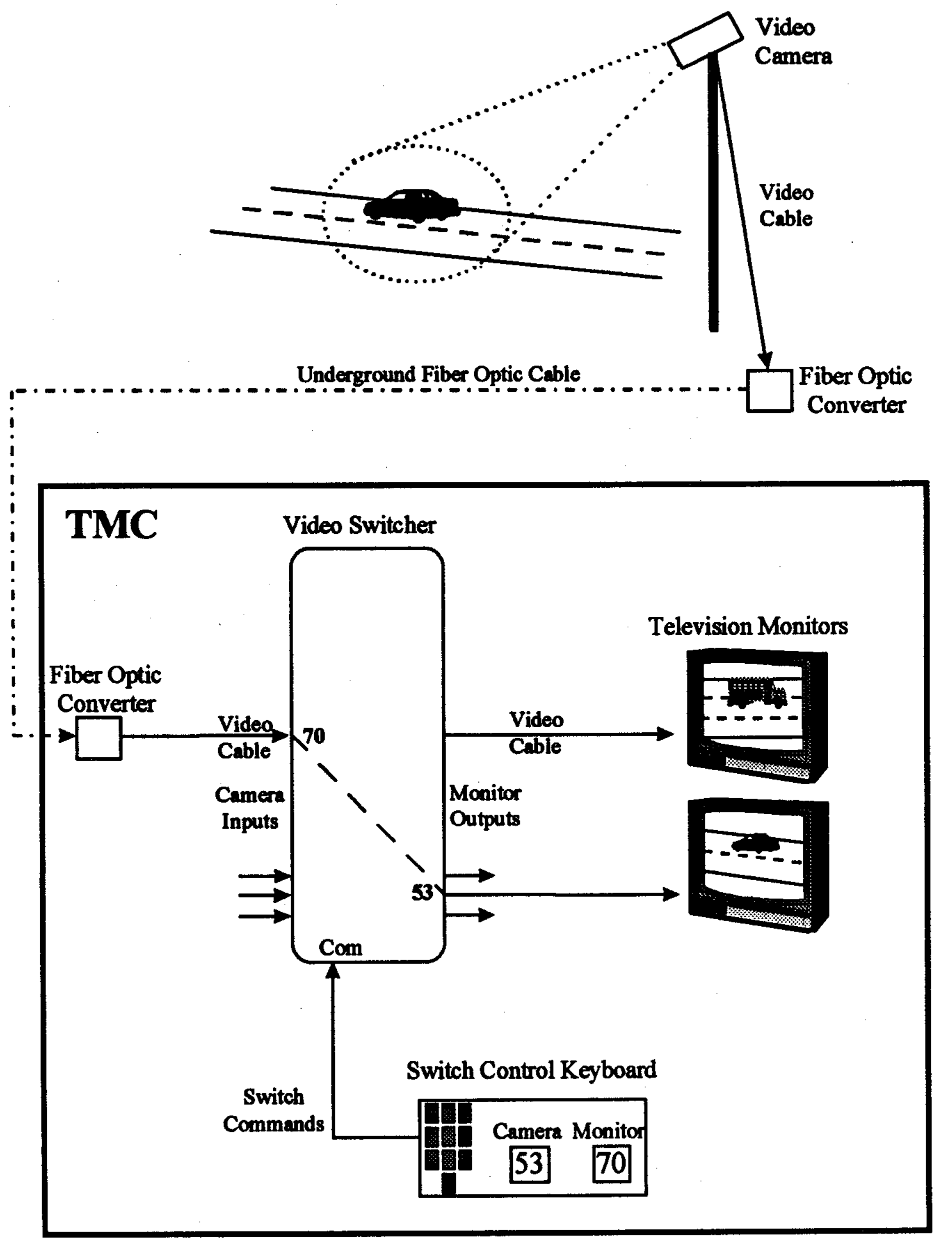

Figure 2.1 - Zone 1 camera video-communication methodology

Zone 2

There are twenty-four Zone 2 cameras, numbered 18-41 (camera numbers 16 and 17 were not included). Refer to Figure 1.2 for the approximate locations of these cameras, and Appendix B for characteristics. Zone 2 cameras are a newer type of camera which is better-suited for use with machine-vision. Some of their characteristics *as they existed at the beginning of this research* were:

- Cameras are PTZ at the base of the pole (which is more desirable for machine vision).
- No wipers exist.
- The cameras have special housings designed to protect them from weather effects.
- Video signals are converted to fiber-optic signals near the base of the camera poles.
- Fiber-optic lines carry the signals to the "Autoscope Shelter," which is located in the southeast corner of I-394 and Trunk-Highway 100 (TH-100) (See Figure 1.2).
- In the Autoscope Shelter, the fiber-optic signals are converted back into normal video, and sent to the Autoscope devices for machine-vision processing (four signals per Autoscope device).
- Each Autoscope device outputs a single video signal.
- These six output signals are fed into a series of two small video switchers, and the output is sent to the "Communications Shelter," which is located in the southwest corner of I-394 and TH-100 (See Figure 1.2).
- In the Communications Shelter, the selected signal goes through a series of conversions to prepare it to be sent to the TMC along a fiber-optic line.
- At the TMC, the fiber-optic signal is converted back into normal video, and sent to the TMC's large video switcher.
- The TMC has assigned identification number 193 to this signal.
- Viewing these cameras' images at the TMC requires a monitor and a keyboard or software-switching device, which is used to choose camera number 193. A series of communications with the six Autoscopes and the two switchers located in the Autoscope shelter suffices to view a particular signal from the twenty-four available cameras. (See Appendix C for instructions on choosing the correct signal.)

Note that only one of the twenty-four signals can be viewed at any one time from the TMC. A summary of these characteristics can be viewed in Figure 2.2.

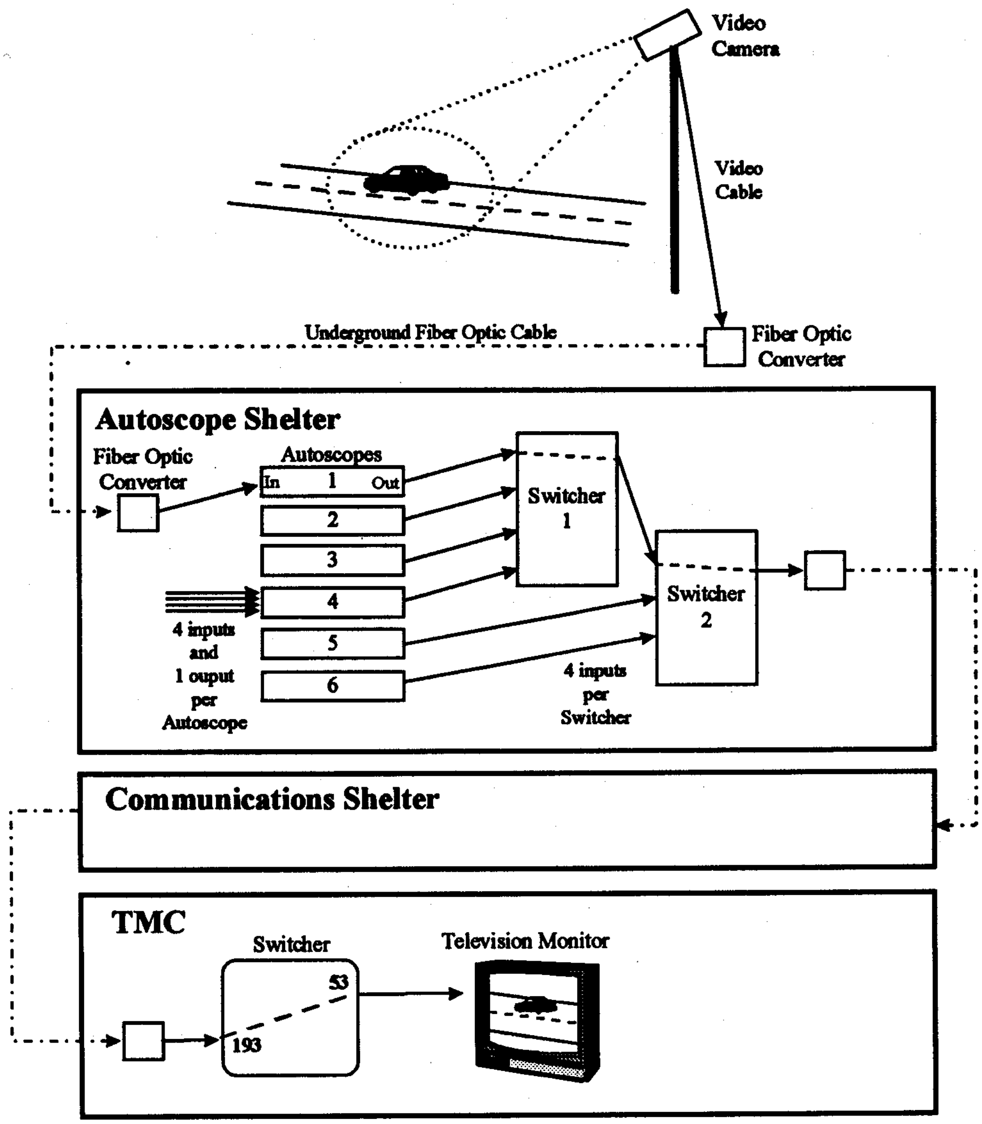

Figure 2.2 - Zone 2 camera video-communication methodology

Figure 2.3 summarizes the overall video communications utilized by the I-394 MVS.

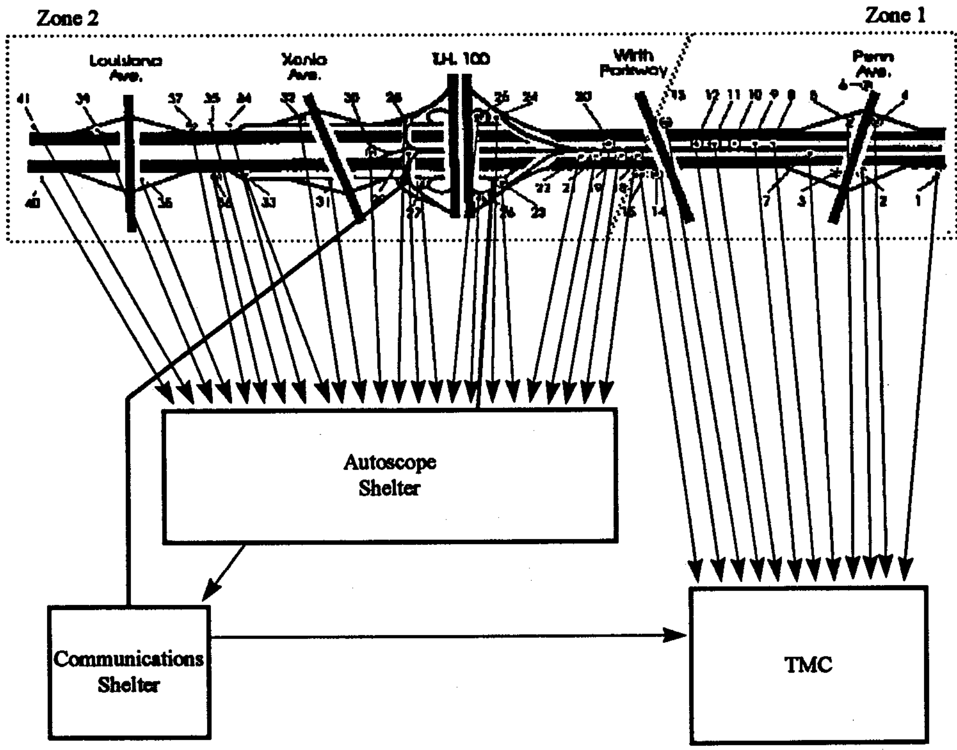

Figure 2.3 - I-394 MVS Video Communications

2.2. Autoscope Configuration and Communications

Zone 1

There were two Autoscope devices (version 2003) located at the TMC which serviced the twelve camera signals from Zone 1. Each device accepted six camera inputs, in two pairs. The pairing is an important distinction, because the 2003 Autoscope devices are very sensitive to "phasing" within an input pair. In other words, the two camera signals must be "in phase" in order for the detection to occur properly. ("In phase" means the wave patterns are moving together in approximately the same way. An "out-of-phase" wave pattern would occur if one signal's peaks coincided with the other signal's valleys.) This restriction forced some unusual pairings of camera numbers. (The more recent 2004 Autoscope devices do not have this phasing restriction.) Table 2.1 contains the distribution of camera pairs among the two Autoscopes, numbered 0:2 and 0:3.

