

## **REPORT ON THE TECHNICAL ISSUES SURROUNDING THE DEMONSTRATION OF THE SIGN MANAGEMENT AND RETROREFLECTIVITY TRACKING SYSTEM (SMARTS) TECHNOLOGY -- SUMMER OF 2000**

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### **INTRODUCTION**

The Midwestern Resource Center of the Federal Highway Administration (FHWA) entered into a contract with the Transportation Infrastructure Center (TIC) at the University of Missouri-Columbia (UM-C) to assist them in demonstrating a new technology for measuring the retroreflectivity of highway signs while traveling at regular highway speeds. The goal was to schedule demonstrations in ten upper Midwest states and complete the weeklong demonstrations over the summer of 2000. FHWA wanted to demonstrate this technology as quickly as possible. As the director of the TIC, I set up the schedule for the visits with the ten State Departments of Transportation and the Division Offices of the FHWA. Mr. Joseph Turner, a senior Civil Engineering student at UM-C, drove this van throughout the ten states and was an active participant in the demonstrations. He drove the research van, operated the sophisticated equipment and related computers, trouble shot vehicle, equipment, computer and software problems when they occurred in the field, and became so well versed in the technology that he was able to present the technology by himself at several sites including: FHWA's ITS engineers in Kansas City, engineers in Kenosha County, Wisconsin and The National Rural ITS meeting in Branson, Missouri. What follows is Joe's summary report.

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### **SMARTS REPORT**

The nighttime visibility of highway signs is essential for the safety, comfort and guidance of the motoring public. Recent highway crash statistics show that while 25% of the travel is at night nearly 55% of the fatalities occur at night. Better highway sign visibility can help to reduce these kinds of statistics. In 1954 the MUTCD required that signs needed to be reflectorized (or illuminated). An ASTM specification has been developed for the reflectivity of new signs and now the U.S. Congress in 1993 established a requirement for in service retro-reflectivity of signs.

Since the retro-reflectivity (nighttime visibility) of signs deteriorates over time due to the sun's rays and other environmental factors, a method for measurement of the in place retro-reflectivity needed to be developed. The Federal Highway Administration in cooperation with 34 state DOT's and the US Naval Research Labs have developed a Sign Management and Retro-reflectivity Tracking System (SMARTS). This system has been designed to fit into a van and be driven at highway speeds while making the necessary measurements. This results in accurate digitized readings collected without interference to traffic and equally important does it very quickly and safely for the worker.

During the summer of 2000, the FHWA's Sign Management and Retroreflectivity Tracking System (SMARTS) vans were presented for demonstration to traffic officials from various agencies across the country. In the East, Southeast and West the FHWA used their own staff to demonstrate the SMARTS van, however the Midwestern Region entered into a contract with the University of Missouri-Columbia and I was selected as the student whose summer job would be to cover the Midwest helping to demonstrate this leading edge technology. Most of the participants at the demonstrations were State Department of Transportation officials and related technical people. This report will highlight the SMARTS van and its equipment's operation, its behavior under varying conditions; as well as addressing the observations, questions, and concerns about the system as raised by those who were introduced to the SMARTS system this summer. *Note that throughout this report, the word "camera" will be used to refer to the data collecting equipment on the roof of the vehicle which includes the turret, laser range finder, strobe light, two cameras and related computer interfacing hardware.*

#### **PROJECT OVERVIEW:**

The dates and locations the SMARTS van visited during the summer of 2000 are as follows:

April 15: Missouri Traffic Conference – Columbia, MO

May 15-19: Illinois Department of Transportation (District 6 and Headquarters) – Springfield, IL

May 22: FHWA Midwestern Resource Center – Olympia Fields, IL

June 5-6: Iowa Department of Transportation (District 6) – Cedar Rapids, IA

June 8-9: Iowa Department of Transportation (District 1 and Headquarters) – Ames, IA