Autoscope #	Autoscope Input #	Autoscope Camera #	TMC Camera #
0:2	1	4	70
	2	5	71
	3	2	67
	4	7	73
	5	8	74
	6	9	75
0:3	1	1	66
	2	11	77
	3	12	78
	4	13	80
	5	14	81
	6	15	82

Table 2.1 - Zone 1 Autoscope Camera Distributions

Also, an additional 2003 Autoscope device (numbered 0:0, with four available camera inputs) was located at the TMC, which was primarily a demonstration and data display tool, and was not being used as a part of the I-394 MVS per se.

Autoscopes 0:2 and 0:3 are located in the basement of the TMC, in the "Telemetry Room." The "Scopeserver PC," which was used to configure and control the I-394 MVS and described in the next section, was located on the main floor and configured to communicate directly with these two Autoscopes. This type of communication is referred to as "single drop."

Zone 2

The twenty-four cameras located in Zone 2 are serviced by six Autoscope devices located in the Autoscope Shelter (see Figure 1.2). Each device accepts four camera inputs, in two pairs (see Figure 2.2). The same phasing restriction again forced some unusual numberings. Table 2.2 contains the distribution of camera pairs among the six Autoscopes, numbered 8:1 through 8:6, consecutively. (The "8" refers to "node 8," the TMC communications node that services the Autoscope Shelter.)

Autoscope #	Autoscope Input #	Autoscope Camera	TMC Camera #
8:1	1	18	193
	2	19	
	3	20	
	4	21	
8:2	1	22	193
	2	23	
	3	24	
	4	25	
8:3	1	26	193
	2	27	
	3	28	
	4	29	
8:4	1	30	193
	2	33	
	3	32	
	4	31	
8:5	1	37	193
	2	35	
	3	34	
	4	36	
8:6	1	38	193
	2	39	
	3	40	
	4	41	

Table 2.2 - Zone 2 Autoscope Camera Distributions

Unlike the Autoscopes at the TMC, the Autoscopes in the Autoscope Shelter share a single communication line (which minimizes the number of lines running the long distance from I-394 to the TMC). This communication method is referred to as "multi-drop." The six Autoscopes can share a single communication line by using a device called a "line sharer," and the Autoscope software distinguishes between the six lines by using the identification numbers (8:1-8:6).

2.3. TMC Scopeserver PC and Hardware Configuration

The personal computer at the TMC which is used to control and configure the I-394 MVS is called the "Scopeserver PC." There were a number of distinguishing characteristics regarding the Scopeserver PC configuration:

- The Scopeserver PC was a 486 computer with 12 megabytes of RAM and 3.2 megabytes of drive space, running the Windows 3.1 operating system.
- The Scopeserver PC had an ethernet card and a network connection to the TMC's local area network (LAN).
- A special video card, called Super VideoWindows (SVW) and manufactured by New Media Graphics Co., was used so the PC could accept and display live moving-video images.
- A set of local devices was used to support the systems operational capabilities, including another Autoscope (0:0), a monitor, a VCR, two video-witching devices, and a keyboard switcher to control the TMC master video switcher.
- Four monitor numbers (53,54,55,56) were allocated to the system for either exclusive or shared use.
- To accommodate the many devices and communication needs, a Digi PC/8e Intelligent Asynchronous Serial Communications Board made by Digi International is used (hereafter referred to as "Digi Board"). This device effectively expands a single communication port into eight. This is important because without such a device, PCs only have two available communication ports.
- Two RS-232 serial-communication lines are converted into RS-422 (differential twisted pair) so they can travel the long distance to the Autoscopes in the basement (0:2-0:3).

- One serial-communication line is converted into fiber and sent to the Autoscope Shelter, where it is used to communicate with six Autoscopes (8:1-8:6).
- Another serial-communication line was also converted to fiber and sent to the Autoscope Shelter, where it is used to communicate with the two video switchers located there.
- The 16-bit versions of the Autoscope software applications ("Supervisor," "ScopeServer," "Traffic Data Formatter," "Autograph") all resided on the Scopeserver PC.
- A second computer, called the "Supervisor PC," was also included as part of this installation. It's use, however, was primarily for demonstrations and data display, and it will not again be considered in this report.

Many of these characteristics can be viewed in diagrams which follow this section. Figure 2.5, Figure 2.6, and Figure 2.7 are detailed schematics of the configurations of the TMC hardware, the Communications Shelter, and the Autoscope Shelter, respectively. Figure 2.4 is a menu of the different communication lines used in the diagrams.