June 12-13: Wisconsin County Engineers Association Conference – LaCrosse, WI

June 14: Wisconsin Department of Transportation (District 6) – Eau Claire, WI

June 15: Wisconsin Department of Transportation (District 3) – Green Bay, WI

June 16: Wisconsin Department of Transportation (District 1 and Headquarters) – Madison, WI

June 19-21: FHWA ATSSA Conference – Kansas City, MO

June 26-27: Michigan Department of Transportation (Headquarters) – Lansing, MI

June 28: Michigan Department of Transportation (Detroit Metro District) – Southfield, MI

July 7: Kenosha County Highway Department – Kenosha, WI

July 10: 3M – Cottage Grove, MN

July 11: Minnesota Department of Transportation (District 4) – Morris, MN

July 12-14: Minnesota Department of Transportation (Metro Office) – Minneapolis/St. Paul, MN

July 17-18: Indiana Department of Transportation (Greenfield District) – Indianapolis, IN

July 19: Indiana Department of Transportation (Seymour District) – Bloomington, IN  
July 20: Indiana Department of Transportation (Fort Wayne District) – Fort Wayne, IN  
July 24: Nebraska Department of Roads (District 1) – Lincoln, NE  
July 25: Nebraska Department of Roads (District 4) – Grand Island, NE  
July 26: Nebraska Department of Roads (District 6) – North Platte, NE  
July 31-Aug. 1: Ohio Department of Transportation (District 6 & Headquarters) – Columbus, OH  
August 2: Ohio Department of Transportation (District 4) – Boston Heights, OH  
August 3: Ohio Department of Transportation (District 1) – Bowling Green, OH  
August 7-8: Kansas Department of Transportation (District 1) – Topeka, KS  
August 9: Kansas Department of Transportation (District 5) – Wichita, KS  
August 14-16: National ITS Rural “RATTS “ Conference – Branson, MO



This is the vehicle and equipment that was used for these presentations and demonstrations: (License Plate: DOT 40911)

During this project, the van traveled a total of 14,103 miles. Approximately 470 hours were devoted during the course of the summer. 280 people were introduced to the technology, and a significant percentage of those actually tried operating the equipment themselves. An estimated 5800 signs were photographed and analyzed during this project (rough estimate assuming 200 signs each demonstration day for 29 demonstration days).

At each visit, a presentation was conducted on the need for visible highway signs, aspects of this relating to the MUTCD, federal legislation, the history of sign visibility technology, and detail on the science of retroreflectivity and its measurement. These presentations ended with a discussion of the SMARTS van, its operation and most importantly, showing how the data to be collected would apply to state or local jurisdictions' Sign Management Programs. Following this classroom presentation, the SMARTS van itself was showcased: the van and its computers, cameras, lasers etc. Following this introduction the remainder of the week was spent taking people out in the van to actually collect data using the SMARTS van. At the end of each run (usually an hour or so) we would download the data from the onboard computer to a CD-ROM and give it to state (or local) engineers who requested a copy. In nearly all states we spent time measuring signs on many different types of highways within the

state (rural, urban, arterial, highway, Interstate, etc.). As we collected data and demonstrated the equipment, I noted problems encountered, solutions developed, opinions and concerns expressed and, in general, kept track of what was said. What follows is a detailed listing of these observations. They are presented so as to contribute to improving the implementation of this state-of-the-art technology. In general the van, equipment, cameras and computers all worked very well. Making the computers more robust to withstand the tough operating environment (rough roads and extreme temperatures) is strongly suggested.

#### **OPERATOR CONTROL:**

During the field demonstrations, participants were given the opportunity to ride in the second seat of the van situated behind a computer screen and operate a computer mouse to track the highway signs that were displayed on the computer screen. The sign was being “videoed” by the camera system on the roof of the van as the van moved down the highway. The most common difficulty encountered by those operating the equipment for the first time was the difficulty in effectively controlling the computer’s mouse so as to control the motion of the camera. This was especially true when the road being traveled upon was rough. A common complaint was the sensitivity setting of the computer’s mouse was too high. However, the mouse speed was set to the slowest possible setting in the Windows© control panel. Also, it was noted by many that the motion of the camera was also too sensitive to the motion of the mouse. A slight movement of the mouse caused a radical motion of the camera.