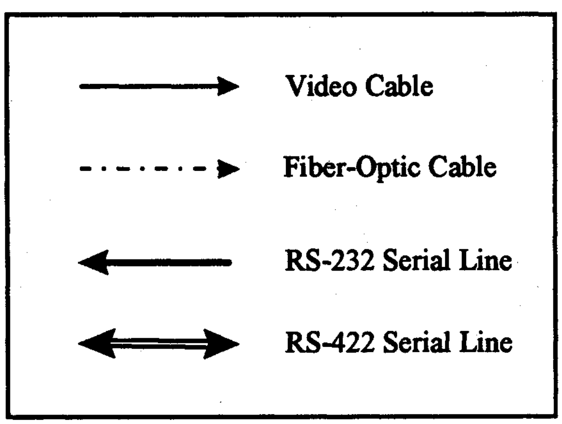

Figure 2.4 - Menu for following figures

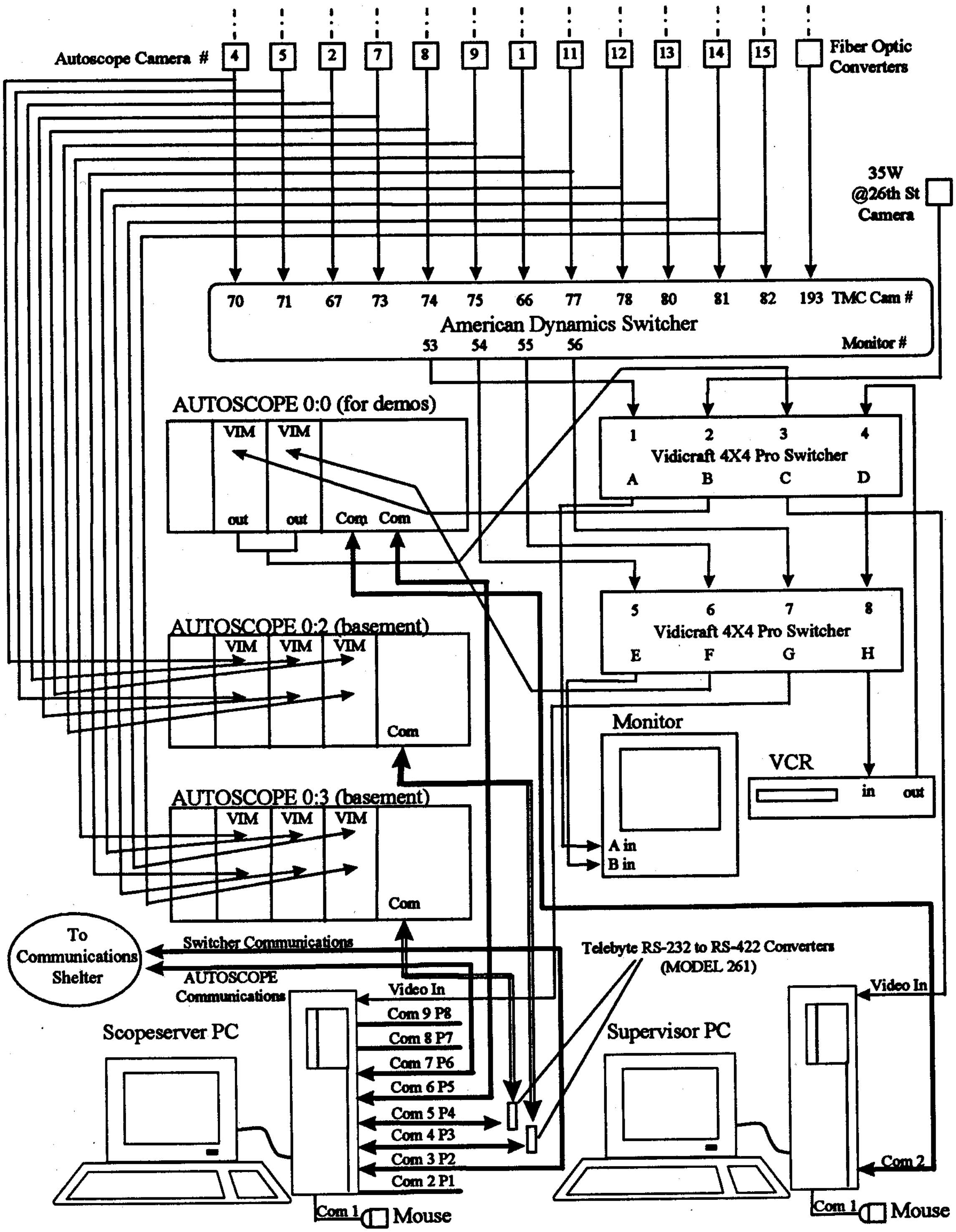

Figure 2.5 - TMC machine-vision hardware schematic

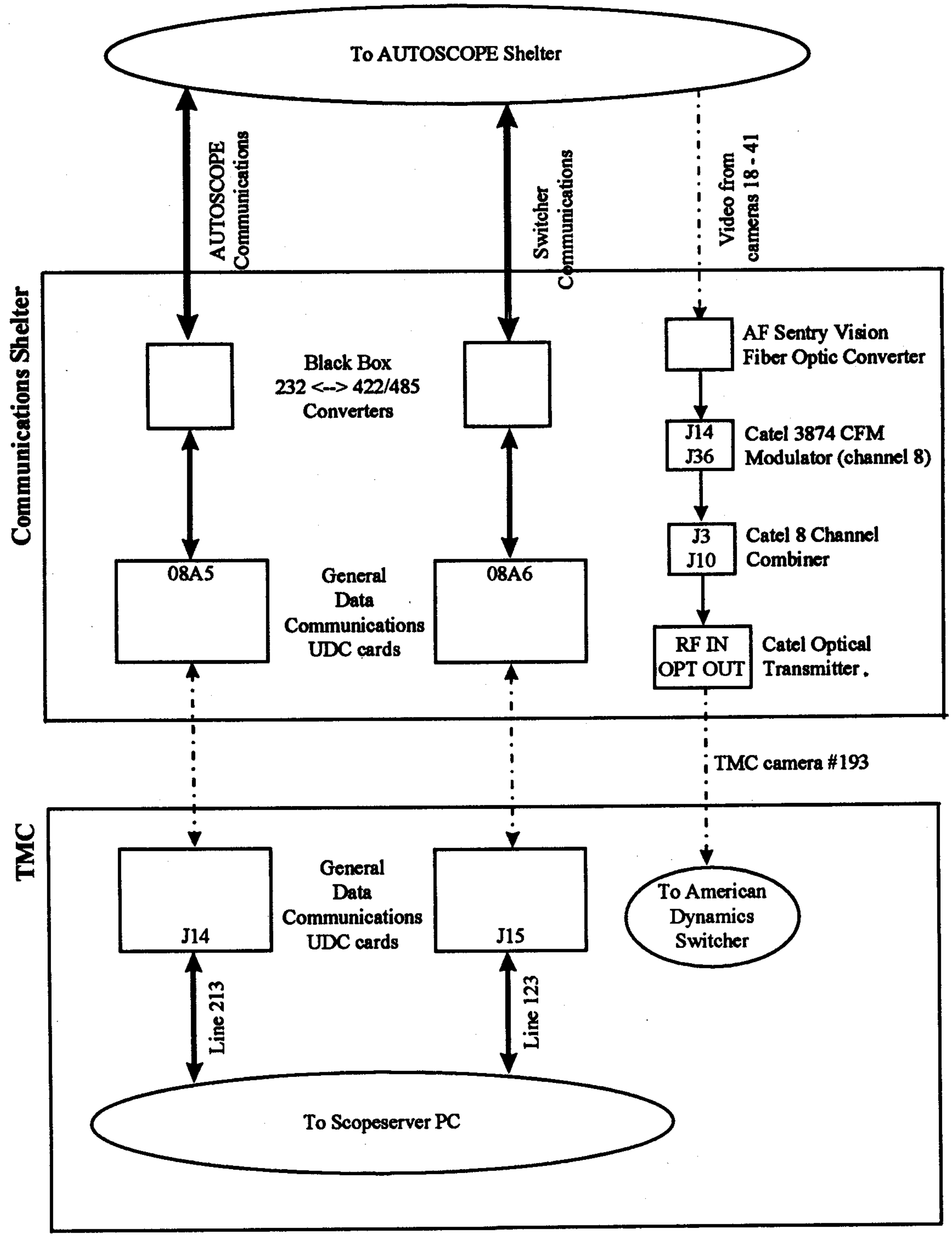

Figure 2.6 - Communications Shelter schematic

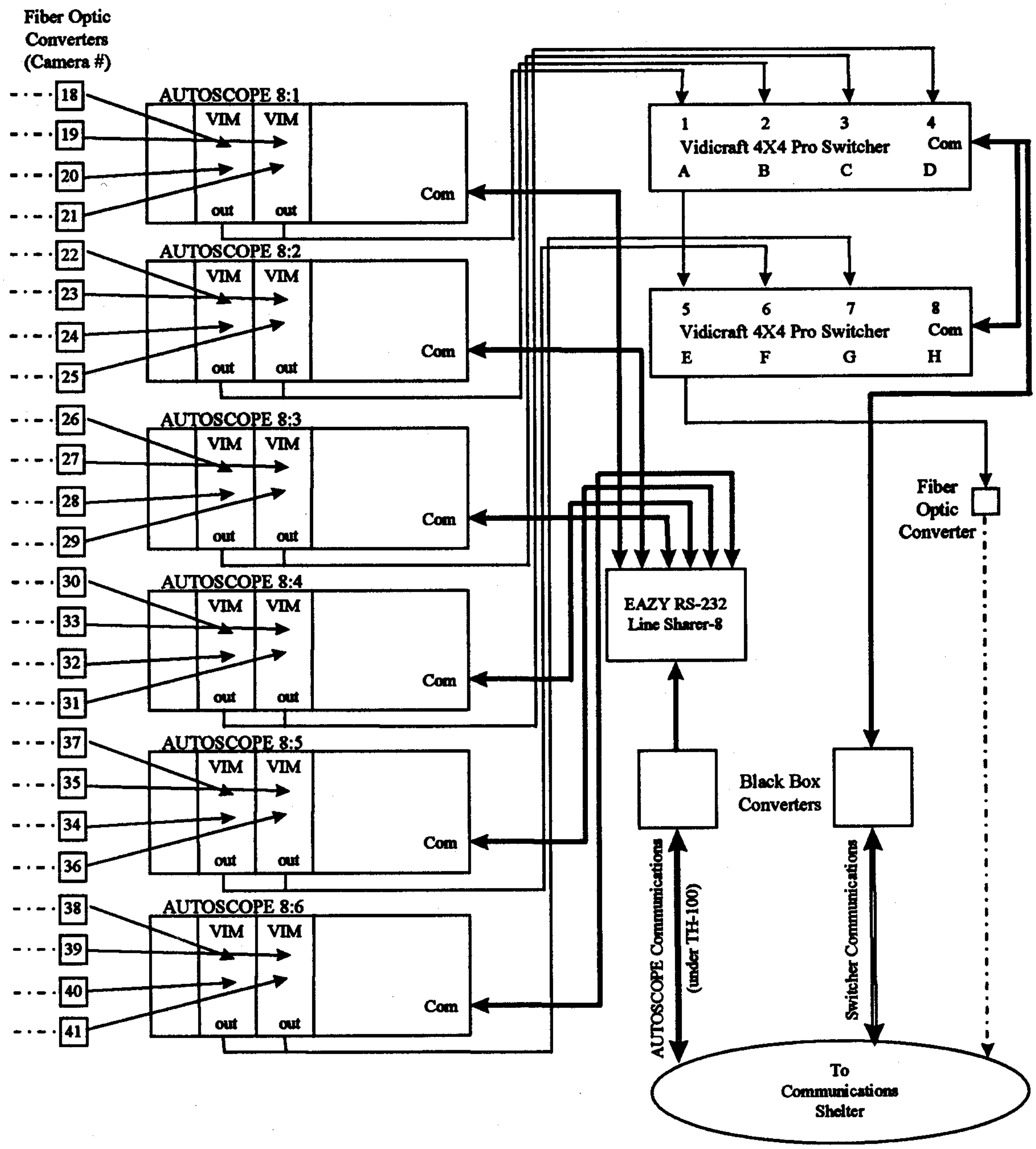

Figure 2.7 - Autoscope Shelter schematic

3. SYSTEM DIAGNOSTICS

3.1. Camera and Video Status

The cameras originally installed for the I-394 MVS have seen little attention or maintenance over the past few years. Consequently, they are in a variety of states of functionality. Some of the problems encountered include:

- *Wipers stuck in the field of view* - Some of the Zone 1 cameras are obstructed by wipers.
- *Casing obstruction* - Some of the Zone 1 cameras have moved inside of their protective casings, causing the casing to be visible on one side or the other.
- *Moisture in/on the face plate* - When moisture seeps into a camera's face plate, the distortion can degrade Autoscope detection. Another moisture problem was observed during winter when icicles formed in some cameras' fields of view. This is likely a function of poor camera design, and seems to affect Zone 1 cameras the most.
- *Dirt on the face plate* - Some of the camera faces need cleaning.
- *Dead signal* - The video signals from some cameras appear to never reach the Autoscopes.
- *Noisy video signal* - A noisy signal, characterized by white snow, wavy lines, or a "white-out" situation , will prohibit Autoscope from making accurate measurements.

The cameras that appear to have the most problems are located in Zone 1. Of the Zone 2 cameras, approximately one-third are in good working order. Table 3.1 summarizes the working status of the thirty-six cameras/video signals as of January 1996. The signals/images were tested at the point where they entered the Autoscopes using a portable monitor and an oscilloscope.

Autoscope #	Autoscope Camera #	Visual Status	Signal Integrity	Gain Value (in mv)
0:2	4	Cloudy	Noisy	175
	5	Right obstruction	Noisy	220
	2	Good	Slightly noisy	240
	7	Right obstruction	Very Noisy	250
	8	Dead	-	-
	9	Good	Very Noisy	250
0:3	1	Cloudy & Icicles	Very Noisy	160
	11	Dead	-	-
	12	Good	Slightly noisy	250
	13	Good	Slightly noisy	260
	14	Dead	-	-
	15	Good	Slightly noisy	300
8:1	18	Good	Good	250
	19	Dead	-	-
	20	Good	Good	200
	21	Dead	-	-
8:2	22	White	Good	2800
	23	White & Moisture	Good	2600
	24	Good	Good	250
	25	None	Noisy & Flat	-
8:3	26	White	Good	4200
	27	Dead	-	-
	28	Moisture	Good	660
	29	Good	Good	470
8:4	30	Moisture	Good, but Icicle	270
	31	Dead	Icicle	-
	32	Good	Good	250
	33	Moisture	Good	250
8:5	34	None	Noisy & Flat	-
	35	Good	Good	250
	36	Good	Good	250
	37	Good	Noisy	250
8:6	38	Moisture	Good	260
	39	Noisy	Noisy	?
	40	Good	Noisy	280
	41	Good	Good	200

Table 3.1 - Camera diagnostics (as of January 1996)

To receive a "good" visual status rating, a video image should look clear and stable, and not have any of the following undesirable characteristics:

- No image
- Cloudy/blurry image
- An black-white inverted image
- A whitewashed image
- An obstruction, such as the camera casing or a wiper
- A dirty face plate
- Visible moisture on face plate

Determining the signal integrity was accomplished with assistance from ISS engineers. The following desirable characteristics are presented without definition:

- Against a solid-white background, the difference between the blanking level and the flat white peak should be 350 millivolts (mv). This is not testable in the field.
- The sink pulse (gain) between the front and back porch is optimal at 286 mv. Any level 200-300 mv is acceptable.
- Excess noise (characterized by fuzzy lines, a jumpy wave form, or spikes) should be minimized.

It is likely that some of the aforementioned problems have less to do with the cameras, but are instead a problem with the communications. The major issues appear to surround the fiber-optics used for these video signals. The two most likely explanations for the problems are:

1. The fiber has been cut or damaged
2. The video signal was converted incorrectly

The second reason deserves some clarification. Fiber-optic conversions require a specific signal enhancement, which is a function of the length of the fiber to be traversed. Apparently, the devices which convert the signals from regular video to fiber and vice versa were made to specification at the factory, each one tailor-made for the particular fiber length it was assigned to. Those specifications could have been incorrect initially (perhaps using a greater tolerance for error appropriate for surveillance cameras, but unsatisfactory for machine-vision cameras), or they may simply need adjustment due to time and wear. Unfortunately, *the converters are not adjustable*.

3.2. Autoscope status

All of the Autoscope units in the I-394 MVS are Autoscope version 2003 devices. In addition to the phasing problem already mentioned, this version of Autoscope is apparently susceptible to problems with their video-input and power-supply hardware. (ISS claims that version 2004 eliminates these difficulties.) Even so, when these diagnostics were completed, only two of the eight Autoscope devices had obvious problems. Autoscope 0:3 had a faulty video input module and 8:5 had a faulty power supply. In addition, many of the video cables feeding the Autoscopes are greatly worn and in need of repair or replacement, particularly in the basement of the TMC.

Another observation about the Autoscopes is the difference between the Zone 1 and Zone 2 specifications. Recall that Zone 1 had two Autoscopes with six inputs each, and Zone 2 had six Autoscopes with four inputs each. It is generally a good idea to have a consistent configuration across a system. This way, the system is easier to understand and simpler to maintain.

3.3. Scopeserver PC Status

The Scopeserver PC and its related hardware (VCR, monitor, switchers, converters) are located on the main floor of the TMC, next to the operations center. This hardware is struggling to occupy a small space in the corner of an already overcrowded room. The Scopeserver PC is very obsolete by current standards, low on processing power, memory, and drive space. This limitation will critical if the PC is used to collect data from all Autoscopes simultaneously. In addition, the

Windows 3.1 operating system is not multi-tasking, and generally considered unstable.

The software also suffers from some obsolescence. For example, the manufacturer of the Super VideoWindows card has gone out of business, so this product is neither supported nor can it compete with current products. In fact, ISS now recommends a different video card made by Hauppage, Inc. (see *Hardware Upgrades* below).

4. EQUIPMENT REPAIRS

It is clear from the completed diagnostics that the I-394 Lab cannot realize its full potential without some significant repairs. Therefore, a plan was initiated with the intent of completing these repairs. In general, the assistance of outside groups was necessary to attempt to accomplish this task. Two of these groups are Mn/DOT oraganizations: the Electronic Services Section (ESS) and the Traffic Management Center (TMC). The other group is Image Sensing Systems, Inc. (ISS). Each group will be discussed separately.

4.1. Electronic Services Section

ESS is the Mn/DOT organization which maintains and services much of the electronic freeway-operations equipment, including controllers and cameras. After diagnostics were completed, CTS unofficially contracted with ESS for repair of the camera and communication problems. After multiple meetings, however, it became clear that except for a few minor changes (some bad cable ends were replaced), little headway was being made. In hindsight, there are a number of likely reasons for this unsuccessful endeavor:

- The ESS technicians have a number of other pressing jobs to accomplish, with a relatively small staff.
- There is no budget for (and therefore they were not being compensated for) this work, so it did not take priority.
- They did not have access to good portable video-repair and diagnostics equipment.

In addition, it became apparent late in the research that ESS was not allowed to work with the fiber-optic cables, where it is presumed many of the problems reside. (The fiber is under the jurisdiction of the TMC.) This obviously limited the effectiveness of their work.

Despite these limitations, it should be noted that the ESS technicians were very helpful to the researchers on other occasions. In particular, they helped redirect cameras to specific areas of the roadway needed for University research projects, and they changed all of the Zone 1 cameras to be PTZ at the base of the pole, making a consistent PTZ configuration for the entire system. (The CTS' ITS Lab provided materials and parts for this change.)

4.2. Traffic Management Center

The cooperation of the TMC was necessary for two reasons. First, the Scopeserver PC, three Autoscopes, and other hardware were located at the TMC, and second, the TMC has jurisdiction over the fiber-optic communications. The first reason causes difficulties, due to the shortage of space at the TMC. The I-394 MVS takes up floor and desk space, and because the system historically has seen infrequent use, it is generally considered to be a waste of that space. This attitude is exacerbated by the fact that the TMC has no specific research mission, so their emphasis is on activities that support operations and operational tests. (As an example, refer to Section 5.3 for a list of changes made to the I-394 MVS. In fact, these changes caused a user of the I-394 MVS to necessarily interrupt operations to verbally request use of one camera or another. Perhaps these modifications were necessary. Nevertheless, none of the researchers using the system were ever queried about the changes prior to their taking place.) Another access problem arose with regards to the Telemetry Room, where the two Autoscopes are located. During diagnostics, repairs, and upgrades, it was common for researchers to enter that room to work on the Autoscopes and related systems. This was, however, became an unacceptable arrangement due to the sensitive nature of the other operational equipment located in that room. A stricter access policy was therefore introduced. Although this policy is acceptable for the working of the I-394 MVS, it further illustrates the difficulties involved in using and maintaining a research system that is interwoven with an operations system.

As previously mentioned, the fact that the TMC has jurisdiction over the fiber-optic communications was not known until late in this research. When it finally became clear that ESS was not allowed to work with that equipment, an attempt was made to negotiate with some of the TMC engineers for help. The major problem appears to be with the converters, which are not configurable. CTS agreed to buy some test equipment and configurable converters to help the TMC engineers attempt these repairs. Unfortunately, the equipment was on back-order for a long time, and has only recently arrived. Nevertheless, since the TMC suffers from the same lack of resources that ESS does, it is unlikely that any significant progress would have been made, even with the new equipment.

4.3. Image Sensing Systems, Inc.

ISS has a vested interest in the success of machine-vision technologies applied to ITS, so it is not surprising that they have been extremely helpful throughout this research. In particular, they helped diagnose and fix the problems encountered with the Autoscope devices, making numerous trips to the ITS Lab, the TMC, and the I-394 sheds.

5. COMMUNICATIONS SOLUTION

The primary objective of this research was to establish a communications link between the University's ITS Lab and the I-394 MVS via the TMC. Ideally, such a link would make remote detection, experiment configuration, and detailed data collection possible. This data would subsequently provide researchers with valuable information for improving traffic modeling, incident detection, and control planning. The solution that was chosen to meet the aforementioned objective has four major components: video transmission, Autoscope configuration, TMC system modifications, and the serial communications solution.

5.1. Video Transmission

Independent of this research, an initiative was undertaken by the University's CTS ITS Institute to gain access to a portion of the TMC's live surveillance-video images. This goal was accomplished by using a microwave system to establish a one-way connection between the TMC and the ITS Lab. A microwave dish was installed at the TMC, and a system for converting surveillance video into frequency modulated (RF) microwave signals was put in place. In addition, a microwave dish was installed at the top of Moos Health Sciences Tower (across the street from the CTS) to receive the microwave signal from the TMC, and send that RF signal to the CTS. (The two microwave dishes must have "line-of-sight" in order for this to work correctly.) Any kind of RF tuner (frequency demodulator), such as a VCR, can then be used at the ITS Lab to choose one of forty different live surveillance video images, just as they appear at the TMC. This system became operational in September 1995, and is illustrated in Figure 5.1.

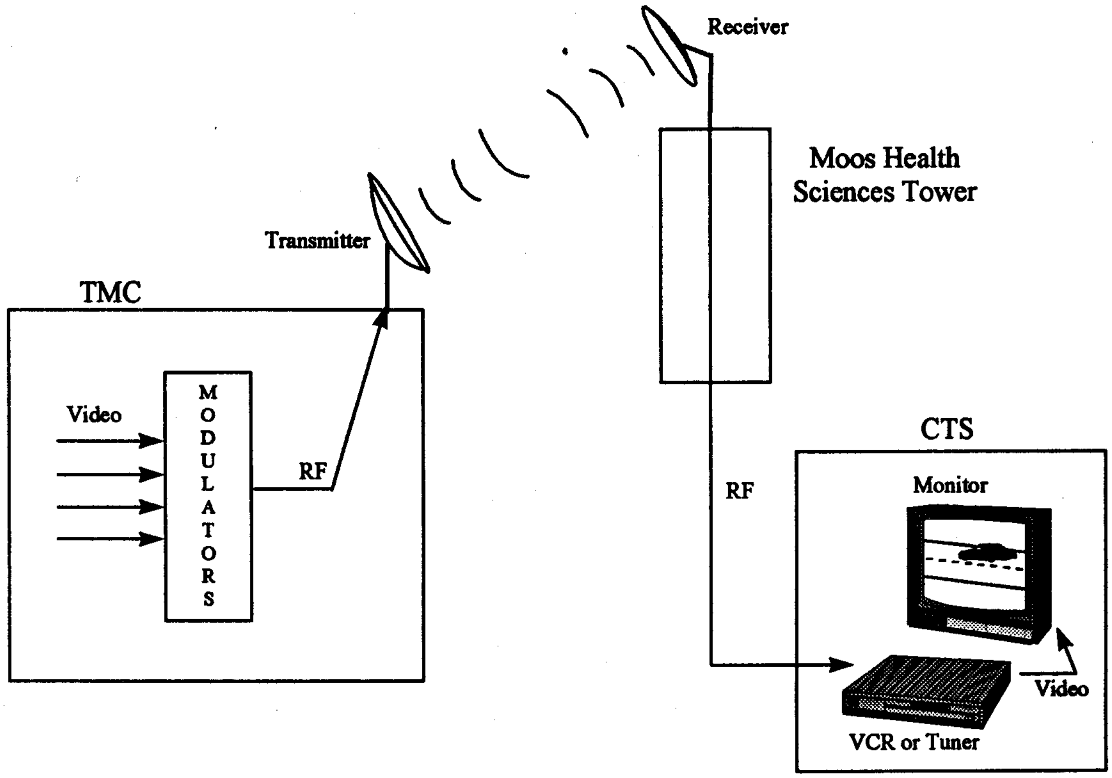

Figure 5.1 - Microwave video transmission system

Recall that the I-394 MVS requires access to thirteen video signals (twelve Zone 1 + one Zone 2). In order for lab users to view the different I-394 MVS cameras, these live video images needed to be sent to the ITS Lab. Fortunately, space for the thirteen signals was allocated to the microwave system. Table 5.1 summarizes the channel allocations for the microwave system, with special attention placed on the thirteen machine-vision video signals. Appendix D contains a report which describes the ITS Lab video transmission system in greater detail. The microwave system has proven to be very reliable, and the signal degradation due to this system is minimal.