Many people also had difficulty understanding how the motion of the camera was governed by the position of the pointer on the screen (the “crosshair”) relative to the center green square in the camera’s field of view. During operation, many participants would overcompensate in trying to redirect the camera’s motion when the camera would drift from its front position. Many participants had various suggestions for a better type of pointer controlling device instead of a standard computer mouse ranging from a joystick to a track-and-ball system, to even a “steering wheel” type of control. Some investigation into a more user-friendly control system may be warranted.

#### **WEATHER CONDITIONS AND EQUIPMENT SETTINGS**

As expected, the effective operation of the equipment is extremely weather and lighting condition dependent. The setting of the color shutter is highly important for obtaining quality data. During periods of partly cloudy skies, and even mostly cloudy skies, the amount of sunlight present can change dramatically and frequently. It was observed that the color shutter setting must be continually monitored during these situations, and adjusted as necessary. It was discovered that the best way to check this setting of the **color camera**, during collection of data, is

to observe the clarity and brightness of the **black-and-white** picture that appears for a brief moment on the monitor as the strobe flashes and the pictures and data are being recorded. A clear and legible black-and-white photograph is a reliable indicator of the best setting for the color shutter. Of course, this is assuming that the sign photographed for this observation has good retroreflectivity. Therefore, for best results, it is suggested that there be a particular sign that should accompany the van solely for the purpose of setting the color shutter prior to actual road sign data collection. This “setting” of the color shutter should be made by setting the sign at the prescribed 200 foot distance from the camera, manually taking the picture, observing the clarity of the black-and-white picture along with the calculated percent dynamic range, and adjusting the color shutter setting accordingly. For best results, a sign with areas of both good and poor retroreflectivity would be desired. Further, since the percent dynamic range and the black-and-white photograph are indicators of the quality of the data, it would be desired that both be displayed somewhere on the data collection screen, so that both could be continuously monitored during data collection. This would enable the color shutter to be continuously set at the appropriate level for the lighting conditions present during the collection of data. The ability to do this would result in fewer elements of incomplete or poor quality data. Thus, it would also result in less time spent relocating signs that were not photographed and analyzed to the best quality. *Note that “quality” here refers to the reliability of the data obtained, based on image quality produced by the equipment and certain related numerical output, not the retroreflective properties of signs that are analyzed.*

Since the setting of the color shutter is highly important to the reliability of the data, it would be desired that there be finer increments of change between one setting and an adjacent setting. It was observed that in many instances, a particular color shutter setting was too low, but the next highest setting was too high, making it impossible to set the color shutter at an optimum level. This mainly occurred when cloud cover was not constant, and lighting conditions were changing continuously.

In addition to the lighting dependent conditions noted above, it should be noted that failure to adjust the color shutter setting for the outdoor lighting conditions can result in undesired behaviors by the system. When not properly set, the automatic tracking system will not function properly. Manual control of the camera is required when this occurs. Also, pictures that are collected will tend to be incomplete, meaning that the picture will not be centered on the sign. In many cases, only half or three-quarters of a sign may be photographed. This is most common with the black-and-white photograph. Another occurrence related to improper setting of the color shutter is that the system may fail to record both photographs. One picture, but not the other, will be stored in memory.

There are a few other factors that occasionally interfere with the operation of the SMARTS system. For road signs next to traffic signals, such as street name signs located between signals, collecting data from those signs can be difficult because of the light emitted from the signal itself. The automatic tracking of the system tends to lock onto the illuminated traffic signal. Also, in some instances there may be other objects on the roadway that are brightly colored that “attract” the SMARTS system. Some of these objects include trailers on trucks, advertising billboards, towers, water towers, guardrails, and even the retroreflective pavement markings on the road. Also, in areas where patches of trees are along the road, the system will also sometimes direct itself toward the edges of treelines.