Video Source	Connection Point	Microwave Mod #	TMC Function	ITS Lab Channel #
AS Camera #2	At AS 0:1 Input	6	I-394 MVS	6
AS Camera #4	At AS 0:1 Input	7	I-394 MVS	7
AS Camera #5	At AS 0:1 Input	8	I-394 MVS	8
AS Camera #7	At AS 0:1 Input	10	I-394 MVS	10
AS Camera #8	At AS 0:2 Input	12	I-394 MVS	12
AS Camera #9	At AS 0:2 Input	13	I-394 MVS	13
AS Camera #1	At AS 0:2 Input	C	I-394 MVS	16
AS Camera #11	At AS 0:2 Input	D	I-394 MVS	17
AS Camera #12	At AS 0:3 Input	E	I-394 MVS	18
AS Camera #13	At AS 0:3 Input	F	I-394 MVS	19
AS Camera #14	At AS 0:3 Input	G	I-394 MVS	20
AS Camera #15	At AS 0:3 Input	H	I-394 MVS	21
AS Cameras #19-41	At #193 Video Mux	I	I-394 MVS (Zone 2)	22
Monitor #53	?	K	I-394 MVS Monitor	24
Monitor #49	Monitor #49	AA	North Operator	37
Monitor #52	Monitor #52	BB	South Operator	38
Monitor #50	Monitor #50	II	KBEM announcer	45
Monitor #58	Monitor #58	JJ	KBEM announcer	46
Monitor #51	Monitor #51	KK	BARCO display	47
Monitor #53	Monitor #53	LL	Genesis/Trilogy	48
Monitor #62	Monitor #62	MM	Shared with St. Paul.	49
Monitor #48	Monitor #48	NN	Shared with Mpls.	50
Monitor #31	Monitor #31	CC	South Station	39
Monitor #32	Monitor #32	DD	South Station	40
Monitor #33	Monitor #33	EE	South Station	41
Monitor #34	Monitor #34	FF	South Station	42
Monitor #35	Monitor #35	GG	South Station	43
Monitor #36	Monitor #36	HH	South Station	44
Monitor #07	Monitor #07	L	North Station	25
Monitor #08	Monitor #08	M	North Station	26
Monitor #09	Monitor #09	N	North Station	27
Monitor #10	Monitor #10	O	North Station	28
Monitor #11	Monitor #11	P	North Station	29
Monitor #12	Monitor #12	Q	North Station	30
Monitor #13	Monitor #13	S	North Station	31
Monitor #14	Monitor #14	R	North Station	32
Monitor #15	Monitor #15	T	North Station	33
Monitor #16	Monitor #16	U	North Station	34
Monitor #17	Monitor #17	V	North Station	35
Monitor #18	Monitor #18	W	North Station	36

Table 5.1 - ITS Lab microwave channel mappings

5.2. Autoscope Configuration

As was previously mentioned, the design and installation differences in configuration between Zone 1 and Zone 2 increase complexity, complicate maintenance, and interfere with the setup and central objectives of the lab. In particular, there was the desire to "emulate" Autoscopes in the field by using local Autoscopes in the lab. In other words, a detector configuration could be more easily observed and manipulated using local Autoscopes, rather than trying to communicate with the devices in the field. Unfortunately, the current version of Autoscope (2004) has a maximum of four camera inputs, while Autoscopes 0:2 and 0:3 (at the TMC) had six inputs. There was no way to emulate these configurations remotely.

As a solution, Autoscope 0:0, which was only being used for demonstration purposes, was moved to the basement, renumbered as 0:1, and the cameras were redistributed among the three Autoscopes (0:1, 0:2, 0:3). Instead of two Autoscopes with six cameras each, now there are three Autoscopes with four cameras each. There is now a consistent configuration of four cameras per Autoscope for the whole system. Table 5.2 shows the new configuration.

Autoscope #	Autoscope Input #	Autoscope Camera #
0:1	1	4
	2	5
	3	2
	4	7
0:2	1	8
	2	9
	3	1
	4	11
0:3	1	12
	2	13
	3	14
	4	15

Table 5.2 - Reconfiguration of TMC Autoscopes

5.3. TMC System Modifications

A number of hardware upgrades were necessary in order to support the chosen communications solution (which will be described shortly). In addition, some hardware changes were made by the TMC that affected this project.

Hardware Upgrades

Here is a list of different hardware upgrades made to the TMC equipment and Scopeserver PC.

- For security reasons, the TMC network cable was unplugged.
- In order to accommodate the new Autoscope (0:1) in the basement a new serial line needed to be added. Fortunately, an RS-422 line was already available between the Scopeserver PC and the basement. The Autoscope was reconfigured to accept RS-422 (instead of RS-232), and an RS-232/RS-422 converter was provided by the ITS Lab to connect the line to the PC.
- A external modem was added to the system. Initially, a 14.4 Kbps modem was chosen, but a 28.8 Kbps modem eventually replaced it.
- The Windows 3.1 operating system was replaced by Windows NT 3.51. This was to provide more robustness, and to accommodate new 32-bit software.
- To support the operating system change, the memory was upgraded from 12 MB to 24 MB
- The obsolete Super VideoWindows card was replaced by a more current Hauppage Win/TV Cinema Pro card, which works under NT.
- A new NT driver for the Digi Board was installed.
- One of the 4X4 video switchers became unnecessary (but should be kept as a spare).

TMC Changes

Here is a list of different hardware changes made by the TMC.

- The keyboard switcher was removed from the system. The TMC offered to provide us with the 32-bit software switcher application instead. This helped make the decision to choose NT. At the writing of this report, the switcher application has not been received or installed. (Note: Use of this application will most likely require reconnecting the Scopeserver PC to the TMC network. The security issues surrounding that prospect have not been discussed.)
- Three of the four monitor numbers are no longer available to the I-394 MVS (53 is left).
- A new TMC switcher is being installed at the TMC. This may affect the I-394 MVS.

Figure 5.2 summarizes the new TMC system configuration.

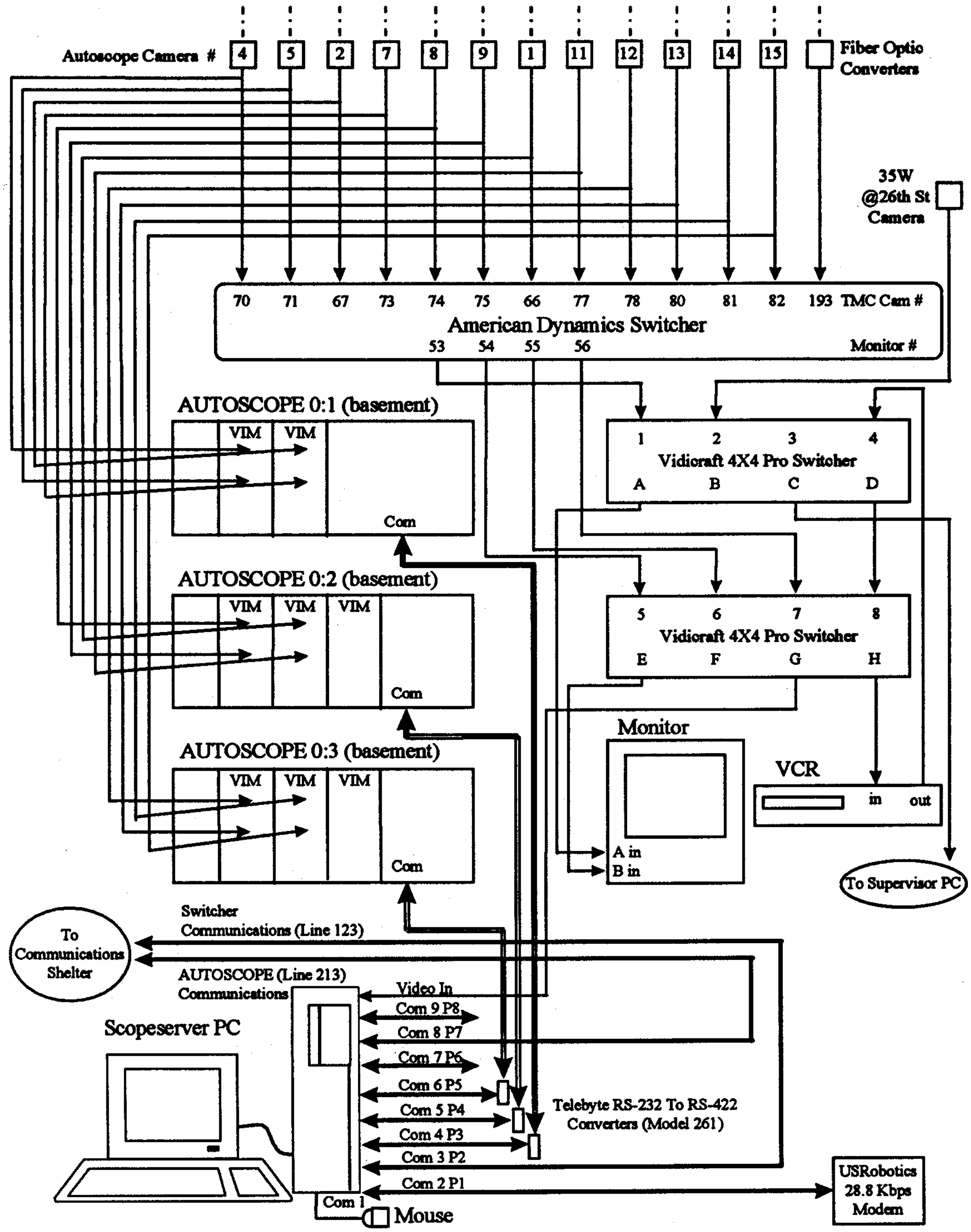

Figure 5.2 - TMC modified hardware schematic

5.4. Serial Communications Solution

Remote-Control Software

In order to activate the I-394 Lab, a way needed to be devised to control the I-394 MVS remotely, without having to resort to the expensive solution of running new communication lines across the city. The solution to this problem was achieved by using "remote control software," computer software that allows a user to "take over" another computer remotely using a regular telephone line and a modem. The software selected for this task was Symantec Norton's PCAnywhere.

Initially, this solution was implemented with 16-bit software under Windows 3.1, using a 14.4 Kbps modem. Unfortunately, this set-up was unstable, causing frequent loss of communications or operating system lockup. After many tests and modifications, it was determined that the cause of the problem is likely the inherent instability of Windows 3.1, not being a true multitasking operating system. For this reason, and others mentioned earlier, a change was made to Windows NT 3.51, and to the new 32-bit PCAnywhere software. In addition, a 28.8 Kbps modem was installed (at each end) to help maximize the communication speed. (Mn/Dot supplied the dedicated phone line, and the ITS Lab supplied the two modems.) The next section will give a detailed description of the hardware configuration in the ITS Lab. With the remote control software, the Scopeserver PC at the TMC may now be controlled remotely from the ITS Lab. In this way, cameras may be selected, Autoscope software can be run, detectors can be configured, and data can be transferred (manual ftp). However, the connection is slow and cumbersome for machine-vision purposes, and not a good long-term solution for the I-394 Lab.

I-394 Lab Configuration

The I-394 Lab at the ITS Lab is centered around a workstation with a specific configuration for communication and machine-vision detection. Components of the set-up are:

- A 90 MH Pentium PC, with 32 MB RAM and 1.2 GB hard drive
- A local monitor and VCR, with connections to the RF microwave signal
- A local Autoscope 2004
- A 28.8 Kbps modem
- A Digi Board PC/4e Board to accommodate the extra devices
- Windows NT 3.51
- Hauppage Win/TV Cinema Pro card
- 32-bit PCAnywhere software
- 32-bit Autoscope software

See Figure 5.3 for a pictorial description of this set-up. Appendix C is a user's guide for utilizing the I-394 Lab.

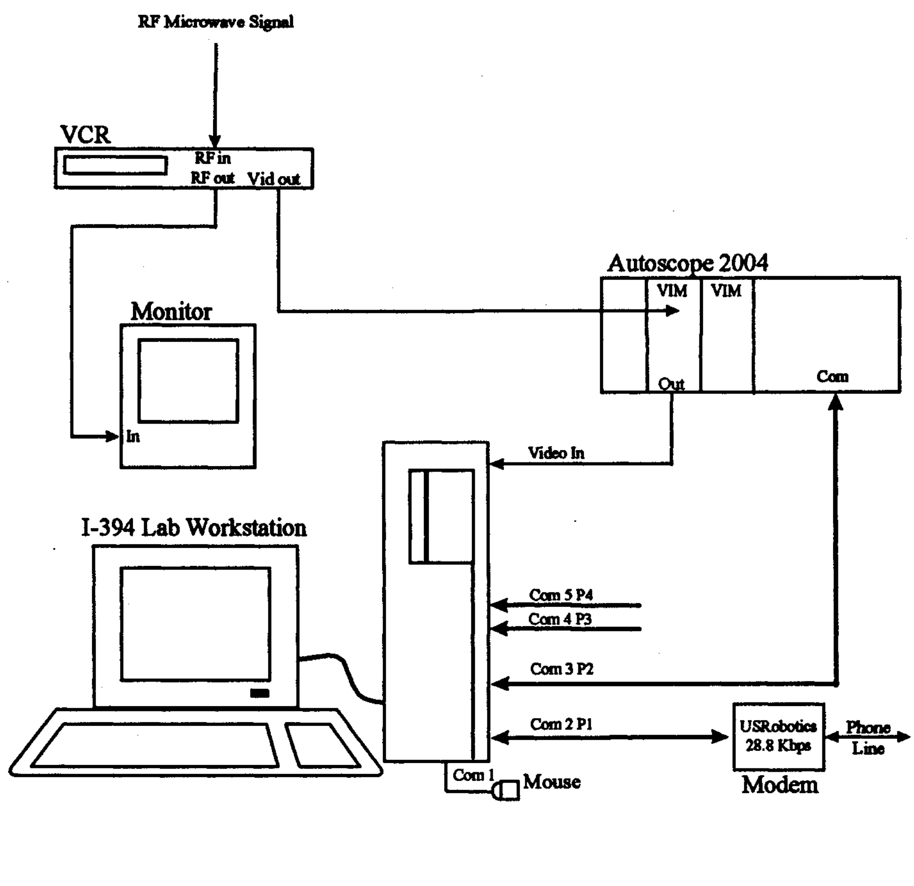

Figure 5.3 - CTS I-394 Lab Workstation Configuration

In addition to the connections to the TMC I-394 MVS, the I-394 Lab also allows for local detection, by using the live video microwave feeds, and a local Autoscope device. This method is good for small and temporary machine-vision experiments. It is worth noting, however, that the video quality is not great at the ITS Lab, which can degrade detection accuracy. This is primarily due to the communications problems mentioned in Chapter 3 (the microwave system doesn't appear to affect the signal quality very much at all).

6. CONCLUSION

6.1. Recommendations

There were a number of lessons learned in this research. Consequently, these are some recommendations which may improve the I-394 Lab (and were deemed beyond the scope or resources of this project). Making some or all of these changes and enhancements will increase the probability that the I-394 Lab will become the one-of-a-kind and truly useful ITS tool it has the potential to be.

Better PCs

The PCs being used, particularly at the TMC, should be upgraded to larger, more powerful ones. They will be more robust, faster, and capable of processing data collection from all the I-394 cameras simultaneously.

Upgrade Autoscopes

The Autoscope 2003 devices should all be upgraded to 2004 devices. The 2004 devices are more reliable, have many new detection features, and do not have the phasing limitations of the 2003 devices. Upgrading to these devices would allow for a more intuitive renumbering of the cameras. Such a renumbering would put contiguous cameras which are detecting the same traffic direction together in one Autoscope. This makes sense because:

- A researcher is most likely to be interested in contiguous cameras going in a single direction.
- It is less likely for overlap to occur between researchers, which would allow for more experiments to be conducted simultaneously.

Upgrade Zone 1 cameras

The Zone 1 cameras are quite old, and in bad working order. It would be best to replace all of them.

Repair Communications

This is the most critical change needed by this system. All of the fiber-optic converters should be replaced with adjustable converters, so that communication problems may be specified and repaired. In addition, a new system design is recommended, one which minimizes the number of conversions the video signals must go through before entering the Autoscopes. Also, the process of splitting the signals in half - with one-half going to the Autoscopes and the other to the microwave system - is further compromising the signal integrity. More sophisticated signal splitters should be included that minimize signal integrity reduction.

Establish a Maintenance Budget

Complicated systems like this need ongoing maintenance and financing to be truly useful. In general, it is recommended that Mn/DOT establish an ITS equipment and maintenance budget. It is also recommended that ESS and the TMC be given a mission to support research projects and operational tests, thereby facilitating space and staff assignments. It probably goes without saying that the different organizations within Mn/DOT need better cooperation to make these initiatives happen.

Redistribute TMC Equipment

Having machine-vision specific equipment located in the TMC's Telemetry Room is probably not a wise arrangement, and alternatives should be explored. One possibility is to find or make more space for the I-394 MVS equipment in or near the TMC. For example, an external climate-controlled shed outside of the building would minimize intrusion in operations activities. Another alternative would be to bypass the TMC and run communication lines directly to the ITS Lab from I-394. This would also be expensive, however.

Implement a High-Speed Communications Alternative

As was stated earlier, the PCAnywhere modem connection is quite slow and tedious. Other faster alternatives should be explored. Some options may be:

- Direct serial communications from the TMC to the ITS Lab
- Installing an ISDN or T1 telephone line
- Using Internet capabilities
- Expanding the microwave system to be bi-directional

All of these solutions could be costly, but communications deregulation and advancing technology should help reduce the expense.

Temporary Alternative

While more permanent solutions to the aforementioned problems are being negotiated, there is an alternative technique for obtaining machine-vision information from the I-394 Lab. Specifically, a researcher could take advantage of the Zone 2 cameras by configuring a detection experiment directly at the Autoscope Shed. In this way, most of the communications problems are avoided, and operations are minimally affected. A relatively high-powered laptop computer with Autoscope software and a portable monitor would be sufficient to control the system from that location. The are some disadvantages to this alternative. First of all, traveling to I-394 to set-up, update the system, or collect data is very inconvenient. Another disadvantage is restricted access hours (10 AM - 2 PM) to avoid interfering with peak-hour operations. It would also be impossible to monitor the system remotely - to verify that detection is occurring correctly. Nevertheless, this temporary alternative could be quite valuable in obtaining as-of-yet unavailable traffic-flow information. This would not only advance the science, it would also help justify the perceived need for a machine-vision facility like the I-394 Lab.

6.2. Future Direction

Determining the future of the I-394 Lab without any assurance of improvement to the I-394 MVS is difficult. There is, however, some valuable work which would enhance the research capabilities of the ITS Lab and not depend on the I-394 MVS.

ITS Lab Database Infrastructure

The ITS Laboratory is in great need of a solid database structure to manage multiple kinds of useful traffic data for research and development. The TMC currently collects data from over 3000 loop detectors throughout the Twin Cities freeway system. This information is not currently readily available in the ITS Lab. A traffic data management system for collecting, configuring, storing, and retrieving this data in an easy and intuitive fashion would be a great tool for traffic modeling, model calibration and validation, control testing, and traffic monitoring. In addition, if and when the I-394 Lab can be made functional and robust, this database system will provide a backbone on which to build tools using machine-vision data as well. Future research efforts could concentrate on developing such a traffic-data management system.

Development of a Machine-Vision Laboratory

A machine-vision laboratory, which uses live video and local machine-vision devices, would be a valuable addition to the ITS Lab. Such a lab could be used for both machine-vision research and training. Future research could design and develop such a laboratory environment.

Integration with Simulation Research

The research being conducted to develop a "Simulation Laboratory" will require automated access to traffic-sensor data. Some work will need to be done to make this integration possible.

APPENDIX A

Autoscope Detector Types (version 2004)

APPENDIX A

Autoscope Detector Types (version 2004)

Count Detector
- optimized for accurate volumes
- sensitive to vehicle motion
- good vehicle separation, even at long range (sensing gaps)
- typically oriented crosslane
- model to compensate for dynamic shadows and leading headlight reflections

Presence Detector
- optimized for accurate occupancy
- holds presence for stopped vehicles
- especially useful for turn-lane control
- typically oriented downlane
- directional capability -- actuate only in direction of traffic flow

Speed Detector
- measures vehicle speeds
- classifies vehicles by length
- associated with count detector -- drawn upstream from count
- tracks vehicle using pattern recognition
- as accurate as loops
- verified with radar

Detector Functions
- combine output of several detectors to one EIM output pin
- use Boolean "AND" or "OR" operation
- eliminate need for wired OR at controller terminal block in the field
- output functions consistent with Econolite ASC/2 Advanced System Controller

Station Detector
- combines multiple detectors
- reports results over specified period of time
- each station detector can have a unique time interval
- collects total volume, average flow rate, average speed, average time occupancy, time headway, vehicle classification counts

APPENDIX B

I-394 Camera Installation Characteristics

APPENDIX B

I-394 Camera Installation Characteristics

Camera Number	Camera Direction	Main Traffic Direction	Main Lanes	HOV Lanes	Ramps
1	E	E	3	0	0
2	E	E	0	0	1
4	E	W	0	0	2
5	W	W	0	0	1
7	E	E	2	2	1
8	E	W	2	2	0
9	W	W	3	2	0
11	unknown				
12	W	W	3	2	0
13	E	W	3	2	0
14	unknown				
15	W	E	3	2	0
18	W	E	3	0	0
19	E	E	3	2	0
20	E	W	4	0	0
21	E	E	2	2	1
22	W	E	2	1	1
23	E	E	2	0	1
24	E	W	2	0	1
25	N	N (to W)	4	0	1
26	N	N (from E)	3	0	0
27	E	E	2	0	2
28	W	W	2	1	1
29	E	E	2	0	2
30	W	W	2	1	2
33	W	E	4	0	1
32	W	W	3	0	1
31	W	E	3	0	1
37	W	W	4	0	1
35	E	W	4	0	0
34	E	W	3	0	1
36	E	E	3	1	0
38	E	E	3	0	0
39	W	W	3	0	1
40	E	E	3	1	0
41	W	W	3	0	0

APPENDIX C

User's Guide

APPENDIX C

User's Guide

Assumptions:

It is assumed that the user is familiar with the following areas:

- Personal Computer, VCR, and monitor operations,
- Windows NT, and
- Autoscope operations, including:

1. Opening communications, and
2. Laying detectors, saving detector files and downloading them to an Autoscope unit.

Instructions:

Follow these instructions to start the connection:

Configuring VCR and Monitor

1. Turn VCR and monitor on. Set the monitor to channel 3 and set the VCR to video mode.

Turning modem on

2. Make sure the modem is on.

3. Turn on I394 Lab workstation computer and monitor.

Getting into Windows NT

4. Select **Windows NT Workstation Version 3.51**.

5. Press **Crtl+Alt+Del** to log on.

6. Enter your username and password, then press **ENTER**. (If you do not have one or both, please contact the ITS Laboratory manager).