The SMARTS system was also operated, during one demonstration, during a heavy rainfall. The system’s ability to track a road sign and take a picture is minimally affected. The reliability of the data and the quality of the pictures taken during these conditions are uncertain however. The primary problem encountered when using the equipment during such weather conditions is water on the front of the camera mount, which obstructs the camera’s view. In general we tried to avoid collecting data in the rain, because even if the readings were accurate (of which we are not sure) the clarity of the picture would be severely compromised.

## COMPUTER

The computer that controls the SMARTS system appears to be developing a graphics-processing problem. When the computer is operating for long periods of time, the Windows© graphics become distorted, especially the icons on the SMARTS programs. One area that is a particular problem is the area of the sign evaluation program that displays the histogram. When these graphics distortions occur, it is usually the histogram that distorts first. This, and much more severe problems, seems to occur more readily when the temperature in the cabin of the van rises above standard room temperature, and/or outside moisture is present in the van. This is especially a problem during the summer months, when the temperature inside the van can reach extremely high levels, and humidity levels are high. To counteract this, it is important to make sure the cabin temperature is as close to normal room temperature as possible, and the air inside the vehicle is dry, **before** starting the computer. It is just as important to maintain this controlled climate inside the van **during operation** of the SMARTS system. The more severe computer problems related to temperature and humidity are lock-ups, crashes, loss of data, operating errors, booting difficulties, etc.

Because the computer which operates the SMARTS system is part of a moving vehicle, and since any object in a moving vehicle is subject to erratic, sometimes violent motion (especially on a bumpy road), the

computer is subject to periodic disruptions in its operation which can compromise data collection and processing. Because of this, during actual collection of data on the road, it is highly important to **save the data often at regular time intervals**. This is to prevent a significant loss of retroreflectivity data should a computer problem occur. In several instances throughout this demonstration project, varying amounts of data were lost when a malfunction would occur, such as a lock-up or a frequent volatile memory storage problem that this particular computer was prone to. On occasion during operation, the computer would display a message indicating that there was an inability to store data to certain locations of the random access memory. To correct the problem, whatever data not saved to the hard disk that was in the RAM had to be purged. This could present a significant problem if large amounts of sign data were not written to the hard disk, but rather existed only in the RAM.

Many times throughout the project, those introduced to the technology requested a personal copy of the data collected during the field demonstrations. A copy, along with the sign evaluation software, was provided to all who requested it without problem. However, a couple of things were noticed. First, while the software and data are compatible with all versions of Windows© encountered during this project ('98, NT), **computers that are connected to certain networks** (such as those for some state departments of transportation) **may reject the installation of the software**. It is believed that this is due to network-wide safeguards, which prevent such software installation. While this does not directly relate to the SMARTS program itself, this fact should be made clear to anyone who would wish to use the software on such a computer. Second, while the sign evaluation software may install properly on a computer, the data itself may not be able to be read by the program when accessed directly from the compact disc. This problem is evident when the program window will appear on the screen, but no pictures or retroreflectivity data appear or can be accessed. If this occurs, the user should **copy** all sign management databases, along with all accompanying image files, directly **to** a directory on the **computer's hard disk** from the CD-ROM, and access the data directly from the hard drive. In all cases where this problem occurred, this corrected the problem, and the software operated correctly.

#### **PARTICIPANT INPUT**

The following items are the most frequently noted observations/comments/suggestions noted by those who participated in the summer 2000 demonstrations of the SMARTS technology:

- A device, similar to the SMARTS van, that could be developed to determine the dimensions (size) of a road sign in the same manner as the SMARTS van determines the retroreflectivity of road signs would be useful.