Opening the pcANYWHERE32 group box

7. In the Windows NT Program Manager, open the group box icon labeled pcANYWHERE32. You can either:

- Double-click on the icon, **OR**
- Press **Ctrl-Tab** until the icon is highlighted and press **ENTER**.

Starting pcANYWHERE

8. To start pcANYWHERE:

- Double-click on the icon, **OR**
- Click on the icon and press **ENTER**.

Making the connection

9. To connect to the TMC Scopeserver computer, select the **Remote Control** under the local main menu. Then select **TMC Scopeserver** icon. You can either:

- Double-click on the icon, **OR**
- Click on the icon and press **ENTER**.

The software will use the modem to dial to the TMC, and the TMC Scopeserver screen will appear (If this does not occur, contact the ITS Laboratory Manager.

Note: From this point forward, the directions refer to the TMC ScopeServer computer, and no longer to the I-394 Lab workstation. Due to phone line limitations, the TMC ScopeServer computer will appear to be very slowly. The best strategy is to be patient, and execute only one action at a time. (Try to avoid multiple mouse clicks.)

Opening the Supervisor Group box

10. In the Windows NT Program Manager, open the group box icon labeled Autoscope Supervisor Toolkit. You can either:

- Double-click on the icon, **OR**
- Press **Ctrl-Tab** until the icon is highlighted and press **ENTER**.

Starting the Supervisor

11. To start the Autoscope Supervisor application:

- Double-click the icon, **OR**
- **Tab** to the icon and press **ENTER**.

Opening communications with an Autoscope

12. To open communications with one of Interstate 394 Autoscopes, choose one of the following:

At the TMC

AS 0:1 Cam 4, 5, 2, 7 - Com 4 19200 DC Single Drop
AS 0:2 Cam 8, 9, 1, 11 - Com 5 19200 DC Single Drop
AS 0:3 Cam 12, 13, 14, 15 - Com 6 19200 DC Single Drop

In the field

AS 8:1 Cam 18, 19, 20, 21 - 8:1 on Com 8 19200 DC Multi Drop
AS 8:2 Cam 22, 23, 24, 25 - 8:2 on Com 8 19200 DC Multi Drop
AS 8:3 Cam 26, 27, 28, 29 - 8:3 on Com 8 19200 DC Multi Drop
AS 8:4 Cam 30, 33, 32, 31 - 8:4 on Com 8 19200 DC Multi Drop
AS 8:5 Cam 37, 35, 34, 36 - 8:5 on Com 8 19200 DC Multi Drop
AS 8:6 Cam 38, 39, 40, 41 - 8:6 on Com 8 19200 DC Multi Drop

Opening a camera

13. Open one of the cameras where the detectors are going to

be implemented.

Viewing the image

14. To lay detectors, First grab the still image of the video to be processed by the Autoscope device. To do this, click the **Get Compressed Frame** icon along the upper middle edge of the Camera window. The **Compressed Image Quality** dialog box will appear (Enter 1 to get the best image). Click **OK** to begin image compression and transfer.

Note: Grabbing a still image is a **must**. Because of the pcANYWHERE limitations, you can not see live video from Workstation #4. In general, grabbing a still image is recommended even with live video present because it's more accurate.

Laying the detectors

15. Using the compressed image, lay the desired detectors. (Refer to the Autoscope User's Guide for instructions on choosing and configuring detector types).

Saving the detector file

16. Save the detector configuration file permanently store the file modifications. From the **FILE** menu, click either:

- **Save Detector File** if the file has already a name, **OR**
- **Save Detector File As** if a new of different file name will be used.

Downloading a layout file to the Autoscope device

17. The detector file enables the Autoscope device to perform full traffic detection but only after it has been downloaded to the device. (If a detector file already exists for that camera input, the new file will replace that file.. From the **File** menu, click **Send Detector File to Autoscope**. A message will appear, click either:

- **Yes** to continue the download procedure. The MVP will stop collecting traffic data while receiving the new file, **OR**
- **No** to stop downloading.

Verifying detection with live video

18. To verify that the detection is working properly, the monitor can be used to view a channel based on the Autoscope you are selecting:

AS 0:1 - AS 0:3 Use the VCR remote to choose the appropriate channel to view the live video (look at the **ITS Channel Assignment Table** for the right channel).

AS 8:1 - AS 8:6 To verify one of these cameras, channel 22 is the only channel assigned for this viewing purpose. To switch between Autoscopes, there is a terminal application called SWITCHER.TRM. To get to this, open the Windows NT

Program Manager. Then open the group box icon labeled Accessories, you can either:

- Double-click on the icon, **OR**
- Press **Ctrl-Tab** until the icon is highlighted and press **ENTER**.

To start Terminal application:

- Double-click the icon, **OR**
- **Tab** to the icon and press **ENTER**.

Open a file named SWITCHER.TRM and you'll see an application for the switching purpose, and at the bottom of it, there are icons/buttons that you can click on for a specific task. The following table describes the buttons:

Switcher Functions

Key Name	Command	Function
@AC01^M	@AC01^M	Automatic configuration mode. It automatically tells to Pro Switchers to number themselves in ascending order (in this case start with number 1)
8:1 1-1	@SW01V1A^M	Assign video from Input 1 of Pro Switcher number 1 to Output A
8:2 2:1	@SW01V2A^M	Assign video from Input 2 of Pro Switcher number 1 to Output A
8:3 3:1	@SW01V3A^M	Assign video from Input 3 of Pro Switcher number 1 to Output A
8:4 4:1	@SW01V4A^M	Assign video from Input 4 of Pro Switcher number 1 to Output A
SW 2 to x-1	@SW02V1A^M	Assign video from Input 1 of Pro Switcher number 2 to Output A
8:5 x-2	@SW02V2A^M	Assign video from Input 2 of Pro Switcher number 2 to Output A
8:6 x-3	@SW02V3A^M	Assign video from Input 3 of Pro Switcher number 2 to Output A

Disconnecting the modem

19. To disconnect the modem communications, click on the end remote control button (the second one from the right on the very top menu) and press **ENTER** to ensure the disconnection.

ITS Channel Assignment

Autoscope unit	Autoscope Camera	ITS channel
0:1	4	7
	5	8
	2	6
	7	10
0:2	8	12
	9	13
	1	16
	11	17
0:3	12	18
	13	19
	14	20
	15	21
8:1 - 8:6	19 - 41	22

APPENDIX D

Real-Time Video for ITS Research

APPENDIX D

Real-Time Video for ITS Research

Authored by: Lowell A. Benson
Center for Transportation Studies' ITS Lab Manager

This paper explains and documents the selection of Traffic Management Center (TMC) video sources for transmission to the University's ITS LABORATORY at the Center for Transportation Studies (CTS). It also describes the other laboratory video sources. Comments or corrections to this paper should be brought to the attention of the laboratory manager @ 625-8339.

The Mn/DOT TMC has over 170 surveillance cameras and 36 machine vision cameras on the 200^+ freeway miles in and around the Minneapolis/St. Paul metropolitan area. By the year 2000, there will be about 200 cameras. Video signals from the cameras have been distributed to TMC control room display banks and to selected operator stations via a 256 x 64 output baseband switch. Fourteen of the 64 outputs are shared by the Highway patrol, Hennepin Co., Mn/DOT maintenance departments, and the cities of Minneapolis and St. Paul. A critical consideration in sharing video collected and provided by the TMC is to avoid degradation of their video signals, therefore direct connections and "T's" to TMC's video switch are restricted. Instead, the shared installations connect co-axial cables to the output of video displays or to the amplified input to the Autoscope™ units in the basement electronics room. These video signal outputs are connected to University provided modulators which in turn feed radio frequency (RF) co-axial cables. The cables connect to a microwave subsystem which transmits the video channels 2.3 miles to the top of Moos Tower on the University campus. From Moos Tower, the signal is linked with an RF repeater to the video electronics room of the ITS LABORATORY. The laboratory in the University's Transportation and Safety Building distributes video signals via a broadband network to displays, projectors, recorders, computers, and machine vision units.

The principal research, education, and training purpose of real-time video in the laboratory is incident detection research using machine-vision equipment strategically placed along the I-394 corridor. A logical extension of the automated detection is the verification and subsequent advisory messages to other drivers and response teams, i.e. the management of the incident. These simple objectives guide the video connections as detailed in paragraphs 1 through 5 below:

1. There are fourteen machine vision video connections, one is the multiplexed selection from the six Autoscope™ units (24 cameras) presently located in a cabinet along the I-394 freeway west of Minneapolis. Twelve are the video inputs from 12 non-multiplexed cameras along I-394 presently being fed to the three Autoscope™ units in the TMC telemetry room. The fourteenth machine vision feed is connected to the video output from the Autoscope™ supervisor PC in the TMC first floor. This video feed set is used to experiment with incident detection and ramp metering strategies based on machine vision detection. It will also be used to correlate detection algorithms with the digitized loop detector data which is being linked from TMC to the laboratory over an Internet path.
2. TMC surveillance cameras #905 through #917 cover I-394 from its Hwy. 169 intersection to the I-394 and I-94 junction. This includes the 3.5 mile I-394 Autoscope™ camera installation area. These camera outputs are displayed on the North Station, monitors #7 through #18 as the third 10 second stage of their six salvo sequence. In addition to calls

routed from the 911 center, this is the current procedural means of noticing incidents that cause congestion on this freeway segment.

3. When a TMC operator receives a call or notices an incident, he typically connects his desk top monitor to the camera input nearest the reported incident area. While watching the desktop monitor, the operator will pan, zoom, or tilt the selected camera to get a closer look at the incident, i.e. verification step. Then the operator follows TMC standard procedures for recording and taking action to initiate responses to the incident. Since verification of incidents and avoidance of false alarms is paramount to an effective electronic system, the video from the North & South operator stations, the KBEM announcer stations, the Trilogy/Genesis data capture station, and the information station are sent to the laboratory. These incident processing positions use TMC monitors #49 through #53 and #58.
4. A secondary research purpose is to conduct experiments in the optimization of ramp metering algorithms. An earlier Civil Engineering & TMC cooperative research project for ramp meter optimization tried some algorithms on the 35W freeway section in the Highway 62 and I35W commons area. The ability to observe this area during future cooperative tests and trials was the incentive for us to select South Station monitors 31 through 36 which display cameras #613 through #620 as part of a four stage salvo sequence. This covers Interstate I35W from 86th St. to 50th St. including the commons area with Highway 62 cross town freeway.
5. A third research thrust at the University deals with arterial streets and their interaction with the freeway system. This research is to be conducted in cooperation with the cities of Minneapolis and Saint Paul,

therefore it is anticipated that observation of the same video screens could be beneficial. Monitors #48 and #62 input to the transmission system provide a common visual reference screen with each of these cities.

It should be noted that the TMC salvo sequencing of the North and South station displays facilitates using the ITS LABORATORY as a demonstration extension of the TMC for visitor tours, i.e. the visitors will be able to glimpse the freeway system from 78 cameras in addition to the ones mentioned in paragraphs 3 through 5 above. These 10 or 15 second glimpses cover the I35W/I94 common area, the I35W/H36 common area, the I35E/I94 common area, portions of I494 & H62 to the west of I35W, I94 from the Lowry tunnel to downtown St. Paul, the I35E/H36 junction area, the I35W/I694 junction area, the I35W/Hwy10 junction area, the I394/H169 junction area, and the I94/I694 common area. Tables III through VII provide specific ITS LABORATORY video distribution channel assignments and their relationships to the TMC cameras.

Table I. TMC to ITS Laboratory Video Signal Connections

VIDEO SOURCE	TMC CONNECT POINT	MODULATOR PHYSICAL LOCATION	TMC FUNCTION DESCRIPTION	Channel Count	ITS Laboratory Channel #
Autoscope Cameras 1,2,4,5	Autoscope ID 0:1 inputs	TMC telemetry room - rack # 3	I-394 & Penn Ave. intersection machine vision inputs	4	6,7,8,10
Autoscope Cameras 7,8,9,11	Autoscope ID 0:2 inputs	TMC telemetry room - rack # 3	I-394 & Penn Ave. intersection machine vision inputs	4	12,13,16,17
Autoscope Cameras 12==>15	Autoscope ID 0:3 inputs	TMC telemetry room - rack # 3	I-394 from Penn to Wirth Pkwy machine vision inputs	4	18==>21
Autoscope Cameras 19 ==>41	I-394 video multiplex (193)	TMC telemetry room - rack # 3	I-394 from Wirth to Louisiana machine vision inputs	1	22
Supervisor PC	Video out card	Back room on 1st floor @TMC	TMC demonstration & setup use	1	24
Surveillance cameras 905=>910	North Station Monitors 7==>12	Bottom of North Station video racks* (ops room left wall)	I-394 from CR 73 to Vernon Avenue plus 5 others is salvo	6	25==>30
Surveillance cameras 911=>917 (less 916)	North Station Monitors 13==>18	Bottom of North Station video racks* (ops room left wall)	I-394 from Hwy100 to I-94 (Autoscope covered area) plus 5 others in salvo	6	31==>36
Surveillance cameras 613=>620	South Station Monitors 31==>36	Bottom of South Station video racks* (ops room right wall)	South 35W and Hwy. 62 commons plus 3 others in salvo	6	39==>44
KBEM Announcer Station	Monitors #50 & #58	Bottom of South Station video racks*	KBEM informational congestion or incident focus points	2	45 & 46
South Operator Control	Monitor #52	Bottom of South Station video racks*	Congestion & Incident Management	1	38
North Operator Control	Monitor #49	Bottom of North Station video racks*	Congestion & Incident Management	1	37
Information Stations	Monitors #51 & #53	Bottom of South Station video racks*	Barco Display and Genesis/Trilogy	2	47 & 48
Minneapolis Distribution	Monitor #48	Bottom of South Station video racks*	Coordination with City of Mpls	1	50
St. Paul Distribution	Monitor #62	Bottom of South Station video racks*	Coordination with City of St. Paul	1	49

The Traffic Management Center's video distribution system overlays each switch output with a two line information table as described in Table II. Note that this information won't show up on the Autoscope™ channels because they don't go through the video switch. It also may not show up on some of the traffic management screens that are direct computer outputs.

Table II. TMC On-Screen Information

Mn/DOT Camera No.	Freeway under surveillance	Date
Display mode	Freeway crossing street/highway	Time

The ITS LABORATORY has set up other video sources for research and demonstrations. These are listed in table III by the laboratory channel number. Others will be added as needs develop. The Mod # column refers to the electronic modulator number used to couple the source to the RF system. These modulators are located in room #214A of the Transportation and Safety Building.

Table III. Demonstration Facility Channels

Channel #	Video Source	Mod #	Notes
2	Campus	2	Down link via campus cable system
3	Campus	3	Parking Admin.'s Video Switch - local operations center
4	Roof Top	4	Autoscope™ camera @ Washington & Union
5	tbd	5	
9	tbd	9	
11	tbd	11	
51	VCR #1	OO	By Video Electronics room
52	tbd	PP	
53	tbd	QQ	
54	VCR #2	RR	By machine vision research area

55	tbd	SS	
56	tbd	TT	
57	tbd	UU	
58	tbd	VV	
59	tbd	WW	
60	tbd	XX	
61	HFRL	YY	Fiber optics link from Onyx computer display driver
62		ZZ	

Table IV. I-394 Machine-Vision Inputs to Laboratory

Channel #	Mod #	Video Source	Notes
06	6	Autoscope Camera 2	East Bound on-ramp from Penn & bike path
07	7	Autoscope Camera 4	West Bound off-ramp to Penn
08	8	Autoscope Camera 5	West Bound on-ramp from Penn
10	10	Autoscope Camera 7	East Bound off-ramp to Penn
12	12	Autoscope Camera 8	West Bound; on-ramp from Penn
13	13	Autoscope Camera 9	West Bound, west of Penn
16	C	Autoscope Camera 1	East Bound, east of Penn
17	D	Autoscope Camera 11	Westbound(rear)Penn & Wirth (East/HOV/West(rear))
18	E	Autoscope Camera 12	West Bound(rear), East of Wirth Parkway
19	F	Autoscope Camera 13	West Bound(front), East of Wirth Parkway
20	G	Autoscope Camera 14	I-394 @ Wirth Parkway
21	H	Autoscope Camera 15	East Bound, West of Wirth Parkway
22	I	Autoscope Cameras 19-41, Video multiplex (cam #193)	I-394 from Wirth to Louisiana Ave.
24	K	Autoscope Supervisor PC	Hauppaughe card output

Table V. Traffic Management Action Stations

Channel #	Mod #	Video Source	Notes
37	AA	TMC Monitor #49	North Operator Control Position
38	BB	TMC Monitor #52	South Operator Control Position
45	II	TMC Monitor #50	KBEM announcer station
46	JJ	TMC Monitor #58	KBEM announcer station
47	KK	TMC Monitor #51	Information officer screen display
48	LL	TMC Monitor #53	Genesis/Trilogy operational test station
49	MM	TMC Monitor #48	St. Paul video coordination Monitor output
50	NN	TMC Monitor #62	Minneapolis video coordination Monitor output

TABLE VI. Surveillance Sequencing @ South Station

Channel	Mod #	Video Source	Salvo 1*	Salvo 2	Salvo 3	Salvo 4
39	CC	TMC Monitor #31	620 = I-35W & 50th St.	117 = TH 62 & TH 100	427 = I-494 & TH 169	212 = TH 100 & Benton
40	DD	TMC Monitor #32	619 = I-35W & Diamond Lake	116 = TH 62 & France Ave.	426 = I-494 & W Bush Lake	210 = TH 100 & 66th
41	EE	TMC Monitor #33	617 = I-35W & Lyndale Ave.	115 = TH 62 & Xerxes Ave.	425 = I-494 & East Bush Lake	329 = TH 169 & TH 55
42	FF	TMC Monitor #34	615 = I-35W & 66th St.	616 = I-35W & TH 121	424 = I-494 & TH 100	328 = TH 169 & Cedar Lake
43	GG	TMC Monitor #35	614 = I-35W & 76th St.	618 = I-35W & TH 62	423 = I-494 & France	327 = TH 169 & Minnetonk a
44	HH	TMC Monitor #36	613 = I-35W & 86th St.	114 = TH 62 & Portland	422 = I-494 & Penn Ave.	326 = TH 169 & TH 7

*Salvo format lists camera number, main route, & intersecting street/highway

TABLE VII. Freeway Surveillance Sequencing @ North Station

Chan #	Mod #	Video Source	Salvo 1*	Salvo 2	Salvo 3	Salvo 4	Salvo 5	Salvo 6
25	L	TMC Monitor #07	813 = I-94 & TH169	829 = I-94 & Tunnel East	905 = I-394 & CR 73	641 = I35W & TH 118	626 = I-35W & I-94	11 = I-35E & Maryland
26	M	TMC Monitor #08	814 = I-94 & Boone Ave.	830 = I-94 & Tunnel West	906 = I-394 & TH 169	640 = I35W & CoRd I	835 = I-35W & 3rd Ave.	12 = I-35E & Larpenteur
27	N	TMC Monitor #09	815 = I-94 & CoRd81	832 = I-94 & Tunnel West	907 = I-394 General Mills	639 = I35W & TH 10	625 = I35W & Chicago	6 = I-35E & TH36
28	O	TMC Monitor #10	816 = I-94 & Zane Ave.	833 = I-94 & Lyndale Ave.	908 = I-394 & Texas	638 = I35W & TH 96	624 = I-35W & 26th St.	13 = I-35E & Little Canada
29	P	TMC Monitor #11	817 = I-94 & Brooklyn Blvd.	834 = I-94 & TH 65	909=I-394& Hampshire	637 = I35W & I694	701 = I-694 & TH 252	1 = TH 36 & Cleveland
30	Q	TMC Monitor #12	818 = I-94 & Xerxes Ave.	835 = I-94 & 3rd Ave. So.	910=I-394 Vernon Ave.	636 = I-35W & CoRd E2	702 = I-694 & University	2 = TH 36 & Snelling
31	S	TMC Monitor #13	819 = I-94 & Humbolt Ave.	836 = I-94 & Franklin Ave. W	911=I-394& TH 100W	635 = I-35W & TH 88	703 = I-694 & Central	3 = TH 36 & Lexington
32	R	TMC Monitor #14	820 = I-94 & 57th Ave.	837 = I-94 & Franklin Ave. E	912=I-394& TH 100E	634 = I-35W & CoRd C	704 = I-694 & Silver LkRd	4 = TH 36 & Dale
33	T	TMC Monitor #15	821 = I-94 & 49th Ave.	838 = I-94 & Lexington Pkwy	913=I394& France Ave.	633 = I35W & TH 280	705 = I-694 & Long LkRd	5 = TH 36 & Rice
34	U	TMC Monitor #16	822 = I-94 & 42nd Ave.	839 = I-94 & I-35E	914=I394& Wirth Pkw	632 = I35W & Industrial	219 = TH 100 & Duluth	6 = TH 36 & I-35E
35	V	TMC Monitor #17	823 = I-94 & Lowry Ave.	840 = I-94 & I-35E	915=I394& Penn Ave.	631 = I35W & Johnson	218 = TH 100 & TH 55	7 = TH 36 & Edgerton
36	W	TMC Monitor #18	824 = I-94 & Broadway St.	840 = I-94 & I-35E	917=I394 & I94	630 = I35W & Hennepin	217 = TH 100 & Glenwood	8 = TH 36 & TH 61

*Salvo format lists camera number, main route, & intersecting street/highway