- The measured values for the coefficient of reflectivity were too high to be useful for any significant application without appropriate correlation factors. Those who viewed the equipment could not make sense of the obtained values. Measured values will have to correspond to the reflective guidelines that are being established to be useful.
- A type of algorithm that could determine the exact Global Positioning System (GPS) coordinates of the road sign itself would be more useful in sign management than the GPS coordinates of the rear of the vehicle.
- The van and its equipment were impressive to almost all of the participants, but the cost of the equipment would make it prohibitive for most agencies. If only a sample or a small percentage of signs would be needed for an actual application, the hand-held retroreflectometers may be adequate enough, and less expensive than the mobile unit.
- It would be ideal if the data obtained using the SMARTS's software could automatically download its recorded data to one of the more widely used sign management programs (i.e. Cartegraph, SignView), so that the SMARTS's software could be used to update existing sign management databases.
- When the system records a picture, the black-and-white picture that is recorded is displayed in the viewing area for about a second. This was a disturbance to one operator, especially when attempting to take pictures in an area with a large density of signs. Most however, considered this as simply an indication that the picture was taken. If this momentary still picture were not displayed, some other indicator that the picture was taken would be necessary, since most who operate the system do not look for the flash of light on the sign when the picture is taken.
- The tracking system does not move the mount fast enough for side images of signs located on the right side of the roadway.
- The GPS location (given in degrees latitude and longitude) is okay, especially with its high level of accuracy. However, the datum in which these coordinates are recorded needs to be known so that the collection of data can be useful for other applications.
- It would be desired that the system take a picture even if the automatic tracking were lost. This could be accomplished by having the system calculate the last tracking angle, distance, and speed of the vehicle, to determine where and when to automatically take the photograph.

- It would be most beneficial if the van could be developed to also incorporate a system for measuring the reflectivity of pavement markings by recording a reading every 1/10 of a mile so that it could be determined if remarking were necessary. It was suggested that there be a type of arm that could extend from the side of the van that would take these readings as the vehicle travels down the highway.
- One concern that was voiced was that the SMARTS system is recording data at an angle that is different from what motorists will see on the road because of the fact that the recording unit is higher than the motorists' eye level.
- For the van itself, a type of sensor on the vehicle that would warn the driver when he/she is getting too close to an object. It can sometimes be difficult to see when backing up, simply because of the size and length of the vehicle. This would be most useful when parking in a parking lot where vehicles are parked close together, and other places where space is limited. It can sometimes be difficult to pull into and out of a parking space, especially when there is only one space available between two cars, and cars are located behind.
- The green square that represents the camera's center of view on the monitor is sometimes too lightweight or too light in color to see for some of the participants.
- Would desire that the evaluation software might be able to sort signs by level of  $R_q$ , so that actual useful query of a database could be performed. This would be so that a person reviewing the data would not have to scroll through thousands of signs to locate those that are unacceptable. This would require that the standards be programmed into the software, and the program may be able to sort and list only those signs that measure unacceptable.
- It is desired that there be some way of making the sign evaluation software compatible with existing Sign Inventory Management Systems (SIMS). It was stated that GPS coordinates do not provide a meaningful location of a sign to people. Also, most agencies do not use GPS in their SIMS. It would be desired that the programming might be able to use the GPS data, along with existing sign location data, to identify a given sign using GPS and the highway that the van is collecting data on.
- A type of camera stabilizing system for the turret may be beneficial. This may help provide for better quality pictures. Oftentimes, on bumpy roads, the black-and-white picture may be incomplete; only part of

a sign may be photographed. This seems to be due to the vehicle hitting a bump in the road as the black-and-white picture is being taken.

- Since some people, during demonstrations (and possibly during actual use) may want to know the reflectivity of the sign immediately, an output area displaying this on the data collection screen may be useful.
- A type of rigid-body housing for the turret would be highly beneficial in protecting the turret during transport, when the system is not in use but the vehicle is in transit. This housing could be something as simple as a custom-fit durable "box" that could be pinned to the roof of the vehicle when the SMARTS equipment is not in operation. This would help protect the turret from potential damage caused by bugs, birds, road debris (rocks, flying asphalt), hail, and rain.
- It should also be noted that one person who operated the equipment during a demonstration experienced mild motion sickness from operating the system. This was most likely due to the constant, erratic movement of the picture on the monitor, and the motion of the vehicle. As when operating any computer, it may be wise to recommend that persons should not operate the system for more than about an hour continuously.